CHATTER DETECTION AND AVOIDANCE USING A SENSORY TOOL HOLDER

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1. Introduction

In a modern, networked production, the possibility of optimizing the machining process can be achieved by the use of work piece- and tool-side sensors and actuators. Thereby, the application possibilities of sensors and actuators move closer to the process due to a progressive reduction of their size. The use of intelligent tool systems allows recording data of the machining process near the cutting zone and applying them for in-process control of process parameters.

2. Sensor implementation

Machining processes with long and slender tools or with minor wall thickness of the work piece can lead to instabilities, which can result in chatter marks on the work piece surface as illustrated in figure 1.

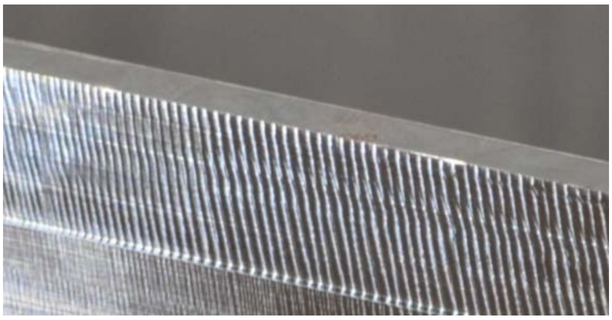

Fig. 1. Chatter marks on a thin-walled work piece.

The most vivid form of chatter is the so-called regenerative chatter effect. Self-excited vibration can occur by cutting of wavy surfaces, which are generated by the previous tool rotation. This has direct impact on the cutting depth. The crossing of small defects in the work piece surface can then lead to the destabilization of the milling process [1]. In order to avoid dynamic instabilities or process failures a sensor integration for a tool holder SK 45 was developed. The approach for this sensor system integration attached on the tool holder is to gain more detailed process information compared to e.g. the sensing of the spindle engine power and therefore, be able to detect chatter vibrations in an early stage. Figure 2 depicts the sensor system and the sensor signal receiving unit. Small capacitive sensors with single sensing axis have been chosen for this solution, which can be implemented in in three different slots for vibration measurement in radial, axial or tangential direction. An analogue radio transmitter proceeds the vibration data out of the rotational system to the receiver unit. The antenna of the transmitter is positioned alongside the outer surface of the housing in the shape of a cylindrical ring. The system is sealed and can therefore be applied with cooling lubricant.

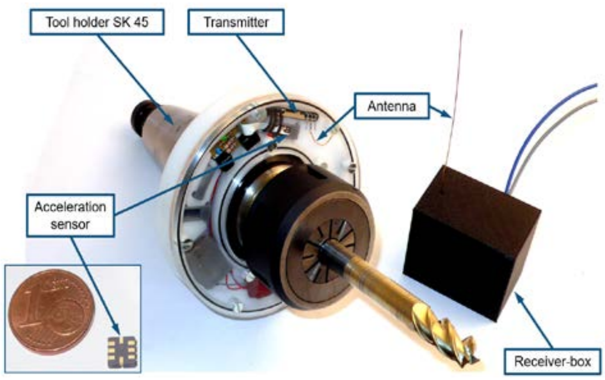

Fig. 2. Measurement Ring and receiving unit.

3. Adaptive control of cutting parameters

A condition monitoring system (CMS) was implemented in a B&R control system of a Hüller Hille machine tool. Figure 3 illustrates this application with the data flow from the sensory system to the machine tool control system. The output of the received vibration data is forwarded to the CMS in which algorithms are used to analyze the data with respect to process instabilities or process failures. The analogue signal output of the receiver conforms the interface to the machine tool control system in this application. This test rig represents a specific case of implementing a condition monitoring system in a machine tool control system. Due to a development project within a collaboration between the IFT and the control system provider, it was possible to integrate a CMS directly into the control system. This solution can act as a faster opportunity to initiate countermeasures in the machining process compared to an external CMS. Other control systems do not open the possibility of a direct integration of a CMS. In such cases, the data analysis has to be conducted in an external evaluation unit. Therefore, the time to initiate countermeasures increases and a reaction of the axis drives on detected chatter vibration occurs more slowly.

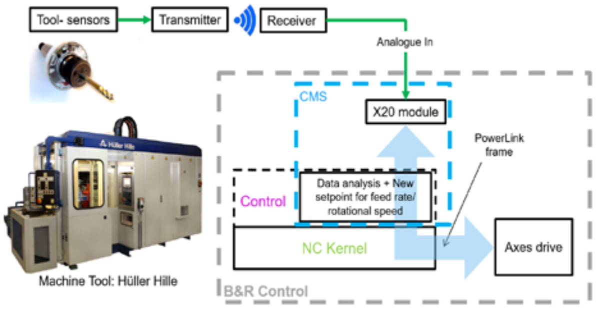

Fig. 3. Coupling of CMS to control system.

In order to react correctly on chatter vibrations, Figure 4 has to be considered, which shows a stability lobe diagram. A stability lobe diagram depicts that specific combinations of spindle speed and cutting depth lead to instable machining processes, which can result in chatter vibrations [2]. By reducing the feed rate or shifting of the spindle speed, it is possible to move the process out of instable into stable machining zones.

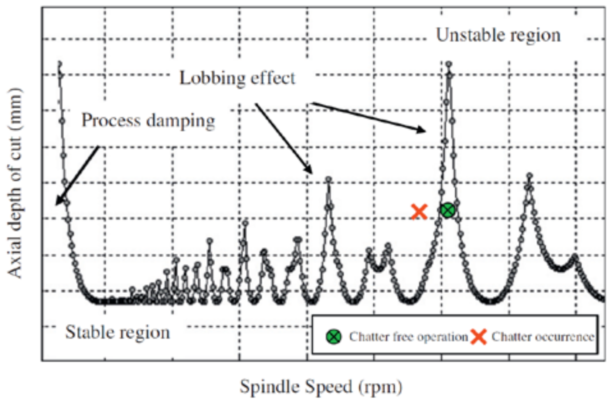

Fig. 4. Stability lobe diagram [2].

With the realized test set up shown in Figure 3 it was possible to achieve an automated adaption of the feed rate if an exceedance of a predefined vibration limit can be detected by the measuring system. Therefore, this experiment reflects the approach of an automated reaction of the machine tool based on vibration data of a sensory system. Due to the implementation close to the cutting zone even vibrations of small tools can be controlled and monitored.

4. Remarks

As a result of the experimental evaluation the following remarks and findings can be summarized:

- The approach of the presented sensory system integration attached on a tool holder enables to acquire process vibration data near the cutting zone.
- A condition monitoring system (CMS) analyzes the received data of the integrated sensor system in order to detect process instabilities or process failures. However, this opens the opportunity for process documentation and monitoring.
- By coupling the CMS with the machine tool control system, countermeasures can be initiated to stable the machining process and thus an in-process-control will be introduced.

5. Outlook

A miniaturization of the measurement system could lead further towards an industrial application. Aside from the detection of instable milling processes, the prevention of drill breakage for drills with $D < 3$ mm could be an area of application. Strategies of how to initiate the right countermeasures to stable an instable processes needs further research work.

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