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Introduction

Receptance coupling is a method to acquire the assembled Frequency Response Function (or receptance or compliance) at the tool tip. The assembled Frequency Response Function information can be used to predict chatter vibrations. Typically, the spindle dynamics do not change over the time (this should be checked regularly for preventive maintenance purposes) but the tool dynamics change whenever a new tool is inserted into a tool holder and as well as after each tool change. This tool dynamics can be predicted by a FEM (Finite Element Method) to accurately come up with the tool dynamics. This requires material properties and the tool geometries.

Advantages

The typical practice in shops to acquire predictions of FRFs is to measure the FRFs of each end mill used in the shop using impact modal tests with an instrumented piezoelectric force hammer and a vibration sensor. The Receptance Coupling technique allows coupling of analytical or experimental FRFs of the components in obtaining the response of the assembly. This eliminates the time consuming and repetitive FRF tests for each tool after each tool change.
1 Introduction to the Software :

There are three sections in the Receptance Coupling module- Software:

1. Tool Coupling: Enables the identification of tool holder / spindle assembly on the machine tool and coupling of tools to the tool holder.

2. Coupling of Holder and Tool Assembly to Spindle: Enables the identification of the spindle on the machine tool and coupling of Shrink fit tooling to the spindle.

3. Tool Length Tuning: Guides in the selection of the optimum tool length for the selected tooling. It optimizes the tool length to achieve maximum productivity by utilizing the maximum spindle speed on the machine.
2 Tool Coupling:

2.1 Experimental Procedure to Identify the Tool Holder / Spindle Assembly:

Apparatus:

It is recommended to use a medium length blank tool to perform the experiments to identify the tool holder spindle assembly.

Experimental Procedure:

Insert the blank tool into the holder so that the stick out $L_2$ is 40-50 mm. The length inserted inside of the tool holder does not play an important role, although it has to be in the range recommended by the tool holder manufacturer. Attach an accelerometer on the blank tool and apply the impact hammer to acquire the frequency response functions. Perform at least 5-10 impact tests to average FRFs.

Three impact hammer tests are required:

Direct Transfer Function Measurement at the tool tip (TF 11)

Cross Transfer Function Measurement between the tool tip, and a point on the blank at a distance $L$ from the toolholder. $L$ is recommended to be 10-20 mm (TF 12)

Direct Transfer Function Measurement at location $L$ from the tool holder. (TF 22)
2.2 Identification Using the Software:

To Start, select Identify Tool - Holder Spindle Assembly button.

2.2.1 Identification - Geometry Parameters:

Input the blank tool dimensions and properties used to perform the experiments.
Although it is recommended to use a blank tool to perform the experiments, in the case of an end mill is used to perform the experiments the software allows the user to input the end mill geometry.

The cutter diameter for a 4 fluted end mill is 80% of the tool shank diameter.

Press Next to input the FRF impact measurements.
2.2.2 Identification - Impact Measurements:

Import the 3 measured FRF files. The measured frequency response files have to be displacement – force FRF’s.

Press the Run Identification Button to start the Identification procedure.

Once the identification procedure is complete, a prompt save window appears. Press Save. The software saves the identified spindle tool holder assembly project file, with the measurement files.
Press Next to Tool Coupling.
2.2.3 Tool Coupling

Input the cutting tool dimensions and material you want to couple to the tool holder.

Measurement Point 2: $L_1$ is fixed from the previous step in the identification procedure and is given as additional information. It is disabled and cannot be changed in this step.

Press Tool Coupling to Start the Coupling Procedure.

Once the Tool Coupling is completed, you can export the predicted FRF at the tool tip or plot in Modal Analysis.

Press Exit to go to the main menu.
2.3 Loading Existing Tool Holder Spindle Assemblies:

Press Load Existing Tool-Holder / Spindle

Browse for existing tool holder-spindle projects .rcf files and open the existing spindle tool holder assembly.

Couple a tool to the tool holder as explained in 2.2.3
3 Coupling of Holder and Tool Assembly to Spindle

3.1 Experimental Procedure to Identify the Spindle Holder Connection:

Apparatus:
It is recommended to use a shrink fit tool holder without any tool to perform the experiments for the identification of the spindle holder connection.

Experimental Procedure:
Insert the shrink fit tool holder into the spindle. Attach an accelerometer on the holder shank and apply the impact hammer to acquire the frequency response functions. Perform at least 5-10 impact tests to average FRFs.

Three impact hammer tests are required:

Direct Transfer Function Measurement at the tip of the holder shank (TF 11)

Cross Transfer Function Measurement between the tip of the holder shank, and the tool holder flange (TF 12)

Direct Transfer Function Measurement on the tool holder flange (TF 22)
3.2 Identification Using the Software:
To Start, select Identify Spindle / Holder Connection button.

3.2.1 Identification - Geometry Parameters:

Input the shrink fit dimensions used to perform the experiments: (The dimensions are provided in the tool holder manufacturer catalogue)

Press Next to input the FRF impact measurements.
3.2.2 Identification - Impact Measurements:

Import the 3 measure FRF files. The measured frequency response files have to be displacement – force FRF’s.

Press the Run Identification Button to start the Identification procedure.

Once the identification procedure is complete, a prompt save window appears. Press Save. The software saves the identified spindle tool holder assembly project file, with the measurement files.

Press Next to Tool Holder Coupling.
### 3.2.3 Tool Holder Coupling

Input the tool holder dimension and cutter dimensions in specified fields.

The cutter diameter for a 4 fluted end mill is 80% of the tool shank.

Recommended damping ratios for carbide tools are 0.01-0.03.

Press Tool Holder Coupling to Start the Coupling Procedure.

Once the Tool Coupling is completed, you can export the predicted FRF at the tool tip or plot in Modal Analysis.

Press Exit to go to the main menu.
3.3 Loading Existing Spindle / Holder Connections:

Press Load Existing Spindle / Holder Connection

Browse for and open existing spindle holder project .rsf-files.

Couple a tool / tool holder assemblies to the spindle -as explained in 3.2.3

3.4 Some Useful Tips:

Notes: Ways to minimize the noise and increase accuracy of the predictions
• Perform more than 10 impact hammer tests
• Apply the impact hammers consistently at the same location (slight deviation from the appropriate location may cause big deviations).
  ▶ Select the appropriate damping ratio. The damping ratio can vary from 1% to 5% depending on materials.

Limitation of the software

The accuracy of the software depends on the measurement noise. This software is used for guidance, and it is not an absolute final solution.