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Detecting Milling Chatter in Real Time with Low Latency Using Smart Tool Holder

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***Abstract*—In metal cutting, chatter is an unstable dynamic response that can lead to poor machining quality and shorten tool life. If chatter can be detected in a shorter time, processing losses can be minimized. To achieve the goal of real-time data-driven detection, this research proposes and investigates the use of two-dimensional sensor data as images to train a chatter detection model in milling. The authors use bending moments measured by sensors embedded in the Smart Tool Holder (STH) system developed in and accelerometers mounted on the cutting spindle. The results show that models based on bending moment or acceleration are both effective, but the former has lower detection time delay.**

I. Introduction

Instant detection of chatter occurrences facilitates the development of controls that improve productivity and reduce costs. The Stability Lobe Diagram (SLD) [1] is currently a relatively mature method for chatter prediction and evaluation. This method is based on analyzing the stability of the cutting dynamic system to find the stable boundary of chatter occurrence, but it is not suitable for real-time detection. Real-time detection requires sensors to capture signals from the machining process and use physical models or data-based algorithms to identify chatter. The commonly used sensors are accelerometers [2], [3], but the measurement locations are farther away from the tool tip, the lower signal-to-noise ratio causing it delay. This study uses a Smart Tool Holder (STH) system for real-time detection of chatter. Since the force sensor is placed on the tool holder, it has higher sensitivity and can detect subtle chatter and reduce latency.

II. Methodology

The STH system is implemented by authors' laboratory's self-developed sensing tool holder combined with a machine learning model. In this chatter detection application, the authors first conducted a chatter cutting experiment to obtain a training data set. The experimental parameter settings were based on the established SLD is carried out in the stable zone and chatter zone covered by the processing parameters. The signal used is the bending moment of the tool holder in the X and Y directions, which is drawn as a phase plane diagram. The resulting image is binarized and normalized for model training. During processing, the bending moment signal is transmitted to the computer in real time through WiFi, then the model detects whether chatter occurs currently.

This study compares the chatter detection effect based on the STH with the commonly used vibration sensor accelerometer. The system settings are as shown in Fig. 1. The accelerometer signal is captured by the DAQ card and processed in the same way to perform chatter detection on the model.

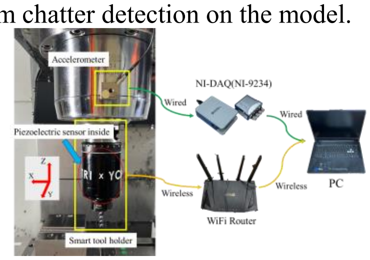

Fig. 1. Chatter detection system hardware configuration diagram.

III. Results and Conclusions

The test experiment uses a four-edged tungsten end mill (EMS445) to perform slot milling of medium carbon steel (S50C). The cutting process is divided into three stages as shown in Fig. 2, corresponding to stable cutting, slight chatter, and serious chatter conditions. The detection model uses Adaboost, which has the best training effect.

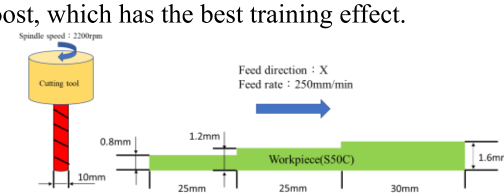

Fig. 2. Chatter detection effect test experimental setup.

The comparison of chatter detection effects between accelerometer-based and STH-based methods is shown in Table I. The results show that STH-based recognition can detect slight chatter at the early stage, showing lower delay and higher sensitivity.

Table I. Chatter Detection Test Results

Chatter detection method	Detection delay time after chatter occurs
STH bending moment signal	0.185 seconds (at slight chatter area)
Accelerometer signal	7.115 seconds (at serious chatter area)

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