CutPro 11 - User Manual

USER MANUAL

MAL Manufacturing Automation Laboratories Inc.

Getting Started

1 Getting Started

manufacturing automation laboratories CUTPRO

Introduction

CUTPRO VERSION 11

CutPro is an analytic and time-domain machining process simulation software package, developed for off-line machining process optimization.

CutPro can be used by several end users for the following purposes:

- ✓ Machine Design
- ✓ Spindle Design
- ✓ Cutting Tool Design
- ✓ Process Design
- ✓ NC Programming
- ✓ Cutting Tool Selection and Optimization
- ✓ Troubleshooting Vibration Problems in machining

1.1 What is CutPro?

manufacturing automation laboratories CUTPRO

What is CutPro?

Today top production engineers use CUTPRO to analyze, troubleshoot and optimize machining operations throughout the entire machining process. For more than two decades, CUTPRO's unique algorithms have assisted our customers in releasing untapped productivity opportunities within their existing equipment, tooling and machining processes. It has also assisted them in selecting or designing new equipment and tooling. End-users such as production engineers, tool designers, machine designers, control designers, spindle designers and more can all use CUTPRO to their benefit. See what our customers have to say by visiting our

testimonials online at http://www.malinc.com/about-us/testimonials/.

Why use CutPro?

Research for CUTPRO is based on MAL UBC, which is the largest and most credited laboratory in this field of research in North America. Based on highly specific knowledge, CUTPRO is a user-friendly software delivering the most advanced and comprehensive machining process solutions available. Taking the first step to becoming your productivity partner, our machining experts carefully listen to your objectives and recommend the right combination system to match your needs and budget. Our integrated support system can be used to contact our wide range of machining experts or software developers, and we will get back to you within a day or less, minus weekends and holidays.

Summary

CUTPRO has become the choice for well-known manufacturing companies striving to deliver parts on-time with minimum production errors and scrap rates. Users have successfully implemented this leading edge machining technology and achieved the lowest possible cost per component, with the highest possible performance.

1.2 License Information

manufacturing automation laboratories CUTPRO

License Information

Manufacturing Automation Laboratories Inc. (MAL) reserves the right to modify or discontinue the software or the software specification identified in this document without notice. MAL advises its customers to obtain the latest version of the software specifications to verify, before placing orders, that the information being relied upon by the customer is current. MAL makes no warranties, expressed or implied, including without limitation the implied warranties of merchantability and fitness for a particular purpose, regarding the software. MAL does not warrant, guarantee or make any representations regarding the use or the results of the use of the software in terms of its correctness, accuracy, reliability, currentness or otherwise. You assume the entire risk as to the results and performance of the software.

In no event will MAL and its directors, officers, employees or agents be liable to you for any consequential, incidental or indirect damages (including damages for loss of business profits, business interruption, loss of business information, and the like) arising out of the use or inability to use the software even if MAL has been advised of the possibility of such damages. MAL's liability to you for actual damages from any cause whatsoever, and regardless of the form of the action (whether in contract, tort

(including negligence), product liability or otherwise), shall in no case exceed the invoiced amount paid for the right to use the software and the documentation.

1,284,737. 2005/12/30. MAL Manufacturing Automation Laboratories, Inc., 2829 Highbury Street, Vancouver, BRITISH COLUMBIA V6R 3T7 Representative for Service! Representant pour Signification: OVEN WIGGS GREEN & MUTALA LLP, SUITE 480 -THE STATION, 601 WEST CORDOVA STREET, VANCOUVER, BRITISH COLUMBIA, V6B1G1

CUTPRO

WARES:

(1) Computer software for use in optimizing the performance of machining equipment.

(2) Machine tools for use in the metal working industry and control systems for such machine tools.

SERVICES:

Consulting in the field of the design and operation of machine tools. Used in CANADA since at least as early as 1999 on wares (1).

Proposed Use in CANADA on wares (2) and on services.

MARCHANDISES:

(1) Logiciels pour l'optimisation du rendement du materiel d'usinage.

(2) Machines-outils pour utilisation dans l'industrie du travail des metaux et systemes de commande pour lesdites machines-outils.

SERVICES:

Consultation en conception et exploitation de machines-outils. Employee au CANADA depuis au moins aussi tot que 1999 en liaison avec les marchandises(1).

Emploi projete au CANADA en liaison avec les marchandises (2) et en liaison avec les services.

Trademarks

Pentium is a trademark of Intel Corporation. Microsoft, MS-DOS are registered trademarks and Windows XP, Windows Vista, Windows 7, Windows 8, Windows 8.1 are trademarks of Microsoft Corporation. IBM and PC/AT are registered trademarks of International Business Machines Corporation. All other trademarks are trademarks or registered trademarks of their respective owners

1.3 System Requirements

manufacturing automation laboratories CUTPRO

System requirements

Required hardware and software:

- **PC:** PC with a Intel/AMD processor with a minimum of 2 cores at 3.0Ghz
- **Operating System:** We highly recommend updating to the latest service pack for best compatibility.
  - Windows 10
  - Windows 8 or 8.1
  - Windows 7
  - Windows Vista SP1 or later
  - Windows XP SP3
  - Windows Server 2008 (Server Core not supported)
  - Windows Server 2008 R2 (Server Core supported with SP1 or later)
  - Windows Server 2003 SP2.
- **Memory:** We recommend a minimum of 6GB of RAM.
- **Hardlock Key / Network License:** Will be provided when the software is purchased.

1.4 User Interface overview

manufacturing automation laboratories CUTPRO

User Interface overview

CutPro's user interface follows the standard layout used by most Windows applications:

- Main windows
- Modules

1.4.1 Main Windows

manufacturing automation laboratories CUTPRO

Main Windows

The main windows of CutPro's user interface are as follows:

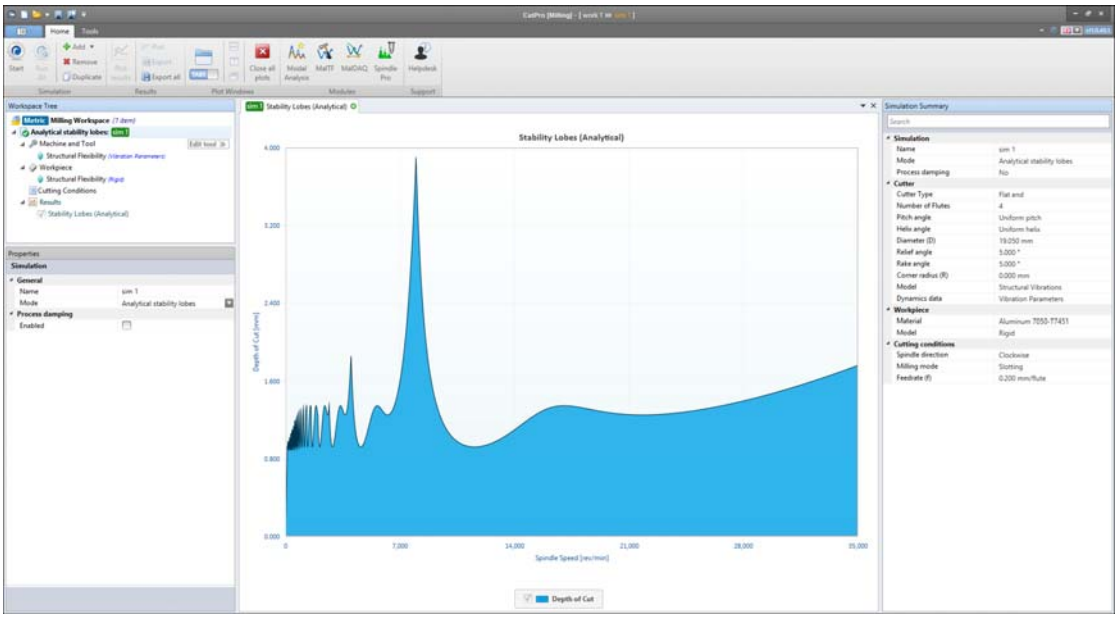
Ribbon Bar: Contains a series of tabs and buttons, each enabling access to the various functionality available in CutPro. Ex. File, Home and Tools.

Workspace Tree: Displays all of the elements of a CutPro project. The order of elements corresponds to the order that you will configure each item.

Plots: Located in the center of the program window, and contains plotted charts dependant on the task performed at hand.

Properties: Displays all information corresponding to the selected item in the workspace tree.

Simulation Summary: Displays all of the parameters in the current simulation.



1.4.2 Workspace Tree

manufacturing automation laboratories CUTPRO

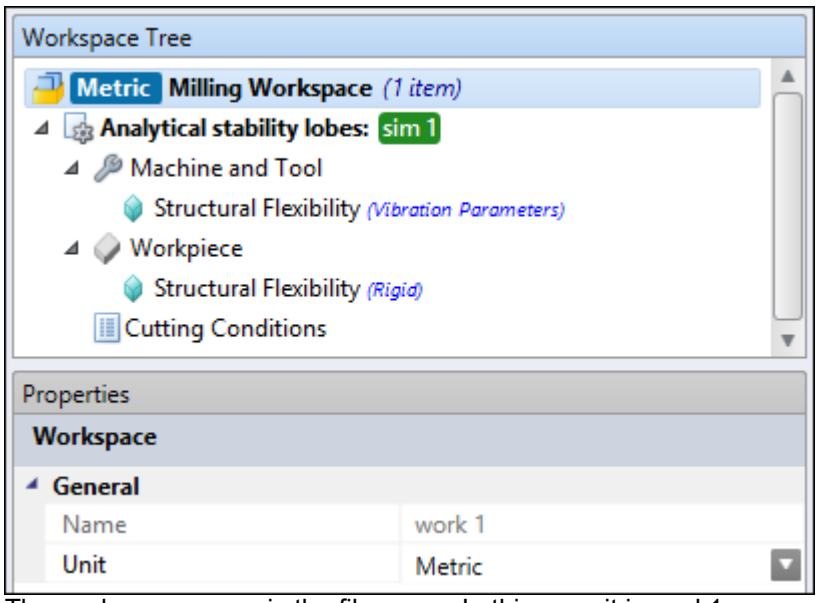
Simulation

The “Simulation Workspace Tree” uses a top-to-bottom workflow process, and there are a
few main tabs which require attention in milling (for example):

- **Workspace** Define the name and unit system
- **Simulation mode** Milling analysis
- **Machine & Tool** Tooling geometries/orientation and properties
  - **Structural Flexibility** Flexibility data for the Machine & Tool structure
- **Workpiece** Material properties during machining
  - **Structural Flexibility** Flexibility data for the Workpiece/Fixture structure
- **Cutting Conditions** Speeds, feeds, engagement and operation parameters

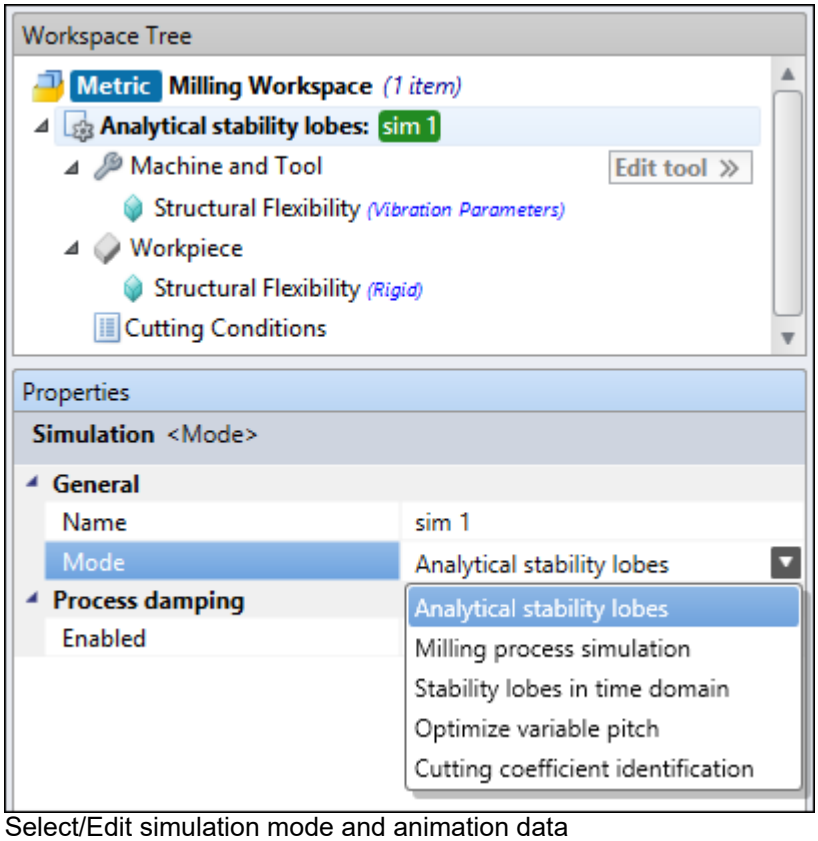
Results Plots of information obtained from the simulations

Workspace



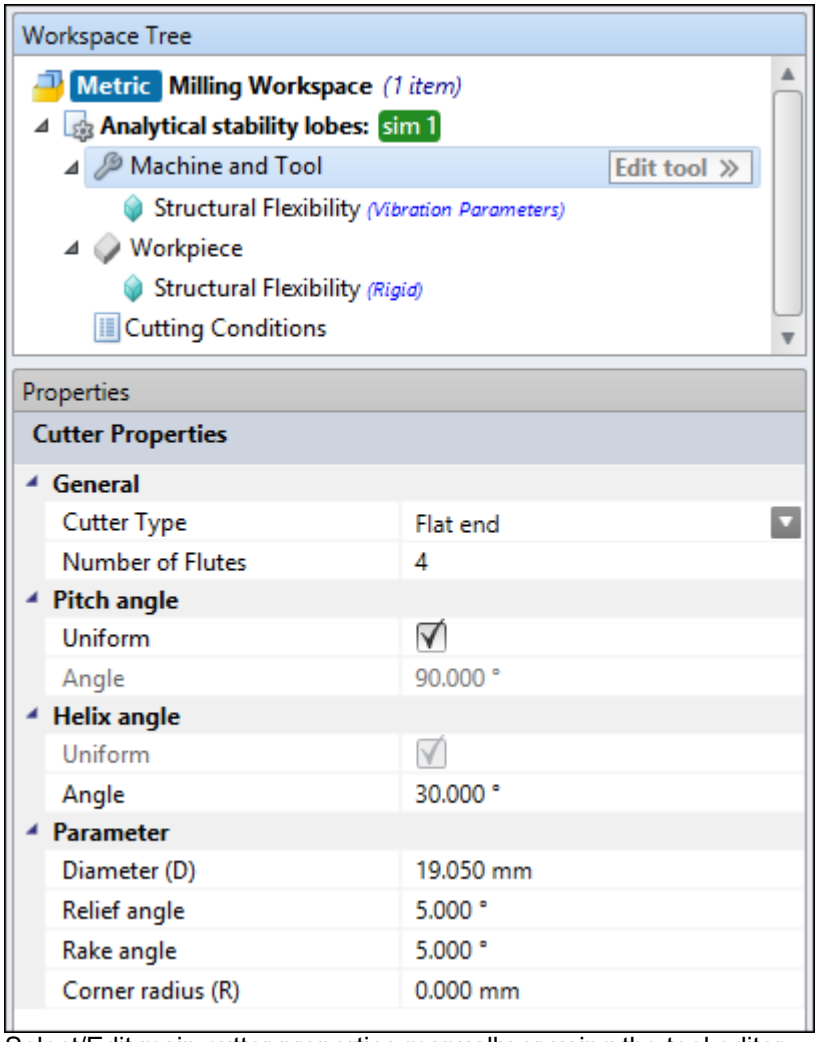
The workspace name is the file name. In this case it is work1.cws

Simulation mode



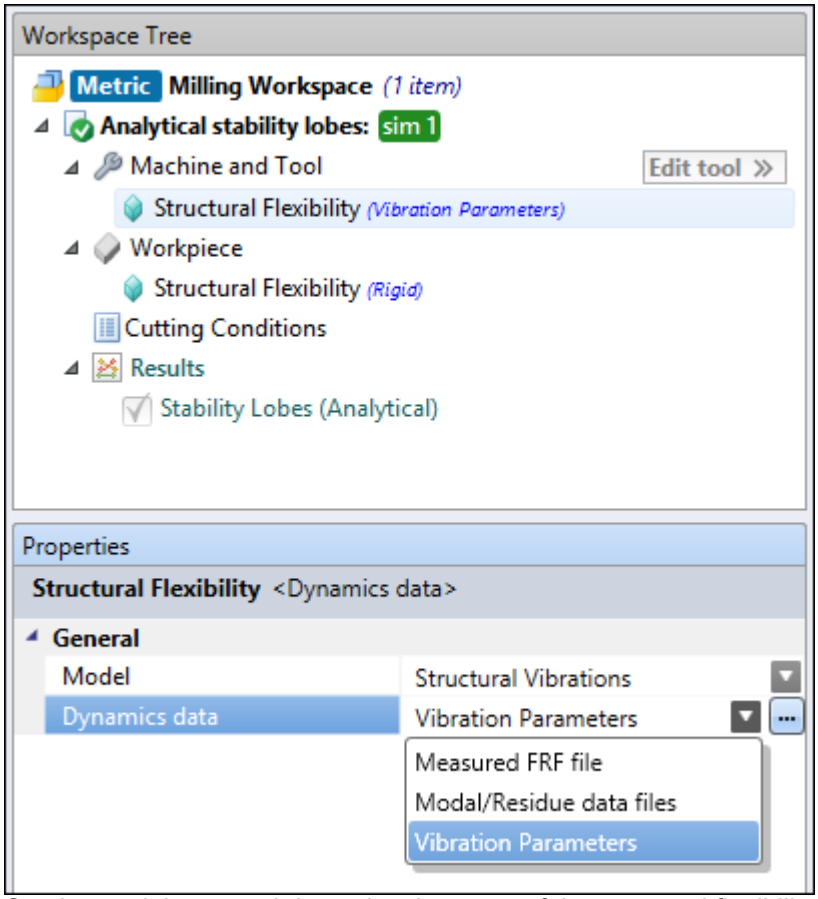
Select/Edit simulation mode and animation data

Machine & Tool



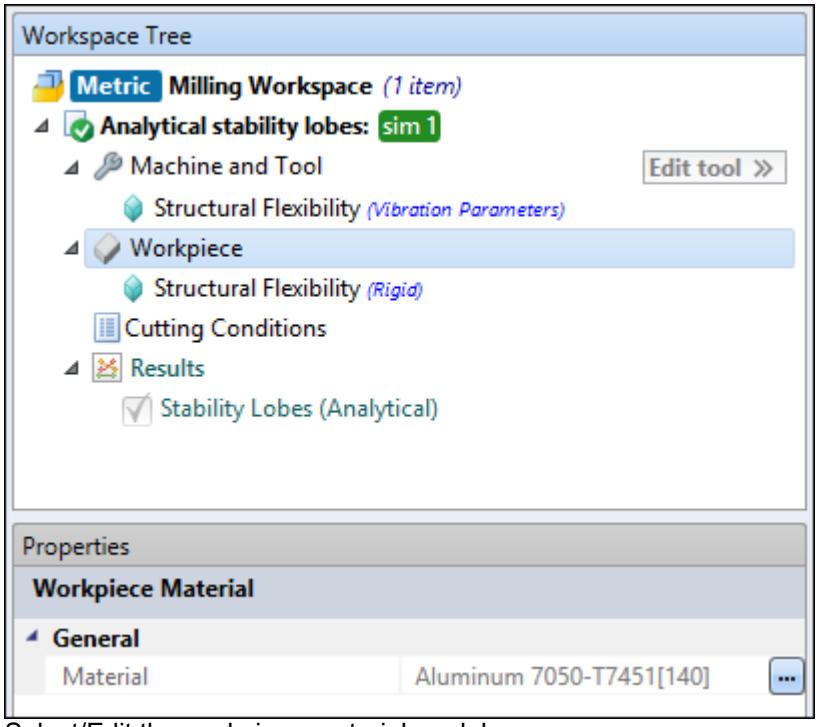
Select/Edit main cutter properties manually or using the tool editor

Structural Flexibility (Machine & Tool)



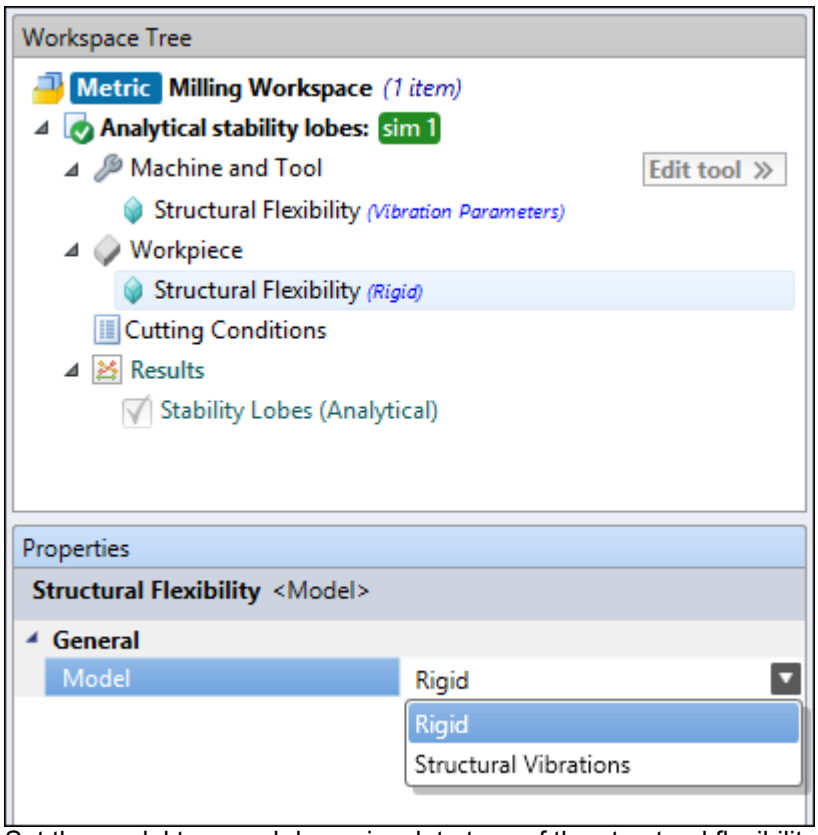
Set the model type and dynamics data type of the structural flexibility

Workpiece



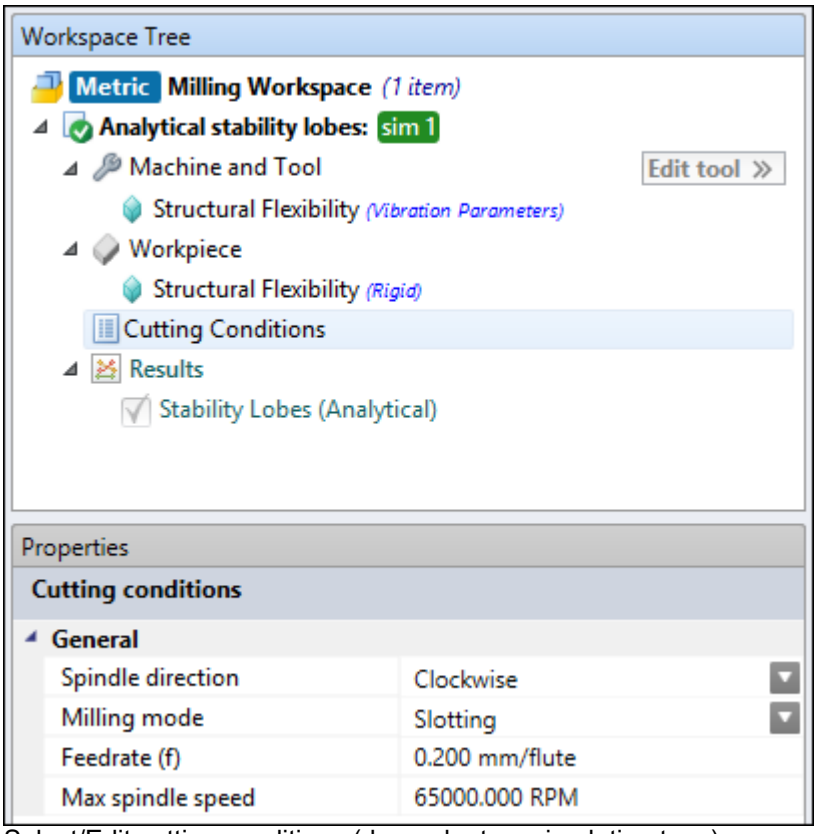
Select/Edit the workpiece material model

Structural Flexibility (Workpiece)



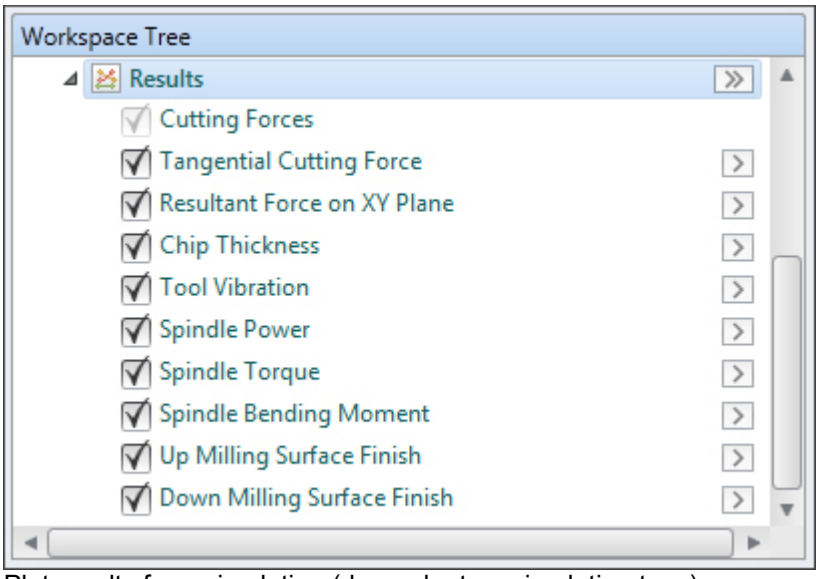
Set the model type and dynamics data type of the structural flexibility

Cutting Conditions



Select/Edit cutting conditions (dependant on simulation type)

Results



Plot results from simulation (dependant on simulation type)

1.4.3 Modules

manufacturing automation laboratories CUTPRO

CutPro Modules

CutPro comes with various package options known as Modules, the user can customize their own package option:

Each module has it's own manual

CutPro: Milling Simulation: Simulates milling operations (cutpro.exe)
See http://www.malinc.com/products/cutpro/milling/ for an introductory description

CutPro: Boring/Turning Simulation: Simulates boring/turning operations (cutpro.exe)
See http://www.malinc.com/products/cutpro/boringturning/ for an introductory description.

CutPro: Drilling Simulation: Simulates drilling operations (cutpro.exe)
See http://www.malinc.com/products/cutpro/drilling/ for an introductory description.

CutPro: Modal Analysis (MODAL): Analysis of tap testing data (modal.exe)
See http://www.malinc.com/products/cutpro/modal-analysis/ for an introductory description

CutPro: Tap Testing (MALTF): Plots data done from a tap test (maltf.exe)
See http://www.malinc.com/products/cutpro/maltf/ for an introductory description.

CutPro: Data Acquisition (MALDAQ): Records data from experimentation (maltf.exe)
See http://www.malinc.com/products/cutpro/maldaq/ for an introductory description.

1.4.4 Tabs

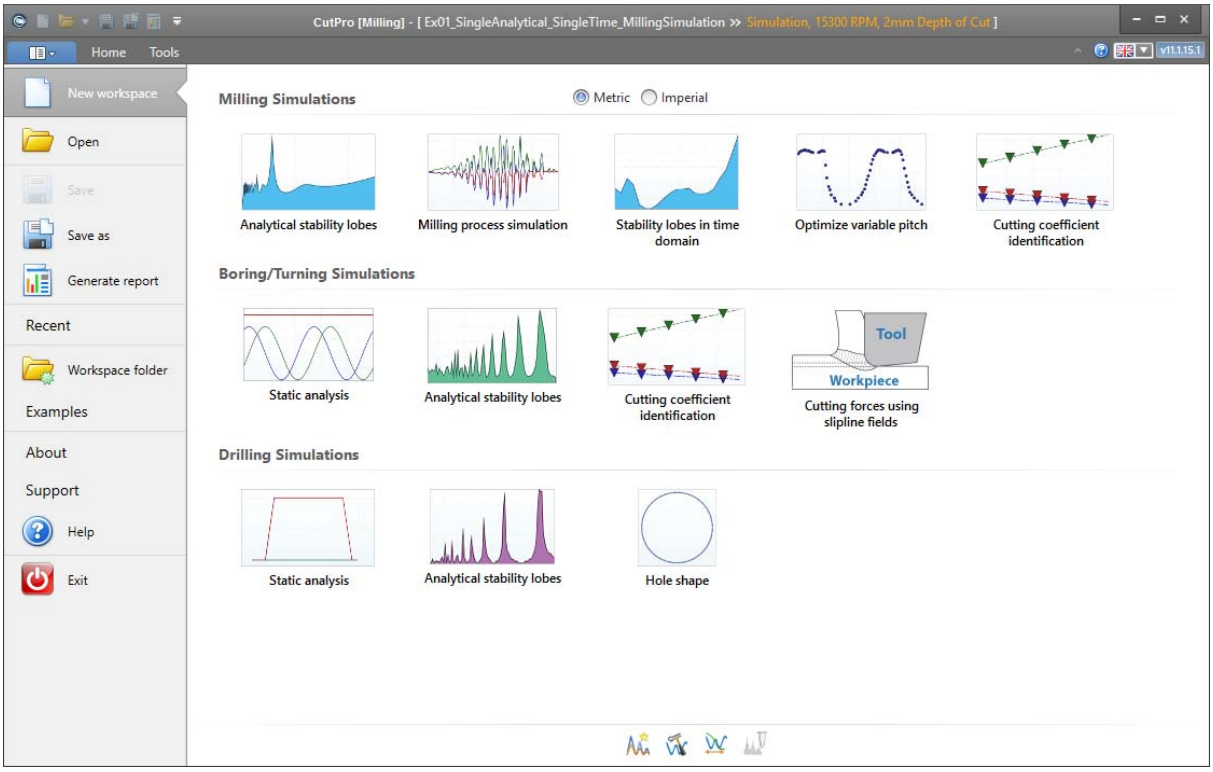
manufacturing automation laboratories CUTPRO

Tabs

CutPro consists of three main tabs:

- File tab (Book Icon)
- Home tab
- Tools tab

File Tab

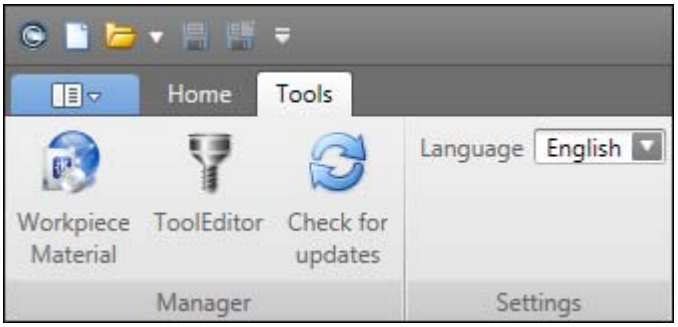


- Quick access to file management
- Report Generator
- Workspace creation with unit selection
- Example workspaces
- Support
- Help

Home Tab:

- Used to control simulations and result plots
- Quick-access to CutPro Modules
- Quick-access to technical support within CutPro

Tools Tab:



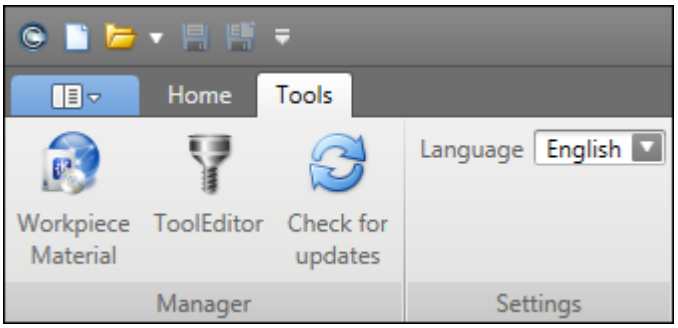
- Managers
- Language Settings.

1.4.5 Managers

manufacturing automation laboratories CUTPRO

Managers

Accessed under the "Tools", the Manager section is mainly used for managing workpiece material definitions and cutting tool files in your tool library



The Workpiece material manager is the central location in CutPro for defining materials and their properties.
Using this function the user can simply load a pre-existing material inside a project rather than creating it on-the-fly.

The Tool Editor is used to define and save tool geometry / tools, or perform receptance coupling.
Using this function the user can simply load a pre-existing tool inside a project rather than creating it on-the-fly.

The Check for Updates will do just that, it will notify the user if there is a new CutPro Version and Installation available.
CutPro does this automatically, however if you select "Remind me later", you will have to manually update CutPro using this button.

1.4.6 Buttons, Keyboard shortcuts & Warning symbols

manufacturing automation laboratories CUTPRO

Buttons, Keyboard shortcuts & Warning symbols

Home tab buttons

Start: Runs the selected simulation

Add: Add a new simulation in the active workspace

Remove: Removes selected simulation in the active workspace

Duplicate: Duplicates selected simulation in the active workspace

Plot Results: Plots all results from selected simulation

Plot: Plot selected result from simulation

Export: Export select plot as a (*.csv) file in desired location

Export All: Exports all plots to (*.csv) files in desired location

Close all plots: Removes the plots from the Plot Window (does not delete plot)

Tabs: Results plots are laid out in tabs

Multi-windows: Result plots are laid out in seperate windows

Helpdesk: Integrated CutPro support. Click to submit support tickets on-the-fly.

Tools tab buttons

Workpiece Material Manager: Allows the user to define materials

Tool Editor: Allows the user to define cutting tools in a tool database

Check for Updates: Manually check for software updates (CutPro does this during start-up)

Language: Select the desired language for CutPro

Main Function buttons

File Tab: Quick access to file management

Checkbox: Allow/Deny added functions

Dropdown Menu: Select appropriate property from list

Plot: Plots single result graph

Plot All: Plots all results

Plot Function buttons

Cursor: Observe chart

Pan: Pan chart

Zoom horizontal: Zoom in X axis only

Zoom vertical: Zoom in Y axis only

Zoom box: Select boxed area to zoom (Zoom XY)

Reset zoom: Reset chart to original status

Save chart: Saves the active plot

Clipboard Cut: Copies the active plot

Print Chart: Prints the active plot

Feed **Active axis**: Allows user to select this axis

Feed **Inactive axis**: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

TRACK OFF **Track**: Shows the cursor location values

FFT OFF **FFT**: Takes a Fast Fourier Transform of the graph

Harmonics OFF **Harmonics**: Displays the harmonics (harmonic frequencies) of the selected frequency

Workpiece Material Manager buttons

Unit toggle: Toggles unit system between Metric/Imperial

Close **Close**: Closes the workpiece material manager

New category: Creates a new material category

Delete category: Deletes a material category

New **New material**: Creates a new material

Delete **Delete material**: Deletes a material

Apply **Apply changes**: Accept changes

Cancel **Cancel**: Deny changes/cancel window

Drop-down Menu: Select appropriate property from list

Checkbox: Allow/Deny added functions

Collapse Menu: Hides/Shows menu

Right-click Function buttons

Right click on Plot: Panning, zooming, chart reset, save, copy and print.

Double Right click on Surface Finish Plot: View surface finish plotted on planes

Right click on Simulation: Start, remove or duplicate

Right click on Results: Exports all results as (*csv) file

Right click on Result: Exports selected result as (*csv) file

Keystroke Shortcuts

Start: Ctrl + R

Add: Ctrl + A

Remove: Ctrl + D

Duplicate: Ctrl + K

Warning Symbols

Warning: A warning note regarding the task at hand

Error: Input not valid

Simulation Warning: Simulation properties have changed

CutPro Modules

2 CutPro Modules

manufacturing automation laboratories CUTPRO

CutPro Modules

CutPro comes with various package options known as Modules, the user can customize their own package option:

Each module has it's own manual

CutPro: Milling Simulation: Simulates milling operations (cutpro.exe)
See http://www.malinc.com/products/cutpro/milling/ for an introductory description

CutPro: Boring/Turning Simulation: Simulates boring/turning operations (cutpro.exe)
See http://www.malinc.com/products/cutpro/boringturning/ for an introductory description.

CutPro: Drilling Simulation: Simulates drilling operations (cutpro.exe)
See http://www.malinc.com/products/cutpro/drilling/ for an introductory description.

CutPro: Modal Analysis (MODAL): Analysis of tap testing data (modal.exe)
See http://www.malinc.com/products/cutpro/modal-analysis/ for an introductory description

CutPro: Tap Testing (MALTF): Plots data done from a tap test (maltf.exe)
See http://www.malinc.com/products/cutpro/maltf/ for an introductory description.

CutPro: Data Acquisition (MALDAQ): Records data from experimentation (maldaq.exe)
See http://www.malinc.com/products/cutpro/maldaq/ for an introductory description.

2.1 Milling Simulation

manufacturing automation laboratories CUTPRO

CutPro: Milling Simulation - Overview

The “Simulation Workspace Tree” uses a top-to-bottom workflow process, and there are a
few main tabs which require attention in milling (for example):

Workspace Define the name and unit system

Simulation mode Analytical stability, milling process simulation, stability lobes in time domain, optimize variable pitch & cutting coefficient

identification

- **Machine & Tool** Tooling geometries/orientation and properties
  - **Structural Flexibility** Flexibility of the tool, holder, spindle and machine
- **Workpiece** Material properties
  - **Structural Flexibility** Flexibility of the workpiece / fixture setup
- **Cutting Conditions** Speeds, feeds, and operation parameters
- **Results** Plots of information obtained from the simulation

2.1.1 Workspaces

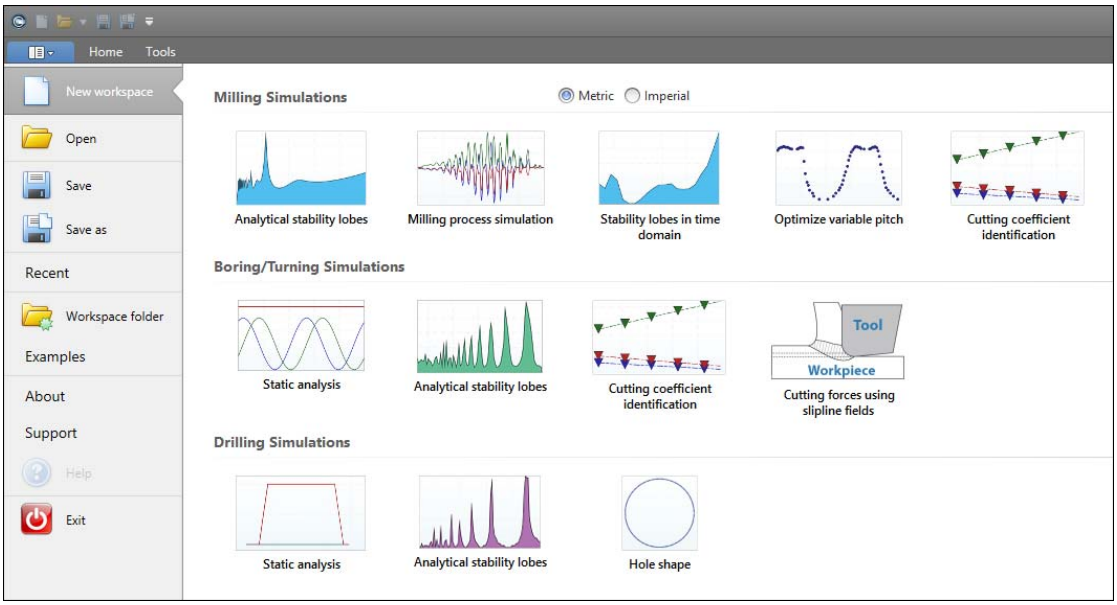
manufacturing automation laboratories CUTPRO

Workspace - Overview

In CutPro the user can define what is called a "Workspace".
Inside of this workspace file (*.cws) one can perform multiple simulations simultaneously and compare them to one-another.

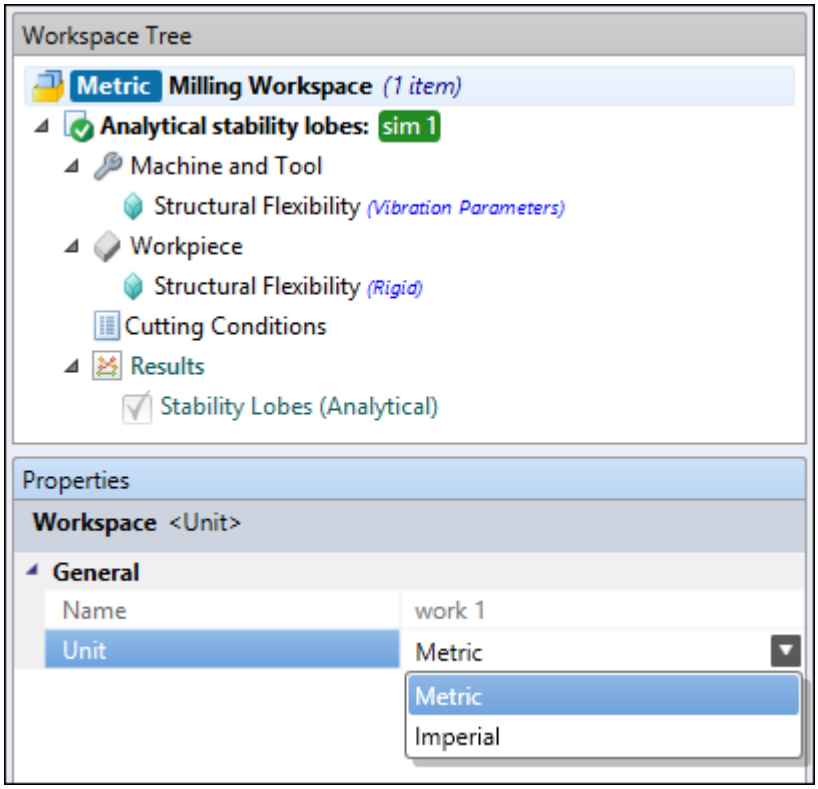
Creating, opening and saving a workspace

A workspace may be managed under the file tab, here you may also define the unit system of preference:



Unit system in CutPro

Both Metric and Imperial unit systems for a workspace can be swapped/converted anytime:

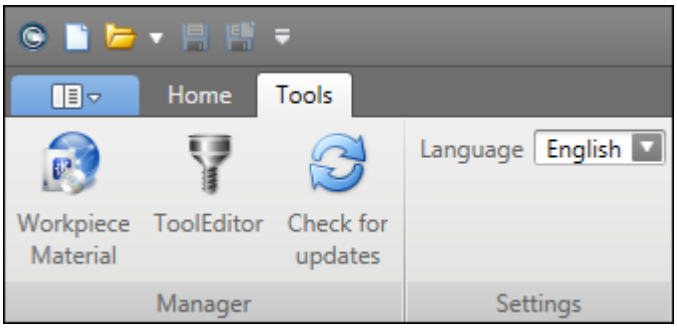


2.1.2 Managers

manufacturing automation laboratories CUTPRO

Managers - Overview

Accessed under the "Tools", the Manager section is mainly used for managing workpiece material definitions and cutting tool files in your tool library



The Workpiece material manager is the central location in CutPro for defining materials and their properties.
Using a material added with this function, the user can simply load their desired material into a project.

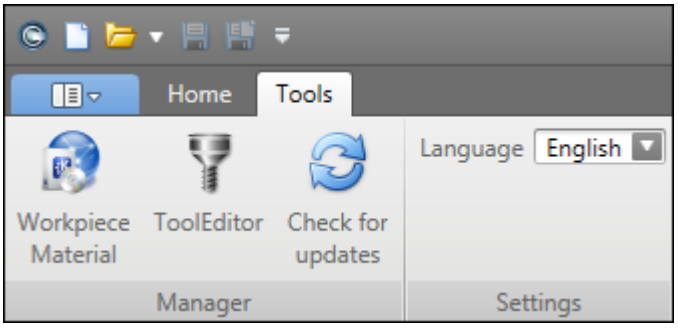
The Tool Editor is used to define and save tool geometry / tools, or perform receptance coupling.
Using this function the user can simply load a pre-existing tool inside a project rather than creating it on-the-fly.

The Check for Updates will do just that, it will notify the user if there is a new CutPro Version and Installation available.
CutPro does this automatically, however if you select "Remind me later", you will have to manually update CutPro using this button.

2.1.2.1 Workpiece Material Manager

manufacturing automation laboratories CUTPRO

Workpiece Material Manager - Overview

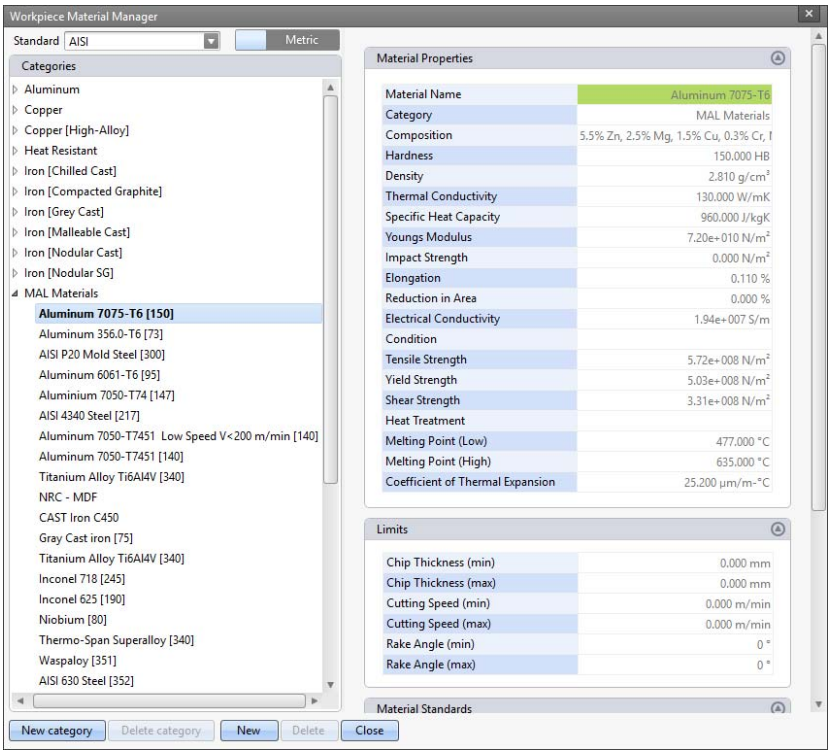


The Workpiece Material Manager contains two general category of workpiece definitions:

- Standardized workpiece materials (Pre-existing, with CutPro installation)
  Ex. Aluminum 7050-T6 (AISI Standard Material)
- User-defined workpiece materials (New: Defined by the Customer or by MAL through material characterization services)
  Ex. Secret in-house material

Regardless of which category of material you are using, the following information and data is present.

- Material properties(1)
- Coefficient parameters(2)(3)
- Limits(4)
- Material Standards



(1) **Material properties** are only used for reference, these properties are not meaningful for machining simulation

(2) **Coefficient parameters** are only shown for user-defined workpiece materials

(3) **Coefficient parameters** are the only numbers entered into the Material Manager which change simulation results--they are essential for accurate simulations

(4) **Limits** affect the range in which the force model was created, however these entries are not used within CutPro calculations.

2.1.2.1.1 Material properties

manufacturing automation laboratories CUTPRO

Material properties

The *"Material Properties"* tab displays the specifications of the material given in either unit system:

- Material Properties [Metric units]
- Material Properties [Imperial units]

**Units may be toggled at any time in the Workpiece Material Manager*

Material Properties

Material Name	
Category	MAL Materials
Composition	
Hardness	0.000 HB
Density	0.000 g/cm³
Thermal Conductivity	0.000 W/mK
Specific Heat Capacity	0.000 J/kgK
Youngs Modulus	0.000 N/m²
Impact Strength	0.000 N/m²
Elongation	0.000 %
Reduction in Area	0.000 %
Electrical Conductivity	0.000 S/m
Condition	
Tensile Strength	0.000 N/m²
Yield Strength	0.000 N/m²
Shear Strength	0.000 N/m²
Heat Treatment	
Melting Point (Low)	0.000 °C
Melting Point (High)	0.000 °C
Coefficient of Thermal Expansion	0.000 µm/m-°C

Purpose

The *"Material Properties"* section is primarily used for reference in order to better understand how the material behaves. These properties are not used in CutPro's engine, this is due to the fact that many tests used to identify these properties are far different than machining. For example, the strain rates of the material under machining are extremely high in comparison to that of a tensile test.

2.1.2.1.1.1 Metric units

manufacturing automation laboratories CUTPRO

Material properties - METRIC units

Material name

Category

Composition

Hardness [*HB*]

Density [*g/cm³*]

Thermal Conductivity [*W/mK*]

Specific Heat Capacity [*J/kgK*]

Youngs Modulus [*N/m²*]

Material Properties

Material Name	Aluminum 7075-T6
Category	MAL Materials
Composition	5.5% Zn, 2.5% Mg, 1.5% Cu, 0.3% Cr, I
Hardness	150.000 HB
Density	2.810 g/cm³
Thermal Conductivity	25.200 W/mK
Specific Heat Capacity	960.000 J/kgK
Youngs Modulus	7.20e+010 N/m²
Impact Strength	0.000 N/m²
Elongation	0.110
Reduction in Area [%]	0.000
Electrical Conductivity	1.94e+007 S/m
Condition	
Tensile Strength	5.72e+008 N/m²
Yield Strength	5.03e+008 N/m²
Shear Strength	3.31e+008 N/m²
Heat Treatment	
Melting Point (Low)	477.000 °C
Melting Point (High)	635.000 °C
Coefficient of Thermal Expansion	0.000 µm/m-°C

Impact Strength	[*N/m²*]
Elongation	
Reduction in Area	[*%*]
Electrical Conductivity	[*S/m*]
Condition	
Tensile Strength	[*N/m²*]
Yield Strength	[*N/m²*]
Shear Strength	[*N/m²*]
Heat Treatment	
Melting Point (Low)	[*°C*]
Melting Point (High)	[*°C*]
Coefficient of Thermal Expansion	[*µm/m-°C*]

2.1.2.1.1.2 Imperial units

manufacturing automation laboratories CUTPRO

Material properties - IMPERIAL units

Material name

Category

Composition

Hardness [*HB*]

Density [*lb/in*^{3}]

Thermal Conductivity [*BTu/hr-ft°F*]

Specific Heat Capacity [*BTu/lb°F*]

Youngs Modulus [*lbf/ft*^{2}]

Impact Strength [*lbf/ft*^{2}]

Elongation

Reduction in Area [*%*]

Electrical Conductivity [*S/ft*]

Condition

Tensile Strength [*lbf/ft*^{2}]

Yield Strength [*lbf/ft*^{2}]

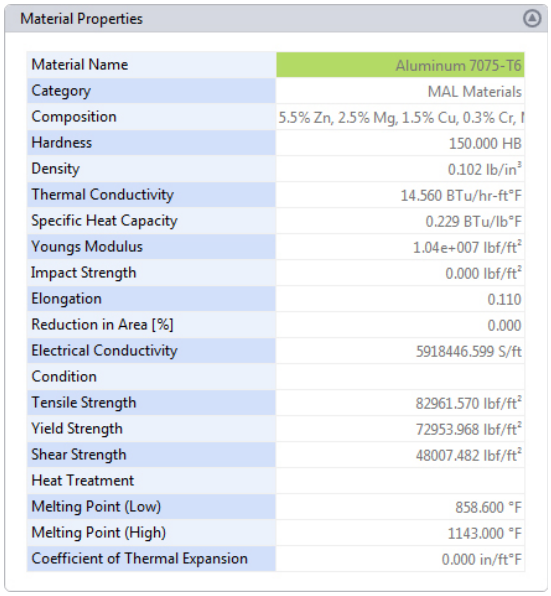
Shear Strength [*lbf/ft*^{2}]

Heat Treatment

Melting Point (Low) [*°F*]

Melting Point (High) [*°F*]

Coefficient of Thermal Expansion [*in/ft°F*]



Material Properties

Material Name	Aluminum 7075-T6
Category	MAL Materials
Composition	5.5% Zn, 2.5% Mg, 1.5% Cu, 0.3% Cr, I
Hardness	150.000 HB
Density	0.102 lb/in^3
Thermal Conductivity	14.560 BTu/hr-ft°F
Specific Heat Capacity	0.229 BTu/lb°F
Youngs Modulus	1.04e+007 lbf/ft^2
Impact Strength	0.000 lbf/ft^2
Elongation	0.110
Reduction in Area [%]	0.000
Electrical Conductivity	5918446.599 S/ft
Condition	
Tensile Strength	82961.570 lbf/ft^2
Yield Strength	72953.968 lbf/ft^2
Shear Strength	48007.482 lbf/ft^2
Heat Treatment	
Melting Point (Low)	858.600 °F
Melting Point (High)	1143.000 °F
Coefficient of Thermal Expansion	0.000 in/ft°F

2.1.2.1.2 Coefficient parameters

manufacturing automation laboratories CUTPRO

Coefficient parameters

The *"Coefficient parameters"* tab offers 9 different force models which may be used to characterize user-defined materials.

METRIC Units

- Average cutting coefficient model
- Orthogonal to oblique model
- Exponential chip thickness model
- Semi-mechanistic model
- Sandvik model
- Kienzle model
- Rake face model

**Imperial Units are not supported for Force Models*

Coefficient Parameters

Force Model	Rake Face Model
Kte (N/mm)	24.76
Kre (N/mm)	27.36
Kae (N/mm)	0
Ku (N/mm²)	1000.78
Kv (N/mm²)	1526.5514

Purpose

The *"Coefficient parameters"* section is used for defining a *force model* for a user material(1). The *force model* consists of constants or equations that are used in CutPro's engine. Using dynamometers and experiments, the material is machined and force data is collected. This data i used in constructing a *force model* which characterizes how the material behaves under various machining conditions. The model is then used to calculate cutting forces, torque, power and so on. If there are any inaccuracies with this model (material characterization), the simulations in CutPro will be completely wrong. If you are working with your own custom material and are not familiar with the science behind this, we encourage customers to contact MAL Inc for assistance.

(1) **Coefficient parameters** are only shown for user-defined workpiece materials

2.1.2.1.2.1 Average cutting coefficient model [Metric]

manufacturing automation laboratories CUTPRO

Average cutting coefficient model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$

$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$

$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]

2.1.2.1.2.2 Orthogonal to oblique model [Metric]

manufacturing automation laboratories CUTPRO

Orthogonal to oblique model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$
$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$
$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{tc} = \frac{\tau}{\sin \varphi_n} \frac{\cos(\beta_n - \alpha_n) + \tan \eta_c \sin \beta_n \tan i}{c}$$
$$K_{rc} = \frac{\tau}{\sin \varphi_n \cos i} \frac{\sin(\beta_n - \alpha_n)}{c}$$
$$K_{ac} = \frac{\tau}{\sin \varphi_n} \frac{\cos(\beta_n - \alpha_n) \tan i - \tan \eta_c \sin \beta_n}{c}$$
$$c = \sqrt{\cos^2(\varphi_n + \beta_n - \alpha_n) + \tan^2 \eta_c \sin^2 \beta_n}$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]

τ ("t"): shear stress [N/mm²]	ϕ_n ("f"): shear angle [°]
β_n ("b"): friction angle [°]	α_n: rake angle [°]
η: chip flow angle [°]	*i*: helix angle [°]

2.1.2.1.2.3 Exponential chip thickness [Metric]

manufacturing automation laboratories CUTPRO

Exponential chip thickness

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$

$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$

$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{te} = K_{re} = K_{ae} = 0.0$$

$$K_{tc} = KT \cdot h^{-p}$$

$$K_{rc} = KR \cdot KT \cdot h^{-q}$$

$$K_{ac} = KA \cdot KT \cdot h^{-r}$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]

dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]
KT : tangential shearing coef. parameter	p : tangential chip thickness order
KR : radial shearing coef. parameter	q : radial chip thickness order
KA : axial shearing coef. parameter	r : axial chip thickness order

2.1.2.1.2.4 Semi-mechanistic model [Metric]

manufacturing automation laboratories CUTPRO

Semi-mechanistic model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$
$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$
$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{te} = K_{re} = K_{ae} = 0.0$$
$$K_{tc} = k_n \left[\cos\alpha_n + k_f \cos\eta \sin\alpha_n + k_f \tan i \sin\eta \right]$$
$$K_{rc} = k_n \left[-\frac{\sin\alpha_n}{\cos i} + k_f \cos\alpha_n \frac{\cos\eta}{\cos i} \right]$$
$$K_{ac} = k_n \left[\tan i \cos\alpha_n - k_f \sin\eta + k_f \tan i \cos\eta \sin\alpha_n \right]$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]
α_n: rake angle [°]	k_n : cutting pressure on rake face

i: helix angle [°]	k_f : cutting pressure rate on flank face
η: chip flow angle [°]	

2.1.2.1.2.5 Sandvik model [Metric]

manufacturing automation laboratories CUTPRO

Sandvik force model

Equations:

$$dF_t = K_{tc} * h * dz$$
$$dF_r = K_{rc} * h * dz$$
$$dF_a = K_{ac} * h * dz$$
$$K_{tc} = K_t * h^{-p}$$
$$K_{rc} = K_c * h^{-q}$$
$$K_{ac} = K_r * h^{-r}$$

Parameters:

dF_t : differential tangential force [N]	
dF_r : differential radial force [N]	
dF_a : differential axial force [N]	
	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]

2.1.2.1.2.6 Kienzle model [Metric]

manufacturing automation laboratories CUTPRO

Kienzle force model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$

$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$

$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{te} = K_{re} = K_{ae} = 0.0$$

$$K_{tc} = K_u(\sin\eta \sin i + \cos\eta \cos i \sin\alpha_n) + K_v(\cos\alpha_n \cos i)$$

$$K_{rc} = K_u(\cos\alpha_n \cos\eta) - K_v \sin\alpha_n$$

$$K_{ac} = K_u(-\sin\eta \cos i + \cos\eta \sin i \sin\alpha_n) + K_v(\cos\alpha_n \sin i)$$

$$K_u = K_{u_{1.1}} h^{(-u)}$$

$$K_v = K_{v_{1.1}} h^{(-v)}$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]

dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]
α_n: rake angle [°]	K_u : cutting pressure parallel to rake face
i: helix angle [°]	K_v : cutting pressure normal to rake face
η: chip flow angle [°]	$K_{u1.1}$: Coefficient parallel to rake face
u: parallel to rake face chip thickness order	$K_{v1.1}$: Coefficient normal to rake face
v: normal to rake face chip thickness order	

2.1.2.1.2.7 Rake face model [Metric]

manufacturing automation laboratories CUTPRO

Rake face force model

Equations:

$$dF_u = K_u h\, dz$$

$$dF_v = K_v h\, dz$$

$$\begin{bmatrix} dF_r \\ dF_t \\ dF_a \end{bmatrix} = [A] \begin{bmatrix} dF_u \\ dF_v \end{bmatrix} + dS \begin{bmatrix} K_{re} \\ K_{te} \\ K_{ae} \end{bmatrix}$$

Parameters:

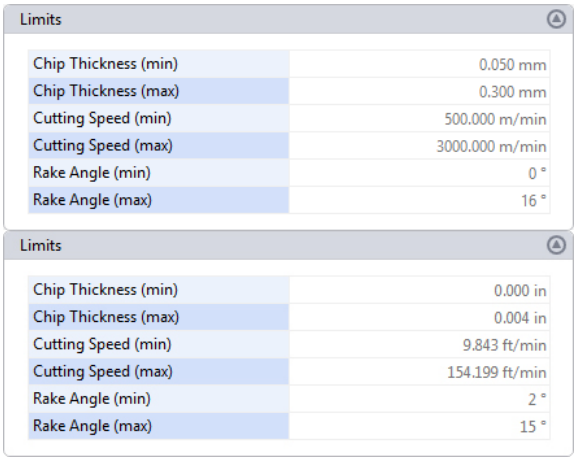
dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dF_u : differential friction force [N]	K_u : Friction coefficient on the rake face [N/mm^2]
dF_v : differential normal force [N]	K_v : Normal coefficient on the rake face [N/mm^2]
dz : differential axial depth of cut [mm]	h : chip thickness [mm]
dS : differential cutting edge length [mm]	A : Transformation matrix between the rake face CS and RTA CS

2.1.2.1.3 Limits

manufacturing automation laboratories CUTPRO

Limits

The *"Limits"* tab displays the limits of the material characterization given in either unit system:



Limits

Chip Thickness (min)	0.050 mm
Chip Thickness (max)	0.300 mm
Cutting Speed (min)	500.000 m/min
Cutting Speed (max)	3000.000 m/min
Rake Angle (min)	0 °
Rake Angle (max)	16 °

Limits

Chip Thickness (min)	0.000 in
Chip Thickness (max)	0.004 in
Cutting Speed (min)	9.843 ft/min
Cutting Speed (max)	154.199 ft/min
Rake Angle (min)	2 °
Rake Angle (max)	15 °

	Metric	Imperial
Chip Thickness	mm	in
Cutting Speed	m/min	ft/min
Rake Angle	°	°

**Units may be toggled at any time in the Workpiece Material Manager*

Purpose

The *"Limits"* section is used for defining the limits of user-defined material characterization models, or for viewing the limits of provided material characterization models. These values determine the conditions in which the material was characterized. For example, in the above test, perhaps the following was done:

Chip Thickness: 0.050 mm, 0.100 mm, 0.150 mm, 0.200 mm, 0.250 mm, 0.300 mm.
Rake Angles: 0°, 4°, 8°, 12°, 16°.
Cutting Speeds: 500 m/min, 1000 m/min, 1500 m/min, 2000 m/min, 2500 m/min, 3000 m/min

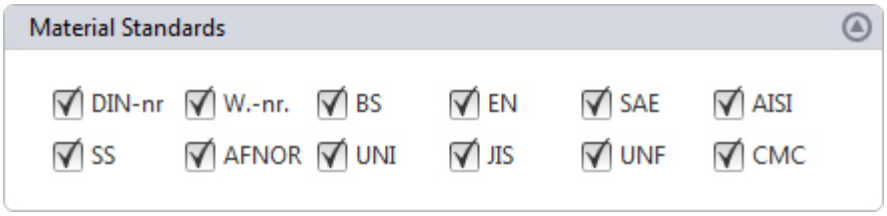
This allows the material to be defined for various feeds, rake angles and speeds. As a result, you can expect fully accurate simulations within these min and max ranges. If your simulation is out of range, for example rake 18, you can still expect to see a good accuracy. It is up to the user to decide how suitable the material limits are based on the application. If you require assistance on this topic, you can contact MAL's support team within CutPro.

2.1.2.1.4 Material standards

manufacturing automation laboratories CUTPRO

Material standards

The *"Material standards"* tab displays the material standards which the selected material belongs in, and changes the name of the material based on the selected standard. The following standards are available:



DIN-nr : German Institute for Standardization # (Deutsches Institut für Normung e.V.)
W.-nr. : German material number (Werkstoffnummer)
BS: British Standards
EN: European Committee for Standardization
SAE: Society of Automotive Engineers
AISI: American Iron and Steel Institute
SS: Swedish Standards Institute (Svensk Standard Standardisering)

AFNOR: French national organization for standardization (Association Française de Normalisation)

UNI: Italian National Standards Institute (Ente Nazionale Italiano di Unificazione)

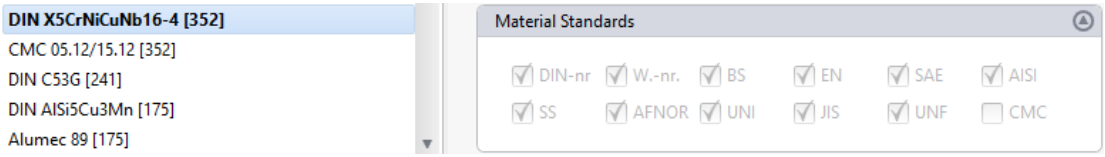
JIS: Japanese Industrial Standards (日本工業規格)

UNE: Spanish Material Standards (Una Norma Española)

CMC: Coromant Material Classification (Sandvik)

Purpose

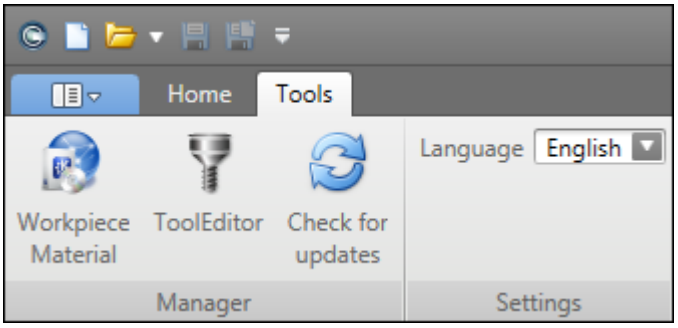
The *"Material standards"* section is simply used to filter materials by standards. Not every material is available in all standards, for example:



2.1.2.2 Tool Editor

manufacturing automation laboratories CUTPRO

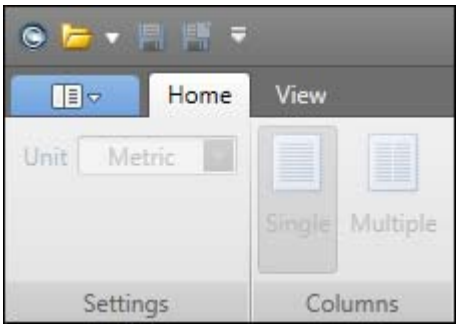
Tool Editor - Overview



The Tool Editor currently contains two ways to construct tools:

- Milling Cutters (Graphical interface for building tools easily)
- Receptance Coupling (Allows FRF coupling to construct a tool)

There are three Navigation tabs within the Tool Editor



- File Tab (Book Icon): Used is used for creating, opening and saving tools
- Home Tab: Used for editing tool geometry properties and managing tool files
- View Tab: Used for toggling view settings on/off

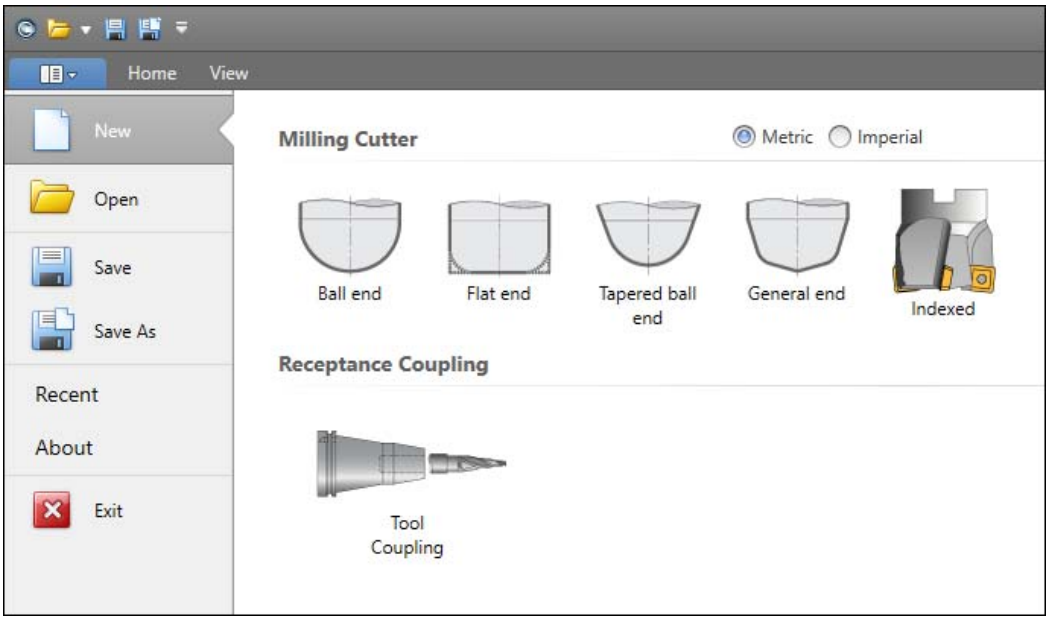
2.1.2.2.1 Milling Cutter

Tool Editor - Milling Cutter

There are 5 possible Milling tool types:

- Flat
- Ball-end
- Tapered ball-end
- General
- Indexed

Once the desired tool type is selected, you may begin entering parameters.

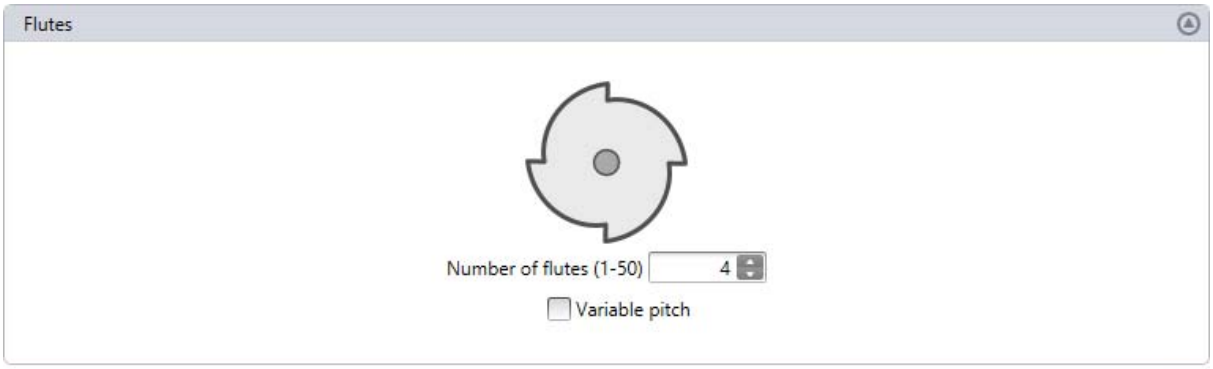


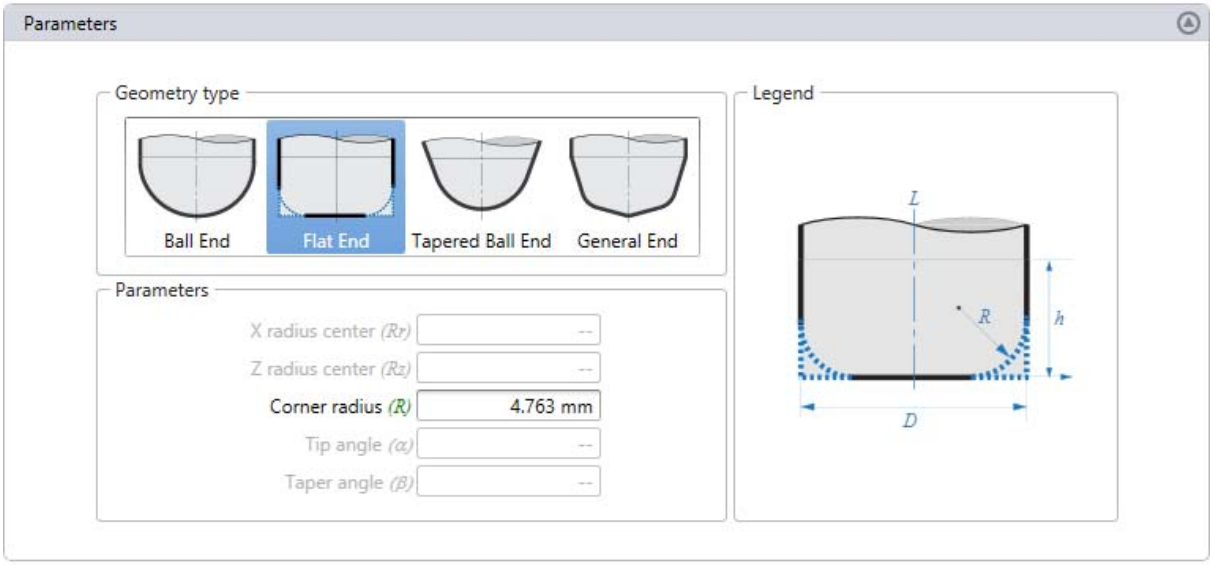
2.1.2.2.1.1 Flat

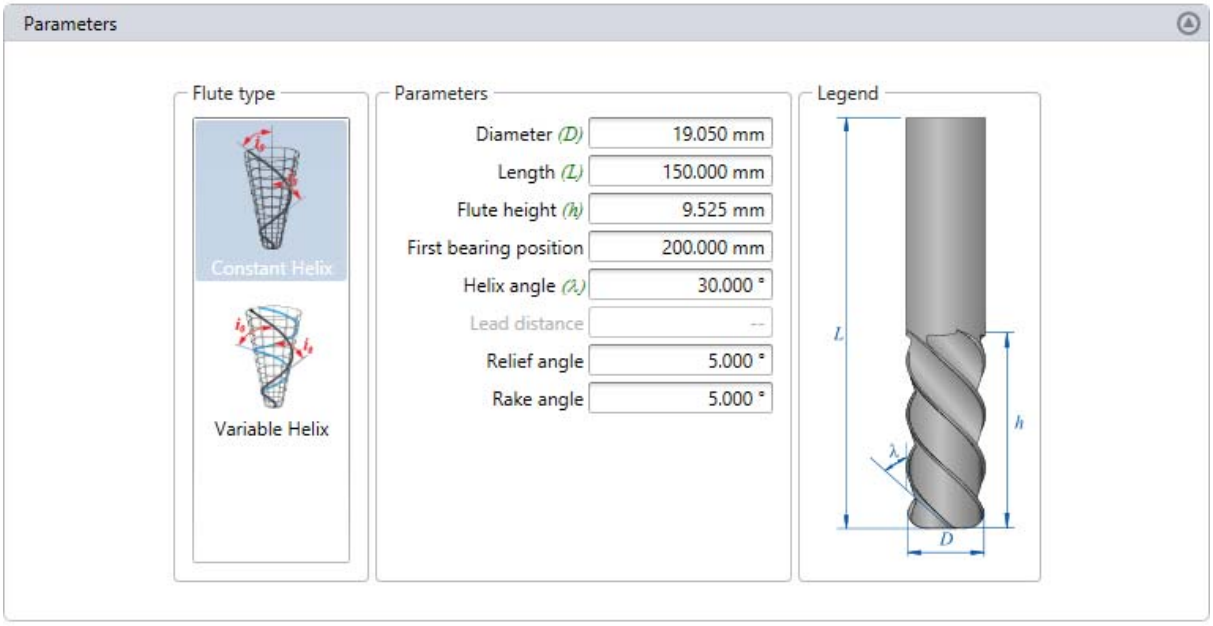
manufacturing automation laboratories CUTPRO

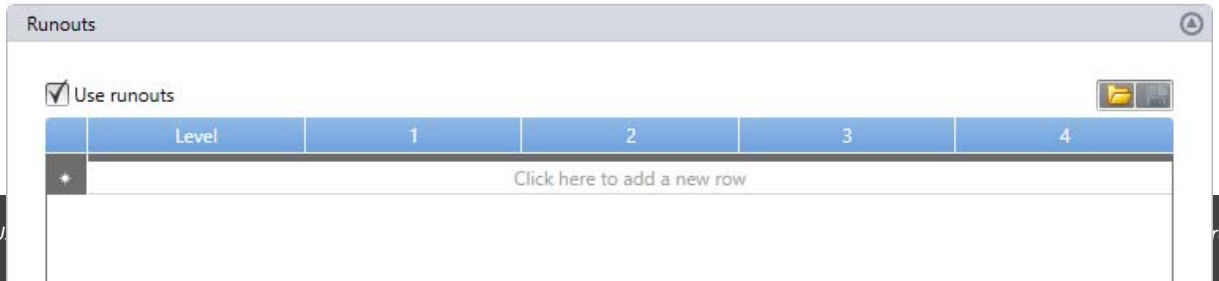
Tool Builder - Flat

The following options are available for a Flat tool:


Flutes
Number of flutes (1-50)
4
Variable pitch


Parameters
Geometry type
Ball End
Flat End
Tapered Ball End
General End
Parameters
X radius center (Rr)
Z radius center (Rz)
Corner radius (R)
4.763 mm
Tip angle (α)
Taper angle (β)
Legend
L
R
h
D


Parameters
Flute type
Constant Helix
Variable Helix
Parameters
Diameter (D)
19.050 mm
Length (L)
150.000 mm
Flute height (h)
9.525 mm
First bearing position
200.000 mm
Helix angle (λ)
30.000 °
Lead distance
Relief angle
5.000 °
Rake angle
5.000 °
Legend
L
h
λ
D

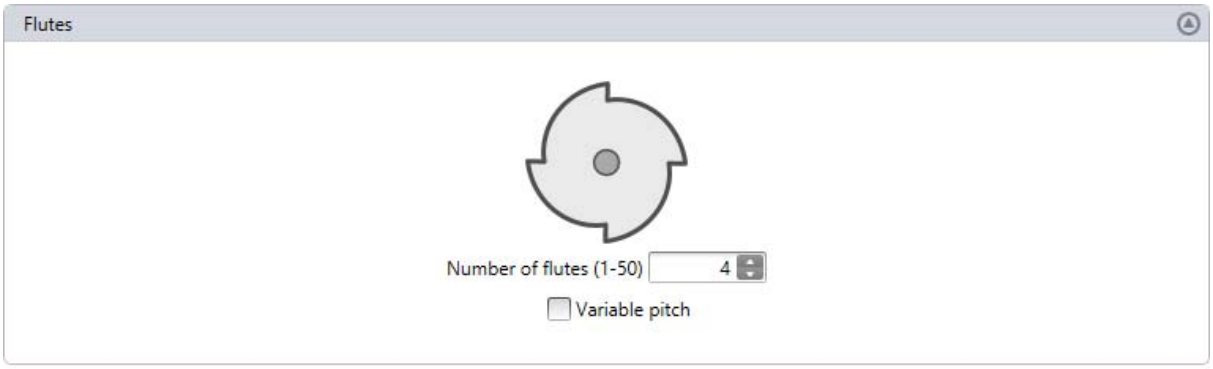

Runouts
Use runouts
Level
1
2
3
4
Click here to add a new row

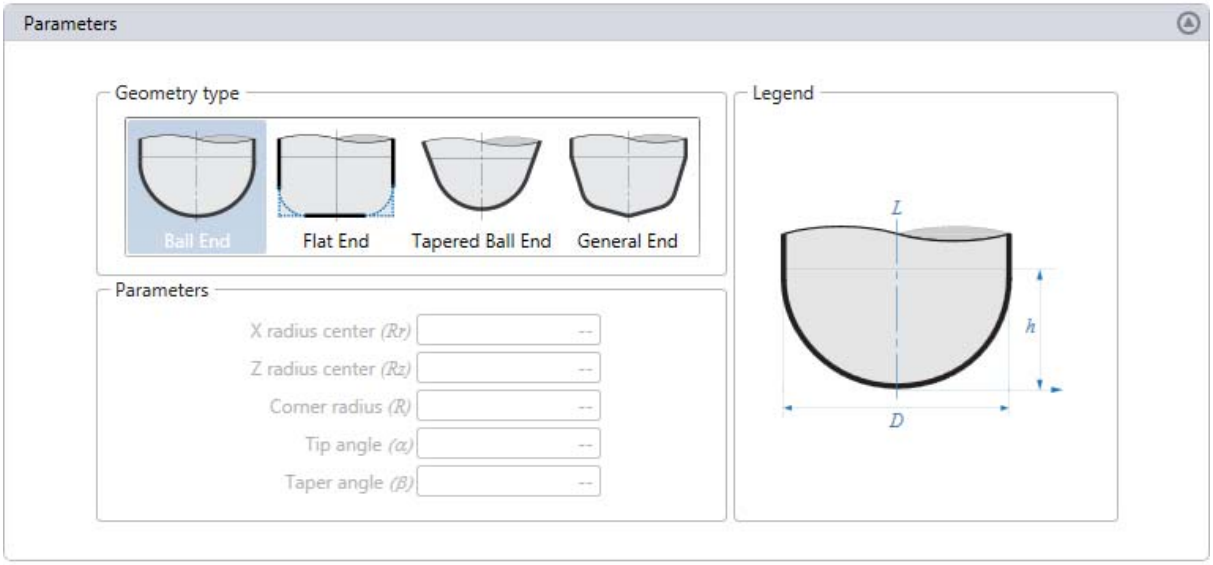
Check the Cutter properties/definitions page for further details

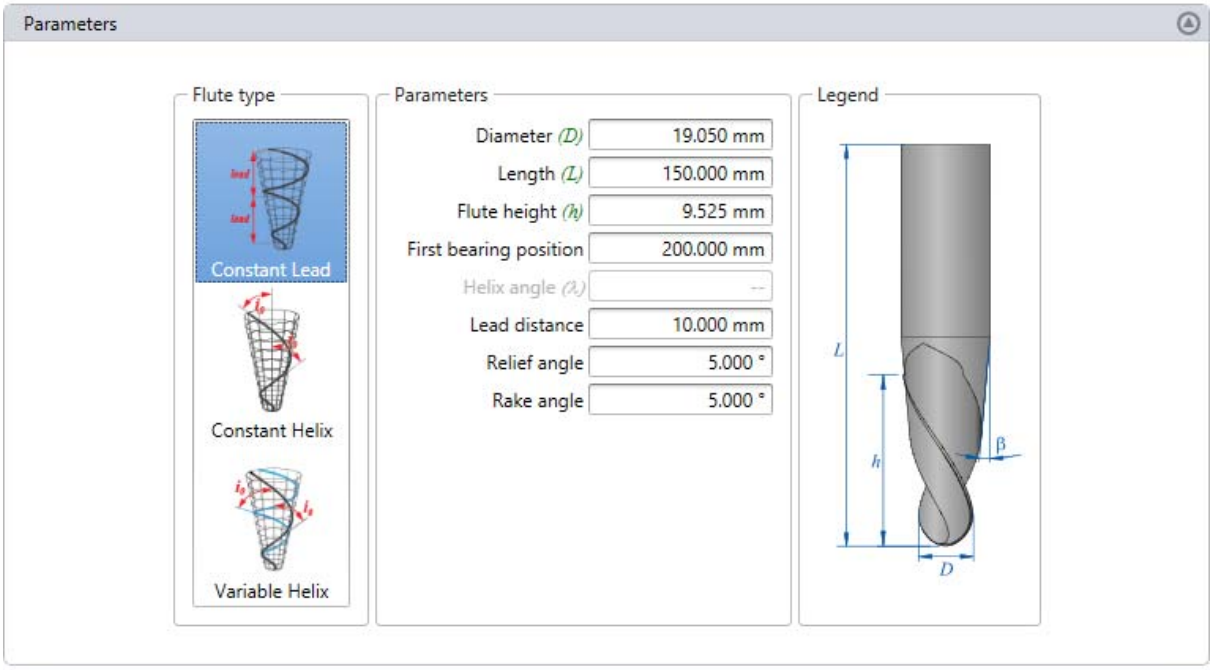
2.1.2.2.1.2 Ball-end

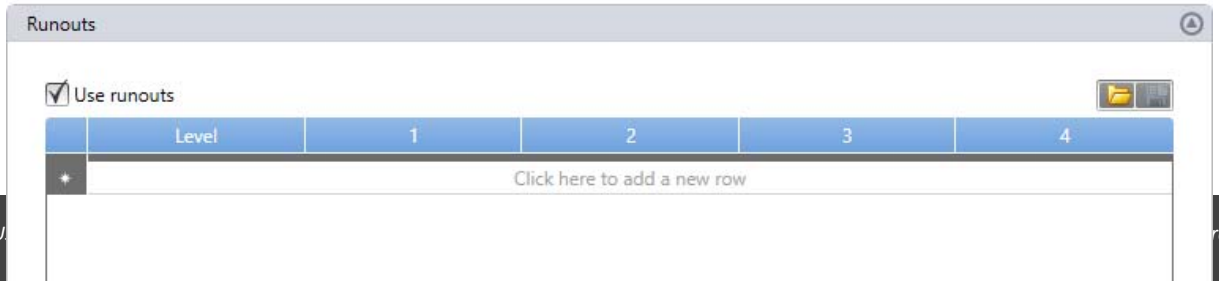
Tool Builder - Ball-end

The following options are available for a Ball-end tool:


Flutes
Number of flutes (1-50)
4
Variable pitch


Parameters
Geometry type
Ball End
Flat End
Tapered Ball End
General End
Parameters
X radius center (Rr)
Z radius center (Rz)
Corner radius (R)
Tip angle (α)
Taper angle (β)
Legend
L
h
D


Parameters
Flute type
Constant Lead
Constant Helix
Variable Helix
Parameters
Diameter (D)
19.050 mm
Length (L)
150.000 mm
Flute height (h)
9.525 mm
First bearing position
200.000 mm
Helix angle (λ)
Lead distance
10.000 mm
Relief angle
5.000 °
Rake angle
5.000 °
Legend
L
h
β
D

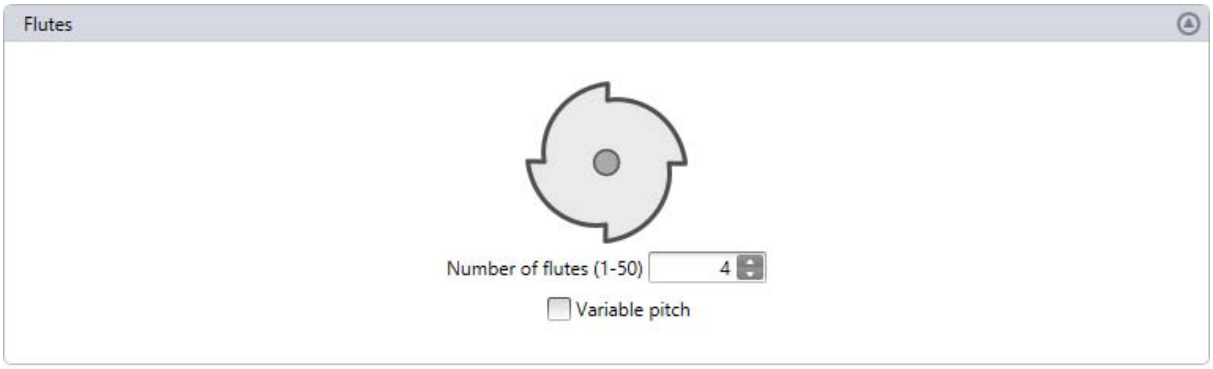

Runouts
Use runouts
Level
1
2
3
4
Click here to add a new row

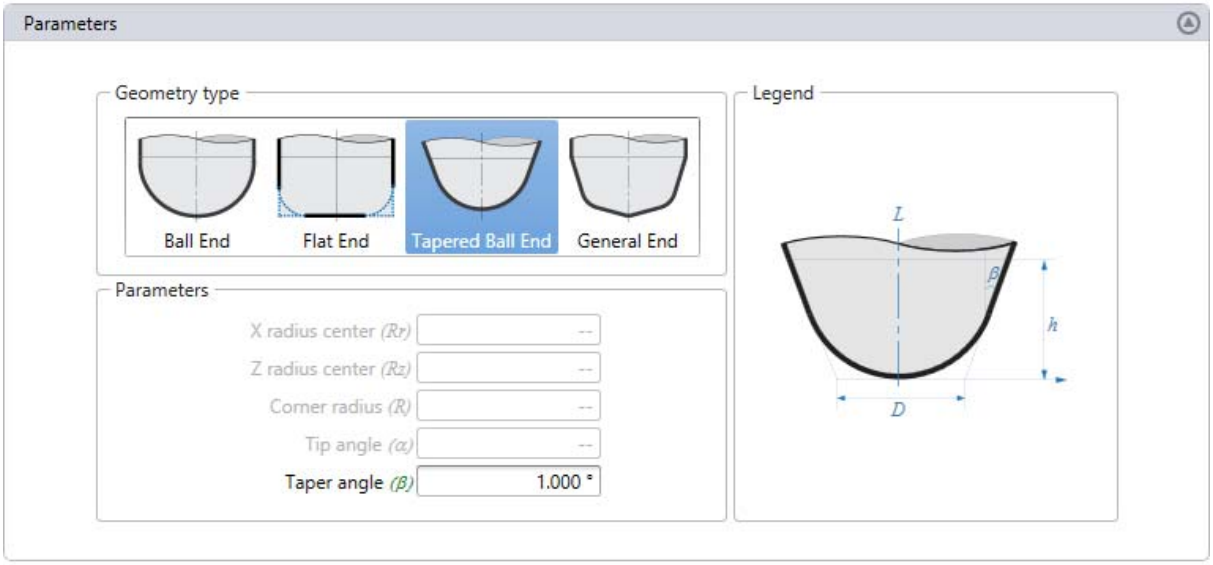
Check the Cutter properties/definitions page for further details

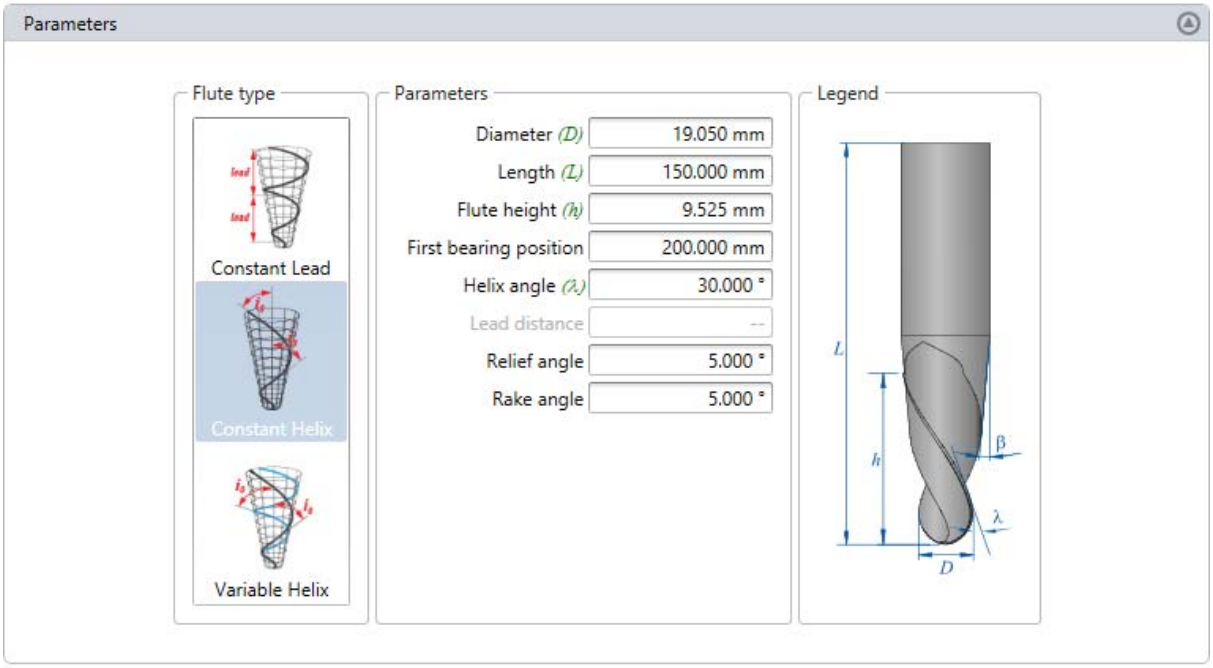
2.1.2.2.1.3 Tapered ball-end

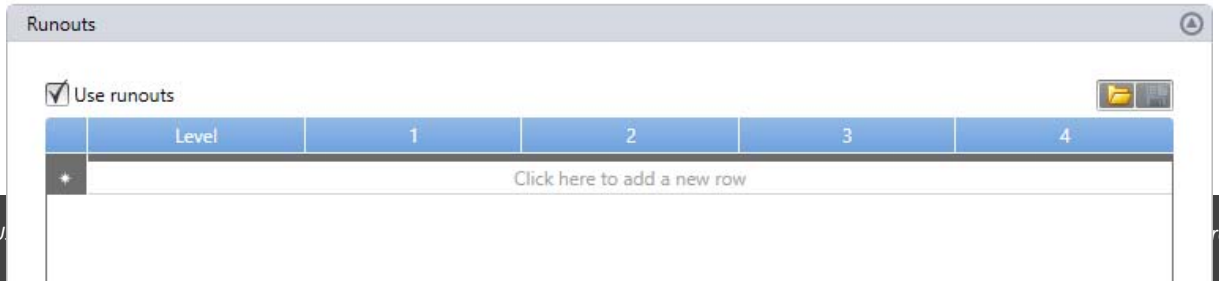
Tool Builder - Tapered ball-end

The following options are available for a Tapered ball-end tool:


Flutes
Number of flutes (1-50)
4
Variable pitch


Parameters
Geometry type
Ball End
Flat End
Tapered Ball End
General End
Parameters
X radius center (Rr)
Z radius center (Rz)
Corner radius (R)
Tip angle (α)
Taper angle (β)
1.000 °
Legend
L
β
h
D


Parameters
Flute type
Constant Lead
Constant Helix
Variable Helix
Parameters
Diameter (D)
19.050 mm
Length (L)
150.000 mm
Flute height (h)
9.525 mm
First bearing position
200.000 mm
Helix angle (λ)
30.000 °
Lead distance
Relief angle
5.000 °
Rake angle
5.000 °
Legend
L
h
β
λ
D

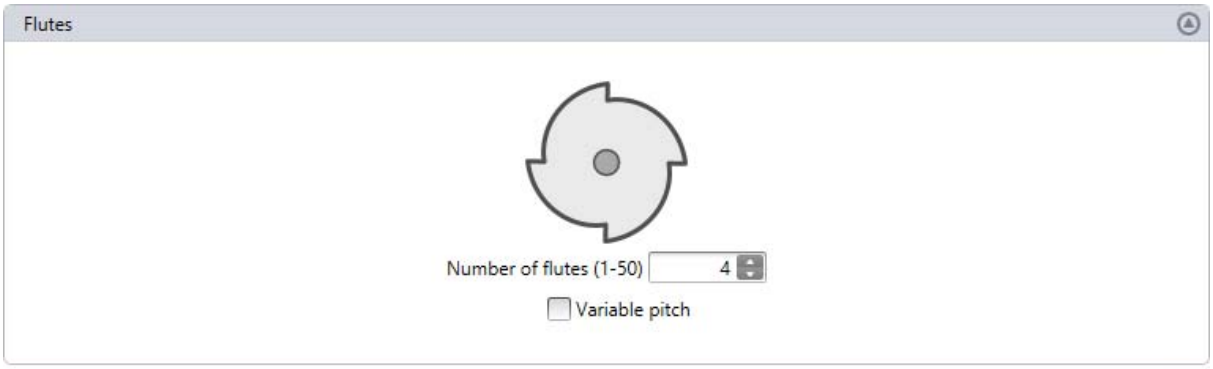

Runouts
Use runouts
Level
1
2
3
4
Click here to add a new row

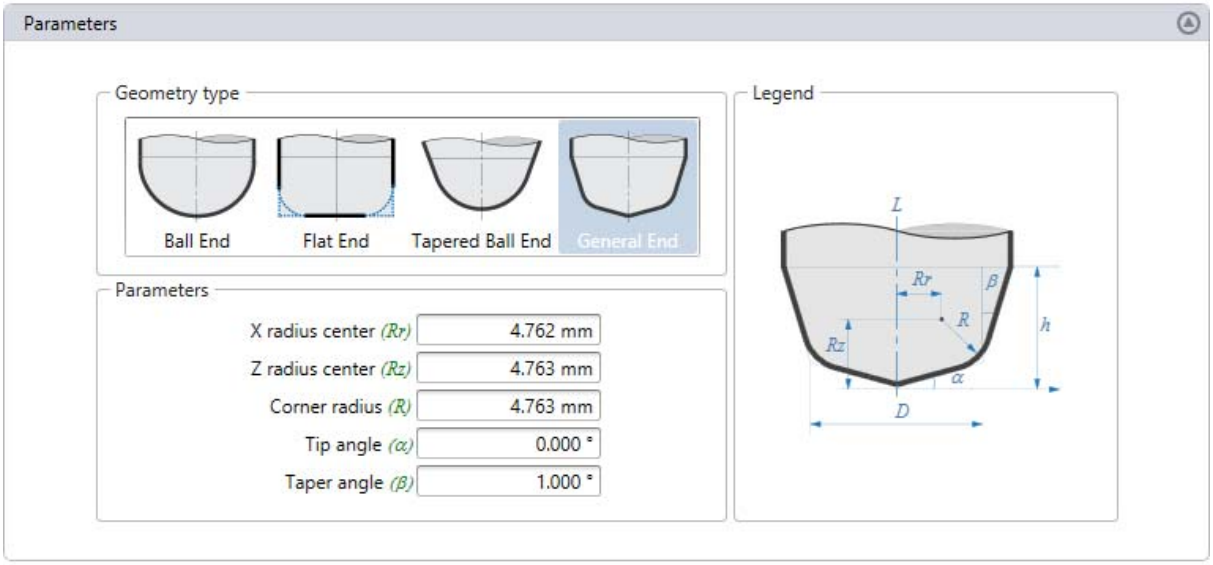
Check the Cutter properties/definitions page for further details

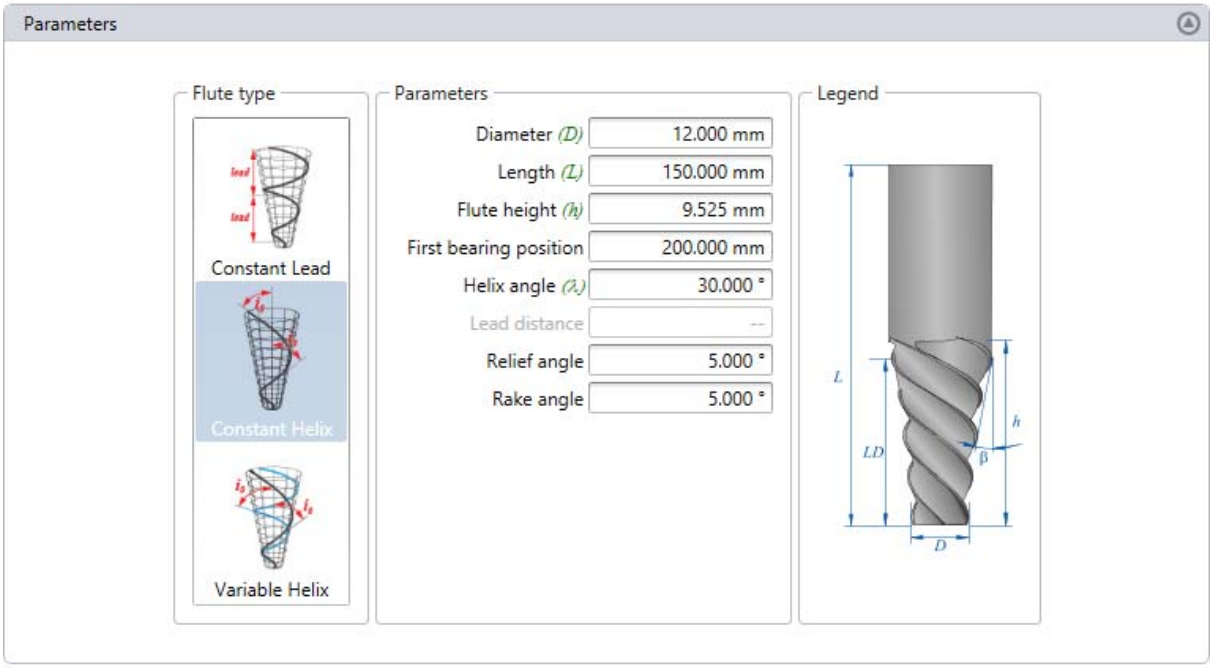
2.1.2.2.1.4 General

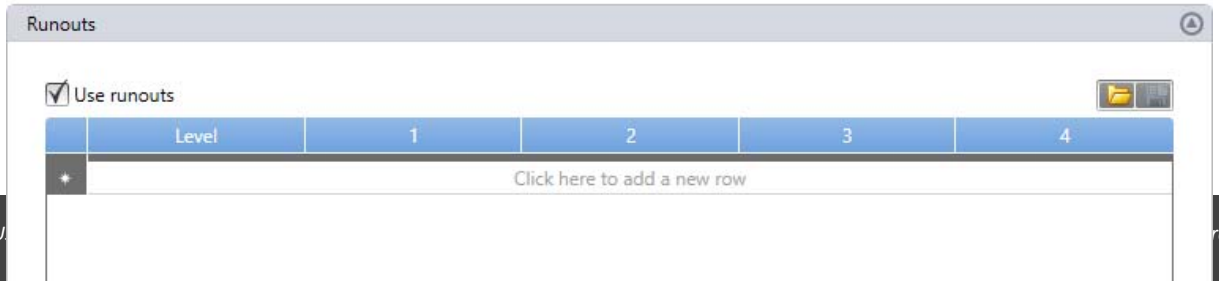
Tool Builder - General

The following options are available for a General tool:


Flutes
Number of flutes (1-50)
4
Variable pitch


Parameters
Geometry type
Ball End
Flat End
Tapered Ball End
General End
Parameters
X radius center (Rr) 4.762 mm
Z radius center (Rz) 4.763 mm
Corner radius (R) 4.763 mm
Tip angle (α) 0.000 °
Taper angle (β) 1.000 °
Legend
L
Rr
β
R
h
Rz
α
D


Parameters
Flute type
Constant Lead
Constant Helix
Variable Helix
Parameters
Diameter (D) 12.000 mm
Length (L) 150.000 mm
Flute height (h) 9.525 mm
First bearing position 200.000 mm
Helix angle (λ) 30.000 °
Lead distance --
Relief angle 5.000 °
Rake angle 5.000 °
Legend
L
LD
h
β
D

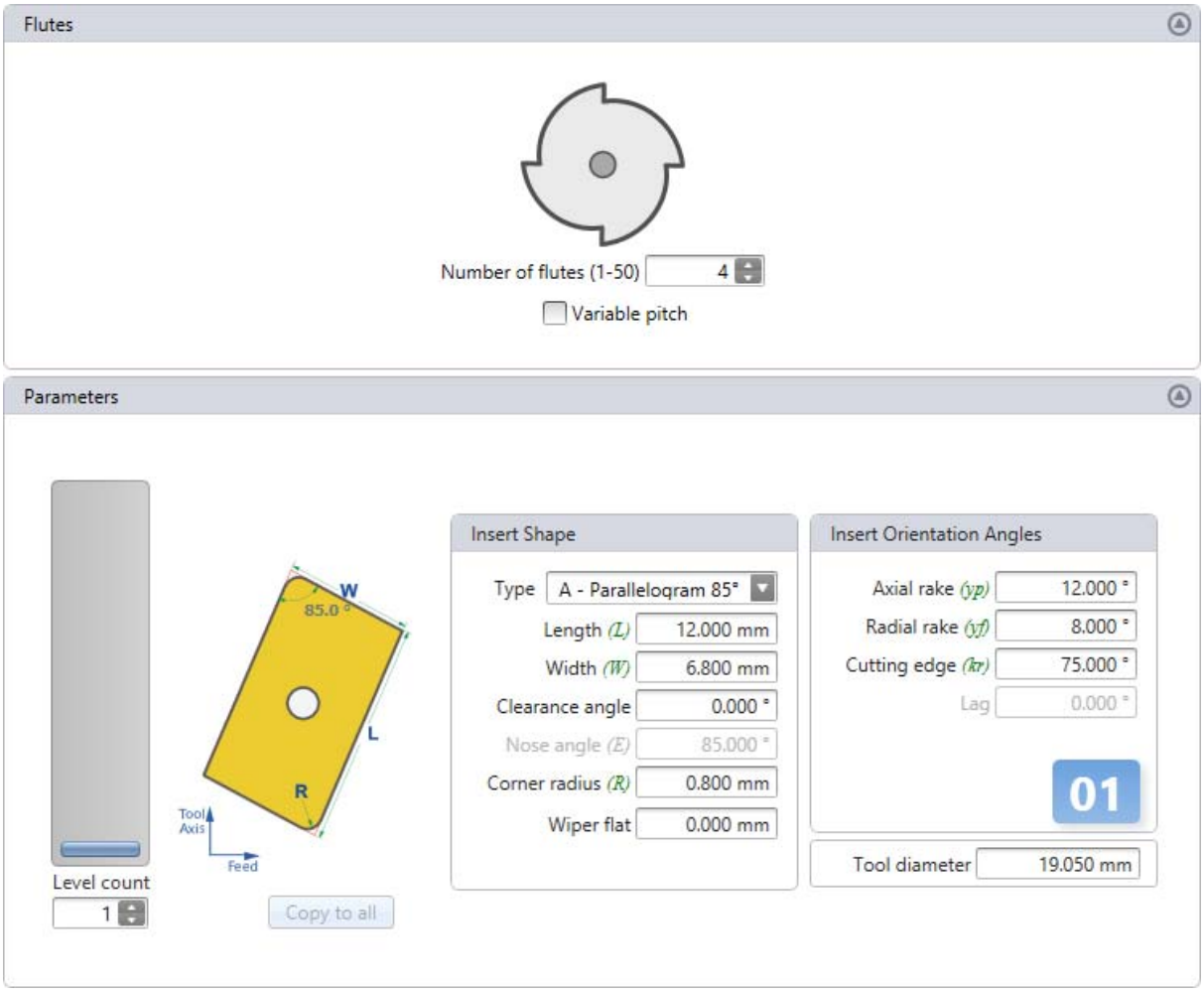

Runouts
Use runouts
Level
1
2
3
4
Click here to add a new row

Check the Cutter properties/definitions page for further details

2.1.2.2.1.5 Indexed

Tool Builder - Indexed

The following options are available for an Indexed tool:



Check the Indexable cutter properties/definitions page for further details

2.1.2.2.2 Receptance Coupling

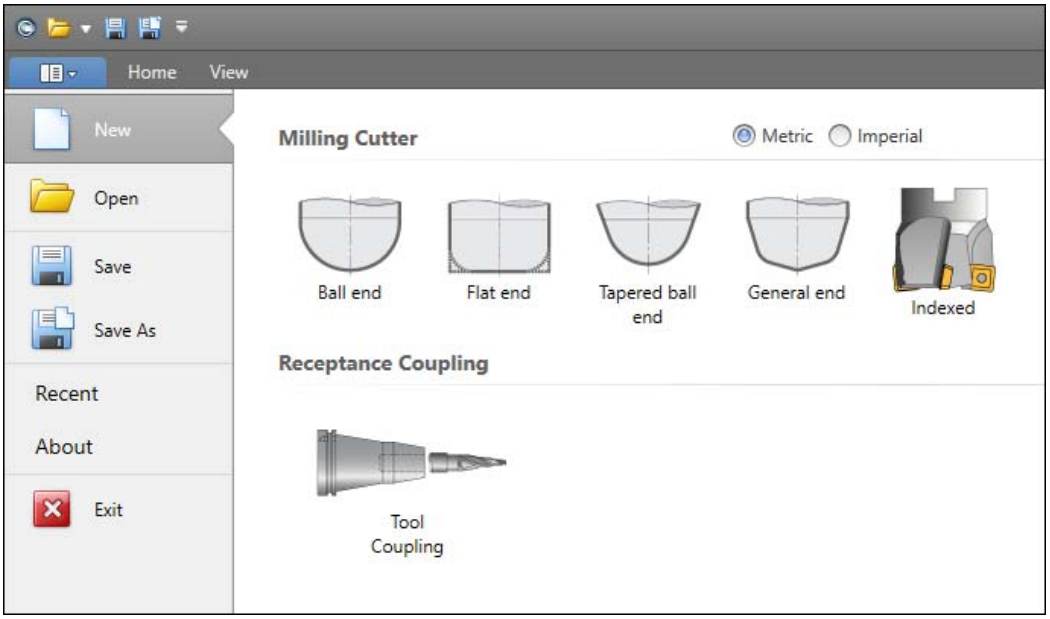
manufacturing automation laboratories CUTPRO

Tool Editor - Receptance Coupling

Receptance Coupling allows the user to perform less tap test measurements, and determine the predicted FRF of several cutting tools & holders at their tip.

This is done by decoupling the spindle from the holder & tool interface connection, as shown below.

We are then able to create predicted tool-tip FRFs by inputting holder and tool geometries, along with their material properties.



How to use Receptance Coupling

Step 1: Use the Tap Testing module or similar software and measure 3 or 6 FRFs.

Step 2: Use the FRF measurements to create a new spindle definition.

Step 3: Enter your holder geometry and tool geometry and save them, or load existing ones.

Step 4: Run coupling and save the predicted tool tip FRF with the direction (X and/or Y).

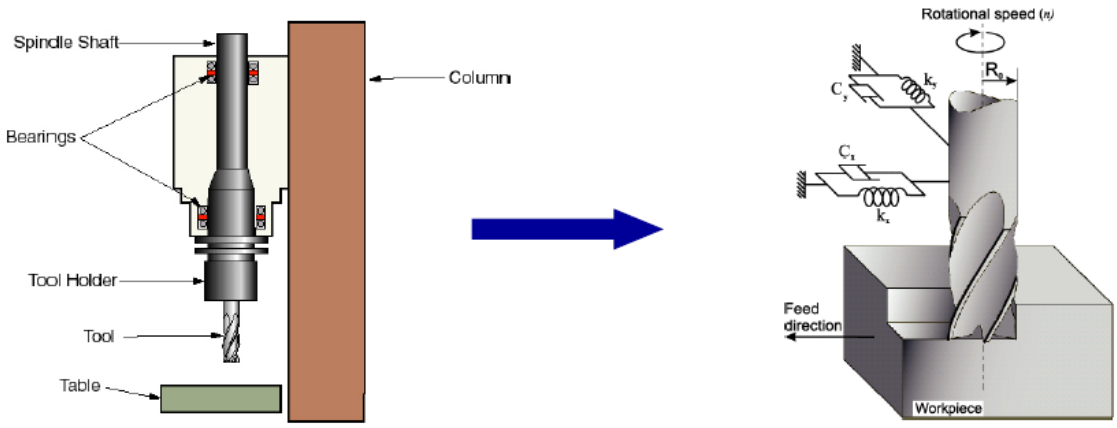
2.1.2.2.2.1 Spindle tap testing

manufacturing automation laboratories CUTPRO

Receptance Coupling - Spindle tap testing

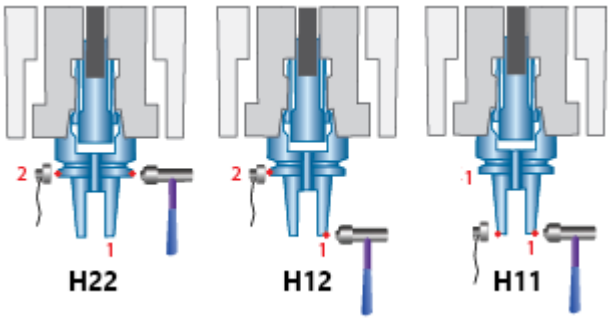
Before performing a spindle tap test, first we must consider which directions of the machine we wish to measure. In the case of milling, there are two main axes in which the tool travels: The X and Y axes of the machine tool. In order to accurately predict stability (how deep/wide can i cut), forces (how aggressively can I cut) and so on, we must measure these two axes. **A good rule of thumb is to always measure both the X and Y axes of the spindle.**

Why do we need both axes?



The reason for these two measurements is because the structure of the machine, including the spindle itself, are not 100% symmetrical in the X and Y axes. This means that one direction, X or Y, will be more rigid or flexible than the other. If you have a machine which is relatively symmetric, you may wish to only measure one direction, such as X for example.

What else do we need for tap testing?



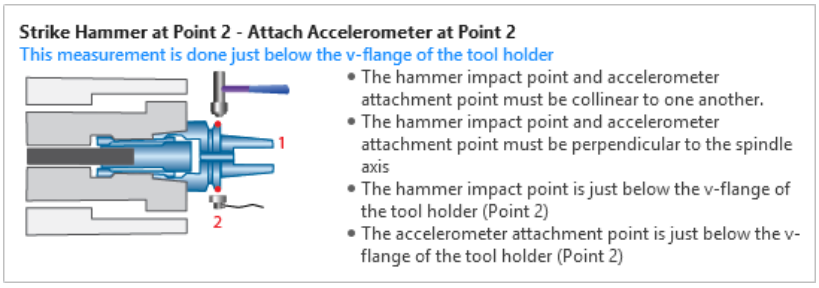
A tool holder (This will be subtracted from the measurements)

Remember to note the tool holder model

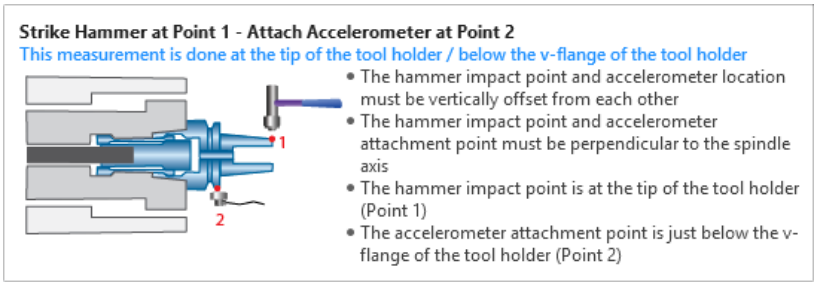
Here are the three options you may choose for Spindle tap testing, figures for each test are shown below: For assistance with tap testing, please refer to the Tap Testing Module.

- Tap test **Machine X** only and export 3 FRFs **(**H11X.frf - H12X.frf - H22X.frf**)**
- Tap test **Machine Y** only and export 3 FRFs **(**H11Y.frf - H12Y.frf - H22Y.frf**)**
- Tap test both **Machine X and Machine Y** and export 6 FRFs **(**H11X.frf - H12X.frf - H22X.frf**) + (**H11Y.frf - H12Y.frf - H22Y.frf**)**

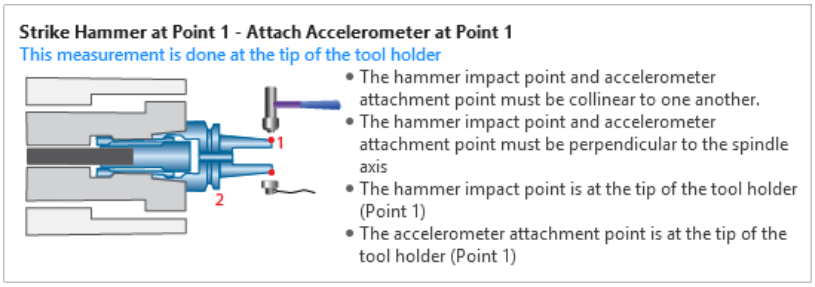
H22



H12



H11



2.1.2.2.2.2 New spindle definition

manufacturing automation laboratories CUTPRO

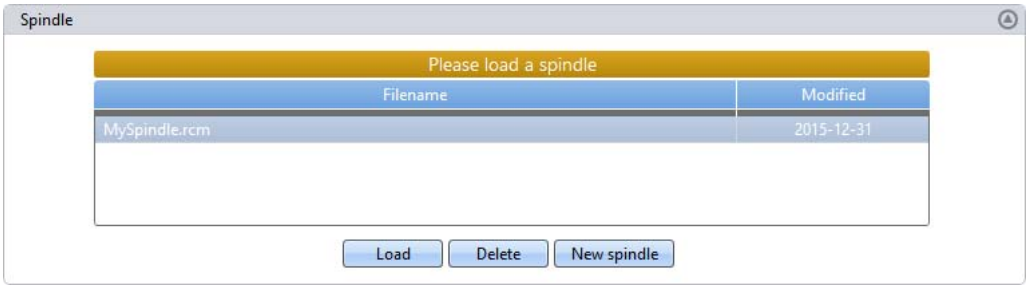
Receptance Coupling - New spindle definition

Requirements

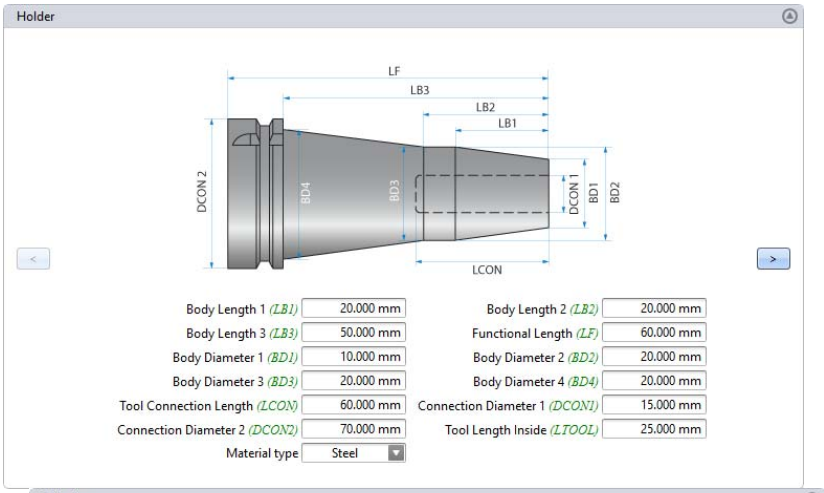
- H11, H12 and H22 measurements (Spindle tap testing)
- Exported FRFs of the above measurements (*.frf)
- Tool holder geometry from the tap tests

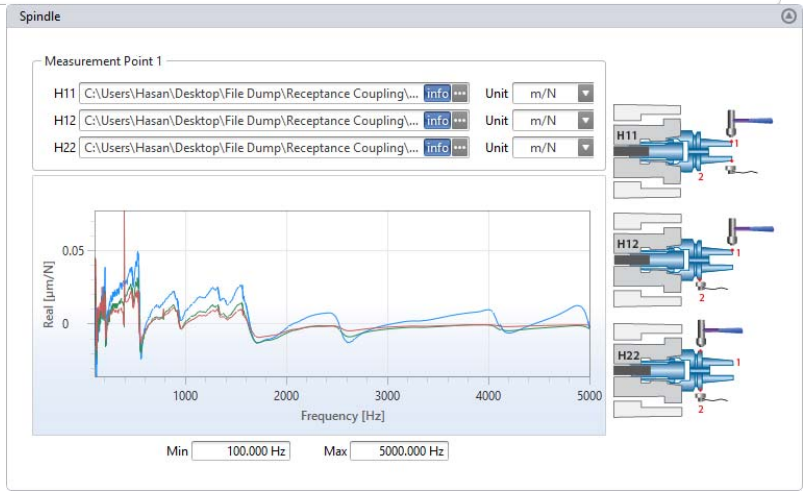
Creating a new spindle definition

Under the new Tool coupling document, click on 'New Spindle' from the *Spindle* section.

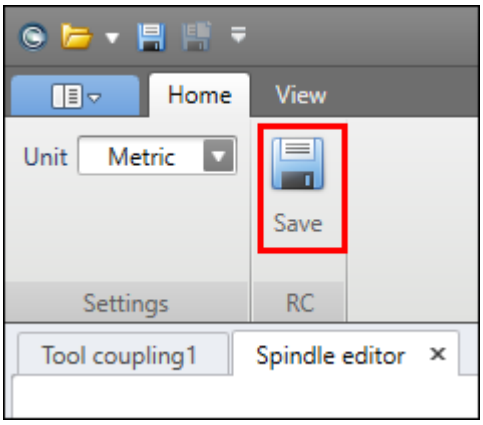


Notice that a new tab called 'Spindle editor' has been opened. Enter or load your tool holder geometry, and load your FRFs.

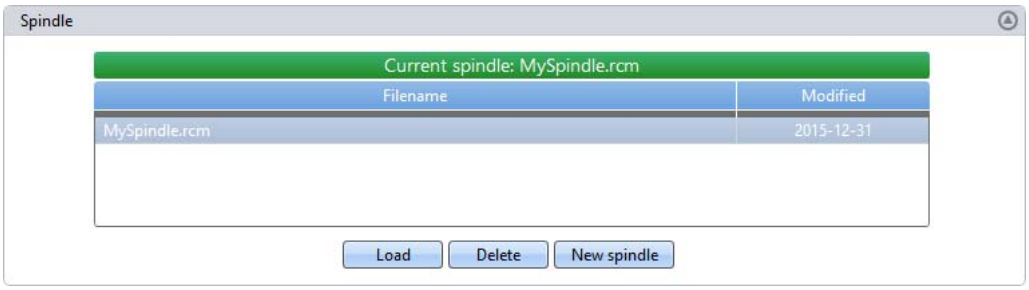




When you are finished, click the 'Save' button shown in the top left under RC. This will save your spindle definition as an **(*.rcm)** file.



You can then load your spindle the next time by selecting the appropriate **(*.rcm)** file and clicking "Load". Notice that the current spindle is highlighted in green.



2.1.2.2.2.3 Holder/Tool definitions

manufacturing automation laboratories CUTPRO

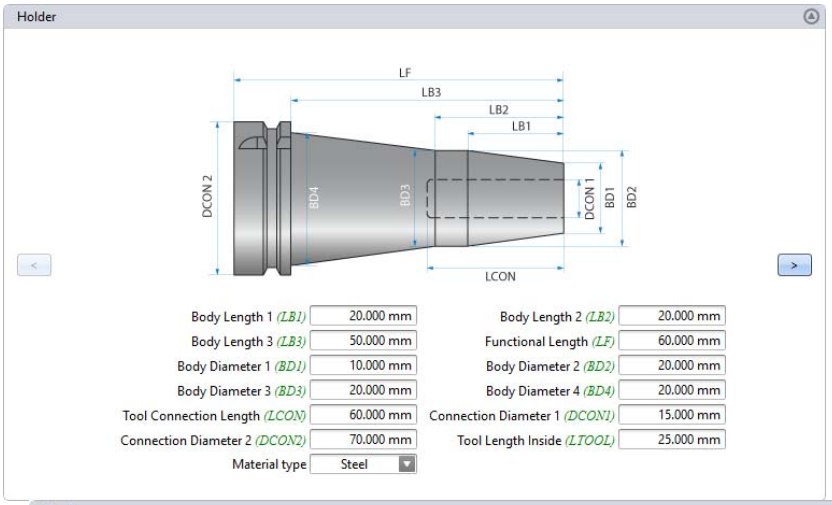
Receptance Coupling - Holder/Tool definitions

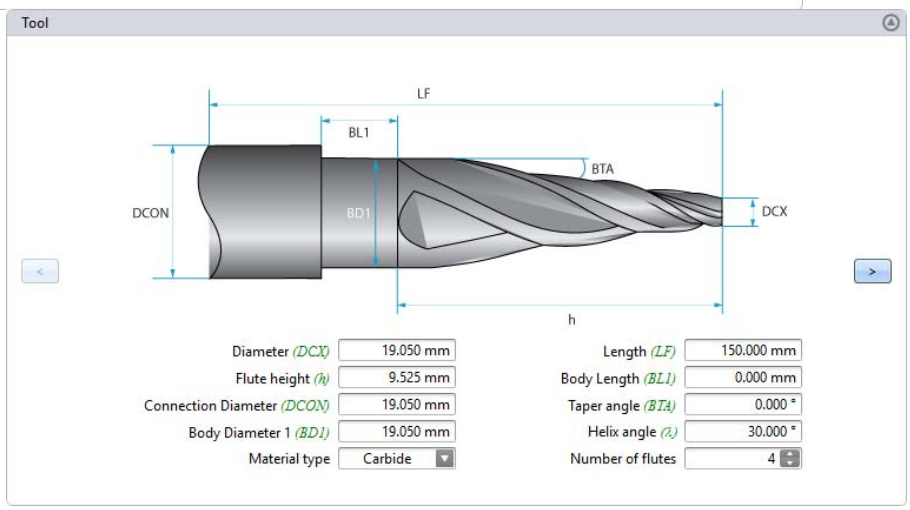
Requirements

- All holder and tool geometries
- The tool holder must be a shrink-fit holder
- The cutting tool must be solid carbide or steel

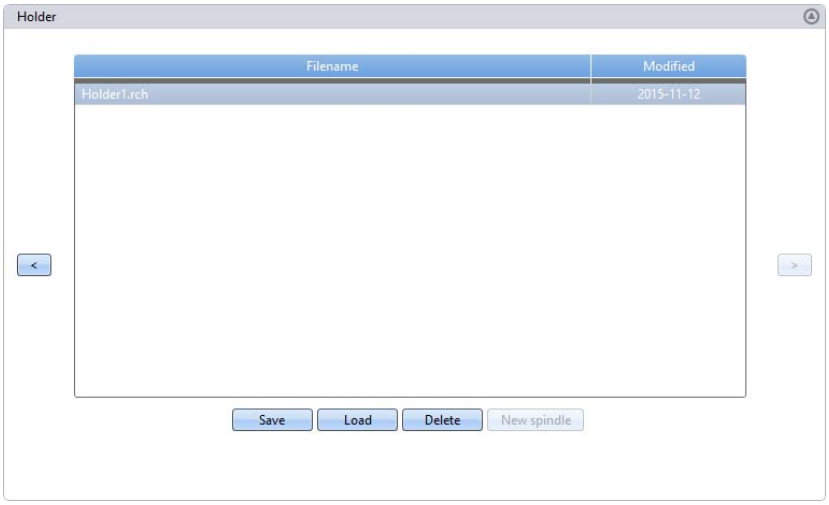
Creating a new Holder or Tool definition

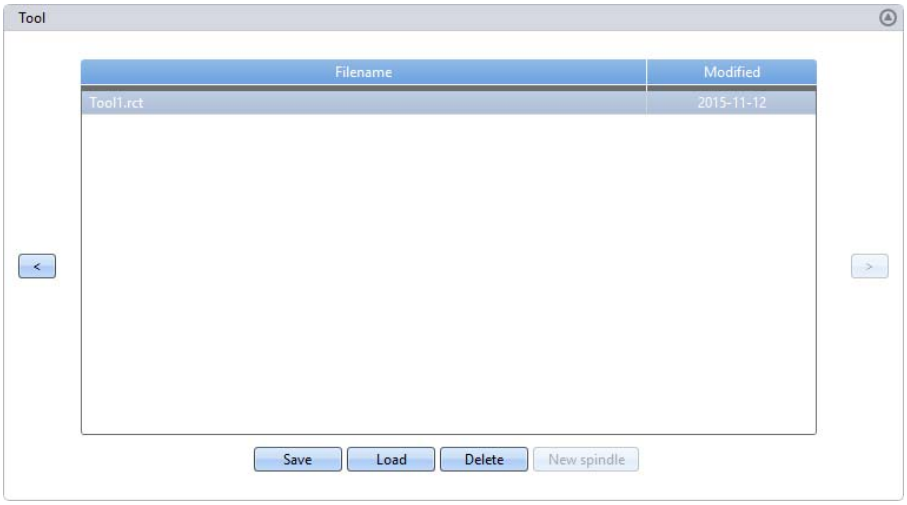
Enter the geometries of your holder or tool, and click the blue forward/right arrow for each.





Notice a list of files for your **holders (*.rch)** and your **tools (*.rct)**. Here you can save you can save or load these files. Click the blue return/left arrow to go back.





2.1.2.2.2.4 Run coupling

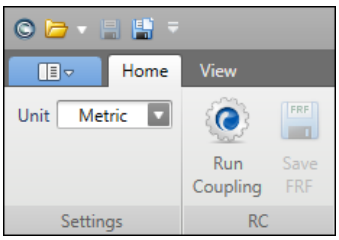
manufacturing automation laboratories CUTPRO

Receptance Coupling - Run coupling

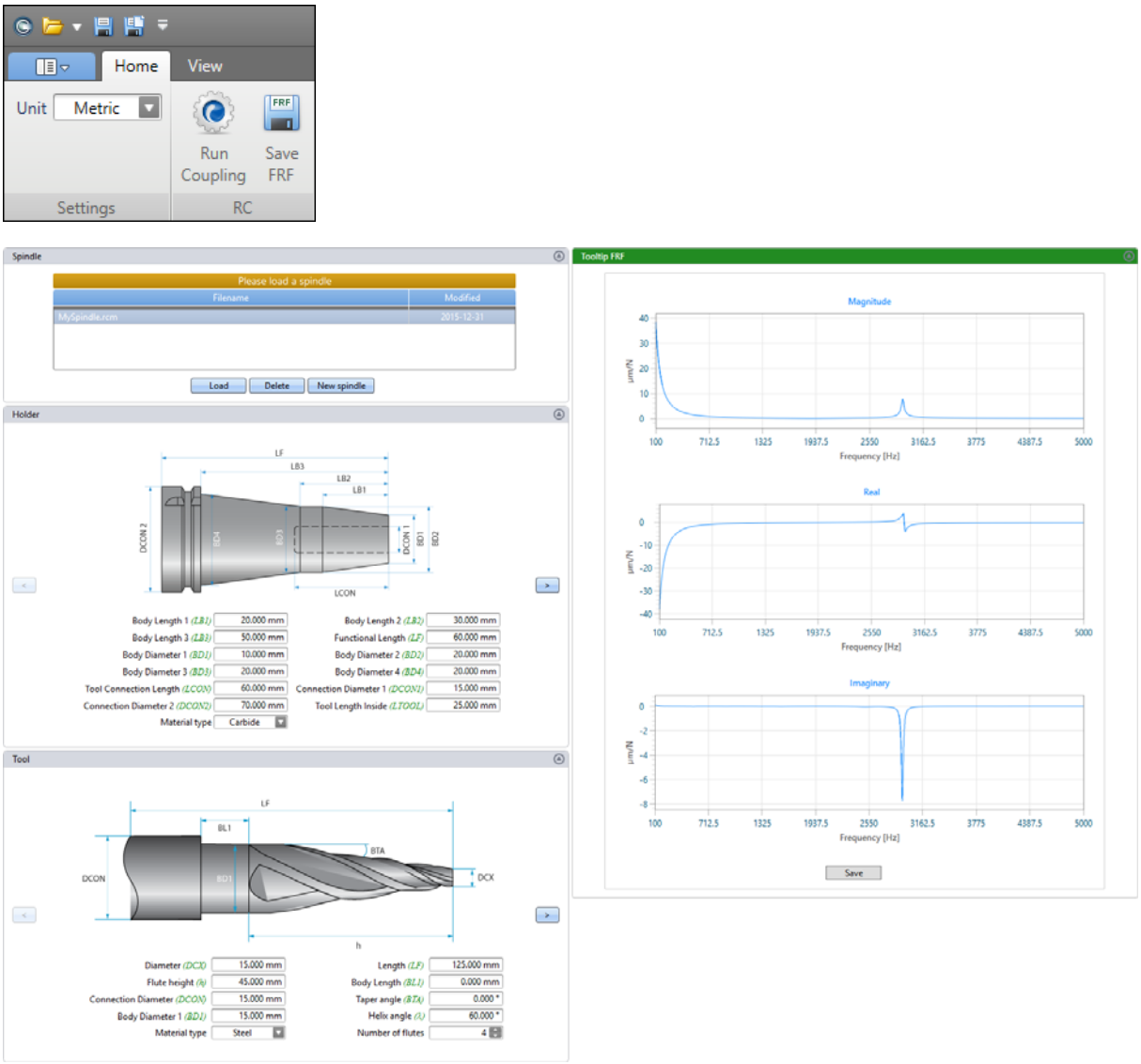
Requirements

- **(*.rcm)** file for Spindle tap test
- **(*.rch)** file or unsaved input geometry for Holder
- **(*.rct)** file or unsaved input geometry for Tool

Once the Spindle, Holder and Tool have been defined, click on *'Run Coupling'* in the top left menu



After results generation, notice the predicted tooltip FRF appear on the right, and a 'Save FRF' button along with it.

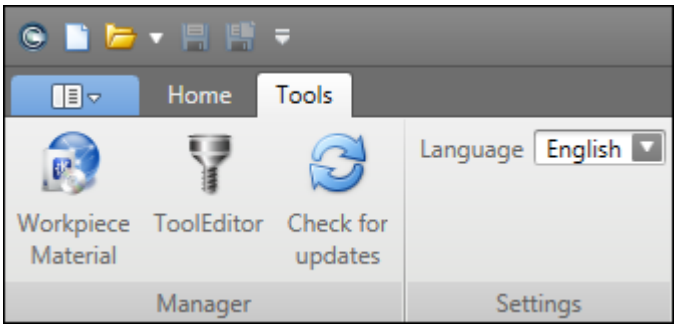


Once the tooltip FRF has been saved, you may use it within CutPro just like any other CutPro FRF.

Please contact us for further information in regards to Receptance Coupling.

2.1.2.3 Check for Updates

Check for updates - Overview



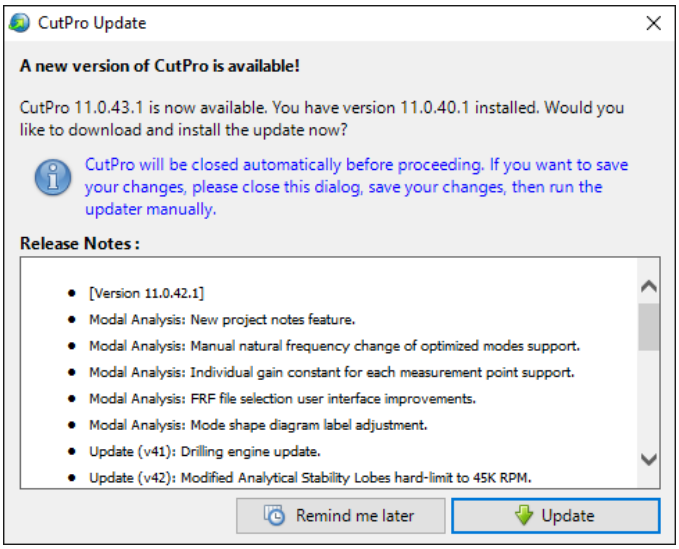
Click on the 'Check for updates' button to see if a new CutPro version has been released:

1) If a new version isn't available

CutPro will tell you your current version and tell you that it's up-to-date.

2) If a new version is available

CutPro will show an update prompt along with the update contents.



3) If you cannot update at all

Please contact us if the update button is not visible in CutPro although you have an older version.

This likely means that your Updates have expired.

2.1.3 Simulation Modes

manufacturing automation laboratories CUTPRO

Simulation Modes - Overview

Inside of the active Workspace, the user can define many simulations, and also various simulation modes may be selected:

- Analytical stability lobes
- Milling process simulation
- Stability lobes in time domain
- Optimize variable pitch
- Cutting coefficient identification

Useful Functions for Simulation

Add: Add a new simulation in the active workspace

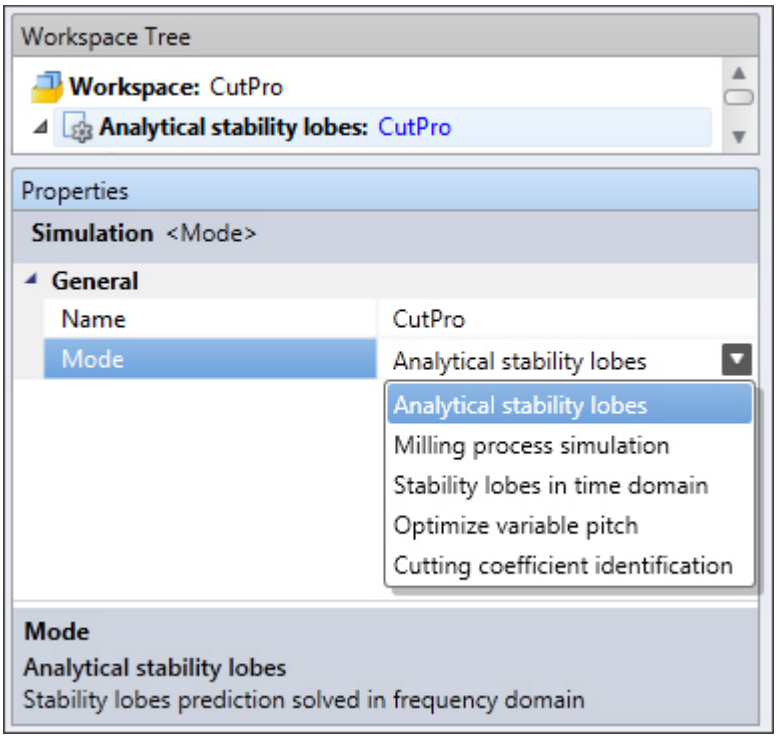
Remove: Removes selected simulation in the active workspace

Duplicate: Duplicates selected simulation in the active workspace

2.1.3.1 Analytical stability lobes

manufacturing automation laboratories CUTPRO

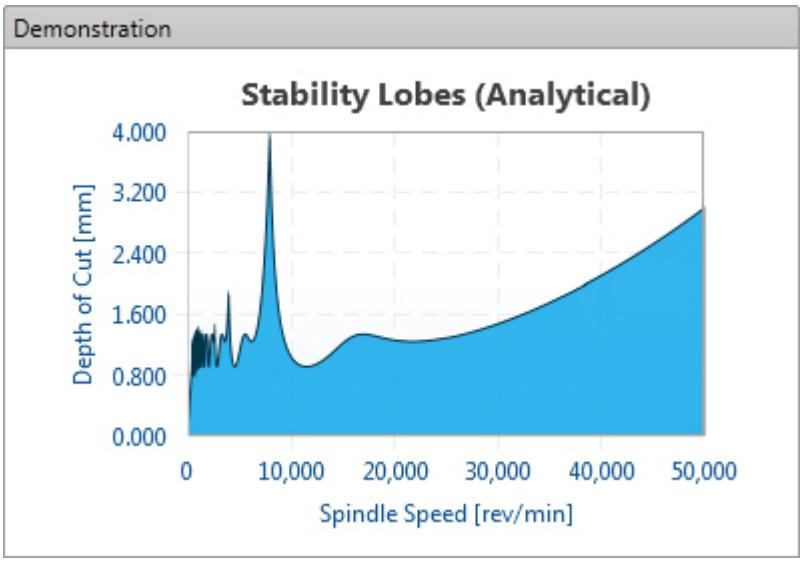
Analytical stability lobes



What is this?

Analytical stability lobes provide the user with what is called a "Stability Pocket", which denotes a productive location for chatter-free cutting:

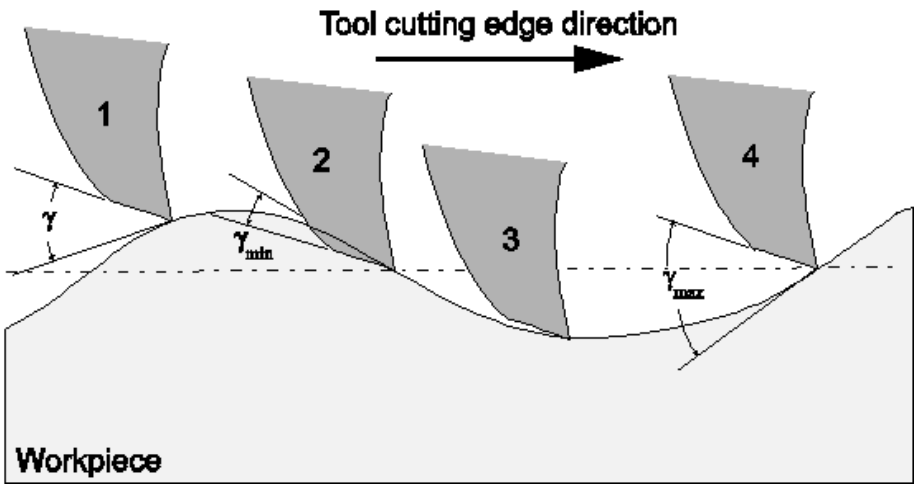
This is a fast analytical stability lobe prediction solved in a frequency domain. It generates the stability lobes by indicating the axial/radial depth of cut and spindle speeds for a fixed width of cut.

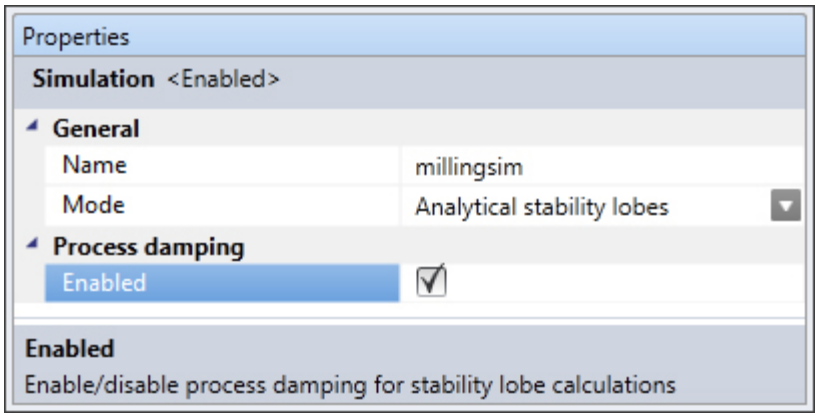


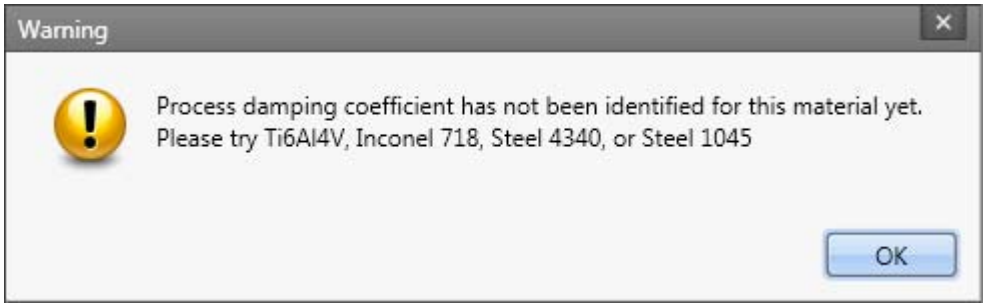
Additional Features:

Process damping (Available for certain materials only)

Heat resistant materials such as titanium and steel alloys that are frequently used in thin walled components can only be cut at low cutting speeds.
When machining these materials at low speeds, it is known that the chatter stability limit increases due to additional damping caused by the process.
This phenomenon is called process damping. Due to the sharpness of the cutting edge, part of the chip is forced to go under the tool and causes interference on the tool clearance flank.

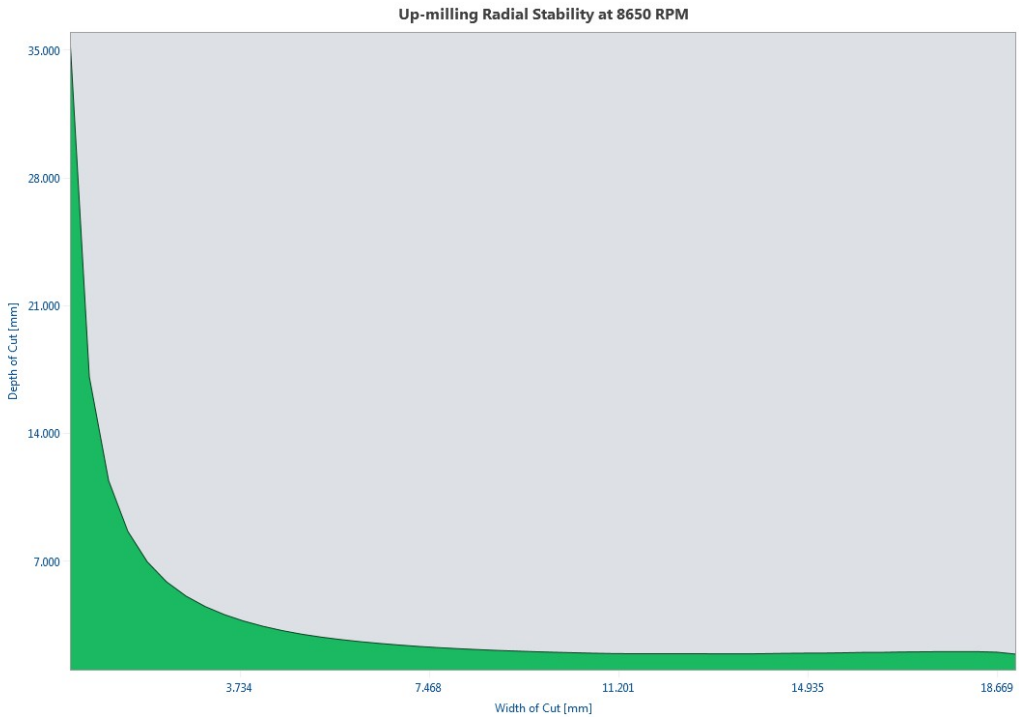






Radial Stability (Available for Down-Milling and Up-Milling)

Simulates the potential depth of cut versus width of cut.

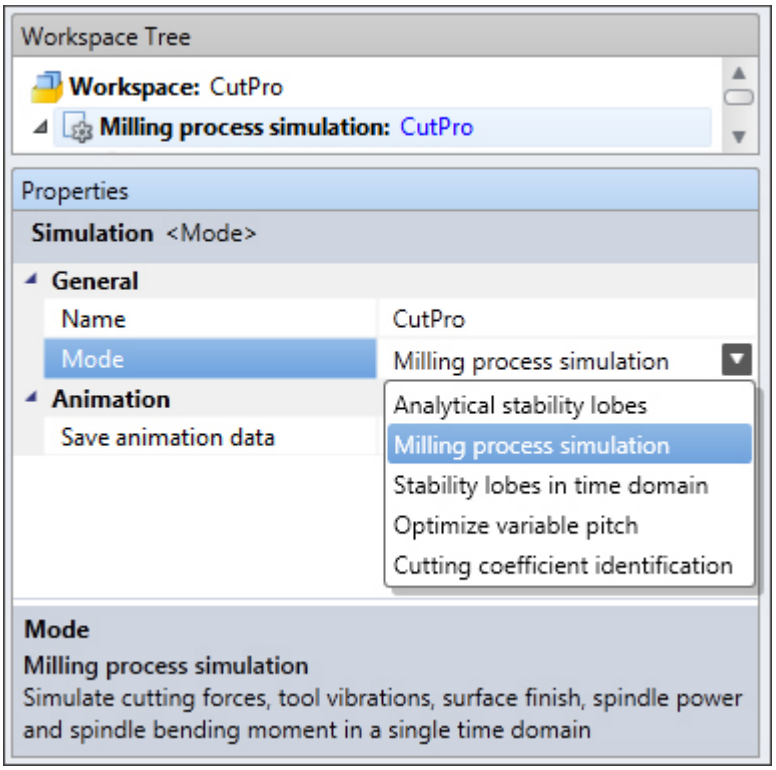


Properties	
Cutting conditions	
General	
Spindle direction	Clockwise
Milling mode	Up-milling
Feedrate	0.200 mm/flute
Radial width of cut (b)	9.000 mm
Radial stability	
Enabled	☑
Spindle speed	8650 RPM

2.1.3.2 Milling process simulation

manufacturing automation laboratories CUTPRO

Milling process simulation



What is this?

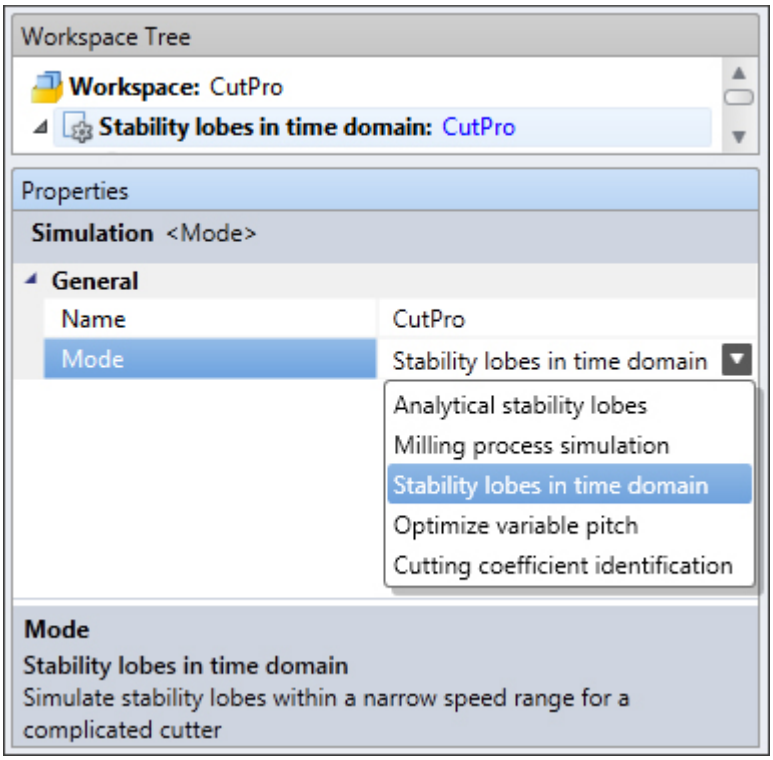
Milling process simulation provides the user with expected cutting forces which may be used to optimize cutting:

For a given cutter geometry, cutting conditions (depth, width, speed, feed, cutter, material, structural dynamic parameters of the machine and work piece), cutting forces, chip load, vibrations, torque, bending moment at a spindle location indicated by the length from the tool tip, surface finish, and animation of chip removal are simulated.

2.1.3.3 Stability lobes in time domain

manufacturing automation laboratories CUTPRO

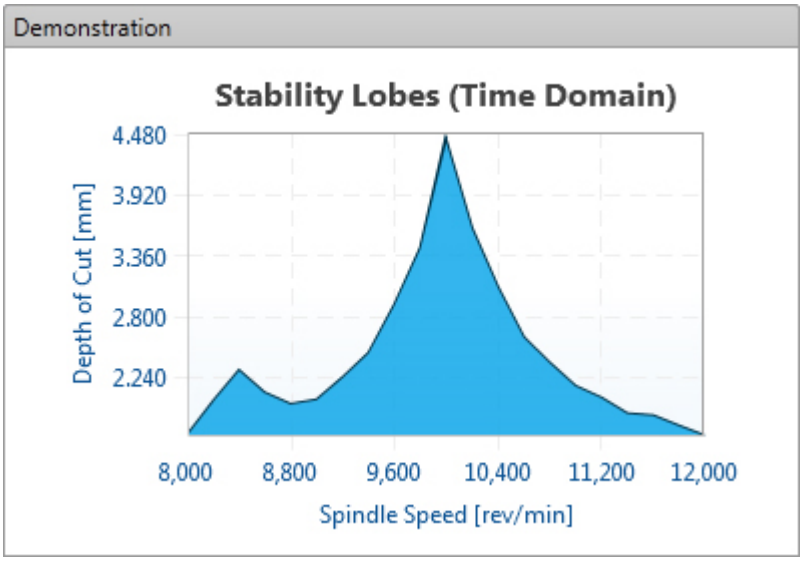
Stability lobes in time domain



What is this?

Stability lobes in time domain provide the user with more accurate resutls for a "Stability Pocket", which denotes a productive location for chatter-free cutting:

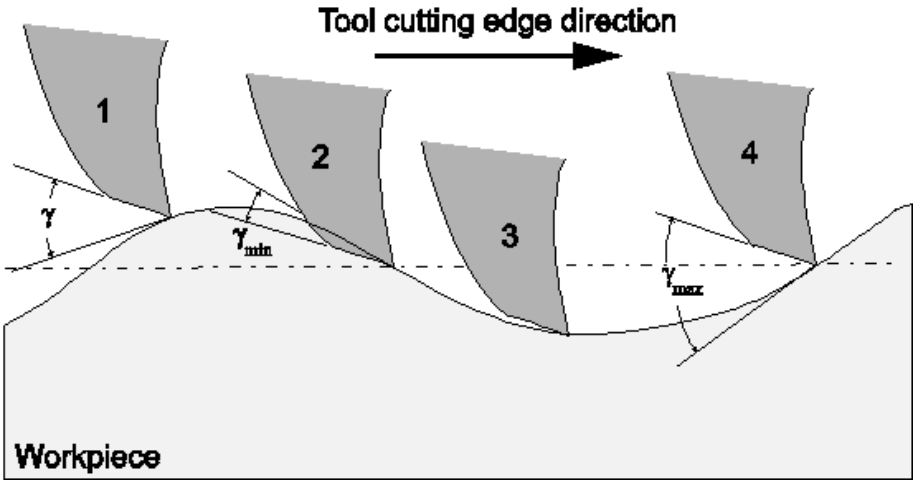
This simulates the stability lobes using semi-discrete simulations, and takes a long time. We recommend that you use the analytical stability lobe modes first due to it's speed. However, if you wish to simulate stability lobes within a narrow speed range for a complicated cutter, you should use this option as it is more accurate.

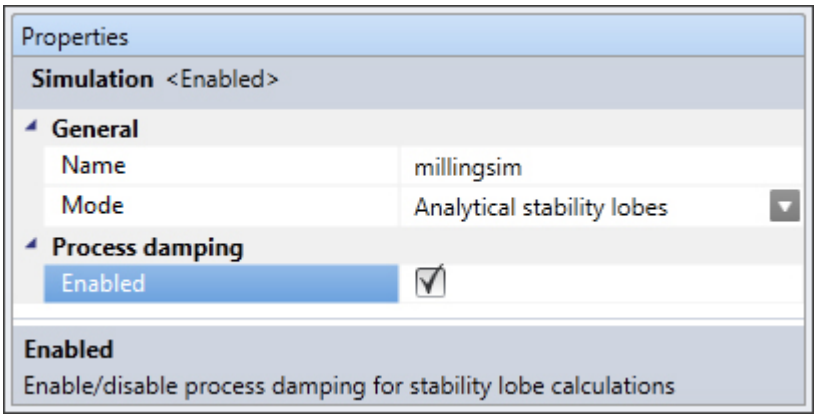


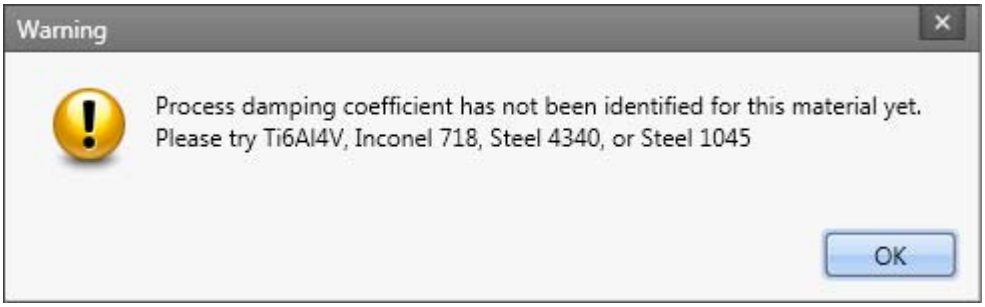
Additional Features:

Process damping (Available for certain materials only)

The heat resistant materials such as titanium and steel alloys that are frequently used in thin walled components can only be cut at low cutting speeds.
When machining these materials at low speeds, it is known that the chatter stability limit increases due to additional damping caused by the process.
This phenomenon is called process damping. Due to the sharpness of the cutting edge, part of the chip is forced to go under the tool and causes interference on the tool clearance flank.

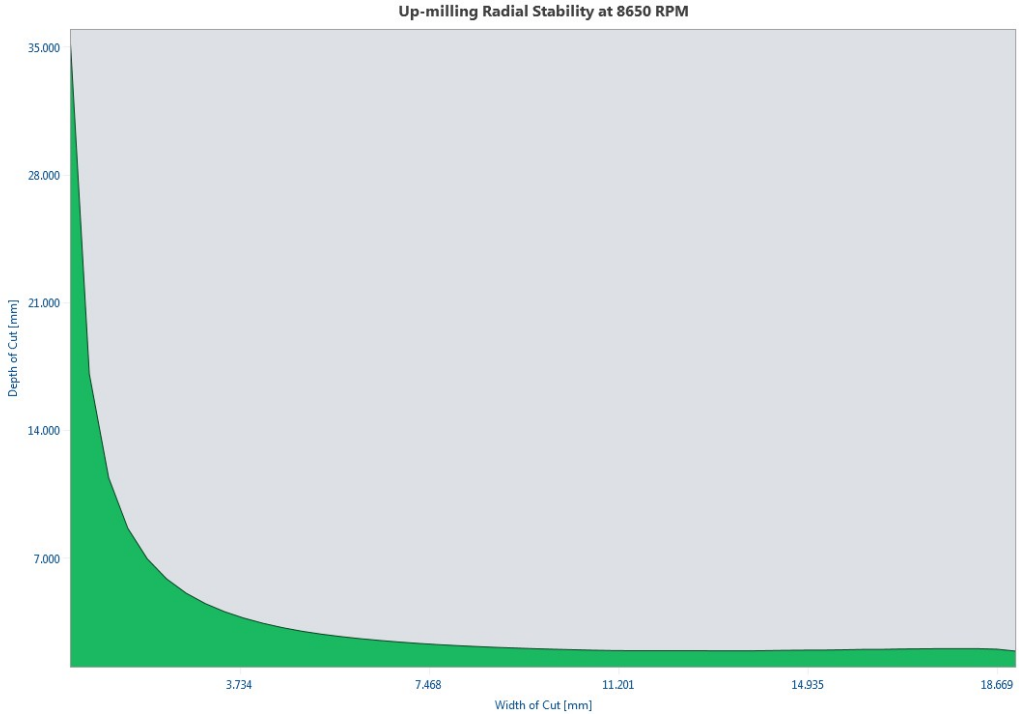


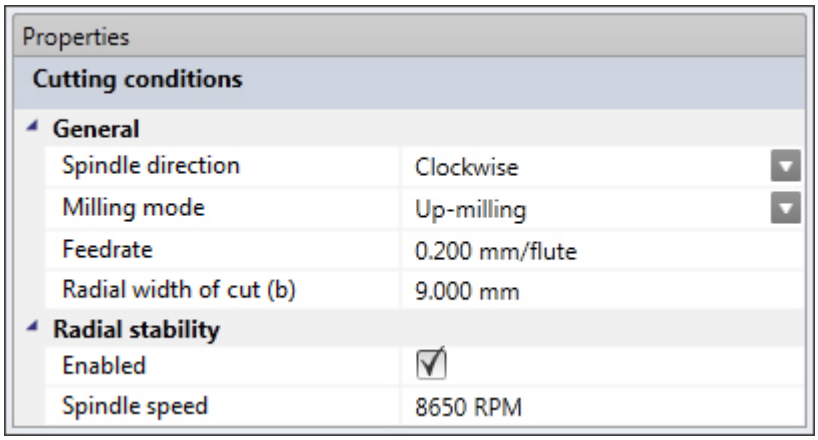




Radial Stability (Available for Down-Milling and Up-Milling)

Simulates the potential depth of cut versus width of cut.

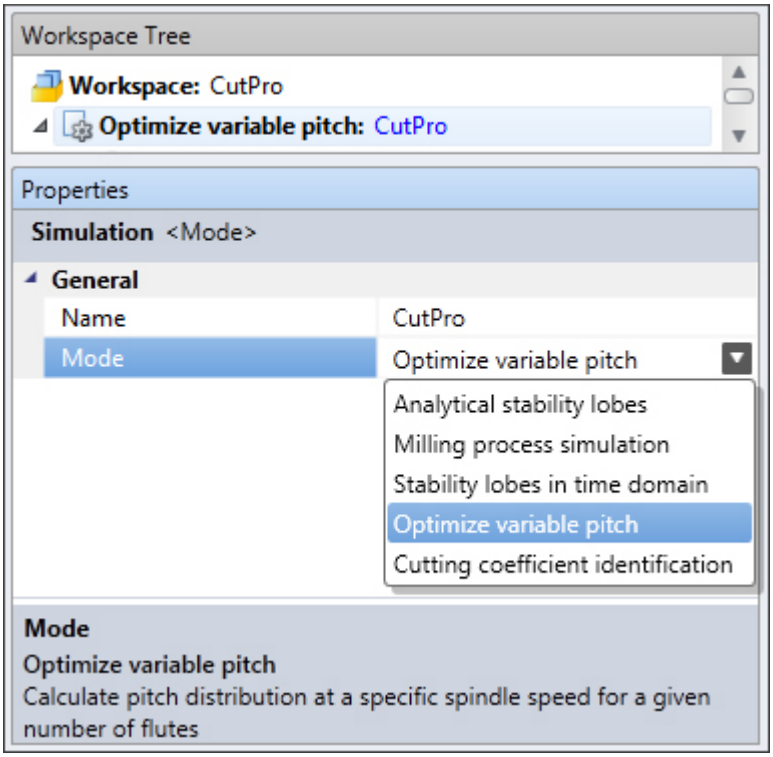




2.1.3.4 Optimize variable pitch

manufacturing automation laboratories CUTPRO

Optimize variable pitch

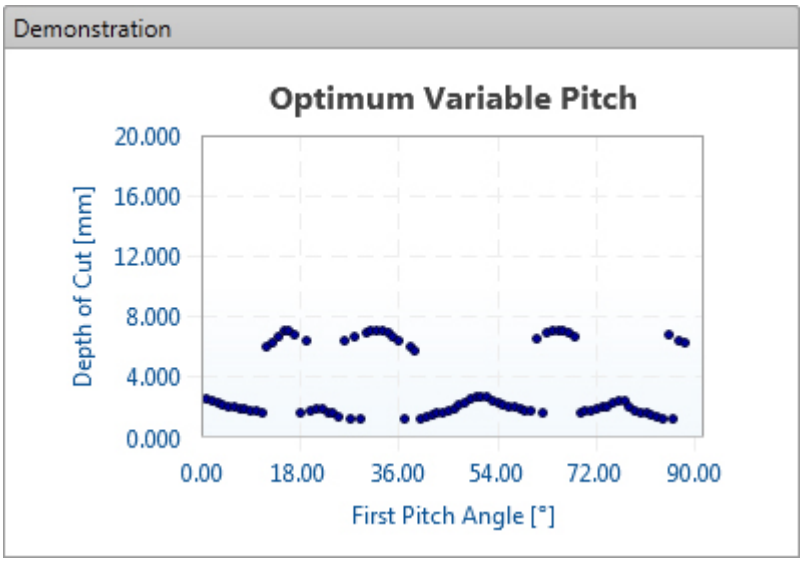


What is this?

Optimum variable pitch provides the user with a simulation of performance for

a variable pitch cutter:

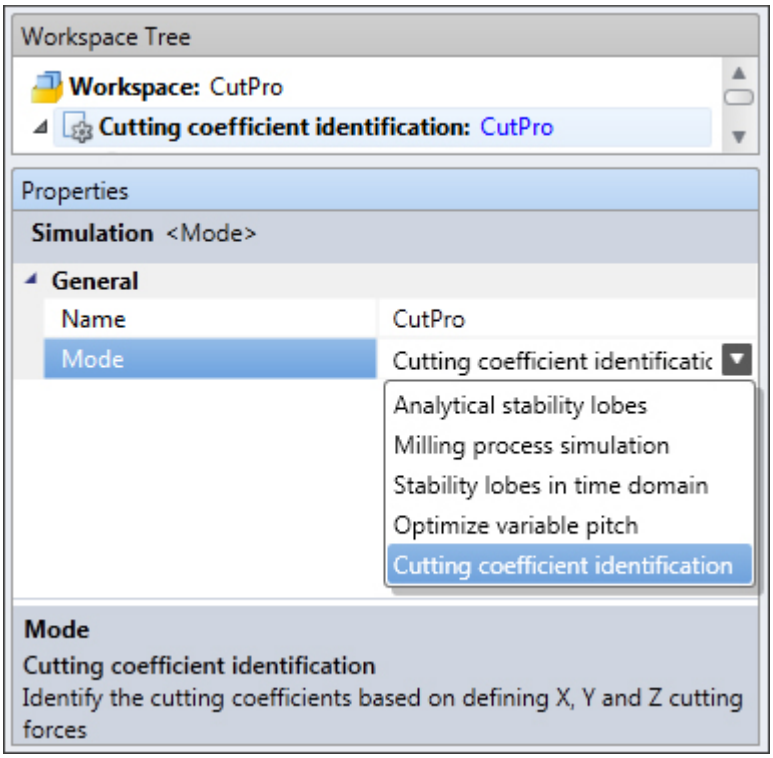
This automatically calculates the pitch distribution at a specific spindle speed for a given number of flute.
The user can then select practical combinations from the graphical output.



2.1.3.5 Cutting coefficient identification

manufacturing automation laboratories CUTPRO

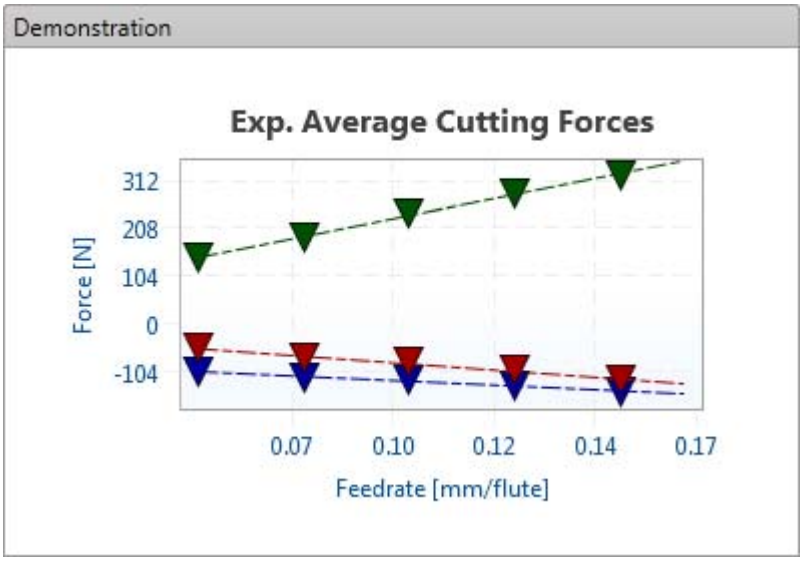
Cutting coefficient identification



What is this?

Cutting coefficient identification provides the user with expected cutting forces for a material:
Note that CutPro has a material database which may already contain the material of interest.

If one does not know the cutting constants of a material-cutter combination, milling experiments are conducted.
The cutting forces in x,y and z are then measured, and provided to this simulation. Finally, the cutting coefficients are identified for the material.



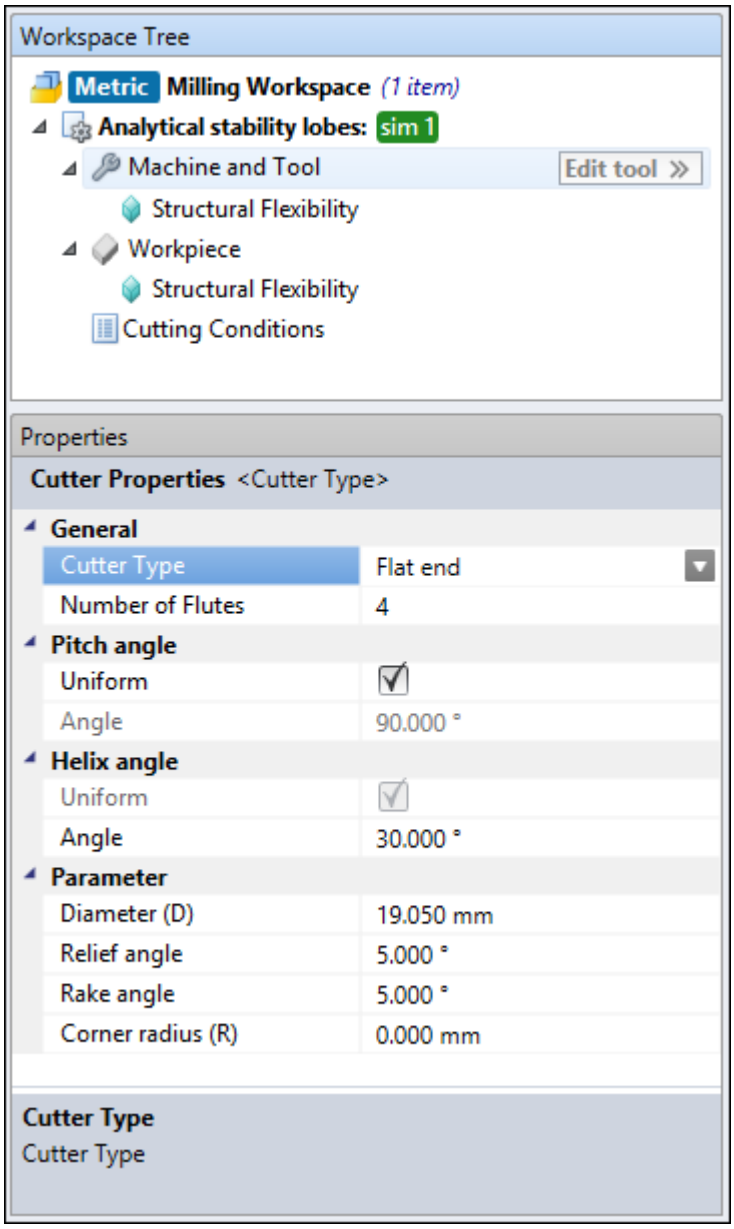
2.1.4 Machine & Tool

manufacturing automation laboratories CUTPRO

Machine & Tool - Overview

Here the user may select/edit properties related to the machine & tool, such as:

- Tool geometry (Machine and Tool tab)
- Structural flexibility
- Edit tool



2.1.4.1 Tool Geometry

manufacturing automation laboratories CUTPRO

Machine & Tool - Tool Geometry

In **CUTPRO** milling there are five types of cutters which can be simulated:

- Flat
- Ball-end

- Tapered ball-end
- General
- Indexable

Check the Cutter properties/definitions page for further details

2.1.4.1.1 Cutter properties/definitions

manufacturing automation laboratories CUTPRO

Cutter properties/definitions

- Geometry types
- General tool geometry parameters figure
- Number of flutes
- Pitch
- Run-out
- Run-out file editor
- Run-out example
- Serration
- Serration file editor
- Serration example
- Length
- First bearing position
- Lead distance
- Lead/Helix angle
- Rake/Relief angle
- Taper angle
- Tip angle

- Corner radius

2.1.4.1.1.1 Geometry types

manufacturing automation laboratories CUTPRO

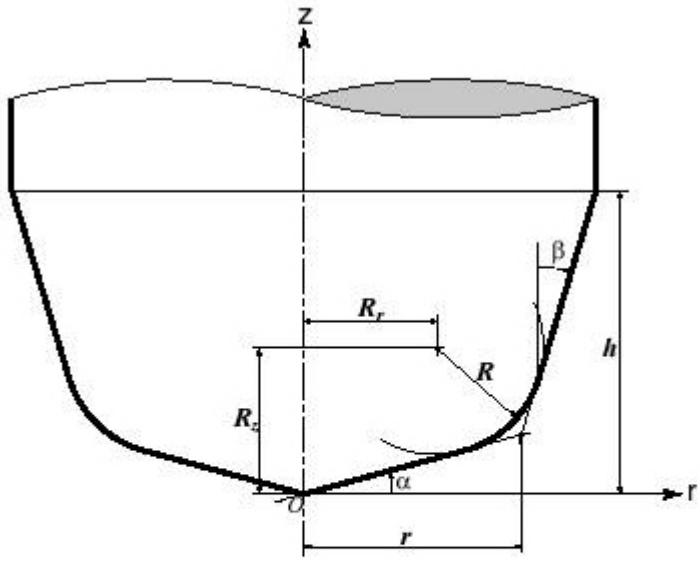
Geometry types

- Flat
- Ball-end
- Tapered ball-end
- General
- Indexable

2.1.4.1.1.2 General tool geometry parameters figure

manufacturing automation laboratories CUTPRO

General tool geometry parameters figure



Cutter Parameters:
- r : Radius of cutter [mm]
- R : Corner radius [mm]
- R_r : r coordinate of corner radius center [mm]
- R_z : z coordinate of corner radius center [mm]
- α : Slope angle for the first line [degree]
- β : Slope angle for the second line [degree]
- h : Valid cutting edge height [mm]

2.1.4.1.1.3 Number of flutes

manufacturing automation laboratories CUTPRO

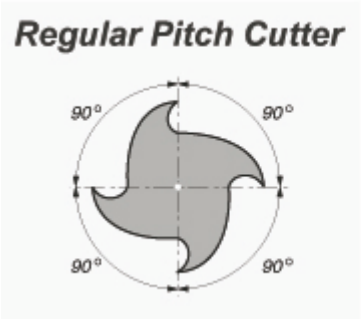
Number of flutes

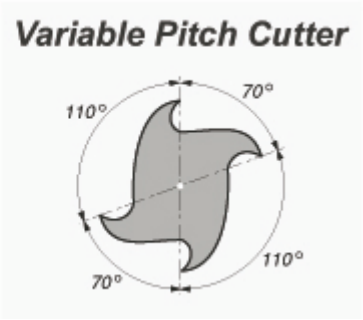
The number of teeth (flutes) on the cutter. The pitch angles will be the same for uniform pitch cutters.
The pitch angles are obtained using **(360°/number of flutes)**. For non-uniform pitch the pitch angles must be entered by user.
The pitch angles must be bigger than zero and the summation of all pitch angles must be **360°**.

2.1.4.1.1.4 Pitch

manufacturing automation laboratories CUTPRO

Pitch





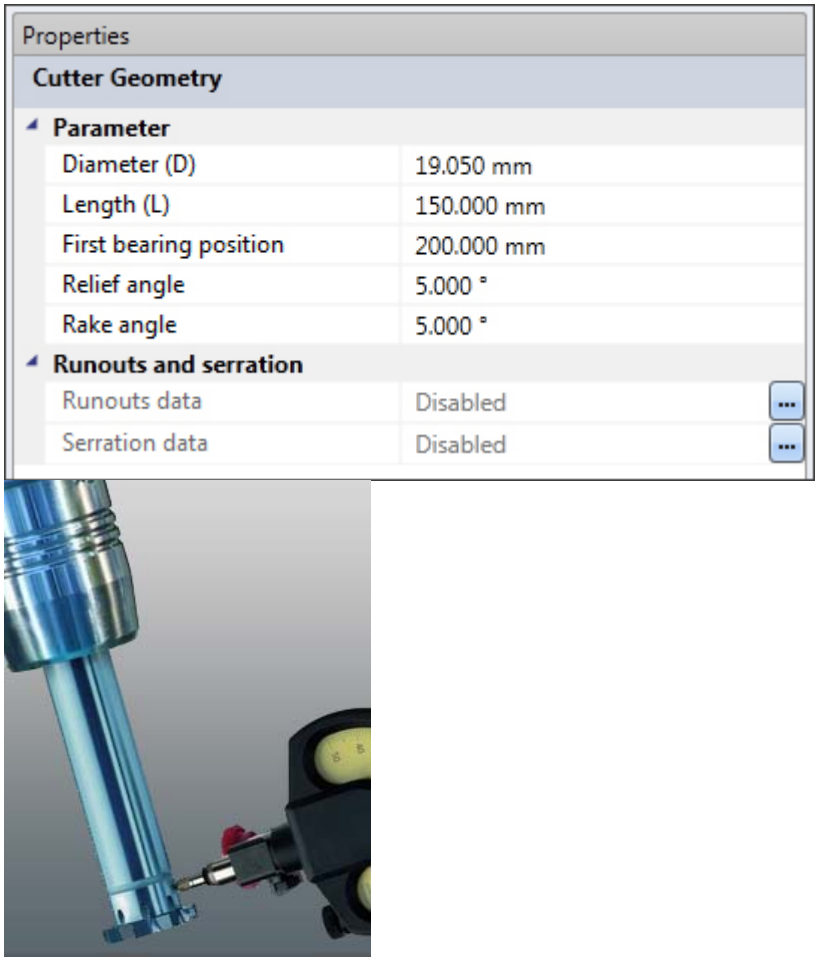
Uniform/Regular	Equal spacing is placed between cutter teeth **(360°/ number of flutes)**
Non-uniform/Variable	You must specify the pitch angles between successive teeth. The Pitch angles must be bigger than zero and the summation of all pitch angles must be **360°**.

2.1.4.1.1.5 Run-out

manufacturing automation laboratories CUTPRO

Run-out

Run-outs are defined as deviations from the ideal/design coordinates of the cutter. By checking the run-out option the user can design very complex, irregular cutter geometry. In this case, the user digitizes the cutter at small increments, and provides the digitized envelope in a run-out file.



Click on the file tab to access runouts data:

File Tab: Quick access to file management

- Selecting and editing a run-out file
- Run-out Example

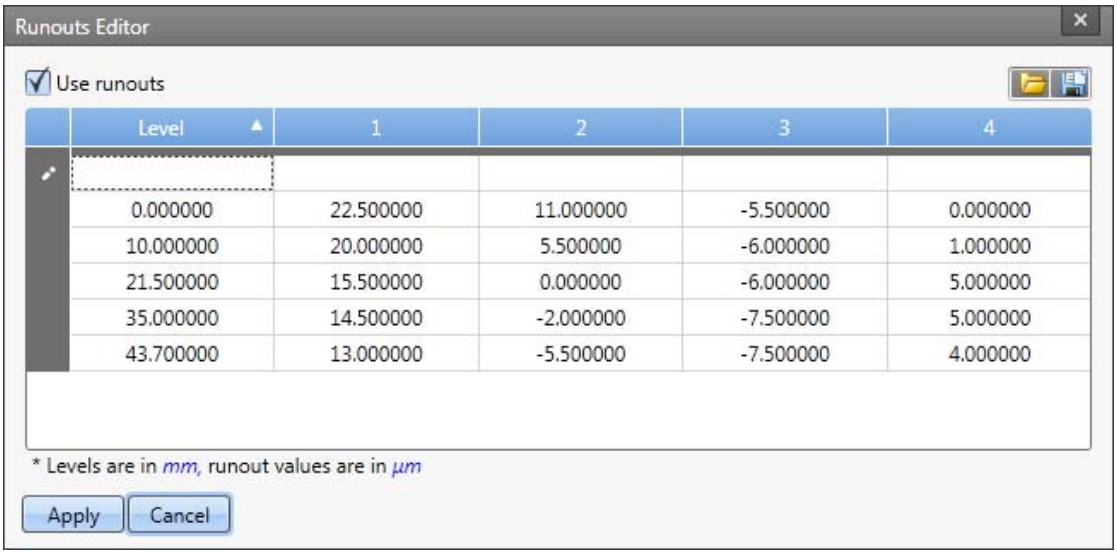
2.1.4.1.1.6 Run-out file editor

manufacturing automation laboratories CUTPRO

Run-out file editor

In a run-out file, the user defines deviations of each cutter tooth from its ideal

geometry, at a series of axial locations along the depth-of-cut. The run-out file editor consists of a table. The first column lists the axial locations at which deviations have been measured; the other columns correspond to the deviations for each cutter tooth.



File

Import Open an existing run-out file.

Export Save the currently open run-out file under the same name.

Exit Exit the Run-out Editor window.

Edit (*Right-click*)

Cut Cut the selected range of cells.

Copy Copy the selected range of cells.

Paste Paste the clipboard contents onto the table at the selected place.

Delete Delete the selected range of cells.

Insert Row Insert an empty row at the selected place.

Delete Row Delete the selected row.

Units (*Changed in Workspace*)

Metric Levels are in [*mm*], runout values are in [*µm*]

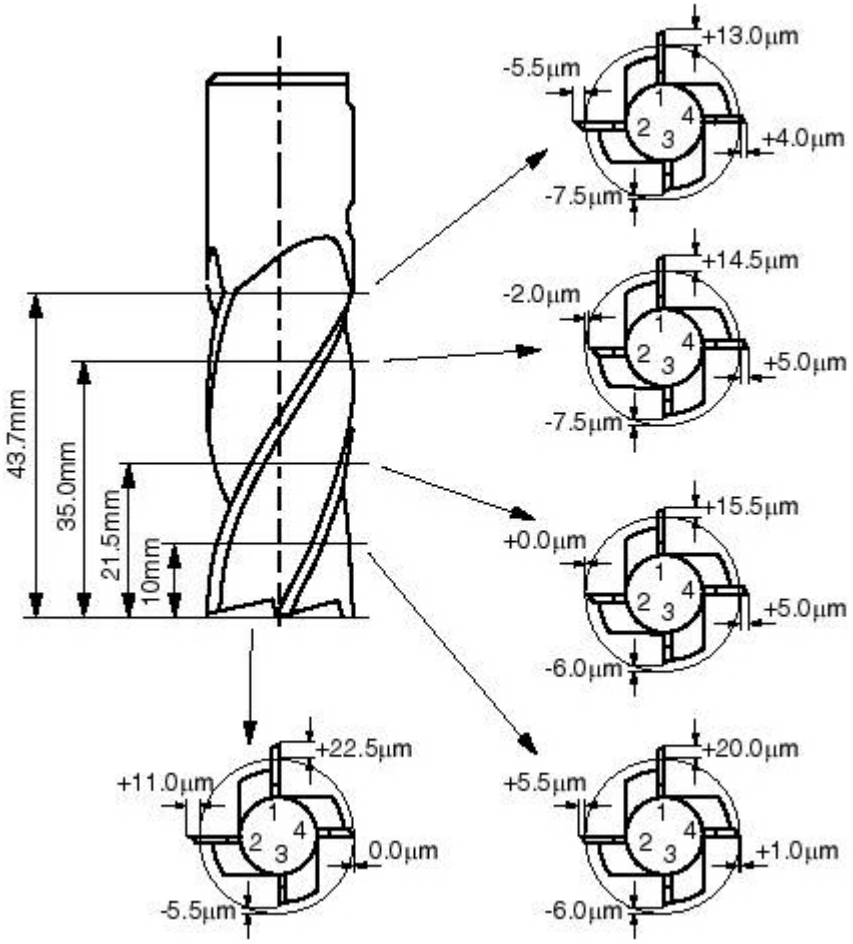
Imperial Levels are in [*inch*], runout values are in [*mils/thou*]

2.1.4.1.1.7 Run-out example

manufacturing automation laboratories CUTPRO

Run-out example

The run-out has been measured for the following cutter:



The corresponding run-out file will be entered as follows:

Runouts Editor

Use runouts

Level	1	2	3	4
0.000000	22.500000	11.000000	-5.500000	0.000000
10.000000	20.000000	5.500000	-6.000000	1.000000
21.500000	15.500000	0.000000	-6.000000	5.000000
35.000000	14.500000	-2.000000	-7.500000	5.000000
43.700000	13.000000	-5.500000	-7.500000	4.000000

* Levels are in *mm*, runout values are in *µm*

Apply Cancel

2.1.4.1.1.8 Serration

manufacturing automation laboratories CUTPRO

Serration

Serrations are defined as wavy profiles along the cutting edge.
They are designed to have a phase shift from one flute to another to prevent unstable cutting.

Properties

Cutter Geometry

Parameter	
Diameter (D)	19.050 mm
Length (L)	150.000 mm
First bearing position	200.000 mm
Relief angle	5.000 °
Rake angle	5.000 °
Runouts and serration	
Runouts data	Disabled
Serration data	Disabled

Click on the file tab to access serration data:

File Tab: Quick access to file management

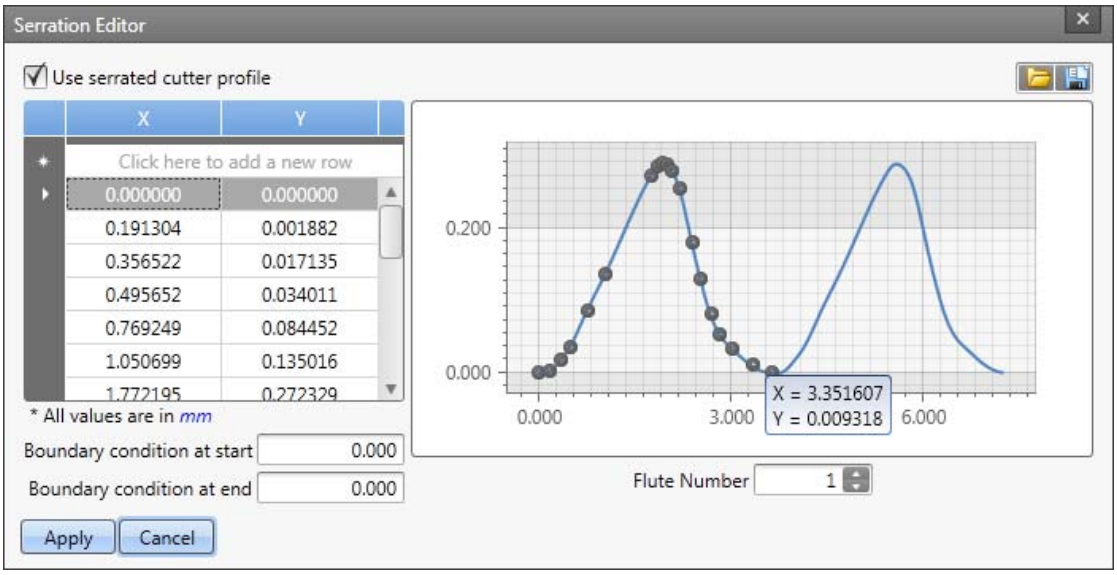
- Selecting and editing a serration file
- Serration Example

2.1.4.1.1.9 Serration file editor

manufacturing automation laboratories CUTPRO

Serration file editor

In a serration file, the user defines deviations of a cutter tooth serration from its geometry.
The serration file editor consists of a table: The first column lists the axial locations at which deviations have been measured; the other column corresponds to the outward deviations for each point of measurement.



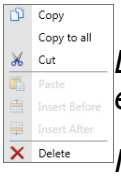
File

Import Open an existing serration file.

Export Save the currently open serration file under the same name.

Exit Exit the Serration Editor window.

Edit (*Right-click*)



Cut Cut the selected range of cells.

Copy Copy the selected range of cells.

Paste Paste the clipboard contents onto the table at the selected place.

Delete Delete the selected range of cells.

Insert Row Insert an empty row at the selected place.

Delete Row Delete the selected row.

Units (*Changed in Workspace*)

Metric Values are in [*mm*]

Imperial Values are in [*inch*]

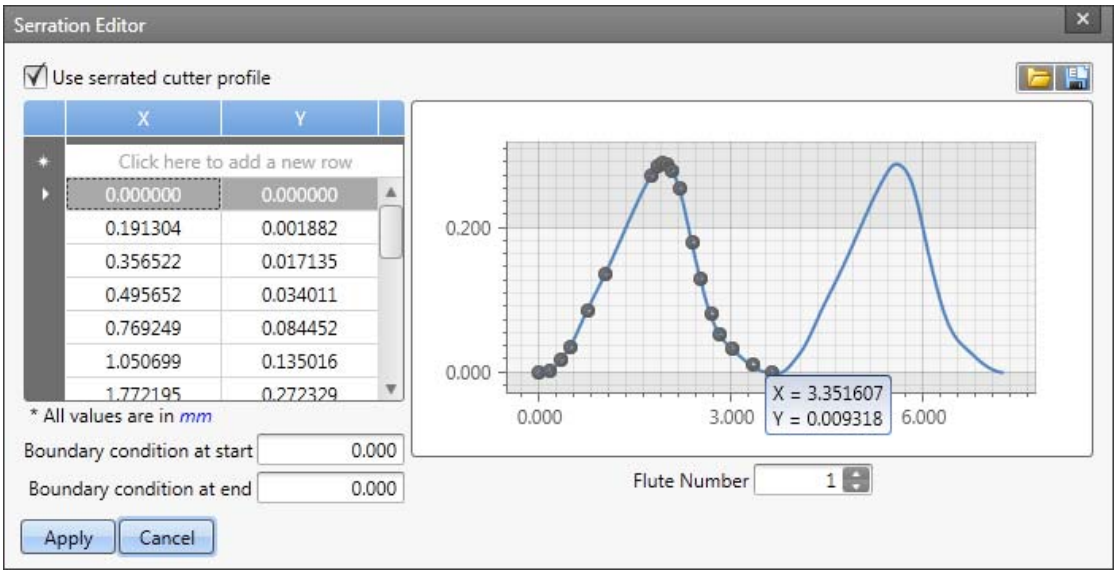
2.1.4.1.1.10 Serration example

manufacturing automation laboratories CUTPRO

Serration example

A serration has been measured for the following cutter on one of its serrated profiles:

The corresponding serration file will be entered as follows:



2.1.4.1.1.11 Length

manufacturing automation laboratories CUTPRO

Length

The Length parameter is defined as the length from the tool tip to the tool holder shank face.

2.1.4.1.1.12 First bearing position

manufacturing automation laboratories CUTPRO

First bearing position

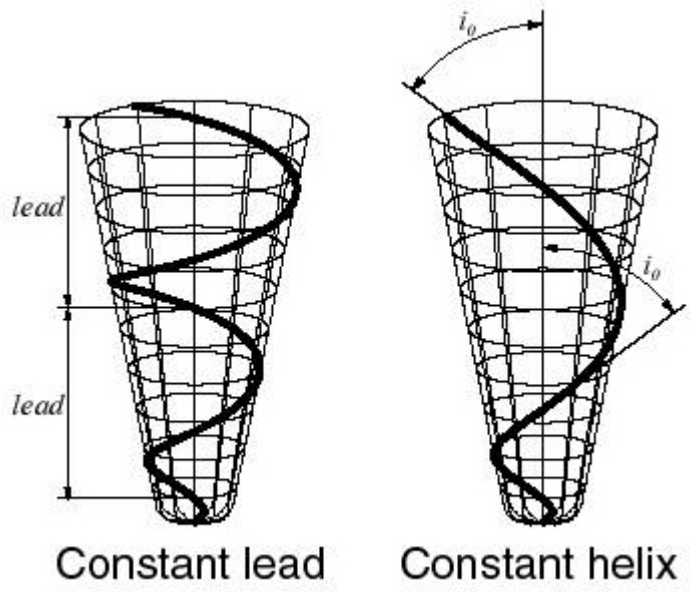
The first bearing position parameter is defined as the distance from the tool tip to the first bearing on the spindle. The first bearing on the spindle
is the bearing located closest to the tool. Measure/retrieve this dimension down to the point where the tool holder face meets the spindle. This
dimension can be called A, and will remain constant regardless of which tool is in the machine. The remaining distance, B, is the distance from
the tool holder connection interface to the tool's tip. We can then say L = A + B, where A is constant and B is dependent on the cutting tool/holder.

2.1.4.1.1.13 Lead distance

manufacturing automation laboratories CUTPRO

Taper angle

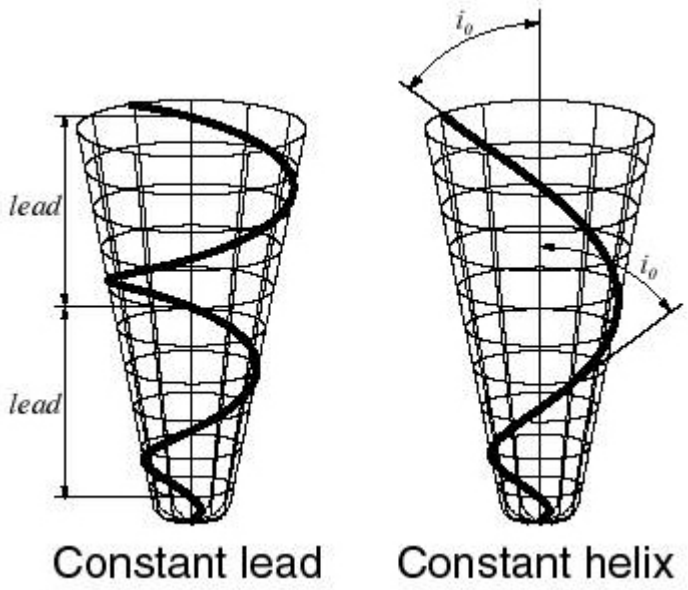
Flute height in Z (axial) direction for one step: see lead dimension (*io*)



2.1.4.1.1.14 Lead/Helix angle

manufacturing automation laboratories CUTPRO

Flute type figure

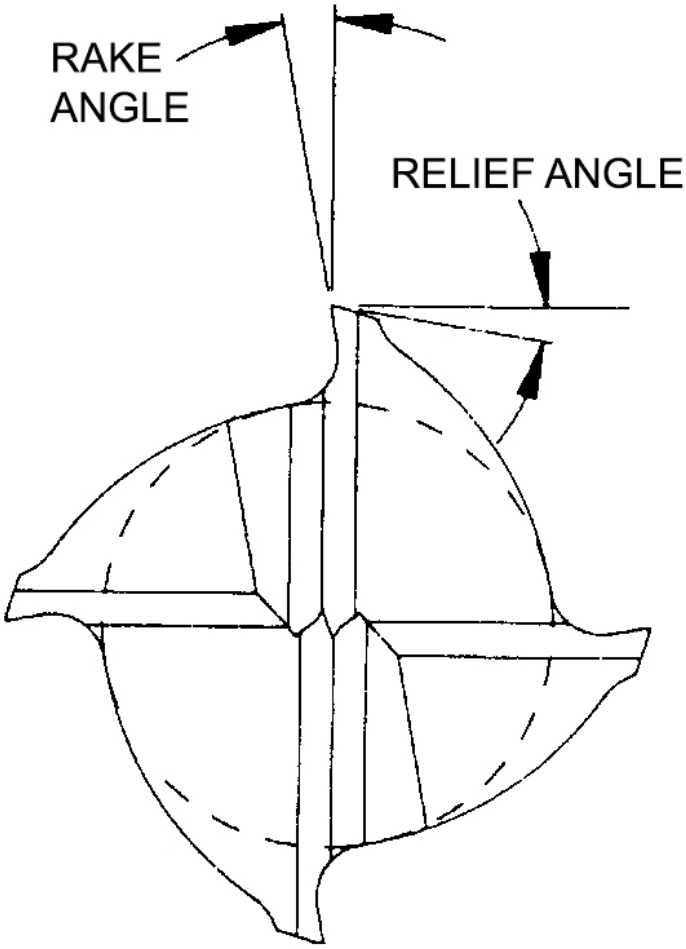


Constant Lead	Distance between flutes along the tool axis is equal
Constant Helix	The helix angle of the flutes remain constant

2.1.4.1.1.15 Rake/Relief angle

manufacturing automation laboratories CUTPRO

Relief angle

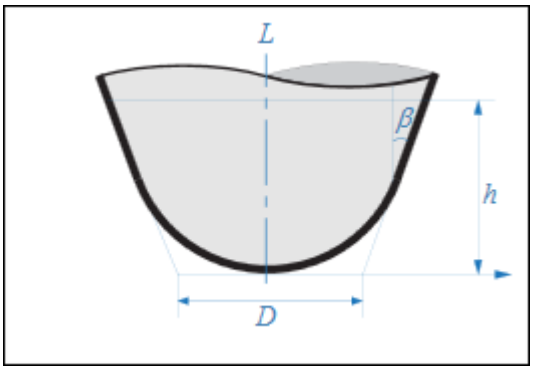


2.1.4.1.1.16 Taper angle

manufacturing automation laboratories CUTPRO

Taper angle

See *(β) symbol in figure*



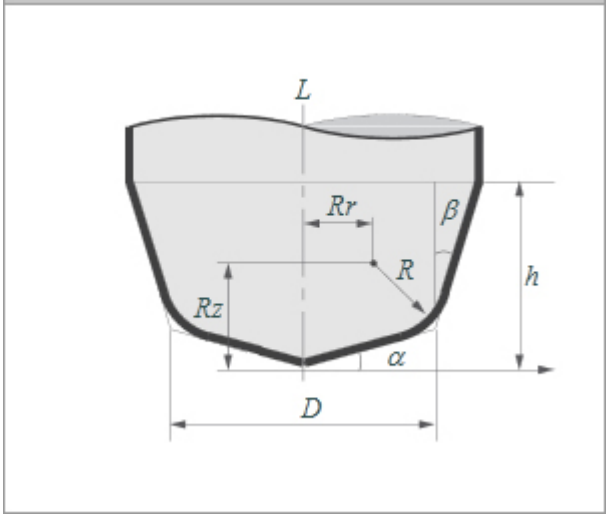
2.1.4.1.1.17 Tip angle

manufacturing automation laboratories CUTPRO

Taper angle

See *(α) symbol in figure*

Demonstration

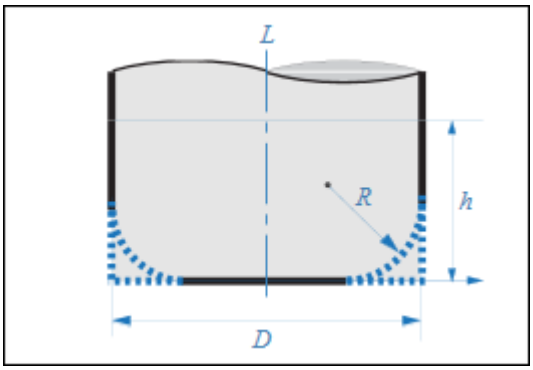


2.1.4.1.1.18 Corner radius

manufacturing automation laboratories CUTPRO

Corner radius

See *(R) symbol in figure*



2.1.4.1.2 Flat

CUTPRO

Machine & Tool - Flat endmill

Flat Endmill

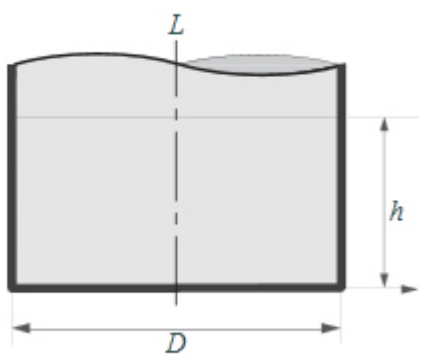
The following parameters define flat endmills:

Properties

Cutter Properties

General	
Cutter Type	Flat end
Number of Flutes	4
Pitch angle	
Uniform	☑
Angle	90.000 °
Helix angle	
Uniform	☑
Angle	30.000 °
Parameter	
Diameter (D)	19.050 mm
Length (L)	150.000 mm
First bearing position	200.000 mm
Relief angle	5.000 °
Rake angle	5.000 °
Corner radius (R)	0.000 mm
Runouts and serration	
Runouts data	Disabled
Serration data	Disabled

Demonstration



Check the Cutter properties/definitions page for further details

NOTE: Available parameters are dependent on simulation type

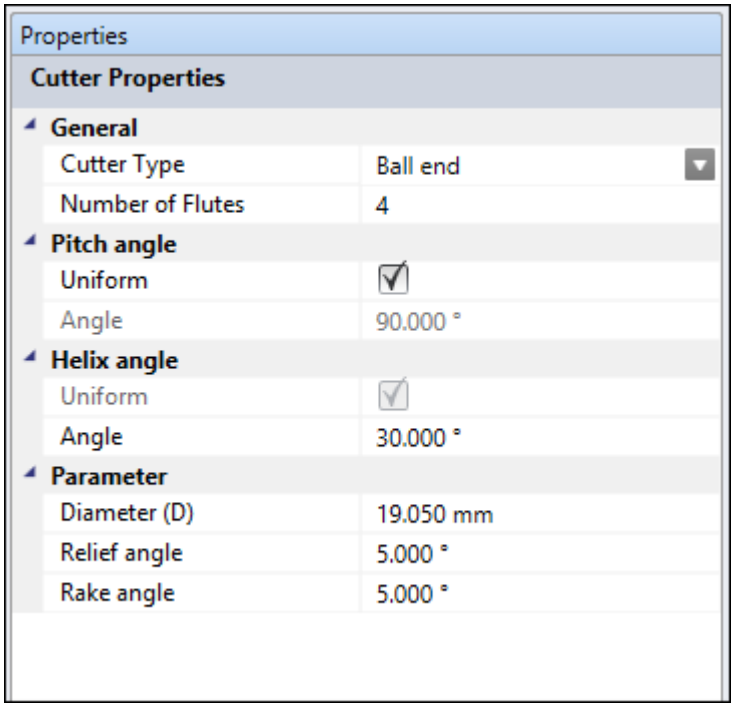
2.1.4.1.3 Ball-end

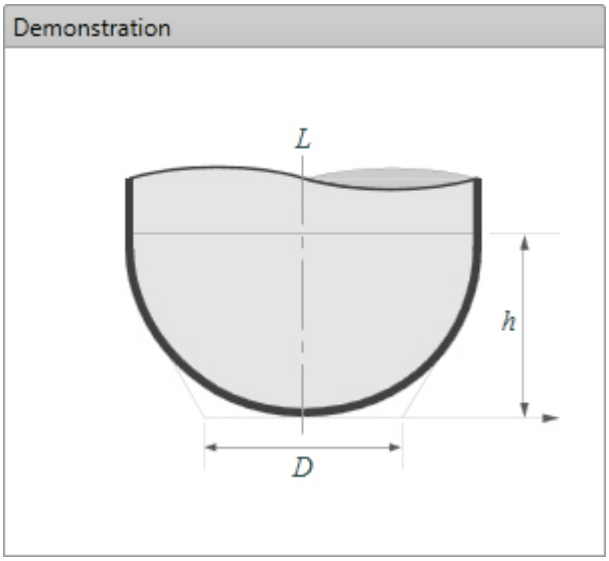
manufacturing automation laboratories CUTPRO

Machine & Tool - Ball-end endmill

Ball-end Endmill

The following parameters define an ball-end endmill:





Check the Cutter properties/definitions page for further details

NOTE: Available parameters are dependent on simulation type

2.1.4.1.4 Tapered ball-end

manufacturing automation laboratories CUTPRO

Machine & Tool - Tapered ball-end endmill

Tapered ball-end Endmill

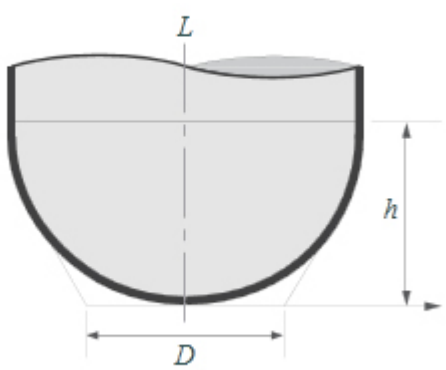
The following parameters define an tapered ball-end endmill:

Properties

Cutter Properties

General	
Cutter Type	Tapered ball end
Number of Flutes	4
Pitch angle	
Uniform	☑
Angle	90.000 °
Helix angle	
Uniform	☑
Angle	30.000 °
Parameter	
Diameter (D)	19.050 mm
Length (L)	150.000 mm
First bearing position	200.000 mm
Relief angle	5.000 °
Rake angle	5.000 °
Taper angle (β)	1.000 °
Runouts and serration	
Runouts data	Disabled
Serration data	Disabled

Demonstration



Check the Cutter properties/definitions page for further details

NOTE: Available parameters are dependent on simulation type

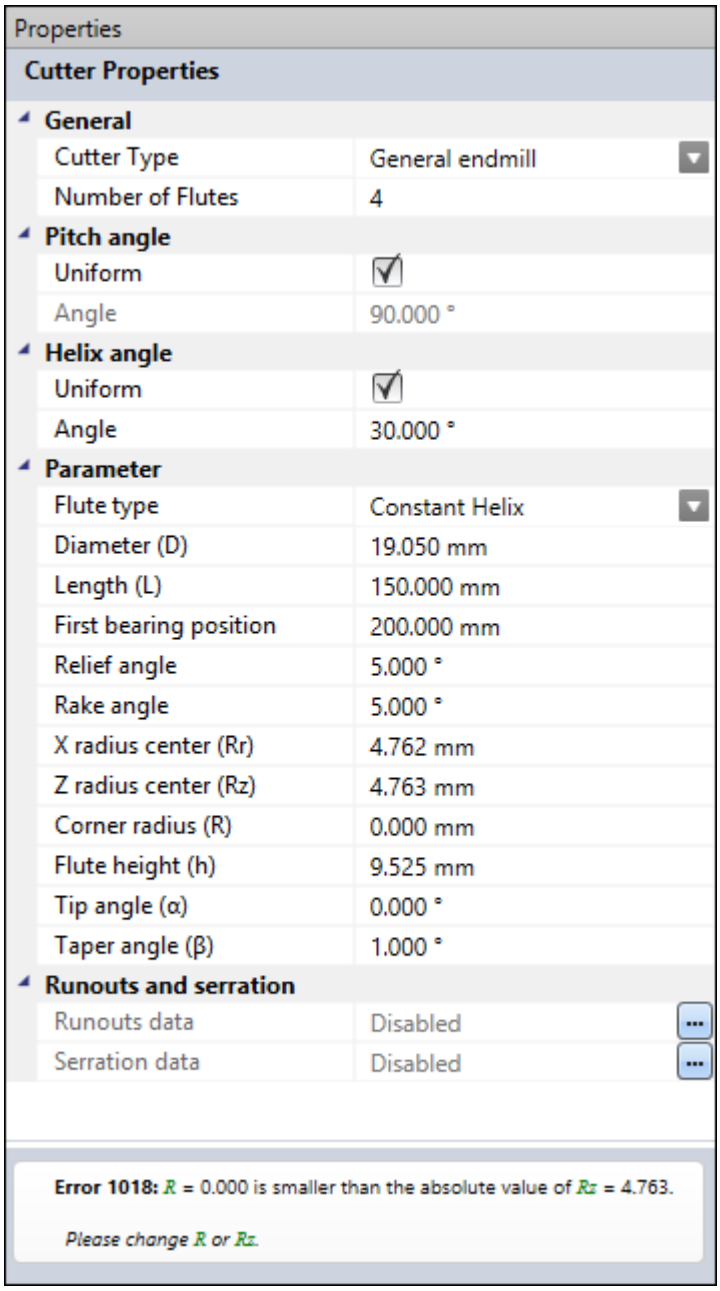
2.1.4.1.5 General

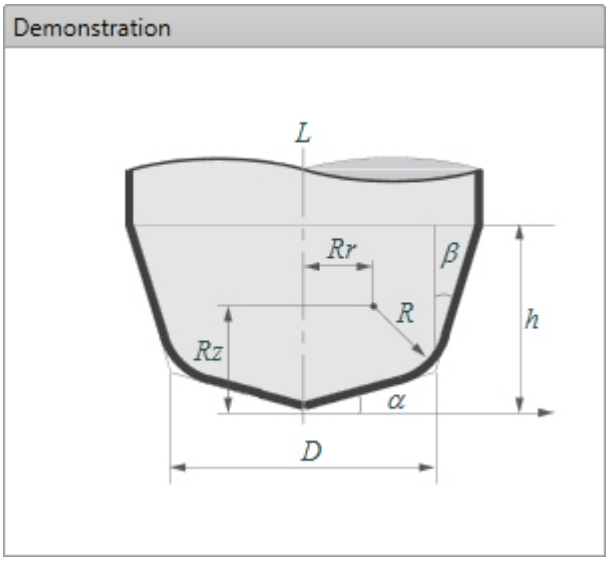
manufacturing automation laboratories CUTPRO

Machine & Tool - Cutter geometry

General Endmill

All parameters can be used to define an general endmill:





Check the Cutter properties/definitions page for further details

NOTE: Available parameters are dependent on simulation type

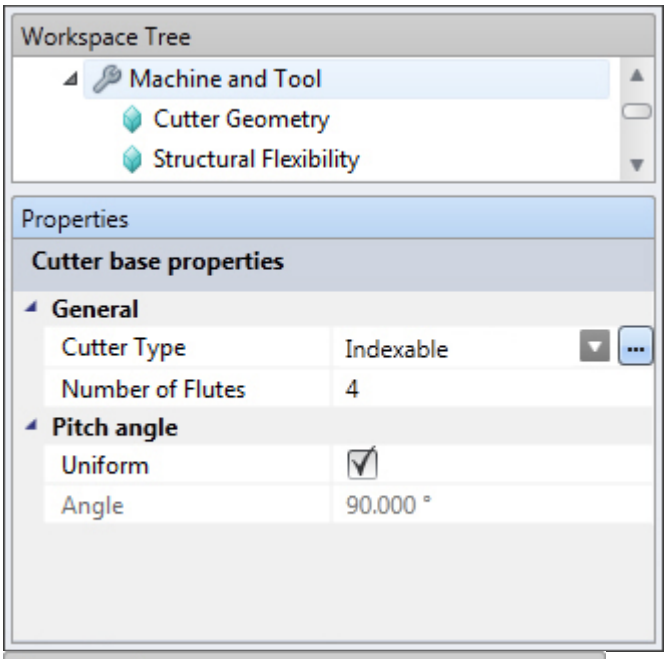
2.1.4.1.6 Indexable

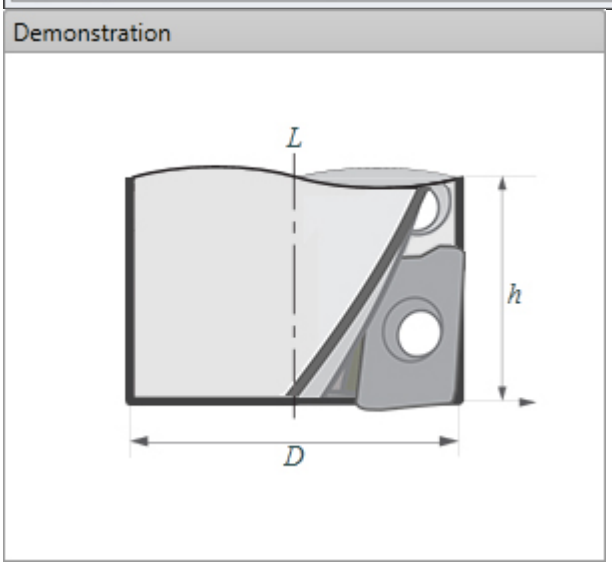
manufacturing automation laboratories CUTPRO

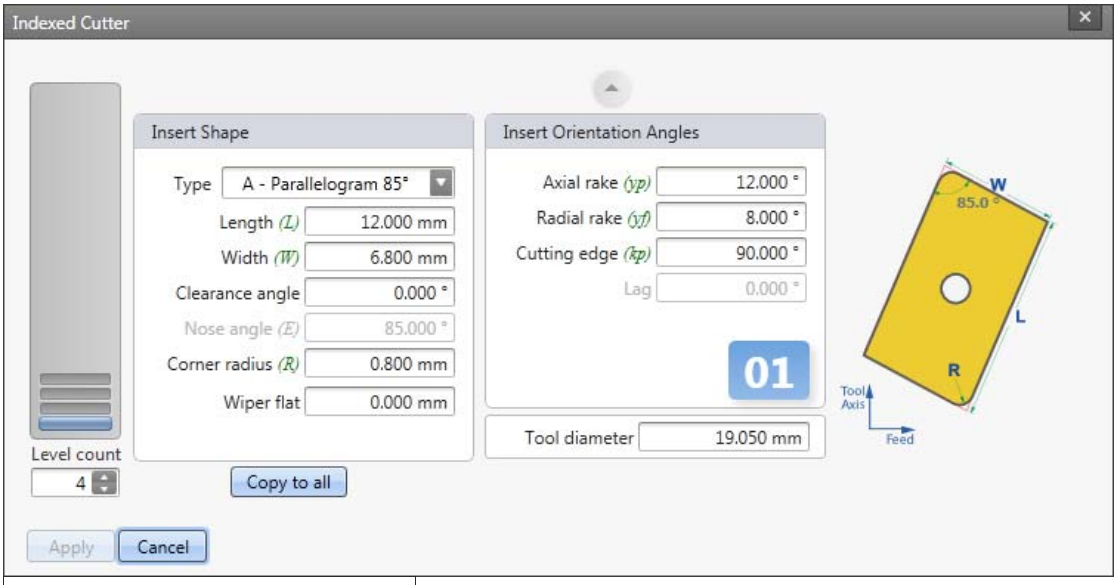
Machine & Tool - Cutter geometry

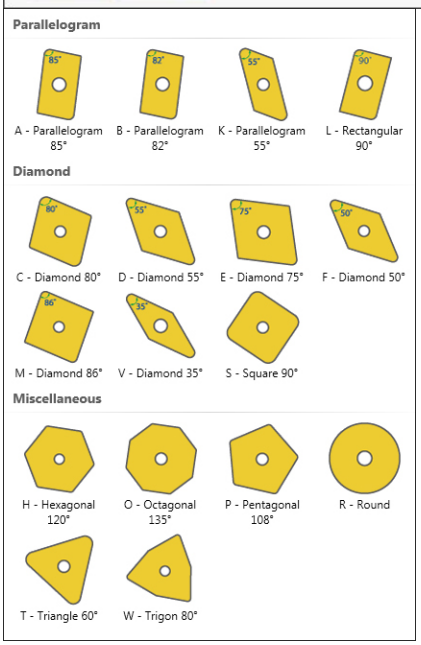
Indexable Cutter

The following parameters define an indexable endmill:







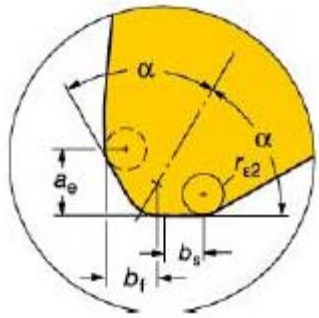


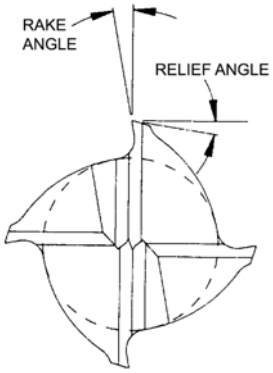
Indexable cutter parameters:

# of flutes	Same as number of inserts on each level of the cutter
Level Count	The number of insert levels along the height of the tool
Current level	The current selected level (The selected level will turn blue colored)
Insert shape	The currently selected insert on the current level (The selected insert will be displayed on the right hand side)

Insert orientation parameters:

Length (L)	The length of the insert, as displayed above.

Width (W)	The width of the insert, as displayed above.
Corner radius (R)	The corner radius of the insert, as displayed above.
Wiper flat (b_s)	
Tool diameter	The diameter of the cutter
Clearance angle (Relief)	Relief angle of the cutting insert.
Radial rake angle	Rake angle of the cutting insert.
Axial rake angle	Axial rake angle of the currently selected insert.
Cutting edge angle (Lead angle)	Cutting edge angle of the currently selected insert.
Lag angle	Lag angle of the currently selected insert. This is incremental from the previous insert center on the same level.



Other commands

The following commands are also available under indexable cutter geometry:

Insert Type	Displays various insert types to select from.
Copy to all	Copies the currently selected insert and its orientation parameters to all levels of the cutter.
Apply	Applies indexed cutter parameters and closes window
Cancel	Closes indexed cutter window without making changes

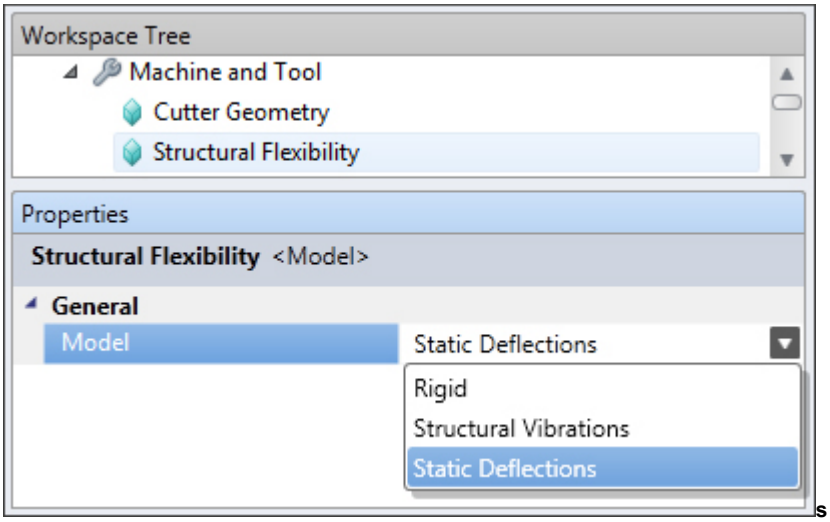
2.1.4.2 Structural flexibility

manufacturing automation laboratories CUTPRO

Machine & Tool - Structural flexibility

Machine & Tool simulation models available:

- Rigid model
- Structural vibrations model
- Static deflections model



2.1.4.2.1 Rigid model

manufacturing automation laboratories CUTPRO

Structural flexibility - Rigid machine & tool model

- Effects of machine & tool vibrations are not included in the simulation
- Machine/cutter is assumed rigid
- Simulation will be under static conditions.

Chip models

- Exact kinematics (*chip thickness is calculated using discretization of the surface*)
- Approximation (*chip load calculation using sinusoidal approximation*)

2.1.4.2.2 Structural vibrations model

manufacturing automation laboratories CUTPRO

Structural flexibility - Structural vibrations machine & tool model

Machine & tool has structural flexibility

Dynamics data

Measured FRF (*for analytical stability lobes & variable pitch simulations only*)

X, Y and Z frf file	Uses a file containing real and imaginary parts of the measured frequency response function. These files are created using the MALTF module or similar.

Modal/residue data files

X, Y and Z modal/residue file	Uses a file containing modal parameters. These modal parameter files are created using the Modal Analysis program.

Vibration parameters

This uses the following dynamic parameters. It only allows for a single dominant mode in each of the X- and Y-directions.

Natural frequency	Natural frequency of the system in [Hz]
Damping ratio	Damping ratio for that mode
Stiffness	Stiffness of the system [N/m]

Transfer function values are calculated using following equation in frequency domain:

$$\Phi = \frac{\omega_n^2 k}{\omega_n^2 - \omega^2 + i\,2\zeta\omega_n\omega}$$

2.1.4.2.2.1 Measured FRF File

manufacturing automation laboratories CUTPRO

Structural flexibility - Measured FRF File

The structural flexibility of the machine & tool structure must be used in some simulation cases.

It is particularly needed for determining the chatter free machining stability of the system.

Introduction to FRF Measurements
Using a modal impact hammer as an input sensor, and an accelerometer (for example) as an output sensor, we can impact the
system to take what is called a transfer function measurement. The transfer function tells us the relationship between the input and
output, which in this case is the relationship between Force and Deflection over a frequency range.This is also known as an FRF,
a Frequency Response Function, which tells us how much the system will deflect at certain frequencies. Sometimes you will need to
manually filter out certainly frequencies of interest and create a custom-fitted curve; this is known as modal analysis.

The supplied module MALTF is used for this measurement, please refer to the MALTF manual for further information.
Also refer to Modal Analysis for modifying the measured FRF.
If you require further assistance in this technical area, please contact our Support Helpdesk.

FRF File Details (2015+)

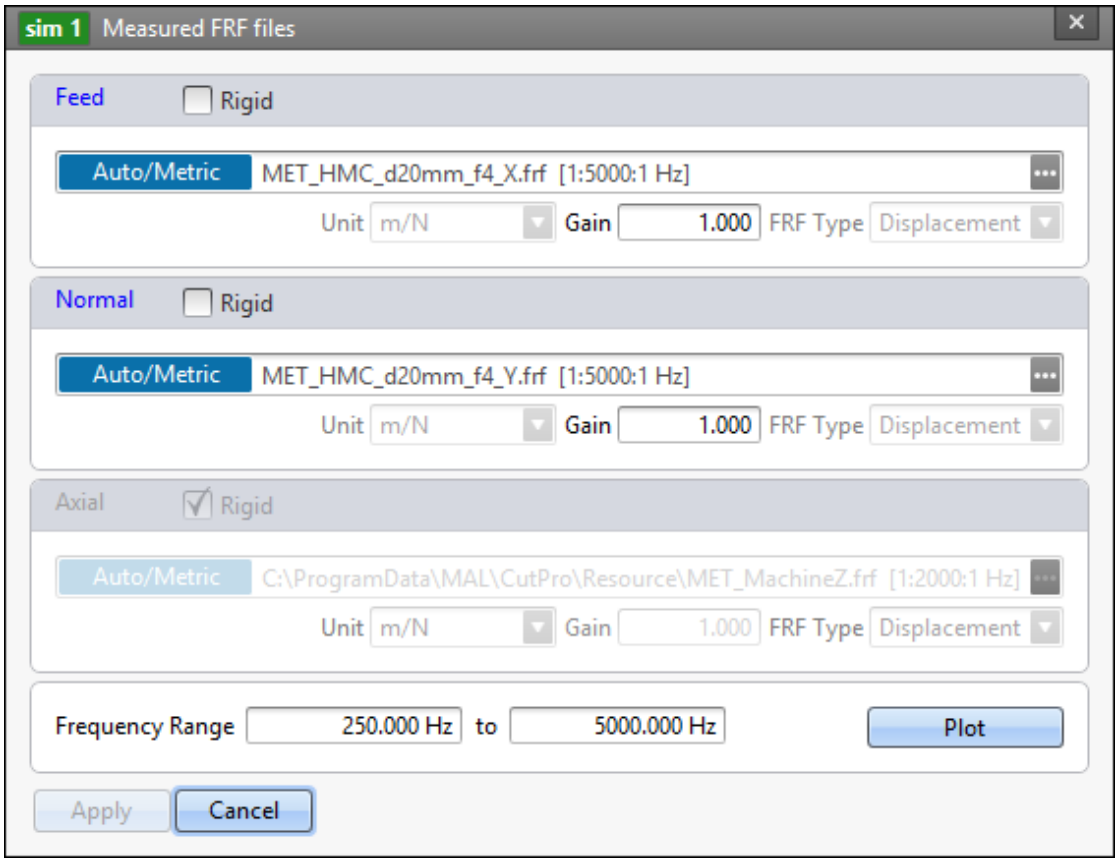
In the latest version of FRF files, you will notice that there are 3 columns of collected data.
Row 1 represents a Frequency in Hz (as shown in columns 4 and 5)
Row 2 represents a Real Part of the FRF in m/N (as shown in columns 6 and 7)
Row 3 represents a Imaginary Part of the FRF in m/N (as shown in columns 8 and 9)
Older FRFs from MALTF (Before 2015) will not contain units in the file, and will be m/N if metric or in/lbf if imperial.

MET_Gxx.frf

```
101 1.182750E-006   -2.252787E-008  Freq    Hz  Real    m/N Imag    m/N
102 1.180777E-06    -2.281263E-08
103 1.17893E-06 -2.309951E-08
104 1.177204E-06    -2.338855E-08
105 1.175596E-06    -2.367978E-08
106 1.174103E-06    -2.397325E-08
107 1.17272E-06 -2.426899E-08
108 1.171446E-06    -2.456704E-08
109 1.170277E-06    -2.486745E-08
110 1.16921E-06 -2.517024E-08
111 1.168243E-06    -2.547548E-08
112 1.167374E-06    -2.578319E-08
113 1.166599E-06    -2.609343E-08
114 1.165916E-06    -2.640624E-08
115 1.165325E-06    -2.672165E-08
116 1.164821E-06    -2.703973E-08
117 1.164404E-06    -2.736051E-08
118 1.164072E-06    -2.768404E-08
119 1.163822E-06    -2.801037E-08
120 1.163654E-06    -2.833956E-08
121 1.163565E-06    -2.867165E-08
122 1.163555E-06    -2.900669E-08
123 1.163621E-06    -2.934473E-08
124 1.163762E-06    -2.968583E-08
125 1.163977E-06    -3.003005E-08
```

Using the Interface

There are 3 axes where FRF files can be applied. These will depend on the type of operation.
In the case of milling, the Axial axis (spindle) is far far more rigid than than the Feed and Normal axes.
CutPro sets it to rigid by default for this reason.



Units: Newer FRF files (2015) contain their unit system within the file and will display Auto.
However, if you are using older files (before 2015) you must manually define the file unit type as shown above.

Gain: The gain value is used to stretch/shrink the Y axis values of the FRF file, or swap directions by adding a -1.0.

FRF Type: This is the FRF file type which is either a Displacement or Acceleration type FRF (selected in MALTF).

Frequency Range: Used to cut off the lower range and higher range of the raw FRF measurement.

Plot: Displays the FRF plots based on the input files and settings.

2.1.4.2.2.2 Modal/Residue data files

manufacturing automation laboratories CUTPRO

Structural flexibility - Modal/Residue data files

The structural flexibility of the machine & tool structure must be used in some simulation cases.
It is particularly needed for determining the chatter free machining stability of the system.

Introduction to FRF Measurements and Modal/Residue data files
The transfer function tells us the relationship between the input and output, which in this case is the relationship between Force and
Deflection over a frequency range.This is also known as an FRF, a Frequency Response Function, which tells us how much the system
will deflect at certain frequencies. Sometimes you will need to manually filter out certainly frequencies of interest and create a
custom-fitted curve; this is known as modal analysis. Using a modal analysis software such as ours, you can output what is called
modal parameters. The modal parameters are stored in a (*.CMP) file

The supplied module MALTF is used for this measurement, please refer to the MALTF manual for further information.
Also refer to Modal Analysis for modifying the measured FRF.
If you require further assistance in this technical area, please contact our Support Helpdesk.

CMP File Details (2015+)

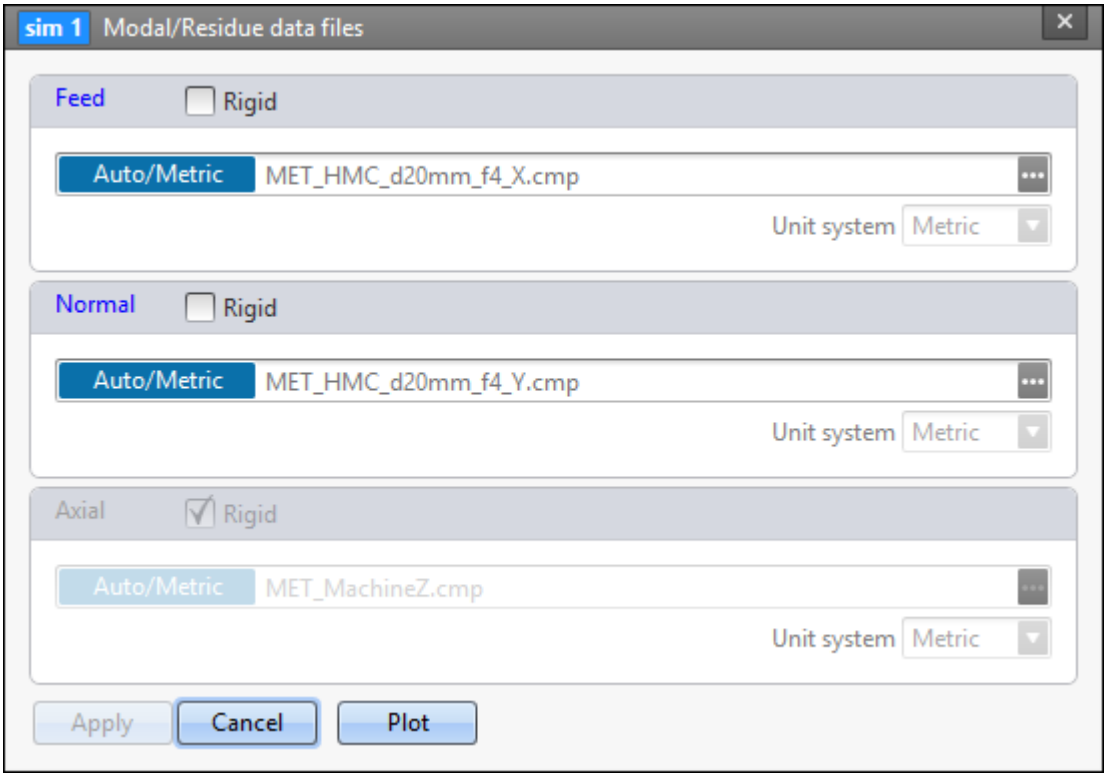
The CMP file consists of modal parameters. These include the number of modes fitted,
points, natural frequencies, modal stiffness, dampening ratio, locations, unit system etc.
Older CMPs from Modal Analysis (Before 2015) will not contain the unit system in the file.
The "Metric" or "Imperial" tag will be missing, please refer to the modal analysis units page
for full details on this topic.

MET_Gxy.cmp

```
MODES    1
PNTS     1
REALM    1
WN   369.153037852127
ZETA     8.85693947383282E-03
MASS     -7.46255401869783
STIFK    -40147581.1191804
LOCNS    0
MODSH    -0.3660634
METRIC
```

Using the Interface

There are 3 axes where CMP files can be applied. These will depend on the type of operation.
In the case of milling, the Axial axis (spindle) is far far more rigid than than the Feed and Normal axes.
CutPro sets it to rigid by default for this reason.



Units: Newer CMP files (2015) contain their unit system within the file and will display Auto.
However, if you are using older files (before 2015) you must manually define the file unit type as shown above.

Plot: Displays the CMP plots based on the input files and settings.

2.1.4.2.2.3 Vibration parameters

manufacturing automation laboratories CUTPRO

Structural flexibility - Vibration parameters

The structural flexibility of the machine & tool structure must be used in some simulation cases.
It is particularly needed for determining the chatter free machining stability of the system.

Introduction to FRF Measurements and Vibration parameters
The transfer function tells us the relationship between the input and output, which in this case is the relationship between Force and
Deflection over a frequency range. This is also known as an FRF, a Frequency Response Function, which tells us how much the system
will deflect at certain frequencies. Sometimes you will need to manually filter out certainly frequencies of interest and create a
custom-fitted curve; this is known as modal analysis. Using a modal analysis software such as ours, you can output what is called
modal parameters. The modal parameters are stored in a (*.CMP) file.

Some customers use other 3rd party softwares (non-MAL) to obtain these parameters, and as a result may not have
file compatibility. In this case, customers can use the Vibration Parameters window to manually enter parameters.

The supplied module MALTF is used for this measurement, please refer to the MALTF manual for further information.
Also refer to Modal Analysis for modifying the measured FRF.
If you require further assistance in this technical area, please contact our Support Helpdesk.

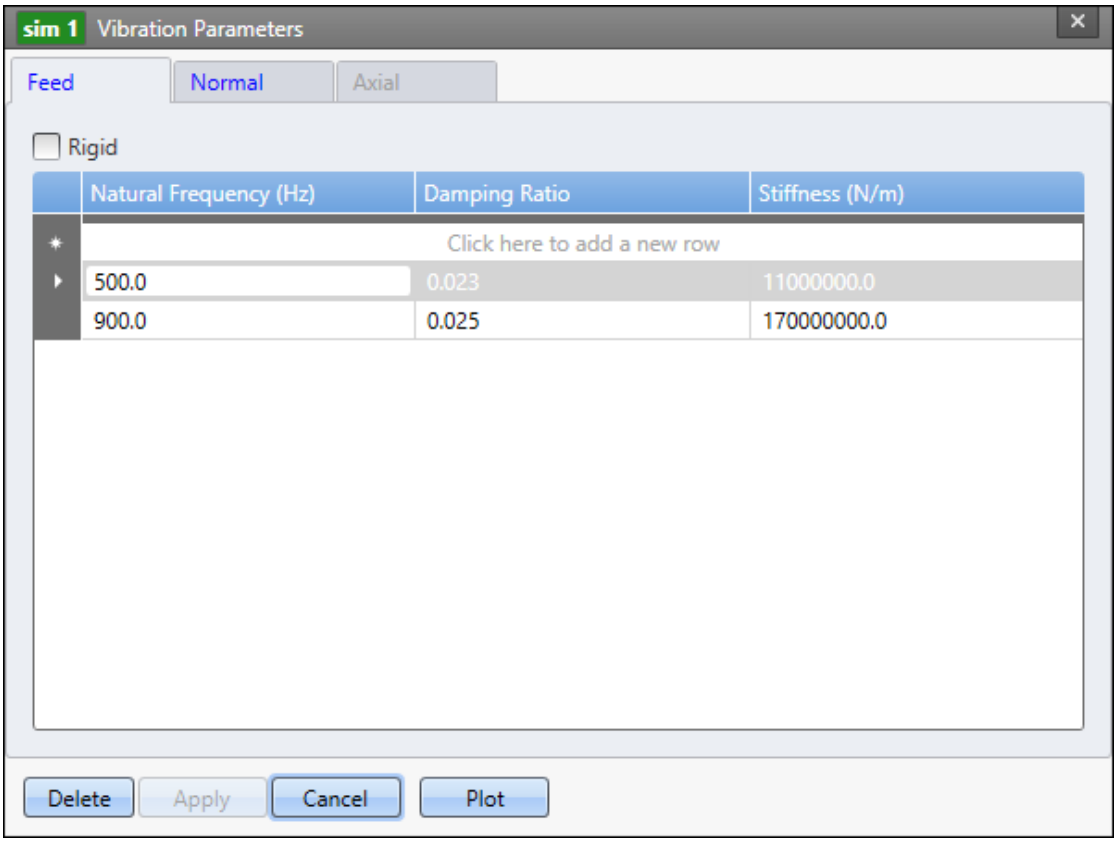
Vibration Parameter Details (2015+)

As mentioned above, the CMP file consists of modal parameters. These include natural frequencies, modal stiffness and dampening ratios.
If you have selected Vibration Parameters, you must manually enter these values corresponding to your FRF.

Using the Interface

There are 3 axes where vibrations parameters can be applied. These will depend on the type of operation.

In the case of milling, the Axial axis (spindle) is far far more rigid than than the Feed and Normal axes.
CutPro sets it to rigid by default for this reason.

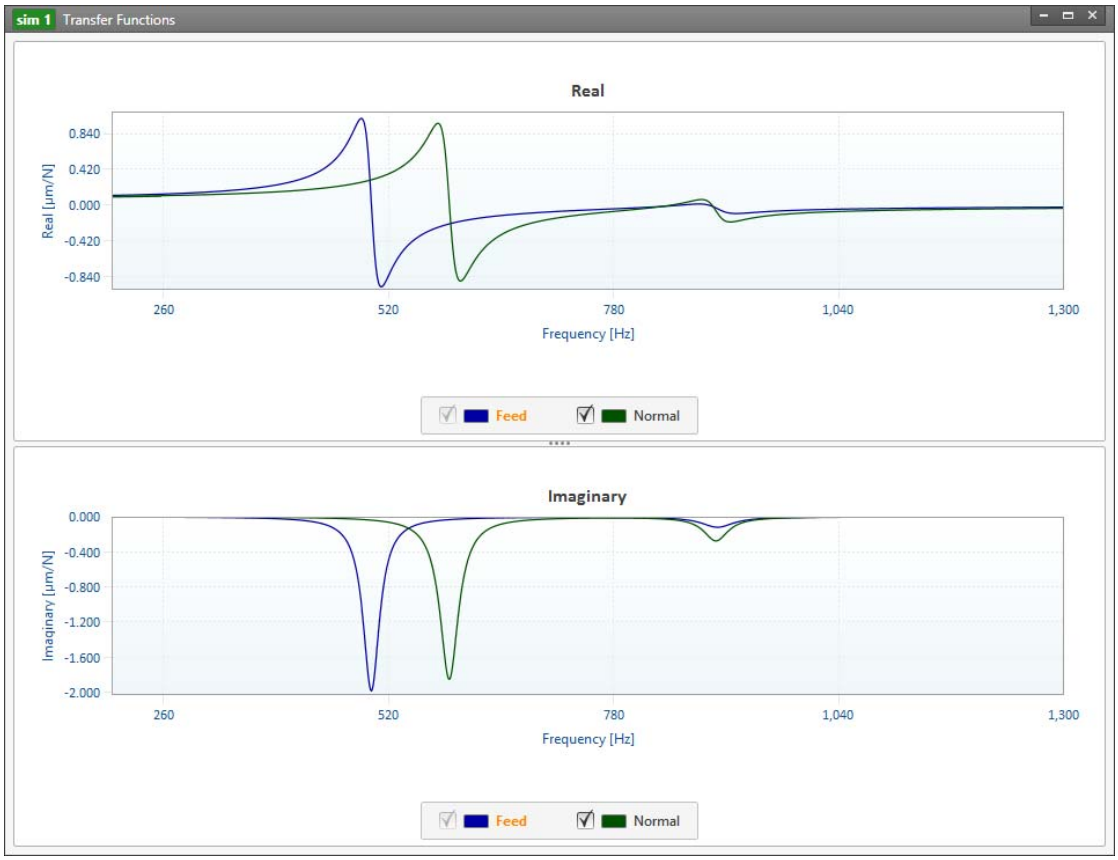


Natural Frequncy (Hz): Newer CMP files (2015) contain their unit system within the file and will display Auto.
However, if you are using older files (before 2015) you must manually define the file unit type as shown above.

Damping Ratio: Unitless damping ratio

Stiffness: Modal stiffness in N/m (Metric) or lbf/in (Imperial)

Plot: Displays the vibration parameters plot based on the vlues you have input.



2.1.4.2.3 Static deflections model

manufacturing automation laboratories CUTPRO

Structural flexibility - Static deflections machine & tool model

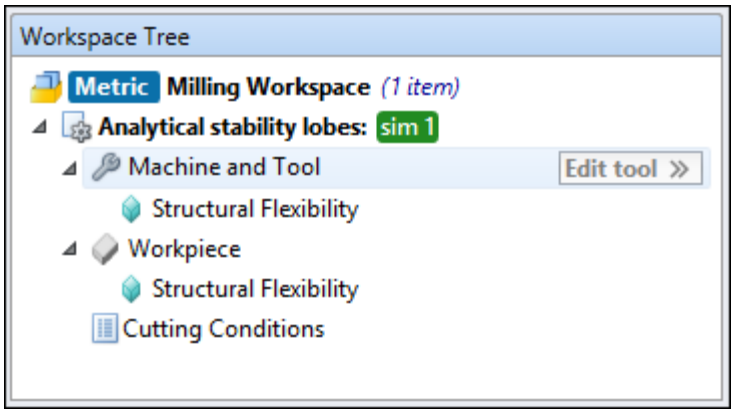
- Dynamic effects of machine/tool vibrations are not included
- Static deflection of cutter is included based on:
  - o Clamp Stiffness
  - o Modal Elasticity.

2.1.4.3 Edit tool

manufacturing automation laboratories CUTPRO

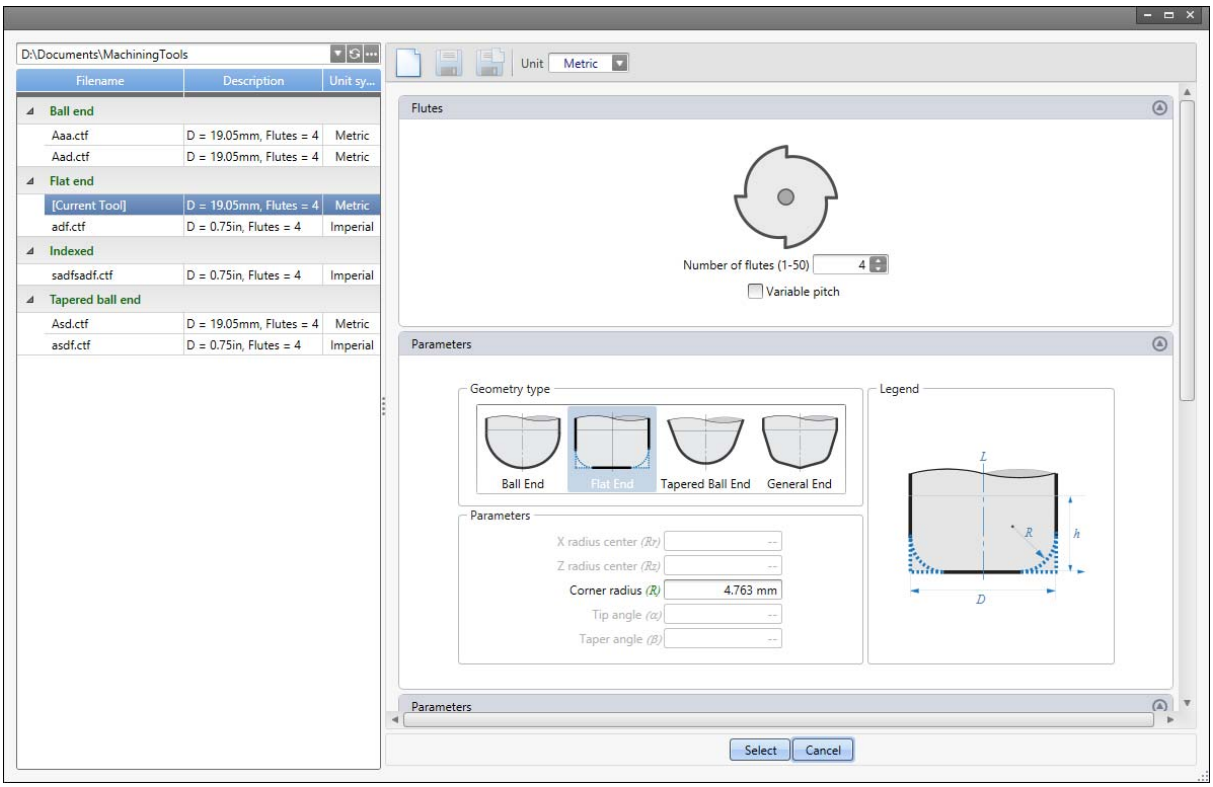
Machine & Tool - Edit Tool

If you wish to edit tool parameters within the Tool Editor, or wish to change to another tool, click the "Edit tool" button:



Edit Tool Window

The edit tool window is used for swapping the current tool in the project, and/or for modifying the current tool's parameters:

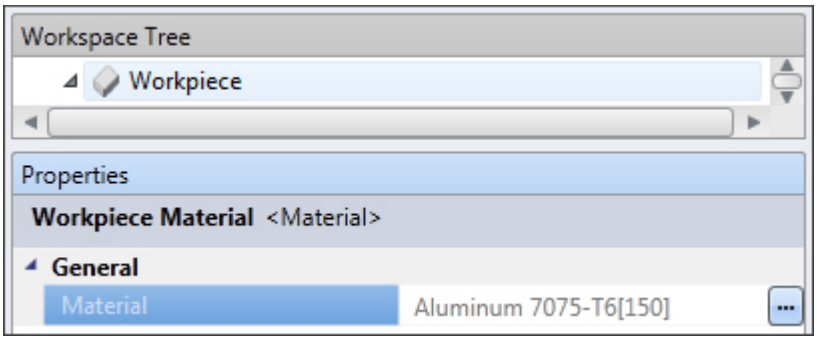


2.1.5 Workpiece

CUTPRO

Workpiece - Overview

Under the workpiece category of simulation, the user is to select a workpiece material:



Once the material has been selected, parameters involving structural flexibility may be defined.

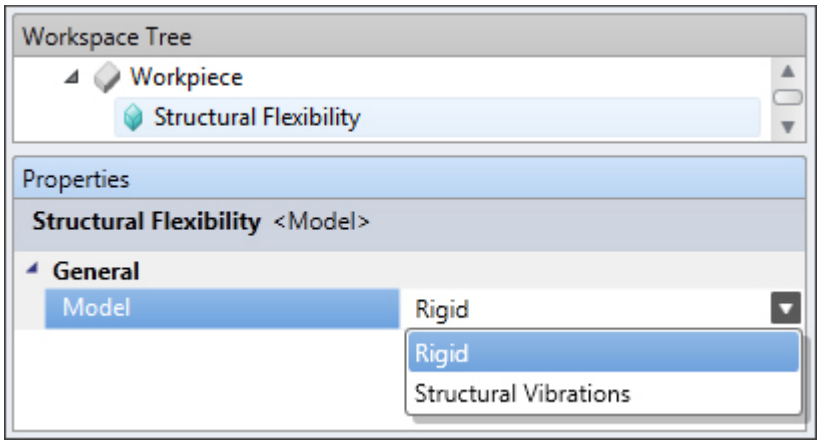
2.1.5.1 Structural Flexibility

CUTPRO

Workpiece - Structural flexibility

Workpiece simulation models available:

- Rigid model
- Structural vibrations model



2.1.5.1.1 Rigid model

manufacturing automation laboratories CUTPRO

Structural flexibility - Rigid workpiece model

- Effects of workpiece vibrations are not included in the simulation
- Workpiece is assumed rigid
- Simulation will be under static conditions.

2.1.5.1.2 Structural vibrations model

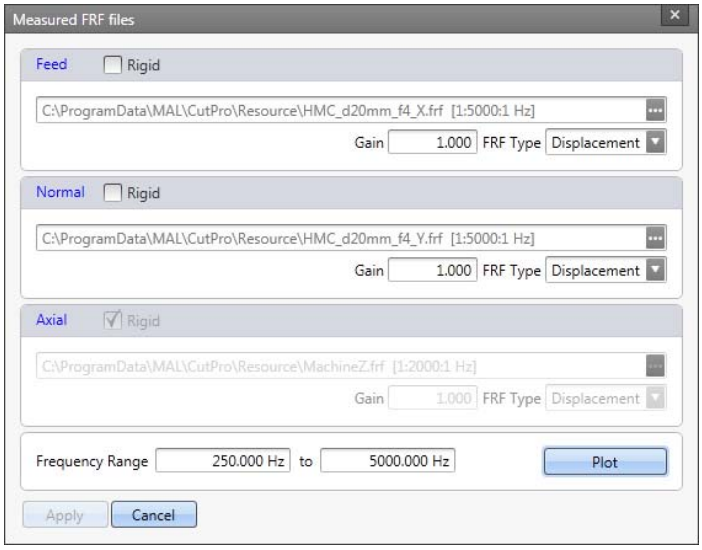
manufacturing automation laboratories CUTPRO

Structural flexibility - Structural vibrations model

Workpiece has structural flexibility

Dynamics data

- **Measured FRF (***for analytical stability lobes & variable pitch simulation only***)**



- **Modal/residue data files**

X modal/residue file	Uses a file containing modal parameters. These modal parameter files are created using the Modal Analysis program.
Y modal/residue file	Uses a file containing modal parameters. These modal parameter files are created using the Modal Analysis program.

- **Vibration parameters**

  This uses the following dynamic parameters. It only allows for a single dominant mode in each of the X- and Y-directions.

Natural frequency	Natural frequency of the system in [Hz]
Damping ratio	Damping ratio for that mode
Stiffness	Stiffness of the system [N/m]

Transfer function values are calculated using following equation in frequency domain:

$$\Phi = \frac{\omega_n^2 k}{\omega_n^2 - \omega^2 + i\,2\zeta\omega_n\omega}$$

2.1.6 Cutting Conditions

manufacturing automation laboratories CUTPRO

Cutting Conditions - Overview

Milling Mode

The following milling modes and defining parameters are available for the cylindrical endmill type:

- Down-milling
- Up-milling
- Slotting
- Face-milling

2.1.6.1 Down-milling

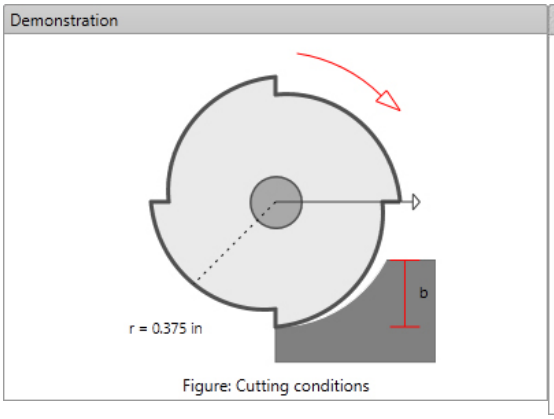
manufacturing automation laboratories CUTPRO

Down-milling

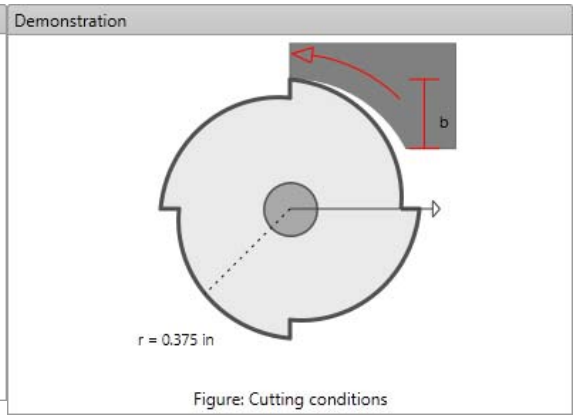
Also known as *Climb Milling*.

Spindle Direction
Enter the direction of cutter rotation **[*cw / ccw*]:**

Clockwise



Counter-clockwise

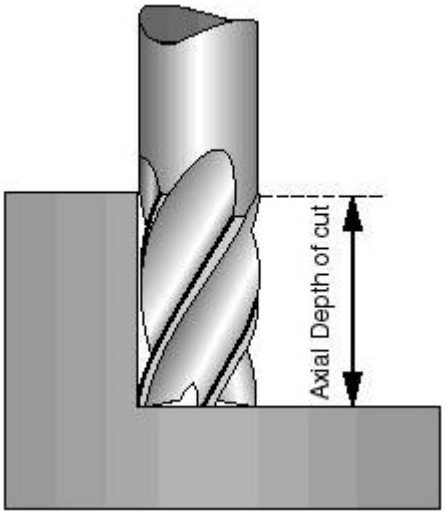


Feedrate
Enter the feed rate of the cutting operation as **[*mm/flute*]** or **[in/flute]**. If the feed rate is as **[*mm/min*]**, use the following equation to convert:

$$(\text{feed rate [mm/tooth]}) = \frac{(\text{feed rate [mm/min]})}{(\text{number of flute}) * (\text{spindle speed[rev/min]})}$$

Spindle Speed
Enter the spindle speed, in revolutions per minute **[*rpm*]**. Available only for certain simulation modes.

Axial Depth of Cut
Enter the axial depth of cut from tool tip up to workpiece surface level. Available only for certain simulation modes.



Width of Cut
Enter the width of cut from tool edge towards it's full diameter.

Number of Revolutions
Enter the number of cutter revolutions to be simulated. Available only for certain simulation modes.

Min. surface speed & max. surface speed
Enter the minimum surface speed and maximum surface speed. Available only for certain simulation modes.

*parameters vary dependant on simulation

2.1.6.2 Up-milling

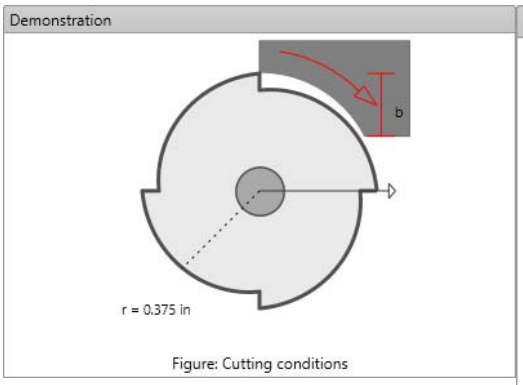
manufacturing automation laboratories CUTPRO

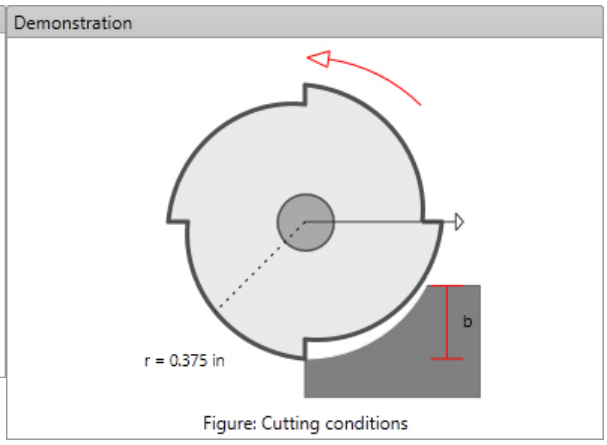
Up-milling

Also known as *Conventional Milling*.

Spindle Direction
Enter the direction of cutter rotation **[*cw / ccw*]:**

Clockwise **Counter-clockwise**



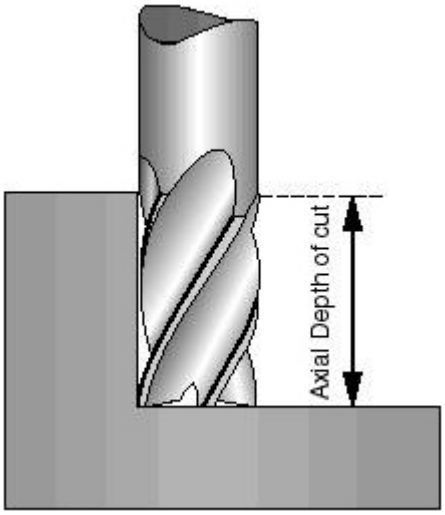


Feedrate
Enter the feed rate of the cutting operation as **[*mm/flute*]** or **[in/flute]**. If the feed rate is as **[*mm/min*]**, use the following equation to convert:

$$(\text{feed rate [mm/tooth]}) = \frac{(\text{feed rate [mm/min]})}{(\text{number of flute}) * (\text{spindle speed[rev/min]})}$$

Spindle Speed
Enter the spindle speed, in revolutions per minute **[*rpm*]**. Available only for certain simulation modes.

Axial Depth of Cut
Enter the axial depth of cut from tool tip up to workpiece surface level. Available only for certain simulation modes.



Width of Cut
Enter the width of cut from tool edge towards it's full diameter.

Number of Revolutions
Enter the number of cutter revolutions to be simulated. Available only for certain simulation modes.

Min. surface speed & max. surface speed
Enter the minimum surface speed and maximum surface speed. Available only for certain simulation modes.

***parameters vary dependant on simulation**

2.1.6.3 Slotting

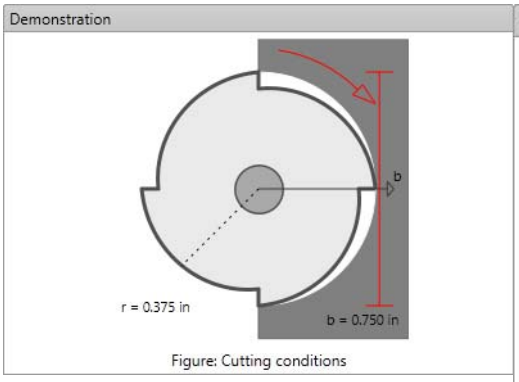
manufacturing automation laboratories CUTPRO

Slotting

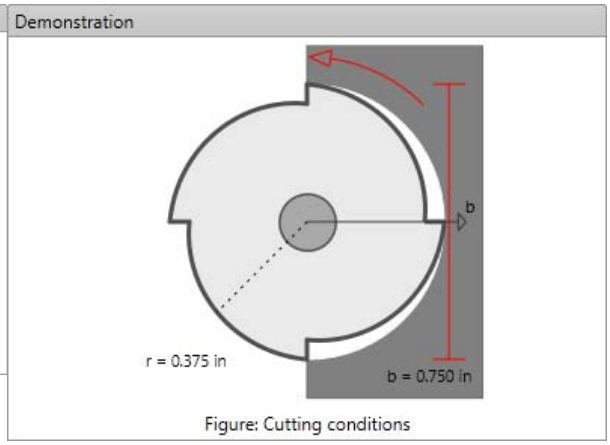
Uses *full* width of cut / cutter diameter.

Spindle Direction
Enter the direction of cutter rotation **[*cw / ccw*]:**

Clockwise



Counter-clockwise



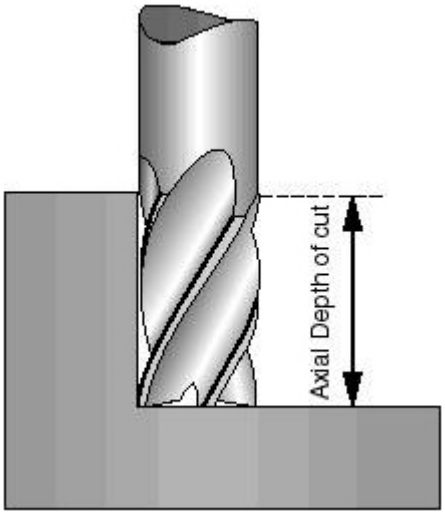
Feedrate
Enter the feed rate of the cutting operation as **[*mm/flute*]** or **[in/flute]**. If the feed rate is as **[*mm/min*]**, use the following equation to convert:

$$(\text{feed rate}[\text{mm/tooth}]) = \frac{(\text{feed rate}[\text{mm/min}])}{(\text{number of flute}) * (\text{spindle speed}[\text{rev/min}])}$$

Spindle Speed

Enter the spindle speed, in revolutions per minute **[*rpm*]**. Available only for certain simulation modes.

Axial Depth of Cut
Enter the axial depth of cut from tool tip up to workpiece surface level. Available only for certain simulation modes.



Number of Revolutions
Enter the number of cutter revolutions to be simulated. Available only for certain simulation modes.

Min. surface speed & max. surface speed
Enter the minimum surface speed and maximum surface speed. Available only for certain simulation modes.

***parameters vary dependant on simulation**

2.1.6.4 Face-milling

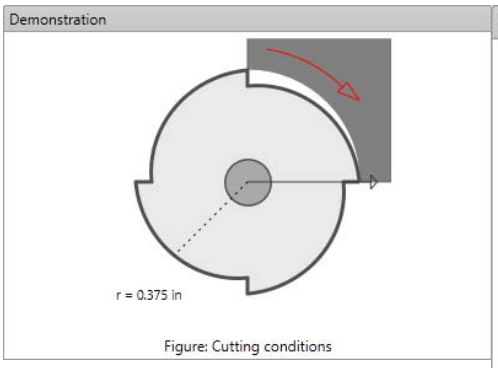
manufacturing automation laboratories CUTPRO

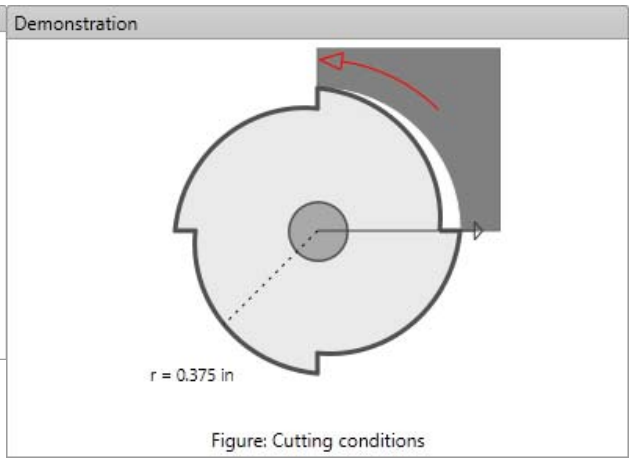
Face-milling

Uses the *bottom of the tool* to machine the surface of the workpiece.

Spindle Direction
Enter the direction of cutter rotation **[*cw / ccw*]:**

Clockwise **Counter-clockwise**



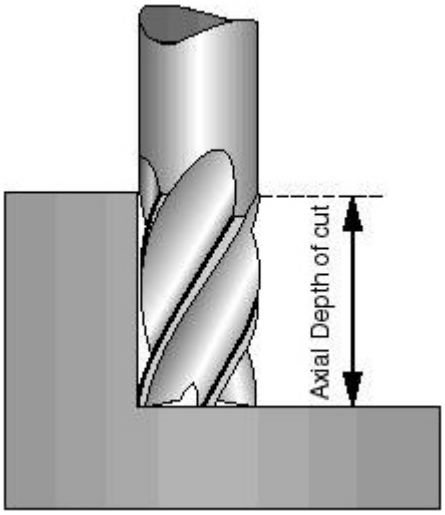


Feedrate
Enter the feed rate of the cutting operation as **[*mm/flute*]** or **[in/flute]**. If the feed rate is as **[*mm/min*]**, use the following equation to convert:

$$(\text{feed rate [mm/tooth]}) = \frac{(\text{feed rate [mm/min]})}{(\text{number of flute}) * (\text{spindle speed[rev/min]})}$$

Spindle Speed
Enter the spindle speed, in revolutions per minute **[*rpm*]**. Available only for certain simulation modes.

Axial Depth of Cut
Enter the axial depth of cut from tool tip up to workpiece surface level. Available only for certain simulation modes.



Entrance/Exit Angles
Enter the entrance/exit tool angles between 0 and 180 degrees.

Number of Revolutions
Enter the number of cutter revolutions to be simulated. Available only for certain simulation modes.

Min. surface speed & max. surface speed
Enter the minimum surface speed and maximum surface speed. Available only for certain simulation modes.

***parameters vary dependant on simulation**

2.1.7 Results

manufacturing automation laboratories CUTPRO

Results - Overview

Using graphs in CutPro (*Plot Results buttons*)

- **Forces**
  - XYZ cutting forces
  - XY resultant force
  - Tangential force
  - Experimental average cutting forces
- **Chip data**
  - Chip thickness
  - About dynamic chip thickness
- **Vibrations**
  - Tool vibrations
  - Workpiece vibrations
- **Spindle parameters**
  - Spindle power
  - Spindle torque
  - Spindle bending moment
- **Surface finishes**
  - Up-milling surface finish
  - Down-milling surface finish
- **Stability lobes**
  - Analytical
  - Analytical with variable pitch
  - Time domain
- **Variable pitch**
  - Optimum variable pitch
- **Fast Fourier Transform [FFT]**
  - FFT

2.1.7.1 XYZ cutting forces

manufacturing automation laboratories CUTPRO

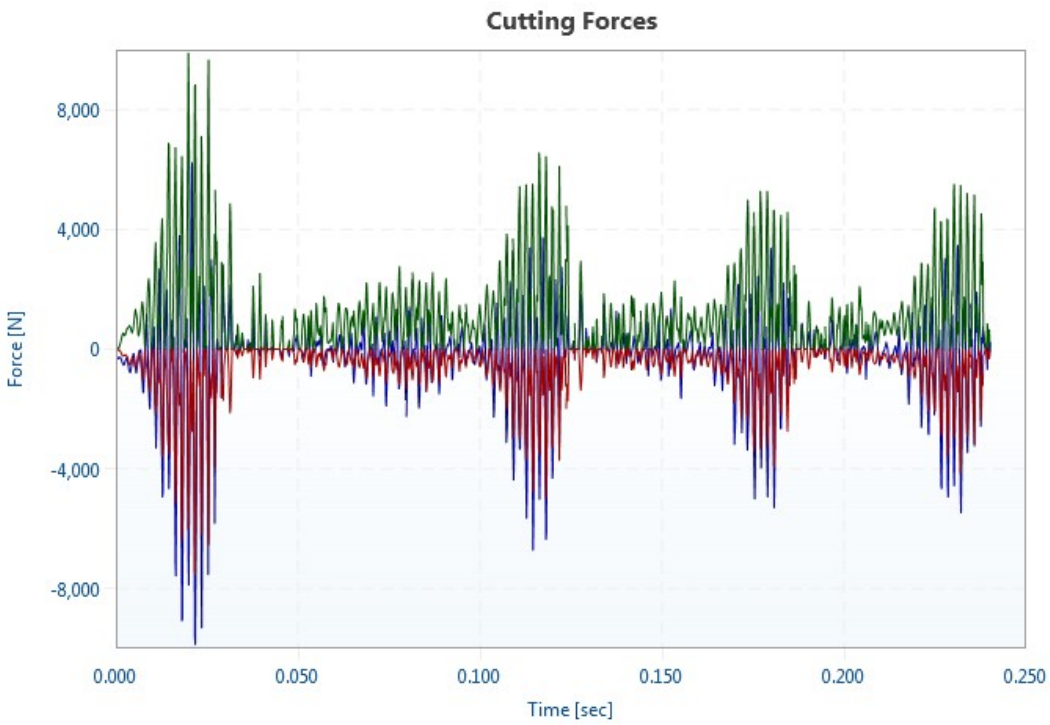
All forces

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot cutting forces.
The results of this plot will look something like the figure below:



Blue = Feed force, Green = Normal force, and Red = Axial force

In order to toggle through desired results on this plot, the following buttons may be used:

Feed **Active axis**: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

2.1.7.2 XY resultant force

manufacturing automation laboratories CUTPRO

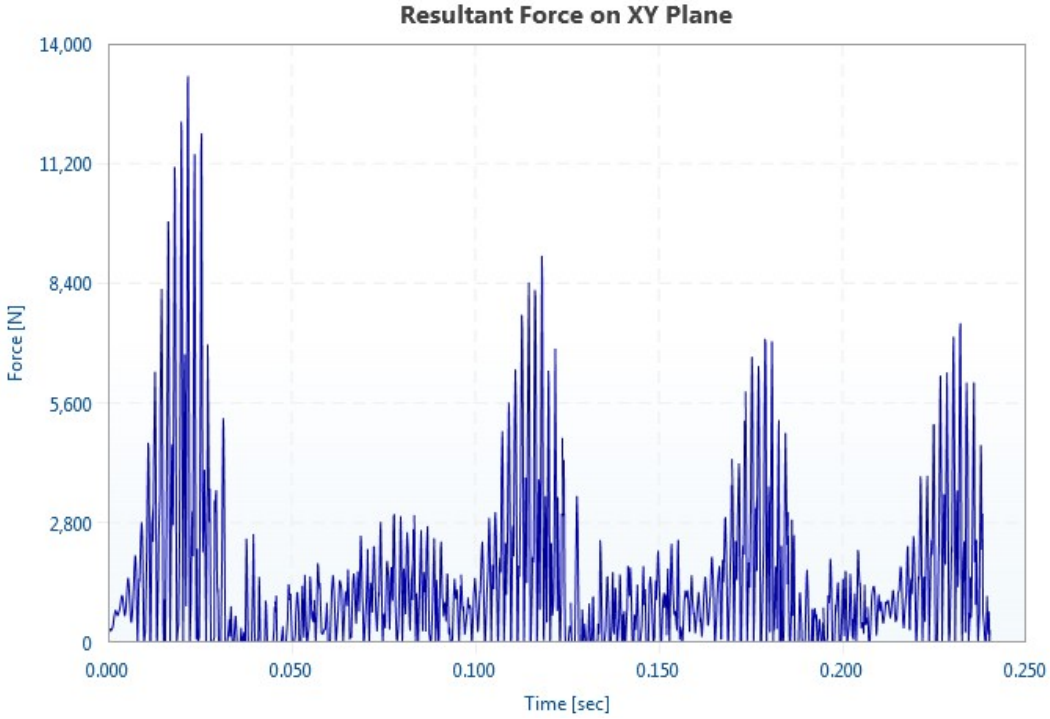
XY resultant force

There are two available buttons which may be used to plot xy resultant forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot XY resultant force.
The results of this plot will look something like the figure below:



Blue = XY resultant force

2.1.7.3 Tangential force

manufacturing automation laboratories CUTPRO

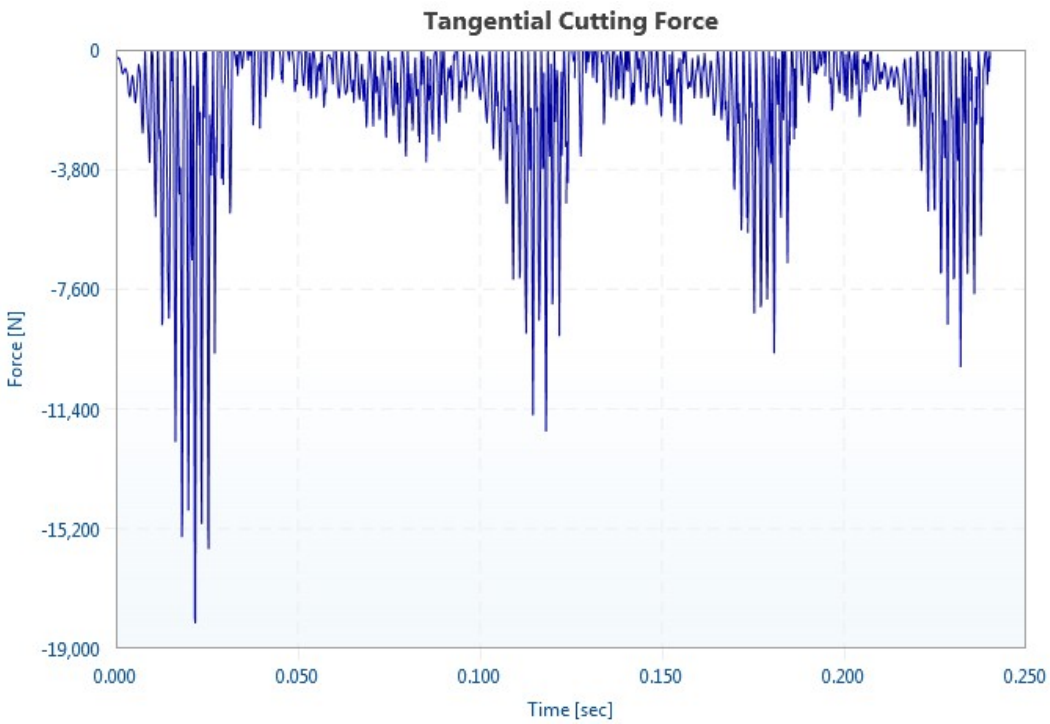
Tangential force

There are two available buttons which may be used to plot tangential cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot tangential cutting force.
The results of this plot will look something like the figure below:



Blue = Tangential cutting force

2.1.7.4 Experimental average cutting forces

manufacturing automation laboratories CUTPRO

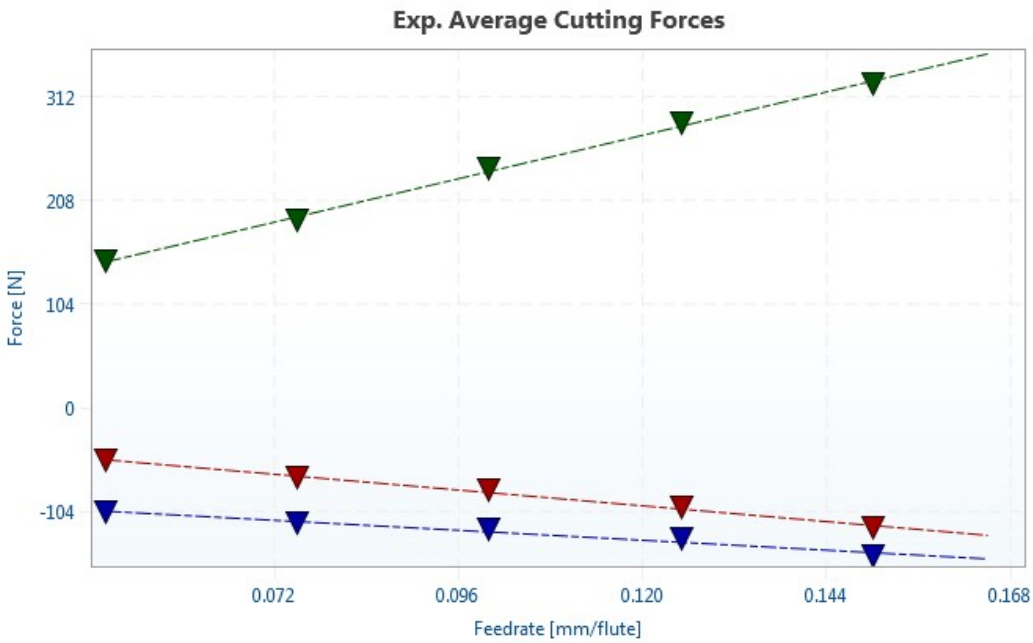
Experimental average cutting forces

There are two available buttons which may be used to plot experimental average cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot experimental average cutting forces.
The results of this plot will look something like the figure below:



Blue = Feed force, Green = Normal force, and Red = Axial force

2.1.7.5 Chip thickness

manufacturing automation laboratories CUTPRO

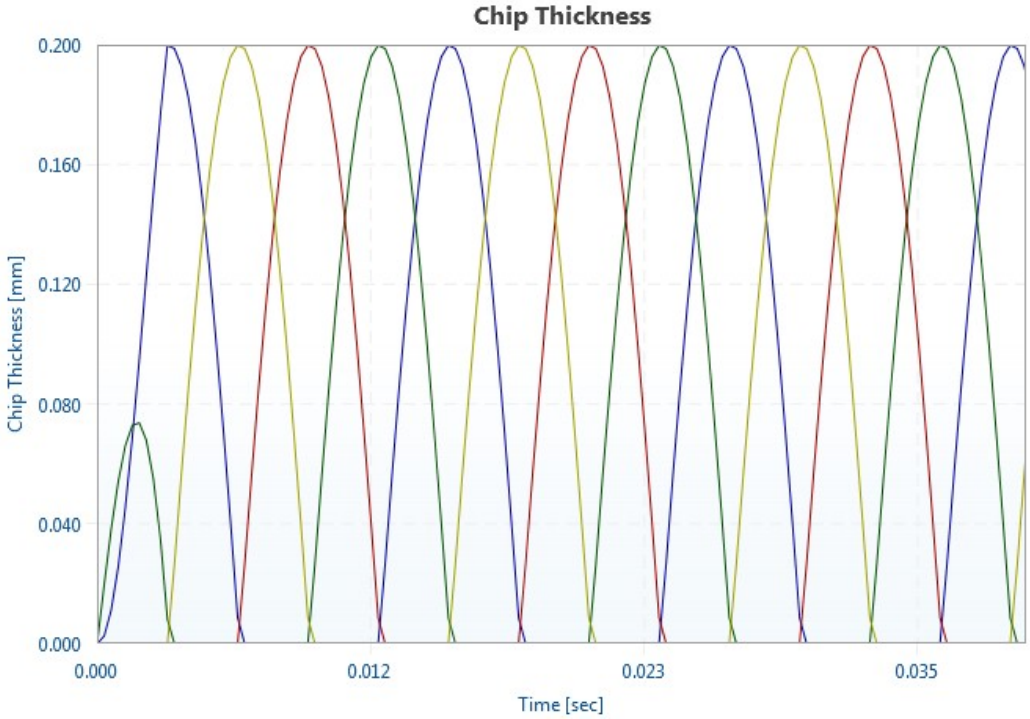
Chip thickness

There are two available buttons which may be used to plot chip thickness:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot chip thickness.
The results of this plot will look something like the figure below:

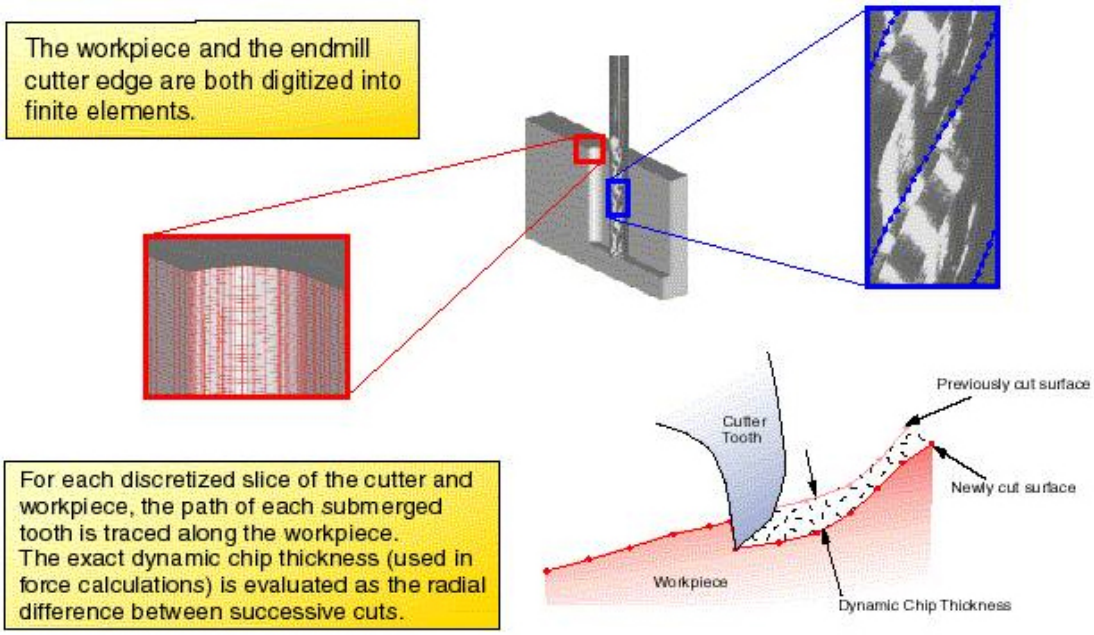


This specific plot is for a 4-fluted cylindrical endmill (4 colors representing 4 flutes)

2.1.7.6 About dynamic chip thickness

manufacturing automation laboratories CUTPRO

About dynamic chip thickness



2.1.7.7 Tool vibrations

manufacturing automation laboratories CUTPRO

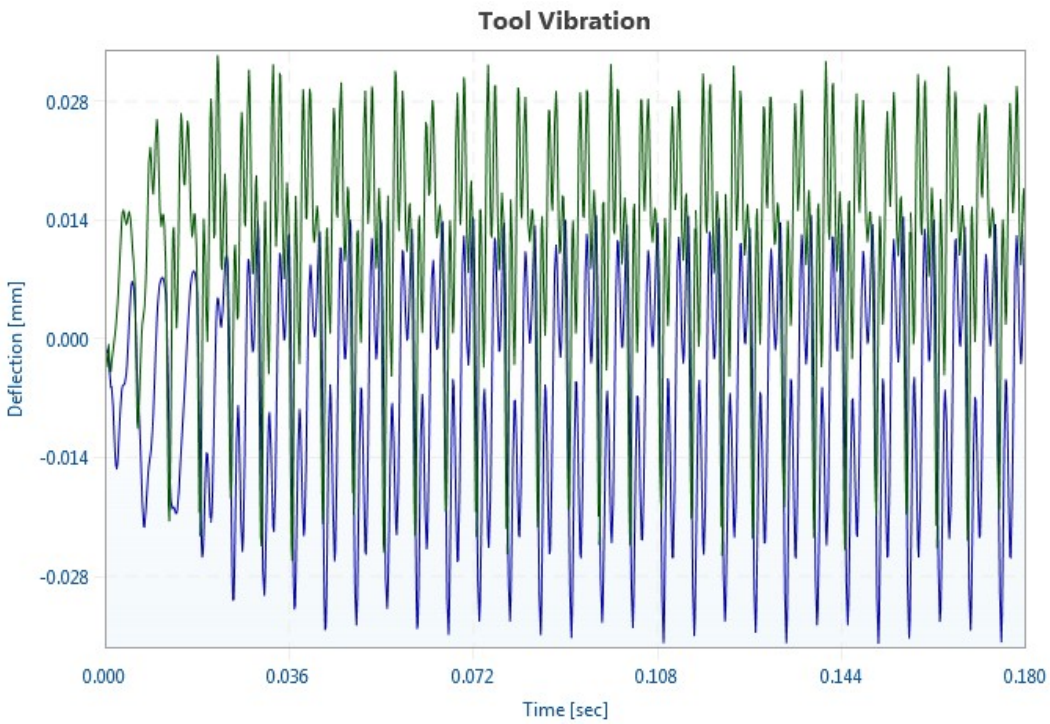
Tool vibrations

There are two available buttons which may be used to plot tool vibration:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot tool vibration.
The results of this plot will look something like the figure below:



Blue = Feed vibrations, Green = Normal vibrations

2.1.7.8 Workpiece vibrations

manufacturing automation laboratories CUTPRO

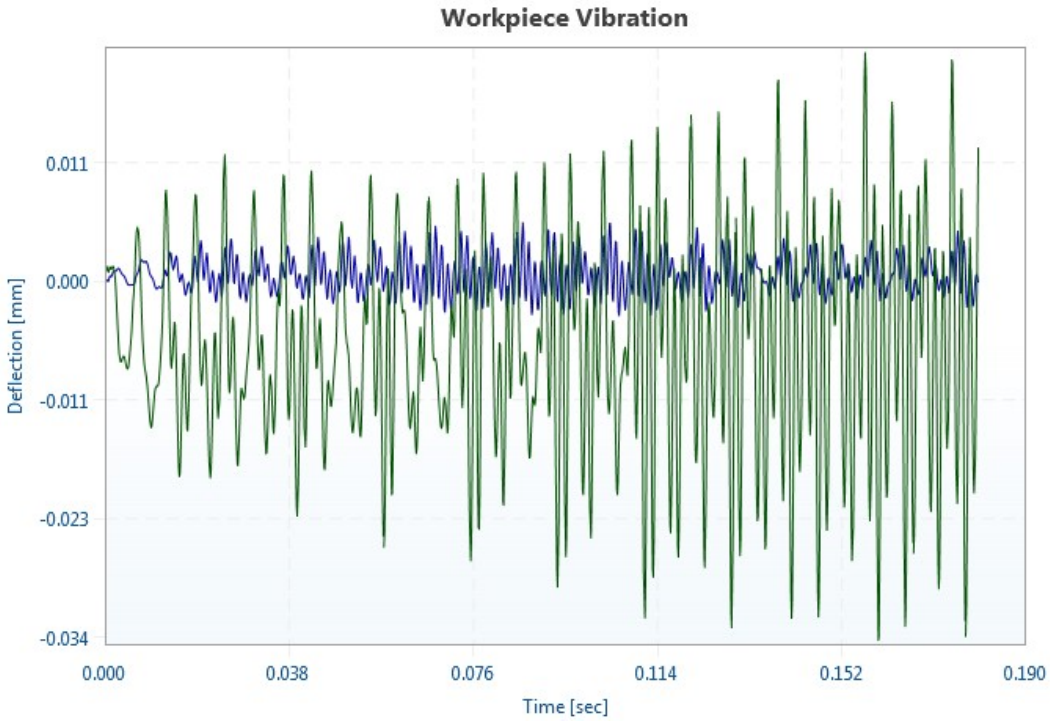
Workpiece vibrations

There are two available buttons which may be used to plot workpiece vibration:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot workpiece vibration.
The results of this plot will look something like the figure below:



Blue = Feed vibrations, Green = Normal vibrations

2.1.7.9 Spindle power

manufacturing automation laboratories CUTPRO

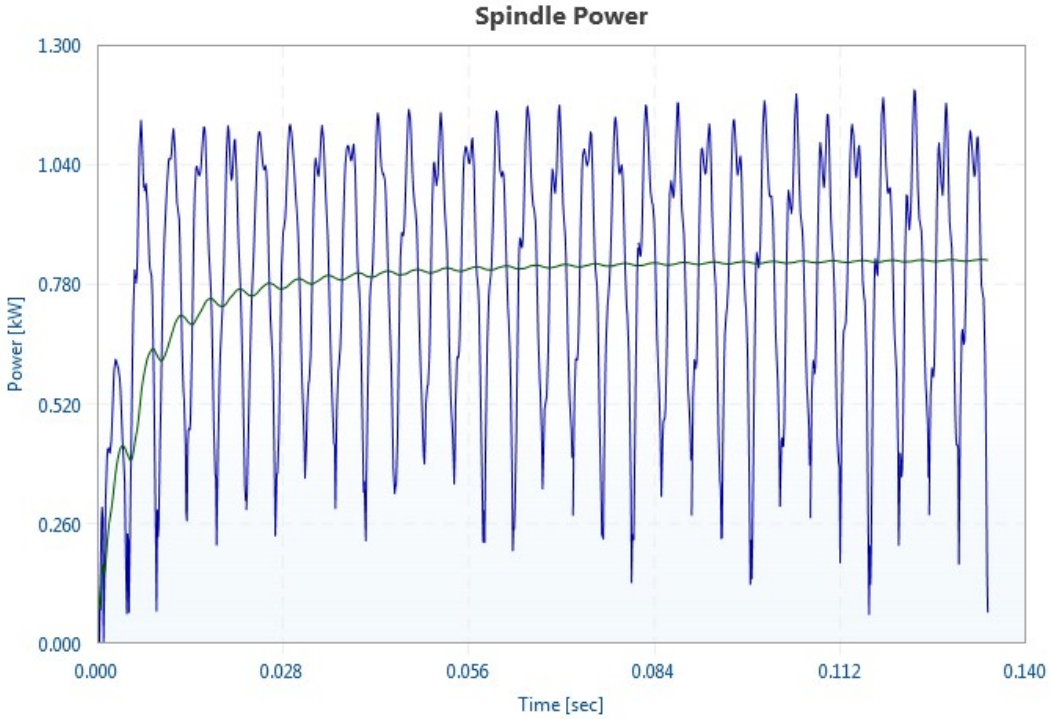
Spindle power

There are two available buttons which may be used to plot spindle power:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot spindle power.
The results of this plot will look something like the figure below:



Blue = Instantaneous power, Green = Cumulative average power

2.1.7.10 Spindle torque

manufacturing automation laboratories CUTPRO

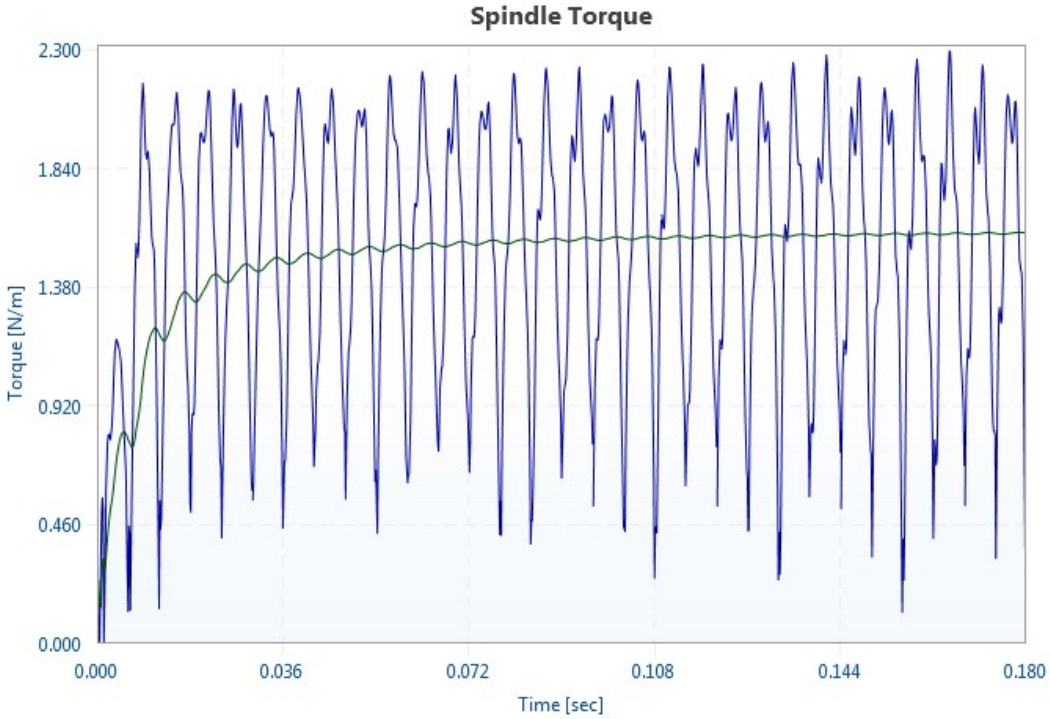
Spindle torque

There are two available buttons which may be used to plot spindle torque:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot spindle torque.
The results of this plot will look something like the figure below:



Blue = Instantaneous power, **Green = Cumulative average** power

2.1.7.11 Spindle bending moment

manufacturing automation laboratories CUTPRO

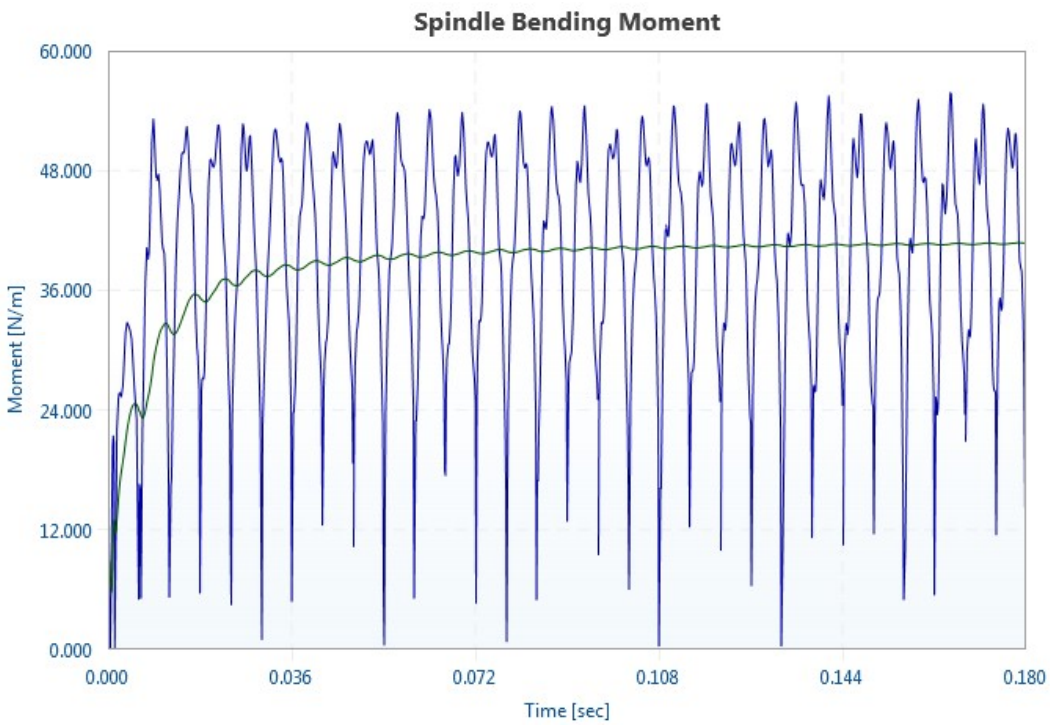
Spindle bending moment

There are two available buttons which may be used to plot spindle bending moment:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot spindle bending moment.
The results of this plot will look something like the figure below:



Blue = Instantaneous power, **Green = Cumulative average** power

2.1.7.12 Up-milling surface finish

manufacturing automation laboratories CUTPRO

Up-milling surface finish

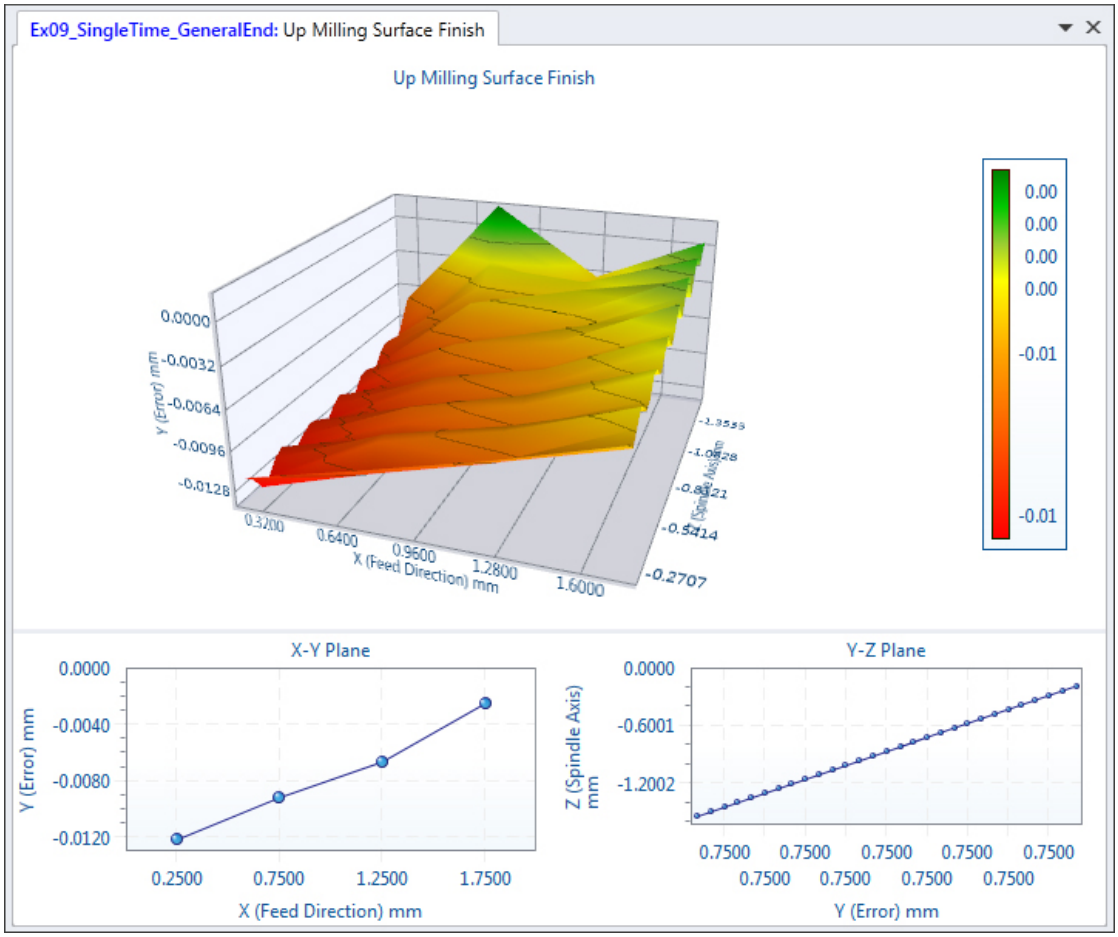
There are two available buttons which may be used to plot up-milling surface finish:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Double Right click on Surface Finish Plot: View surface finish plotted on planes

Not all simulations have an option to plot up-milling surface finish.
The results of this plot will look something like the figure below:



2.1.7.13 Down-milling surface finish

manufacturing automation laboratories CUTPRO

Down-milling surface finish

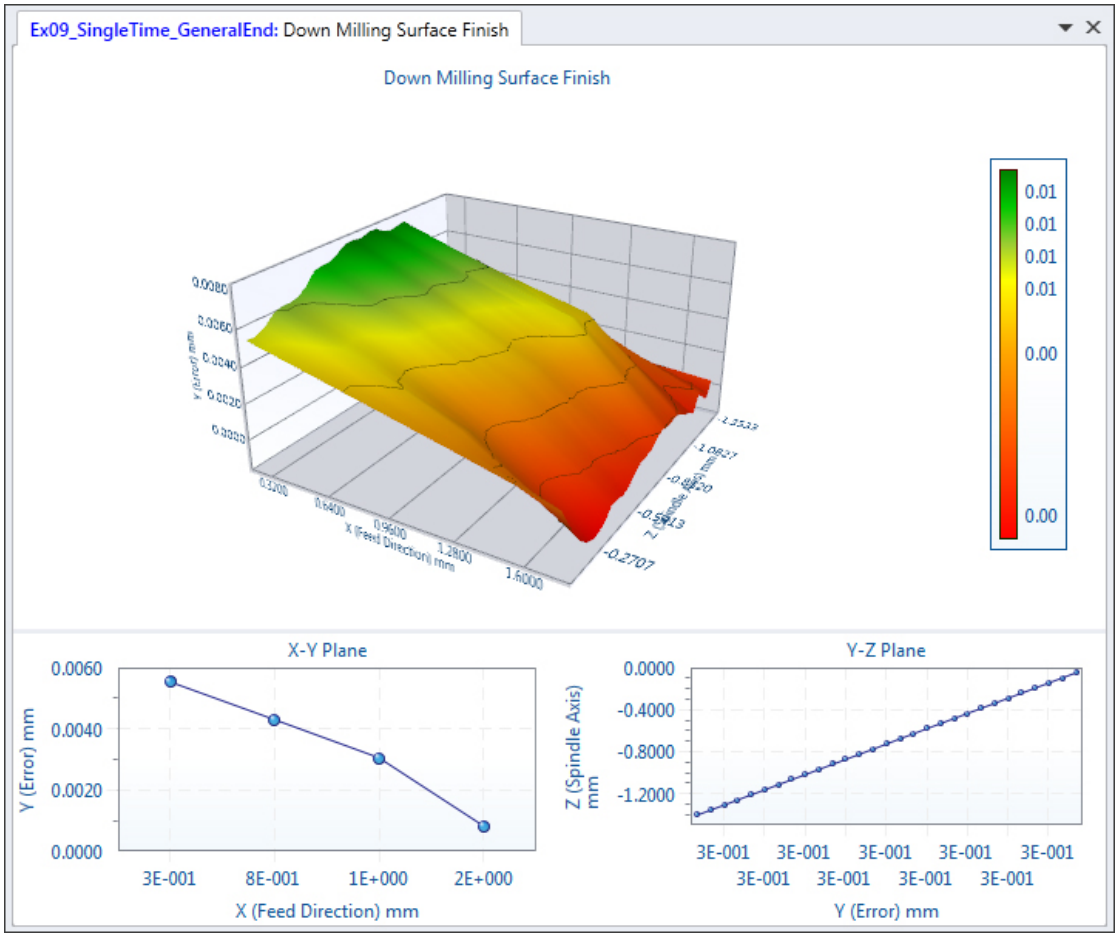
There are two available buttons which may be used to plot down-milling surface finish:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Double Right click on Surface Finish Plot: View surface finish plotted on planes

Not all simulations have an option to plot down-milling surface finish.
The results of this plot will look something like the figure below:



2.1.7.14 Stability lobes (analytical)

manufacturing automation laboratories CUTPRO

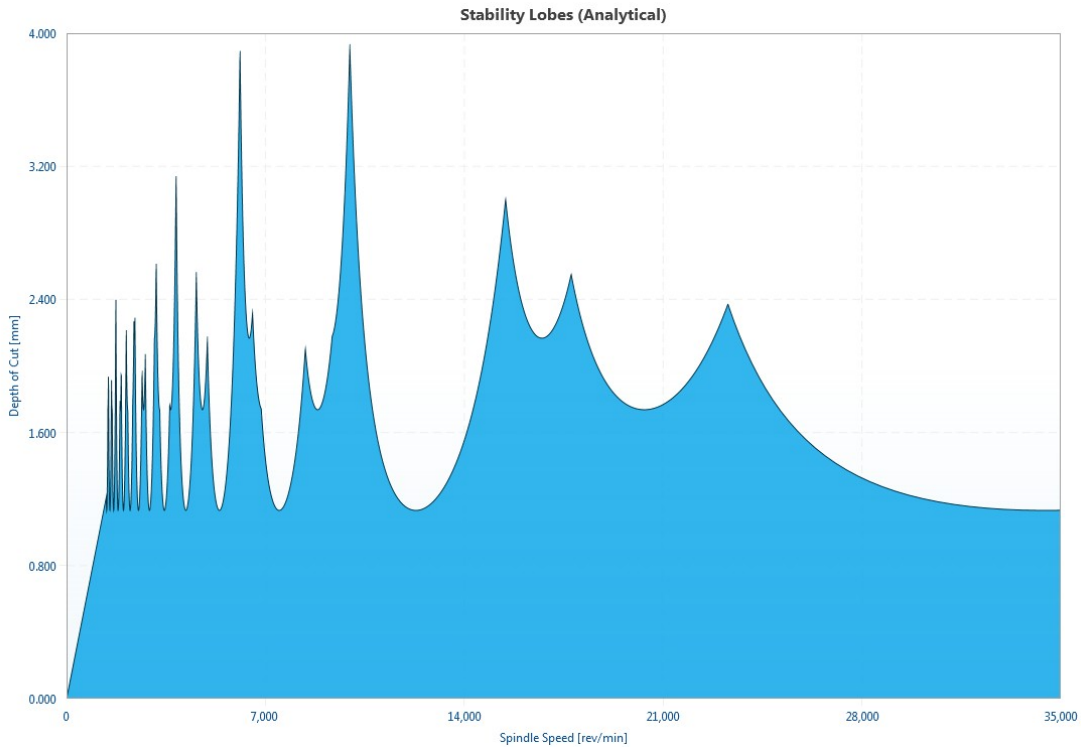
Stability lobes (analytical)

There are two available buttons which may be used to plot analytical stability lobes:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot analytical stability lobes.
The results of this plot will look something like the figure below:



2.1.7.15 Stability lobes (analytical - variable pitch)

manufacturing automation laboratories CUTPRO

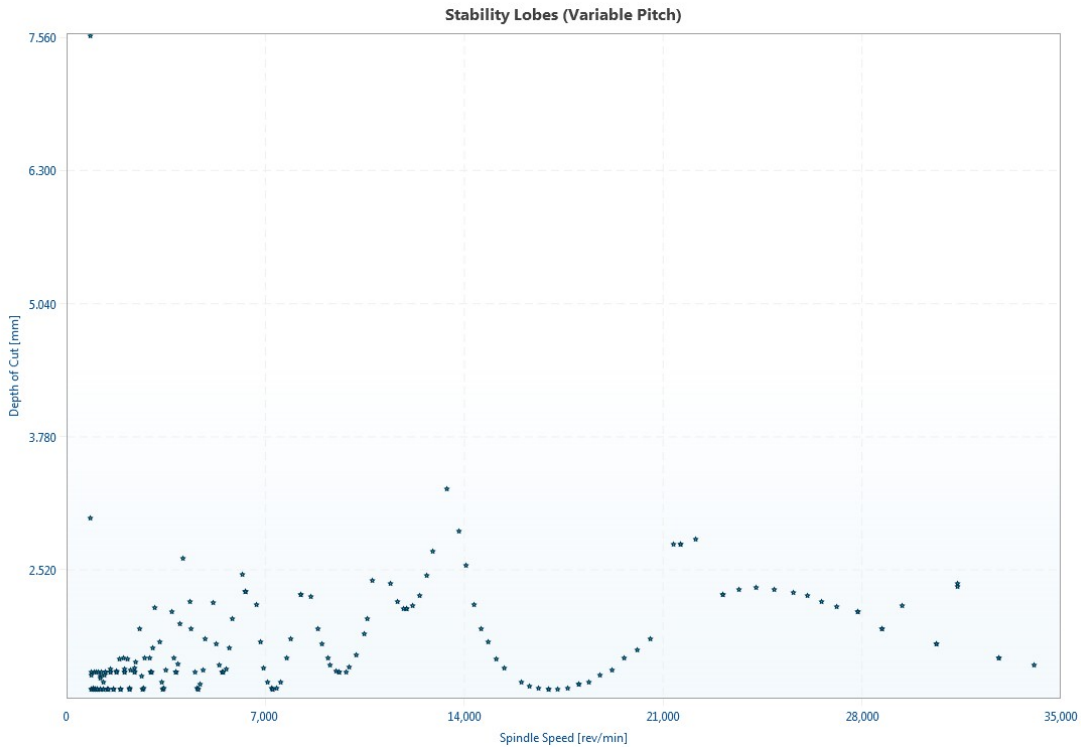
Stability lobes (analytical - variable pitch)

There are two available buttons which may be used to plot analytical stability lobes for a variable pitch cutter:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot analytical stability lobes for a variable pitch cutter. The results of this plot will look something like the figure below:



2.1.7.16 Stability lobes (time domain)

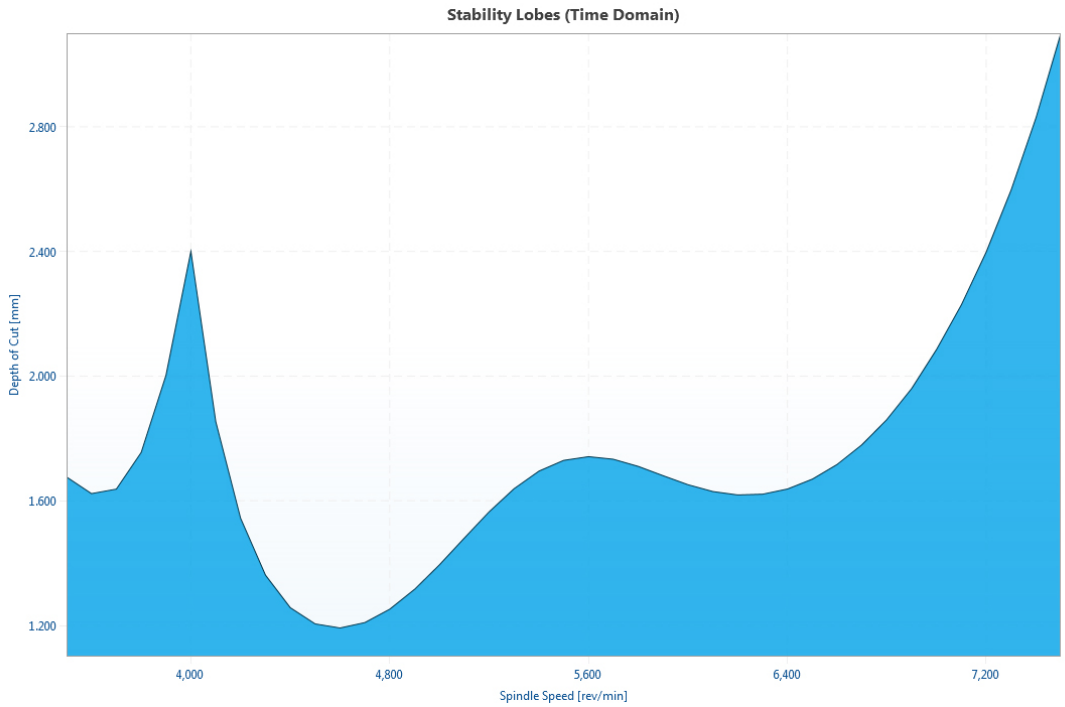
manufacturing automation laboratories CUTPRO

Stability lobes (time domain)

There are two available buttons which may be used to plot analytical stability lobes in time domain:

- **Plot**: Plots single result graph **(Located under results in simulation)**
- **Plot**: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot analytical stability lobes in time domain.
The results of this plot will look something like the figure below:



2.1.7.17 Optimum variable pitches

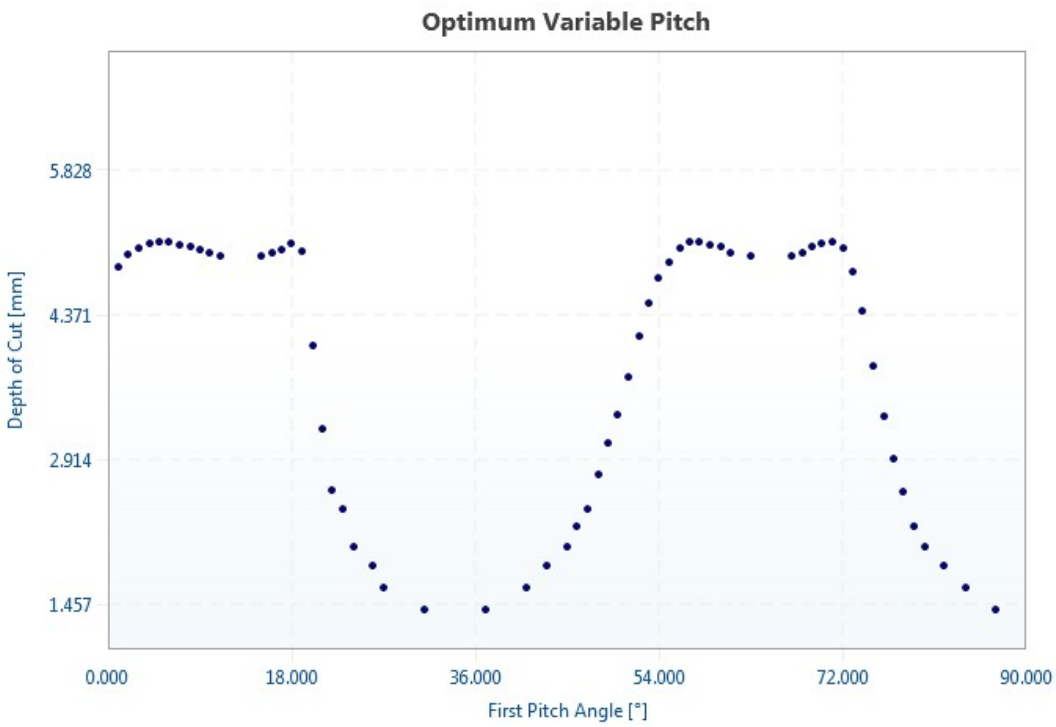
manufacturing automation laboratories CUTPRO

Optimum variable pitches

There are two available buttons which may be used to plot optimum variable pitch:

- **Plot**: Plots single result graph **(Located under results in simulation)**
- **Plot**: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot optimum variable pitch.
The results of this plot will look something like the figure below:



2.1.7.18 Fast Fourier Transform [FFT]

manufacturing automation laboratories CUTPRO

Fast Fourier Transform [FFT]

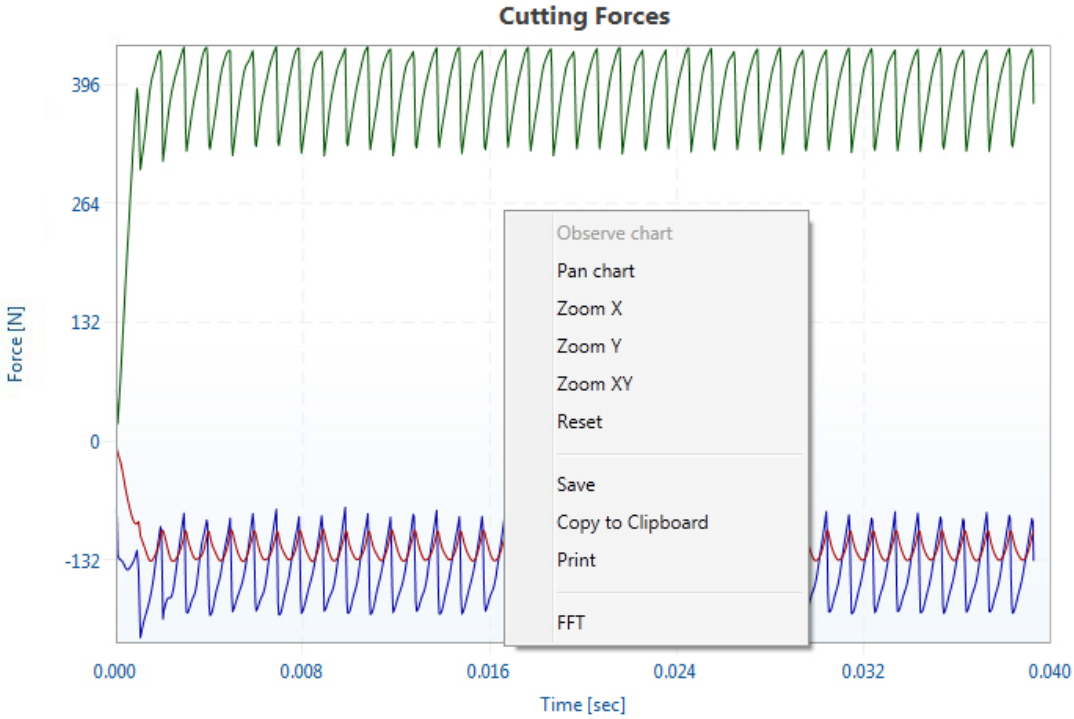
There are two available buttons which may be used to plot an FFT:

Plot: Plots single result graph **(Located under results in simulation)**

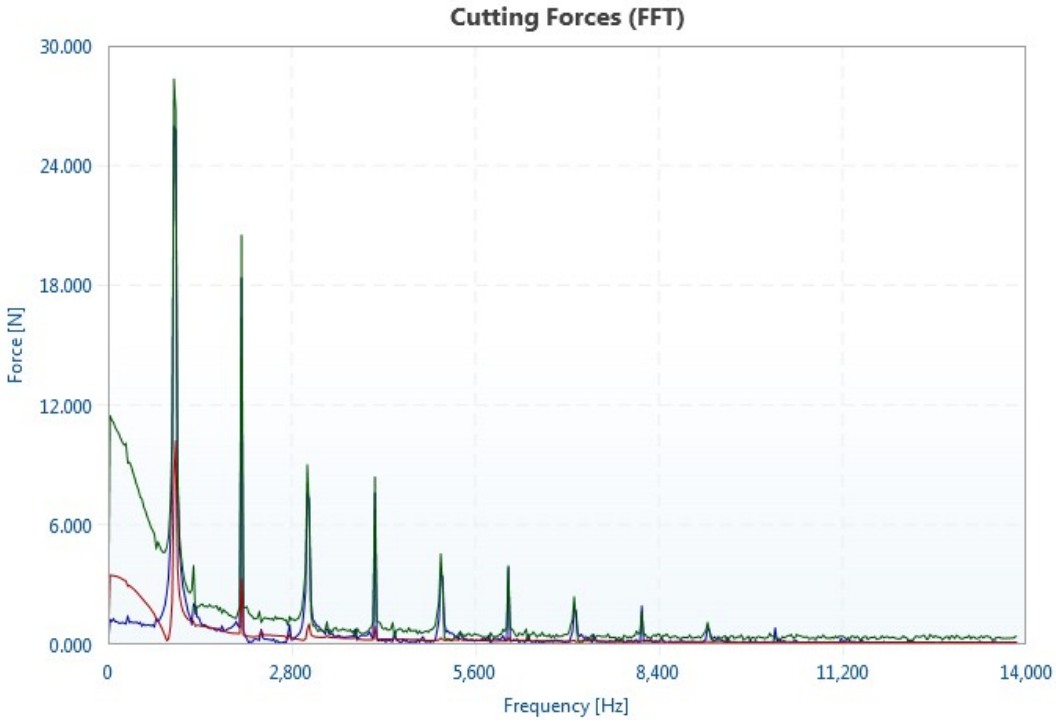
Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot an FFT.
The results of this plot will look something like the figure below:

Right-click on the graph and select "FFT"



An FFT of the desired plot will then be plotted, to reverse this step simply right-click on the plot again.



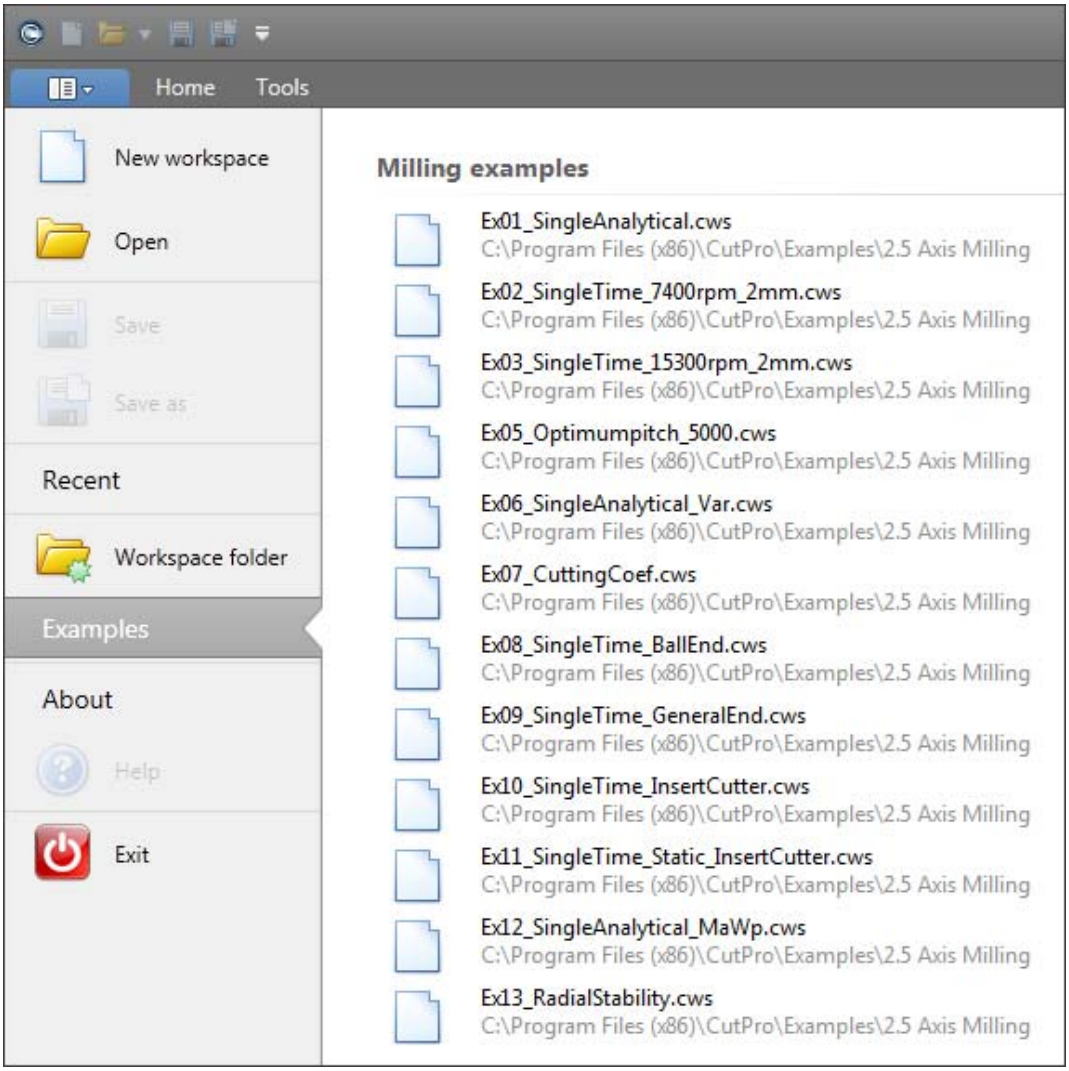
2.1.8 Example Files

manufacturing automation laboratories CUTPRO

Milling Simulation - Example Files

CutPro comes with various example files for simulation in MIlling.

To access these files, click on the "Examples" button as shown below:



2.2 Boring/Turning Simulation

manufacturing automation laboratories CUTPRO

CutPro: Boring/Turning Simulation - Overview

The “Simulation Workspace Tree” uses a top-to-bottom workflow process, and there are a
few main tabs which require attention in boring/turning (for example):

- **Workspace** Define the name and unit system
- **Simulation mode** Static analysis, Analytical stability lobes, Cutting coefficient identification, Cutting forces using slipline fields
- **Machine & Tool** Tooling geometries/orientation and properties
  - **Structural Flexibility** Flexibility of the tool, holder, etc
- **Workpiece** Material properties
  - **Structural Flexibility** Flexibility of the workpiece, fixture and spindle setup
- **Cutting Conditions** Speeds, feeds, and operation parameters
- **Results** Plots of information obtained from the simulation

2.2.1 Workspaces

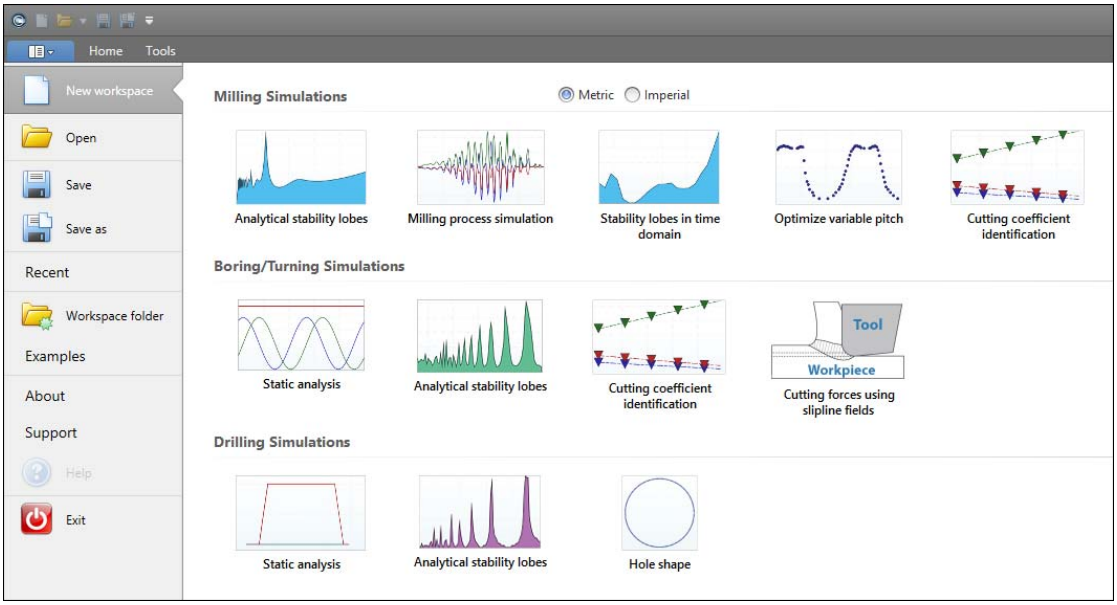
manufacturing automation laboratories CUTPRO

Workspace - Overview

In CutPro the user can define what is called a "Workspace".
Inside of this workspace file (*.cws) one can perform multiple simulations simultaneously and compare them to one-another.

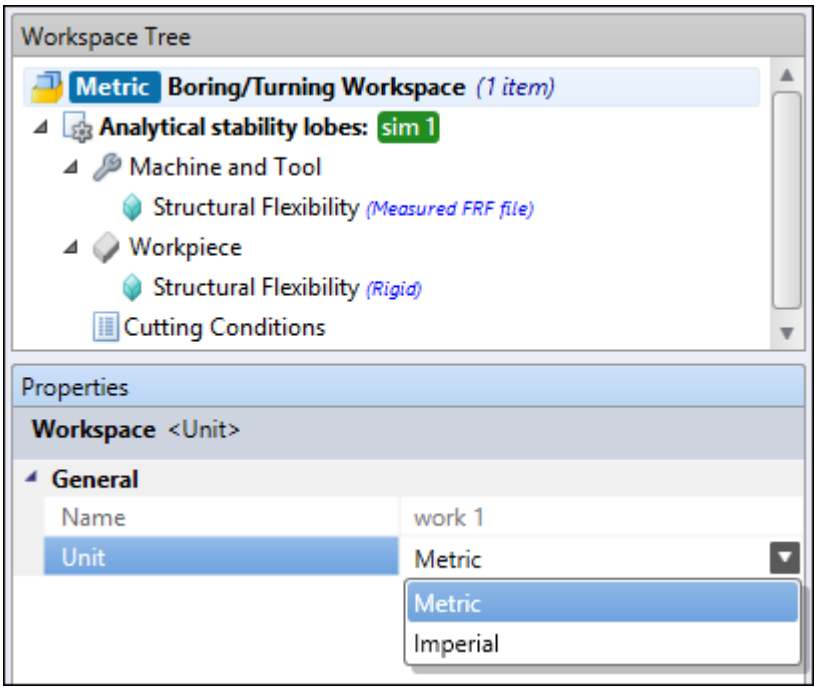
Creating, opening and saving a workspace

A workspace may be managed under the file tab, here you may also define the unit system of preference:



Unit system in CutPro

Both Metric and Imperial unit systems for a workspace can be swapped/converted anytime:

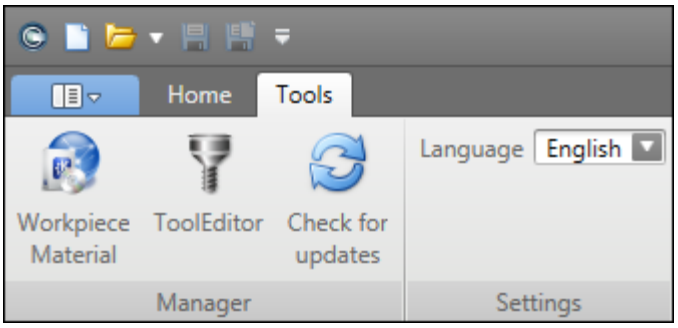


2.2.2 Managers

manufacturing automation laboratories CUTPRO

Managers - Overview

Accessed under the "Tools", the Manager section is mainly used for managing workpiece material definitions and cutting tool files in your tool library



The Workpiece material manager is the central location in CutPro for defining materials and their properties.
Using this function the user can simply load a pre-existing material inside a project rather than creating it on-the-fly.

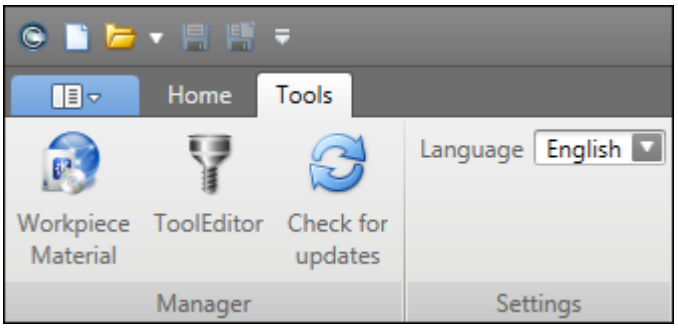
The Tool Editor is used to define and save tool geometry / tools, or perform receptance coupling.
Using this function the user can simply load a pre-existing tool inside a project rather than creating it on-the-fly.

The Check for Updates will do just that, it will notify the user if there is a new CutPro Version and Installation available.
CutPro does this automatically, however if you select "Remind me later", you will have to manually update CutPro using this button.

2.2.2.1 Workpiece Material Manager

manufacturing automation laboratories CUTPRO

Workpiece Material Manager - Overview

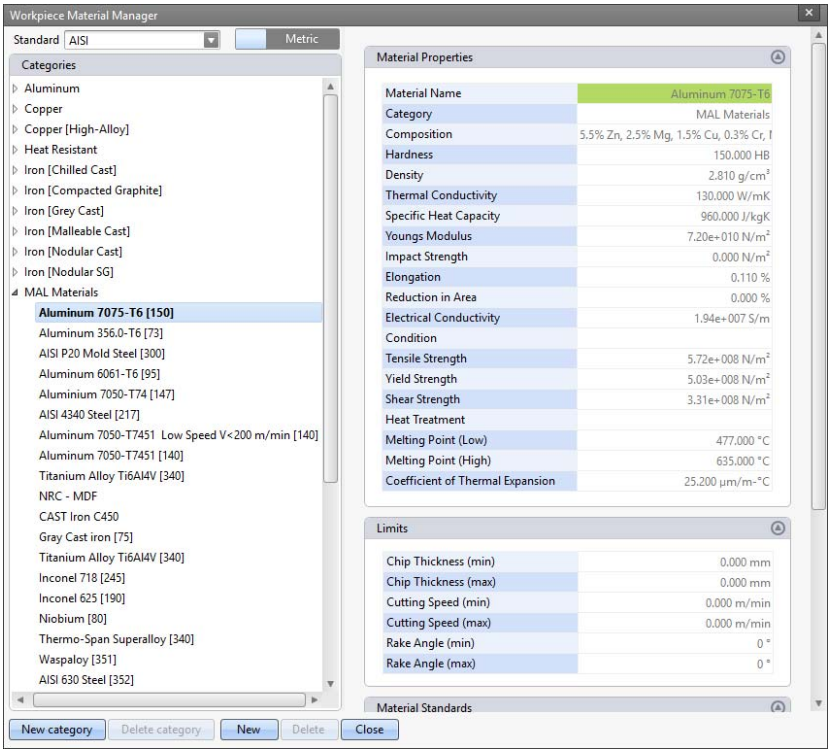


The Workpiece Material Manager contains two general category of workpiece definitions:

- Standardized workpiece materials (Pre-existing, with CutPro installation)
  Ex. Aluminum 7050-T6 (AISI Standard Material)
- User-defined workpiece materials (New: Defined by the Customer or by MAL through material characterization services)
  Ex. Secret in-house material

Regardless of which category of material you are using, the following information and data is present.

- Material properties(1)
- Coefficient parameters(2)(3)
- Limits(4)
- Material Standards



(1) **Material properties** are only used for reference, these properties are not meaningful for machining simulation

(2) **Coefficient parameters** are only shown for user-defined workpiece materials

(3) **Coefficient parameters** are the only numbers entered into the Material Manager which change simulation results--they are essential for accurate simulations

(4) **Limits** affect the range in which the force model was created, however these entries are not used within CutPro calculations.

2.2.2.1.1 Material properties

manufacturing automation laboratories CUTPRO

Material properties

The *"Material Properties"* tab displays the specifications of the material given in either unit system:

- Material Properties [Metric units]
- Material Properties [Imperial units]

**Units may be toggled at any time in the Workpiece Material Manager*

Material Properties

Material Name	
Category	MAL Materials
Composition	
Hardness	0.000 HB
Density	0.000 g/cm³
Thermal Conductivity	0.000 W/mK
Specific Heat Capacity	0.000 J/kgK
Youngs Modulus	0.000 N/m²
Impact Strength	0.000 N/m²
Elongation	0.000 %
Reduction in Area	0.000 %
Electrical Conductivity	0.000 S/m
Condition	
Tensile Strength	0.000 N/m²
Yield Strength	0.000 N/m²
Shear Strength	0.000 N/m²
Heat Treatment	
Melting Point (Low)	0.000 °C
Melting Point (High)	0.000 °C
Coefficient of Thermal Expansion	0.000 µm/m-°C

Purpose

The *"Material Properties"* section is primarily used for reference in order to better understand how the material behaves. These properties are not used in CutPro's engine, this is due to the fact that many tests used to identify these properties are far different than machining. For example, the strain rates of the material under machining are extremely high in comparison to that of a tensile test.

2.2.2.1.1.1 Metric units

manufacturing automation laboratories CUTPRO

Material properties - METRIC units

Material name

Category

Composition

Hardness [*HB*]

Density [*g/cm³*]

Thermal Conductivity [*W/mK*]

Specific Heat Capacity [*J/kgK*]

Youngs Modulus [*N/m²*]

Impact Strength [*N/m²*]

Elongation

Reduction in Area [*%*]

Electrical Conductivity [*S/m*]

Condition

Tensile Strength [*N/m²*]

Yield Strength [*N/m²*]

Shear Strength [*N/m²*]

Heat Treatment

Melting Point (Low) [*°C*]

Melting Point (High) [*°C*]

Coefficient of Thermal Expansion [*µm/m-°C*]

Material Properties

Material Name	Aluminum 7075-T6
Category	MAL Materials
Composition	5.5% Zn, 2.5% Mg, 1.5% Cu, 0.3% Cr, I
Hardness	150.000 HB
Density	2.810 g/cm³
Thermal Conductivity	25.200 W/mK
Specific Heat Capacity	960.000 J/kgK
Youngs Modulus	7.20e+010 N/m²
Impact Strength	0.000 N/m²
Elongation	0.110
Reduction in Area [%]	0.000
Electrical Conductivity	1.94e+007 S/m
Condition	
Tensile Strength	5.72e+008 N/m²
Yield Strength	5.03e+008 N/m²
Shear Strength	3.31e+008 N/m²
Heat Treatment	
Melting Point (Low)	477.000 °C
Melting Point (High)	635.000 °C
Coefficient of Thermal Expansion	0.000 µm/m-°C

2.2.2.1.1.2 Imperial units

manufacturing automation laboratories CUTPRO

Material properties - IMPERIAL units

Material name

Category

Composition

Hardness [*HB*]

Density [*lb/in*^{3}]

Thermal Conductivity [*BTu/hr-ft°F*]

Specific Heat Capacity [*BTu/lb°F*]

Youngs Modulus [*lbf/ft*^{2}]

Impact Strength [*lbf/ft*^{2}]

Elongation

Reduction in Area [*%*]

Electrical Conductivity [*S/ft*]

Condition

Tensile Strength [*lbf/ft*^{2}]

Yield Strength [*lbf/ft*^{2}]

Shear Strength [*lbf/ft*^{2}]

Heat Treatment

Melting Point (Low) [*°F*]

Melting Point (High) [*°F*]

Coefficient of [*in/ft°F*]

Material Properties

Material Name	Aluminum 7075-T6
Category	MAL Materials
Composition	5.5% Zn, 2.5% Mg, 1.5% Cu, 0.3% Cr, I
Hardness	150.000 HB
Density	0.102 lb/in^3
Thermal Conductivity	14.560 BTu/hr-ft°F
Specific Heat Capacity	0.229 BTu/lb°F
Youngs Modulus	1.04e+007 lbf/ft^2
Impact Strength	0.000 lbf/ft^2
Elongation	0.110
Reduction in Area [%]	0.000
Electrical Conductivity	5918446.599 S/ft
Condition	
Tensile Strength	82961.570 lbf/ft^2
Yield Strength	72953.968 lbf/ft^2
Shear Strength	48007.482 lbf/ft^2
Heat Treatment	
Melting Point (Low)	858.600 °F
Melting Point (High)	1143.000 °F
Coefficient of Thermal Expansion	0.000 in/ft°F

Thermal Expansion

2.2.2.1.2 Coefficient parameters

manufacturing automation laboratories CUTPRO

Coefficient parameters

The *"Coefficient parameters"* tab offers 9 different force models which may be used to characterize user-defined materials.

METRIC Units

- Average cutting coefficient model
- Orthogonal to oblique model
- Exponential chip thickness model
- Semi-mechanistic model
- Sandvik model
- Kienzle model
- Rake face model

**Imperial Units are not supported for Force Models*

Coefficient Parameters

Force Model	Rake Face Model
Kte (N/mm)	24.76
Kre (N/mm)	27.36
Kae (N/mm)	0
Ku (N/mm²)	1000.78
Kv (N/mm²)	1526.5514

Purpose

The *"Coefficient parameters"* section is used for defining a *force model* for a user material(1). The *force model* consists of constants or equations that are used in CutPro's engine. Using dynamometers and experiments, the material is machined and force data is collected. This data i used in constructing a *force model* which characterizes how the material behaves under various machining conditions. The model is then used to calculate cutting forces, torque, power and so on. If there are any inaccuracies with this model (material characterization), the simulations in CutPro will be completely wrong. If you are working with your own custom material and are not familiar with the science behind this, we encourage customers to contact MAL Inc for assistance.

(1) **Coefficient parameters** are only shown for user-defined workpiece materials

2.2.2.1.2.1 Average cutting coefficient model [Metric]

manufacturing automation laboratories CUTPRO

Average cutting coefficient model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$

$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$

$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]

2.2.2.1.2.2 Orthogonal to oblique model [Metric]

manufacturing automation laboratories CUTPRO

Orthogonal to oblique model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$
$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$
$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{tc} = \frac{\tau}{\sin \varphi_n} \frac{\cos(\beta_n - \alpha_n) + \tan \eta_c \sin \beta_n \tan i}{c}$$
$$K_{rc} = \frac{\tau}{\sin \varphi_n \cos i} \frac{\sin(\beta_n - \alpha_n)}{c}$$
$$K_{ac} = \frac{\tau}{\sin \varphi_n} \frac{\cos(\beta_n - \alpha_n) \tan i - \tan \eta_c \sin \beta_n}{c}$$
$$c = \sqrt{\cos^2(\varphi_n + \beta_n - \alpha_n) + \tan^2 \eta_c \sin^2 \beta_n}$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]

τ (“t”): shear stress [N/mm²]	ϕ_n (“f”): shear angle [°]
β_n (“b”): friction angle [°]	α_n: rake angle [°]
η: chip flow angle [°]	*i*: helix angle [°]

2.2.2.1.2.3 Exponential chip thickness [Metric]

manufacturing automation laboratories CUTPRO

Exponential chip thickness

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$

$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$

$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{te} = K_{re} = K_{ae} = 0.0$$

$$K_{tc} = KT \cdot h^{-p}$$

$$K_{rc} = KR \cdot KT \cdot h^{-q}$$

$$K_{ac} = KA \cdot KT \cdot h^{-r}$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]

dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]
KT : tangential shearing coef. parameter	p : tangential chip thickness order
KR : radial shearing coef. parameter	q : radial chip thickness order
KA : axial shearing coef. parameter	r : axial chip thickness order

2.2.2.1.2.4 Semi-mechanistic model [Metric]

manufacturing automation laboratories CUTPRO

Semi-mechanistic model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$
$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$
$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{te} = K_{re} = K_{ae} = 0.0$$
$$K_{tc} = k_n \left[\cos\alpha_n + k_f \cos\eta \sin\alpha_n + k_f \tan i \sin\eta \right]$$
$$K_{rc} = k_n \left[-\frac{\sin\alpha_n}{\cos i} + k_f \cos\alpha_n \frac{\cos\eta}{\cos i} \right]$$
$$K_{ac} = k_n \left[\tan i \cos\alpha_n - k_f \sin\eta + k_f \tan i \cos\eta \sin\alpha_n \right]$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]
α_n: rake angle [°]	k_n : cutting pressure on rake face

i: helix angle [°]	k_f : cutting pressure rate on flank face
η: chip flow angle [°]	

2.2.2.1.2.5 Sandvik model [Metric]

manufacturing automation laboratories CUTPRO

Sandvik force model

Equations:

$$dF_t = K_{tc} * h * dz$$
$$dF_r = K_{rc} * h * dz$$
$$dF_a = K_{ac} * h * dz$$
$$K_{tc} = K_t * h^{-p}$$
$$K_{rc} = K_c * h^{-q}$$
$$K_{ac} = K_r * h^{-r}$$

Parameters:

dF_t : differential tangential force [N]	
dF_r : differential radial force [N]	
dF_a : differential axial force [N]	
	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]

2.2.2.1.2.6 Kienzle model [Metric]

manufacturing automation laboratories CUTPRO

Kienzle force model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$

$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$

$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{te} = K_{re} = K_{ae} = 0.0$$

$$K_{tc} = K_u(\sin\eta \sin i + \cos\eta \cos i \sin\alpha_n) + K_v(\cos\alpha_n \cos i)$$

$$K_{rc} = K_u(\cos\alpha_n \cos\eta) - K_v \sin\alpha_n$$

$$K_{ac} = K_u(-\sin\eta \cos i + \cos\eta \sin i \sin\alpha_n) + K_v(\cos\alpha_n \sin i)$$

$$K_u = K_{u_{1.1}} h^{(-u)}$$

$$K_v = K_{v_{1.1}} h^{(-v)}$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]

dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]
α_n: rake angle [°]	K_u : cutting pressure parallel to rake face
i: helix angle [°]	K_v : cutting pressure normal to rake face
η: chip flow angle [°]	$K_{u1.1}$: Coefficient parallel to rake face
u: parallel to rake face chip thickness order	$K_{v1.1}$: Coefficient normal to rake face
v: normal to rake face chip thickness order	

2.2.2.1.2.7 Rake face model [Metric]

manufacturing automation laboratories CUTPRO

Rake face force model

Equations:

$$dF_u = K_u h\, dz$$

$$dF_v = K_v h\, dz$$

$$\begin{bmatrix} dF_r \\ dF_t \\ dF_a \end{bmatrix} = [A] \begin{bmatrix} dF_u \\ dF_v \end{bmatrix} + dS \begin{bmatrix} K_{re} \\ K_{te} \\ K_{ae} \end{bmatrix}$$

Parameters:

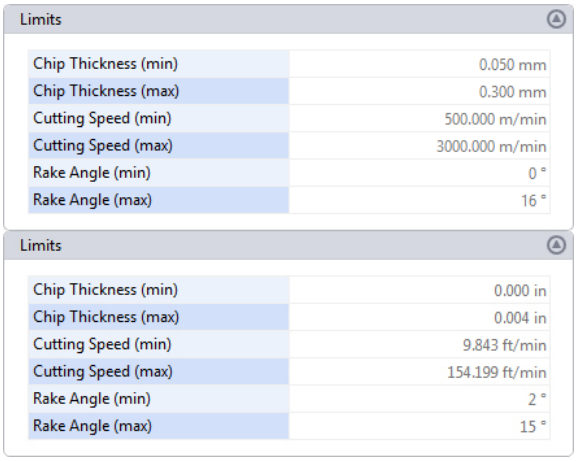
dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dF_u : differential friction force [N]	K_u : Friction coefficient on the rake face [N/mm^2]
dF_v : differential normal force [N]	K_v : Normal coefficient on the rake face [N/mm^2]
dz : differential axial depth of cut [mm]	h : chip thickness [mm]
dS : differential cutting edge length [mm]	A : Transformation matrix between the rake face CS and RTA CS

2.2.2.1.3 Limits

manufacturing automation laboratories CUTPRO

Limits

The *"Limits"* tab displays the limits of the material characterization given in either unit system:



Limits

Chip Thickness (min)	0.050 mm
Chip Thickness (max)	0.300 mm
Cutting Speed (min)	500.000 m/min
Cutting Speed (max)	3000.000 m/min
Rake Angle (min)	0 °
Rake Angle (max)	16 °

Limits

Chip Thickness (min)	0.000 in
Chip Thickness (max)	0.004 in
Cutting Speed (min)	9.843 ft/min
Cutting Speed (max)	154.199 ft/min
Rake Angle (min)	2 °
Rake Angle (max)	15 °

	Metric	Imperial
Chip Thickness	mm	in
Cutting Speed	m/min	ft/min
Rake Angle	°	°

**Units may be toggled at any time in the Workpiece Material Manager*

Purpose

The *"Limits"* section is used for defining the limits of user-defined material characterization models, or for viewing the limits of provided material characterization models. These values determine the conditions in which the material was characterized. For example, in the above test, perhaps the following was done:

Chip Thickness: 0.050 mm, 0.100 mm, 0.150 mm, 0.200 mm, 0.250 mm, 0.300 mm.
Rake Angles: 0°, 4°, 8°, 12°, 16°.
Cutting Speeds: 500 m/min, 1000 m/min, 1500 m/min, 2000 m/min, 2500 m/min, 3000 m/min

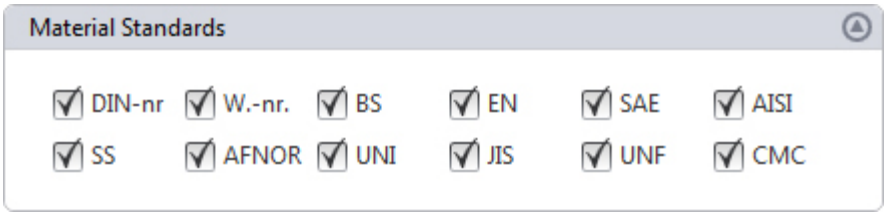
This allows the material to be defined for various feeds, rake angles and speeds. As a result, you can expect fully accurate simulations within these min and max ranges. If your simulation is out of range, for example rake 18, you can still expect to see a good accuracy. It is up to the user to decide how suitable the material limits are based on the application. If you require assistance on this topic, you can contact MAL's support team within CutPro.

2.2.2.1.4 Material standards

manufacturing automation laboratories CUTPRO

Material standards

The *"Material standards"* tab displays the material standards which the selected material belongs in, and changes the name of the material based on the selected standard. The following standards are available:



DIN-nr : German Institute for Standardization # (Deutsches Institut für Normung e.V.)
W.-nr. : German material number (Werkstoffnummer)
BS: British Standards
EN: European Committee for Standardization
SAE: Society of Automotive Engineers
AISI: American Iron and Steel Institute
SS: Swedish Standards Institute (Svensk Standard Standardisering)

AFNOR: French national organization for standardization (Association Française de Normalisation)

UNI: Italian National Standards Institute (Ente Nazionale Italiano di Unificazione)

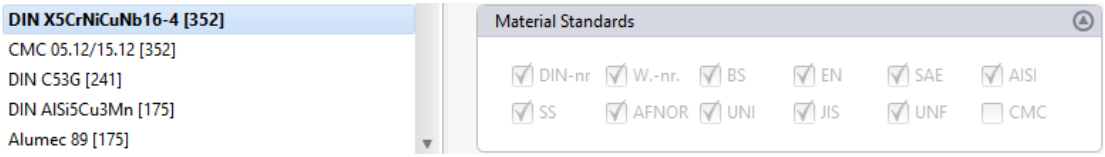
JIS: Japanese Industrial Standards (日本工業規格)

UNE: Spanish Material Standards (Una Norma Española)

CMC: Coromant Material Classification (Sandvik)

Purpose

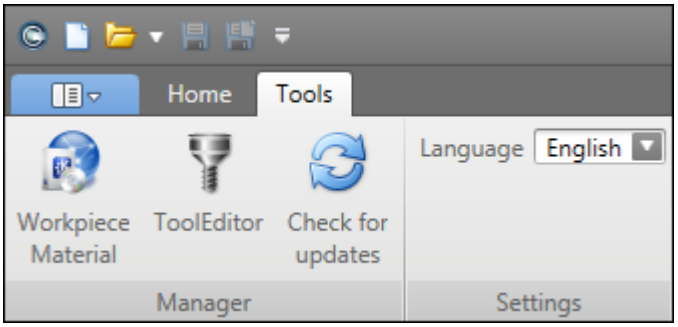
The *"Material standards"* section is simply used to filter materials by standards. Not every material is available in all standards, for example:



2.2.2.2 Check for Updates

manufacturing automation laboratories CUTPRO

Check for updates - Overview



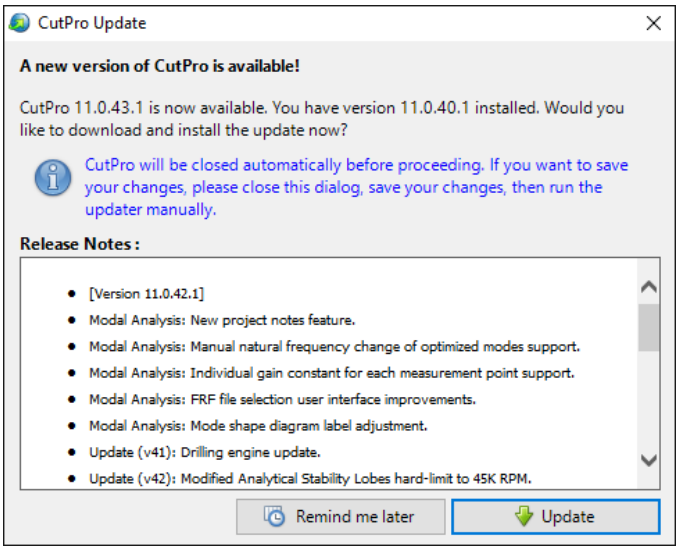
Click on the 'Check for updates' button to see if a new CutPro version has been released:

1) If a new version isn't available

CutPro will tell you your current version and tell you that it's up-to-date.

2) If a new version is available

CutPro will show an update prompt along with the update contents.



3) If you cannot update at all

Please contact us if the update button is not visible in CutPro although you have an older version.

This likely means that your Updates have expired.

2.2.3 Simulation Modes

manufacturing automation laboratories CUTPRO

Simulation Modes - Overview

Inside of the active Workspace, the user can define many simulations, and also various simulation modes may be selected:

- Static Analysis
- Analytical stability lobes
- Cutting coefficient identification

Useful Functions for Simulation

Add: Add a new simulation in the active workspace

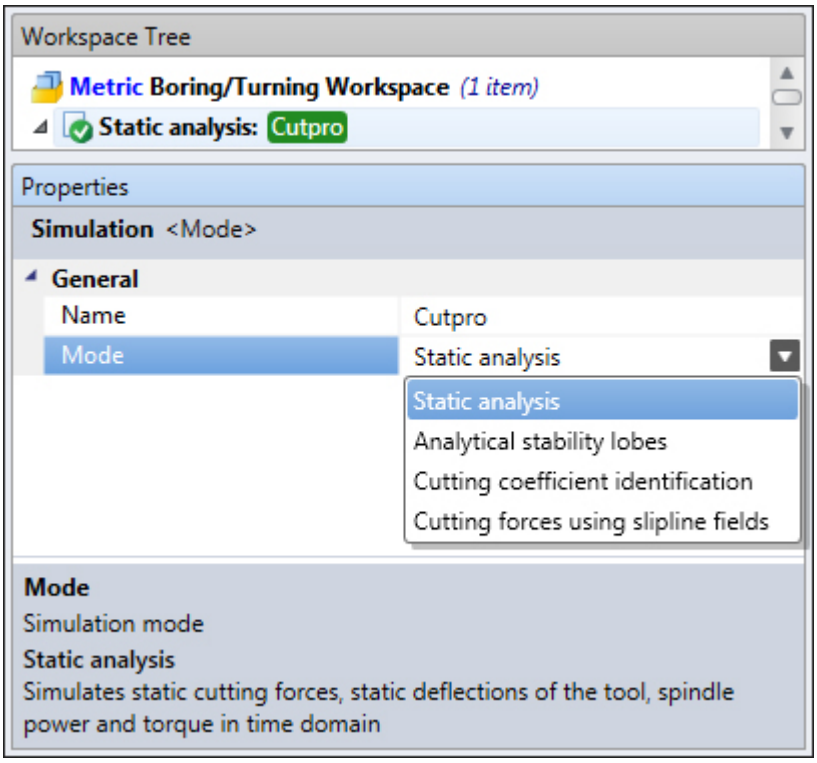
Remove: Removes selected simulation in the active workspace

Duplicate: Duplicates selected simulation in the active workspace

2.2.3.1 Static analysis

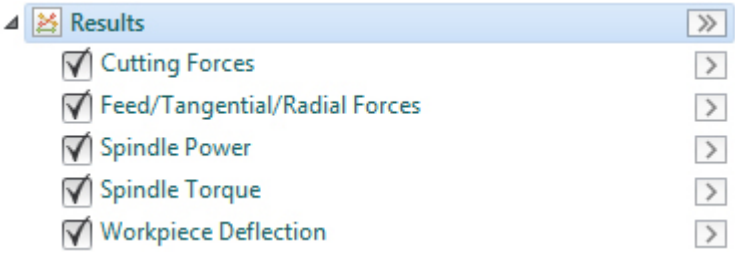
manufacturing automation laboratories CUTPRO

Static analysis



What is this?

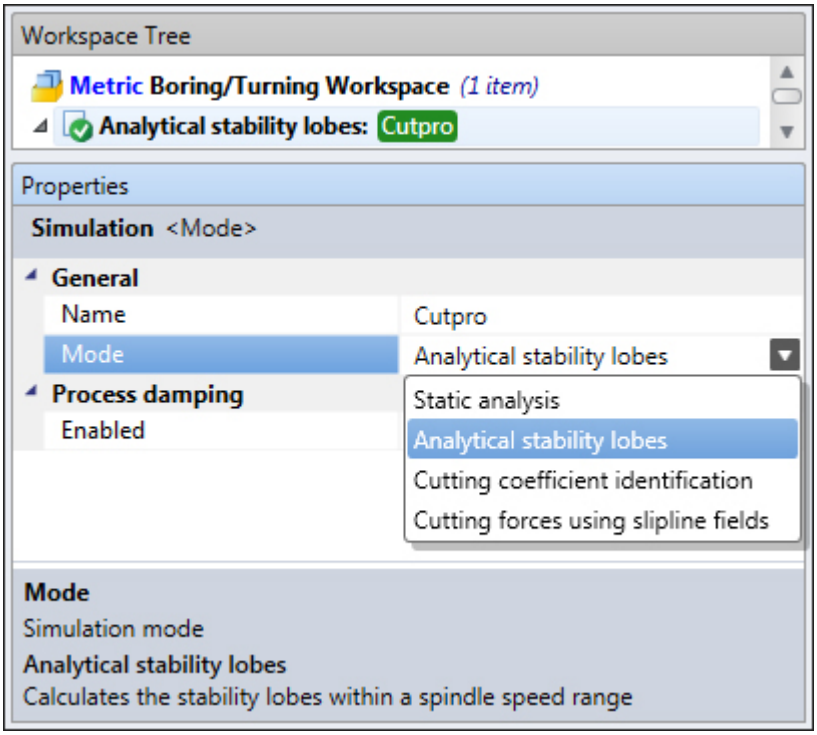
A static (no vibration / rigid) process simulation which provides the user the following results:



2.2.3.2 Analytical stability lobes

manufacturing automation laboratories CUTPRO

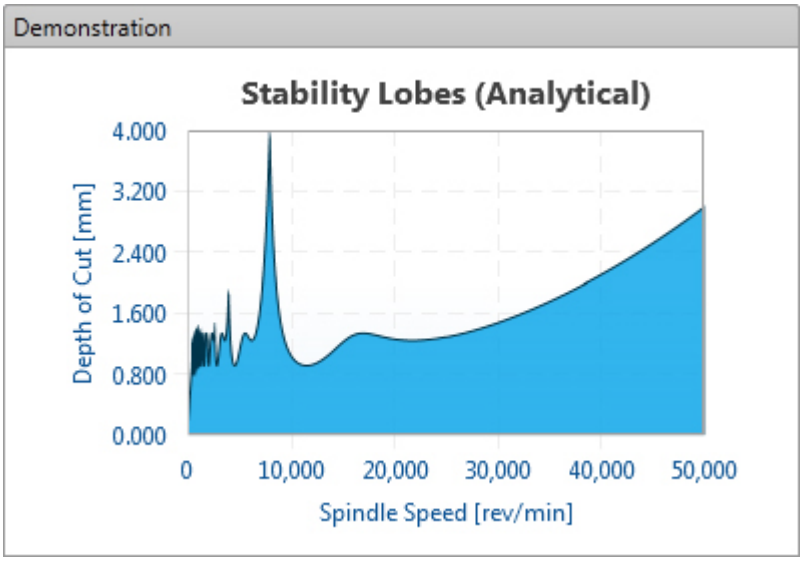
Analytical stability lobes



What is this?

Analytical stability lobes provide the user with what is called a "Stability Pocket", which denotes a productive location for chatter-free cutting:

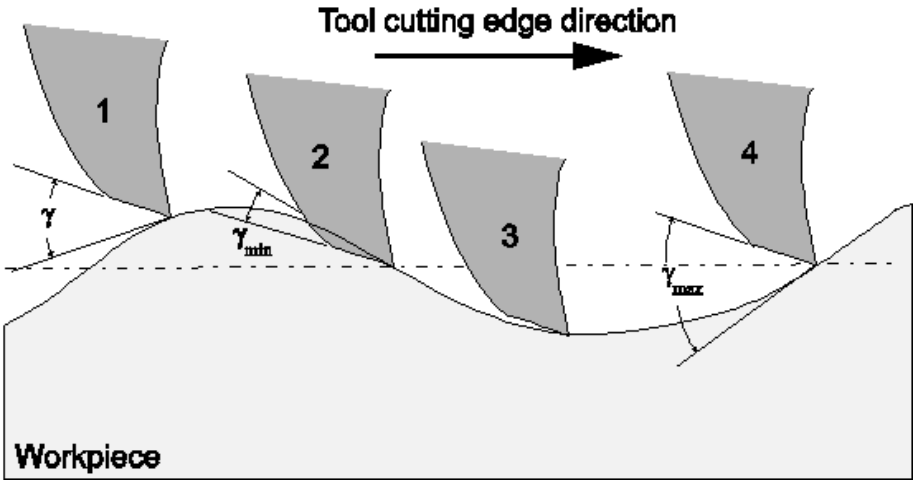
This is a fast analytical stability lobe prediction solved in a frequency domain. It generates the stability lobes by indicating the axial/radial depth of cut and spindle speeds for a fixed width of cut.

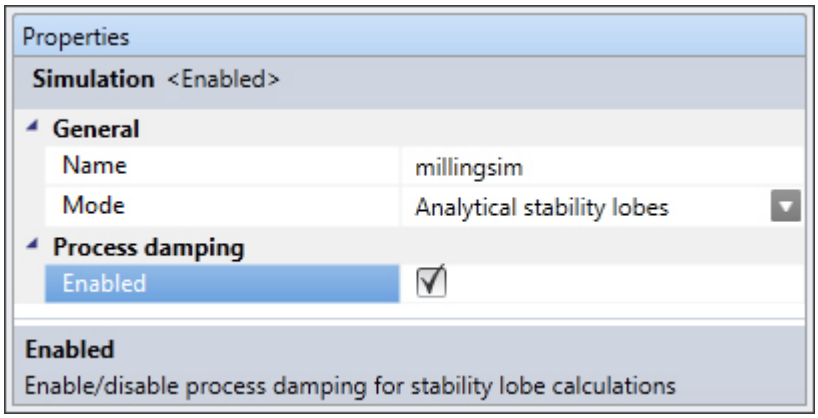


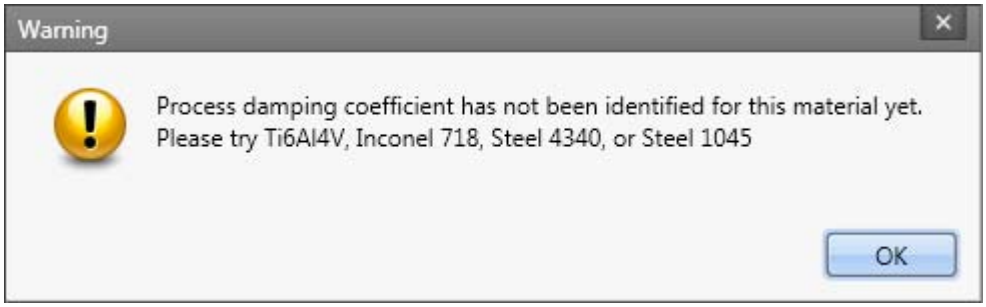
Additional Features:

Process damping (Available for certain materials only)

Heat resistant materials such as titanium and steel alloys that are frequently used in thin walled components can only be cut at low cutting speeds.
When machining these materials at low speeds, it is known that the chatter stability limit increases due to additional damping caused by the process.
This phenomenon is called process damping. Due to the sharpness of the cutting edge, part of the chip is forced to go under the tool and causes interference on the tool clearance flank.



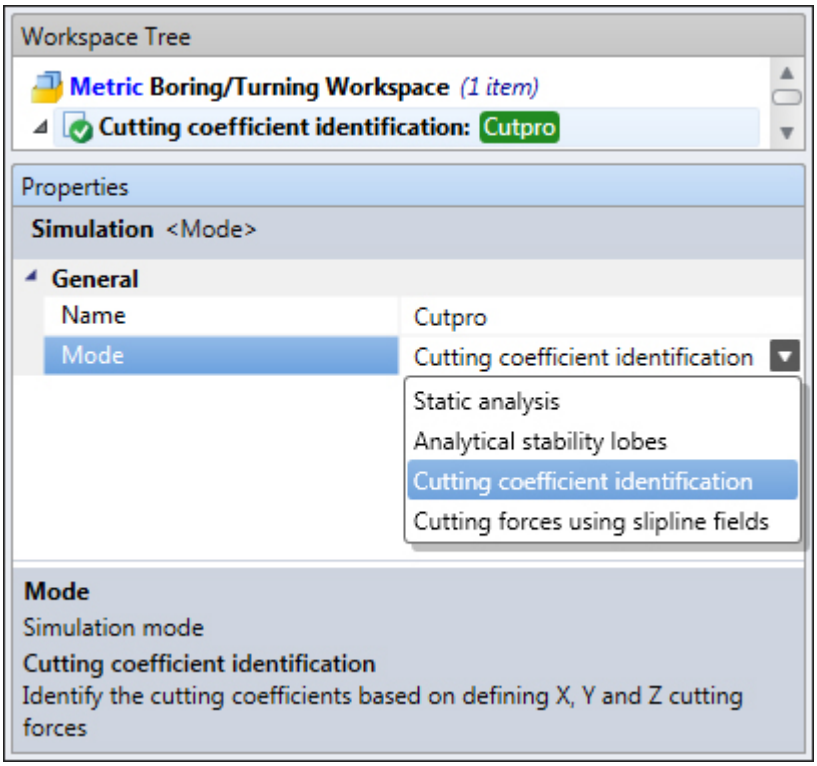




2.2.3.3 Cutting coefficient identification

manufacturing automation laboratories CUTPRO

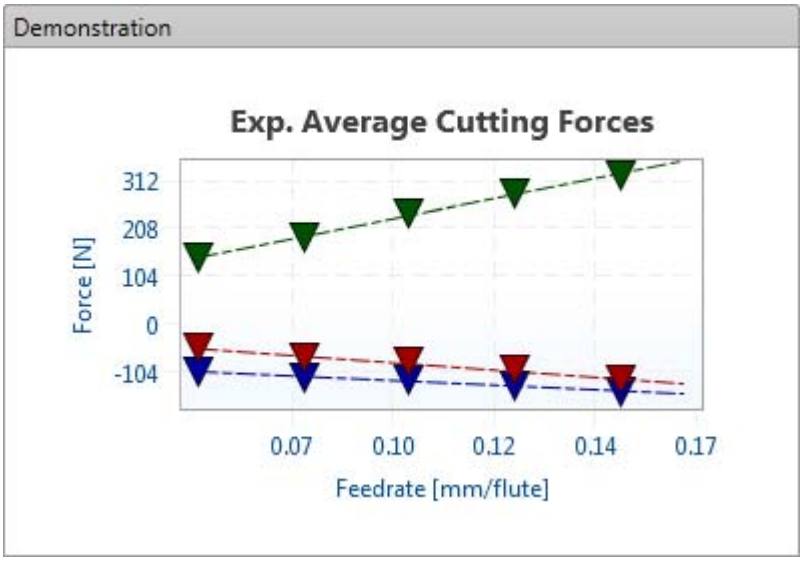
Cutting coefficient identification



What is this?

Cutting coefficient identification provides the user with expected cutting forces for a material:
Note that CutPro has a material database which may already contain the material of interest.

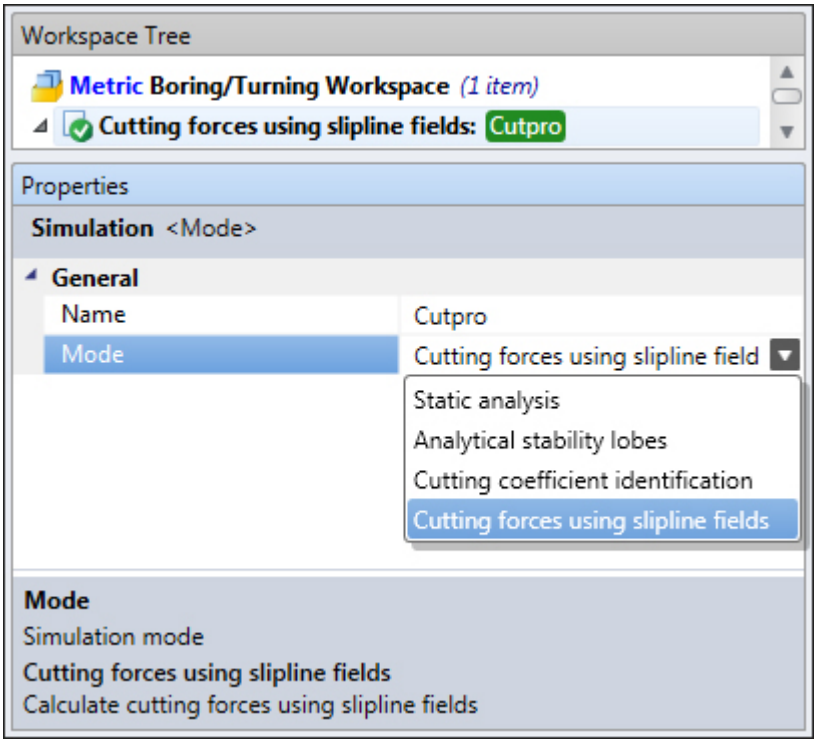
If one does not know the cutting constants of a material-cutter combination, milling experiments are conducted.
The cutting forces in x,y and z are then measured, and provided to this simulation. Finally, the cutting coefficients are identified for the material.



2.2.3.4 Cutting forces using slipline fields

manufacturing automation laboratories CUTPRO

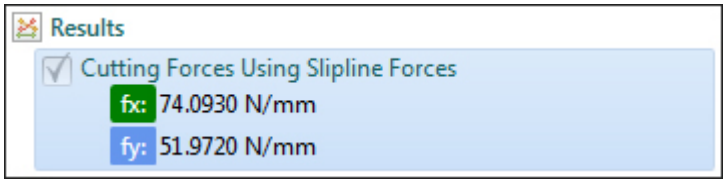
Cutting forces using slipline fields



What is this?

The cutting forces are determined using slip line field theory, which analyzes the stresses while material is being deformed over the rake face of the tool.

The following values are determined from values such as temperate, tool geometry, workpiece properties, and Johnson Cook parameters



Johnson–Cook flow stress model

The Johnson–Cook (JC) model is purely empirical and gives the following relation for the flow stress (σ_y)

$$(1) \qquad \sigma_y(\varepsilon_{\mathrm{p}}, \dot{\varepsilon}_{\mathrm{p}}, T) = [A + B(\varepsilon_{\mathrm{p}})^n]\,[1 + C\ln(\dot{\varepsilon}_{\mathrm{p}}{}^*)]\,[1 - (T^*)^m]$$

Where ε_{p} is the equivalent plastic strain, $\dot{\varepsilon}_{\mathrm{p}}$ is the plastic strain-rate, and A, B, C, n, m are material constants.

The normalized strain-rate and temperature in equation (1) are defined as

$$\dot{\varepsilon}_{\mathrm{p}}{}^* := \frac{\dot{\varepsilon}_{\mathrm{p}}}{\dot{\varepsilon}_{\mathrm{p0}}} \qquad \text{and} \qquad T^* := \frac{(T - T_0)}{(T_m - T_0)}$$

where $\dot{\varepsilon}_{\mathrm{p0}}$ is the effective plastic strain-rate of the quasi-static test used to determine the yield and hardening parameters A,B and n.

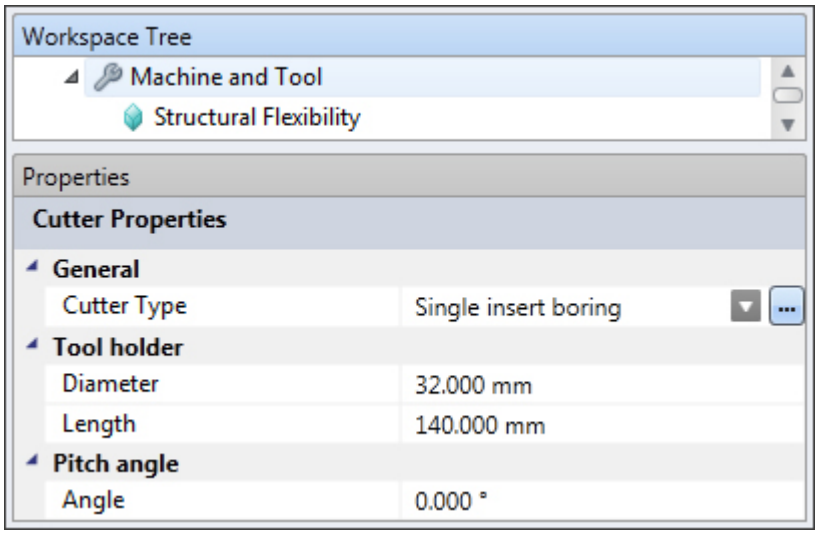
This is not as it is often thought just a parameter to make $\dot{\varepsilon}_{\mathrm{p}}{}^*$ non-dimensional. T_0 is a reference temperature, and T_m is a reference melt temperature.

For conditions where $T^* < 0$, we assume that $m = 1$.

Machine & Tool - Overview

Here the user may select/edit properties related to the machine & tool, such as:

- Cutter geometry
- Structural flexibility



2.2.4.1 Cutter geometry

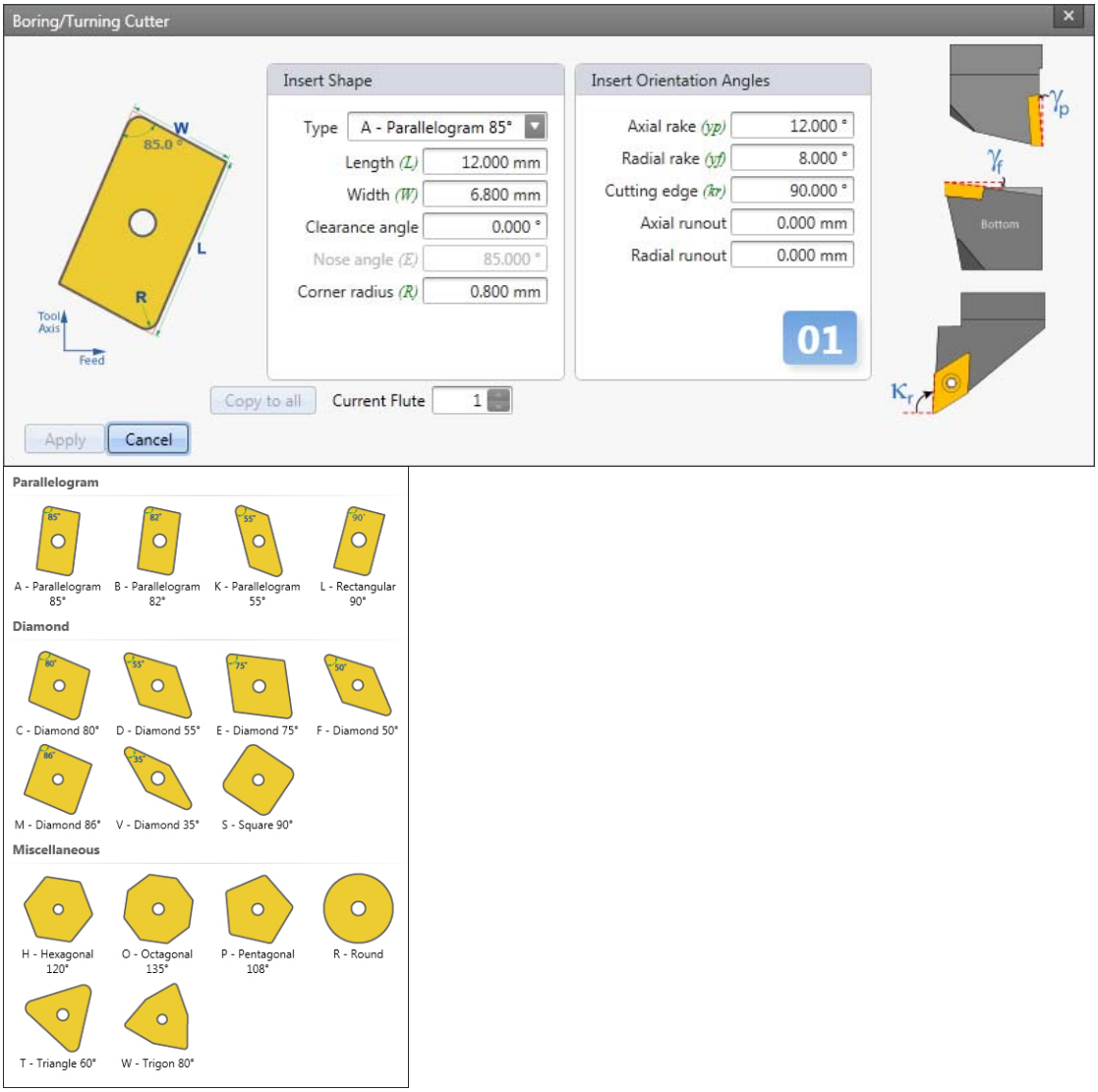
manufacturing automation laboratories CUTPRO

Machine & Tool - Cutter type

In **CUTPRO** boring/turning there are four types of cutters which can be simulated:

- Axial turning
- Radial turning
- Single insert boring
- Multi insert boring

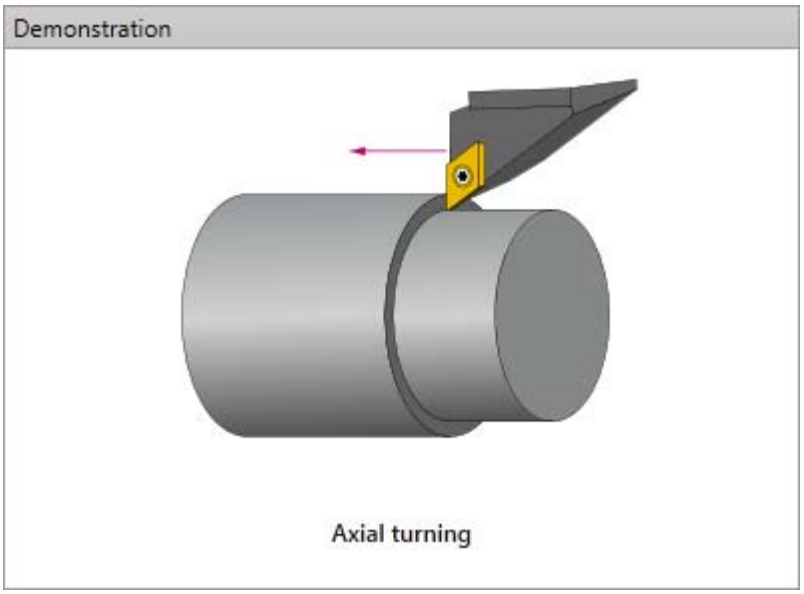
Inserts may be selected as follows:

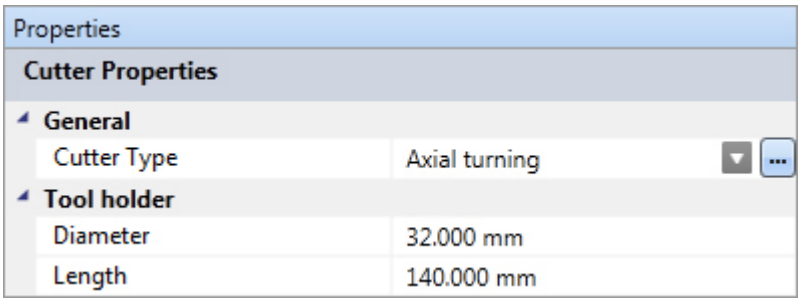


2.2.4.1.1 Axial turning

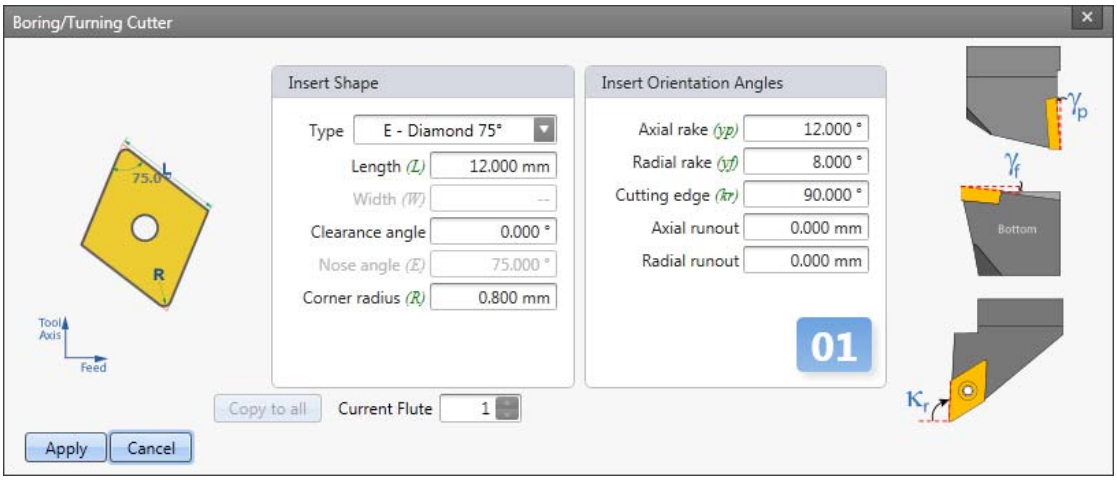
manufacturing automation laboratories CUTPRO

Cutter type - Axial turning





Click on the button to access the cutter designer:

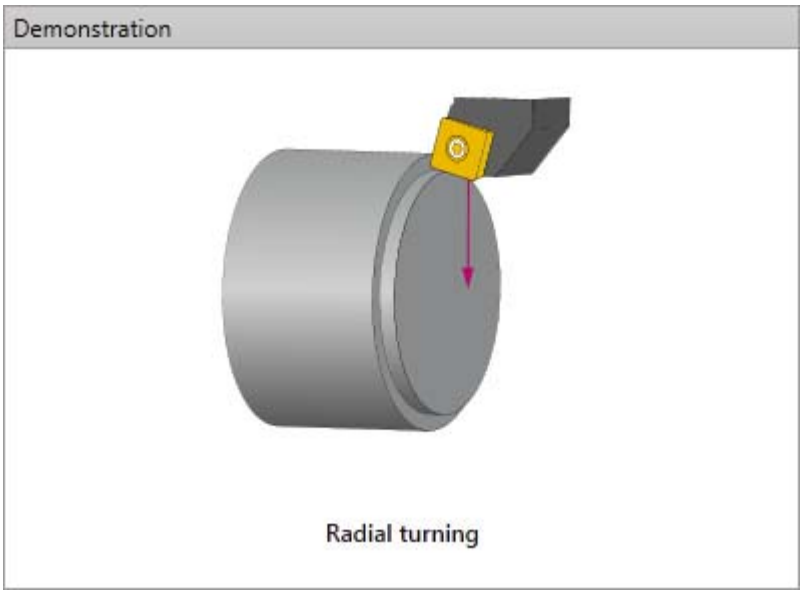


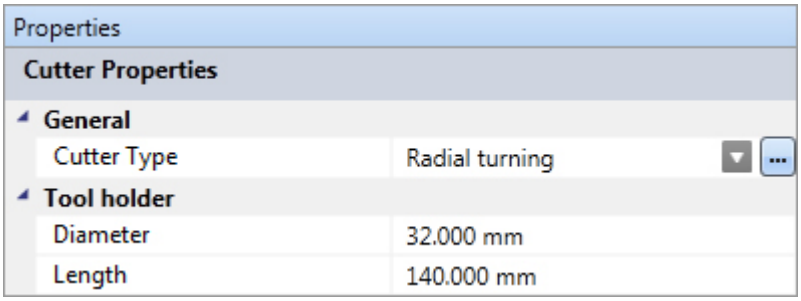
Run-out

Run-outs are defined as deviations from the ideal/design coordinates of the cutter.

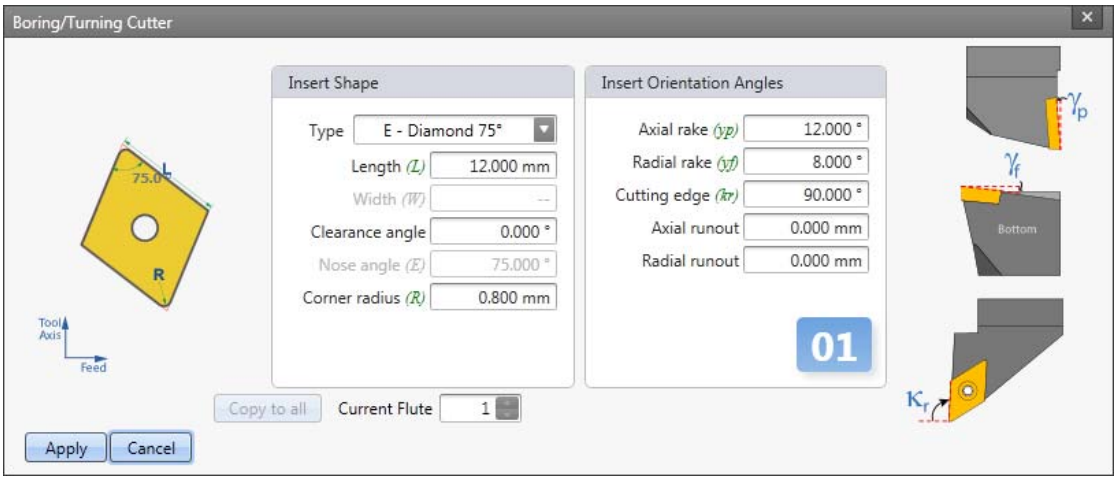
2.2.4.1.2 Radial turning

Cutter type - Radial turning





Click on the button to access the cutter designer:



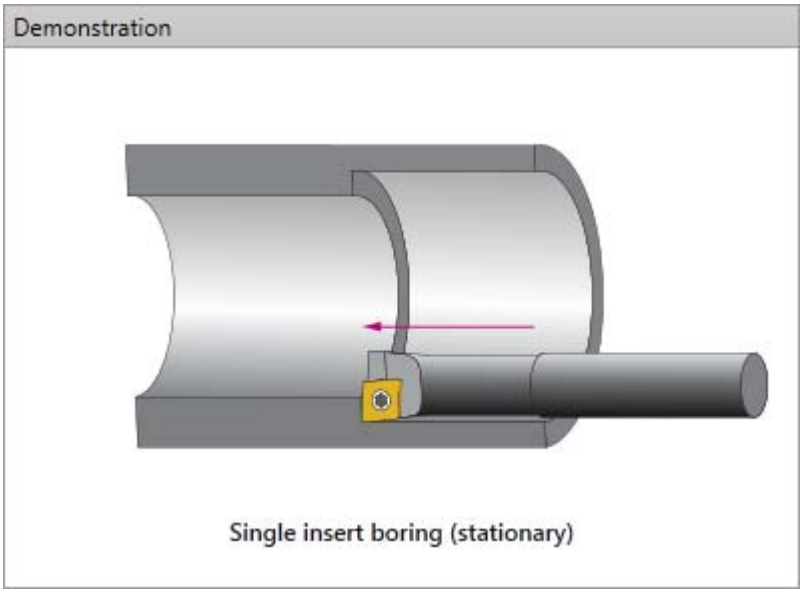
Run-out

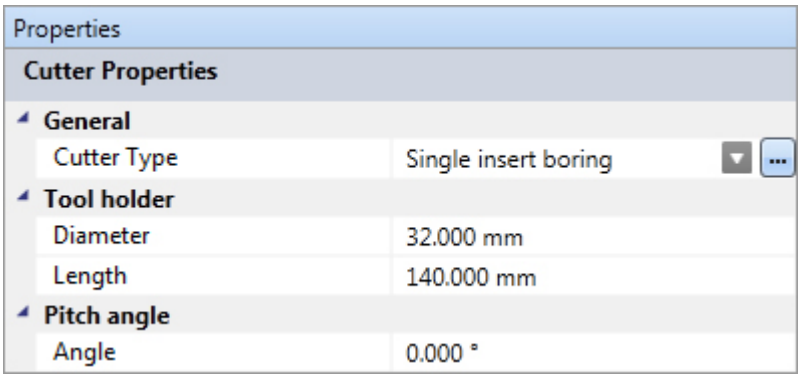
Run-outs are defined as deviations from the ideal/design coordinates of the cutter.

2.2.4.1.3 Single insert boring

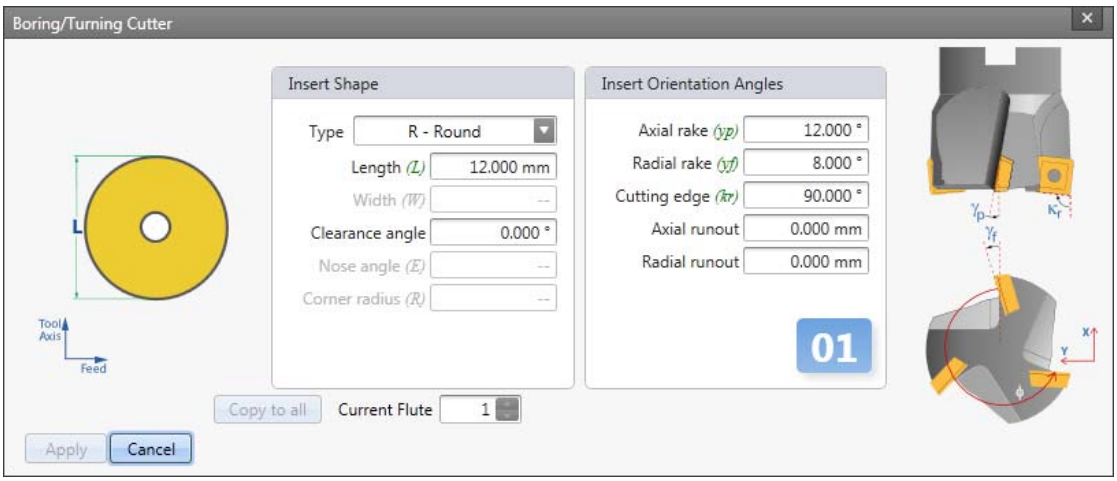
manufacturing automation laboratories CUTPRO

Cutter type - Single insert boring





Click on the button to access the cutter designer:

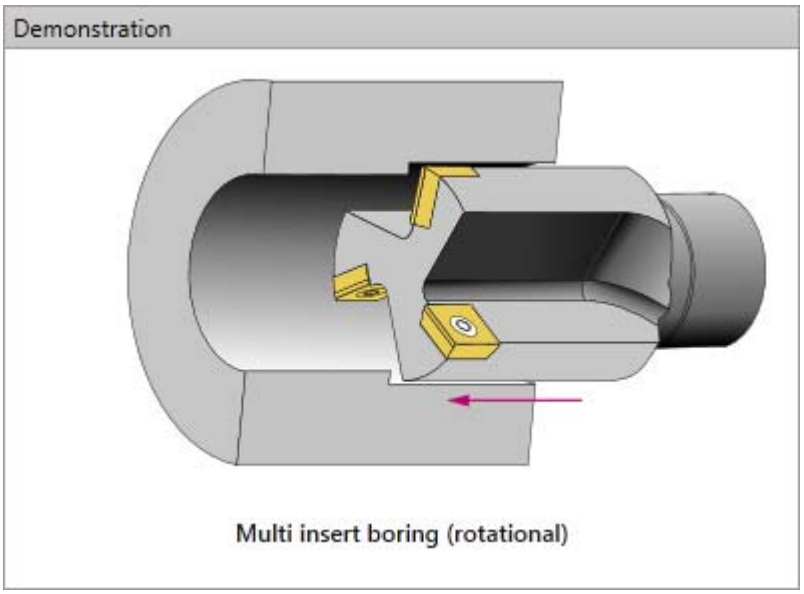


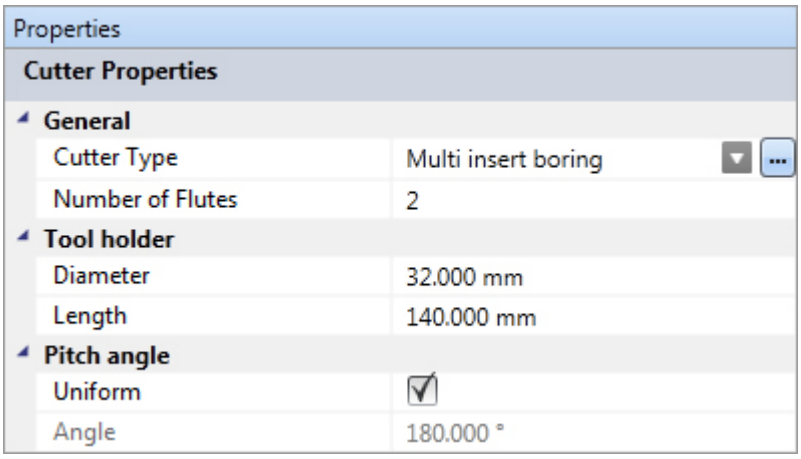
Run-out

Run-outs are defined as deviations from the ideal/design coordinates of the cutter.

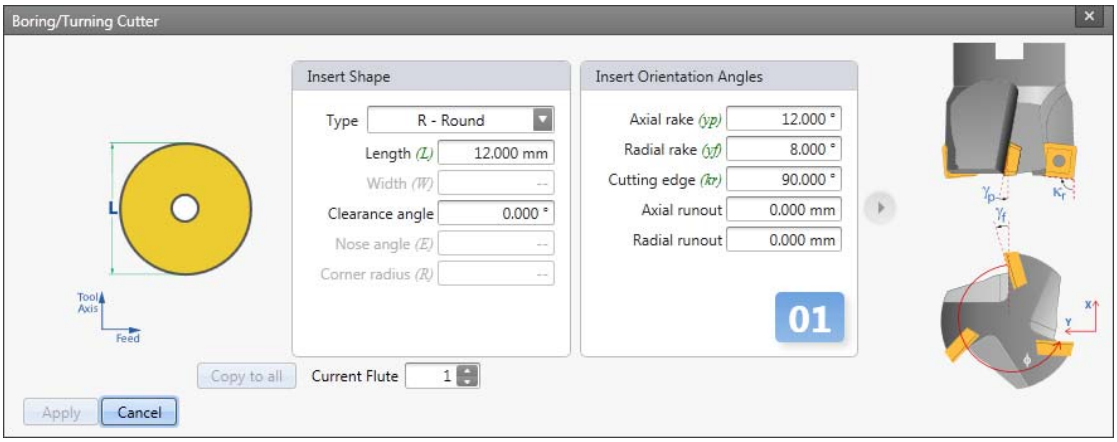
2.2.4.1.4 Multi insert boring

Cutter type - Multi insert boring





Click on the button to access the cutter designer:



Run-out
Run-outs are defined as deviations from the ideal/design coordinates of the cutter.

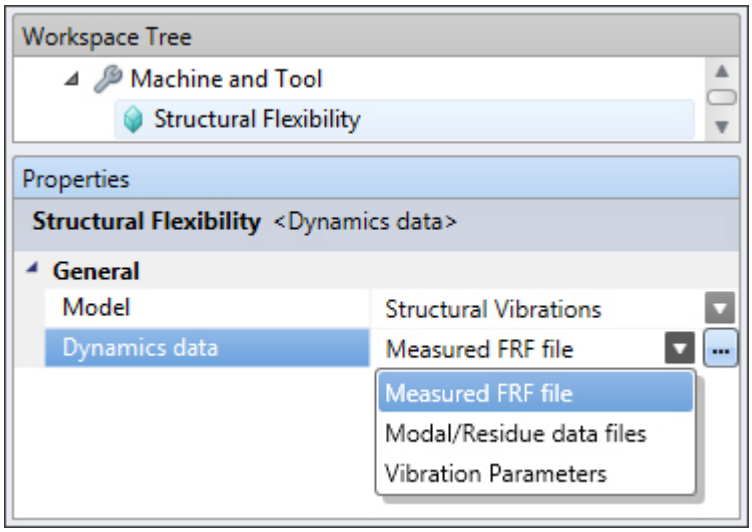
2.2.4.2 Structural flexibility

manufacturing automation laboratories CUTPRO

Machine & Tool - Structural flexibility

Machine & Tool simulation models available:

- Rigid model
- Structural vibrations model



2.2.4.2.1 Rigid model

manufacturing automation laboratories CUTPRO

Structural flexibility - Rigid machine & tool model

- Effects of machine & tool vibrations are not included in the simulation
- Machine/cutter is assumed rigid
- Simulation will be under static conditions.

2.2.4.2.2 Structural vibrations model

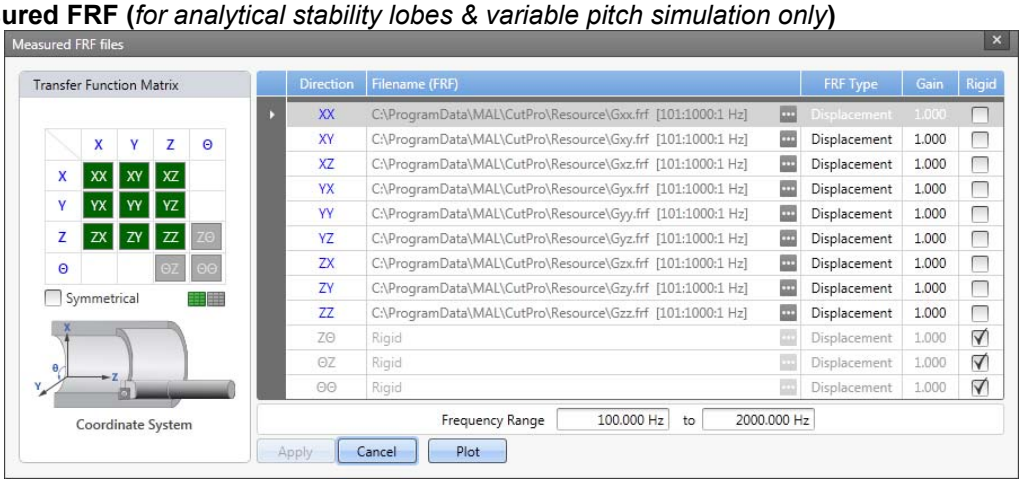
manufacturing automation laboratories CUTPRO

Structural flexibility - Structural vibrations machine & tool model

Machine & tool has structural flexibility

Dynamics data

- **Measured FRF** (*for analytical stability lobes & variable pitch simulation only*)



- **Modal/residue data files**

X modal/residue file	Uses a file containing modal parameters. These modal parameter files are created using the Modal Analysis program.
Y modal/residue file	Uses a file containing modal parameters. These modal parameter files are created using the Modal Analysis program.

- **Vibration parameters**

  This uses the following dynamic parameters. It only allows for a single dominant mode in each of the X- and Y-directions.

Natural frequency	Natural frequency of the system in [Hz]
Damping ratio	Damping ratio for that mode
Stiffness	Stiffness of the system [N/m]

Transfer function values are calculated using following equation in frequency domain:

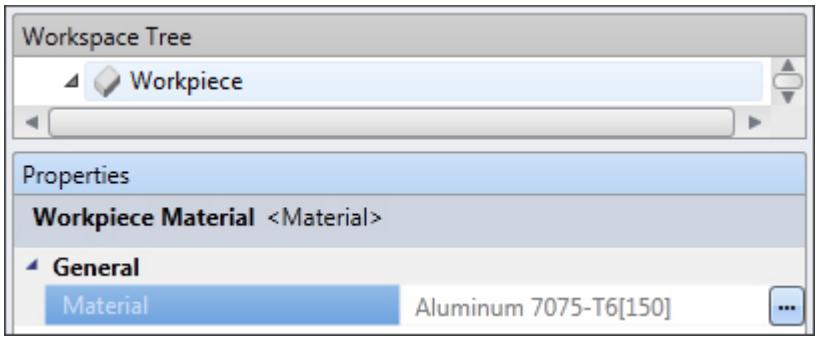
$$\Phi = \frac{\omega_n^2 k}{\omega_n^2 - \omega^2 + i\,2\zeta\omega_n\omega}$$

2.2.5 Workpiece

manufacturing automation laboratories CUTPRO

Workpiece - Overview

Under the workpiece category of simulation, the user is to select a workpiece material:



Once the material has been selected, parameters involving structural flexibility may be defined.

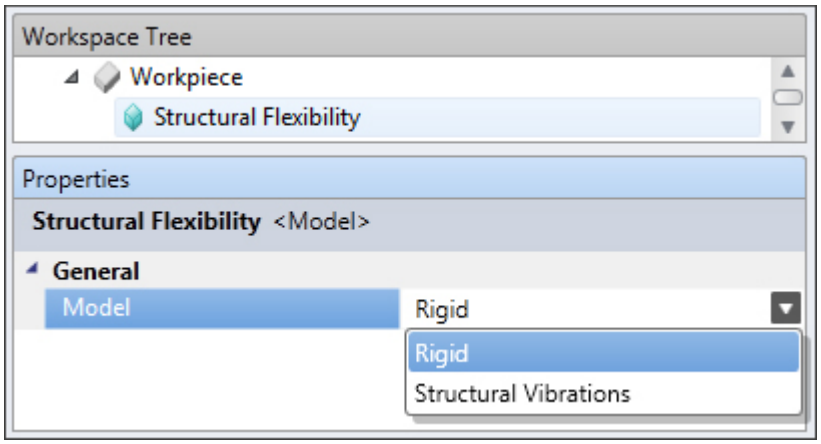
2.2.5.1 Structural Flexibility

manufacturing automation laboratories CUTPRO

Workpiece - Structural flexibility

Workpiece simulation models available:

- Rigid model
- Structural vibrations model



2.2.5.1.1 Rigid model

manufacturing automation laboratories CUTPRO

Structural flexibility - Rigid workpiece model

- Effects of workpiece vibrations are not included in the simulation
- Workpiece is assumed rigid
- Simulation will be under static conditions.

2.2.5.1.2 Structural vibrations model

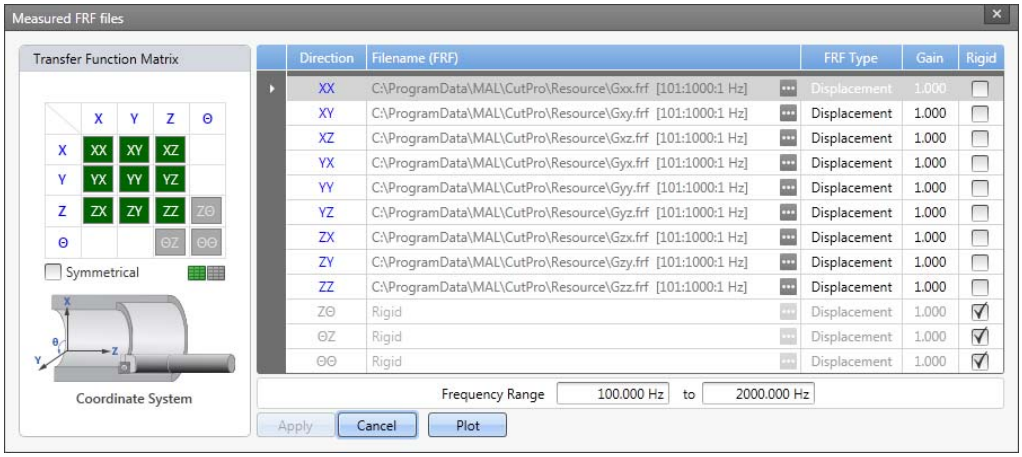
manufacturing automation laboratories CUTPRO

Structural flexibility - Structural vibrations machine & tool model

Workpiece has structural flexibility

Dynamics data

- **Measured FRF (***for analytical stability lobes & variable pitch simulation only***)**



- **Modal/residue data files**

X modal/residue file	Uses a file containing modal parameters. These modal parameter files are created using the Modal Analysis program.
Y modal/residue file	Uses a file containing modal parameters. These modal parameter files are created using the Modal Analysis program.

- **Vibration parameters**

  This uses the following dynamic parameters. It only allows for a single dominant mode in each of the X- and Y-directions.

Natural frequency	Natural frequency of the system in [Hz]
Damping ratio	Damping ratio for that mode
Stiffness	Stiffness of the system [N/m]

Transfer function values are calculated using following equation in frequency domain:

$$\Phi = \frac{\omega_n^2 k}{\omega_n^2 - \omega^2 + i\,2\zeta\omega_n\omega}$$

2.2.6 Cutting Conditions

manufacturing automation laboratories CUTPRO

Cutting Condition - Overview

Turning Mode

The following cutter types must first be selected from "Machine & Tool":

- Axial turning

- Radial turning
- Single insert boring
- Multi insert boring

Cutting conditions may then be set like so:

Properties	
Cutting conditions	
General	
Feedrate	0.100 mm/flute
Spindle speed	2500.000 RPM
Axial depth of cut (a)	3.000 mm
Number of revolutions	20

2.2.7 Results

manufacturing automation laboratories CUTPRO

Results - Overview

Using graphs in CutPro (*Plot Results buttons*)

- **Forces**
  - XYZ cutting forces
  - Feed/Tangential/Radial forces
  - Average cutting forces
- **Spindle parameters**
  - Spindle power
  - Spindle torque
- **Workpiece**
  - Workpiece deflection
- **Stability lobes**
  - Analytical

2.2.7.1 XYZ cutting forces

manufacturing automation laboratories CUTPRO

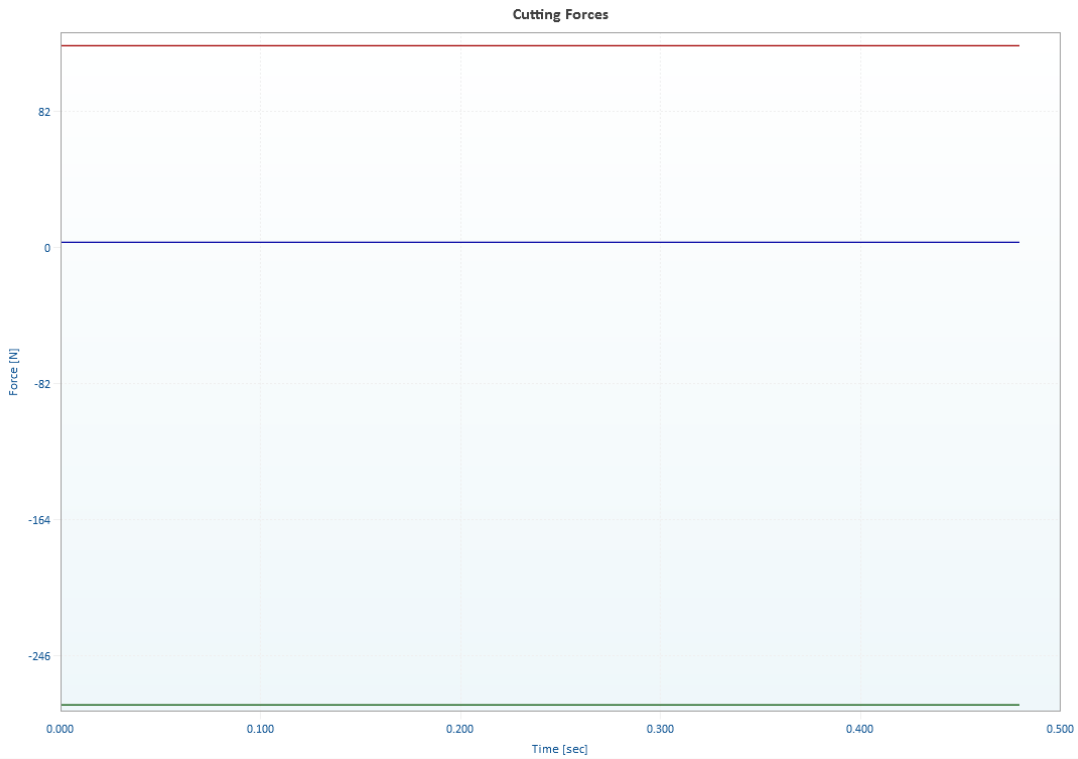
X, Y and Z forces

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot cutting forces.
The results of this plot will look something like the figure below:



Blue = X force, Green = Y force, and Red = Z

In order to toggle through desired results on this plot, the following buttons may be used:

Active axis: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

2.2.7.2 Feed/Tangential/Radial forces

manufacturing automation laboratories CUTPRO

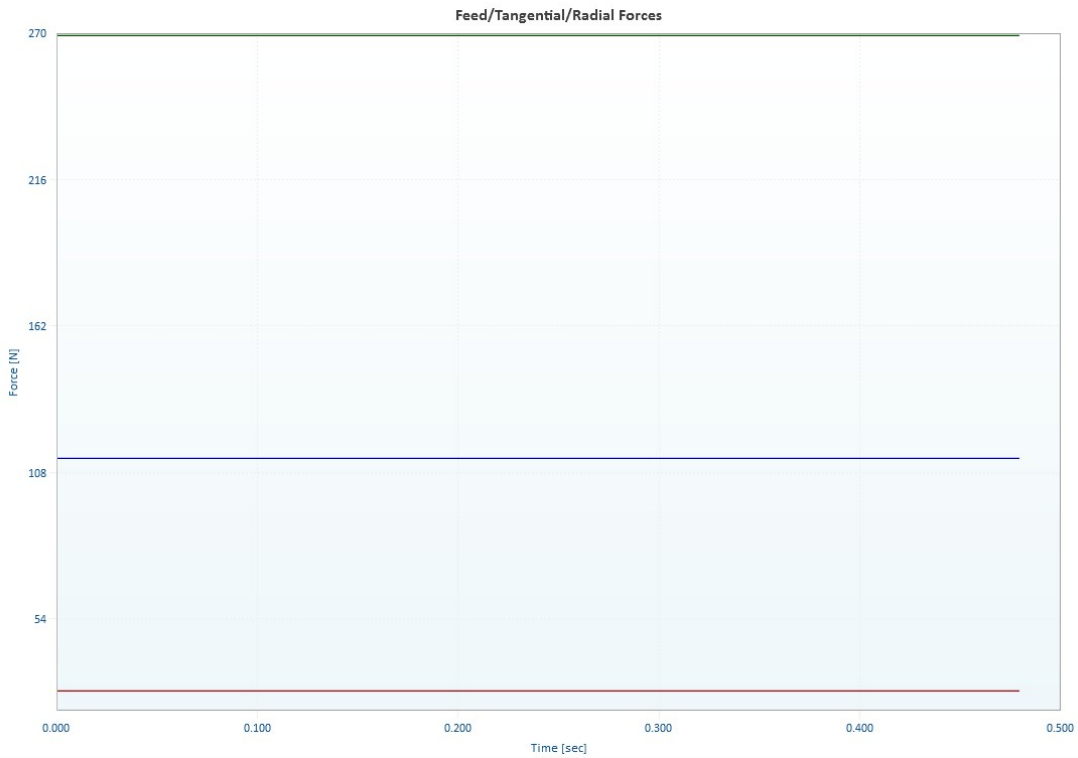
Feed/Tangential/Radial forces

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot feed/tangential/radial forces.
The results of this plot will look something like the figure below:



Blue = Feed Cutting force, Green = Tangential Cutting force, and Red = Radial Cutting force

In order to toggle through desired results on this plot, the following buttons may be used:

Active axis: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

2.2.7.3 Average cutting forces

manufacturing automation laboratories CUTPRO

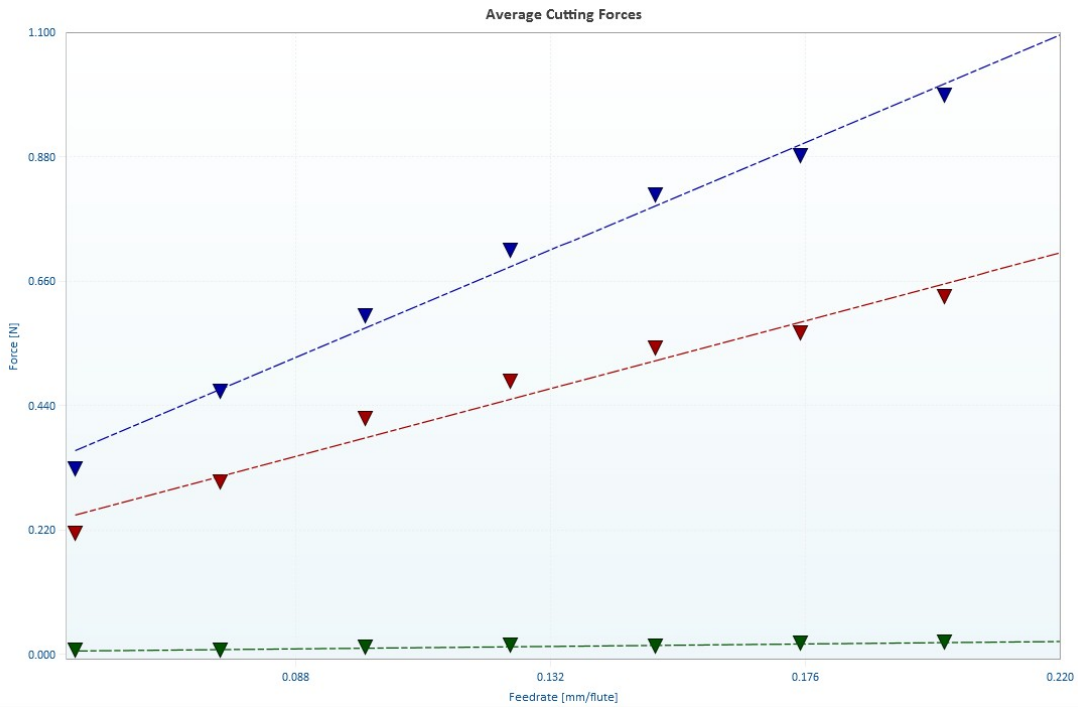
Average cutting forces

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot average cutting forces.
The results of this plot will look something like the figure below:



Blue = X force, Green = Y force, and Red = Z force

In order to toggle through desired results on this plot, the following buttons may be used:

Active axis: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

2.2.7.4 Spindle power

manufacturing automation laboratories CUTPRO

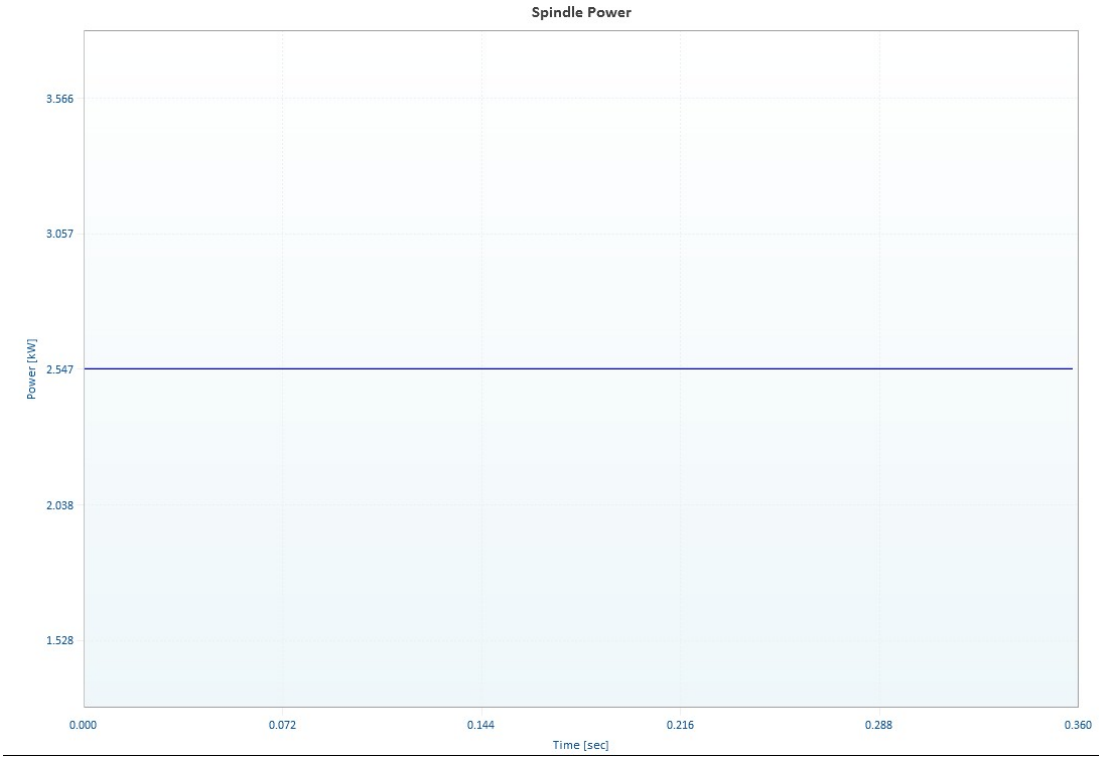
Spindle power

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to spindle power.
The results of this plot will look something like the figure below:



In order to toggle through desired results on this plot, the following buttons may be used:

Feed **Active axis**: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

2.2.7.5 Spindle torque

manufacturing automation laboratories CUTPRO

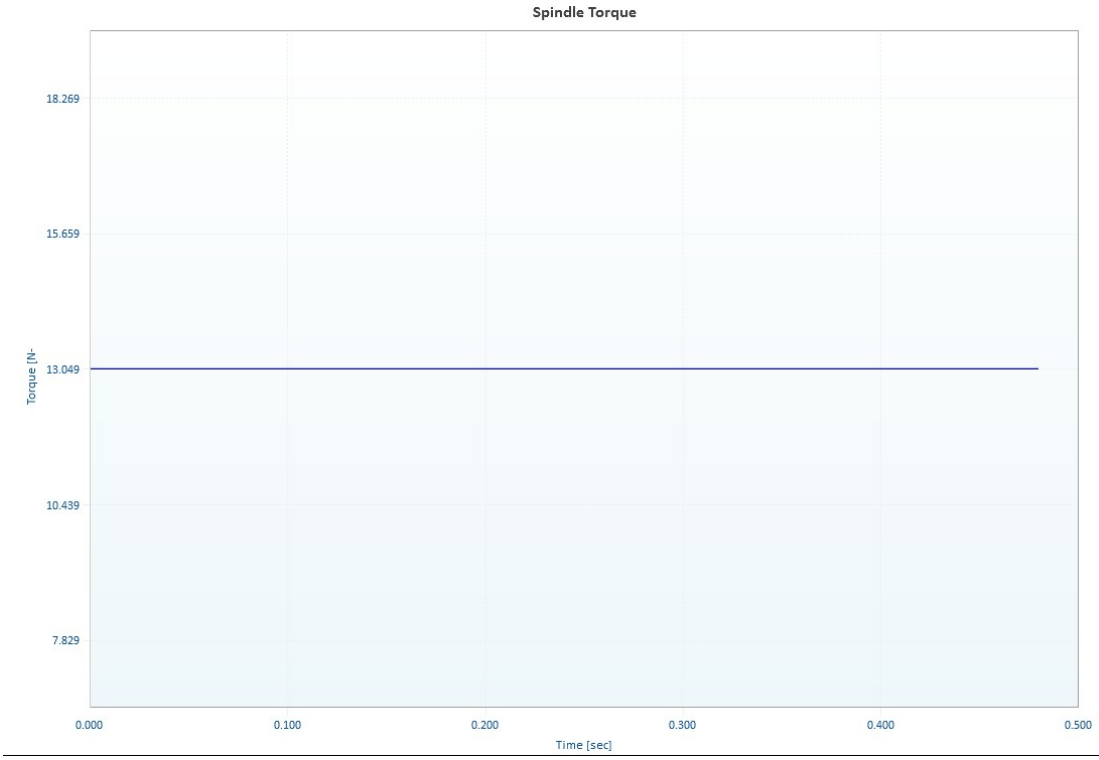
Spindle torque

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot spindle torque.
The results of this plot will look something like the figure below:



In order to toggle through desired results on this plot, the following buttons may be used:

Active axis: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

2.2.7.6 Workpiece deflection

manufacturing automation laboratories CUTPRO

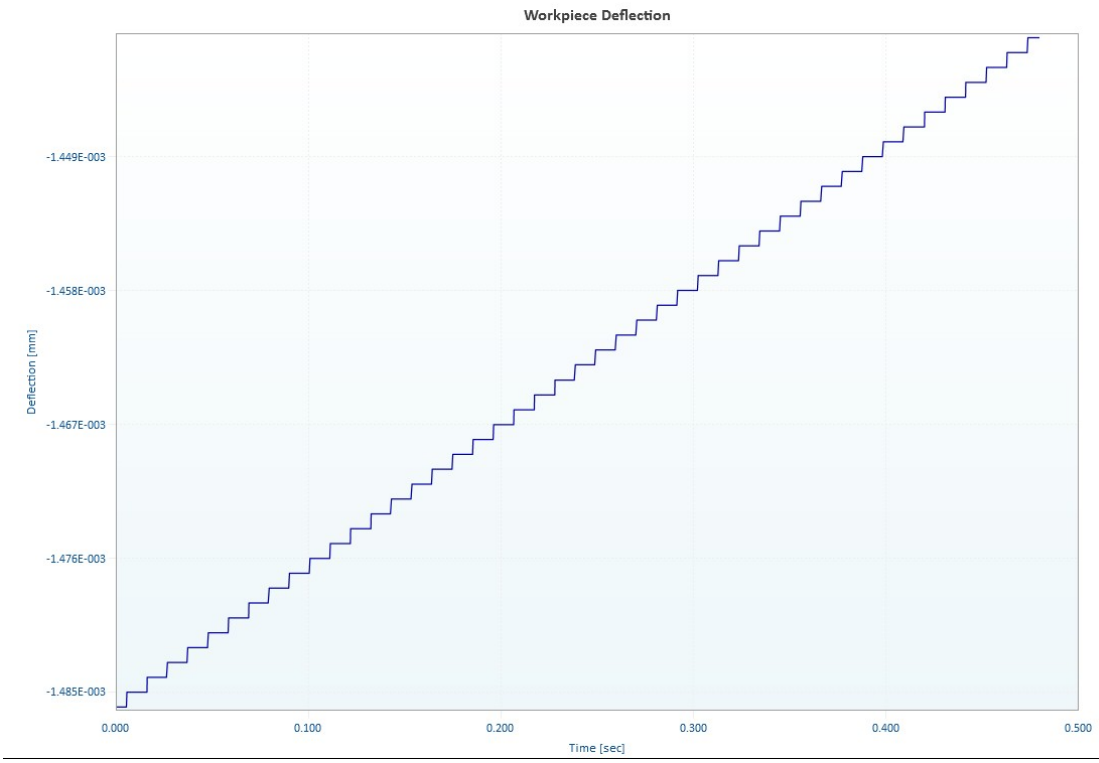
Workpiece deflection

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot workpiece deflection.
The results of this plot will look something like the figure below:



In order to toggle through desired results on this plot, the following buttons may be used:

Active axis: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

2.2.7.7 Analytical stability lobes

manufacturing automation laboratories CUTPRO

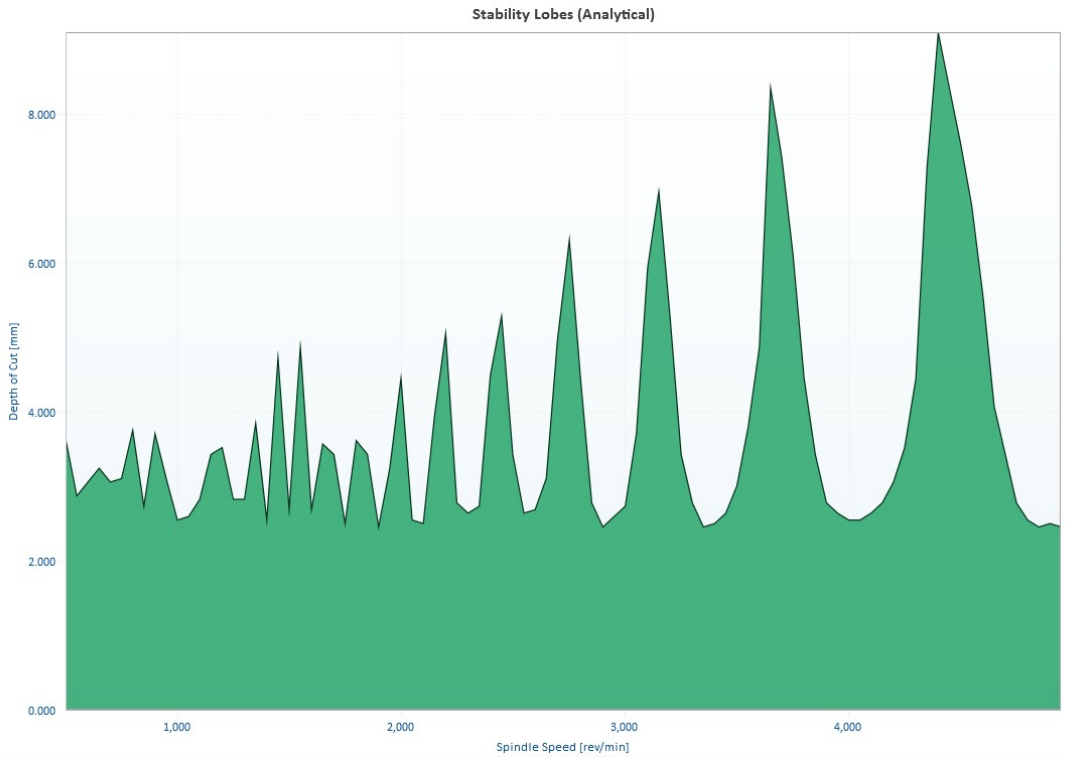
Analytical stability lobes

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to analytical stability lobes.
The results of this plot will look something like the figure below:



Green = Stable cutting

In order to toggle through desired results on this plot, the following buttons may be used:

Active axis: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

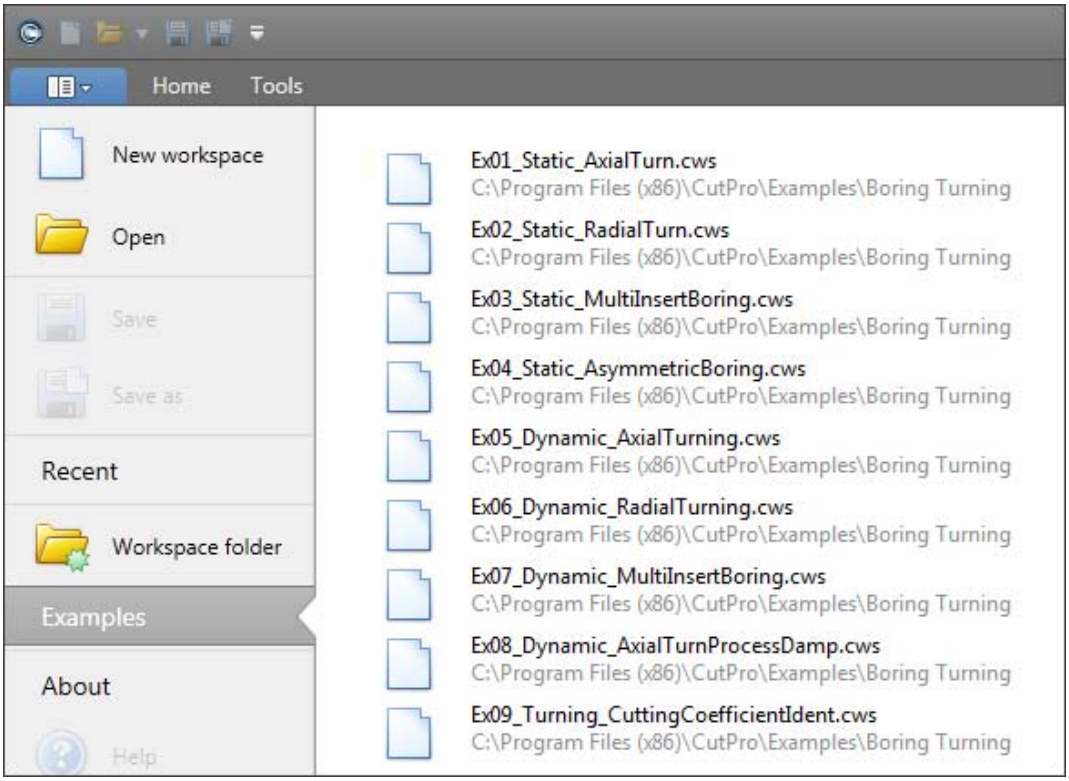
2.2.8 Example Files

manufacturing automation laboratories CUTPRO

Boring/Turning Simulation - Example Files

CutPro comes with various example files for simulation in Boring/Turning.

To access these files, click on the "Examples" button as shown below:



2.3 Drilling Simulation

manufacturing automation laboratories CUTPRO

CutPro: Drilling Simulation - Overview

The “Simulation Workspace Tree” uses a top-to-bottom workflow process, and there are a
few main tabs which require attention in drilling (for example):

- **Workspace** Define the name and unit system
- **Simulation mode** Static analysis, Analytical stability lobes, Hole shape
- **Machine & Tool** Tooling geometries/orientation and properties
  - **Structural Flexibility** Flexibility of the tool, holder, spindle and machine

- **Workpiece** Material properties
  - **Structural Flexibility** Flexibility of the workpiece / fixture
- **Cutting Conditions** Speeds, feeds, and operation parameters
- **Results** Plots of information obtained from the simulation

2.3.1 Workspaces

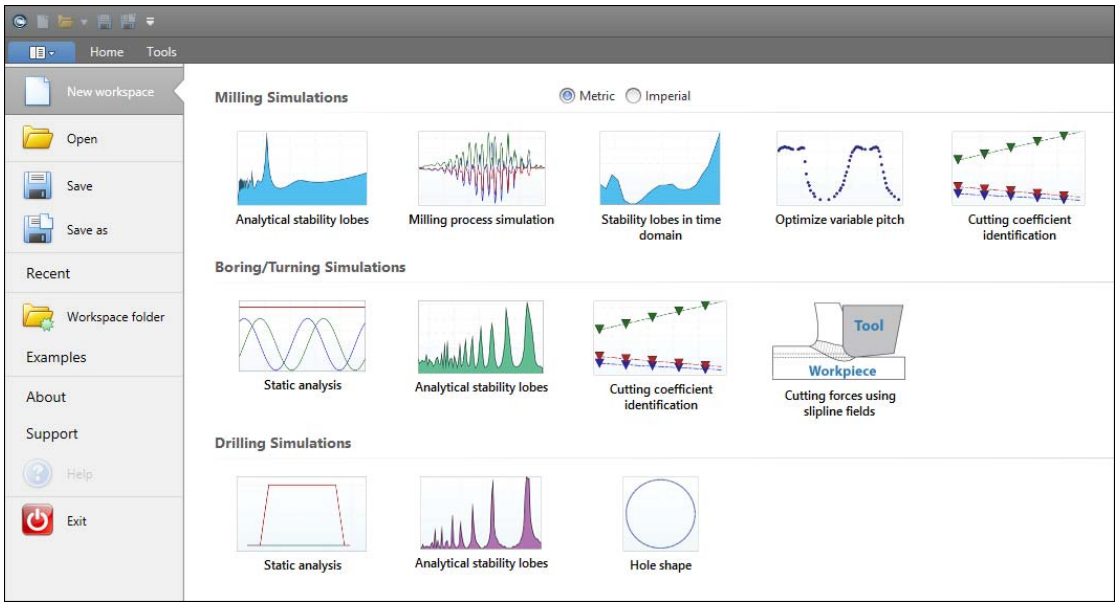
manufacturing automation laboratories CUTPRO

Workspace - Overview

In CutPro the user can define what is called a "Workspace".
Inside of this workspace file (*.cws) one can perform multiple simulations simultaneously and compare them to one-another.

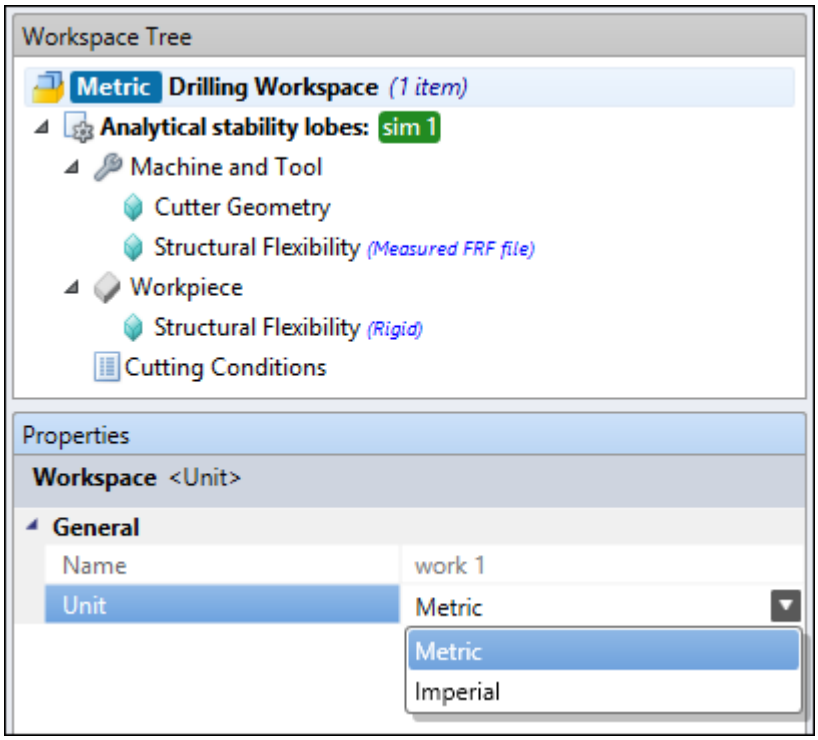
Creating, opening and saving a workspace

A workspace may be managed under the file tab, here you may also define the unit system of preference:



Unit system in CutPro

Both Metric and Imperial unit systems for a workspace can be swapped/converted anytime:

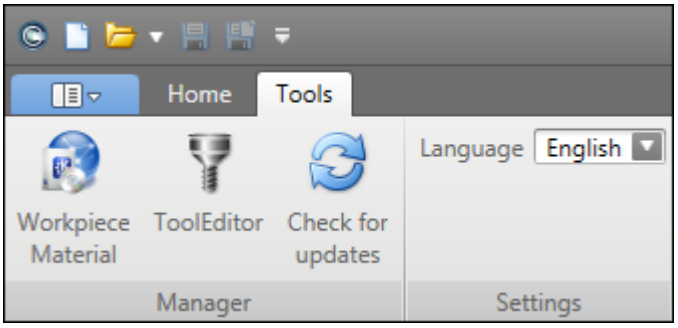


2.3.2 Managers

manufacturing automation laboratories CUTPRO

Managers - Overview

Accessed under the "Tools", the Manager section is mainly used for managing workpiece material definitions and cutting tool files in your tool library



The Workpiece material manager is the central location in CutPro for defining materials and their properties.
Using this function the user can simply load a pre-existing material inside a project

rather than creating it on-the-fly.

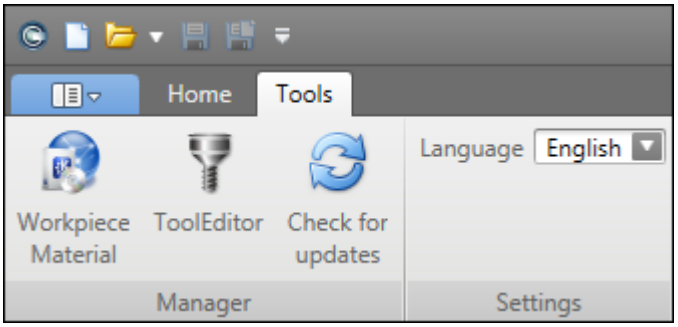
The Tool Editor is used to define and save tool geometry / tools, or perform receptance coupling.
Using this function the user can simply load a pre-existing tool inside a project rather than creating it on-the-fly.

The Check for Updates will do just that, it will notify the user if there is a new CutPro Version and Installation available.
CutPro does this automatically, however if you select "Remind me later", you will have to manually update CutPro using this button.

2.3.2.1 Workpiece Material Manager

manufacturing automation laboratories CUTPRO

Workpiece Material Manager - Overview

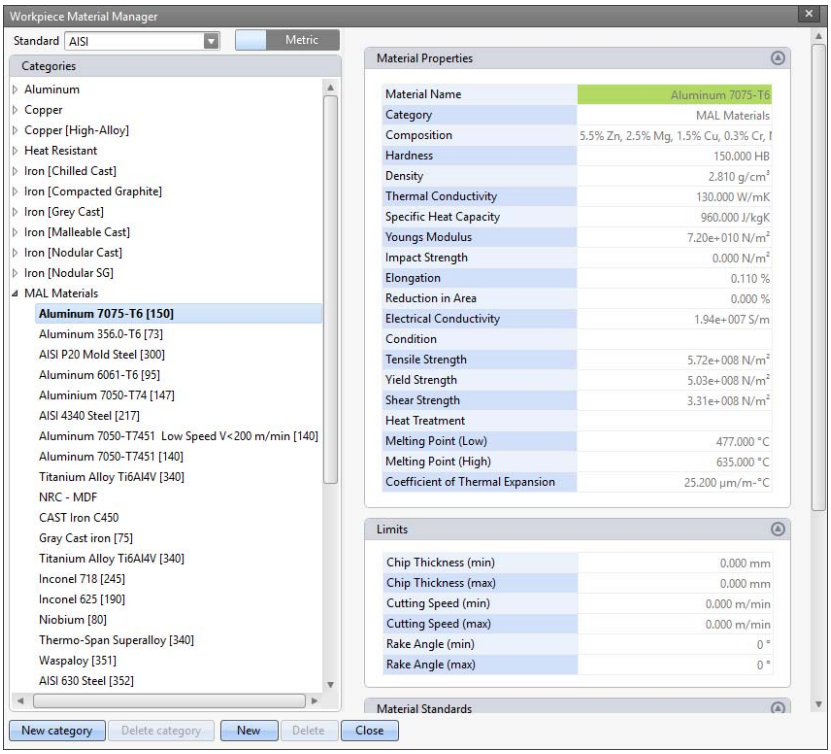


The Workpiece Material Manager contains two general category of workpiece definitions:

- Standardized workpiece materials (Pre-existing, with CutPro installation)
  Ex. Aluminum 7050-T6 (AISI Standard Material)
- User-defined workpiece materials (New: Defined by the Customer or by MAL through material characterization services)
  Ex. Secret in-house material

Regardless of which category of material you are using, the following information and data is present.

- Material properties(1)
- Coefficient parameters(2)(3)
- Limits(4)
- Material Standards



(1) **Material properties** are only used for reference, these properties are not meaningful for machining simulation

(2) **Coefficient parameters** are only shown for user-defined workpiece materials

(3) **Coefficient parameters** are the only numbers entered into the Material Manager which change simulation results--they are essential for accurate simulations

(4) **Limits** affect the range in which the force model was created, however these entries are not used within CutPro calculations.

2.3.2.1.1 Material properties

manufacturing automation laboratories CUTPRO

Material properties

The *"Material Properties"* tab displays the specifications of the material given in either unit system:

- Material Properties [Metric units]
- Material Properties [Imperial units]

**Units may be toggled at any time in the Workpiece Material Manager*

Material Properties

Material Name	
Category	MAL Materials
Composition	
Hardness	0.000 HB
Density	0.000 g/cm³
Thermal Conductivity	0.000 W/mK
Specific Heat Capacity	0.000 J/kgK
Youngs Modulus	0.000 N/m²
Impact Strength	0.000 N/m²
Elongation	0.000 %
Reduction in Area	0.000 %
Electrical Conductivity	0.000 S/m
Condition	
Tensile Strength	0.000 N/m²
Yield Strength	0.000 N/m²
Shear Strength	0.000 N/m²
Heat Treatment	
Melting Point (Low)	0.000 °C
Melting Point (High)	0.000 °C
Coefficient of Thermal Expansion	0.000 µm/m-°C

Purpose

The *"Material Properties"* section is primarily used for reference in order to better understand how the material behaves. These properties are not used in CutPro's engine, this is due to the fact that many tests used to identify these properties are far different than machining. For example, the strain rates of the material under machining are extremely high in comparison to that of a tensile test.

2.3.2.1.1.1 Metric units_2

manufacturing automation laboratories CUTPRO

Material properties - METRIC units

Material name

Category

Composition

Hardness [*HB*]

Density [*g/cm³*]

Thermal Conductivity [*W/mK*]

Specific Heat Capacity [*J/kgK*]

Youngs Modulus [*N/m²*]

Material Properties

Material Name	Aluminum 7075-T6
Category	MAL Materials
Composition	5.5% Zn, 2.5% Mg, 1.5% Cu, 0.3% Cr, I
Hardness	150.000 HB
Density	2.810 g/cm³
Thermal Conductivity	25.200 W/mK
Specific Heat Capacity	960.000 J/kgK
Youngs Modulus	7.20e+010 N/m²
Impact Strength	0.000 N/m²
Elongation	0.110
Reduction in Area [%]	0.000
Electrical Conductivity	1.94e+007 S/m
Condition	
Tensile Strength	5.72e+008 N/m²
Yield Strength	5.03e+008 N/m²
Shear Strength	3.31e+008 N/m²
Heat Treatment	
Melting Point (Low)	477.000 °C
Melting Point (High)	635.000 °C
Coefficient of Thermal Expansion	0.000 µm/m-°C

Impact Strength	[*N/m²*]
Elongation	
Reduction in Area	[*%*]
Electrical Conductivity	[*S/m*]
Condition	
Tensile Strength	[*N/m²*]
Yield Strength	[*N/m²*]
Shear Strength	[*N/m²*]
Heat Treatment	
Melting Point (Low)	[*°C*]
Melting Point (High)	[*°C*]
Coefficient of Thermal Expansion	[*µm/m-°C*]

2.3.2.1.1.2 Imperial units_2

manufacturing automation laboratories CUTPRO

Material properties - IMPERIAL units

Material name

Category

Composition

Hardness [*HB*]

Density [*lb/in*^{3}]

Thermal Conductivity [*BTu/hr-ft°F*]

Specific Heat Capacity [*BTu/lb°F*]

Youngs Modulus [*lbf/ft*^{2}]

Impact Strength [*lbf/ft*^{2}]

Elongation

Reduction in Area [*%*]

Electrical Conductivity [*S/ft*]

Condition

Tensile Strength [*lbf/ft*^{2}]

Yield Strength [*lbf/ft*^{2}]

Shear Strength [*lbf/ft*^{2}]

Heat Treatment

Melting Point (Low) [*°F*]

Melting Point (High) [*°F*]

Coefficient of Thermal Expansion [*in/ft°F*]

Material Properties

Material Name	Aluminum 7075-T6
Category	MAL Materials
Composition	5.5% Zn, 2.5% Mg, 1.5% Cu, 0.3% Cr, I
Hardness	150.000 HB
Density	0.102 lb/in^3
Thermal Conductivity	14.560 BTu/hr-ft°F
Specific Heat Capacity	0.229 BTu/lb°F
Youngs Modulus	1.04e+007 lbf/ft^2
Impact Strength	0.000 lbf/ft^2
Elongation	0.110
Reduction in Area [%]	0.000
Electrical Conductivity	5918446.599 S/ft
Condition	
Tensile Strength	82961.570 lbf/ft^2
Yield Strength	72953.968 lbf/ft^2
Shear Strength	48007.482 lbf/ft^2
Heat Treatment	
Melting Point (Low)	858.600 °F
Melting Point (High)	1143.000 °F
Coefficient of Thermal Expansion	0.000 in/ft°F

2.3.2.1.2 Coefficient parameters

manufacturing automation laboratories CUTPRO

Coefficient parameters

The *"Coefficient parameters"* tab offers 9 different force models which may be used to characterize user-defined materials.

METRIC Units

- Average cutting coefficient model
- Orthogonal to oblique model
- Exponential chip thickness model
- Semi-mechanistic model
- Sandvik model
- Kienzle model
- Rake face model

**Imperial Units are not supported for Force Models*

Coefficient Parameters

Force Model	Rake Face Model
Kte (N/mm)	24.76
Kre (N/mm)	27.36
Kae (N/mm)	0
Ku (N/mm²)	1000.78
Kv (N/mm²)	1526.5514

Purpose

The *"Coefficient parameters"* section is used for defining a *force model* for a user material(1). The *force model* consists of constants or equations that are used in CutPro's engine. Using dynamometers and experiments, the material is machined and force data is collected. This data i used in constructing a *force model* which characterizes how the material behaves under various machining conditions. The model is then used to calculate cutting forces, torque, power and so on. If there are any inaccuracies with this model (material characterization), the simulations in CutPro will be completely wrong. If you are working with your own custom material and are not familiar with the science behind this, we encourage customers to contact MAL Inc for assistance.

(1) **Coefficient parameters** are only shown for user-defined workpiece materials

2.3.2.1.2.1 Average cutting coefficient model [Metric]

manufacturing automation laboratories CUTPRO

Average cutting coefficient model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$

$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$

$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]

2.3.2.1.2.2 Orthogonal to oblique model [Metric]

manufacturing automation laboratories CUTPRO

Orthogonal to oblique model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$
$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$
$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{tc} = \frac{\tau}{\sin \varphi_n} \frac{\cos(\beta_n - \alpha_n) + \tan \eta_c \sin \beta_n \tan i}{c}$$
$$K_{rc} = \frac{\tau}{\sin \varphi_n \cos i} \frac{\sin(\beta_n - \alpha_n)}{c}$$
$$K_{ac} = \frac{\tau}{\sin \varphi_n} \frac{\cos(\beta_n - \alpha_n) \tan i - \tan \eta_c \sin \beta_n}{c}$$
$$c = \sqrt{\cos^2(\varphi_n + \beta_n - \alpha_n) + \tan^2 \eta_c \sin^2 \beta_n}$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]

τ ("t"): shear stress [N/mm²]	ϕ_n ("f"): shear angle [°]
β_n ("b"): friction angle [°]	α_n: rake angle [°]
η: chip flow angle [°]	*i*: helix angle [°]

2.3.2.1.2.3 Exponential chip thickness [Metric]

manufacturing automation laboratories CUTPRO

Exponential chip thickness

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$

$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$

$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{te} = K_{re} = K_{ae} = 0.0$$

$$K_{tc} = KT \cdot h^{-p}$$

$$K_{rc} = KR \cdot KT \cdot h^{-q}$$

$$K_{ac} = KA \cdot KT \cdot h^{-r}$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]

dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]
KT : tangential shearing coef. parameter	p : tangential chip thickness order
KR : radial shearing coef. parameter	q : radial chip thickness order
KA : axial shearing coef. parameter	r : axial chip thickness order

2.3.2.1.2.4 Semi-mechanistic model [Metric]

manufacturing automation laboratories CUTPRO

Semi-mechanistic model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$
$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$
$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{te} = K_{re} = K_{ae} = 0.0$$
$$K_{tc} = k_n \left[\cos\alpha_n + k_f \cos\eta \sin\alpha_n + k_f \tan i \sin\eta \right]$$
$$K_{rc} = k_n \left[-\frac{\sin\alpha_n}{\cos i} + k_f \cos\alpha_n \frac{\cos\eta}{\cos i} \right]$$
$$K_{ac} = k_n \left[\tan i \cos\alpha_n - k_f \sin\eta + k_f \tan i \cos\eta \sin\alpha_n \right]$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]
α_n: rake angle [°]	k_n : cutting pressure on rake face

i: helix angle [°]	k_f : cutting pressure rate on flank face
η: chip flow angle [°]	

2.3.2.1.2.5 Sandvik model [Metric]

manufacturing automation laboratories CUTPRO

Sandvik force model

Equations:

$$dF_t = K_{tc} * h * dz$$
$$dF_r = K_{rc} * h * dz$$
$$dF_a = K_{ac} * h * dz$$
$$K_{tc} = K_t * h^{-p}$$
$$K_{rc} = K_c * h^{-q}$$
$$K_{ac} = K_r * h^{-r}$$

Parameters:

dF_t : differential tangential force [N]	
dF_r : differential radial force [N]	
dF_a : differential axial force [N]	
	K_{tc} : tangential shearing coefficient [N/mm²]
dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]

2.3.2.1.2.6 Kienzle model [Metric]

manufacturing automation laboratories CUTPRO

Kienzle force model

Equations:

$$dF_t = K_{te} \cdot dS + K_{tc} \cdot h \cdot dz$$

$$dF_r = K_{re} \cdot dS + K_{rc} \cdot h \cdot dz$$

$$dF_a = K_{ae} \cdot dS + K_{ac} \cdot h \cdot dz$$

$$K_{te} = K_{re} = K_{ae} = 0.0$$

$$K_{tc} = K_u(\sin\eta \sin i + \cos\eta \cos i \sin\alpha_n) + K_v(\cos\alpha_n \cos i)$$

$$K_{rc} = K_u(\cos\alpha_n \cos\eta) - K_v \sin\alpha_n$$

$$K_{ac} = K_u(-\sin\eta \cos i + \cos\eta \sin i \sin\alpha_n) + K_v(\cos\alpha_n \sin i)$$

$$K_u = K_{u_{1.1}} h^{(-u)}$$

$$K_v = K_{v_{1.1}} h^{(-v)}$$

Parameters:

dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dS : differential cutting edge length [mm]	K_{tc} : tangential shearing coefficient [N/mm²]

dZ : differential axial depth of cut [mm]	K_{rc} : radial shearing coefficient [N/mm²]
h : chip thickness [mm]	K_{ac} : axial shearing coefficient [N/mm²]
α_n: rake angle [°]	K_u : cutting pressure parallel to rake face
i: helix angle [°]	K_v : cutting pressure normal to rake face
η: chip flow angle [°]	$K_{u1.1}$: Coefficient parallel to rake face
u: parallel to rake face chip thickness order	$K_{v1.1}$: Coefficient normal to rake face
v: normal to rake face chip thickness order	

2.3.2.1.2.7 Rake face model [Metric]

manufacturing automation laboratories CUTPRO

Rake face force model

Equations:

$$dF_u = K_u h\, dz$$

$$dF_v = K_v h\, dz$$

$$\begin{bmatrix} dF_r \\ dF_t \\ dF_a \end{bmatrix} = [A] \begin{bmatrix} dF_u \\ dF_v \end{bmatrix} + dS \begin{bmatrix} K_{re} \\ K_{te} \\ K_{ae} \end{bmatrix}$$

Parameters:

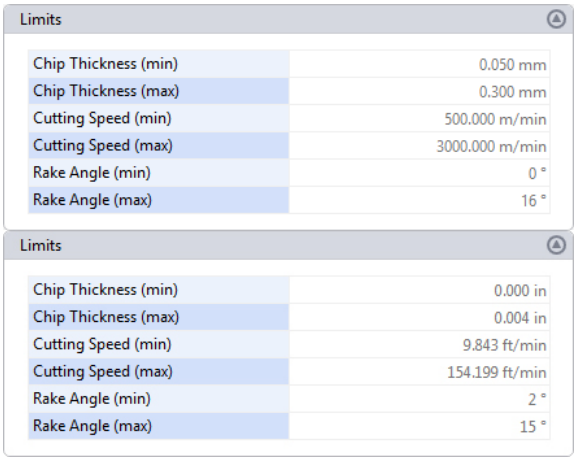
dF_t : differential tangential force [N]	K_{te} : tangential edge force coefficient [N/mm]
dF_r : differential radial force [N]	K_{re} : radial edge force coefficient [N/mm]
dF_a : differential axial force [N]	K_{ae} : axial edge force coefficient [N/mm]
dF_u : differential friction force [N]	K_u : Friction coefficient on the rake face [N/mm^2]
dF_v : differential normal force [N]	K_v : Normal coefficient on the rake face [N/mm^2]
dz : differential axial depth of cut [mm]	h : chip thickness [mm]
dS : differential cutting edge length [mm]	A : Transformation matrix between the rake face CS and RTA CS

2.3.2.1.3 Limits

manufacturing automation laboratories CUTPRO

Limits

The *"Limits"* tab displays the limits of the material characterization given in either unit system:



Limits

Chip Thickness (min)	0.050 mm
Chip Thickness (max)	0.300 mm
Cutting Speed (min)	500.000 m/min
Cutting Speed (max)	3000.000 m/min
Rake Angle (min)	0 °
Rake Angle (max)	16 °

Limits

Chip Thickness (min)	0.000 in
Chip Thickness (max)	0.004 in
Cutting Speed (min)	9.843 ft/min
Cutting Speed (max)	154.199 ft/min
Rake Angle (min)	2 °
Rake Angle (max)	15 °

	Metric	Imperial
Chip Thickness	mm	in
Cutting Speed	m/min	ft/min
Rake Angle	°	°

**Units may be toggled at any time in the Workpiece Material Manager*

Purpose

The *"Limits"* section is used for defining the limits of user-defined material characterization models, or for viewing the limits of provided material characterization models. These values determine the conditions in which the material was characterized. For example, in the above test, perhaps the following was done:

Chip Thickness: 0.050 mm, 0.100 mm, 0.150 mm, 0.200 mm, 0.250 mm, 0.300 mm.
Rake Angles: 0°, 4°, 8°, 12°, 16°.
Cutting Speeds: 500 m/min, 1000 m/min, 1500 m/min, 2000 m/min, 2500 m/min, 3000 m/min

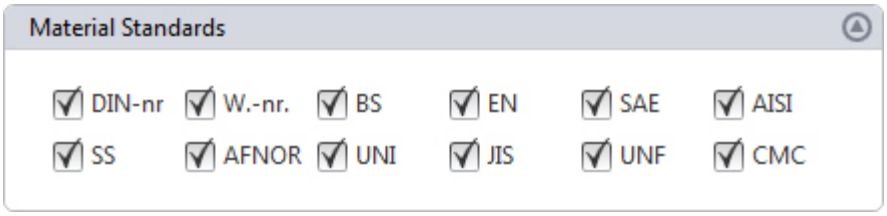
This allows the material to be defined for various feeds, rake angles and speeds. As a result, you can expect fully accurate simulations within these min and max ranges. If your simulation is out of range, for example rake 18, you can still expect to see a good accuracy. It is up to the user to decide how suitable the material limits are based on the application. If you require assistance on this topic, you can contact MAL's support team within CutPro.

2.3.2.1.4 Material standards

manufacturing automation laboratories CUTPRO

Material standards

The *"Material standards"* tab displays the material standards which the selected material belongs in, and changes the name of the material based on the selected standard. The following standards are available:



DIN-nr : German Institute for Standardization # (Deutsches Institut für Normung e.V.)
W.-nr. : German material number (Werkstoffnummer)
BS: British Standards
EN: European Committee for Standardization
SAE: Society of Automotive Engineers
AISI: American Iron and Steel Institute
SS: Swedish Standards Institute (Svensk Standard Standardisering)

AFNOR: French national organization for standardization (Association Française de Normalisation)

UNI: Italian National Standards Institute (Ente Nazionale Italiano di Unificazione)

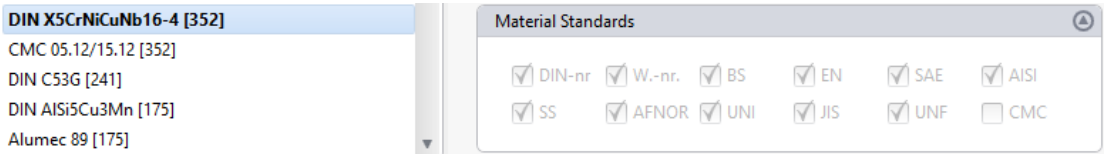
JIS: Japanese Industrial Standards (日本工業規格)

UNE: Spanish Material Standards (Una Norma Española)

CMC: Coromant Material Classification (Sandvik)

Purpose

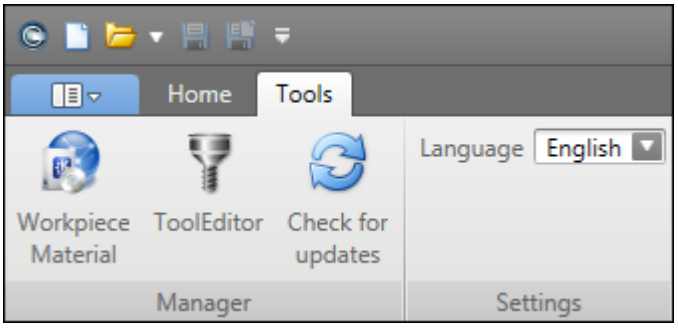
The *"Material standards"* section is simply used to filter materials by standards. Not every material is available in all standards, for example:



2.3.2.2 Check for Updates

manufacturing automation laboratories CUTPRO

Check for updates - Overview



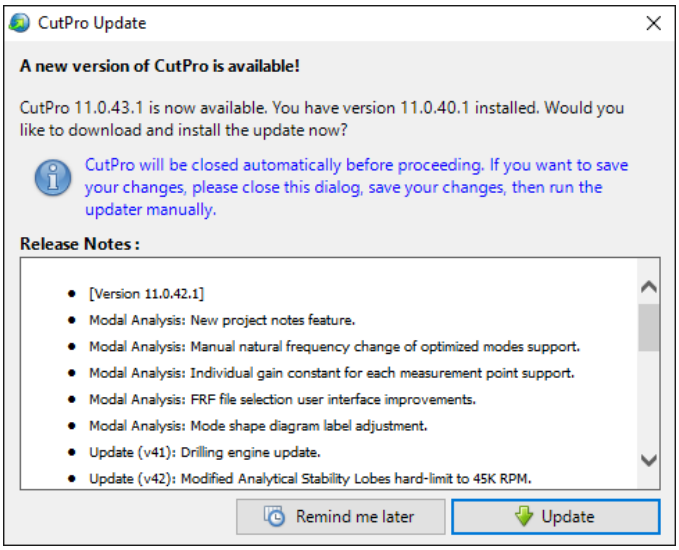
Click on the 'Check for updates' button to see if a new CutPro version has been released:

1) If a new version isn't available

CutPro will tell you your current version and tell you that it's up-to-date.

2) If a new version is available

CutPro will show an update prompt along with the update contents.



3) If you cannot update at all

Please contact us if the update button is not visible in CutPro although you have an older version.

This likely means that your Updates have expired.

2.3.3 Simulation Modes

manufacturing automation laboratories CUTPRO

Simulation Modes - Overview

Inside of the active Workspace, the user can define many simulations, and also various simulation modes may be selected:

- Static Analysis
- Analytical stability lobes

Useful Functions for Simulation

Add: Add a new simulation in the active workspace

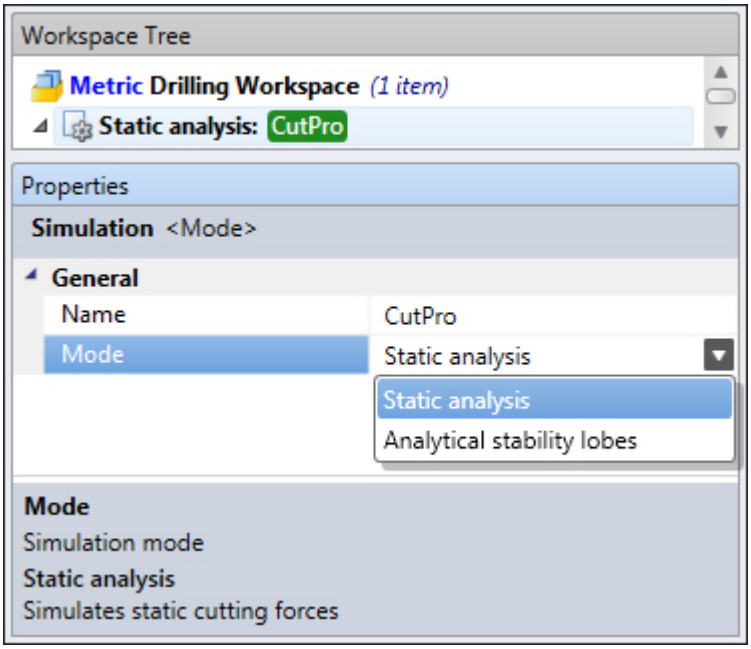
Remove: Removes selected simulation in the active workspace

Duplicate: Duplicates selected simulation in the active workspace

2.3.3.1 Static analysis

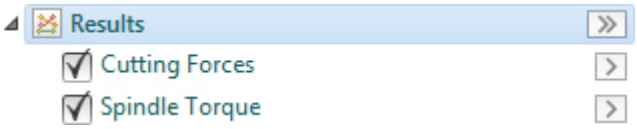
manufacturing automation laboratories CUTPRO

Static analysis



What is this?

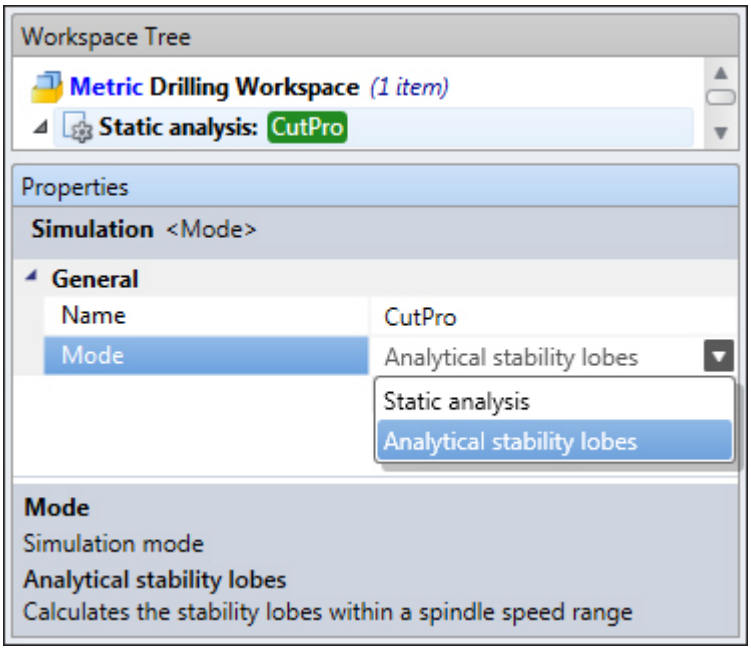
A static (no vibration / rigid) drilling process simulation which provides the user the following results:



2.3.3.2 Analytical stability lobes

manufacturing automation laboratories CUTPRO

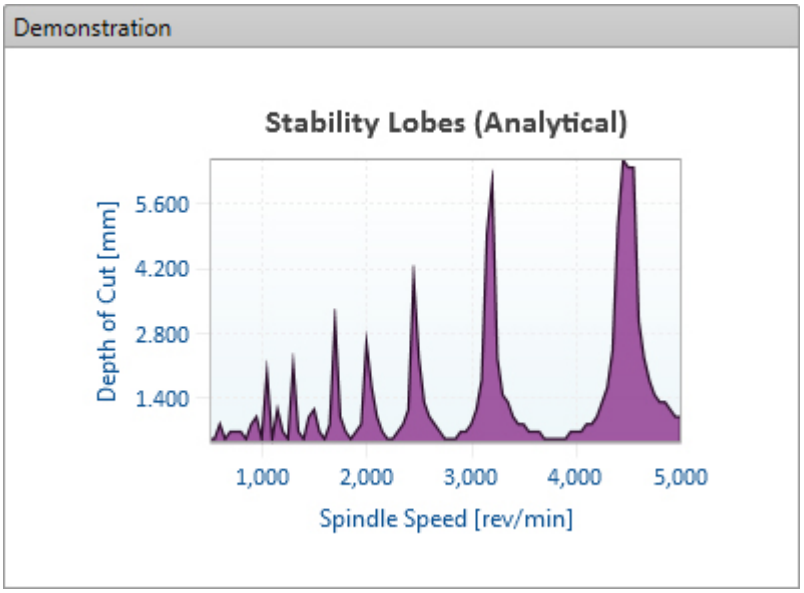
Analytical stability lobes



What is this?

Analytical stability lobes provide the user with what is called a "Stability Pocket", which denotes a productive location for chatter-free cutting:

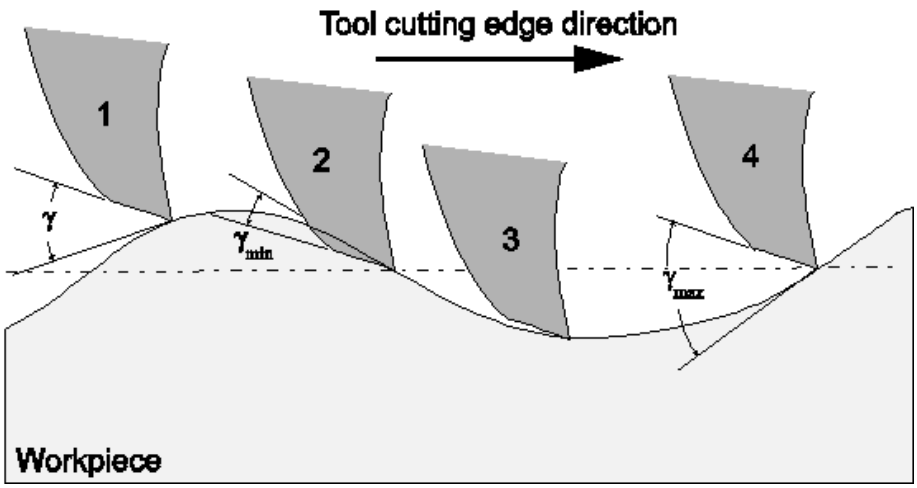
This is a fast analytical stability lobe prediction solved in a frequency domain. It generates the stability lobes by indicating the axial depth of cut and spindle speeds for a fixed width of cut.

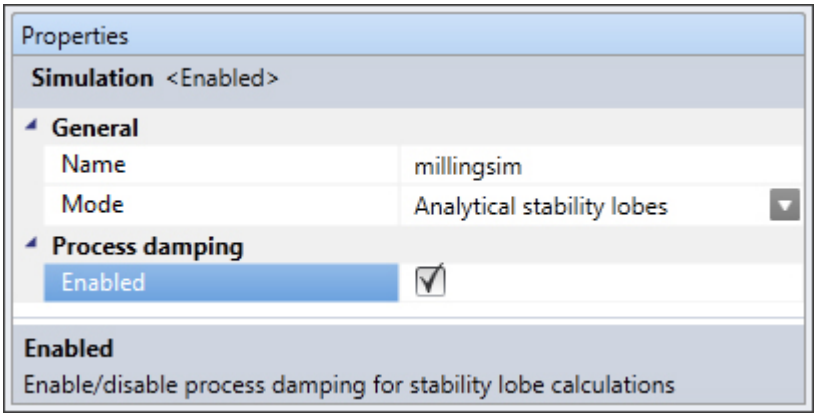


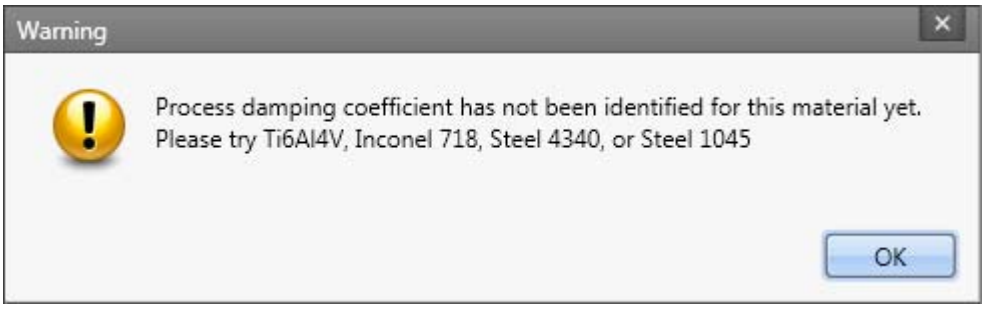
Additional Features:

Process damping (Available for certain materials only)

Heat resistant materials such as titanium and steel alloys that are frequently used in thin walled components can only be cut at low cutting speeds.
When machining these materials at low speeds, it is known that the chatter stability limit increases due to additional damping caused by the process.
This phenomenon is called process damping. Due to the sharpness of the cutting edge, part of the chip is forced to go under the tool and causes interference on the tool clearance flank.







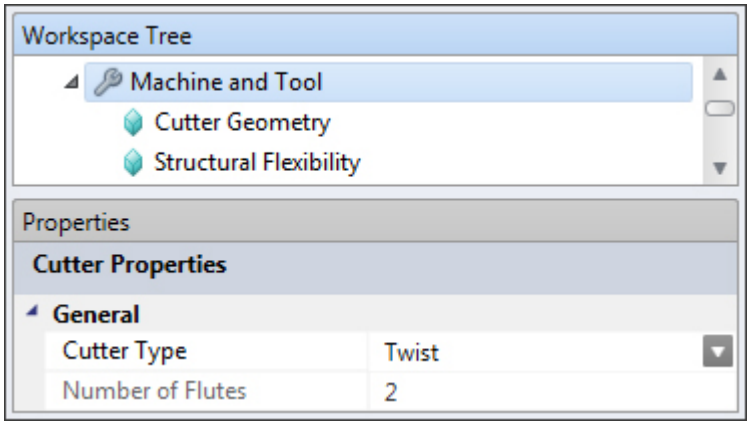
2.3.4 Machine & Tool

CUTPRO

Machine & Tool - Overview

Here the user may select/edit properties related to the machine & tool, such as:

- Cutter geometry
- Structural flexibility



Begin by selecting a cutter type, followed by entering the required number of flutes (if applicable).

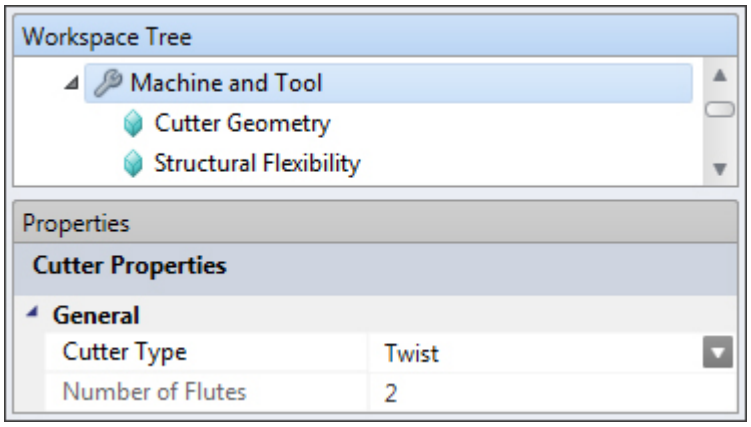
2.3.4.1 Cutter geometry

CUTPRO

Machine & Tool - Cutter type

In **CUTPRO** drilling there are four types of cutters which can be simulated:

- Twist drill
- Point thinning drill
- Arbitrary edge drill

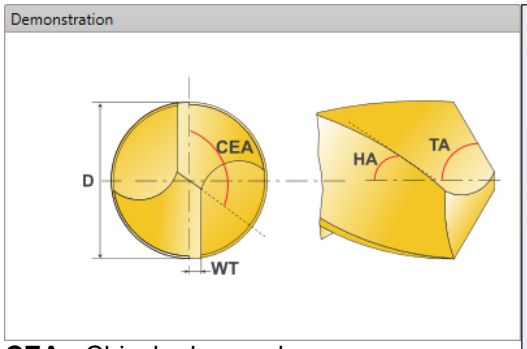


***The cutter geometry window changes according to the tool type selected under machine & tool*

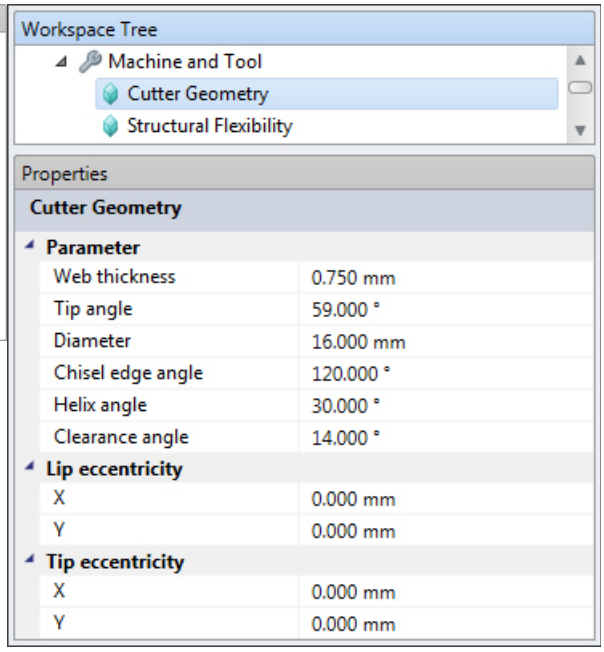
2.3.4.1.1 Twist drill

Cutter geometry - Twist drill

Twist drill geometry can be defined under the Cutter Geometry tab
**can only have 2 flutes

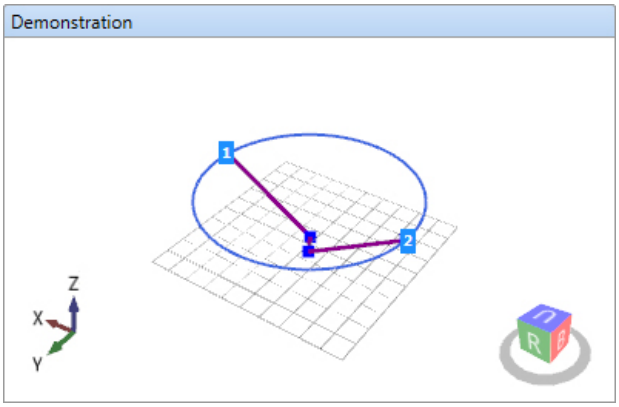


CEA - Chisel edge angle
WT - Web thickness
HA - Helix angle
TA - Tip angle
D - Diameter



Based on the input geometry, an interactive figure will be generated for

visual aid:



Graph Interactions:

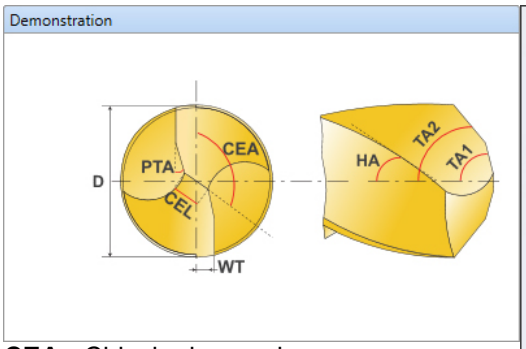
- ***Pan:*** *Center click and Drag*
- ***Rotate:*** *Left click and Drag*
- ***Zoom:*** *Scroll In/Out*
- ***Snap:*** *Click on cube surface to snap to desired view*

2.3.4.1.2 Point thinning drill

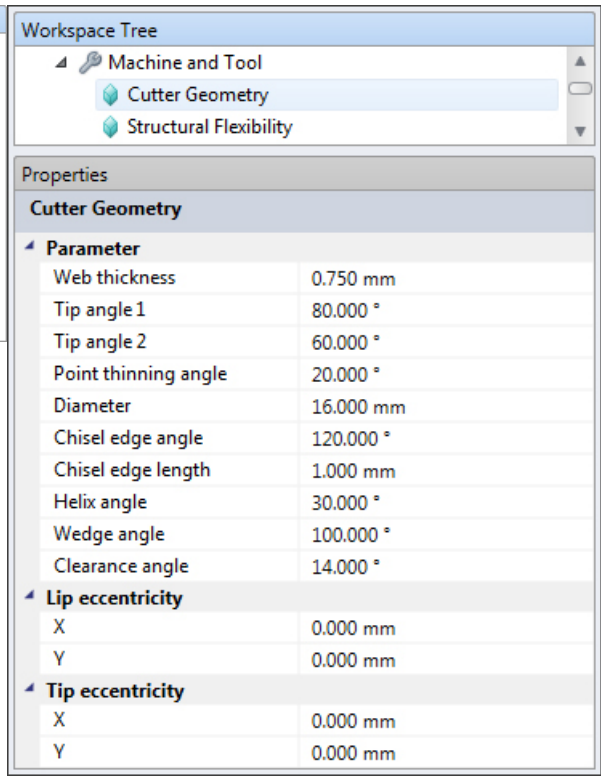
manufacturing automation laboratories CUTPRO

Cutter geometry - Point thinning drill

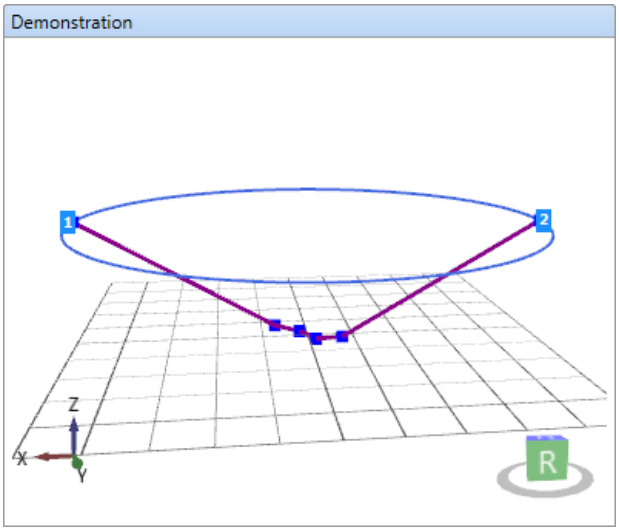
Point thinning drill geometry can be defined under the Cutter Geometry tab
**can only have 2 flutes



CEA - Chisel edge angle
CEL - Chisel edge length
PTA - Point thinning angle
WT - Web thickness
TA1 - Tip angle 1
TA2 - Tip angle 2
HA - Helix angle
D - Diameter



Based on the input geometry, an interactive figure will be generated for visual aid:



Graph Interactions:

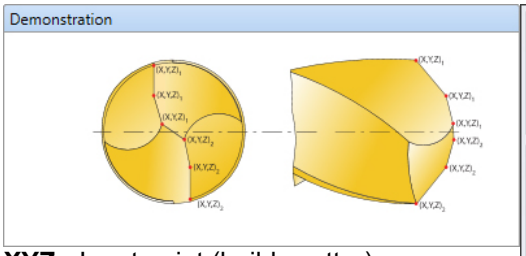
- ***Pan:*** *Center click and Drag*
- ***Rotate:*** *Left click and Drag*
- ***Zoom:*** *Scroll In/Out*
- ***Snap:*** *Click on cube surface to snap to desired view*

2.3.4.1.3 Arbitrary edge drill

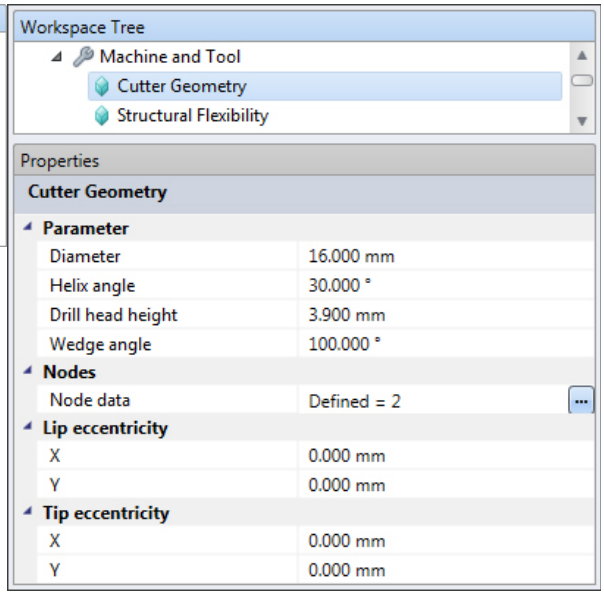
manufacturing automation laboratories CUTPRO

Cutter geometry - Arbitrary edge drill

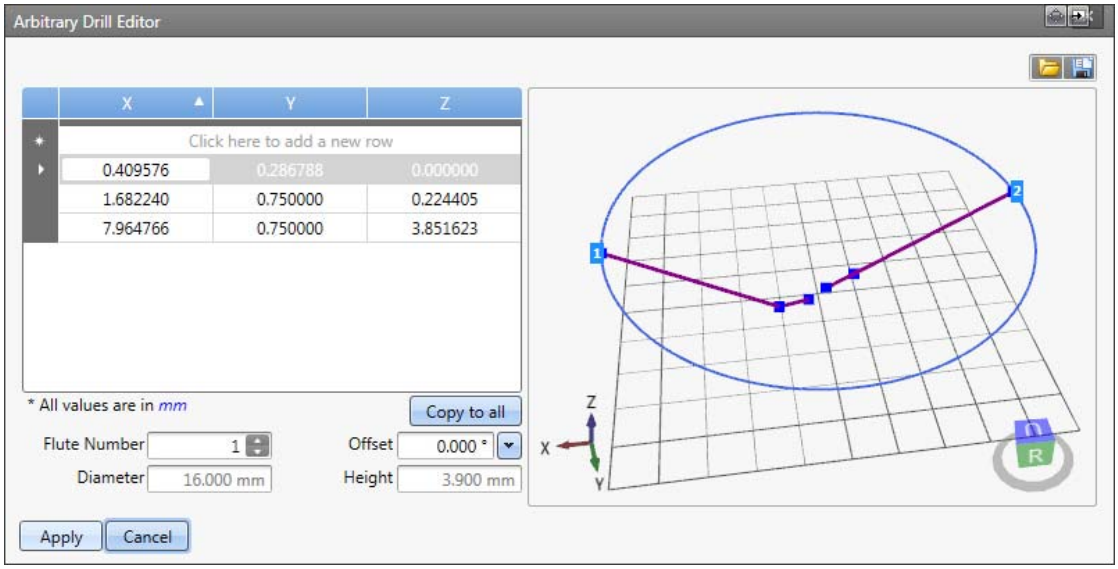
Arbitrary edge drill geometry can be defined under the Cutter Geometry tab



XYZ - Input point (builds cutter)



Click on the button to access the arbitrary drill editor:



Graph Interactions:

Flute Number: Displays the XYZ table corresponding to the selected flute (Flute 1 of 2 in

- o ***Pan:*** *Center click and Drag*
- o ***Rotate:*** *Left click and Drag*
- o ***Zoom:*** *Scroll In/Out*
- o ***Snap:*** *Click on cube surface to snap to desired view*

example above)

Offset: Offsets data points from Flute 1 at desired angle

Copy to all: Copies selected Flute Number points to all Flutes

Import/Export: Opens/Saves arbitrary drill in (*.nod) format

2.3.4.2 Structural flexibility

manufacturing automation laboratories CUTPRO

Machine & Tool - Structural flexibility

Machine & Tool simulation models available:

- Rigid model (Static analysis only)
- Drilling Structural Vibrations model (Analytical stability lobes only)

2.3.4.2.1 Rigid model

manufacturing automation laboratories CUTPRO

Structural flexibility - Rigid machine & tool model

- Effects of machine & tool vibrations are not included in the simulation
- Machine/cutter is assumed rigid
- Simulation will be under static conditions.

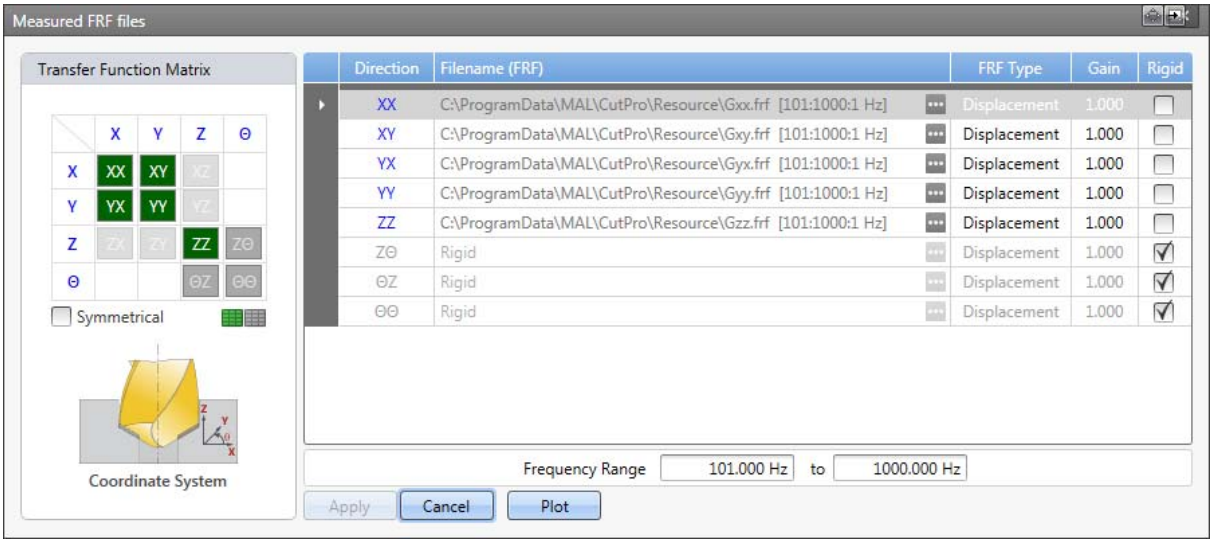
2.3.4.2.2 Structural vibrations model

manufacturing automation laboratories CUTPRO

Structural flexibility - Structural vibrations machine & tool

model

Machine & tool has structural flexibility



Dynamics data

- **Measured FRF (***for analytical stability lobes only***)**

- **Modal/residue data files**

X modal/residue file	Uses a file containing modal parameters. These modal parameter files are created using the Modal Analysis program.
Y modal/residue file	Uses a file containing modal parameters. These modal parameter files are created using the Modal Analysis program.

- **Vibration parameters**

  This uses the following dynamic parameters. It only allows for a single dominant mode in each of the X- and Y-directions.

Natural frequency	Natural frequency of the system in [Hz]
Damping ratio	Damping ratio for that mode
Stiffness	Stiffness of the system [N/m]

Transfer function values are calculated using following equation in frequency domain:

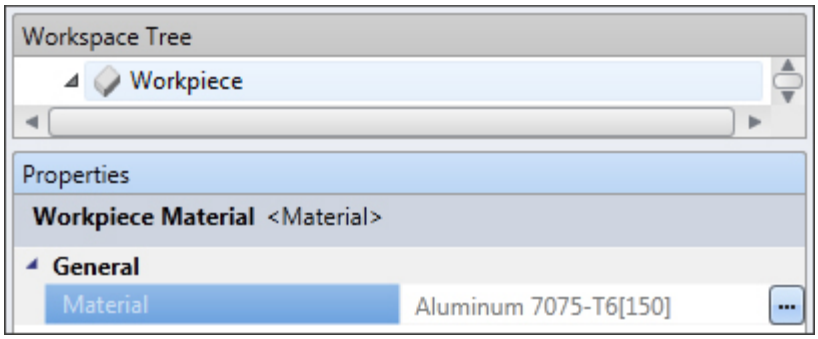
$$\Phi = \frac{\omega_n^2 k}{\omega_n^2 - \omega^2 + i\,2\zeta\omega_n\omega}$$

2.3.5 Workpiece

CUTPRO

Workpiece - Overview

Under the workpiece category of simulation, the user is to select a workpiece material:



2.3.5.1 Rigid model

CUTPRO

Structural flexibility - Rigid workpiece model

- Effects of workpiece vibrations are not included in the simulation
- Workpiece is assumed rigid
- Simulation will be under static conditions.

2.3.6 Cutting Conditions

CUTPRO

Cutting Condition - Overview

Turning Mode

The following cutter types must first be selected from "Machine & Tool":

- Twist drilling
- Point thinning drilling
- Arbitrary edge drilling

Cutting conditions may then be set like so:

Properties	
Cutting conditions	
General	
Feedrate	0.100 mm/flute
Spindle speed	2500.000 RPM
Axial depth of cut (a)	3.000 mm
Number of revolutions	20

2.3.7 Results

manufacturing automation laboratories CUTPRO

Results - Overview

Using graphs in CutPro (*Plot Results buttons*)

- **Forces**
  - XYZ cutting forces
- **Spindle parameters**
  - Spindle torque
- **Stability lobes**
  - Analytical stability lobes

2.3.7.1 XYZ cutting forces

manufacturing automation laboratories CUTPRO

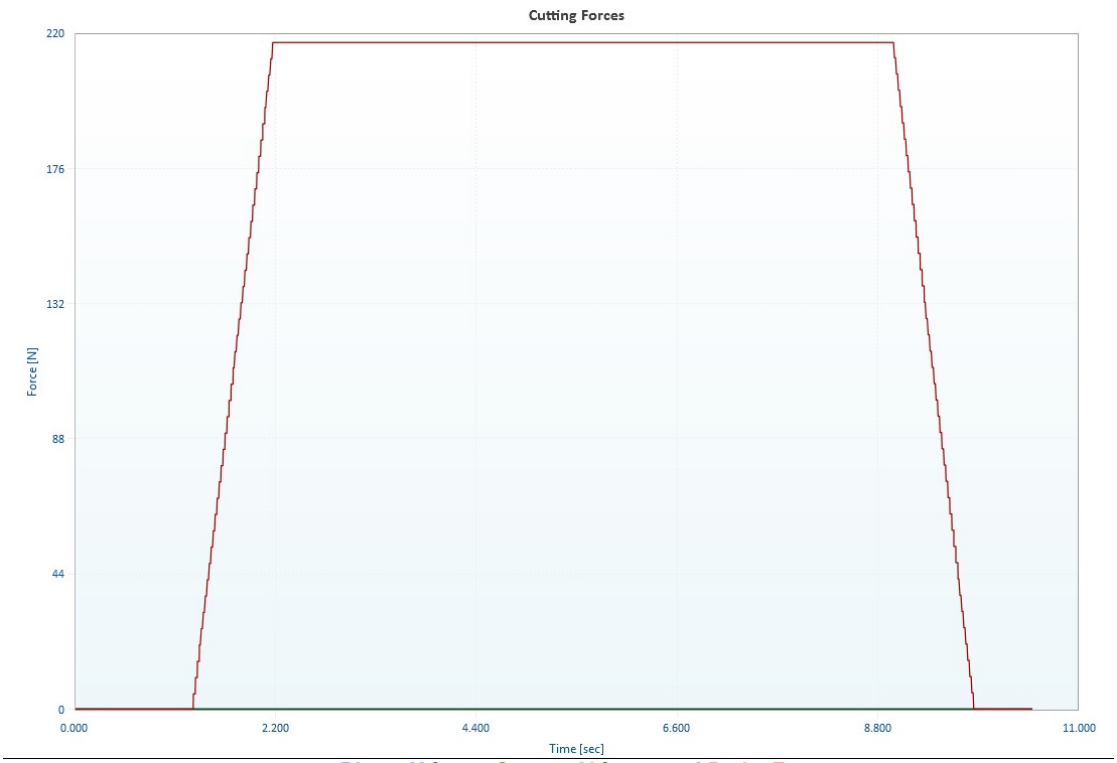
X, Y and Z forces

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot cutting forces.
The results of this plot will look something like the figure below:



Blue = X force, Green = Y force, and Red = Z

In order to toggle through desired results on this plot, the following buttons may be used:

Active axis: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

2.3.7.2 Spindle torque

manufacturing automation laboratories CUTPRO

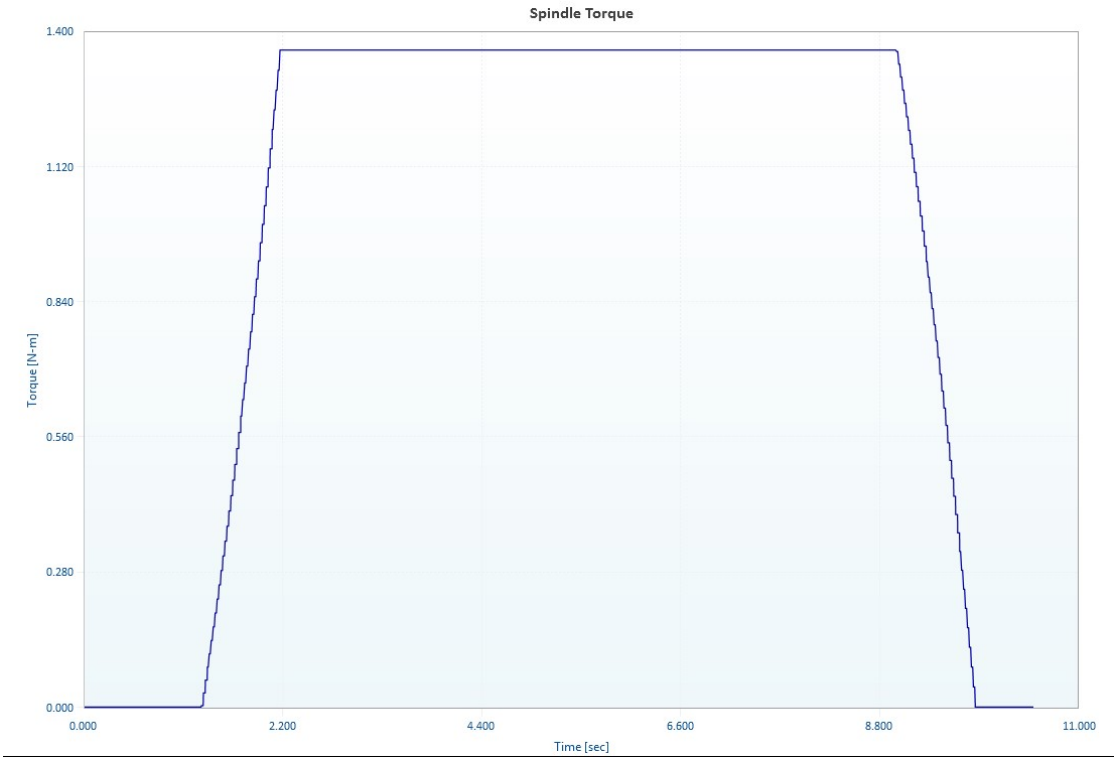
Spindle torque

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to plot spindle torque.
The results of this plot will look something like the figure below:



In order to toggle through desired results on this plot, the following buttons may be used:

Active axis: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

2.3.7.3 Analytical stability lobes

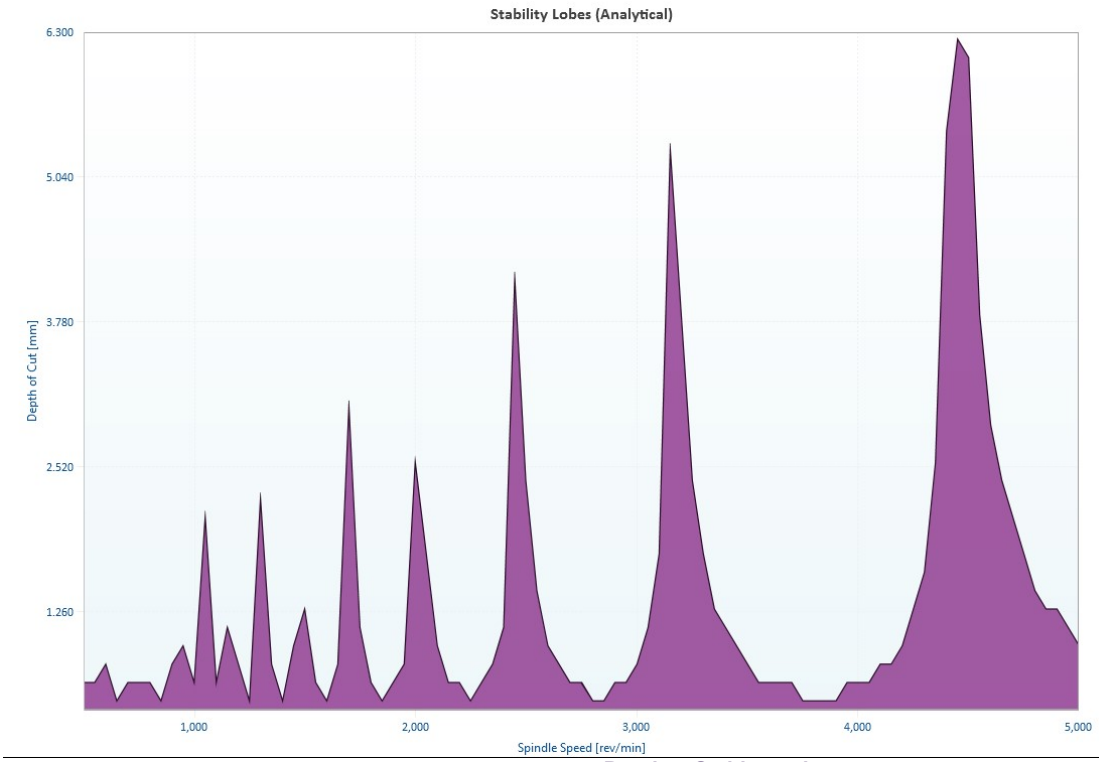
Analytical stability lobes

There are two available buttons which may be used to plot cutting forces:

Plot: Plots single result graph **(Located under results in simulation)**

Plot: Plot selected result from simulation **(Located on main toolbar)**

Not all simulations have an option to analytical stability lobes.
The results of this plot will look something like the figure below:



Purple = Stable cutting

In order to toggle through desired results on this plot, the following buttons may be used:

Active axis: Allows user to select this axis

Inactive axis: Disallows user to select this axis

Change color: Changes the color of the graph for specified axis

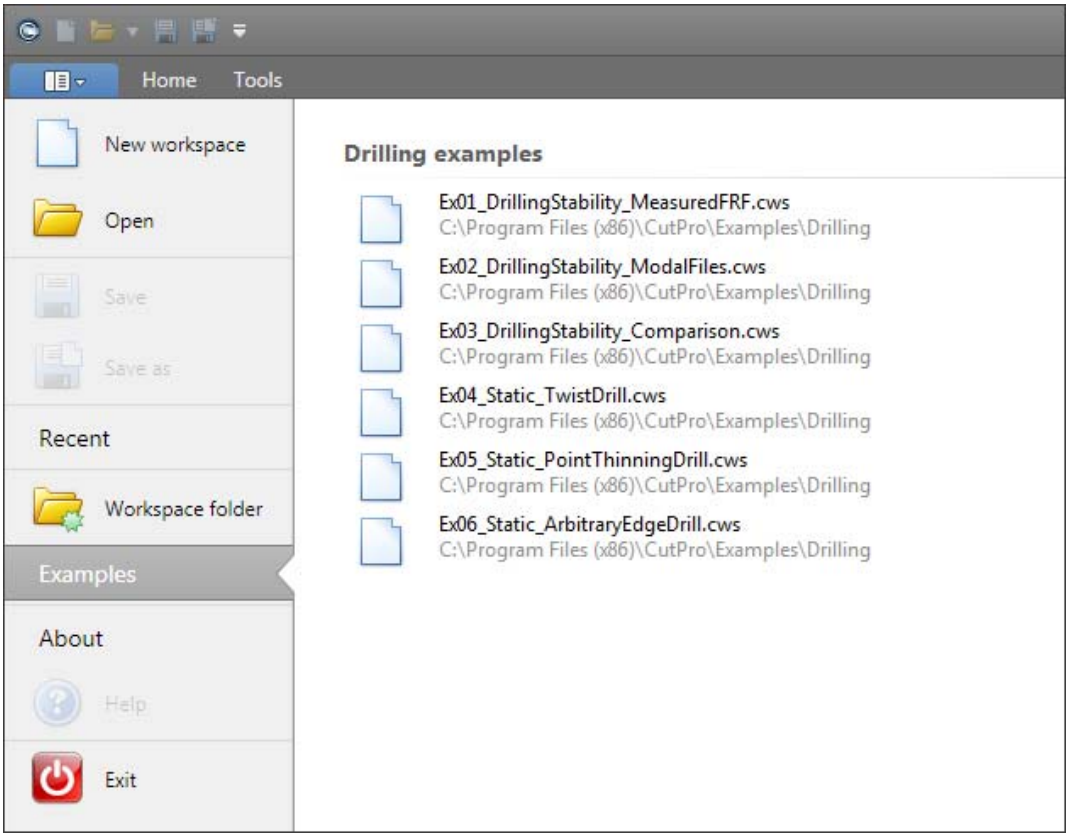
2.3.8 Example Files

manufacturing automation laboratories CUTPRO

Drilling Simulation - Example Files

CutPro comes with various example files for simulation in Drilling

To access these files, click on the "Examples" button as shown below:



2.4 Modal Analysis

manufacturing automation laboratories MODAL ANALYSIS

CutPro: Modal Analysis?

Modal Analysis is a software module (part of the CutPro software package) that determines the dynamic characteristics of a machine tool system and mode shapes from Frequency Response Functions (FRF).

The structure is first measured at various geometric locations on a system, using transfer function measurement software "MALTF". This involves attaching an accelerometer or laser displacement sensor to one end of the structure, and then impacting it from the other end using an impulse hammer.

What is Modal Analysis used for?

Modal analysis is used for modifying raw Frequency Response Function (FRF) data. It is used to simplify the FRF by removing unnecessary modes and applying a curve-fit to those of interest. This is done by analyzing the frequency data, selecting key modes of interest, applying a curve fit, and exporting this data into either a new Fitted FRF or a Modal Parameters CMP file.

2.4.1 Information

2.4.1.1 What is Modal Analysis?

What is Modal Analysis?

Modal Analysis is a software module **(**part of the CutPro software package**)** that determines the dynamic characteristics of a machine tool system and mode shapes from Frequency Response Functions **(**FRF**)**.

The structure is first measured at various geometric locations on a system, using transfer function measurement software "MALTF". This involves attaching an accelerometer or laser displacement sensor to one end of the structure, and then impacting it from the other end using an impulse hammer.

What is Modal Analysis used for?

Modal analysis is used for modifying raw Frequency Response Function (FRF) data. It is used to simplify the FRF by removing unnecessary modes and applying a curve-fit to those of interest. This is done by analyzing the frequency data, selecting key modes of interest, applying a curve fit, and exporting this data into either a new Fitted FRF or a Modal Parameters CMP file. These files are then used for machining simulation within CutPro.

2.4.1.2 License Information

MODAL ANALYSIS

License Information

Manufacturing Automation Laboratories Inc. (MAL) reserves the right to modify or discontinue the software or the software specification identified in this document without notice. MAL advises its customers to obtain the latest version of the software specifications to verify, before placing orders, that the information being relied upon by the customer is current. MAL makes no warranties, expressed or implied, including without limitation the implied warranties of merchantability and fitness for a particular purpose, regarding the software. MAL does not warrant, guarantee or make any representations regarding the use or the results of the use of the software in terms of its correctness, accuracy, reliability, currentness or otherwise. You assume the entire risk as to the results and performance of the software.

In no event will MAL and its directors, officers, employees or agents be liable to you for any consequential, incidental or indirect damages (including damages for loss of business profits, business interruption, loss of business information, and the like) arising out of the use or inability to use the software even if MAL has been advised of the possibility of such damages. MAL's liability to you for actual damages from any cause whatsoever, and regardless of the form of the action (whether in contract, tort (including negligence), product liability or otherwise), shall in no case exceed the invoiced amount paid for the right to use the software and the documentation.

1,284,737. 2005/12/30. MAL

Manufacturing Automation Laboratories, Inc., 2829 Highbury Street, Vancouver, BRITISH COLUMBIA V6R 3T7
Representative for Service! Representant pour Signification: OVEN WIGGS GREEN & MUTALA LLP, SUITE 480 - THE STATION, 601 WEST CORDOVA STREET, VANCOUVER, BRITISH COLUMBIA, V6B1G1

CUTPRO

WARES:

(1) Computer software for use in optimizing the performance of machining equipment.

(2) Machine tools for use in the metal working industry and control systems for such machine tools.

SERVICES:

Consulting in the field of the design and operation of machine tools. Used in CANADA since at least as early as 1999 on wares (1).

Proposed Use in CANADA on wares (2) and on services.

MARCHANDISES:

(1) Logiciels pour l'optimisation du rendement du materiel d'usinage.

(2) Machines-outils pour utilisation dans l'industrie du travail des metaux et systemes de commande pour lesdites machines-outils.

SERVICES:

Consultation en conception et exploitation de machines-outils. Employee au CANADA depuis au moins aussi tot que 1999 en liaison avec les marchandises(1).

Emploi projete au CANADA en liaison avec les marchandises (2) et en liaison avec les services.

Trademarks

Pentium is a trademark of Intel Corporation. Microsoft, MS-DOS are registered trademarks and Windows XP, Windows Vista, Windows 7, and Windows 8 are trademarks of Microsoft Corporation. IBM and PC/AT are registered trademarks of International Business Machines Corporation. All other trademarks are trademarks or registered trademarks of their respective owners

2.4.1.3 System Requirements

MODAL ANALYSIS

System Requirements

Required hardware and software:

- **PC:** PC with a Intel/AMD processor with a minimum of 2 cores at 3.0Ghz
- **Operating System:** Windows 7, 8 or later.
- **Memory:** We recommend a minimum of 6GB of RAM.
- **License:** Will be provided when the software is purchased.

2.4.2 User Interface Overview

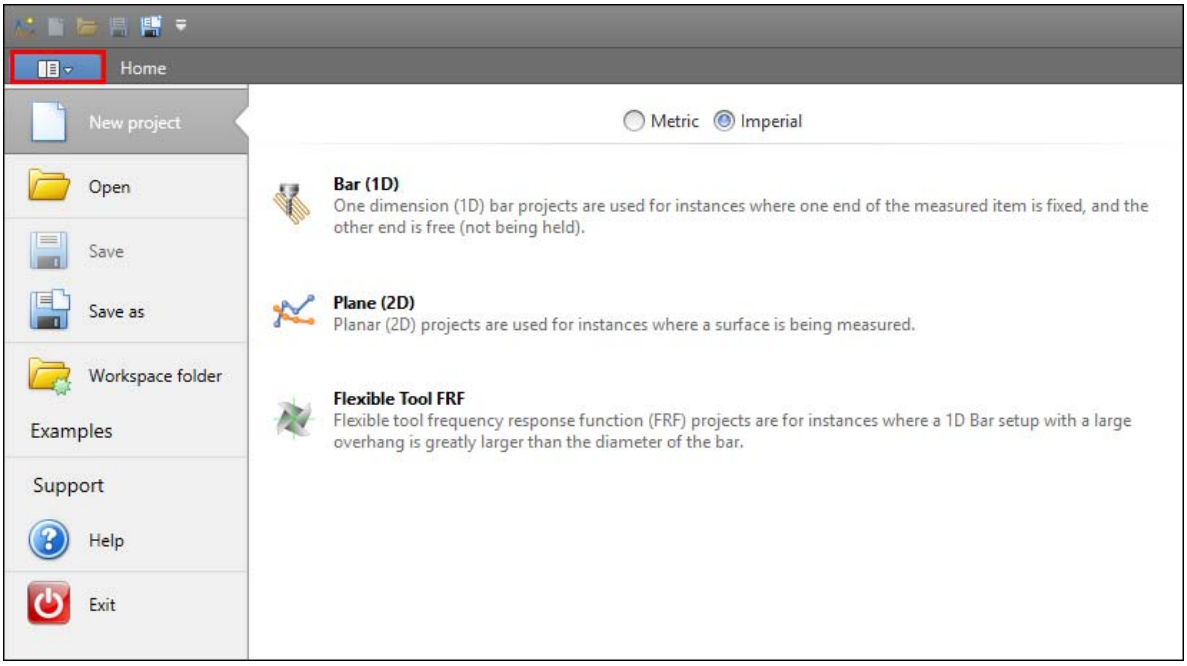
MODAL ANALYSIS

User Interface Overview

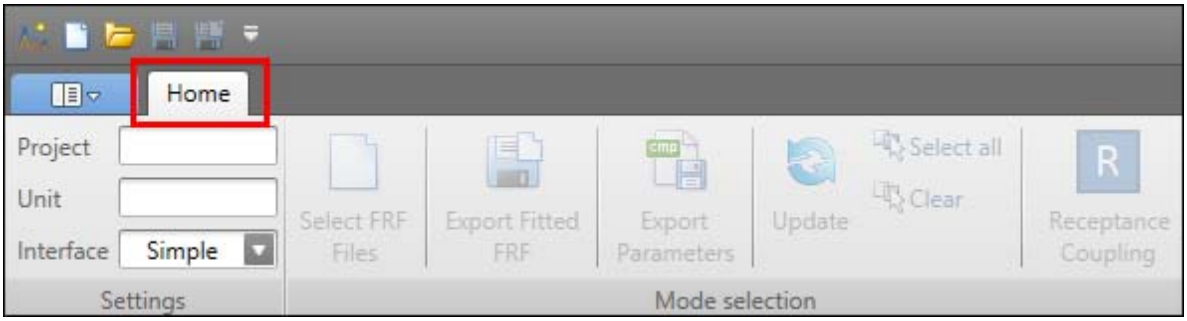
Modal Analysis consists of a file menu, home menu, and two interface types.

➢**The "File" menu** can be found in the Top Left corner of the software, just

underneath the Modal Analysis Icon:

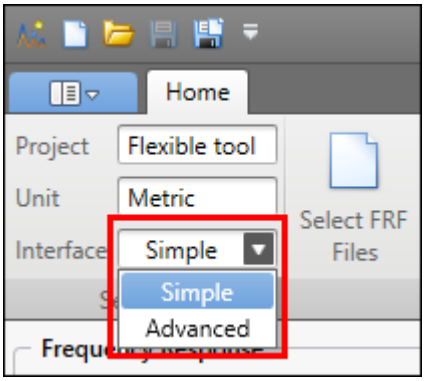


➢**The "Home" menu** can be found in the Top Left corner by clicking on the Home tab button:



➢**The "Interface" selection menu** can

be found in the Top Left corner by clicking on the Home tab button, followed by the arrow next to "Interface":



Simple	The user selects the natural frequency peaks which the software automatically detects.
Advanced	The user defines the left & right area of the natural frequency peak they are interested in.

2.4.2.1 Project Types

MODAL ANALYSIS

Project Types

There are three types of projects to choose from in Modal Analysis. These projects can be created from the File Menu.

All Bar, Plane and Flexible Tool FRF project files are saved as ***.modx** Modal Analysis Project files.

Bar (1D)
One dimension (1D) bar projects are used for instances where one end of the measured item is fixed, and the other end is free (not being held). *Ex: A bar inside a lathe, without a tailstock.*

Plane (2D)
Planar (2D) projects are used for instances where a surface is being measured.
Ex: A square workpiece inside a vice.

Flexible Tool FRF
Flexible tool frequency response function (FRF) projects are for instances where a 1D Bar setup with a large overhang is greatly larger than the diameter of the bar. In these cases, it is near impossible to accurately measure the tip of the 1D Bar setup using an impact hammer or shaker. For this reason, we can estimate the FRF mathematically in this project type.
Ex: A 8mm diameter solid endmill with 50mm stickout from the shrinkfit toolholder face.

2.4.2.1.1 Bar (1D)

MODAL ANALYSIS

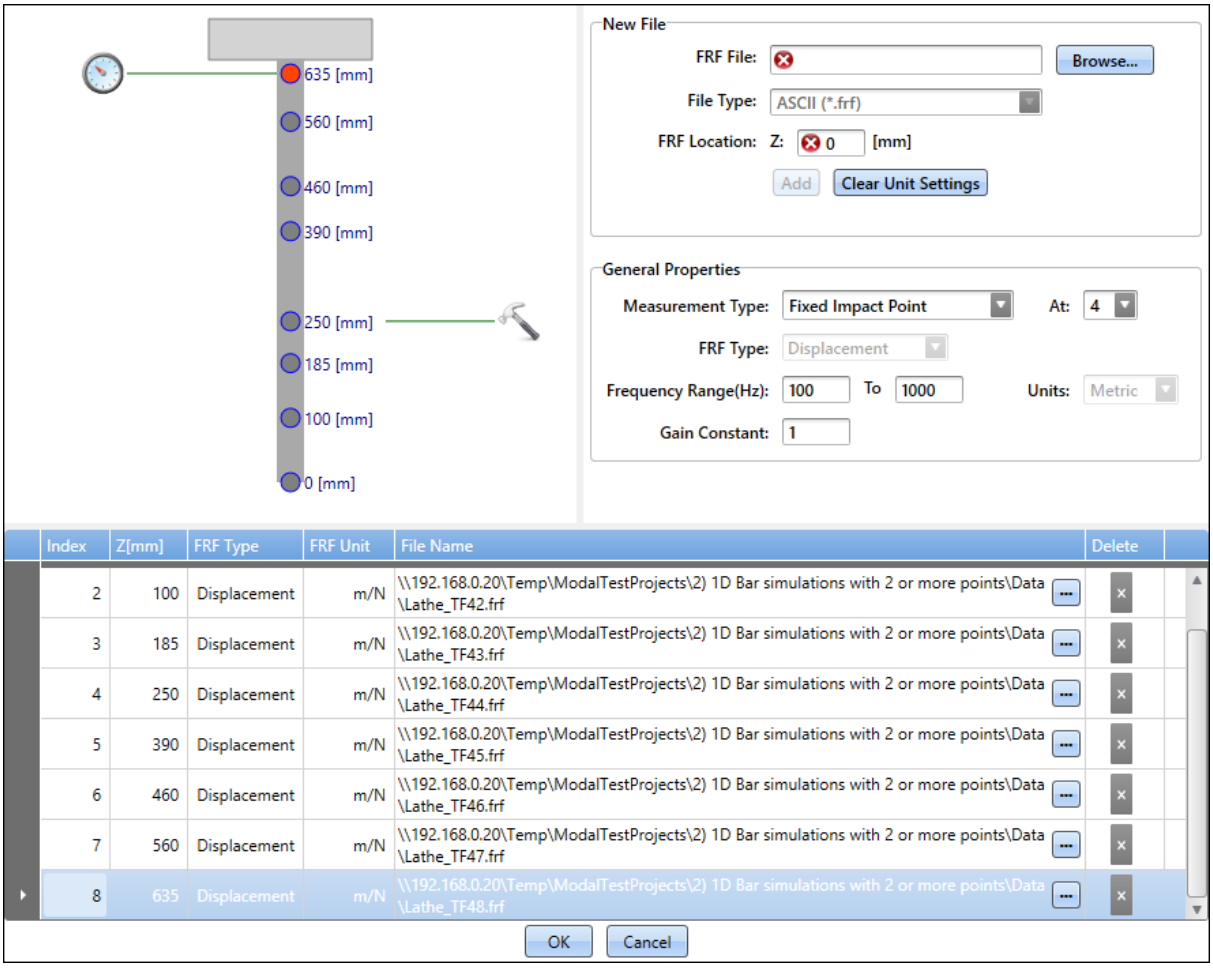
Project Types - Bar (1D)

Bar (1D)

One dimension (1D) bar projects are used for instances where one end of the measured item is fixed, and the other end is free (not being held). *Ex: A bar inside a lathe, without a tailstock.*

Select FRF Files Window

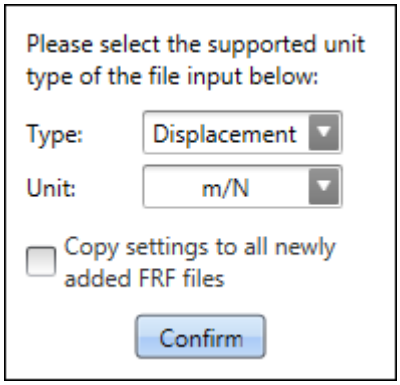
The graphics window in Modal Analysis is response and click-sensitive. The graphics window for 1D Bar simulations is as follows:



Window Legend

New File

- **Browse / FRF File:** Uses windows explorer to find the desired FRF file (*.frf, *.mtb or *.uff files) by clicking browse (Browse... button)
- **File Type:** Defines the file type of all FRF files within the project (*.frf, *.mtb or *.uff)
- **FRF Location:** Defines the location of the measurement point (mm or in)
- **Add:** Adds the select FRF file to the project (Add button):
  When an FRF is added, if the unit is unknown, Modal Analysis will prompt this window:
  Click "Copy settings to all newly added FRF files" to apply the settings to all FRFs added.



- **Clear Unit Settings:** Clears the FRF Type / Unit Type settings which was previously defined as shown above (Clear Unit Settings button)

General Properties

- **Measurement Type:** The user needs to define how the measurement was performed (Fixed Measurement Point or Fixed Impact Point)
- **At:** If two or more files are added, the user needs to define where the impact (hammer) and measurement (accelerometer) locations are (1 to ...)
- **File Type:** Defines the file type of all FRF files within the project (*.frf, *.mtb or *.uff)
- **Frequency Range(Hz):** Defines the range of frequencies which you are interested in (These values are limited by the FRF file's frequency range, and must be within them)
- **Units:** Defines the unit system of the project (Metric or Imperial)

- **Gain Constant:** Defines the gain constant of the measured file **(**Metric or Imperial**)**

FRF Table

- **Index:** Defines the number of the file **(**1 to **...)**
- **Z:** Defines the location of the file. These values can be modified within the table at any time. **(**mm or in**)**
- **FRF Type:** Defines the type of FRF measurement **(**Displacement or Acceleration**)**
- **FRF Unit:** Displays the unit system of the FRF file contents
- **File Name:** Defines the name and location of the FRF file **(***.frf, *.mtb or *.uff files**)**, the files can be selected from the table as well **(...** button**)**
- **Delete:** Allows the user to delete an FRF from the table **(**x button**)**

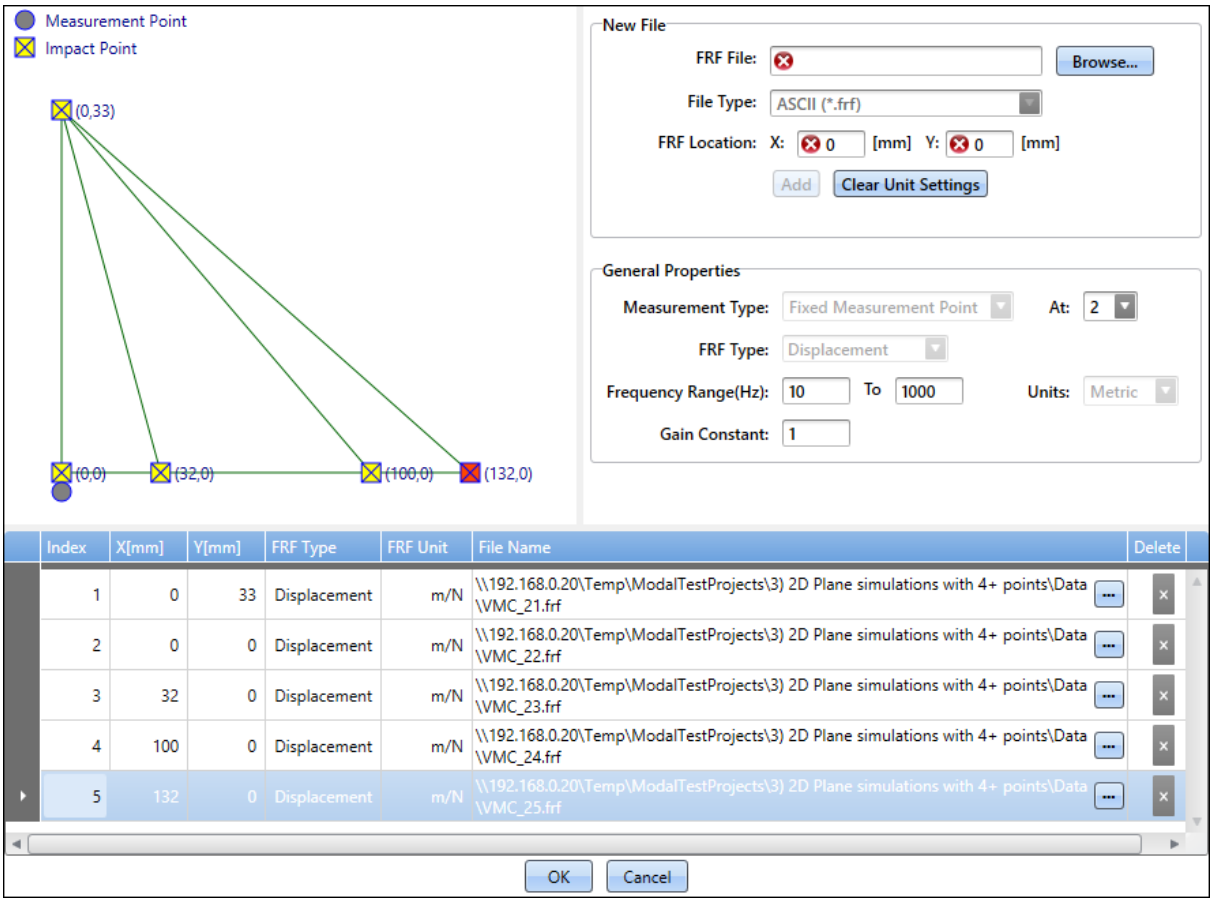
2.4.2.1.2 Plane (2D)

Project Types - Plane (2D)

Plane (2D)
Planar (2D) projects are used for instances where a surface is being measured.
Ex: A square workpiece inside a vice.

Select FRF Files Window

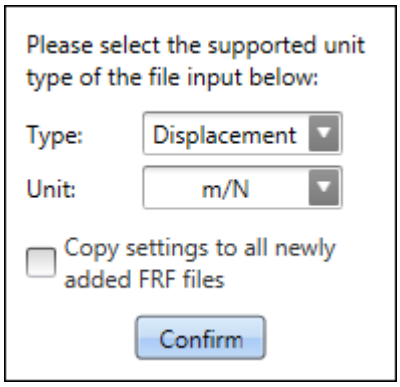
The graphics window in Modal Analysis is response and click-sensitive. The graphics window for 2D Plane simulations is as follows:



Window Legend

New File

- **FRF File / Browse:** Uses windows explorer to find the desired FRF file **(***.frf, *.mtb or *.uff files**)** by clicking browse **(**Browse**...** button**)**
- **File Type:** Defines the file type of all FRF files within the project **(***.frf, *.mtb or *.uff**)**
- **FRF Location:** Defines the location of the measurement point in the X and Y coordinates **(**mm or in**)**
- **Add:** Adds the select FRF file to the project **(**Add button**):**
  When an FRF is added, if the unit is unknown, Modal Analysis will prompt this window:
  Click "Copy settings to all newly added FRF files" to apply the settings to all FRFs added.



- **Clear Unit Settings:** Clears the FRF Type / Unit Type settings which was previously defined as shown above **(**Clear Unit Settings button**)**

General Properties

- **Measurement Type:** The user needs to define how the measurement was performed **(**Fixed Measurement Point or Fixed Impact Point**)**
- **At:** If two or more files are added, the user needs to define where the impact **(**hammer**)** and measurement **(**accelerometer**)** locations are **(**1 to **...)**
- **FRF Type:** Defines the type of FRF measurement **(**Displacement or Acceleration**)**
- **Frequency Range(Hz):** Defines the range of frequencies which you are interested in **(**These values are limited by the FRF file's frequency range, and must be within them**)**
- **Units:** Defines the unit system of the project **(**Metric or Imperial**)**
- **Gain Constant:** Defines the gain constant of the measured file **(**Metric or Imperial**)**

FRF Table

- **Index:** Defines the number of the file **(**1 to **...)**
- **X & Y:** Defines the planar location of the file. These values can be modified within the table at any time. **(**mm or in**)**
- **FRF Type:** Defines the type of FRF measurement **(**Displacement or Acceleration**)**
- **FRF Unit:** Displays the unit system of the FRF file contents
- **File Name:** Defines the name and location of the FRF file **(***.frf, *.mtb or *.uff files**)**, the files can be selected from the table as well **(...** button**)**

- **Delete:** Allows the user to delete an FRF from the table **(**x button**)**

2.4.2.1.3 Flexible Tool FRF

MODAL ANALYSIS

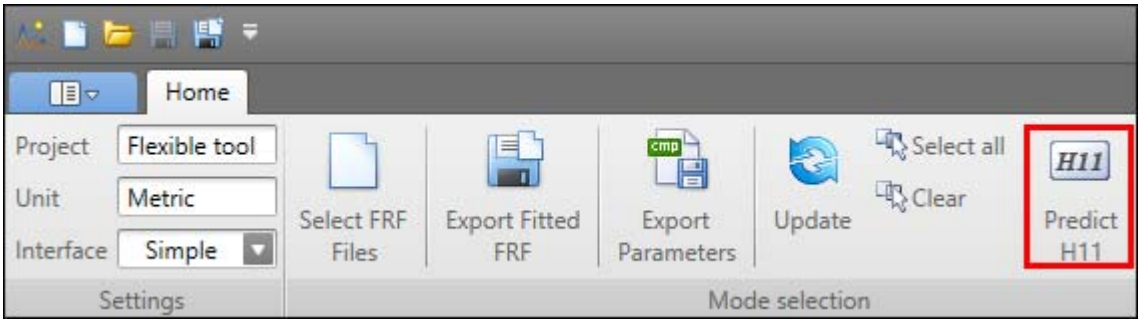
Project Types - Flexible Tool FRF

Flexible Tool FRF

Flexible tool frequency response function (FRF) projects are for instances where a 1D Bar setup with a large overhang is greatly larger than the diameter of the bar. In these cases, it is near impossible to accurately measure the tip of the 1D Bar setup using an impact hammer or shaker. For this reason, we can estimate the FRF mathematically in this project type.
Ex: A 8mm diameter solid endmill with 50mm stickout from the shrinkfit toolholder face.

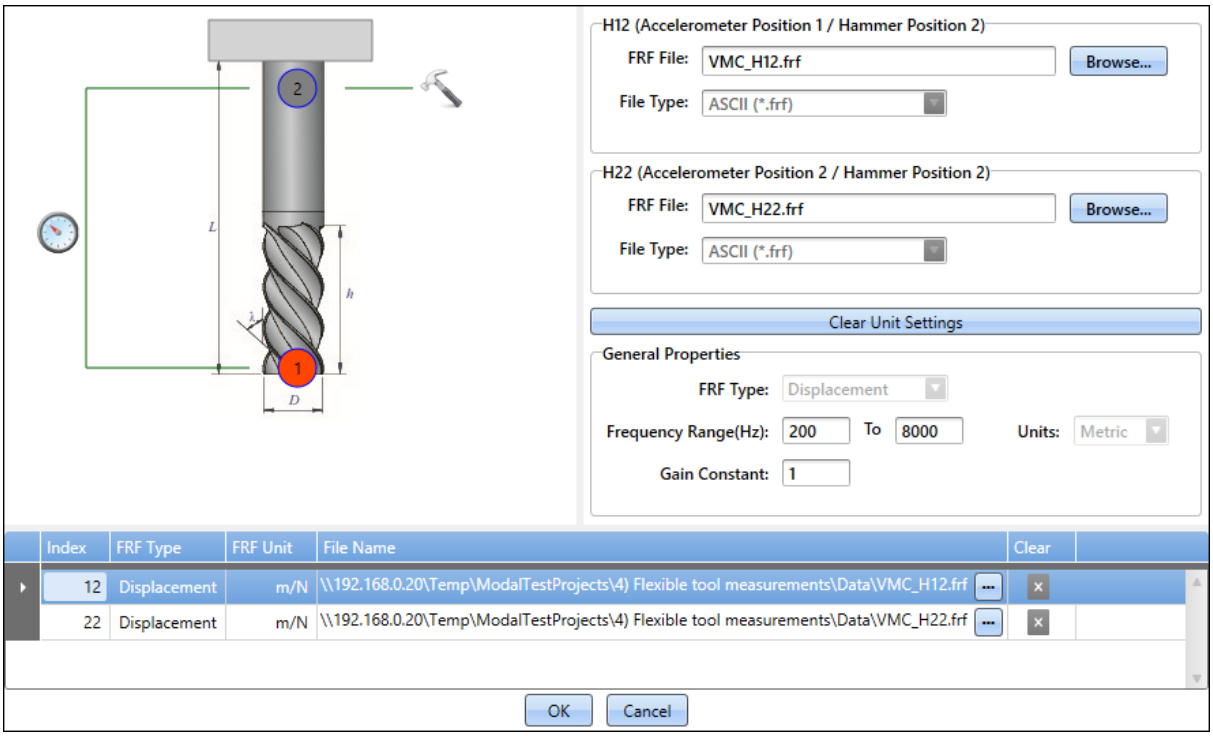
Predict H11 (FRF at the tool tip, as if the accelerometer and hammer were both at the tip

After pressing OK, the user must apply a curve fit via the Update button,on the desired modes. From there, the user can then Predict H11.
*H11 is the predicted FRF at the tool's tip: Accelerometer and hammer are both at the tip of the tool.



Select FRF Files Window

The graphics window in Modal Analysis is response and click-sensitive. The graphics window for Flexible Tool FRF simulations is as follows:



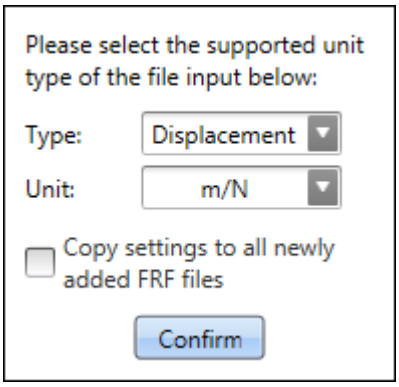
Window Legend

H12 / H22

- **Browse / FRF File:** Uses windows explorer to find the desired FRF file **(***.frf, *.mtb or *.uff files**)** by clicking browse **(**Browse**...** button**)**
- **File Type:** Defines the file type of all FRF files within the project **(***.frf, *.mtb or *.uff**)**

General Properties

When an FRF is added, if the unit is unknown, Modal Analysis will prompt this window:
Click "Copy settings to all newly added FRF files" to apply the settings to all FRFs added.



- **Clear Unit Settings:** Clears the FRF Type / Unit Type settings which was previously defined as shown above **(**Clear Unit Settings button**)**
- **FRF Type:** Defines the type of FRF measurement **(**Displacement or Acceleration**)**
- **Frequency Range(Hz):** Defines the range of frequencies which you are interested in **(**These values are limited by the FRF file's frequency range, and must be within them**)**
- **Units:** Defines the unit system of the project **(**Metric or Imperial**)**
- **Gain Constant:** Defines the gain constant of the measured file **(**Metric or Imperial**)**

FRF Table

- **Index:** Defines the location of the file **(**H12 or H22**)**
- **FRF Type:** Defines the type of FRF measurement **(**Displacement or Acceleration**)**
- **FRF Unit:** Displays the unit system of the FRF file contents
- **File Name:** Defines the name and location of the FRF file **(***.frf, *.mtb or *.uff files**)**, the files can be selected from the table as well **(...** button**)**

2.4.2.2 Simple Modal Analysis

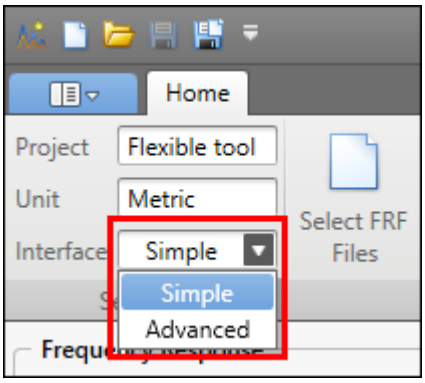
Simple Interface

Inside
Modal
Analys

is, you can switch between interface types at any given time.

- **The "Interface" selection menu** can be found in the Top Left corner by clicking on the Home tab button, followed by the arrow next to "Inte

rface
":



Simple	The user selects the natural frequency peaks which the software automatically detects.
Advanced	The user defines the left & right area of the natural frequency peaks they are interested in. Modes are also automatically detected and listed under the found modes table.

2.4.2.2.1 Menus & Buttons

Simple Interface - Menus & Buttons

Buttons & Boxes:

- **Proj**

ect: Displays the current project type

- **Unit:** Displays the current unit system
- **Interface:** Switch between Simple/Advanced via the drop-down arrow
- **Select FRF File**

s: Displays the Select FRF dialogue. This window varies based on Project Type: Refer to Project Types for details.

- **Export Fitted FRF:** The fitted FRF file ***.frf** (purple)

is exported. Refer to Exported Files for details.

- **Export Parameters:** The fitted CMP file ***.cmp** (purple) is exported. Refer to Exported Files for details.

- **Upd**

ate: Applies a curve-fit based on selected modes.

- **Select All:** Selects all found modes.
- **Clear:** Clears all selected modes.
- **Predict H11 (Flexible Tool FRF mode only**

): Calculates the predicted Frequency Response Function at the tool's tip based on the curve-fit (green).

2.4.2.2.2 Select FRF Files Window

Simple Interface - Select FRF Files Window

The Select FRF Files window is fully dependent on which project type you choose:

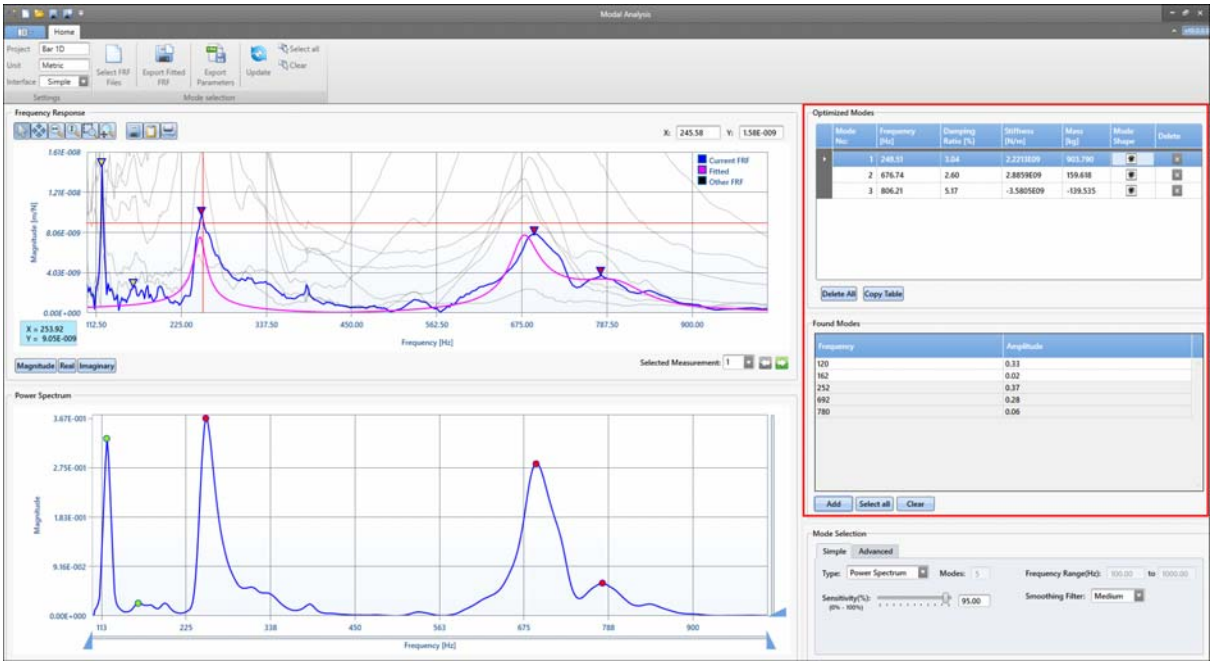
- **Bar (1D)**
- **Plane (2D)**

- Flexible Tool FRF

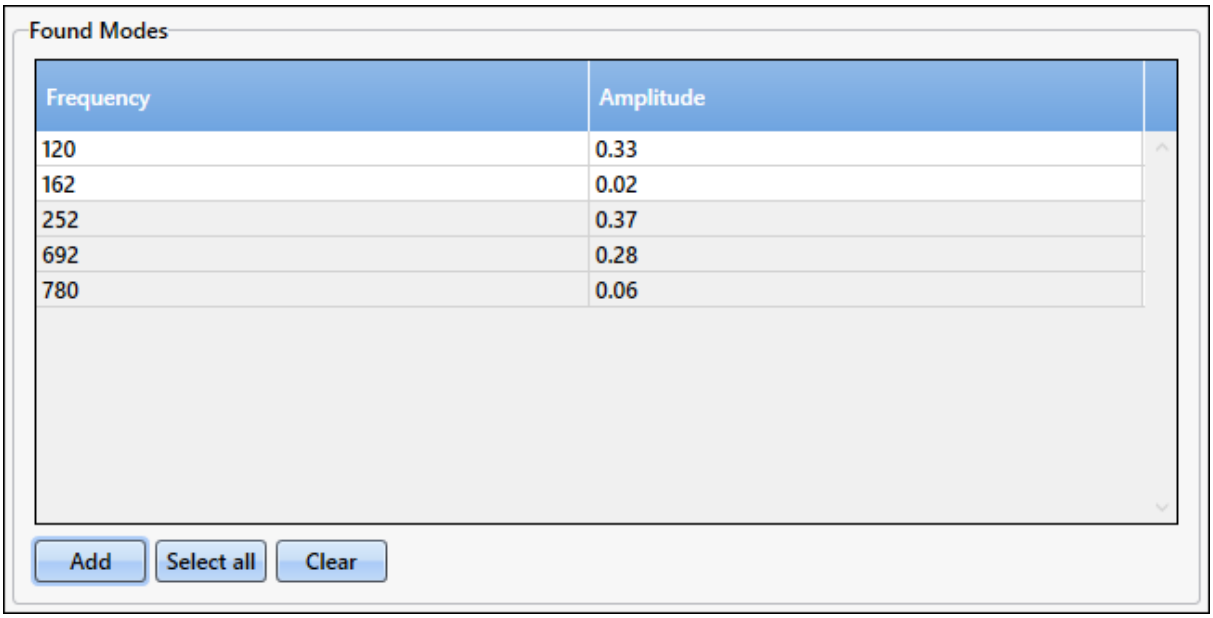
2.4.2.2.3 Found Modes / Optimized Modes

Simple Interface - Found Modes / Optimized Modes

The modes tables in the simple and advanced interface are identical.
It is used for displaying found modes detected in the software, and also for displaying modes which have curve-fitting applied to them.

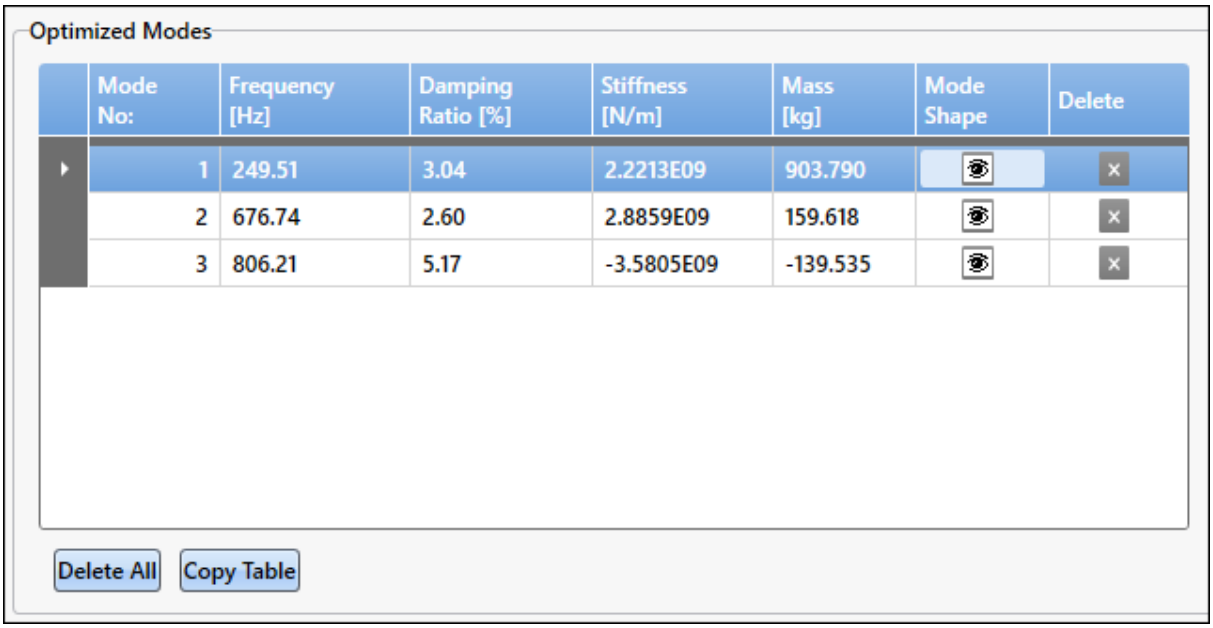


Found Modes - Buttons & Boxes:

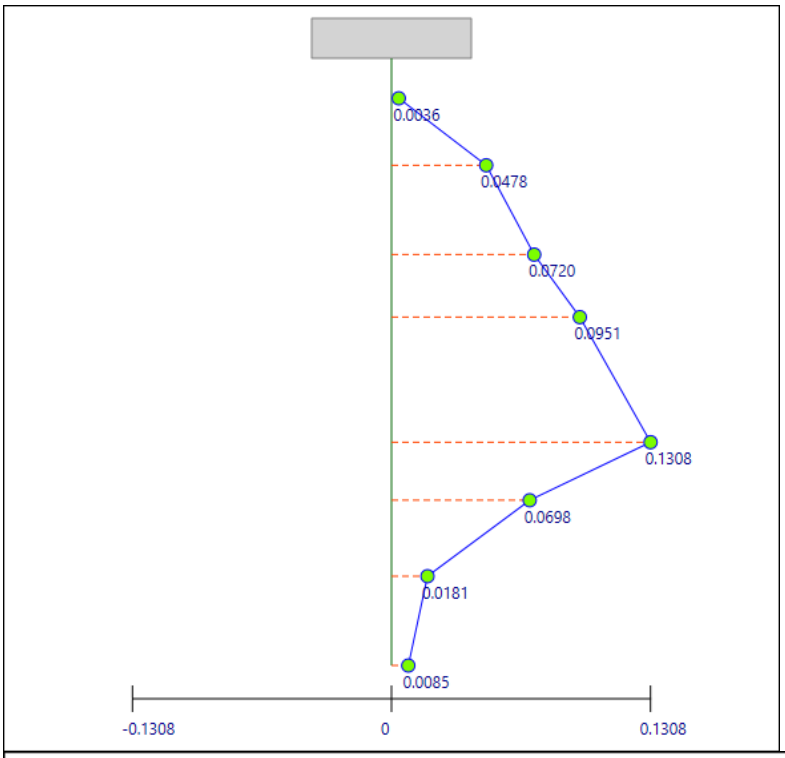


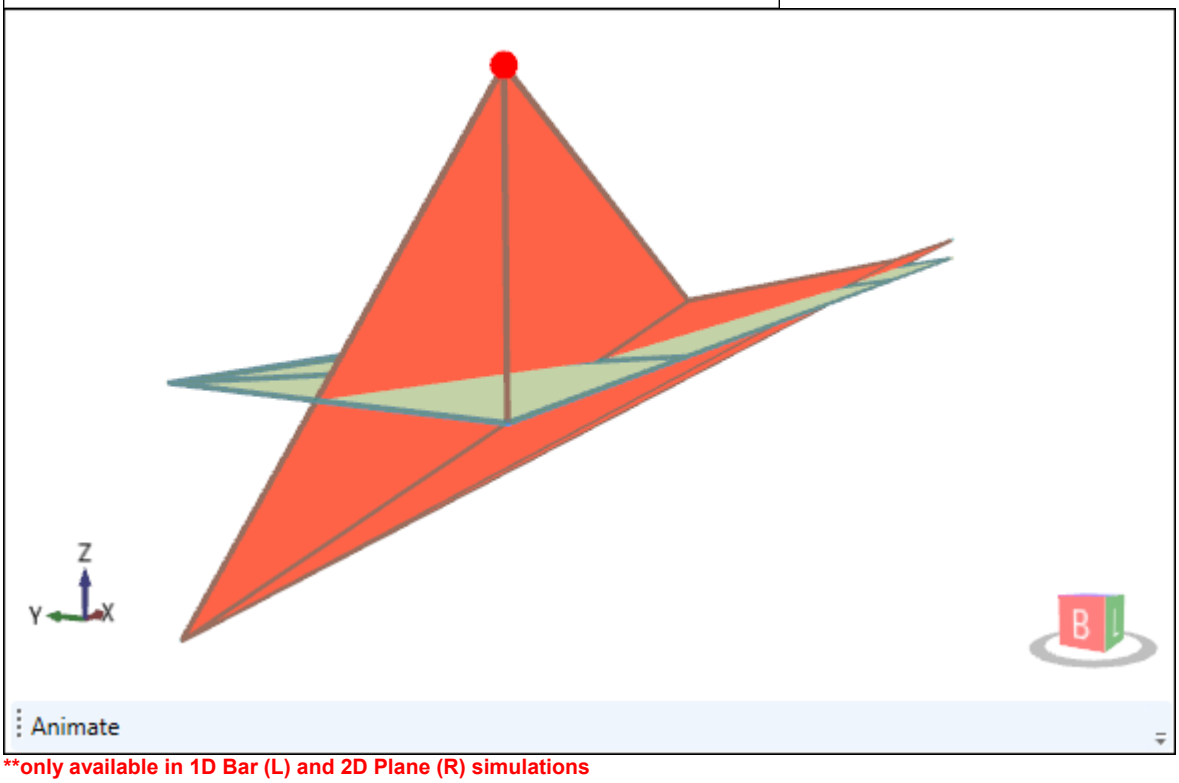
- **Frequency:** Displays the found modes (frequencies) in the table
- **Amplitude:** Displays the amplitude of the correspond mode (frequency)
- **Add:** After selecting a mode (frequency) from the table, click Add to add the mode under Optimized Modes
- **Select all:** Select all modes from the Found Modes table
- **Clear:** Clears the selected mode(s)

Optimized Modes - Buttons & Boxes:



- **Mode No:** Displays the mode number of the corresponding mode **(#)**
- **Frequency:** Displays the frequency value of the corresponding mode **(Hz)**
- **Damping Ratio:** Displays the damping ratio of the select mode **(%)**
  You may double-click the damping ratio value in the table and edit it. This can be done to improve the curve-fit.
- **Stiffness:** Displays the stiffness value of the select mode **(N/m or lbf/in)**
- **Mass:** Displays the mass corresponding to the select mode **(kg or lbs)**
- **Delete:** Deletes the selected mode from the table
- **Mode Shape:** Displays the mode shape (if that mode is excited) of the selected mode in a unitless display:



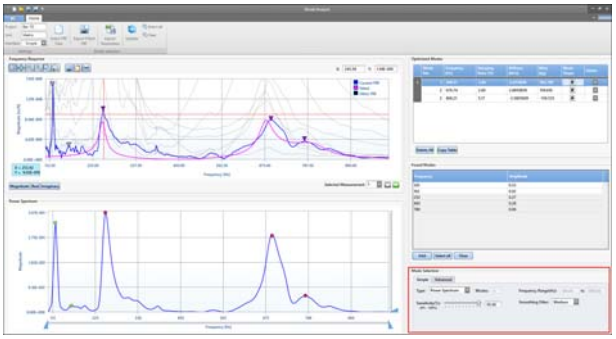


**only available in 1D Bar (L) and 2D Plane (R) simulations

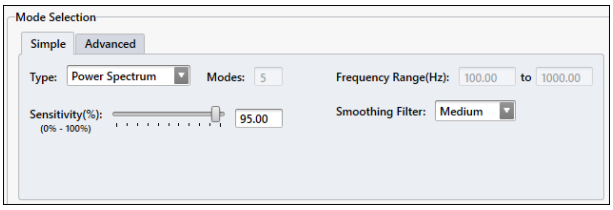
2.4.2.2.4 Mode Selection Dialogue

Simple Interface - Mode Selection

The modes selection box can be found in the lower left corner of Modal Analysis. It is used for modifying how mounds are detected in the software.



Buttons & Boxes:



- **Simple / Advanced:** Switch between the **Simple** / **Advanced** interface types
- **Type:** **Power Spectrum of Mode Indicator Function** or **Mode Indicator Function** selection options
- **Modes:** Displays the **number of modes found** (which are available for curve-fitting)
- **Frequency Range(Hz):** Displays the **frequency range of the FRF file(s)** used. It also relates to the horizontal spanners found in Power Spectrum / Mode Indicator chart.
- **Sensitivity:** Used to modify the

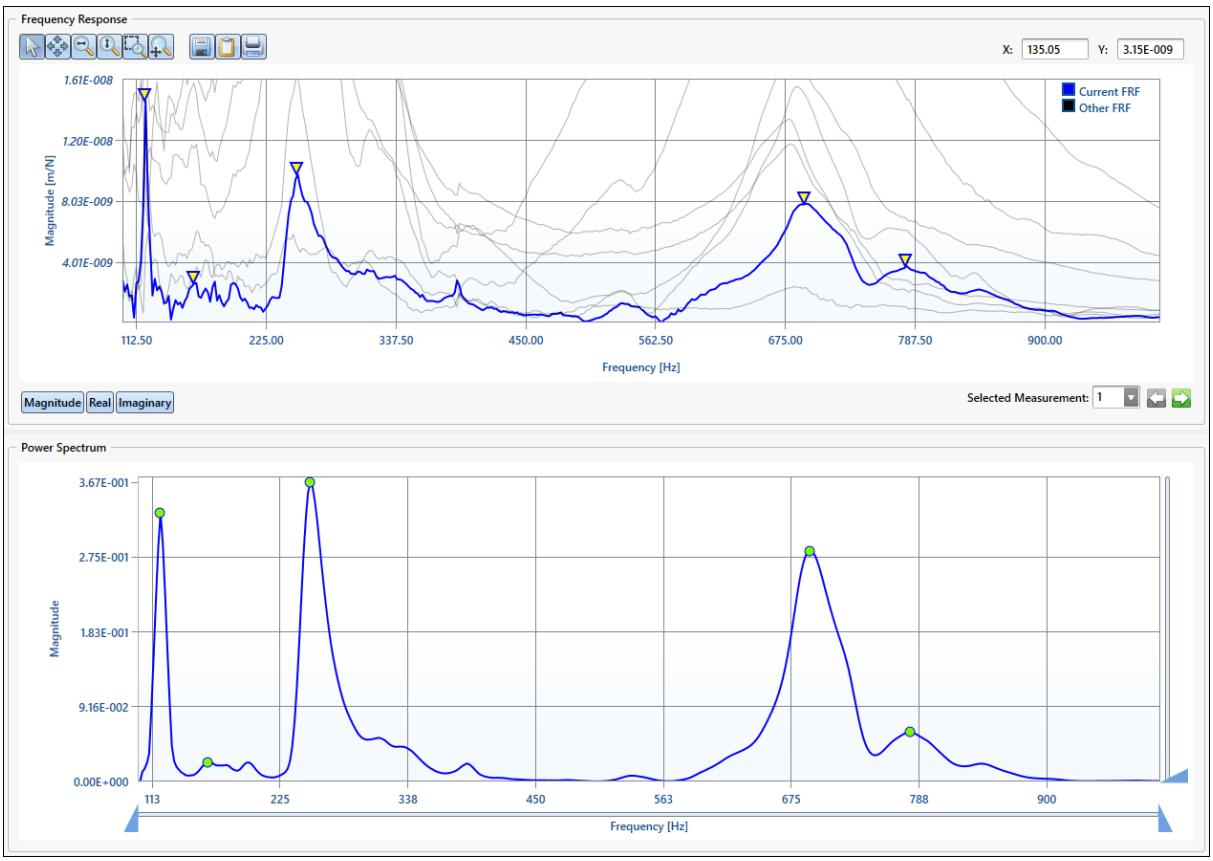
automatic mode finder, **higher sensitivity** finds more modes (main modes) , **lower sensitivity** finds less modes (smaller mode peaks)

- **Smoothing Filter:** **None**, **Weak**, **Medium**, or **Strong** - Determines the strength in which smaller modes are ignored/filtered

2.4.2.2.5 Frequency Response Charts

Simple Interface - Frequency Response Charts

The Frequency Response Charts are where the user applies curve fitting to the FRF(s):



Buttons & Boxes:

- **X/Y Crosshair cursor:** This button is used to enable point selection along the highlighted (blue) FRF, and displays the X/Y location of the cursor. It can also be used to select the modes (yellow

trian
gles)

- **Pan chart:** Used to move the chart in X and Y directions
- **Zoom X:** Used to define a range along the X axis in which only X values are zoomed **(**Y values are left un-zoomed**)**
- **Zoom Y:** Used to define a range along the Y axis in which only Y values are zoomed **(**X values are left un-zoomed**)**
- **Zoom in X & Y:** Define a window in which to zoom in X and Y
- **Save Chart:** Saves an image file **(***.png, *.bmp or *.jpeg**)** of the Frequency Response chart
- **Copy Chart:** Copies the Frequency Response chart as an image
- **Print Chart:** Prints an image of the Frequency Response chart
- **X:** States the X location of the mouse arrow cursor
- **Y:** States the Y location of the mouse arrow cursor
- **Magnitude:** Displays the FRF as a Magnitude vs. Frequency chart
- **Real:** Displays the real portion of the FRF as a Real vs. Frequency chart
- **Imaginary:** Displays the imaginary portion of the FRF as an Imaginary vs. Frequency chart
- **Selected Measurement:** Changes the displayed chart to the corresponding measurement FRF number
- **Power Spectrum / Mode Indicator:** Displays the power spectrum & mode indicator function of the FRF
- **Horizontal Spanner Arrows:** Filters the FRF to ignore modes at Left (lower) and Right (higher) frequencies
- **Vertical Spanner Arrow:** Filters the FRF to ignore lower magnitude modes when dragged upwards

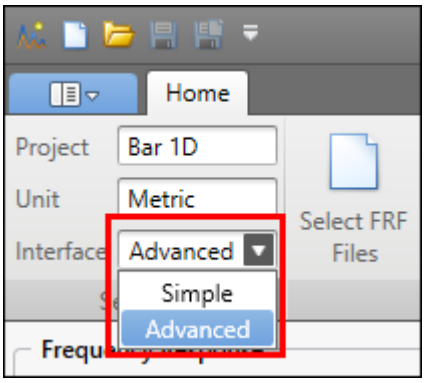
2.4.2.3 Advanced Modal Analysis

Advanced Interface

Inside Modal Analysis, you can switch between interface types at any given time.

- **The "Interface" selection menu** can be found in the Top Left corner by clicking on the Home tab

butt
on,
follo
wed
by
the
arro
w
next
to
"Inte
rfac
e":



Simple	The user selects the natural frequency peaks which the software automatically detects.
Advanced	The user defines the left & right area of the natural frequency peaks they are interested in. Modes are also automatically detected and listed under the found modes table.

2.4.2.3.1 Menus & Buttons

**Adva
nced
Interf
ace -
Men
us &
Butt**

ons

Buttons & Boxes:

- **Project:** Displays the current project type
- **Unit:** Displays the current unit system
- **Interface:** Switch between Simple/Advanced via the drop-down

arrow

- **Select FRF Files:** Displays the Select FRF dialogue. This window varies based on Project Type: Refer to Project Types for details.
- **Export Fitted FRF:** The fitted FRF file

***.frf** (purple) is exported. Refer to Exported Files for details.

- **Export Paramerers:** The fitted CMP file ***.cmp** (purple) is exported. Refer to Exported Files for details.
- **Add:** Adds the

mode to be curve fitted (will be curve-fitted once Method 1 or Method 2 is selected)

To use this action, **left click** on the left of the mode, **right click** on the right of the mode, then click

"Add" from the top menu.

- **Delete:** Deletes the selected mode to be curve fitted (will be curve-fitted once Method 1 or Method 2 is selected) To use this action, select the mode from

the **optimized modes table**, then click "Delete" from the top menu.

- **Delete All:** Clears all modes from the optimized modes table, and removes the curve-fit.
- **Method 1:** Apply a curv

e-fit to added modes by optimizing residue (amplitude).

- **Method 2:** Apply a curve-fit to added modes by non-linear optimization of residue (amplitude), natural frequency, or dam

ping ratio in any combination of each.

- **Predict H11 (Flexible Tool FRF mode only):** Calculates the predicted Frequency Response Function at the tool's tip based on the curve-fit (green).

2.4.2.3.2 Select FRF Files Window

MODAL ANALYSIS

Advanced Interface - Select FRF Files Window

The Select FRF Files window is fully dependant on which project type you choose:

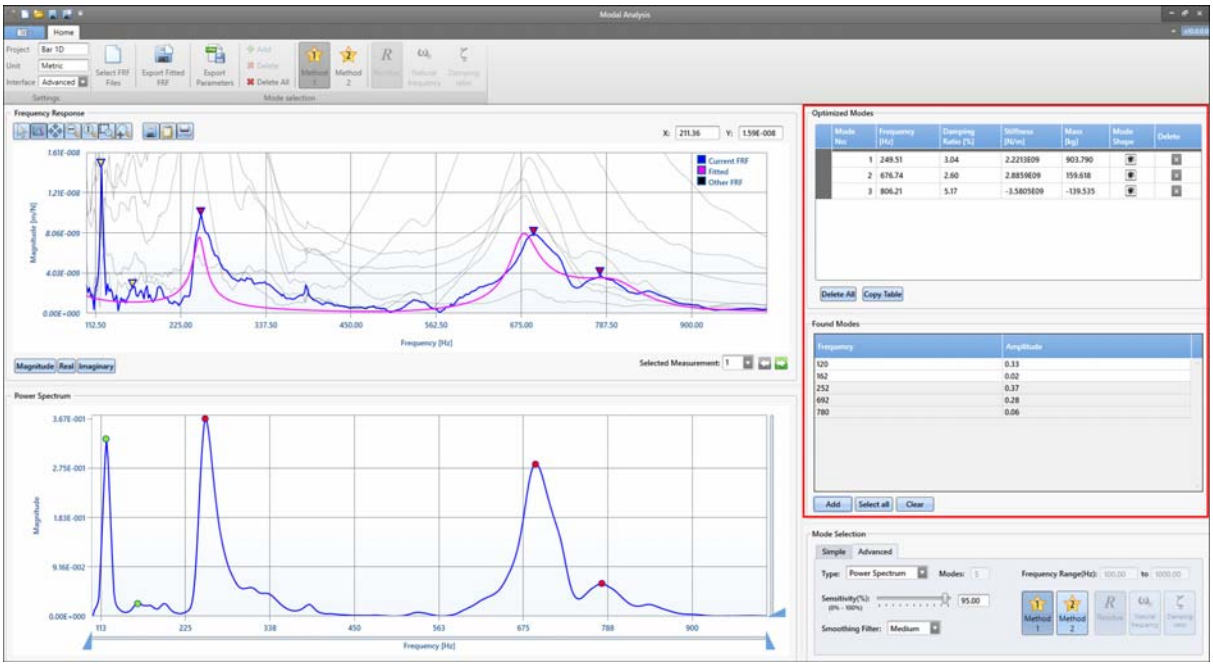
- **Bar (1D)**
- **Plane (2D)**
- **Flexible Tool FRF**

2.4.2.3.3 Found Modes / Optimized Modes

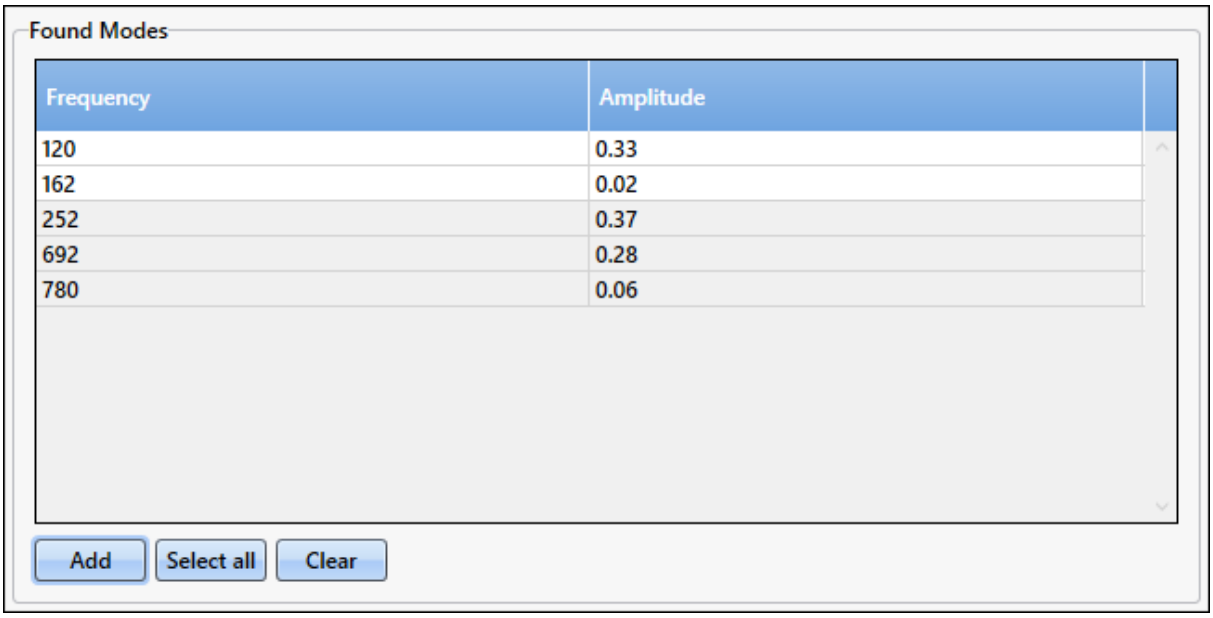
MODAL ANALYSIS

Advanced Interface - Found Modes / Optimized Modes

The modes tables in the simple and advanced interface are identical.
It is used for displaying found modes detected in the software, and also for displaying modes which have curve-fitting applied to them.



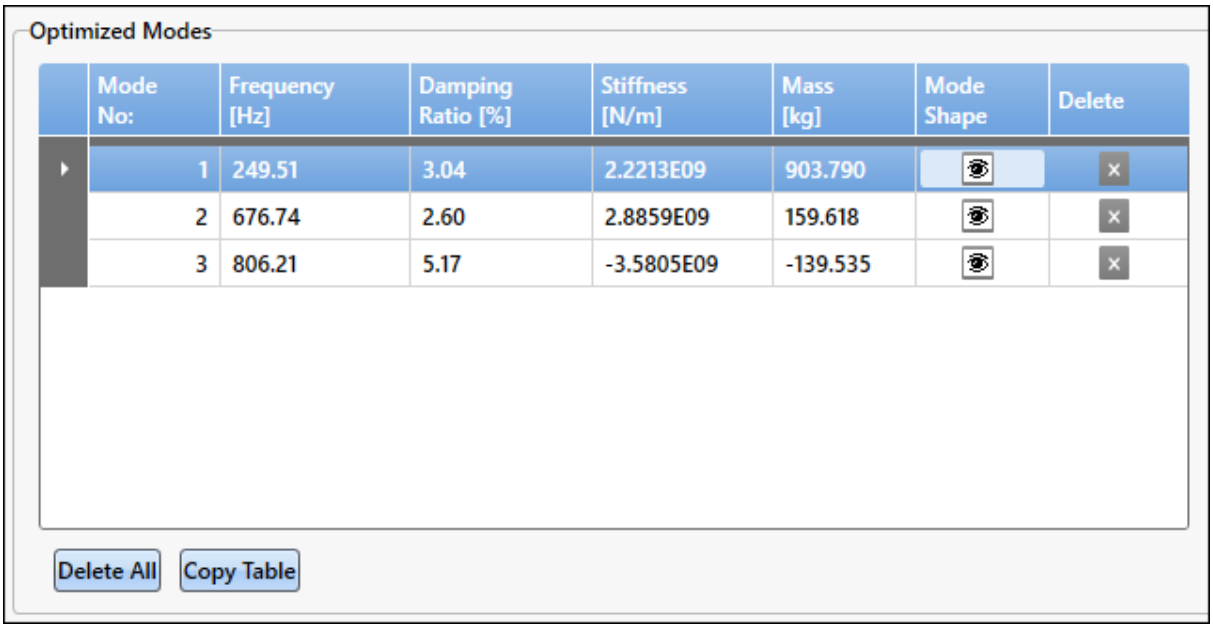
Found Modes - Buttons & Boxes:



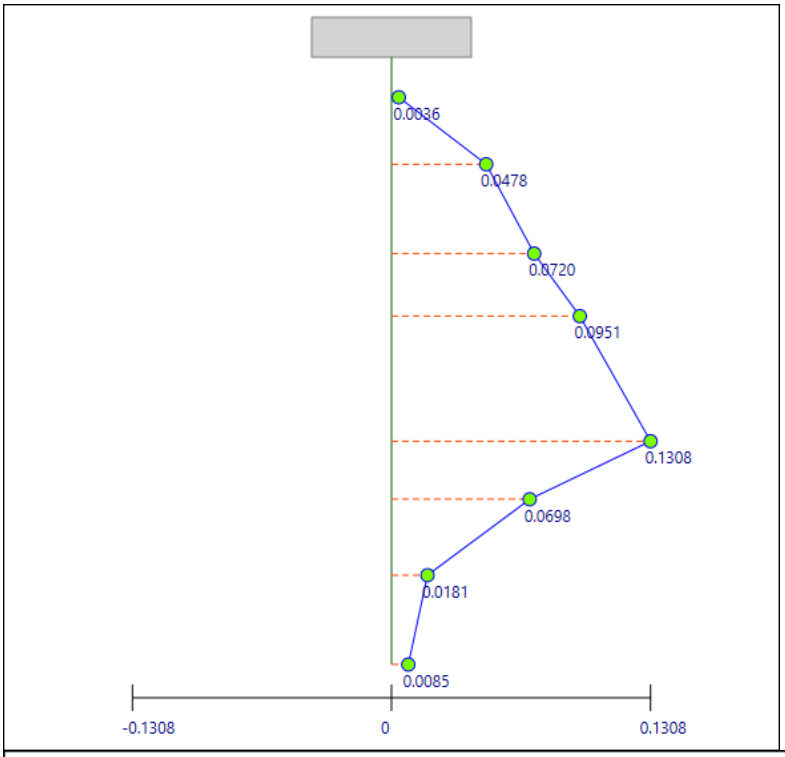
- **Frequency:** Displays the found modes (frequencies) in the table
- **Amplitude:** Displays the amplitude of the correspond mode (frequency)
- **Add:** After selecting a mode (frequency) from the table, click Add to add the mode under Optimized Modes
- **Select all:** Select all modes from the Found Modes table

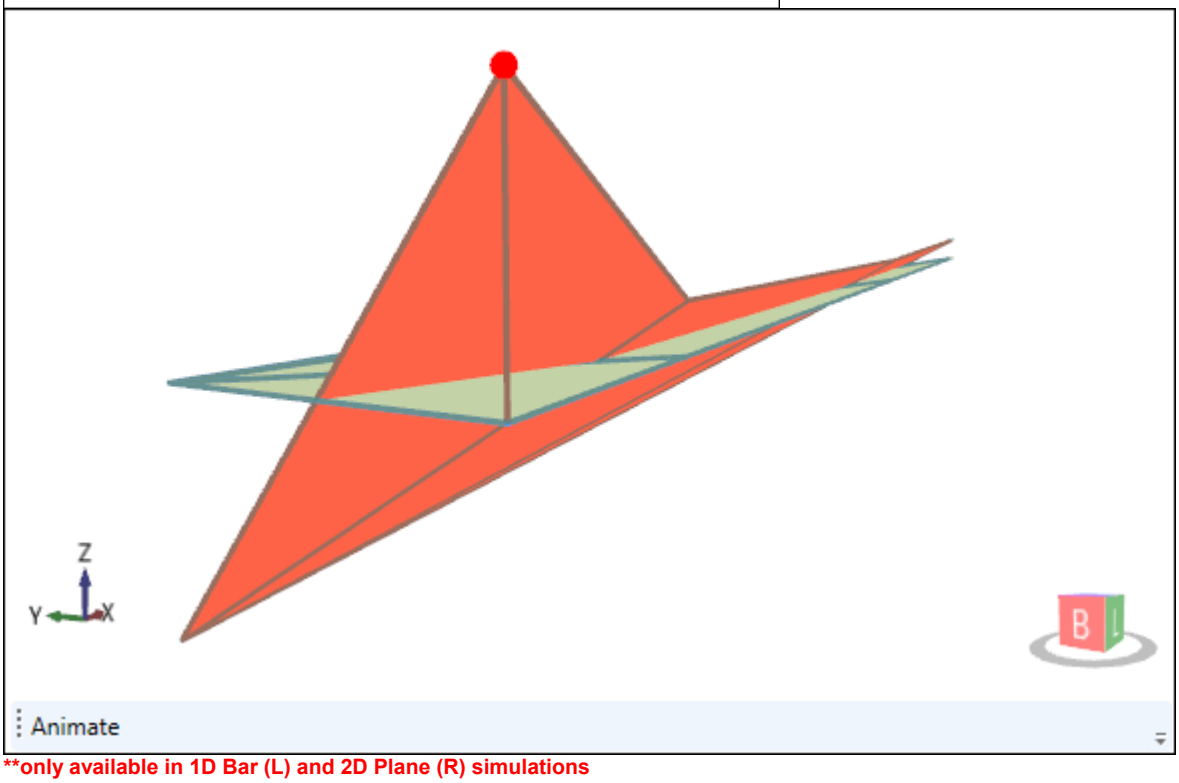
- **Clear:** Clears the selected mode(s)

Optimized Modes - Buttons & Boxes:



- **Mode No:** Displays the mode number of the corresponding mode **(#)**
- **Frequency:** Displays the frequency value of the corresponding mode **(Hz)**
- **Damping Ratio:** Displays the damping ratio of the select mode **(%)**
  You may double-click the damping ratio value in the table and edit it. This can be done to improve the curve-fit.
- **Stiffness:** Displays the stiffness value of the select mode **(N/m or lbf/in)**
- **Mass:** Displays the mass corresponding to the select mode **(kg or lbs)**
- **Delete:** Deletes the selected mode from the table
- **Mode Shape:** Displays the mode shape (if that mode is excited) of the selected mode in a unitless display:



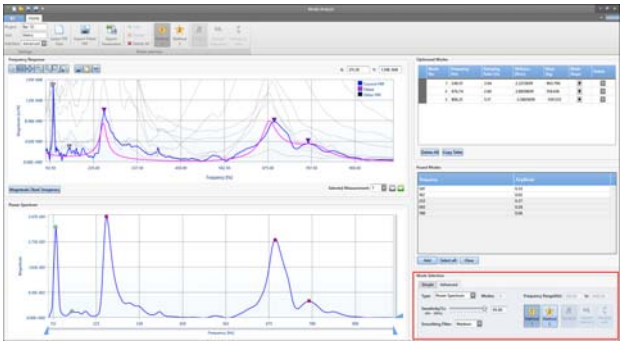


**only available in 1D Bar (L) and 2D Plane (R) simulations

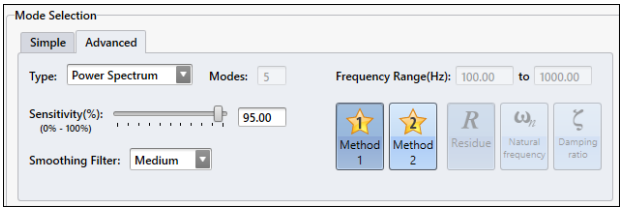
2.4.2.3.4 Mode Selection Dialogue

Advanced Interface - Mode Selection

The modes selection box can be found in the lower left corner of Modal Analysis. It is used for modifying how mounds are detected in the software.



Buttons & Boxes:



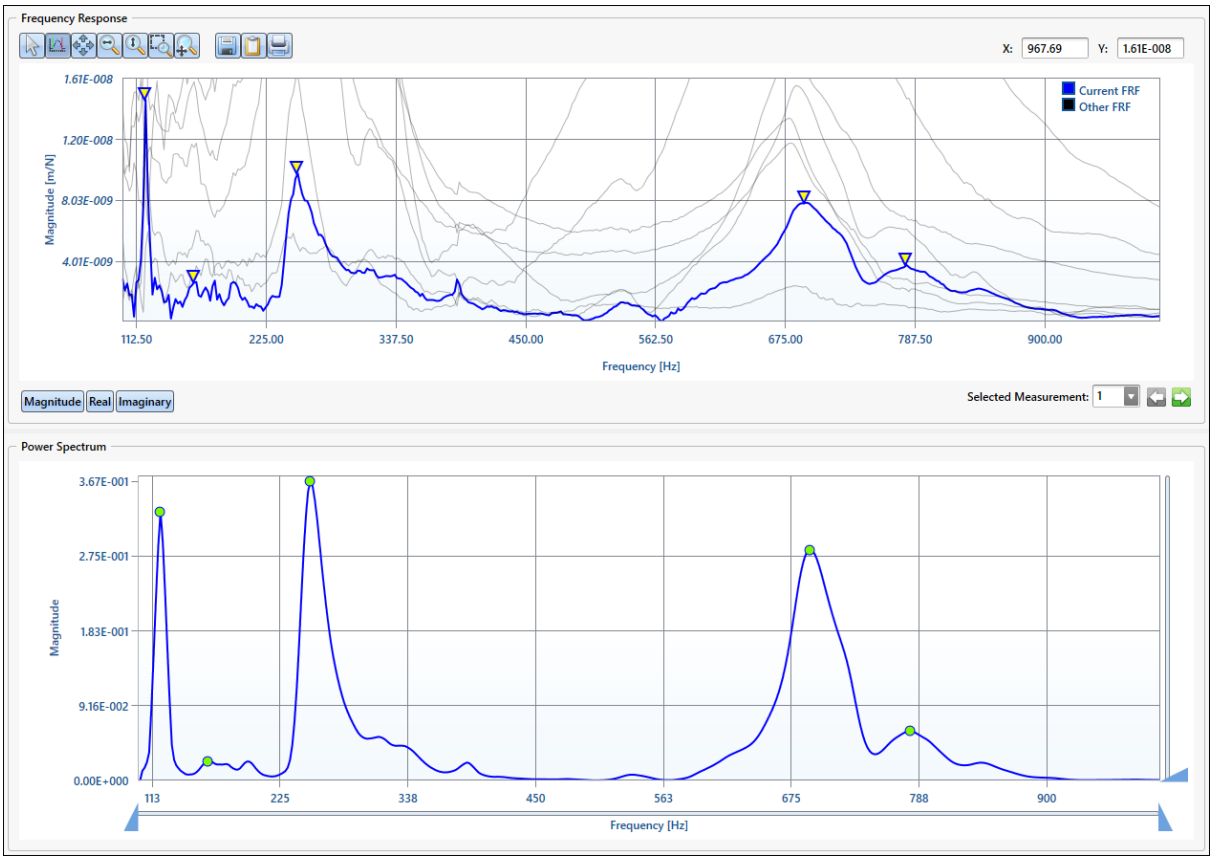
- **Simple / Advanced:** Switch between the **Simple** / **Advanced** interface types
- **Type:** **Power Spectrum of Mode Indicator Function** or **Mode Indicator Function** selection options
- **Modes:** Displays the **number of modes found** (which are available for curve-fitting)
- **Frequency Range(Hz):** Displays the **frequency range of the FRF file(s)** used. It also relates to the horizontal spanners found in Power Spectrum / Mode Indicator chart.

- **Sensitivity:** Used to modify the **automatic mode finder**, **higher sensitivity** finds more modes (main modes) , **lower sensitivity** finds less modes (smaller mode peaks)
- **Smoothing Filter:** **None**, **Weak**, **Medium**, or **Strong** - Determines the strength in which smaller modes are ignored/filtered
- **Method 1:** Apply a curve-fit to added modes by **optimizing residue** (amplitude). Dark blue shaded boxes represent an enabled button
- **Method 2:** Apply a curve-fit to added modes by **non-linear optimization of residue** (amplitude), **natural frequency**, or **damping ratio** in any combination of each

2.4.2.3.5 Frequency Response Charts

Advanced Interface - Frequency Response Charts

The Frequency Response Charts are where the user applies curve fitting to the FRF(s):



Buttons & Boxes:

- **X/Y Crosshair cursor:** This button is used to enable point selection along the highlighted

(blue) FRF, and displays the X/Y location of the cursor. It can also be used to select the modes (yellow triangles)

- **Select Modes:** Enables mode selection
- **Pan chart:** Used to move the chart in X and Y directions
- **Zoom X:** Used to define a range along the X axis in which only X values are zoomed (Y values are left un-zoomed)
- **Zoom Y:** Used to define a range along the Y axis in which only Y values are zoomed (X values are left un-zoomed)
- **Zoom in X & Y:** Define a window in which to zoom in X and Y
- **Save Chart:** Saves an image file (*.png, *.bmp or *.jpeg) of the Frequency Response chart
- **Copy Chart:** Copies the Frequency Response chart as an image
- **Print Chart:** Prints an image of the Frequency Response chart

- **X:** States the X location of the mouse arrow cursor
- **Y:** States the Y location of the mouse arrow cursor
- **Magnitude:** Displays the FRF as a Magnitude vs. Frequency chart
- **Real:** Displays the real portion of the FRF as a Real vs. Frequency chart
- **Imaginary:** Displays the imaginary portion of the FRF as an Imaginary vs. Frequency chart
- **Selected Measurement:** Changes the displayed chart to the corresponding measurement FRF number
- **Power Spectrum / Mode Indicator:** Displays the power spectrum & mode indicator function of the FRF
- **Horizontal Spanner Arrows:** Filters the FRF to ignore modes at Left (lower) and Right (higher) frequencies
- **Vertical Spanner Arrow:** Filters the FRF to ignore lower magnitude modes when dragged upwards

---

2.4.3 Unit Systems

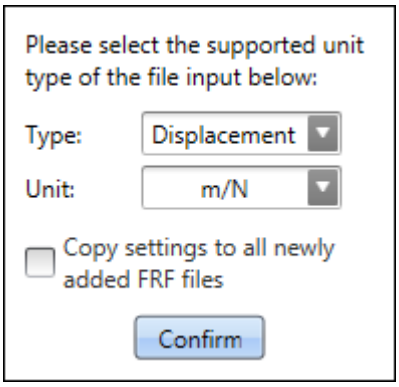
manufacturing automation laboratories MODAL ANALYSIS

Unit Systems

Imported FRF data in Modal Analysis **(***.frf, *.mtb or *.uff files**)** can be varying in units, and sometimes you may wish to mix unit systems.

Modal Analysis will automatically detect the FRF type and unit system of the FRF file if it is noted inside the file contents.

If the FRF type and unit system is not contained in the FRF file, the user must select the appropriate type and unit.
When adding an FRF, if the unit system is unknown, the software will prompt this window:



Two unit systems are used:

- Metric
- Imperial

2.4.3.1 Metric

Unit Systems - Metric

The metric unit system consist of basic metric units such as meters (for length), grams (for mass or weight), and liters (for volume).
Modal Analysis will display the unit system for each parameter. Units such as mm, N/m, and kg are used.

File types:

- **The Frequency Response Function** (*.frf) file format refers to the file format used to store FRF data.
- **The MALTF Document** (*.mtb) file format refers to the file format used within MAL Inc.'s Tap Testing Module: MALTF.
- **The Universal File Format** (*.uff) file format refers to the file format used within various engineering software packages.

Displacement Units:

- **m / N** (meters per newton)
- **µm / N** (micrometers per newton)

Acceleration Units:

- **m / s^2/ N** (meters per seconds squared per newtons)
- **µm / s^2/ N** (micrometers per seconds squared per newtons)
- **g / N** (gravitational acceleration per newtons)

2.4.3.2 Imperial

MODAL ANALYSIS

Unit Systems - Imperial

The imperial unit system consist of basic imperial units such as feet (for length), pounds (for mass or weight), and gallons (for volume).
Modal Analysis will display the unit system for each parameter. Units such as in, lbf/in, and lbs are used.

File types:

- **The Frequency Response Function** (*.frf) file format refers to the file format used to store FRF data.
- **The MALTF Document** (*.mtb) file format refers to the file format used within MAL Inc.'s Tap Testing Module: MALTF.
- **The Universal File Format** (*.uff) file format refers to the file format used within various engineering software packages.

Displacement Units:

- **in / lb-f** (inches per pound force)
- **ft / lb-f** (feet per pound force)

Acceleration Units:

- **in / s^2/ lb-f** (inches per seconds squared per pound force)
- **ft / s^2/ lb-f** (feet per seconds squared per pound force)
- **g / lb-f** (gravitational acceleration per pound force)

2.4.4 Exported Files

MODAL ANALYSIS

Exported Files

There are two possible exported file types available in Modal Analysis:

- **Fitted Frequency Response** (*.frf)

The fitted frequency response file (*.frf) is to be used with simulation of stability lobes with CutPro.

*.FRF files are file consisting of frequency data as follows:

- **Columns 1-3, Row 0 to ?:** Contains the data / numerical values
- **Column 4:** Title of the values in Column 1 (ex. Freq)
- **Column 5:** Unit of the values in Column 1 (ex. Hz)
- **Column 6:** Title of the values in Column 2 (ex. Real)
- **Column 7:** Unit of the values in Column 2 (ex. m/N)
- **Column 8:** Title of the values in Column 3 (ex. Imag)
- **Column 9:** Unit of the values in Column 3 (ex. m/N)

- **Modal Parameters** (*.cmp)

The modal parameters file (*.cmp) is to be used with milling cutting simulation with CutPro.

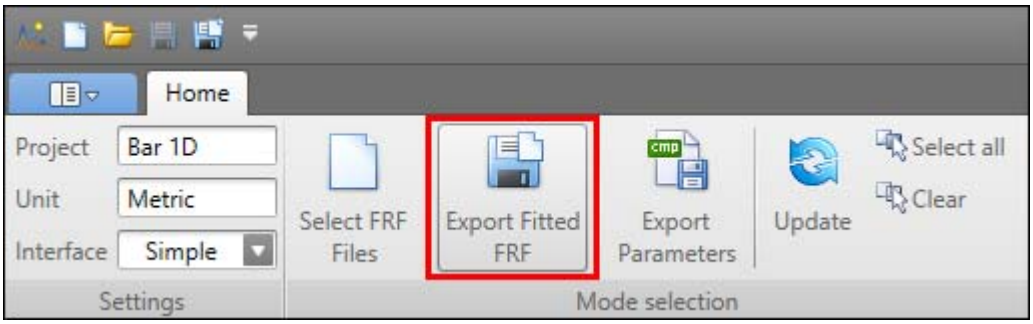
*.CMP files are a text file consisting of frequency data as follows:

- **MODES:** # of modes (natural frequencies) in the curvefit **(**1 to **...)**
- **PNTS:** # of points (FRF files) in file **(**1 to **...)**
- **REALM:** # representing if the fitting is real or imaginary **(**Always 1 **-** Real**)**
- **WN:** The value of the natural frequency / mode **(**Hz**)**
- **ZETA:** The damping ratio of the mode **(**%**)**
- **MASS:** The mass of the object corresponding to the mode **(**kg or lbs**)**
- **STIFK:** The stiffness of the object corresponding to the mode **(**N/m or lbf/in**)**
- **LOCNS:** The point locations of the mode shapes where 0 is the tip **(**0 to **...** in mm or in**)**
- **MODSH:** The point location relating to the mode shape **(**ul**)**
- **METRIC / IMPERIAL:** States the unit system of the file **(**METRIC or IMPERIAL**)**

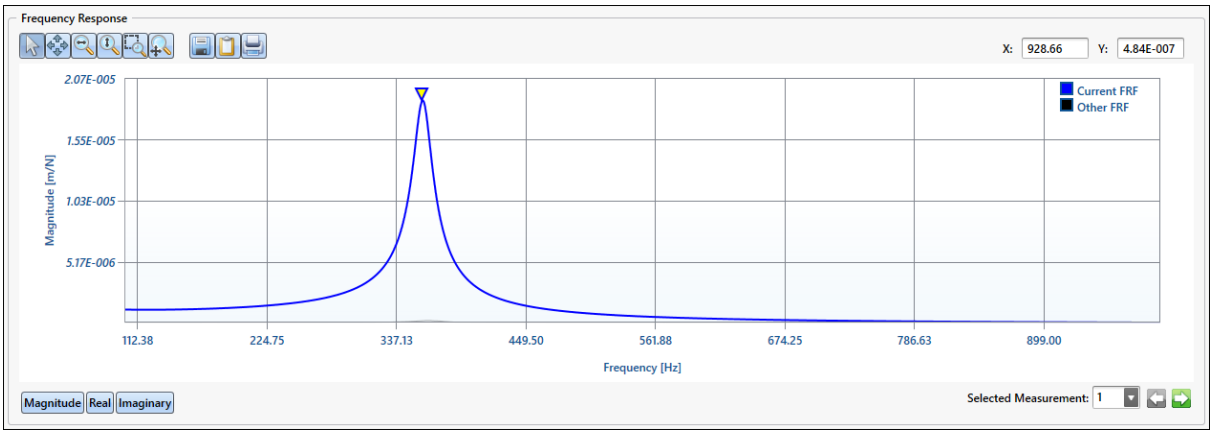
2.4.4.1 Fitted Frequency Response (*.frf)

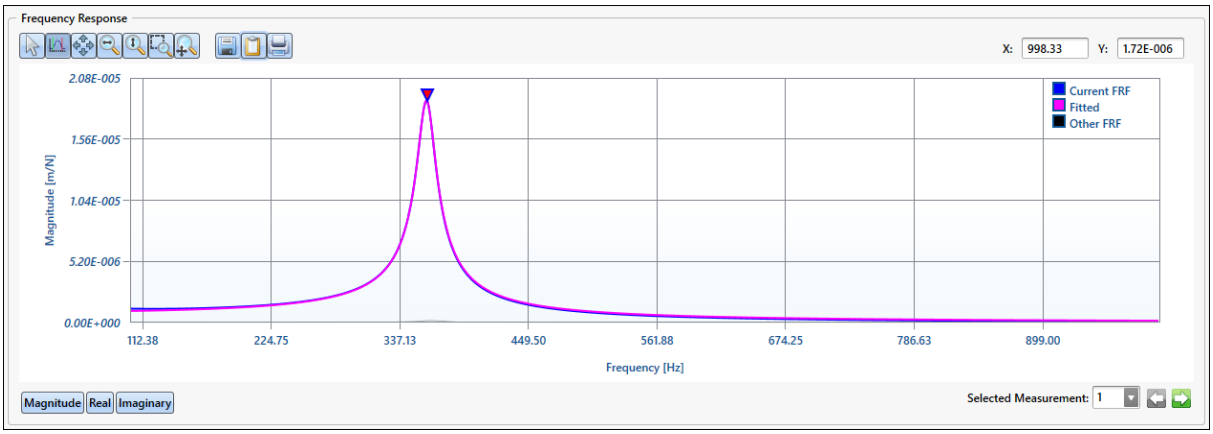
Exported Files - Fitted Frequency Response (*.frf)

The fitted FRF file ***.frf** (purple) can be exported by clicking the **"Export Fitted FRF"** button at the top home menu.
For details relating to it's contents, click here.



The exported FRF will be the curve-fitted FRF (displayed in purple)

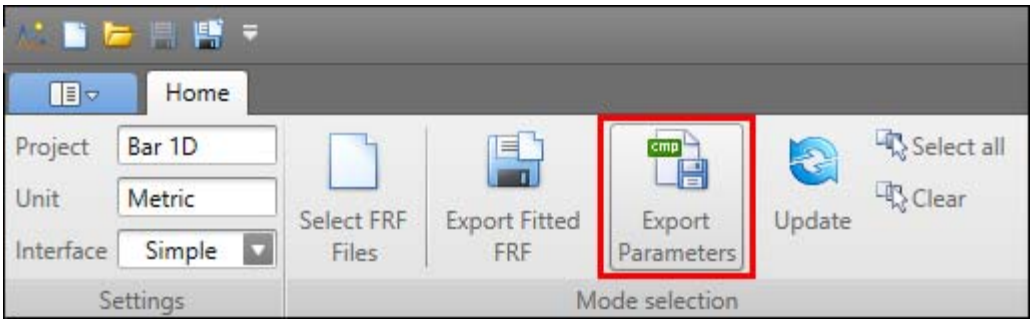




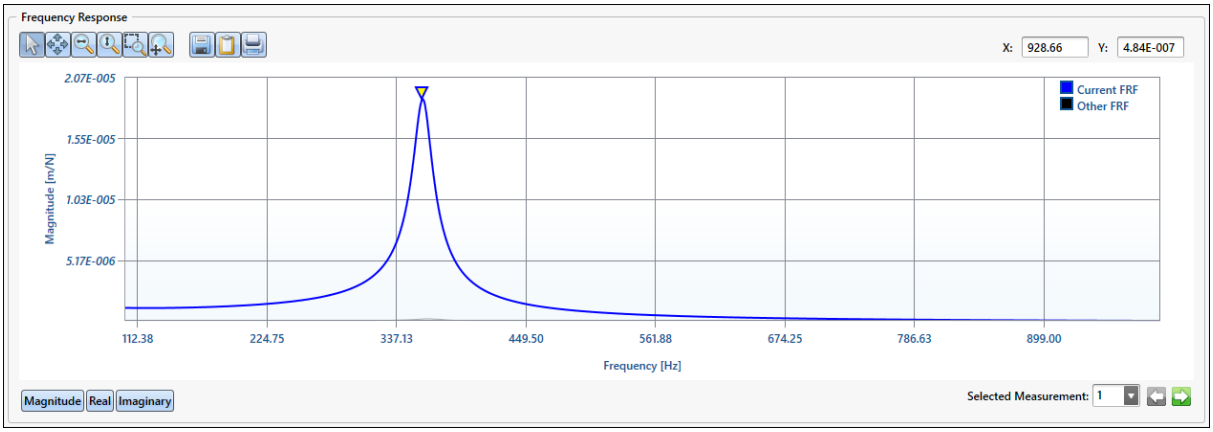
2.4.4.2 Modal Parameters (*.cmp)

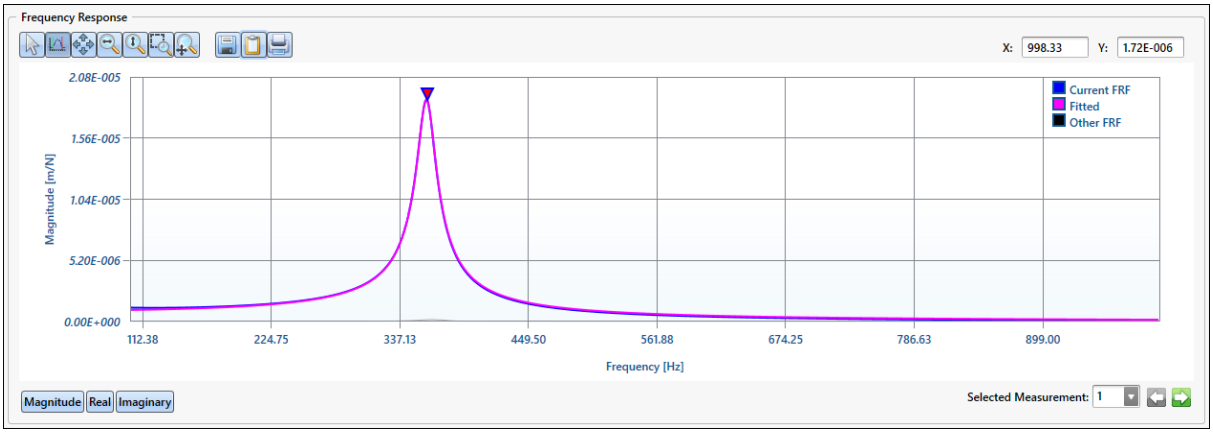
Exported Files - Modal Parameters (*.cmp)

The fitted CMP file ***.cmp** (purple) can be exported by clicking the **"Export Parameters"** button at the top home menu.
For details relating to it's contents, click here.



The exported FRF will be the curve-fitted FRF (displayed in purple)





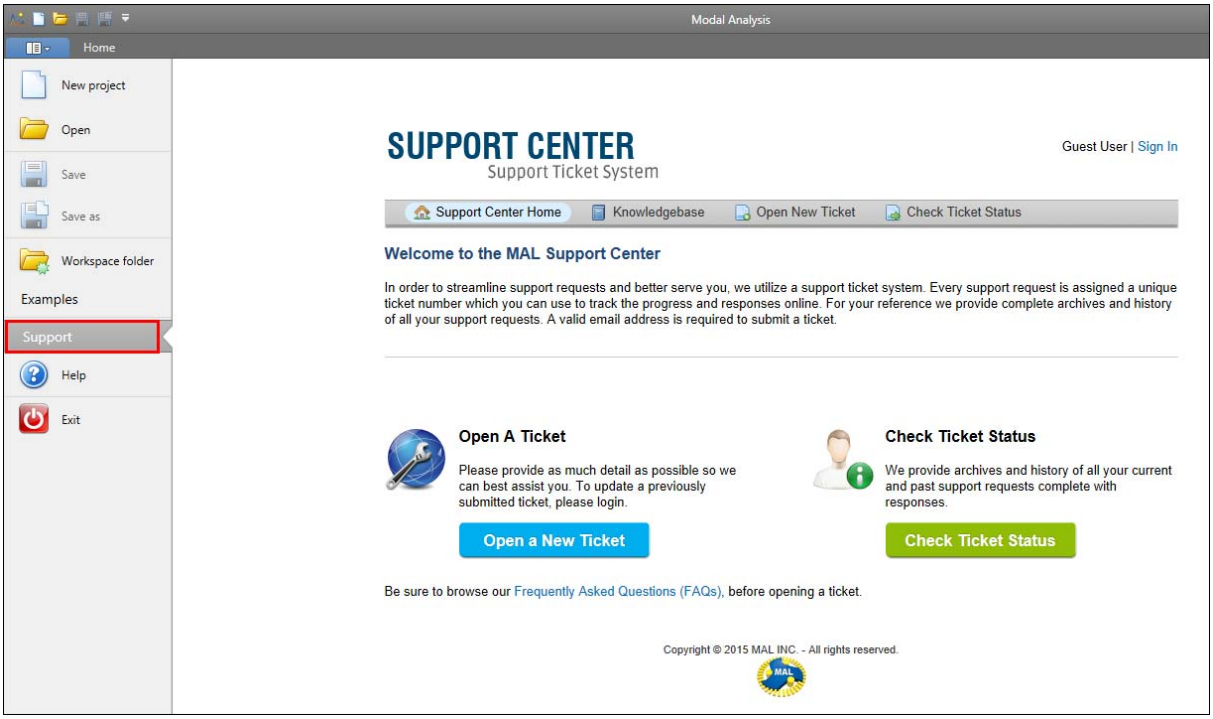
2.4.5 Support

manufacturing automation laboratories MODAL ANALYSIS

Support

At Manufacturing Automation Laboratories, Inc. we provide prompt technical support with 24 hours.

For Technical, software related inquiries, click on the Support butter under the File Menu:



➢http://www.malinc.com/support/

For general contact:

➢http://www.malinc.com/contact/

Phone	+1 (604) 998-4686
Address	Manufacturing Automation Laboratories, Inc. 2829 Highbury Street Vancouver, BC, Canada V6R 3T7

2.4.5.1 Examples

Examples

The examples folder contains pre-made Modal Analysis Projects which can help you understand how to use the software.

To access this folder, click on the "Examples" button under the File Menu:

List of Available Examples:

- 1D Modal Analysis
- 2D Modal Analysis
- Curve Fitting at the tool
- Curve Fitting at the workpiece
- Flexible Tool Measurement
- Modal Parameter Files
- Receptance Coupling
    - o Identification of Tool - Tool Holder Interface
    - o Identification of Tool Holder - Spindle Interface
    - o Tool Tuning

2.5 Tap Testing

MALTF

CutPro: Tap Testing

Congratulations on your purchase of the CutPro: Tap Testing (MALTF) module, which stands for MAL Transfer Function, an Impact modal testing solution from MAL Manufacturing Automation Laboratories, Inc.

MAL Inc. offers inexpensive, easy-to-use tap testing software that is as powerful as the costly and difficult to use packages on the market. Tap testing with an impact hammer is considered to be an art, and the accuracy may be critically dependant on the skill of the user. After years of practical and scientific experience, and collecting feedback from CUTPRO users in the industry, we have designed MALTF with built-in scientific expertise and artificial intelligence. The expert system inspects the quality of the measurement and provides voice-guided instructions to the user.

MALTF Features:

- User friendly graphical user interface.
- Simultaneous testing at multiple measurement points.
- Supports impact force and shakers as exciters and accelerometer, velocity and displacement sensors as vibration output devices.
- Expert measurement quality control system with voice feedback.
- Displays time history, power spectrum, and coherence of the measurements.
- Displays magnitude & phase, real & imaginary parts of the measured FRF's.
- Stores the FRF data in binary or standard ASCII formats.
- Has a built-in engineering report generation system with graphical results.

2.5.1 Information

2.5.1.1 Printing help information

MALTF

Printing help information

If you wish to print just a single section of this on-line help, press the **Print** button on the toolbar (shown below).

Help buttons.

If you wish to print more than a few sections, you should open the *PDF* version of the on-line documentation. The *PDF* produces a much nicer printout.

The *PDF* version is located in the CutPro program directory.

Note: You will need Adobe Acrobat Reader to open the *PDF* file.

2.5.1.2 System requirements

manufacturing automation laboratories MALTF

System requirements

Required hardware and software:

- **PC:** PC with at Pentium 4 1GHz CPU, 1 GB RAM
- **Operating System:** Windows XP, Vista, or 7.
- **Data Acquisition Hardware:** MALTF supports National Instrument's DAQ cards that are supported in NI-DAQmx V8.9. The list of supported drivers can be found here.
- **Hardlock Key / Network Licence:** Will be provided when the software is purchased.

2.5.2 Basic Theory

manufacturing automation laboratories MALTF

Basic Theory

The Frequency Response Function (FRF) or Transfer Function (TF) measurement module has a TF measurement system that is based on impulse hammer tests. Transfer function measurements are taken in Impulse mode with multiple samples taken and averaged to obtain a better representation of the transfer function. The number of samples to be averaged is selected, and the samples are taken one by one.The readings are triggered by impulse hammer input. The results of these tests

can be saved in *.mtb or *.frf format, which are compatible with the Modal Analysis module of CUTPRO Advanced Process Simulation Software from MAL Inc.

2.5.2.1 Vibration

MALTF

Vibration

Machine tool vibration plays an important role in the machining operations because excessive vibration results in poor finish, tool wear, and may damage the spindle bearing systems. First, a simple structure with a single degree of freedom (SDOF) can be modeled using a general equation.

$$m\ddot{x} + c\dot{x} + kx = F_o \sin(\omega t) = F(t)$$

where m is the mass, c is the coefficient of damping, and k is the stiffness of the system. When the damping constant is 0, the system oscillates at its natural frequency ω_n. When damping is present, we need to consider the damping ratio ζ to acquire the damped natural frequency ω_d. In addition, resonance angular frequency ω_r, which is the maximum value of the damped natural frequency, can be found.

$$\omega_n = \sqrt{\frac{k}{m}} \qquad \xi = \frac{c}{2\sqrt{km}} \qquad \omega_d = \omega_n\sqrt{1-\xi^2}$$

$$\omega_r = \omega_n\sqrt{1-2\xi^2}$$

All mechanical systems exhibit some damping, and the damping ratio of most metal structures $\zeta < 0.05$ or less. Typically, the effect of damping on the system is ignored when the damping ratio is small and when the system is not excited at resonant frequencies. By assuming x(t) = X sin(ωt +f) , we can get the following equation:

$$(-\omega^2 m + j\omega c + k)X(\omega) = F(w) = F_o e^{j\alpha} e^{j\omega^t}$$

The resulting amplitude and phase of harmonic vibrations are:

$$\left|\Phi(\omega)\right| = \left|\frac{X}{F_o}\right| = \frac{1}{k}\frac{1}{\sqrt{(1-r^2)^2+(2\xi r)^2}}$$

$$\phi = \tan^{-1}\frac{-2\xi r}{1-r^2}$$

The real and imaginary parts of the transfer function are:

$$\text{Re}: \quad G(\omega) = \frac{1}{k}\frac{1-r^2}{(1-r^2)^2+(2\xi r)^2}$$

$$\text{Im}: \quad H(\omega) = \frac{1}{k}\frac{-2\xi r}{(1-r^2)^2+(2\xi r)^2}$$

Where n r = ω /ω_n and Φ(ω) = G(ω) + jH (ω) . Typically, Φ(ω) is known as the frequency response function (FRF) of the system which is the ratio of the complex amplitude of the displacement to the magnitude F of the forcing function. Also, the real and imaginary (s-plane) of Φ(ω) is known as the transfer function (TF).

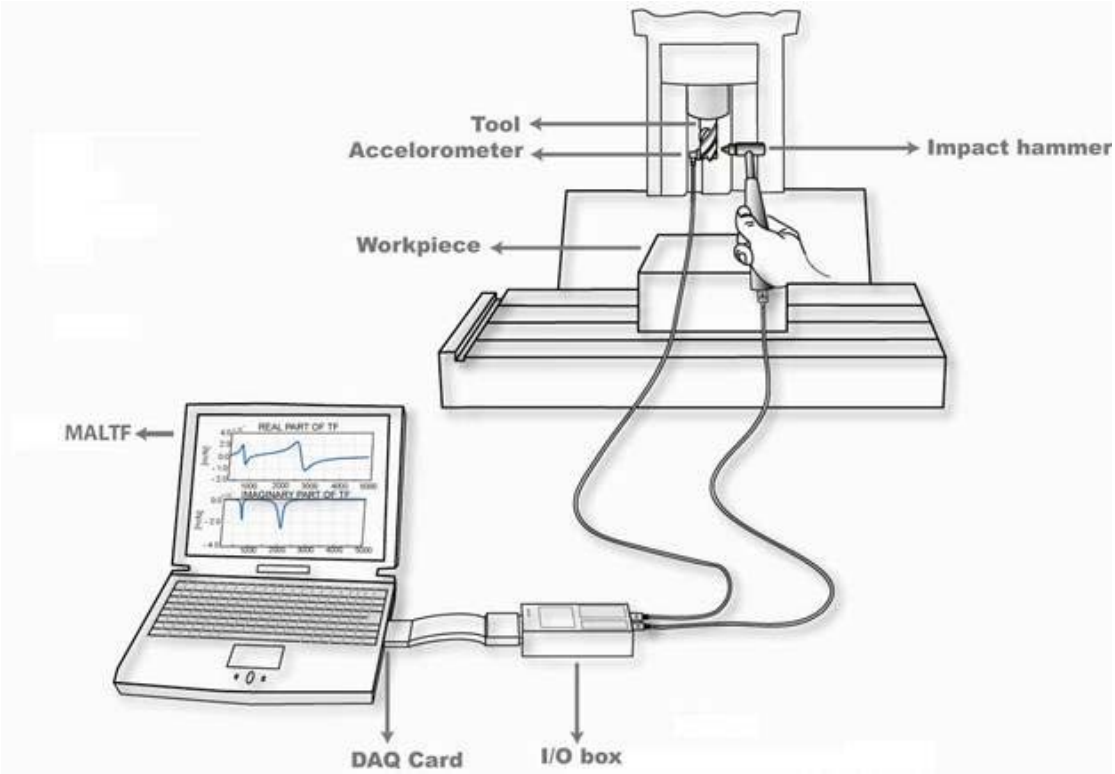
2.5.3 Quick Measurement Guide

2.5.3.1 Measurement setup

manufacturing automation laboratories MALTF

Measurement setup

Following figure shows the proper way to set up the measurement. To get the best results, please make sure the instruments are connected as in the figure, and all cables are in good working order.



Measurement Setup: Hammer is connected to the first and accelerometer cable is connected to the second channel of I/O box.
I/O box is connected to the data acquisition card.

Preparing the hardware:

Following list describes how to setup the hardware for an impact test:

- Connect the signal conditioning box (I/O box) to data acquisition card using the cable provided by National Instruments. If you have a USB data acquisition system, simply connect the I/O box to the computer's USB port.
- If you have a PCMCIA data acquisition system, make sure that first two channels of the I/O box are set to ICP Power On using the switch just above the BNC connection. If you have a USB I/O box, skip this step.
- Connect the hammer to the first channel (Channel 0, AI0) of the I/O box with the BNC cable.
- Connect the accelerometer (or velocity, displacement, force sensor) to the second channel (Channel 1, AI1) with the appropriate adapter cable and BNC cable. If you have multiple sensors for the measurements, connect them to the following channels.

- Attach the accelerometer to the measurement location (end of the cutter etc.) using wax or magnetic base. You may need to clean the surface in order to attach the accelerometer. It is recommended to use tape or rubber band to hold the cable on the tool older or the stationary part of the spindle housing to avoid cable entanglements and to catch the accelerometer if the adhesive fails. Taping the cable has the added advantage of removing the tension from the cable acting on the sensor, which reduces the accuracy of the measurements. If you are attaching to tip of the tool, the accelerometer is best located between the cavities of the helical flutes, or on the smooth cylindrical surface of the indexed cutter body.
- Run MALTF from CutPro window.

2.5.3.2 Measurement settings

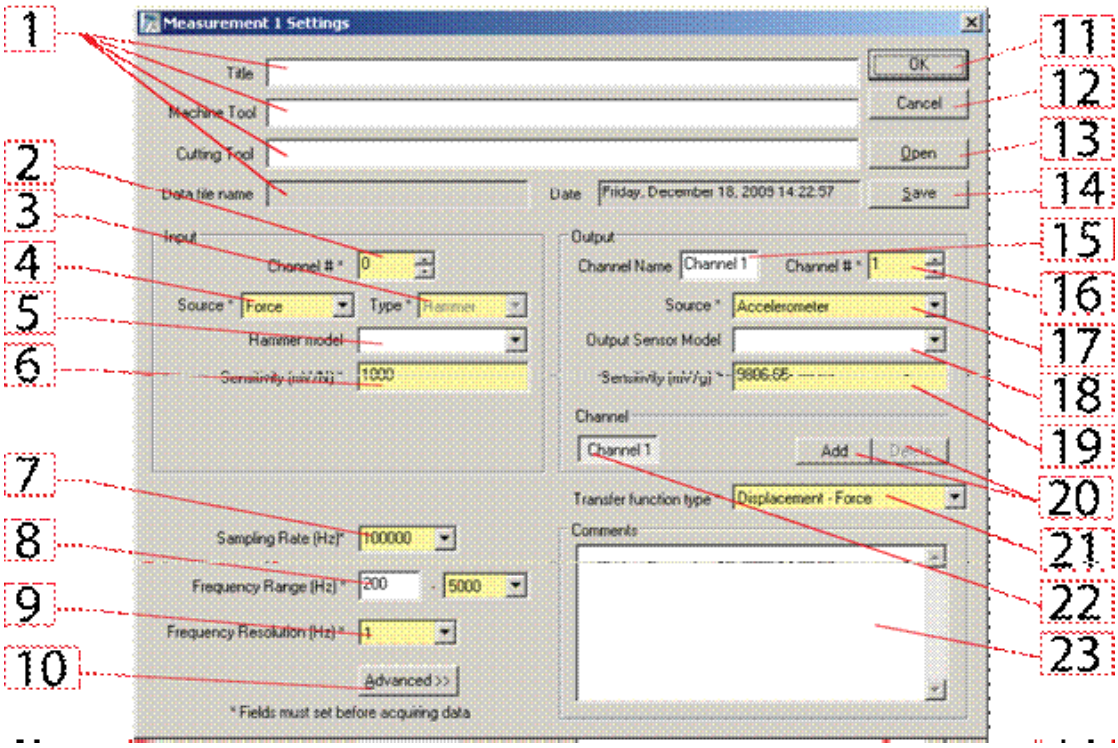
manufacturing automation laboratories MALTF

Measurement settings

In measurement settings window, information yellow colored boxes is mandatory, while the information in white colored boxes is optional.

Follow the following steps to define the measurement settings:

- Check the input (hammer) **Channel # (2)** is correct.
- Input **Sensitivity (6)** value of the hammer obtained from the manufacturer.
- Check the output (accelerometer, etc.) **Channel # (16)** is correct.
- **Input Sensitivity (19)** value of the output sensor. Make sure that the units are correct.
- Set the **Sampling Rate (7)** to a desired value. This value represents the number of data collected in one second.
- Set the **Frequency Range (8)** to a desired value. Make sure that the sampling rate is at least four times the maximum frequency range.
- Set the **Frequency Resolution (9)** to a desired value.
- You can save these values for future reference by clicking on the **Save (14)** button. The values will be saved in *.cfg format. MALTF also remembers the latest measurement settings. Therefore, if you use the same settings over and over, you don't need to set them every time.
- Click **OK (11)** to close the measurement settings window and MALTF main window will be opened automatically.



2.5.3.3 Measurement procedure

manufacturing automation laboratories MALTF

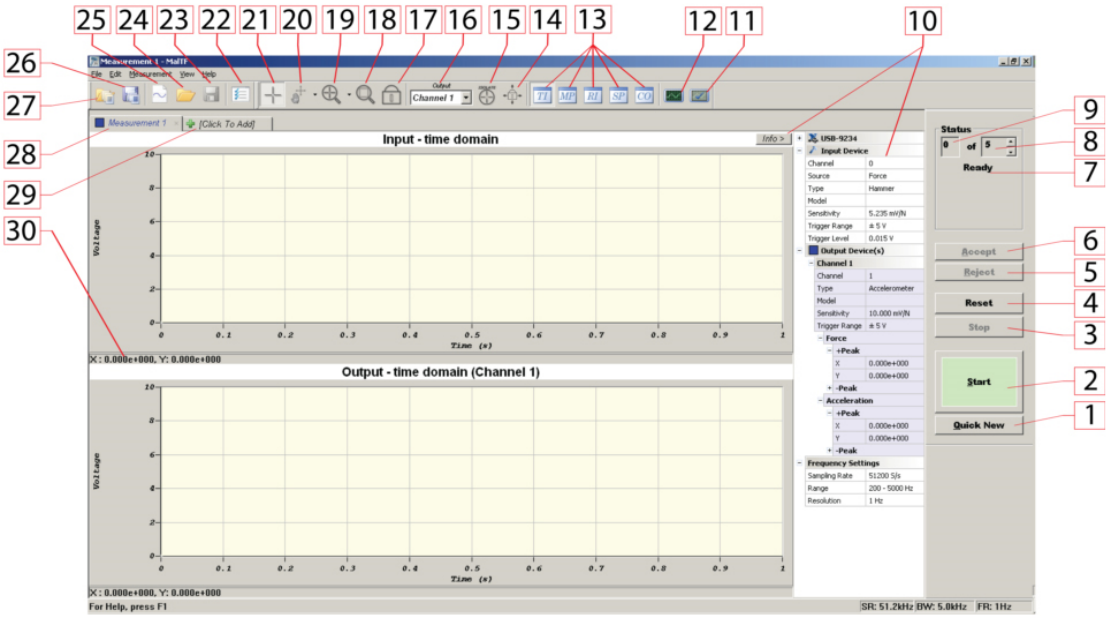
Measurement procedure

In MALTF main window, apply the following procedure:

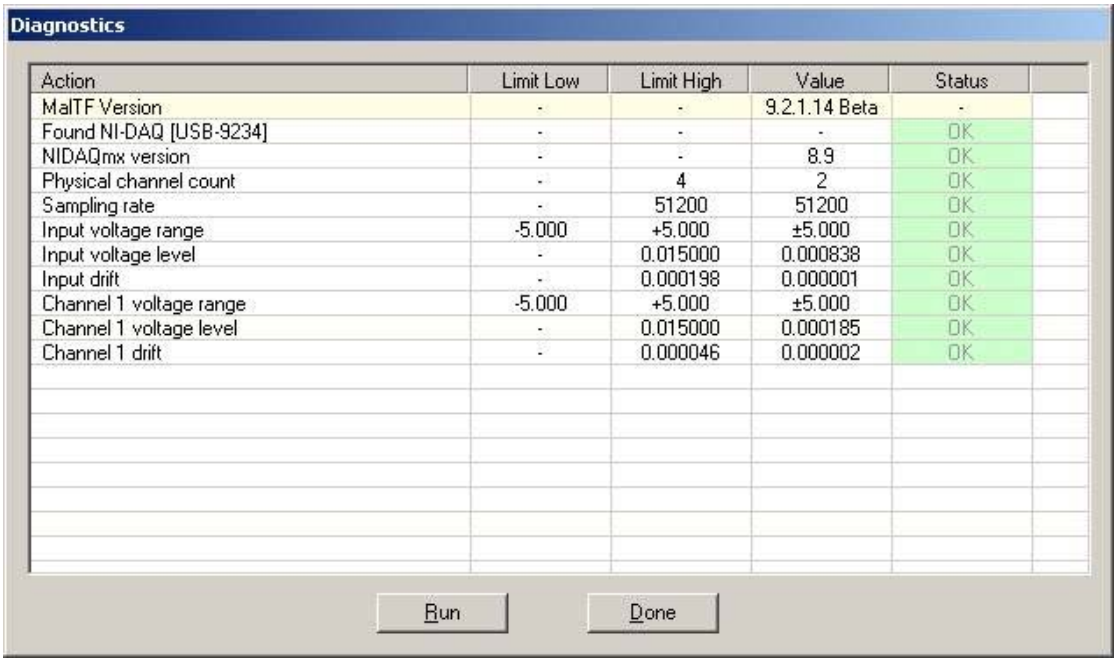
- Set the **Number of Measurements (8)** to a desired value.
- Press **Diagnosis (11)** tool to check your measurement setup. Wait several seconds if you receive drift error in any channel, and then run the diagnostic tool again. Repeat this procedure, until all items in the diagnosis list are green (OK).
- Press the **Start (2)** button to start your measurements. If you use a PCMCIA data acquisition card, make sure that the ICP power is on. If the system is just powered or cables are just connected, there may be a large offset in the data acquisition system. You need to also make sure that there is a signal in the I/O box. This is automatically checked by MalTF by popping up a **Scope (12)** window. If you don't see any signal on the **Scope (12)**, there is either a cable connection or driver problem. If the connections are correct,

you may restart the computer so that Windows can automatically detect the driver again. If the signal is present but indicates more than 0.1V voltage, please wait until it drops to about 0.005. This is caused by the capacitors in the I/O box, and they need to settle down to zero. For USB I/O boxes, settling time is only few seconds, whereas for PCMCIA cards, it is around one minute. When the voltage drops to zero, you can click on Continue or close buttons to start the measurements.

- Give an impact on the cutter opposite to the accelerometer. Impact point and direction should be right opposite of the position and direction of the accelerometer, otherwise your measurements will not be accurate. Make sure that the first impact is slightly stronger than the following impacts, since the first impact is used as a reference to check the maximum voltage set. The result is accepted automatically by MalTF. You can reject it by clicking the **Reject (5)** button.
- Continue the measurements by hitting on the cutter with the hammer. Each time data is collected, MalTF will automatically accept the measurement result if the hit is perfect, or reject if it is not good (double hit, multiple hits, or the hit is too hard). You can manually reject it by clicking the **Reject (5)** button, or accept it by clicking the **Accept (6)** button. If the measurement is accepted, the data will be used to calculate transfer function.
- When enough measurements are collected, MALTF will stop collecting data and process your measurements. You can click **(13)** to see your measurement coherence, input and output spectrums, real and imaginary parts or magnitude and phase of your transfer function. There are several important conclusions you can obtain from these graphs:
    - Check your Coherence **(CO)**. In an ideal case your coherence should be 1 at each frequency. However, due to the limitations of your measurement setup, it will be never perfect. If you receive coherence equal to one in most of the frequency range, your measurement is acceptable. If not, click **Reset (4)** button to repeat your test.
    - Check the Power Spectrum using **SP** button on the tool bar. The power spectrum of the input (top window, the hammer) must not drop to zero where there are natural frequencies, which will be indicated by the peaks in the accelerometer (bottom) window. Otherwise, the measurement will not be able to cover the high frequency region where the hammer signal is close to zero.
- If you want to perform another measurement with the same settings, click **Quick New (1)** button, and another tab **(29)** will appear.



MALTF main window.

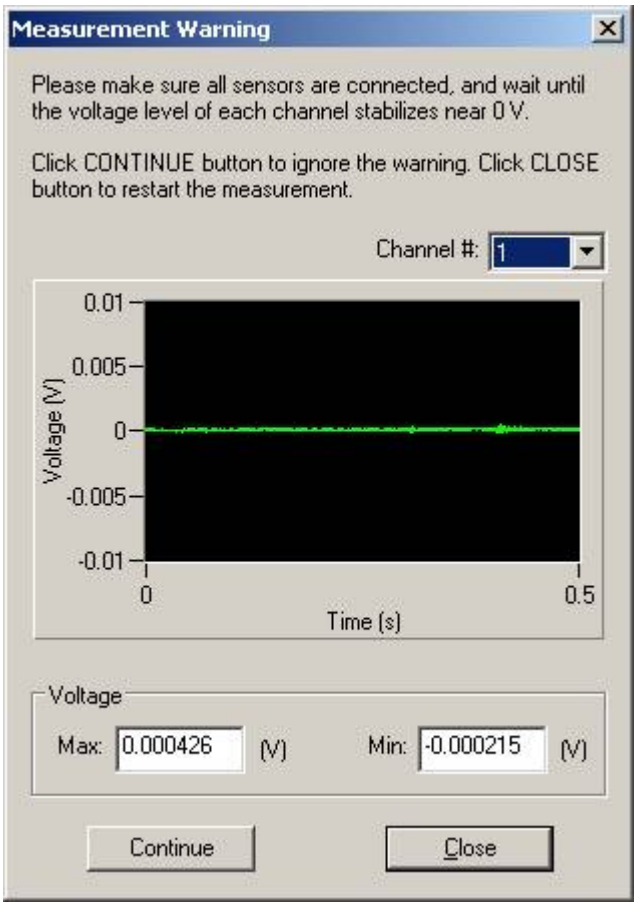


Diagnostics

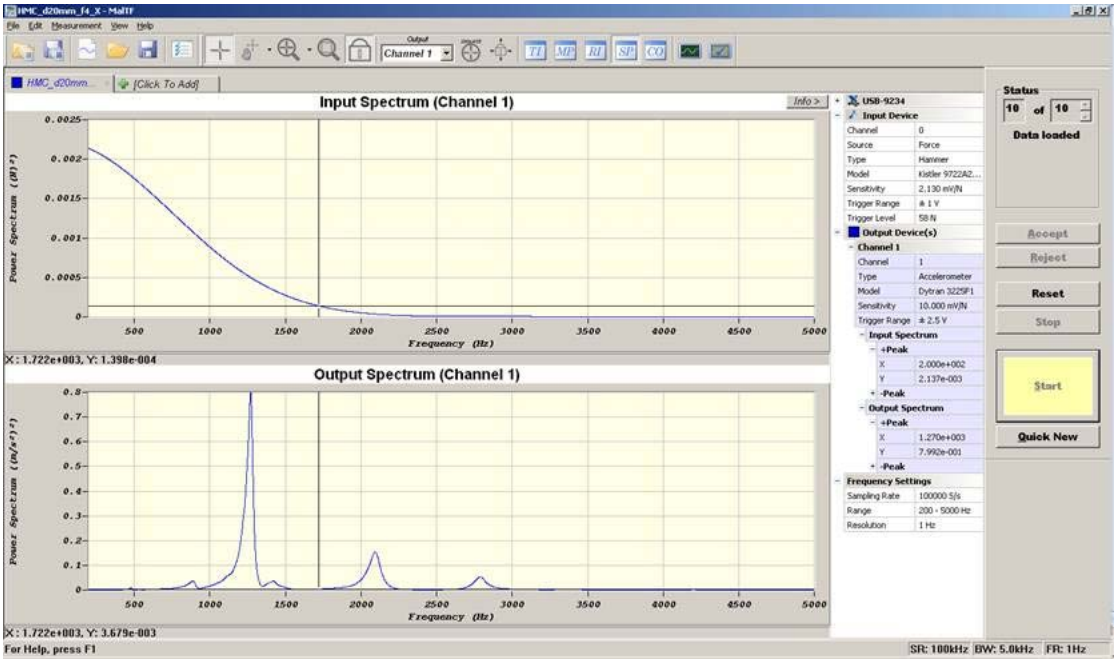
Action	Limit Low	Limit High	Value	Status
MalTF Version	-	-	9.2.1.14 Beta	-
Found NI-DAQ [USB-9234]	-	-	-	OK
NIDAQmx version	-	-	8.9	OK
Physical channel count	-	4	2	OK
Sampling rate	-	51200	51200	OK
Input voltage range	-5.000	+5.000	±5.000	OK
Input voltage level	-	0.015000	0.000838	OK
Input drift	-	0.000198	0.000001	OK
Channel 1 voltage range	-5.000	+5.000	±5.000	OK
Channel 1 voltage level	-	0.015000	0.000185	OK
Channel 1 drift	-	0.000046	0.000002	OK

Run Done

Diagnosis Screen in MALTF.



Scope window in MALTF.



Input spectrum must not drop to zero whenever you see "peaks" (natural frequencies) in the accelerometer spectrum. Otherwise, the measurement is not accurate. MALTF indicates the poor measurement zone by indicating FRF Real and Imaginary parts with broken lines.

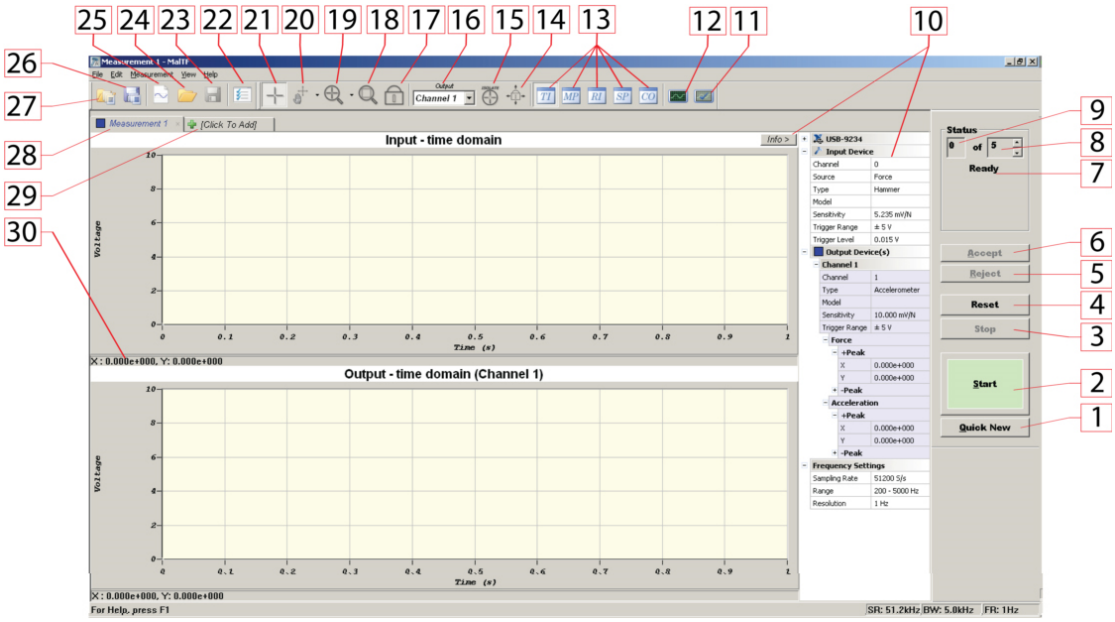
2.5.3.4 Saving & exporting

manufacturing automation laboratories MALTF

Saving & exporting

Following options are available for saving and exporting the measurements in MALTF:

- Saving as **MALTF Binary File (*.mtb)**: MALTF Binary (*.mtb) files include measurement settings, time, transfer function in time and frequency domain, as well as spectrum and coherence data. Basically, this file type is the default file type to save everything related to a measurement. You can click **Save (23)** to save your measurement.
- Saving as **MALTF Workspace File (*.mtw):** If the project consists of different measurements, i.e. Modal Analysis, Feed –Normal direction measurements, you can save the whole project file into one workspace file. If you save as a MALTF workspace file, MALTF will automatically create a folder, save every measurement individually as a *.mtb file, then save the arrangement of the tabs and the state of the program into a *.mtw file. You can click **Save Workspace (25)** to save your workspace.
- Export (All) **FRF file (*.frf)**: FRF files are text based (ASCII) files that contain 3 columns. First column is the frequency in [Hz], second and third columns are the real and the imaginary parts of the transfer function respectively. The unit of the real and imaginary parts is [m/N], even if the selected unit of MALTF is imperial. FRF files can be used in any CutPro, ShopPro, Modal Analysis or any other third party application. When there are multiple measurements, you can export all tabs to separate FRF files by clicking Export All to FRF in the File menu. The other columns of the file contain the units of the FRF file.
- Export (All) **Time file (*.txt):** Time files are also text based (ASCII) files that contain 3 columns. First column is the frequency in [s], second and third columns are the input and output of the measurement respectively. The unit of the input is Force [N] and the unit of the output is Acceleration [m/s^2]; even if the selected unit of MALTF is imperial. When there are multiple measurements, you can export all tabs to separate time domain files by clicking Export All to Time in the File menu.



2.5.4 MALTF Functions

MALTF

MalTF functions

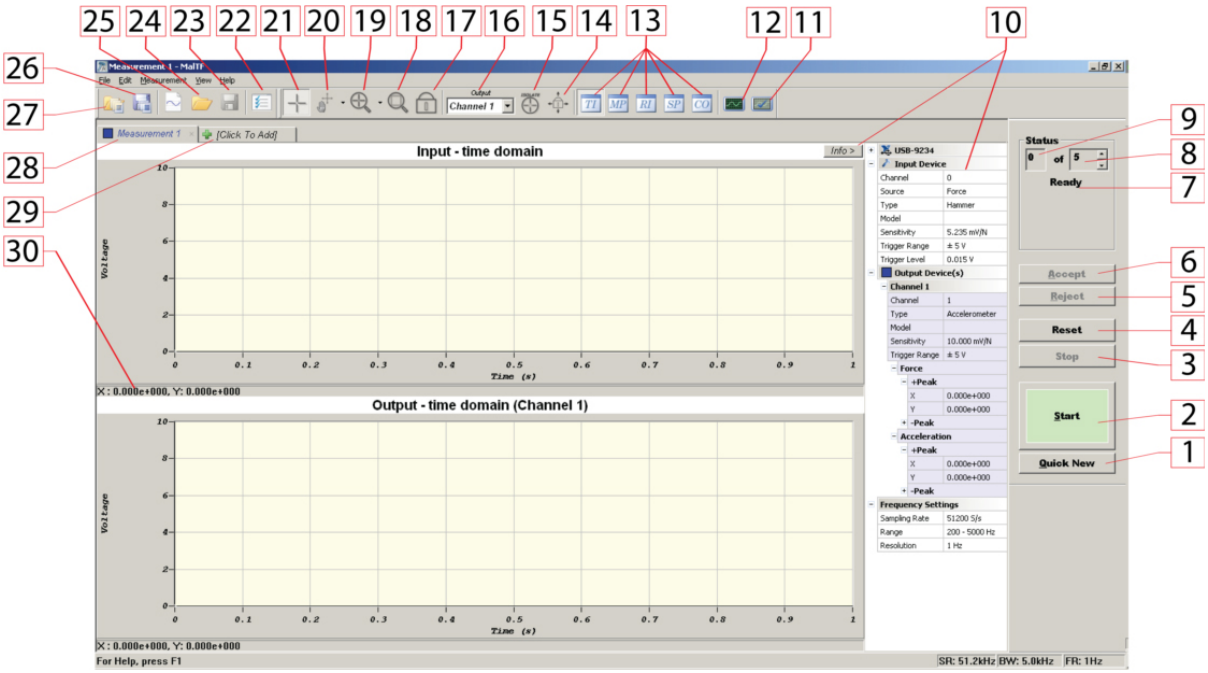
In the following pages, MALTF main window and measurement settings are explained in detail.

- Main window
- Settings window

2.5.4.1 Main window

MALTF

Main window



- **Quick New (1)**
  Quick new button opens up another tab using the same measurement settings from the previous tab. Maximum number of tabs that can be opened in one MALTF window is 8. The shortcut for this button is “q”.

- **Start (2)**
  This button is used to start the measurement. The shortcut for this button is “s”.

- **Stop (3)**
  This button is used to stop the data collection. You can resume by clicking Start button.

- **Reset (4)**
  This button is used to reset the current measurement. It will erase all accepted hits and all calculated data. If you reset, you need to repeat your measurement.

- **Reject (5)**
  This button is used to reject a measurement. When a measurement is rejected, data collected are not used to calculate transfer function, and the system is ready to retake the measurement. The shortcut for this button is “r”.

- **Accept (6)**
  This button is used to accept a measurement. When a measurement is accepted, measurements taken display increases by one, data collected are used to calculate the transfer function, and the system is ready for next measurement.

- **Message Display (7)**
  This box is used to display messages about states of measurement system, measurement instructions, and hammer hit qualities.

- **Measurements Taken Display (8)**
  This window shows the number of measurements that have been accepted so far.

- **Total Measurements Display (9)**

This window allows the user to choose the number of measurements to be taken. In MalTF transfer function is calculated based on samples averaged. For an accurate measurement, it is recommended to set this value to at least 5.

- **Information Window (10)**
  This optional window displays device settings, accelerometer, hammer sensitivities, frequency range, sampling frequency, etc. This window can be opened and closed using the button on the left. In this window, peak values of each graph is automatically calculated and listed. Using the inverse of the peak magnitude, dynamic stiffness of the system can be calculated.

- **Diagnosis Tool (11)**
  MALTF runs diagnosis to determine the state of the measurement set up. Typical set-up problems such as loose connectors, broken cables, malfunctioning I/O box or channel, and damaged accelerometer can be diagnosed using this tool.

- **Scope Window (12)**
  This button is used to open a scope window that shows the voltage of a selected channel. With this window, you can check if the data acquisition device works properly, and if the voltage level of each channel being used drops close to zero, which is mandatory for the measurements.

- **Display Options (13)**
  These options are used to choose the graph to be displayed. There are five options are available to choose from: **TI, RI, MP, SP,** and **CO.**

  - **TI:** Time domain response. This mode is used for transfer function measurements based on input data from the force hammer. Upper graph shows the input channel (hammer), and lower graph shows the output channel (accelerometer, velocity sensor, displacement sensor, or force sensor).

  - **RI:** Real part and imaginary part of the transfer function. In this mode, the upper graph shows the real part and the lower graph shows the imaginary part of the transfer function. The values of this graph can be exported as FRF file.

  - **MP:** Magnitude and phase of the transfer function. In this mode, the upper graph shows the magnitude and the lower graph shows the phase of the transfer function.

  - **SP:** Displays the input and output spectrums. The power spectrum of the input (top window, the hammer) must not drop to zero where there are natural frequencies, which will be indicated by the peaks in the accelerometer (bottom) window. Otherwise, the measurement will not be able to cover the high frequency region where the hammer signal is close to zero.

  - **CO:** Displays the cross spectrum and the coherence. In an ideal case your coherence should be 1 at each frequency. However, due to the limitations of your measurement setup, it will be never perfect. If you receive coherence equal to one in most of the frequency range, your measurement is acceptable. If not, click **Reset (4)** button to repeat your test.

- **Measurement Zoom Lock (14)**
  This button keeps the zoom status of the active tab, when the user selects a different tab. This button is helpful when you want to compare the differences between small portions of different measurements.

- **Isolate (15)**
  Isolate button displays only the active tab, removing the graphs of the other tabs from the background.

- **Output Channel Selection (16)**
  This combo box is used to select the output channel, of which data graph will be displayed.

- **Lock X (17)**
  When this button is in pressed state, X axis ranges of the upper and the lower plots will change simultaneously.

- **Zoom Extents (18)**
  This button is used to zoom out both the upper and the lower plots to original ranges. It basically resets the zoom for both graphs.

- **Zoom In (19)**
  There three options will appear if you click the arrow next to the zoom in button: zoom in both X and Y axes, zoom in X, zoom in Y axis.

- **Pan (20)**
  There are three options under this button: pan in both X and Y axes, pan in X axis, pan in Y axis. These options allow the user to scroll the data by clicking and dragging the plot area of a graph.

- **Cursor (21)**
  When this button is in pressed state, the cursor of a graph will move with the mouse, and the coordinates of the cursor will be displayed in the graph's status bar.

- **Measurement Settings (22)**
  This button opens up the measurement settings dialog box. MALTF will not let you change the settings of a saved file or finished measurement, unless you click the reset button.

- **Save Measurement (23)**
  This button saves the file as *.mtb file. MALTF Binary (*.mtb) files include measurement settings, time, transfer function in time and frequency domain, as well as spectrum and coherence data. Basically, this file type is the default file type to save everything related to a measurement.

- **Open Measurement (24)**
  Opens a (*.mtb) file, from a previous measurement and displays the result.

- **New Measurement (25)**
  This button can be used to open a new measurement tab with new measurement settings. When you click this button, settings window will appear and upon the confirmation of the settings window a new tab will open up.

- **Save Workspace (26)**
  If the project consists of different measurements, i.e. Modal Analysis, Feed –Normal direction measurements, you can save the whole project file into one workspace file. If you save as a MALTF workspace file, MALTF will automatically create a folder, save every measurement individually as a *.mtb file, then save the arrangement of the tabs and the state of the program into a *.mtw file.

- **Open Workspace (27)**

This button opens a previously saved workspace file. Since *.mtw file only contains the tab information, make sure that the remaining *.mtb files are also in the same folder.

- **Active Tab (28)**
  This window shows the name of the active measurement tab. The zoom till be reset according to the active tab, unless the **Measurement Zoom Lock (14)** is active.

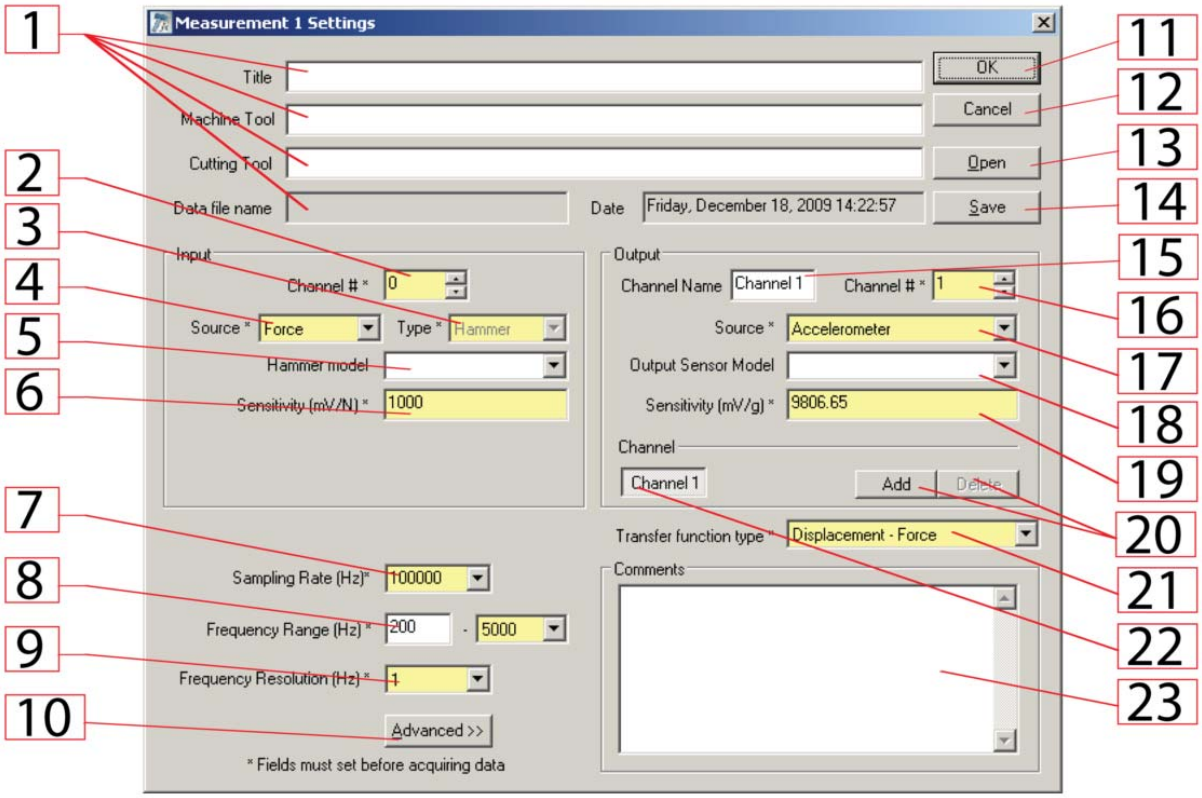
- **Click to Add (29)**
  This button opens a dialog box to ask for a new file or an existing document. If a new measurement is selected, measurement settings window will appear and new tab will be created. Similarly, if open an existing window is selected; selected existing file will be loaded in a new tab.

- **Status Bar (30)**
  Displays the cursor's coordinates.

2.5.4.2 Settings window

manufacturing automation laboratories MALTF

Settings window



- **Miscellaneous Entries (1)**

These boxes are used to enter information about the machine tool, the cutter, and the date of the measurements etc.

- **Input Channel Number (2)**
  This selector is used to select the channel number being used for input sensor (hammer).

- **Input Type (3)**
  This selector is used to choose the input type. The user can choose between hammer and shaker. The hammer is used to actuate the structure with a pulse, while the shaker is used to actuate the structure continuously with random input or sine wave. In the current version, shaker input is disabled.

- **Input Source (4)**
  This selector is used to choose the input source. It is currently set as force.

- **Hammer Model (5)**
  This box is used to choose or enter model name of the input sensor. If both the name and the sensitivity of a model are entered, this model will be saved in model database.

- **Hammer Sensitivity (6)**
  This edit box allows the user to enter the sensitivity of the input sensor. The unit system can be set to metric or imperial by going to Edit - Preferences and opening the Preference dialog box.

- **Sampling Rate (7)**
  This box is used to select sampling rate. MalTF updates the list of sampling rates automatically according to the maximum sampling rate of the data acquisition card, and the number of output channels to be used to collect data.

- **Frequency Range (8)**
  These boxes are used to enter the minimum and maximum frequencies between which MalTF calculates transfer functions.

- **Frequency Resolution (9)**
  This selector is used to choose the frequency resolution, which is the resolution or difference in frequency between each point in transfer function calculations. Frequency resolution equals to the reciprocal of sampling time. In general, lower the frequency resolution is, the longer the duration of the sample, and higher the accuracy of the calculation will be.

- **Advanced (10)**
  This button is used to close the currently opened measurement settings dialog box, and open another one with more parameter settings. For detailed information about advanced measurement settings, please contact MAL Inc.

- **OK (11)**
  Closes the measurement setting dialog box, and the parameters set will be in effect.

- **Cancel (12)**
  Closes the measurement setting dialog box and any changes made will not be used.

- **Open (13)**
  This button opens an existing measurement configuration file *.cfg.

- **Save (14)**
  This button Saves the settings to a measurement configuration file *.cfg.

- **Channel Name (15)**
  This box is used to enter a name for the selected output channel.

- **Output Channel Number (16)**
  This selector is used to choose the channel number being used for the selected output sensor.

- **Output Source (17)**
  This selector is used to choose the output source. The output source can be accelerometer, velocity sensor, displacement sensor, or force sensor.

- **Output Model (18)**
  This box is used to choose or enter model name of the output sensor. If both the name and the sensitivity of a model are entered, this model will be saved in model database.

- **Output Sensor Sensitivity (19)**
  This edit box allows the user to enter the sensitivity of the output sensor. The unit system can be set to metric or imperial by going to Edit - Preferences and opening the Preference dialog box.

- **Add/Delete Output Channel (20)**
  These buttons are used to add and remove output channels from which data will be collected.

- **Output Channel Selected (21)**
  This box displays the name of the channel that currently is selected, and its channel name, channel number, source, sensitivity are shown on the output parameters frame.

- **Transfer Function Type (22)**
  This is used to select the type of transfer function that the user wishes to display. The user can choose acceleration-force or displacement-force (in which case the system will integrate twice) when the output source is an accelerometer, or they can choose velocity-force or displacement-force (in which case the system will integrate once) when the output source is a velocity sensor. In the case that the output source is a displacement sensor, the system will display the transfer function as displacement-force.

- **Comments (23)**
  This box allows users to enter comments about the measurements for their own use.

2.6 Data Acquisition

manufacturing automation laboratories MALDAQ

Introduction

Congratulations on your purchase of MALDAQ, the line of software for impact modal testing solutions from Manufacturing Automation Laboratories.

MAL Inc. offers highly versatile PC-based data acquisition software to measure machining process data such as, force, acceleration, torque, power, and sound pressure which can be used for the diagnosis of machining operations. With CutPro MALDAQ, an entire machining operation can be collected, and the problematic locations on the part can also be tracked. Bottom line, it is an easy to use generic multi-channel data acquisition software with built-in signal analysis features.

MALDAQ Features:

- User friendly graphical user interface.
- Collects up to 8 channels of sensor data simultaneously.
- Logs and streams data to the hard drive.
- Displays real-time data.
- FFT analysis of data windows to identify vibration frequencies and tool run-outs.
- Several digital filtering options.
- Stores data in binary or ASCII text formats.
- Compatible with a variety of data acquisition and operating systems.

2.6.1 Information

2.6.1.1 Printing help information

manufacturing automation laboratories MALDAQ

Printing help information

If you wish to print just a single section of this on-line help, press the **Print** button on the toolbar (shown below).

Help buttons.

If you wish to print more than a few sections, you should open the *PDF* version of the on-line documentation. The *PDF* produces a much nicer printout.

The *PDF* version is located in the CutPro program directory.

Note: You will need Adobe Acrobat Reader to open the *PDF* file.

2.6.1.2 System requirements

manufacturing automation laboratories MALDAQ

System requirements

Required hardware and software:

- **PC:** PC with at Pentium 4 1GHz CPU, 1 GB RAM
- **Operating System:** Windows XP, Vista, or 7.
- **Data Acquisition Hardware:** MALDAQ supports National Instrument's DAQ cards that are supported in NI-DAQmx V8.9. The list of supported drivers can be found here.
- **Hardlock Key / Network Licence:** Will be provided when the software is purchased.

2.6.2 Quick Start Guide

manufacturing automation laboratories MALDAQ

MALDAQ Quick Start Quide

Before starting, follow these steps:

- Ensure the DAQ system (card+I/O box or USB) is properly connected to the computer.
- Start the program by MalDAQ from CutPro interface or by double-clicking MalDAQ.exe in CutPro9\Program folder.
- If you have received the following message, check your hardware connections and try again.

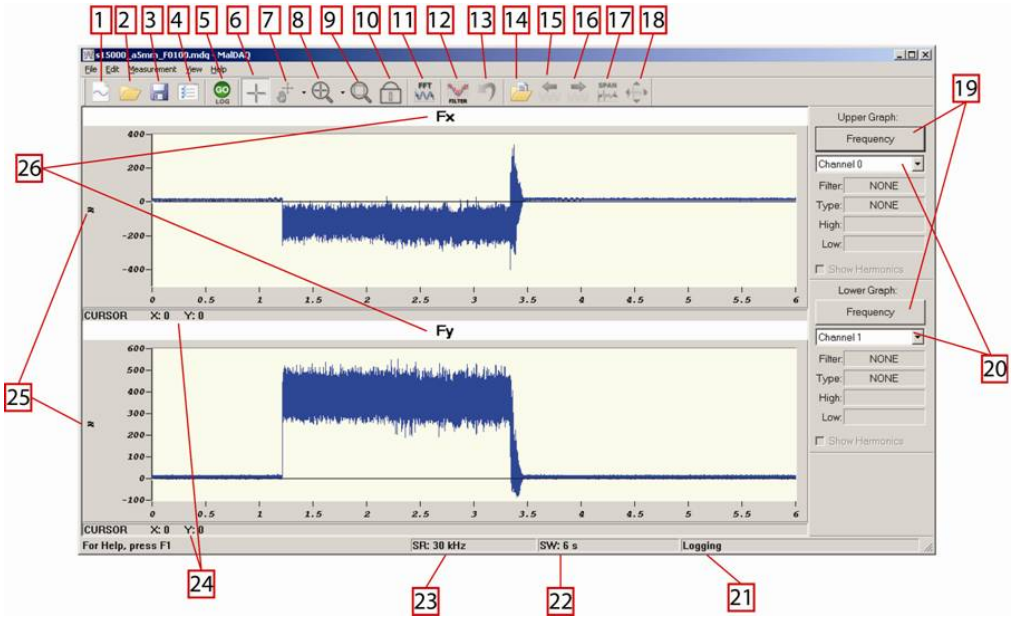
2.6.2.1 Continuous data collection

MALDAQ

MALDAQ Continuous data collection

Follow these steps to perform continuous data collection:

1. Click “MalDAQ” icon in CutPro user interface or open “MalDAQ.exe” from Cutpro9 \Program folder. MalDAQ main window will show up.

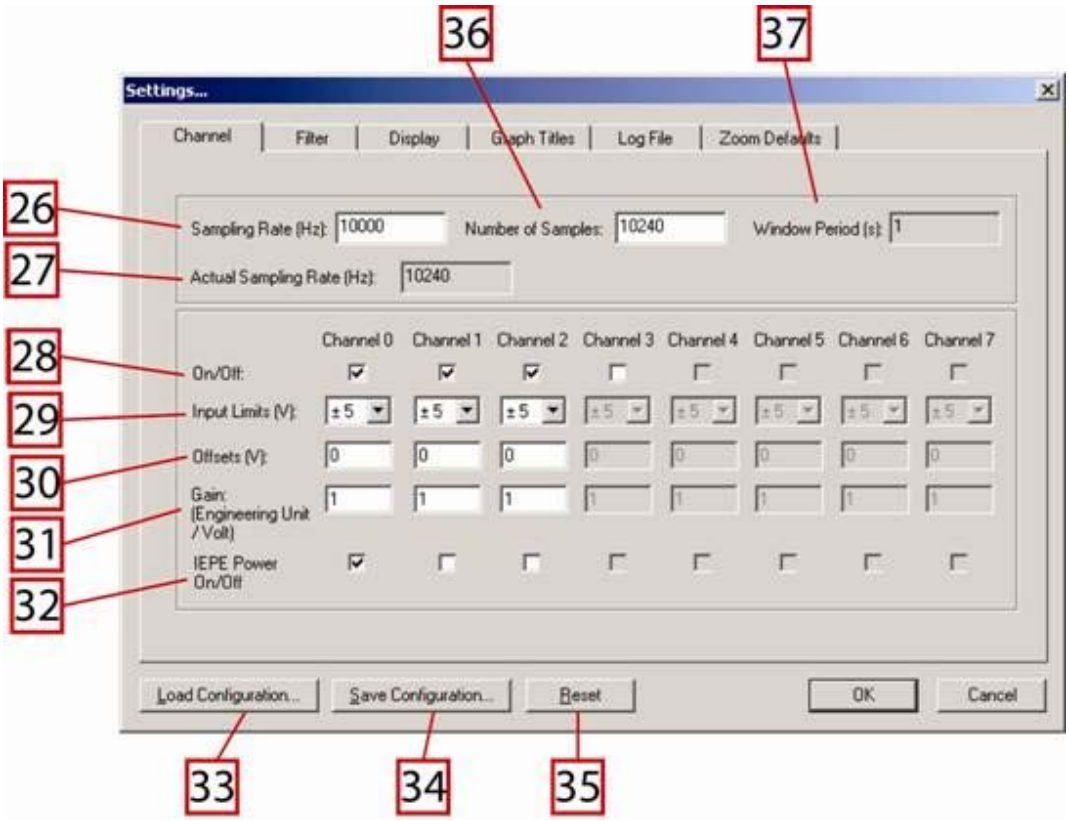


MalDAQ User Interface.

2. Click “**Settings (4)**” button to open the settings window.

3. Check / Uncheck “**On/Off (28)**” to enable the channels to be used for collecting data.

4. Enter the desired “**Sampling Rate (26)**”. If the desired sampling rate is not possible, MalDAQ will automatically adjust the sampling rate and display it as “**Actual Sampling Rate (27)**”. This might occur generally for USB DAQ systems (NI 923x or similar).



Channels Tab in the Settings Window.

5. Set the "**Number of Samples (36)**" to be displayed in one window period. One window period shows the refreshing time of the MalDAQ user interface. For example, if you set the sampling frequency and the number of samples equal, window period will be one second, which means that the new set of data will be displayed on the screen every second.

6. Set the "**Input Limits (29)**" for each channel. For USB DAQ devices, this option can be selected automatically. Refer to your card's manual for more information.

7. Set the "**Offsets (30)**" for each channel. If your DAQ card is malfunctioning and producing and offset value when it is supposed output 0V, you can use this option to eliminate that offset.

8. Set the "**Gain (31)**" of your sensor. The unit of the gain is sensor specific; however, the denominator is always Volts. For example, for piezoelectric dynamometers, gain is the value set on the charge amplifier's gain value. For accelerometers and hammers this value is the inverse of the sensor's sensitivity.

9. If you want to save the data you the hard drive, click on "**Log File**" tab and select "**Continuous Data Logging Mode (47)**". If you do not select a path in this step, MalDAQ will ask you to select it when you click "**GO (5)**".

10. Click "**OK**" to go back to the main window.

11. Select the **Channels (20)** to view in the user interface for top and bottom graphs.

You can either view the time domain or frequency content of the signal by clicking the “**Frequency/Time (19)**” button.

12. Click “**GO (5)**” button to start collecting data; the “**GO (5)**” button will be replaced by “**STOP**” button, which will stop acquiring data.

2.6.2.2 Saving & loading

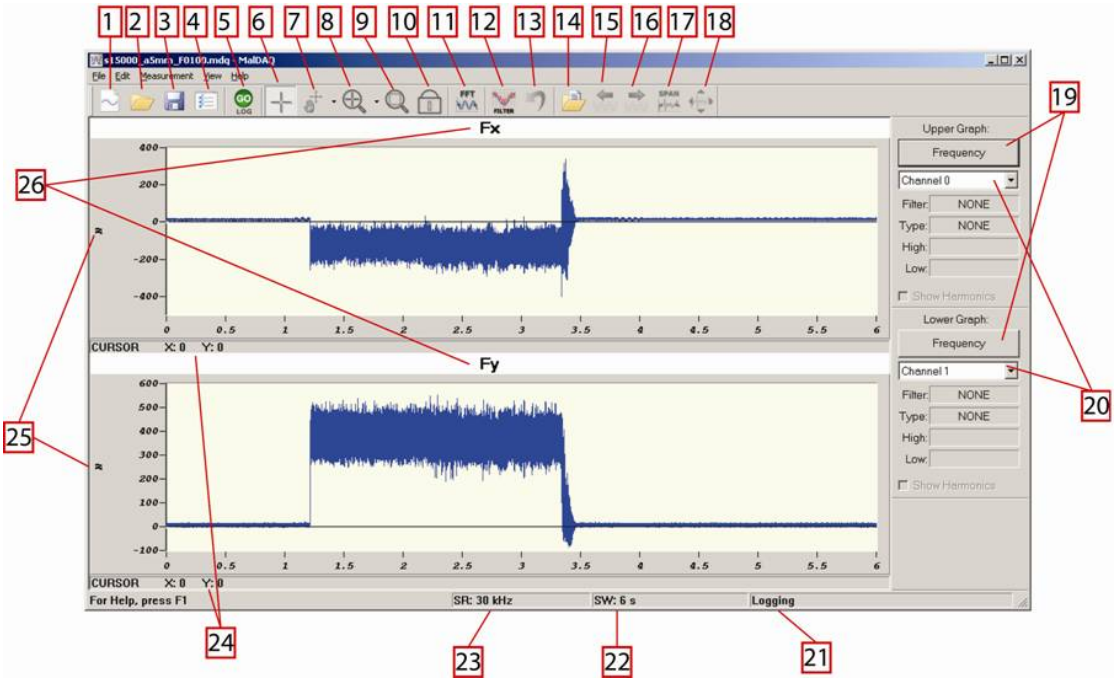
manufacturing automation laboratories MALDAQ

Saving & loading

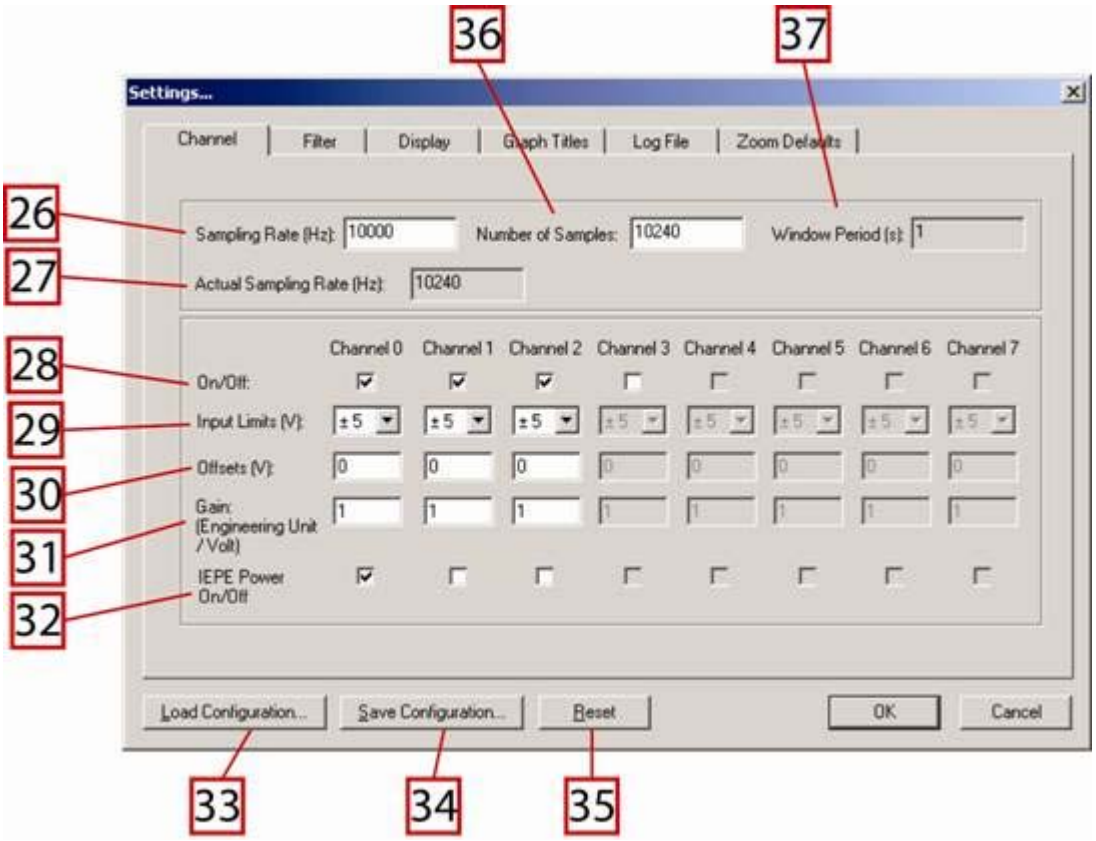
Follow these steps to save or load data:

Saving Data

1. Click “**Save (3)**” button to save the displayed data in a *.mdq file. **NOTE:** if you click “Save” button, MalDAQ will save the data only in the current window. Therefore, if your window period is short, you will save only small amount of data. In order to acquire the whole data, use the “Log File” tab in the settings window and select “**Continuous Data Logging Mode (47)**”.



2. The data in the current window can also be exported as a text file in ASCII format. From top menu, click File -> Export, and save it as a *.mdt file. The first column in the text file represents the time and the other columns represent the active channels **(28)** in the settings window.



Loading Data

1. There are two ways to load data into MalDAQ. The first one is to load data saved as a *.mdq file. In order to load a *.mdq file, click "**Load (2)**" button and select the file to be loaded using the file dialog box. As mentioned before, *.mdq files store only one window period.

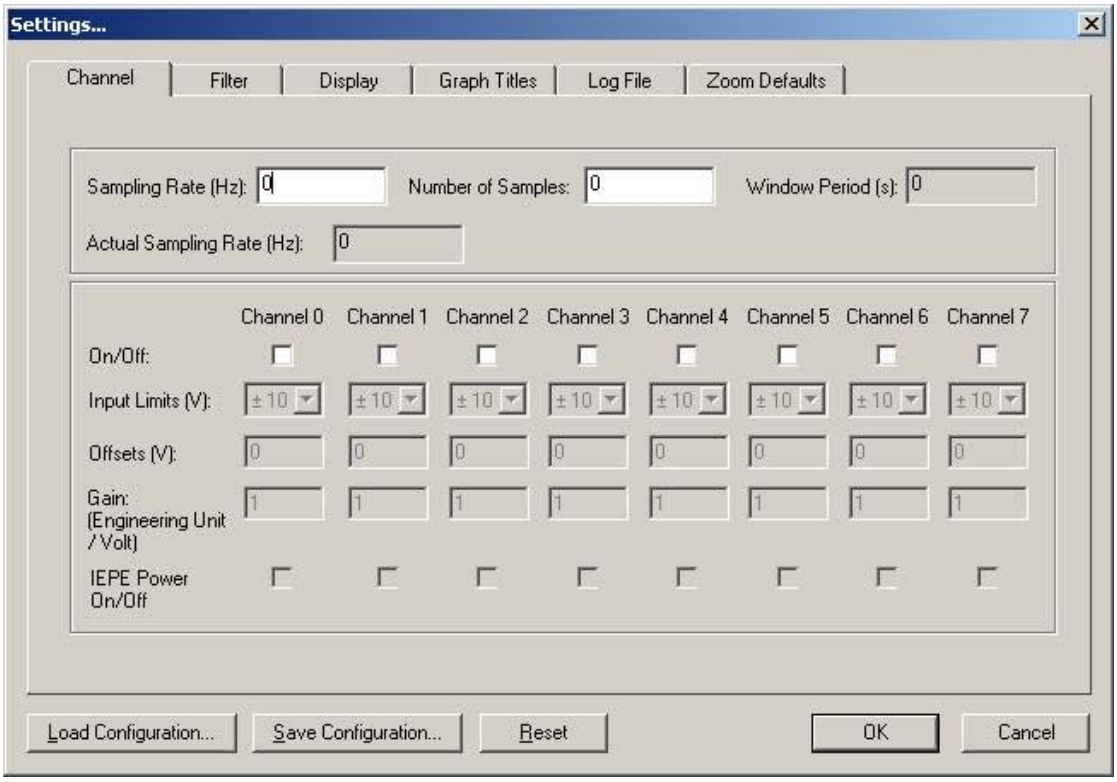
2. In the second method, you can load logged data into MalDAQ, click "**Load Logged Data (14)**" button. Logged data consists of different files in different types. Select the *.cfg data located in that particular folder where your logged data files are. When the data is loaded, it will display only the first window period. In order to display the entire data set, click "**Time Span Window (17)**" to display data between a specific time range or "**Time Span Cursor (18)**" to select with mouse. "**Time Span Cursor (18)**" will display the entire dataset, and set the mouse cursor to X axis zoom. Another way of browsing the logged data is to use the "**Pan Log (15) and (16)**" buttons. By using these buttons, it is possible to horizontally pan the data to left or right.

2.6.3 Settings Window

manufacturing automation laboratories MALDAQ

Settings Window

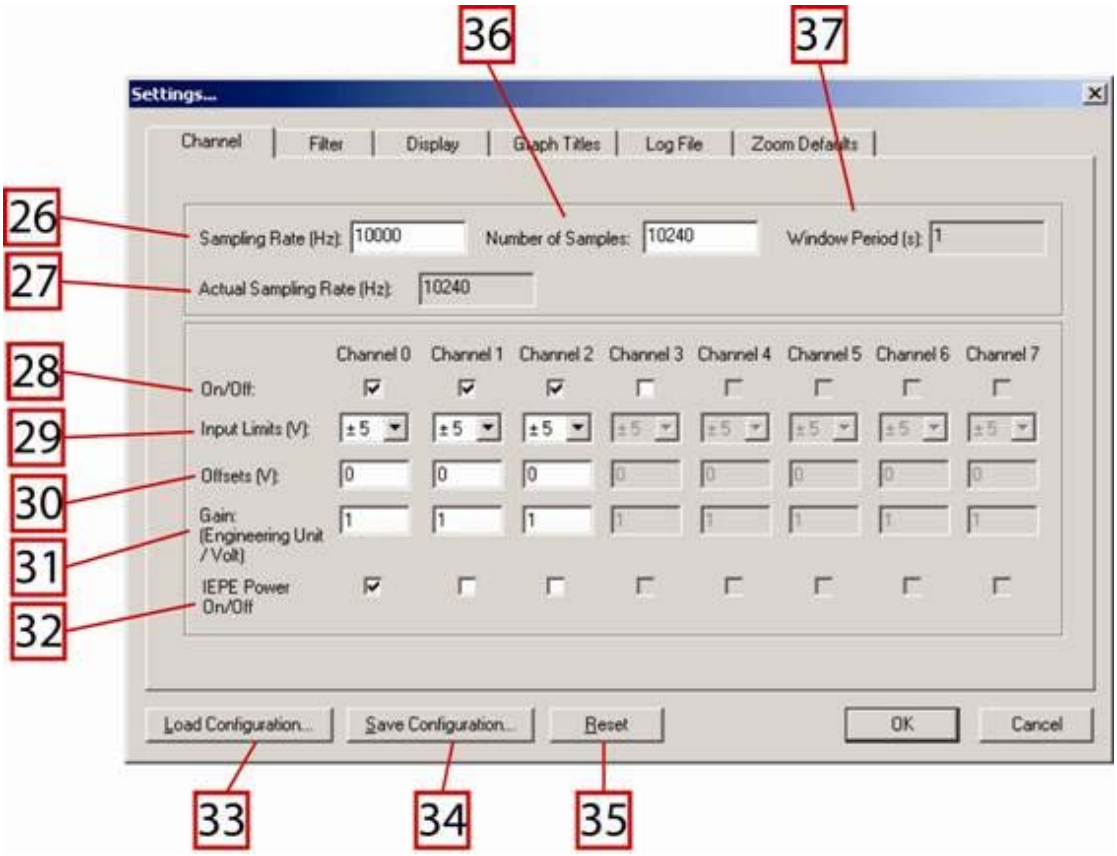
This section explains the settings window in MalDAQ. There are six tabs on the Settings window: Channel, Filter, Display, Graph Titles, Log File, and Zoom Defaults. Following pages explain each tab in detail.



2.6.3.1 Channel tab

manufacturing automation laboratories MALDAQ

Channel tab



- **Sampling Rate (26):** This data specifies the sampling rate in Hz for time-domain data acquisition. The maximum sampling rate is dependent upon the DAQ hardware used. MalDAQ can automatically recognize wide range of National Instruments PCMCIA cards and USB I/O boxes. Current version of MalDAQ includes NIDAQmx v8.9; therefore it supports all instruments supported by NIDAQmx. Refer to National Instruments' website and contact MAL Inc. if you are planning to buy a new DAQ hardware. The absolute maximum sampling rate in MalDAQ is 250,000 Hz; however it is automatically adjusted according to the hardware.

- **Actual Sampling Rate (27):** Depending on the hardware, MalDAQ automatically recognizes the available sampling rates of the hardware and displays the best available sampling rate in this box.

- **Number of Samples (36):** Number of samples determines how much data will be displayed on the screen before it is refreshed. If the number of samples selected is very low compared to the sampling rate, the screen will be refreshed very quickly.

- **Window Period (37):** Window Period is an inactive display, which calculated by Number of Samples / Sampling Rate. It shows how much time is required to refresh the screen and display the new set of data.

- **On/Off (28):** This check box allows the user to select which channels to be used for data collection. Check the box to select the corresponding channel.

- **Input Limits (V) (29):** This option sets the input limits for each channel selected, defining the input range for the channels on the DAQ hardware. These limits should be set as

close to the maximum input as possible. If they are too small, the signal will be cut-off. The more accurate you set this value, less noise you will get. There is a maximum value of +/- 10V for the input limits. This value can be set to lower values than the DAQ hardware's maximum, but it should not be higher. In addition, the actual input signal should not exceed the maximum range for the input voltage. If possible, MalDAQ will automatically recognize and set the maximum input limits of the DAQ device.

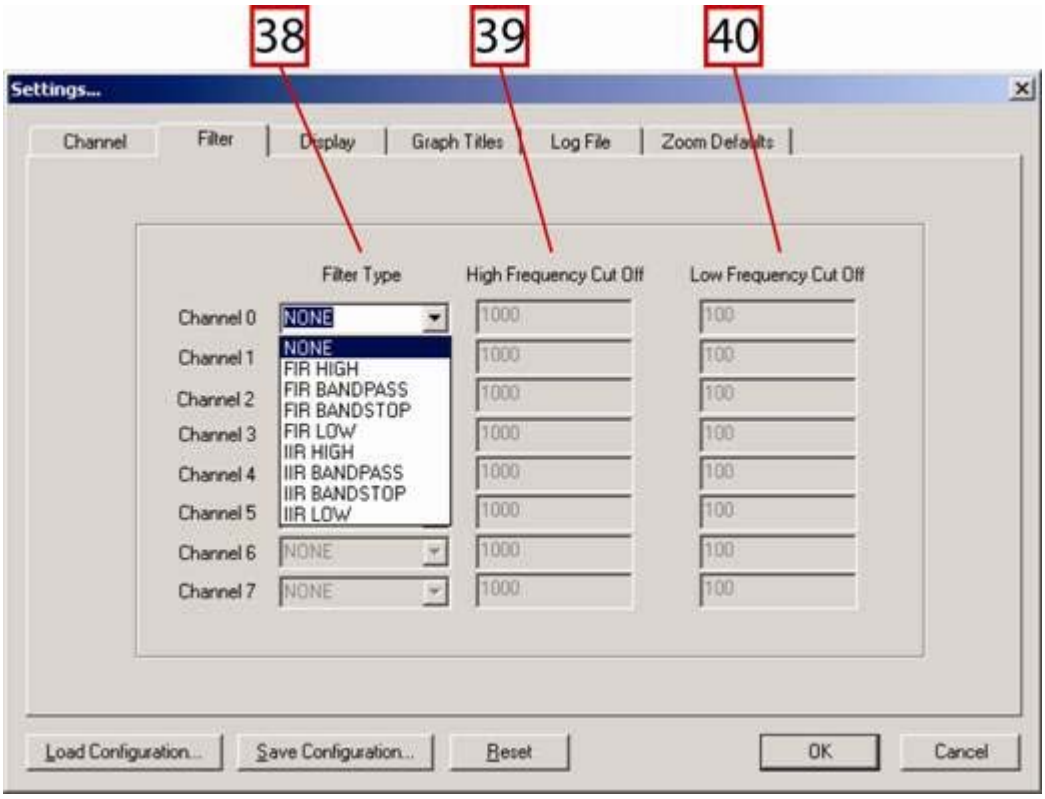
- **Offset (V) (30):** This feature allows the user to enter offsets for particular channels, the offset is in Volts. For example, if Channel 0 outputs 0.3V enter 0.3 here to remove the offset.
- **Gain (Engineering Unit/Volt) (31):** This is the scale factor of the measured unit in Unit/ Volt. It depends on the sensitivity of the charge amplifier and/ or sensor used in data acquisition.
- **IEPE Power On/Off (32):** Check this box if your sensor requires external power to run. This checkbox should be enabled for impact hammers, accelerometers and disabled for force sensors.
- **Load Configuration (33):** This button allows the user to load a System Configuration file previously saved.
- **Save Configuration (34):** this button allows the user to save the current settings into a System Configuration (*.cfg) file for later use.
- **Reset (35):** this button resets the settings to default and deselects all channels. All settings that have been changed will be lost.

2.6.3.2 Filter tab

manufacturing automation laboratories MALDAQ

Filter tab

There are three columns in the Filter tab: Filter Type, High Frequency Cut Off, and Low Frequency Cut Off. Each Setting can be set individually for each channel.



Filter Type (38): There are eight filter types:

FIR HIGH	IIR HIGH
FIR BANDPASS	IIR BANDPASS
FIR BANDSTOP	IIR BANDSTOP
FIR LOW	IIR LOW

FIR stands for Finite Impulse Response and **IIR** stands for Infinite Impulse Response. The **FIR** Filter is designed in terms of the finite impulse response by using Equiripple Filters. This kind of filter has an important property of *linear-phase*; which means the phase-lag of the filter is linear versus frequencies. However, the amplitude response is not very accurate. Select **FIR** Filters only when linear-phase property is required. The **IIR Filter** is designed in terms of the infinite impulse response by using 5th order Butterworth Filter. It is recommended for regular noise filtering, since it has a very good amplitude response.

High-pass filters can be used to filter out the low frequency signals; low-pass filters can be used to filter out the higher frequencies.

Band-pass filters filter out signals of other frequencies other than the selected frequency range; band-stop filters filter out signals from the selected frequency range.

- **High Frequency Cut Off (39):** It is the high cut-off frequency for only the **band-pass**

and **band-stop** filters. It serves no purpose for the **low-pass** and **high-pass** filters.

- **Low Frequency Cut Off (40):** It is the low cut-off frequency for the **band-pass** and **band-stop** filters as well as the cut-off frequency for **low-pass** and **high-pass** frequency.

All Frequencies and coefficient generation are guaranteed to be within 5% of theoretical values. The Minimum frequency for filtering is 200 Hz, as lower values do not allow the mathematics to generate effective coefficients with reasonable roll-off.

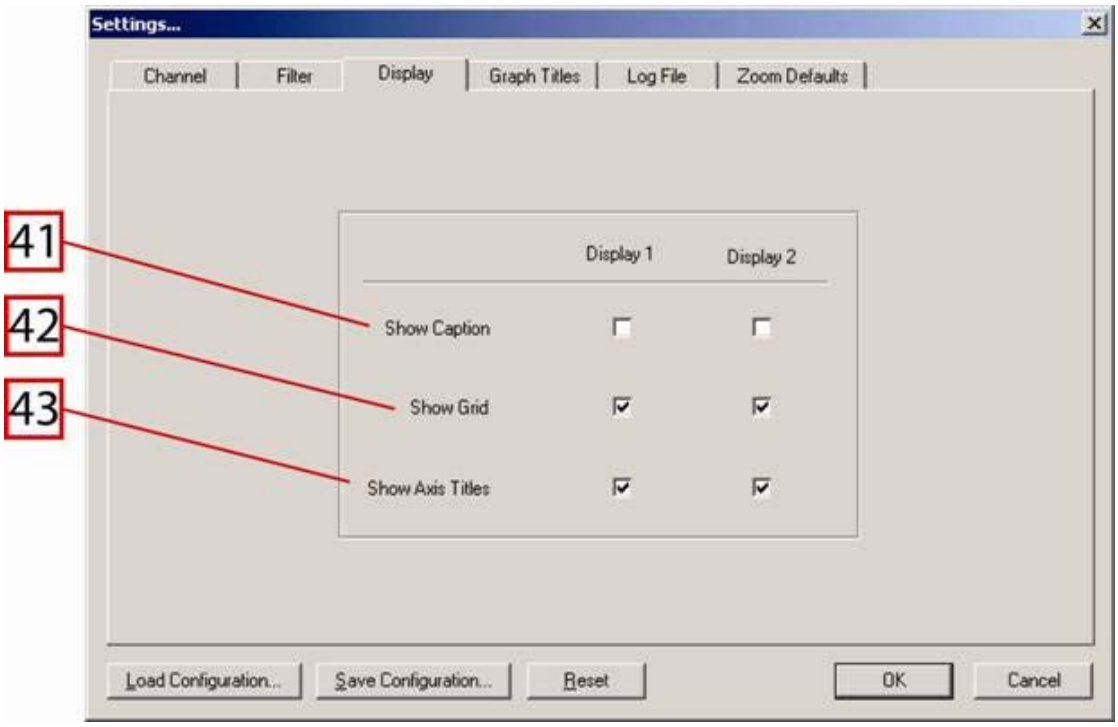
***NOTE**: when using filtering, the calculations can take a lot of time, which may impede on real-time acquisition time constraints. Therefore it may be suggested that if continuous acquisition without data being dropped is of importance, the user should either increase the number of samples to allow more time for calculations, or not use the digital filtering. When data is dropped, transients will show up. Transient behavior will always be seen on the first collected data.*
(transients are filtering responses to new data.)

2.6.3.3 Display tab

manufacturing automation laboratories MALDAQ

Display tab

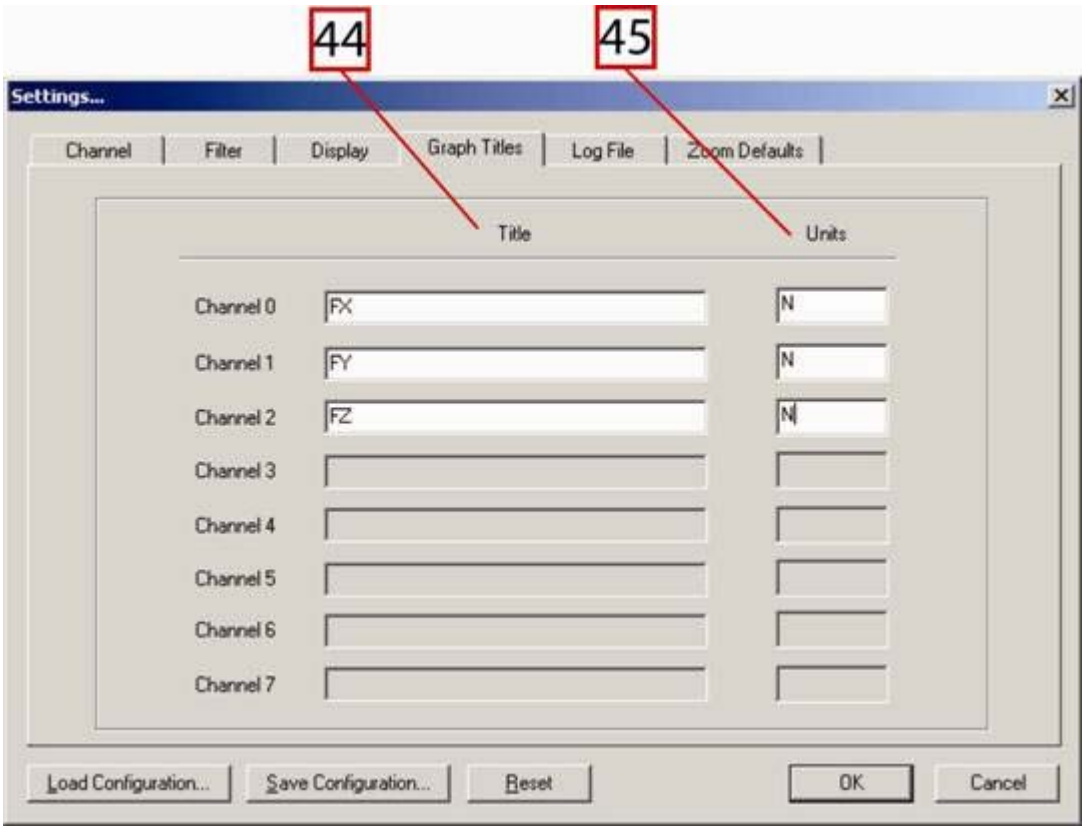
Three display options are available for each display panel in MalDAQ: “**Show Caption**”, “**Show Grid**”, and “**Show Axis Titles**”.



- **Show Caption (41):** This option, when enabled, shows the title of the corresponding graph (Upper and lower graphs in the main window). The text of each graph can be set in the next tab.
- **Show Grid (42):** This option, when enabled, shows the grid on the corresponding graph.
- **Show Axis Titles (43):** This option, when enabled, shows the Y-axis label for each graph window (Can be set in the next tab).

2.6.3.4 Graph titles tab

Graph titles tab



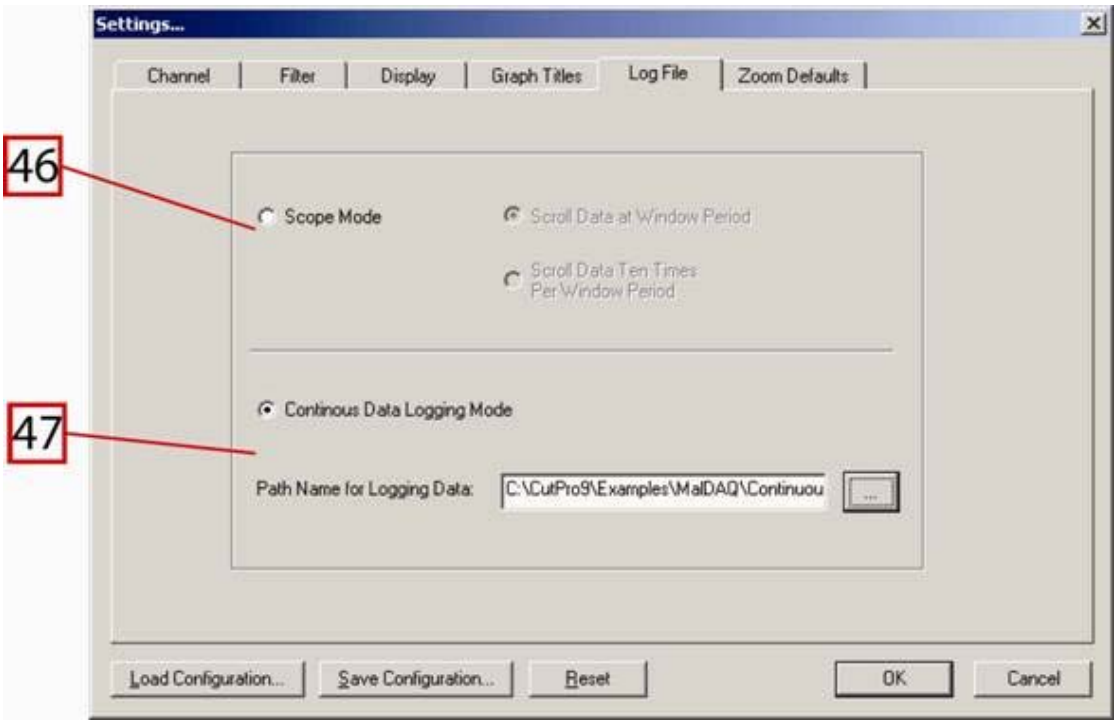
This tab allows the user to label each channel used (**44**) as well as defining its unit (**45**). “Units” column sets th Y-axis labels for each channel. In the figure above, sample titles and their units are entered. The titles and units can be displayed on the graph if appropriate options are selected (see Display Tab).

2.6.3.5 Log file tab

manufacturing automation laboratories MALDAQ

Log file tab

This tab allows the user to select if the measurement will be logged to the hard drive or only displayed on the screen as a scope.



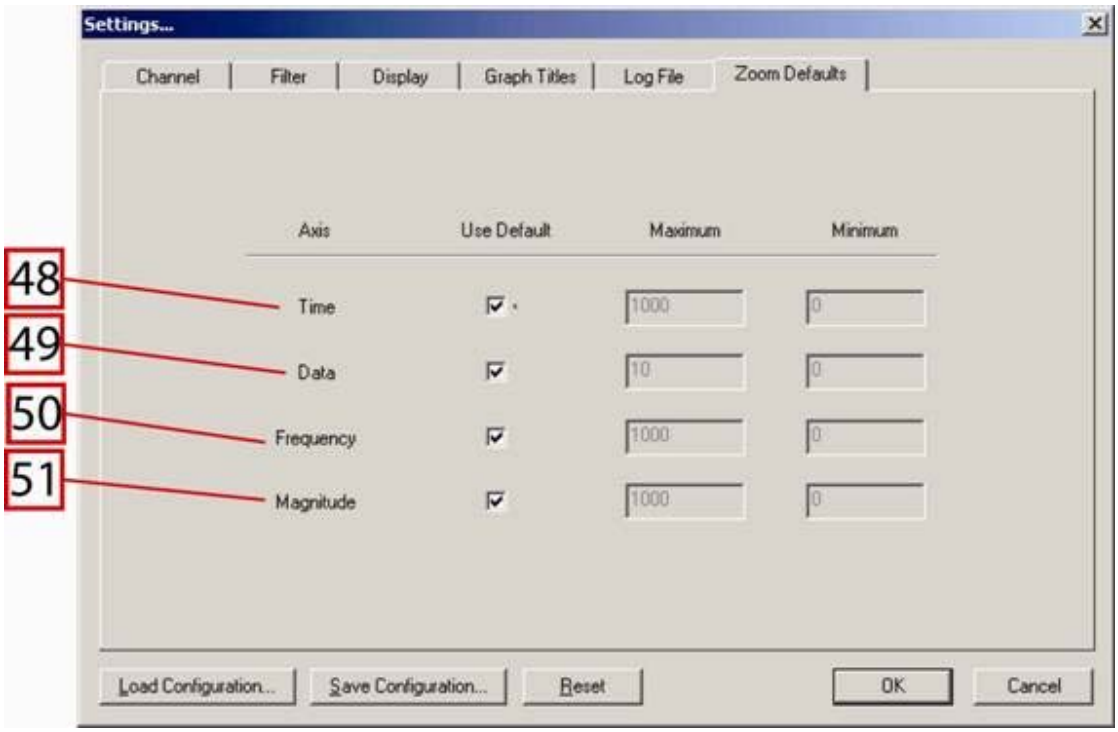
- **Scope Mode (46):** If the “Scope Mode” radio button is selected, the measurements will not be logged on the hard drive. It will be displayed on the screen and refreshed either every window period or on tenth of the window period. For example, when the window period is selected as 50 seconds, MalDAQ will update the graphs either every 50 seconds or 5 seconds. However, the window period always will be 50 seconds. The effect of scrolling will scroll data across the screen in segments simulating an oscilloscope.

- **Continuous Data Logging Mode (47):** If the user selects this option, MalDAQ will save the entire measurement and the measurement settings to the hard drive. User can select the path in this tab, or leave it blank. If it is left blank, MalDAQ will ask user a path file, just after the “**GO**” button is pressed in the main window. MalDAQ will create a folder and save everything in that folder. The data will be saved in the specified *.log file, with a number at the end. For example, if “Test” is selected as the log path name, MalDAQ will create a folder named “Test” in the specified path and will save the data starting from “Test1.log”. After the first log file reaches 100MB, MalDAQ will automatically start writing to a second file, “Test2.log”.

2.6.3.6 Zoom defaults tab

manufacturing automation laboratories MALDAQ

Zoom defaults tab



This tab enables user to edit the zoom defaults of the display. By enabling the "**Use Default**" checkbox, the corresponding axis will be automatically scaled to fit the data collected. If the "**Use Default**" checkbox is disabled, the maximum and the minimum of the corresponding axis can be entered manually. This range will be applied to both displays. User can select between time ranges (**48**), data ranges (**49**), frequency ranges (**50**), and FFT magnitude ranges (**51**).

2.6.4 Main Window

manufacturing automation laboratories MALDAQ

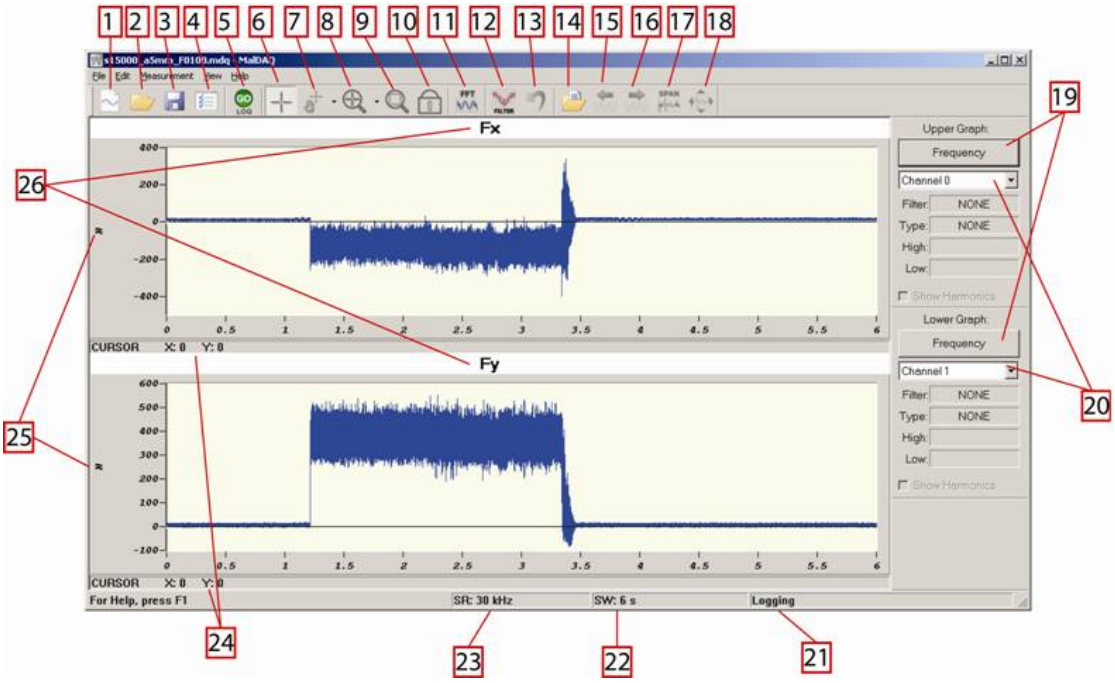
MALDAQ Main Window

This section the manual explains the commands both in the interface and the file menu.

2.6.4.1 Interface

manufacturing automation laboratories MALDAQ

Interface



- **New (1):** Use this button to create a new document in MalDAQ. This replaces any previously opened measurements. MalDAQ asks to save changes to the current document before creating a new document. If the user creates a new document without saving, all changes made will be lost since the last time it has been saved. Before replacing an untitled document, MalDAQ displays the "**Save As**" file dialog box and asks user to name and save the document.

- **Open (2):** Use this button to open a new document in MalDAQ. This replaces any previously opened measurements. MalDAQ asks to save changes to the current document before opening a new document. If the user opens a new document without saving, all changes made will be lost since the last time it has been saved. Before replacing an untitled document, MalDAQ displays the "**Save As**" file dialog box and asks user to name and save the document.

- **Save (3):** Use this button to save the active document under its current name and directory. When you save a new document for the first time, MalDAQ will display the "**Save As**" file dialog so the user can name the document. If you want to save the document with a different name or path, use "**Save As**" from the file menu.

- **Settings (4):** This button opens up the "**Settings**" window. Please see the detailed help for this window.

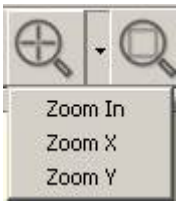
- **Go/Stop (5):** MalDAQ starts collecting data when this button is pressed. It is replaced by "**STOP**" button when collecting data.

- **Cursor (6):** Normally, the user in standard operate mode, indicated by the crosshair. In standard operate mode, you can click on the graph to move cursor around. The graph control will update the "**Cursor Locations (24)**" just below the graph. By default, the cursors are locked to data points.

- **Pan (7):** if the user presses the pan tool, it will switch out of the standard operate and the user can scroll the data in the current window by clicking and dragging the plot area of the graph. The "**Pan**" toolbar allows the user to pan the graphs in X direction, Y direction, and

both X and Y directions. These options are available beside the button on the pull down menu for the toolbar command.

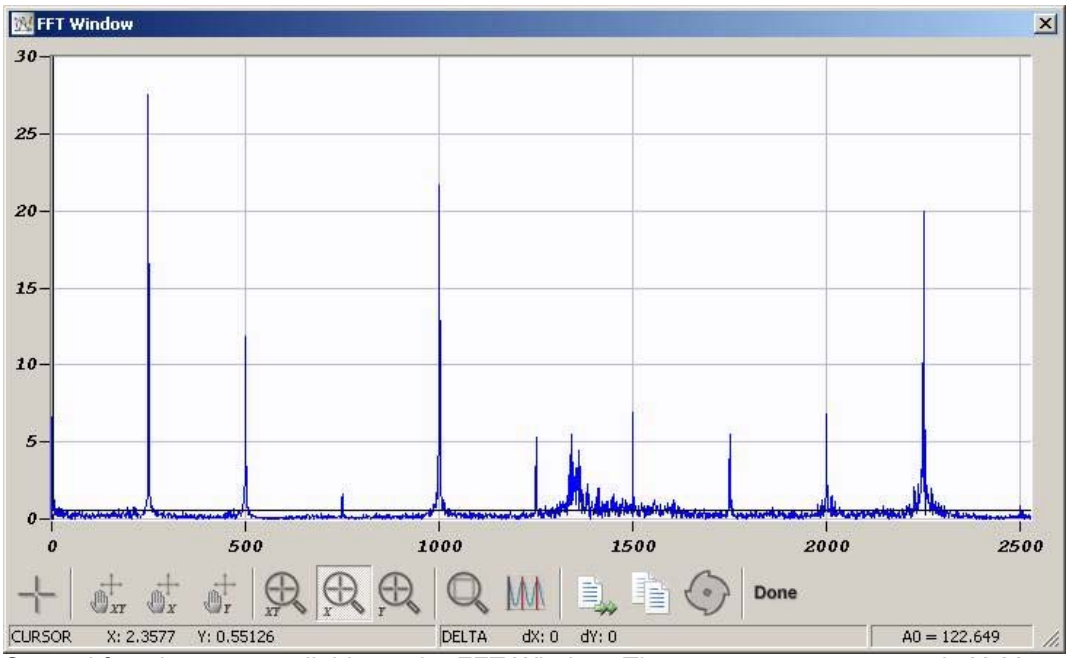
- **Zoom In (8):** This button allows the user to zoom in or out on the graph. If the arrowhead on the right hand edge of the button is pressed a pop-up menu will be shown. "**Zoom In**" zooms by rectangle, "**Zoom X**" keeps the Y axis unchanged, and "**Zoom Y**" keeps the X axis unchanged.



- **Zoom Extents (9):** This button will reset the zoom in both graphs and display the whole data in the current window.

- **Lock X (10):** Use this command to lock the X axes of both graphs in the current view together. Next time either graph is zoomed or panned, the other graph's X axis will be rescaled such that it has the same extents as the zoomed view.

- **FFT Window (11):** This command allows the user to perform a Fourier Transform on a selected region of the graph. To use this command, simply click it and select a region on the graph using the mouse. A new FFT window will open, displaying the Fourier Transform of the selected time range. It is disabled during data acquisition.



Several functions are available on the FFT Window. The user can pan or zoom in X, Y, or both X and Y directions by clicking the appropriate button. The graph can also be reset to the default scale by pressing *Zoom Out*. The *Copy* button copies the FFT graph onto the clipboard. Clicking *OK* buttons closes the FFT window and returns to the main window. You can see the harmonics of the peaks by selecting the "**Show Harmonics**" button and selecting a peak. You can also save and export the FFT graph or detect the chatter frequency by clicking the "**Find Chatter**" button. At the bottom, you can see the position of the cursor, and the difference between two consecutive clicks on the graph. A0 is the average value of the FFT, which corresponds to the average of the selected sample.

- **Kalman Filter (12):** This button displays the Kalman Filter wizard. Detailed help can be found in the following sections of this manual.

- **Revert (13):** This button deletes the Kalman filtered data and reverts to the original data.

- **Load Logged Data (14):** This command allows user to load a previously saved logged data by opening a *.cfg file which contains the path and the filename of the logged data. This command opens a file dialog. To unload the data, simply click this button again.

- **Pan Log Left (15) and Pan Log Right (16):** This command allows the user to pan the logged data to the left and to the right on the x-axis. To pan to the right, click the button with the right arrow; then select a region of the graph with the same width as the desired size of pan. For example, if you wish to pan to the right by 3 grids, simple select 3 grids on the graph. The panning applies to both upper and lower graphs. Note that this button is enabled only after a logged data is loaded.

- **Time Span Window (17):** This command opens a new window which allows the user to enter the start time and the end time in seconds to display the data. The window also displays the sampling frequency and the total duration length of the log. Note that this button is enabled only after a logged data is loaded.

- **Time Span Cursor (18):** This button serves the same purpose as the "**Time Span Window**", except MalDAQ will displayed the entire logged data an you can zoom the desired portion of the logged data by drawing a rectangle around it.

- **Frequency/Time (19):** This button switches the graph between Frequency and Time Domain. Press "**Frequency**" if you wish to view the graph in frequency domain; press "**Time**" if you wish to view the graph in time domain. ***Note:*** *When collecting data in real-time, FFT is only performed if this button is pressed to "Time" (meaning presently in frequency domain). FFT is a computationally intensive action meaning it may impede on real-time constraints. Therefore it may be suggested that if continuous acquisition without data being dropped is of importance, the user should either increase the number of samples to allow more time for calculations, or not use FFT. (Especially in scrolling when often there are large data numbers).*

- **Channels (20):** This box determines which channel to display on the corresponding graph.

- **Log Status (21):** This display shows if the current measurement will be logged to the hard drive. It will display "**Logging**" when the user selects "**Continuous Data Logging Mode**" in settings window, and "**Not Logging**" otherwise.

- **Sampling Window (22):** This label displays the current sampling window time which is set in the settings window.

- **Sampling Rate (23):** This label displays the current sampling rate which is set in the settings window.

- **Cursor Locations (24):** These labels show the X axis and Y axis values of the cursor which is shown with a red crosshair for both graphs.

- **Y axis Labels (25):** These labels will display the units of the graphs if they are entered in settings window.

- **Graph Titles (26):** These labels will display the titles of the graphs if they are entered in settings window.

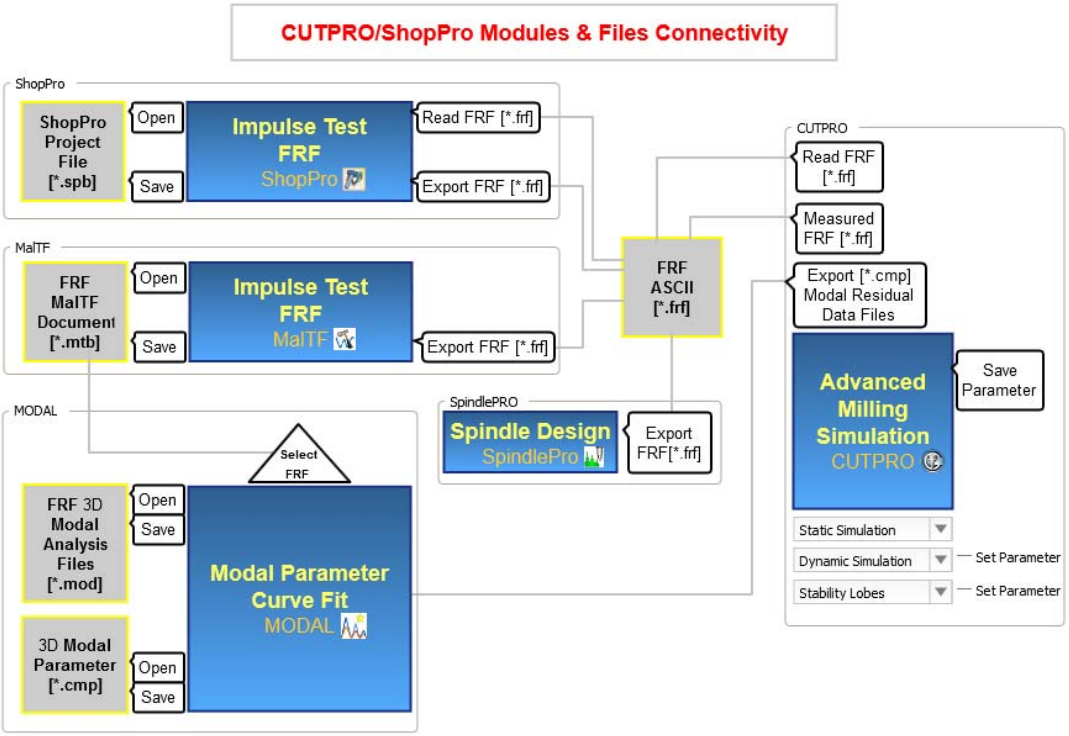
File Formats

3 File Formats

manufacturing automation laboratories CUTPRO

File Formats - Connectivity Graph

The follow graph represents how files are linked between modules in CutPro:



NOTES

- SpindlePro can not be used in imperial units
- ShopPro FRF outputs files in µm/N or inch/lbf, all other modules/softwares are in m/N or inch/lbf.

Training / Videos

4 Training / Videos

manufacturing automation laboratories CUTPRO

Training / Videos

The latest videos in high definition quality are available on our website for free under the training tab.

Training Page: http://www.malinc.com/training/

CutPro Start-to-Finish Guide: http://www.malinc.com/wp-content/uploads/2014/05/CutPro_Guide.pdf

CutPro Video Guide: http://www.malinc.com/training/cutpro-video-manual/

Support / Helpdesk

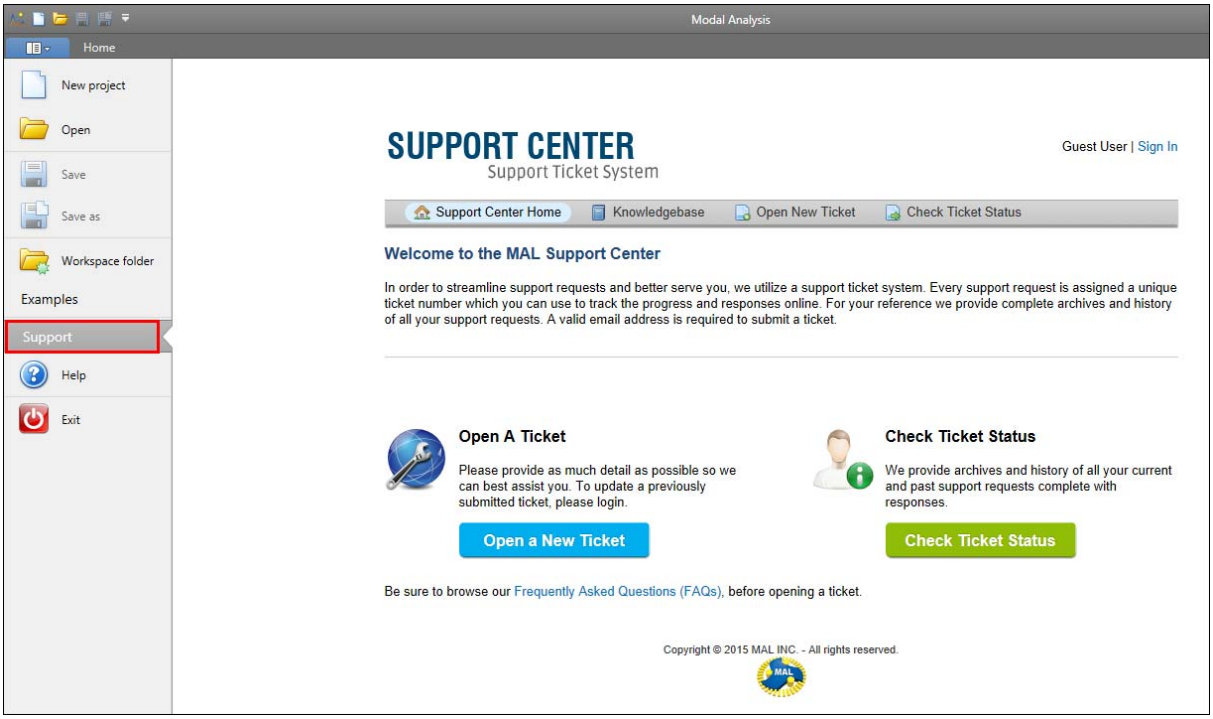
5 Support / Helpdesk

manufacturing automation laboratories CUTPRO

Support

At Manufacturing Automation Laboratories, Inc. we provide prompt technical <u>support with 24 hours.</u>
Please note that MAL staff do not work on Canadian holidays or weekends.

For Technical, software related inquiries, click on the Support butter under the [File Menu](#):



➢http://www.malinc.com/support/

Contacting Manufacturing Automation Laboratories Inc.

Manufacturing Automation Laboratories, Inc.
2829 Highbury Street
Vancouver, BC, Canada
V6R 3T7

Tel: (604) 998-4686
eFax: (604) 608-3265
Critical Emergency (Immediate Assistance Required) : (604) 998-4686 Extension 003 (Hasan Altintas)

Sales: sales@malinc.com
Technical Support: support@malinc.com
Web: http://www.malinc.com/

- T -

- U -

- V -

- W -