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Measurement of tool wear using a non-contact method, using a laser measuring system

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Abstract: *Measurement of tool wear using a non-contact method, using a laser measuring system*. This article examined the tools - straight cutters with a contactless method using a laser sensor. The first aspect of the research was to determine the influence of the spindle rotational speed on the accuracy of laser measurement. The second aspect of the research was to establish the correlation between the diameter of the tool measured with a laser micrometer and the wear of the tool measured with the microscope. A good (R2> 0.8) Pearson's correlation was found between the measured tool diameter and it's wear.

Keywords: tool wear rate, tool diagnostics, non-contact measurement

INTRODUCTION

The increasing demands of customers regarding the accuracy of manufactured products have led engineers to focus their work on improving the process of machining various materials. In order to meet the market needs, the product must be made in a short time with the highest accuracy, which determines the need to minimize failure and leads to lower costs. The technology of measuring the tool with the laser method allows for quick detection of changes in the geometry of the tool and allows for greater automation of the production process. They ensure consistent production quality and minimum downtime.

LITERATURE

The basic device for measuring a tool is e.g. a caliper. It is the cheapest and simplest device. The caliper accuracy is 0.05 mm for a vernier caliper and 0.01 mm for a dial caliper.

A more accurate hand tool is the micrometer. It enables measurements with an accuracy up to 0.1 μm. If more accurate or more complex measurements is needed microscope can be used. The microscope is designed to measure the linear dimensions and angles of small objects using the XY table and the eyepiece ring scale. The XY table can be equipped with optional micrometer, digital or analog heads.

For more advanced methods of measuring the tool, a laser micrometer can be used. The system is composed of a transmitter unit, a receiver unit and a result computing circuit. It has a wide measurement application. Components with large diameters can be examined with

a laser micrometer. As a disadvantage of this device, susceptibility to electrical noise can be pointed. (Mąkowski 2013, Yuqing, Wei 2018)

Another group of advanced automatic measurement systems includes a vision measurement system. The computer vision measurement system consists mainly of a scanning camera, lens, LED illuminator and the cover. The image recorded with the camera goes to a computer with appropriate software for analyzing the collected signals. The accuracy of the technology may be limited depending on various factors. (Skoczyński et al. 2016; Król 2021; Król, Szymona 2021)

Instruments for inspecting the blade allow the measurement and control of the geometry of drills, cutters, countersinks in reflected light. The devices allow manual measurement of the circumferential geometry of the tools. It can be used in the quality control of the tool or directly in the sharpening room during the tool grinding and sharpening process. (Tan et al. 2021)

Milling is a very popular method of woodworking. The main tool during such an operation is a rotary cutter with one or more teeth. The result of milling are geometric elements of a given shape. (Zhou, Xue 2018)

Tool wear is a continuous process - it begins when machining begins and ends when it is finished. During this process, the tool tip works under significant mechanical and thermal loads. The effect of such conditions is changes in the properties of the tool material and wear of the blades, and thus the cutting properties deteriorate. (Jemielniak 1998)

Tool wear monitoring is important issue from the point of view of the economics of long-term machining processes and can be the basis for process automation. Inadequate monitoring of the tool condition can lead to inaccurate machining, damage to the workpiece and even damage to the machine. (Mathew, Srinivasa Pai, Rocha 2008)

Despite many trials and tests, direct methods, such as visual inspection or computer vision of the tool, do not meet the industrial requirements. Probably for this reason, the tool status monitoring systems proposed in the literature are mainly indirect methods, i.e. based on the observation of other parameters accompanying the processing, such as such as cutting forces (static and dynamic), cutting temperature of the workpiece, vibrations (1-10kHz), acoustic emission (50-400kHz). (Garcia-Sanz-Celcedo, Selgado, Gonzalez 2016)

The main task of the monitoring systems is to diagnose the condition of the tool. They are able to determine the level of tool wear and quickly detect the critical dullness of the blade. (Jemielniak 2002)

Laser systems are best suited for measuring tool dimensions and the edge geometry of the blade. (Lipski 2013)

An example of a diagnostic device using laser technology are the LASER CONTROL series devices supplied by BLUM NOVOTEST. Their capabilities include: broken tool detection, single cutting edge monitoring, tool setting, tool profile checking and others. (blum-novotest.com)

The schematic and the actual measurement system are shown in fig. 1.

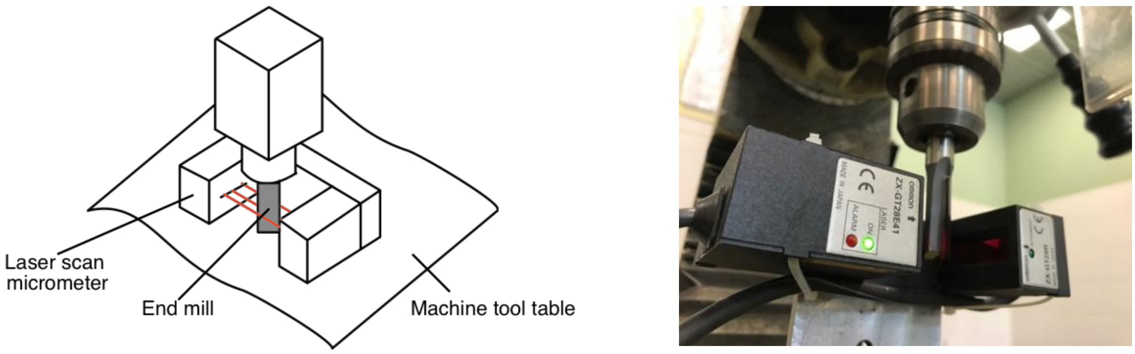

Figure 1. Schematic and the actual measurement system.

Measurement with a laser system is based on scanning a tool placed in the laser beam. The laser micrometer measures the length of the shadow caught by the tool. Proper heating of the spindle with the tool has a great influence on the measuring accuracy with the laser method. Also, if this step is omitted, the spindle bearings of spindle may be damaged. In the exemplary 5-minute warm-up cycle, the spindle runs at 10,000, 18,000, and then 24,000 RPM sequentially for 2, 2, and 1 minutes. This happens automatically on a tool change if the spindle has not been used for an hour or more. (McKibbin)

This paper discusses the monitoring of tool wear of straight router cutter by the change in the cutting diameter measurement. The tool diameter change was compared with the measured flank wear.

MATERIALS

The equipment used for the tests was a Bernardo BF 30 Super drilling and milling machine on which the cutters were mounted. Maximum rotation speed is 2250 RPM. The machine tool was equipped with an electronic speed and drilling depth indicator. Before starting the machining, the spindle warm-up process was carried out.

Stage 1

The first stage of heating up the electro-spindle takes took minutes. The rotational speed was 5000 rotations per minute.

Stage 2

The second stage of heating up the electro-spindle also took two minutes. The rotational speed was 10000 rotations per minute.

Stage 3

The third stage of the heating up the electro-spindle took one minute. The rotational speed was 15000 rotations per minute

Three straight 12 mm cutters were used for the tests, manufactured by Dimar, catalog number: 1070529, diameter –12 mm, working length – 38 mm, total length – 79 mm, working diameter – 12 mm, number of blades – 2.

The first aspect of the research was to check how the rotational speed of the spindle with the mounted cutter affects the accuracy of the test for the new cutter. For this purpose, the laser measurement of the tool diameter at a constant height for different spindle speeds was performed (20 samples per speed).

In the next stage, the tools were blunted in 18 mm thick laminated chip-board using standart 3-axis CNC Machinetool (Buselato JET 130). Tools were blunted by cutting grooves 6 mm deep with the following parameters: spindle speed 18000 RPM and feed of 5.4 m/min. Each tool cut a groove of different length, from 8 to 11 meters approximately.

The laser measurements were made at 70, 80, 90, 100, 110, 120, 130, 140, 150, 200, 250, 300, 350, 400, 500, 600, 700, 800 RPM speeds and four times for each speed with OMRON ZX-GT28E41, while maintaining the recommended principles of measurement.

Manual measurements were made using a Mitutoyo microscope. The average wear for two blades of the same cutter (Dimar 12mm) was calculated. Both methods were correlated.

During blunting, the tool was clamped in an ISO30 holder with ER32 clamping baskets. The tool was clamped in a standard 1-16 mm key chuck, when it was measured on a machine tool.

RESULTS

The results of the tool diameter measurement at different rotational speeds are shown in the figure 2.

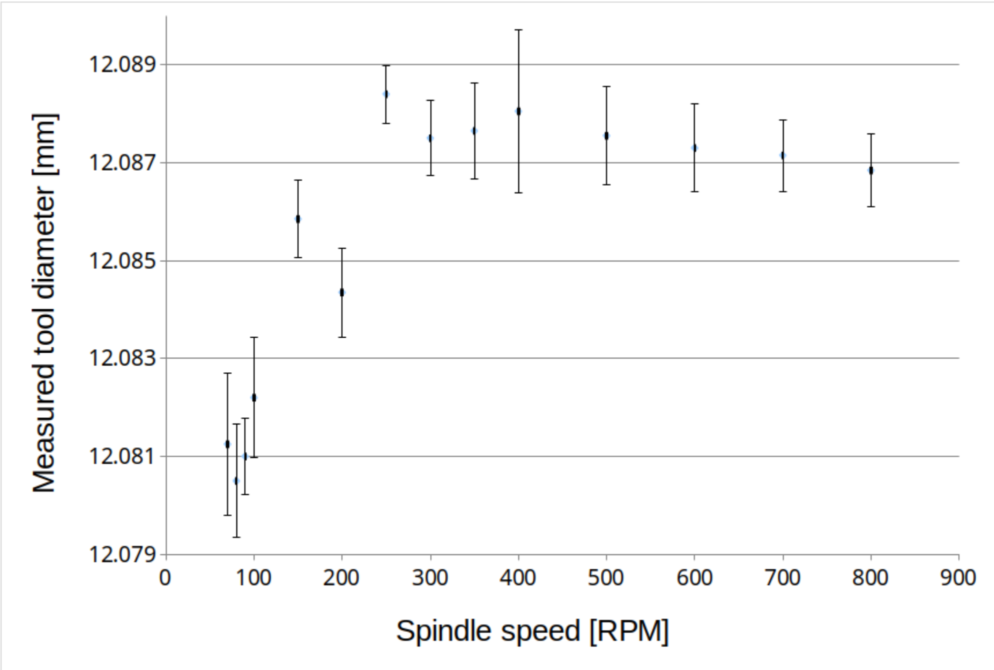

Figure 2. Measured diameter of the tool vs spindle speed

The diagram shows a change (increase) in the measured diameter with an increase in rotational speed in the range from 70 to 250 RPM. Above 250 RPM, the differences between the results for subsequent speeds exceed the standard deviation, therefore it should be assumed that no differences between the means. The mean value of the diameter was 12.088 mm (standard deviation 0.0005 mm). Probably the lowered results below the speed of 250 RPM, are caused by the higher measuring frequency of the device than the frequency of maximum obstruction of the laser beam.

Relation between tool diameter and average tool wear with linear correlation lines are shown in the fig. 3. The linear correlation coefficient was calculated from the formulas for Pearson's correlation coefficients.

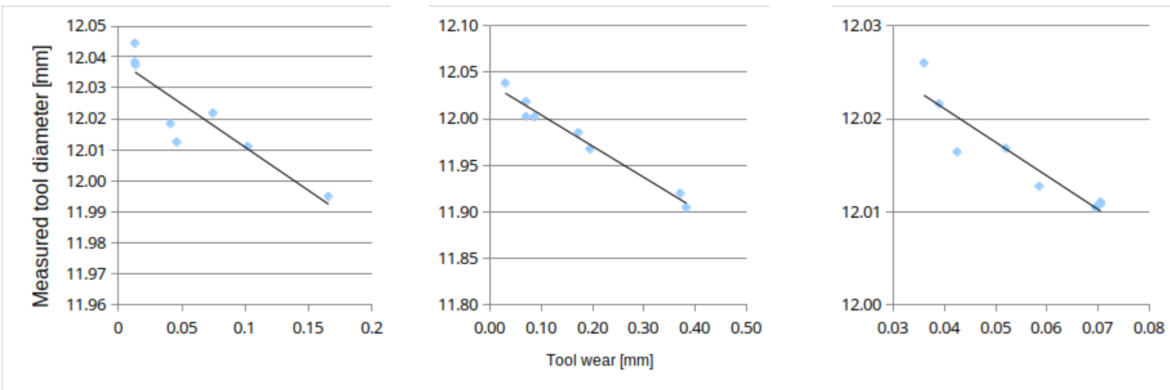

Figure 3. Correlation between tool wear and measured diameter

On the basis of the obtained data and the values of R2 (tab. 1), it can be assumed that the linear model describes the relationship between the diameter of the tool measured by the laser method and the wear of the tool measured by the microscopic method in a good manner.

Table 1. Linear correlation results.

Tool no.	Slope factor	Constant	R^2
1	-0.280	12.039	0.80
2	-0.337	12.037	0.97
3	-0.362	12.035	0.86

On the basis of the obtained data and the values of R2 (tab. 1), it can be assumed that the linear model describes the relationship between the diameter of the tool measured by the laser method and the wear of the tool measured by the microscopic method in a good manner.

CONCLUSIONS

1. Too low a spindle speed can negatively affect the accuracy of the measurement.
2. Measurement of the tool geometry in the context of measuring its wear using the laser method is characterized by an accuracy exceeding required for this type of measurement.
3. The results of the measurement with a laser micrometer allow the degree of tool wear to be indirectly determined with good accuracy ($R2 \geq 0.8$).

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Streszczenie: *Pomiar zużycia narzędzia laserową metodą bezstykową*. W ramach pracy zbadano narzędzia – frezy proste metodą bezstykową przy użyciu czujnika laserowego. Pierwszym aspektem badań było ustalenie wpływu prędkości obrotowej wrzeciona na dokładność pomiaru metodą laserową geometrii freza prostego. Drugim aspektem badań było ustalenie korelacji pomiędzy średnicą narzędzia zmierzoną przy użyciu mikrometra laserowego a zużyciem narzędzia określonym przy użyciu mikroskopu. Wykazano dobrą (R2>0,8) korelację pomiędzy zmierzoną średnicą narzędzia a jego zużyciem.

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