THE COURSE ‘PRACTICE OF EXPERIMENTAL METHODS IN MACHINING’

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Abstract

This article is about the course ‘Practice of experimental methods in machining’. This subject is taught at the Faculty of Mechanical Engineering of the University of West Bohemia, specifically at the Department of Machining. The main part of the article briefly describes the individual experiments and measuring devices used in the experiments. Furthermore, these experiments are described from the perspective of their contribution to students and the preparation of students for real industry. The last part of the article deals with the extension of practical teaching of the subject ‘Practice of experimental methods in machining’ by measuring self-excited oscillation.

Keywords: education; experiments; measurement; cutting forces; vibration

1. Introduction

Preparing students for real industry and expanding their practical knowledge is one of the directions of the Department of Machining Technology. An objective of the Faculty of Mechanical Engineering of the University of West Bohemia is to educate students not only theoretically but also practically. Students can gain practical experience not only during their studies, but also have the opportunity to participate in projects. The Faculty of Mechanical Engineering has a very close relationship with industrial enterprises and the Faculty of Technology is also a part of the Faculty. This institute is a modern engineering and technology research centre. The purpose of this research is to extend the subject ‘Practice of experimental methods in machining’.

The subject which is focused on practical measurement is called ‘Practice of experimental methods in machining’. The main aim of this course is to acquaint students with the basic measuring methods of cutting processes, deepening knowledge in NC programming, metrology and assembly. During the course they carry out experiments under the supervision of teachers. Before each experiment is taught, there is theoretical instruction on the issue and a practical demonstration of the measurement.

2. Experiment description

Students are obliged to complete the following three experiments and a task:

- Experimental measurement of the influence of the entered parameters on cutting forces and roughness of the machined surface.
- Short-term cutting test.
- Long-term cutting test.
- CAM programming and component manufacturing.

It is planned to extend the subject by measuring the stability of the cutting process

2.1. Experimental measurement of the influence of the entered parameters on cutting forces and roughness of the machined surface.

During this experiment, students will learn about the processes of experiment planning, practical measurement and data evaluation using statistics. Part of the experiment is to prepare students for professional practice by improving their skills and teamwork.

Students are divided into pairs and each team is assigned a machined material and the experiment. The assignment contains the experimental procedure, variable factors (cutting speed, feed per revolution, depth of cut) and measured quantities (cutting forces in individual axes, surface roughness). The experiment is performed on the EMCO MAXXTURN 25 lathe, which was purchased for this purpose. [1]

Fig. 1. The EMCO MAXXTURN 25 lathe

Before conducting an experiment, students are required to plan an experiment using an experimental planning method called a full factor plan. [1]

The measured values of the experiment are cutting forces and these are measured using a static three-component dynamometer from Kistler. Subsequently, the measured signal is amplified by 8-channel amplifier 5080, converted by digitizing card 5697 and processed by Dynoware SW.

Fig. 2. Left: three-component dynamometer. Right: 8-channel amplifier 5080 and digitizing card 5697
The roughness of machined surfaces is measured between individual cuts using a MarSurf M 300.

Fig. 3. MarSurf M 300

Part of the experiment is also measurement chip ramming parameters and chip volumetric coefficient. In this experiment, students measure the dimensions of the chip, which are used to calculate the chip ramming parameters. Furthermore, using the experimental method of measuring rollers they determine the volumetric coefficient of chips.

2.2. Short-term cutting test

In terms of time demands, we distinguish two types of cutting tests, short and long term. Short-term cutting performance provides a cost-effective solution to quickly and accurately determine optimum or productive cutting conditions, as well as to compare materials to be machined. [2]

In conventional machining, it is very important to set the correct cutting conditions. An improperly selected cutting speed, feed rate, cutting depth, cutting environment, etc. not only affects the productivity of the machining, but also reduces the life of the cutting edge. These consequences will have a negative effect on machining costs. Reducing costs is a priority objective of any industrial company. [3], [4] Students will learn the real consequences of cutting speed on the wear of the cutting insert. They will also master the basics of the Keyence VHX-6000 microscope.

Fig. 4. Keyence VHX-6000

The experiment is done on the same lathe as in the previous experiment. In this experiment, students measure the wear of the cutting edge as a function of variable cutting speed. The wear of the cutting edge is measured on a Keyence VHX-6000 microscope. Students work in teams of two and are set assignments. The assignment contains a short-term test method, namely Wearrate or A.s. Kondratov. The principle of the experiment is that the students select the initial cutting speed and this speed is used to machine the workpiece for a selected period of time. Subsequently, the cutting speed is increased and it is machined again for a certain period of time. The increase in wear is measured after each time period. The experiment is terminated when the wear reaches a critical value

2.3. Long-term cutting test

This test attempts to approximate real machining processes. The advantage is the high reliability of the results, but these are very time-consuming and costly tests. [5]

The experiment is realized on the multifunctional turning centre CTX BETA 1250. For the selected conditions, the time intervals of insert wear are measured, from which are drawn the graphs showing the wear. The wear of the cutting insert is measured on the Blickle Multicheck PC 500 microscope. The cutting speed has the greatest influence on tool life, therefore a long-term test is performed to determine the dependence of $T - v_c$. The aim of this test is to determine Taylor's relationship from the measured data.

Fig. 5. CTX BETA 1250

Upon completion of this experiment, students will be able to plan a long-term cutting test and evaluate the measured data in practice. Optimizing the machining time and thus achieving minimum costs is a priority task in industrial practice. Furthermore, students will learn to operate a Blickle Multicheck PC 500 microscope.

Fig. 6. Blickle Multicheck PC 500

2.4. CAM programming and component manufacturing

Students study several subjects related to machining technology. In addition, students acquire basic skills in workshop programming (SinuTrain, Heidenhain) and programming with support for the CAM system. In this task, students have the opportunity to apply their theoretical knowledge of machining and programming technology.

As part of this task, students create a program in SolidCAM, which they then discuss with the person in charge. After approval of the program, the part is manufactured on the EMCO Maxxturn 25 lathe. Students then measure the tolerated dimensions using a caliper and a micrometer and then assemble the manufactured parts.

2.5. Measurement of cutting process stability

The machining process is a dynamic phenomenon in which vibration occurs in most cases. These oscillations cause deterioration of the machined surface, reduce tool life, increase machine time and increase machine wear. This is why measuring machine tool dynamics is in great demand today. [6] Therefore, it was decided to incorporate an experiment regarding the measurement of the oscillation of the cutting process into the 'Practice of experimental methods in machining' curriculum.

Before the experiment, students connect the measuring system according to the diagram and then calibrate the measuring equipment. Then they attach the accelerometer to the clamped workpiece using wax. Before measuring the frequency response function, they set the parameters in the TXF Metalmax software according to the manual. [7]

Fig. 7. Diagram of connection

In order to determine the frequency response function, it is necessary to input the impulse into the measured system by impact hammer. Students take the appropriate number of measurements according to the software instructions. The resulting measurements are displayed graphically as real and imaginary graphs of the frequency response function.

Fig. 8. Real and imaginary graph of frequency response function

The real part of the frequency response function is reflected in the lobby of the stability diagram. The stability diagram expresses the relationship between the spindle speed and the depth of cut.

Fig. 8. Diagram stability

In most cases, the cutting conditions change due to the stability of the machining. Most of these changes lead to reduced machining performance. It is these diagrams that are used to determine optimal cutting conditions while maximizing machine performance. Students in this experiment will learn to orientate themselves in the resulting diagrams and propose suitable cutting conditions for a specific workpiece. [7], [8]

3. Conclusion

The high level of education of the students of the Faculty of Mechanical Engineering is a very desirable aspect in the labour market. This subject not only expands their theoretical but also their practical knowledge. The extension of teaching at the Department of Machining Technology with practical measurements is not only beneficial for students, but also for future employers. Individual experiments have taught students how to collaborate, plan experiments and measure on the devices described above. The main aim of this course is for students to see the difference between theory and practice. Furthermore, to be able to predict situations and to be aware of the consequences of making wrong decisions.

The main purpose of this research is to extend the subject 'Practice of experimental methods in machining' by experiment of self-excited vibration measurement. In the future it is a requirement to incorporate further experiments into the subject and prepare students for the real industry.

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