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The influence of tool holder technologies on milling performance

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Abstract

The quality of machined surfaces is significantly influenced by machine vibrations caused by the cutting process. Whereas most publications ignore the influence of the tool holder, this paper considers the dynamic behaviour of the whole cutting system consisting of spindle, tool holder, tool and workpiece. Therefore modal and operational vibration analyses were performed to describe the damping and operational characteristics of two competing tool holder technologies, namely heat shrink (HS) and hydraulic expansion (HE). It is shown that HE has higher damping rates than HS. Therefore, HE showed mainly better surface qualities, a 10 % higher productivity and an up to 300 % higher achievable life time of tools.

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Keywords: milling; damping; tool holder

1. Introduction

Surface quality of machined workpieces is one of the most important parameters in milling processes. It is highly influenced by machine vibrations, because chatter vibrations cause poor surface qualities. Process – machine interaction was widely investigated in previous research [1]. Regarding tool holders, especially the holder-tool assembly was intensely considered. [2] investigates the dynamic characteristics of the conjunction of lengthened heat shrink tool holders and cutting tools in high-speed milling, where [3] models the interface of tool holder and spindle.

In most cases, the influence of process forces on machine vibrations was analyzed and visualized by stability maps [4]. Several models using finite element analyses (FEA) to model the holder-tool assembly and to predict chatter vibrations were published [5]. [6] focuses on the FEA of asymmetric tools, while [7] identifies the holder frequency response function (FRF) directly by experimental modal tests. Furthermore investigations regarding the tool overhang and its influence on damping and vibrations, optimizing the position of the tool in the holder were carried out [8]. [9] investigates the heat shrink tool holder connection stiffness and models the damping of the system for frequency response prediction in milling. [10] investigates the dynamic properties of a milling tool holder in cutter head technology, focuses on identifying the sources of the dominant milling vibration and shows that the bending modes of the tool holder correlate with peaks in the modal and operational vibration analysis of the whole system. To analyze the dynamic behaviour of the holder – spindle assembly with different tool combinations without repeated measuring, an analytic model of the tool – holder system is proposed and validated in [11].

For high quality surfaces during high performance cutting, a good damping behaviour of the whole system, consisting of workpiece, tool, tool holder, spindle and machine structure is important. Available approaches to improve machine tools damping behaviour only focus on damping of spindles [12], guiding [13], and machine tool

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structures [1], what neglects the influence of the tool holder. [14] considers different tool holder technologies, focusing on their influence on productivity and tool life. Due to simplified boundary conditions by modeling the machine structure, most available simulation models ignore the influence of the tool clamping technology. However, because of the technical differences between the various tool clamping technologies, a significant influence on the process machine interaction has to be assumed. This would lead to different vibration characteristics, which directly affect the workpiece quality, as well as the productivity of milling processes and the tool life.

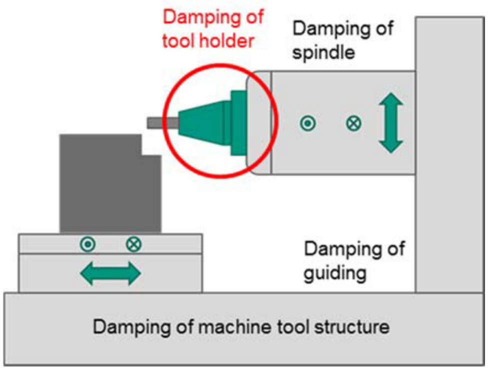

Fig. 1. Deficit of research on damping behaviour of tool holders

Objective of this paper thereby is, to analyze and quantify the influence of tool holders (cf. fig. 1) on damping and operational characteristics during high performance cutting. Therefore two competing tool clamping technologies are compared (cf. fig. 2). Hydraulic expansion (HE), which is the first analyzed technology, clamps the tool by increasing a fluid pressure, causing an elastic deformation of a clamping sleeve in the tool holder shaft. Due to the fluid in the HE, a very high damping effect can be assumed. Heat shrink technology (HS), the second one, uses the thermal expansion, caused by an induction coil, to insert the tool and clamp it after cooling by a press fit, which implies low damping. These two tool holder technologies are compared regarding their vibrational characteristics.

Fig. 2. Analyzed tool holders

Therefore modal and operational vibration analyses were performed to quantify the damping and operational characteristics of the whole system, consisting of spindle, tool holder, tool and workpiece. To investigate the effects of the characteristic damping rates and resonance frequencies on workpiece surface quality, as well as productivity and tool life, several milling tests on different machining centres were finally performed.

2. Modal and operational vibration analyses

2.1. Experimental setup

To investigate the damping and vibrational behaviour of HE and HS technology, modal and operational vibration analyses were performed. Therefore, the accelerations in the tool centre point were recorded in all three planes and converted to a normalized acceleration-frequency response, while the system was stimulated by a hammer at the tool holder. To record the operational vibrations, sensory measurements during high-performance cutting were carried out and analyzed by a Fast-Fourier-Transformation (FFT). The cutting process was performed by basic process steps in a reference workpiece of 16MnCr5. Therefore, one half slot was cut in climb-cut milling and three full slots were cut with depths of 6 mm, 12 mm and 18 mm, all with a cutting speed of 141 m/min and a feed rate of 767 mm/min.

To ensure the results and to avoid specific influences of a machine tool, the measurements were performed on two different horizontal machining centres (MAG-NBH 630 and Heller MC16) and on one vertical machining centre (Chiron FZ 15 S) under similar test conditions. For the HS technology, a SCHUNK Celsio SSF was used, and, for the HE, a SCHUNK Tendo SDF(-E compact) was used. In all experiments a solid carbide end mill type Walter “H4138217-12-0.5/-1” with four cutting edges, a diameter of 12 mm, a length of 83 mm and a TAZ coating was used.

2.2. Results of modal and operational vibration analyses

Fig. 3 shows results of the operational vibration analysis while cutting full slots with depths of 18 mm on the machining centre Heller MC16.

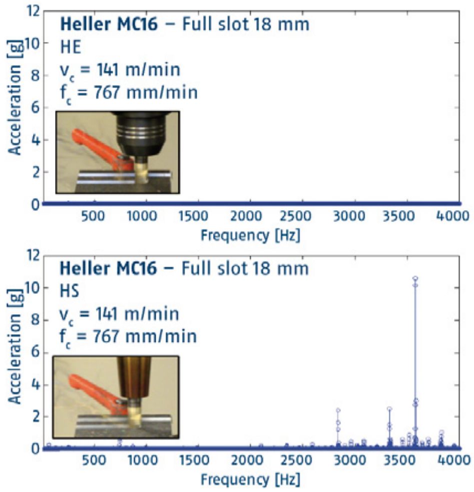

Fig. 3. Operational vibrations with HE (top) and HS (bottom) on Heller MC16