Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 46 (2016) 303 – 306
www.elsevier.com/locate/procedia

7th HPC 2016 – CIRP Conference on High Performance Cutting

Adaptronic applications in cutting machines

Drossel, W.-G. [a] *; *Bucht, A.* [a]; *Pagel, K.* [a]; *Mäder, T.* [a]; *Junker, T.* [a]

[a] *Fraunhofer Institute for Machine Tools and Forming Technology IWU, Reichenhainer Str. 88, 09126 Chemnitz, Germany*

* Corresponding author. Tel.: +49-371-5397-1400; fax: +49-371-5397-1404. *E-mail address:* welf-guntram.drossel@iwu.fraunhofer.de

Abstract

Adaptronic systems are able to improve high performance cutting technologies making them more stable, economic and efficient leading to a higher product quality. The main objectives of adaptronic systems in production technologies, beyond controlling process parameters, are either reducing vibration or generating them. The latter topic is a highly innovative area of research since it offers alternative approaches to improve product quality and optimize machining processes regarding efficiency and economy.
Current research at Fraunhofer Institute for Machine Tools and Forming Technology IWU focuses on facilitating the transfer of scientific knowledge to industrial solutions. Therefore, possible reasons preventing industrial application of adaptronic systems in cutting machines are identified and initial ideas to overcome these problems are presented.

Peer-review under responsibility of the International Scientific Committee of 7th HPC 2016 in the person of the Conference Chair
Prof. Matthias Putz

Keywords: Machine tool, Adaptive control, Vibration assisted machining

1. Introduction

The introduction of new materials continuously increases the complexity of production processes. Thus maintaining efficiency and quality proves to be very challenging. One way facing these challenges is to optimize process parameters. Going one step further advanced machine and tool concepts are being developed at Fraunhofer Institute for Machine Tools and Forming Technology – IWU. Developments concentrate on controlled hybrid processes as well as the application of adaptronic systems in order to achieve stable, economic and efficient processes.

Since adaptronic systems consist of smart materials like piezo ceramics, shape memory alloys, rheological fluids and electromagnetically activated polymers, sensor and actuator functions are integrated within the structure itself. Thus they can be distinguished from classical mechatronic systems (see Fig. 1). The dense concentration of functionality allows adaptronic systems to control the machining process in a direct manner.

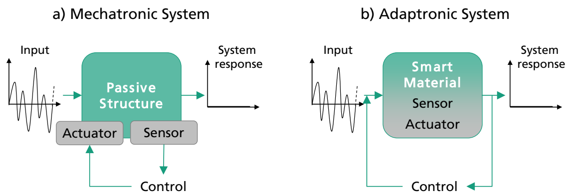

Fig. 1. Structure of (a) mechatronic and (b) adaptronic systems. inspired by [1]

2. Adaptronic applications in cutting machines

In recent years development and research of adaptronic systems in production technologies increasingly focused on the generation of vibrations for improved machining processes. Such systems can be classified in Ultrasonic machining (USM), Vibration Assisted Machining (VAM) and Fast Tool Servos (FTS) [2].

Ultra Sonic Machining dates back to the early 1950s [3]. Using an axially oscillating tool combined with an abrasive

Peer-review under responsibility of the International Scientific Committee of 7th HPC 2016 in the person of the Conference Chair
Prof. Matthias Putz
doi:10.1016/j.procir.2016.05.072

slurry for material removal a hole or a cavity can be pierced in hard and brittle materials, whether electric conductive or not [4].

Combining precision machining with small-amplitude tool vibration VAM can improve production processes significantly. Advantages over conventional precision machining are for instance reduced tool forces, extended tool life, reduced surface roughness, improved form accuracy and greater depth of cut [5].

Connecting conventional drives (large stroke) and fine piezo based (high resolution) drive stages in series FTS systems can improve tool positioning accuracy, reduce tool vibration and even create asymmetric surfaces [6].

Selected adaptronic systems in VAM and FTS applications developed at Fraunhofer IWU are presented in the following chapters.

3. Vibration Assisted Machining application

VAM systems usually comprise an ultrasonic generator that uses a piezoelectric actuator to create reciprocating harmonic motions at high frequency (1 kHz up to 40 kHz) and very low amplitudes (a few 10 µm). However amplitude and frequency of the tool motion are controlled, phase deviation is not. Hence VAM systems are usually applied for improved process properties and not for manufacturing specific geometries [2].

3.1. VAM for drilling fibre reinforced plastics

Most current VAM systems only generate vibrations in feed direction resulting in limited amplitudes and only partially exploited potentials. Torsional vibrations also can enhance different machining processes. Early developments at the Fraunhofer IWU resulted in a prototype VAM system for torsional vibration excitation applied in drilling. Shear oscillational piezoelectric actuators were used to build up this prototype. A controller was developed to excite vibrations in resonance to the tool holder [7]. Investigations proofed the basic concept. A robust torsional VAM system is now being developed addressing the challenges a of drilling and milling carbon fibre reinforced plastics (CFRP).

Milling of CFRP is associated with massive tool wear and quality problems. The fundamental difference between VAM of CFRP and metal is the varying power consumption. Compared to metal the CFRP is softer and comprises a dissimilar dynamical behavior. Therefore the stimulation of vibrations needs less energy than it is needed for metals. Different designs for the VAM systems are needed in consequence. The objective of the project ULTRASPAN is to increase vibration amplitudes of VAM systems in order to improve CFRP milling. Amplitudes of up to 15 µm for the longitudinal excitation and up to 0.8 mrad for torsional vibration excitation are the technical target. This can be reached using optimized piezoelectric transducers and by dynamical optimization of the system design. Shear transducers with an in-plane polarization are used in order to realize the torsional VAM system.

3.2. Multi-purpose rotary vibrational systems for VAM

Presently there are only a few VAM systems commercially available. Focusing on milling processes with geometrically determined cutting edges, there is only one system on the market. This can only be used in combination with particular machine tools of the company group. An industrially utilizable and modular VAM system for machine tools of different supplier companies is not available. Universal and robust VAM systems are still missing.

Driven by industrial needs the BMBF project PERMAVIB intends to fill this gap. The goal is to develop multi-purpose rotary vibrational systems for VAM as depicted in Fig. 2. Fundamental advantages of this universal VAM system are a high-performance piezoelectric actuation with an integrated amplitude control, the compatibility to different machine tools and the autarkic energy supply.

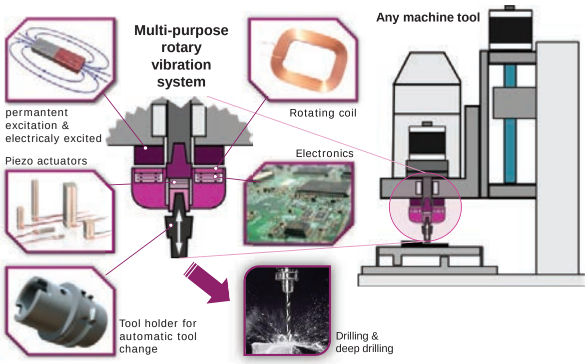

Fig. 2 Overview of project targets within PERMAVIB

The VAM systems will be especially used to enhance the drilling of steel during the PERMAVIB project. Technical goals are a reduction of the process force for up to 40 percent, a reduced chip size to omit locking of chips and the increase of the tool service life for 50 percent by avoiding pick-up cutting edges. VAM enhanced deep hole drilling will be done with drill sizes with a length–diameter ratio of 30 and a 8 mm reference diameter using cemented carbide tools. The length–diameter ratio for drilling is intended in the range between 3 and 5 with a reference diameter of 12 mm also using cemented carbide tools. The use of the VAM systems is generally not only limited to drilling.

4. Fast Tool Servos (FTS) applications

Compared to VAM systems Fast Tool servo (FTS) systems are even more complex. Superimposing the cutting tool with a controlled movement using fine piezo based drive stages allows FTS to manufacture microstructures or complex geometries like non circular bores or turned parts. However, to achieve the high accuracy it is necessary to determine the phase deviation at any time very accurately in order to predict the position of the cutting edge.