Laboratory Practice Energy Efficient Production

Nico Zimmermann[1], Pablo Hernández-Becerro[2], Philip Blaser[1], Josef Mayr[2]
[1]**Institute of Machine Tools and Manufacturing (IWF), ETH Zürich, Switzerland**
[2]inspire AG, Zürich, Switzerland

1 Introduction

The thermal behavior of machine tools has a major contribution to manufacturing inaccuracies. Reducing the thermally induced errors in the whole working space without increasing the energetic demand is a challenge with great scientific and industrial relevance. Therefore, a series of three lab courses with the topic “Energy Efficient Production” oriented towards students in the bachelor program has been set up at IWF during the academic year 2017-2018. These lab courses illustrate the strong relations between precision, productivity and energy efficiency in the context of machine tools.

2 Teaching Concept

The teaching concept of the three lab courses is based on a research orientated approach, which results in a strong interaction between theoretical and practical elements in the context of ongoing research questions. Consequently, the students are motivated to apply their existing engineering knowledge to the current global challenge of energy efficient production.

The Green Machine Tool: How Does Energy Efficient Production Work?
In the first unit, the students elaborate how the carbon dioxide foot print of machine tools can be minimized by considering the whole life cycle of the machine tool and the manufactured products. Methods to analyze and improve the energy efficiency of machine tools in the different phases of their life cycle are introduced and discussed with the students by conducting a power measurement at a five-axis machine tool.

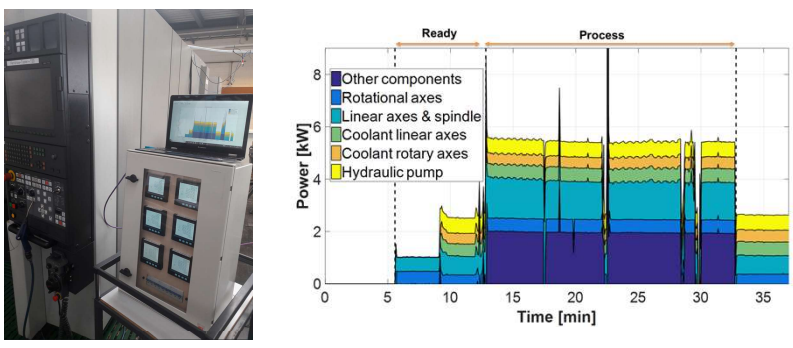

Fig. 1. Measurement device used for the online visualization of the power consumption and an exemplary power measurement of several components during the operational states ready and process. The peaks of the power consumption correspond to acceleration and decelerate of the spindle.

The Deformed Machine Tool: How Do Heat Losses Cause Manufacturing Errors?
The second lab course focuses on the thermal chain of causes, which describes the physical fundamentals leading to a thermal deformation of machine tools. The thermal chain of causes is visualized by measurements and simulations.

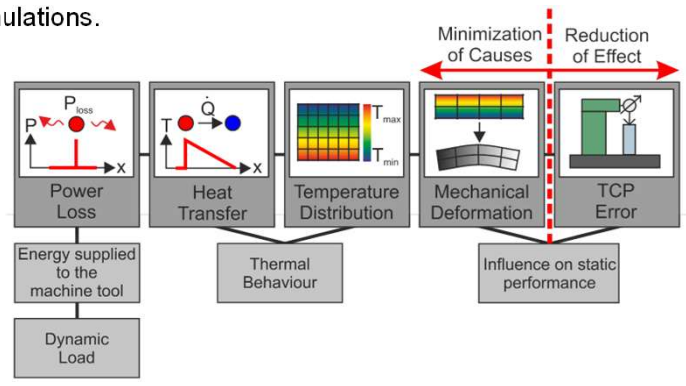

Fig. 2. Thermal chain of causes in the context of machine tools.

Due to the long time constants of machine tools’ thermal behavior, the experimental and simulative investigations are performed on a test bench especially designed for this purpose.

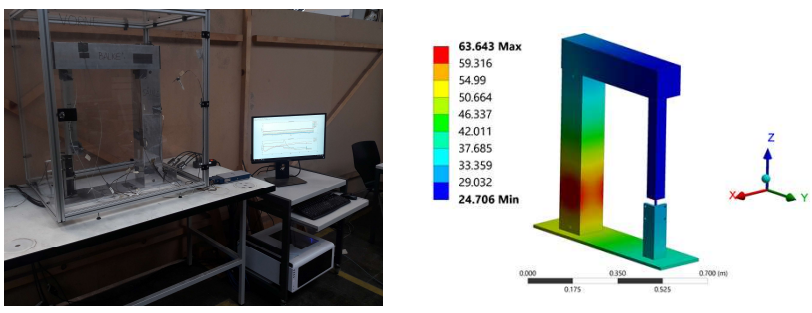

Fig. 4. Experimental setup including the live visualization of the temperature and displacement measurements and exemplary simulation results of developed thermal test bench.

The Machine Tool 4.0: How to make precision manufacturing energy efficient?
The third part aims at illustrating an energy efficient procedure to reduce thermal errors of machine tools by cyber physical systems and cloud computing. The students have the opportunity to create their own compensation models to describe the thermal behavior of a machine tool and to test it on a real five-axis machine tool. Furthermore, the course outlines the potential to increase the accuracy of compensation models when large data sets are available, which is facilitated by the trend towards Industry 4.0.

4 Analysis of student learning

The developed lab courses provide the students a research oriented learning approach, in which the students apply new and existing theoretical skills to ongoing research questions. Thus, the course structure is developed in a strongly interactive manner which enables a direct observation of the stated learning objectives. The different exercises including the measurement, simulation, and computation results are directly presented and discussed by the students during the lab courses, so that the supervisor can directly assess their learning progress. This enables a high- level interaction between the students and the supervisor and ensures their learning success.

5 Lessons learnt

The first runs of the lab courses showed, that the strong interaction between theoretical and practical elements in the context of current research questions results in a high motivation of the students. Furthermore, the students appreciate the connection between technical and social challenges of the given exercises. The three lab courses indicate that the used teaching concept is an excellent way to integrate current research findings and the corresponding research methods into teaching. These lab courses are sustainable in two different ways. First, the lab courses create awareness for the scientific and social challenge of energy efficient high precision manufacturing. Second, the lab courses are sustainable for the enhancements of their academic skills because they are familiarized with engineering and research methods by applying them to a specific problem. The concept of these lab courses can be easily transferred to other fields of research as an innovative concept for research oriented learning and teaching of application competence.

Partners