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**Improved experimental-analytical approach to compute speed-varying tool-tip FRF**

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HIGHLIGTHS

- An efficient method to identify the speed-varying tool-tip FRFs is proposed
- A quick cutting test is combined with the inversion of chatter analytical solution
- Experimental chatter limits are obtained by a dedicated test, called SSR
- By fitting experimental and predicted conditions, speed-varying FRFs are computed
- Speed-varying SLD reconstructed with the computed FRFs is experimentally validated

**Abstract**

Chatter stability prediction is crucial to improve the performances of modern milling process, and it gets even more important at high speeds, for which very productive cutting parameters can be achieved if the suitable spindle speed is selected. Unfortunately, the available chatter predictive models suffer from reduced accuracy at high speed due to inaccuracies in the input data, especially the machine tool dynamics that is acquired in stationary configurations but could sensibly change with spindle speed. In this paper, an efficient method to identify the speed-varying Frequency Response Functions (FRFs) under operational conditions is presented. The proposed approach is based on the definition of some experimental chatter limits (i.e., chatter frequency and related depth of cut), obtained by a dedicated test, called Spindle Speed Ramp-up. The experimental results are then combined with the analytical stability solution. By minimizing the differences between the experimental and predicted chatter conditions, a dedicated algorithm computes the speed-varying FRFs. Few tests and simple equipment (i.e., microphone) are enough to calculate the FRFs in a wide range of spindle speeds. The proposed technique was validated in real machining applications, the identified tool-tip FRFs are in accordance with expected trend reported in scientific literature. Speed-varying stability lobe diagram reconstructed with the computed FRFs is proven to be accurate in predicting stable cutting parameters.

*Keywords*: Chatter, Milling, Dynamics, Spindle, In-process dynamics identification

## 1. INTRODUCTION

The milling process could be significantly affected by detrimental vibrations, that represent one of the main limitations to further increase the process performance. The unstable vibration, known as chatter, is the most dangerous phenomenon because it could grow uncontrollably, causing poor surface finish, excessive tool wear and possible tool breakage, hence affecting productivity [1].

In the last decades many chatter prediction methods have been developed [2]; the main result of these approaches is a chart showing chatter-free combinations of cutting parameters, known as Stability Lobe Diagram (SLD). These diagrams are very useful, especially at high speeds where lobes are spaced and higher depth of cut can be safely exploited if the appropriate spindle speed is selected. However, at high spindle speeds every predictive model shows reduced accuracy, generally not caused by the approximation introduced in the