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Research Article

THE APPLICATION OF UNIVERSAL CNC MACHINE TOOL FOR SPUR GEARS MANUFACTURING

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ABSTRACT
The article introduces two variants of making spur gears by using universal CNC machine tools with universal shank cutter. The measurement of the chosen parameters of geometric structures of gear tooth surface were carried out as well as their comparison was made.

Keywords: spur gear, CNC machine, CAD/CAM software, roughness.

THE CHARACTERISTICS OF THE USED PRODUCTION OR MANUFACTURING METHODS

Gears are mostly made with gear millers. In this kind of manufacturing, special tools are also used [1, 4, 6, 9]. If expectations concerning toothing accuracy are lower, gears can be also madewith universal machine tools. However, special tools are required here as well. The development of computer technology generated new opportunities in the sphere of manufacturing. There are machine CNC tools for producing gears [7, 8]. More options of CNC machine tools, in comparison with conventional ones, made it possible to make the gear's toothing with universal machine tools, and in addition, with the use of universal tools. These tools are shank cutters, half-side milling cutters and ball end mills [1, 4, 5].

The research introduced in the present paper is related to spur gears made in two different methods. The first option – the working of gear tooth form with the parallel setting of milling cutter pivot and the worked gear. The second option – the working of further gear spaces with the radial setting of milling cutter pivot, in comparison to the gear pivot. Both options are depicted in Figure 1.

For the preparation of the NC code, CAD/CAM software was used in both cases [2, 3]. In the first case, the flat toothing profile corresponding to the gear's front section was the model of the gear. The tool's movement path was obtained by using the machining contour cycles 2,5D. In the second case, a solid model was used. Cycles of roughing and 3D finishing were used for machining simulation. The machining project was prepared in the Inventor and HyperMill software. The machining was done on the milling plotter. Gears have 15 and 17 teeth and the module pitch of the gear was 5 mm. Gears were made of aluminium alloy (PA4). Machining parameters: tool's rotational speed s = 18 000 rot/min, travelling speed f = 200 mm/min and the depth of cut for contour machining a_p = 0,3 mm and for 3D machining a_p = 0,2 mm.

THE MEASUREMENT AND COMPARISON GEARS TEETH ROUGHNESS

Roughness of manufactured gears was measured. The measured parameters were: arithmetic mean roughness deviation (*Ra*), and the roughness according to ten points of profile (*Rz*). The measurement was done along the tooth line and along the tooth profile. The measurement method is presented in the Figure 2.

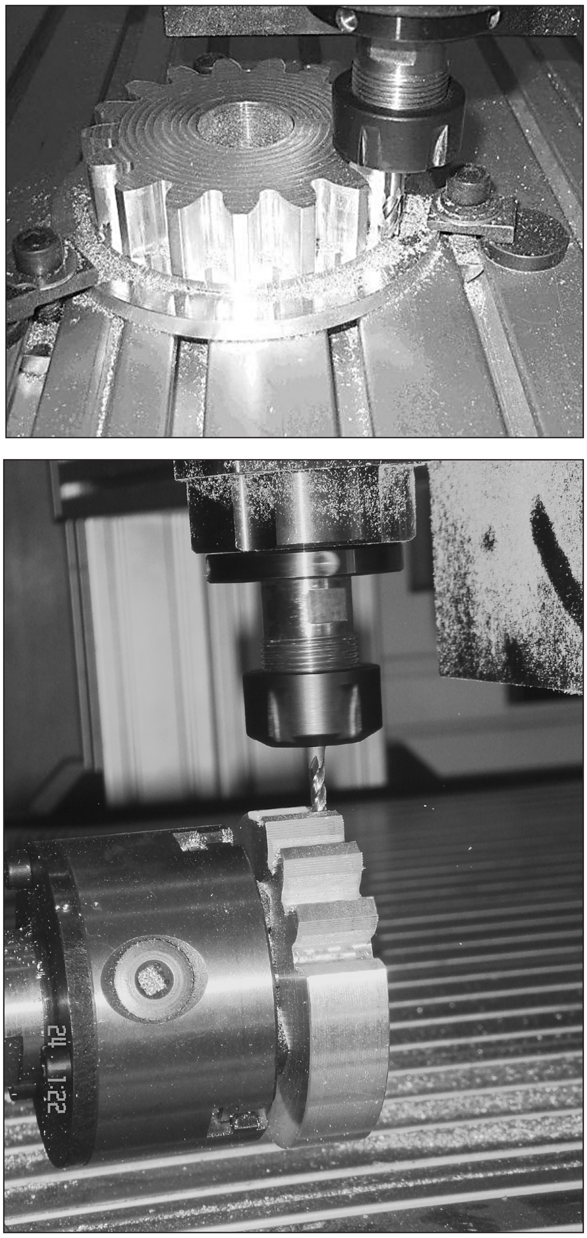

Fig. 1. The methods of gears manufacturing on the universal machine tool

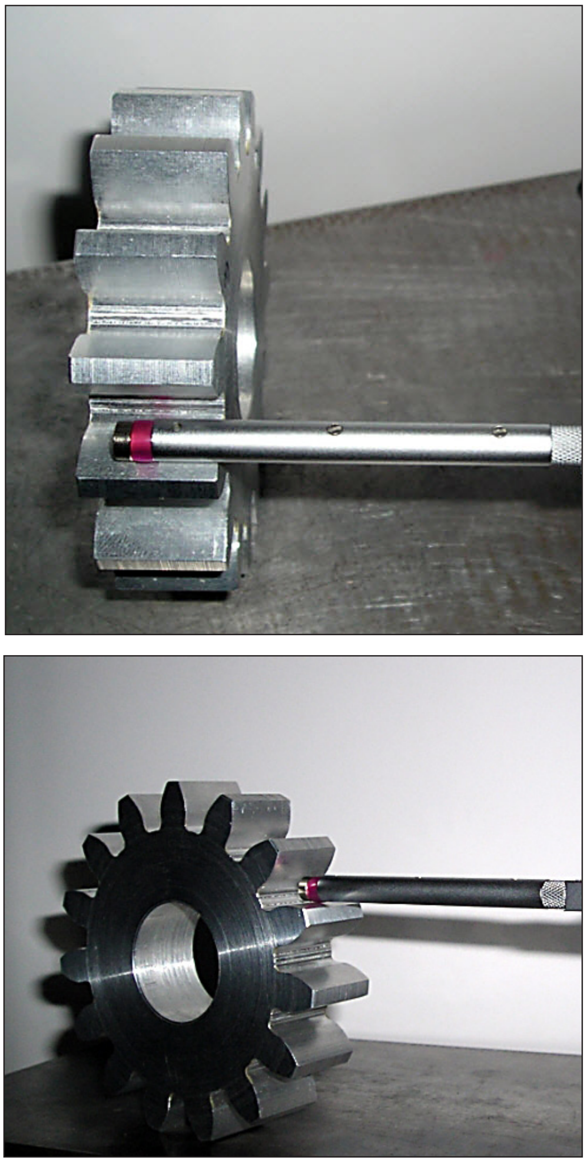

Fig. 2. The measurement of gear roughness on Surtronik 3+

Roughness on teeth surfaces was measured on the Surtronik 3+ profilometer. For measurements four teeth from each gear were chosen randomly. The measurement was repeated five times on every chosen tooth.

The length of measuring section amounted correspondingly Lc = 4.0 mm for the measurement along the tooth line and Lc = 2.5 mm along the tooth profile. The results from the gears measurements are shown in Table 1.

No significant differences in roughness between these two machining methods were noticed. In Figure 3 roughness diagrams from measurement along tooth line are shown.

Roughness changes during the measurement along the tooth profile can be noticed. Ra parameter for the first gear was 1.94 μm, and 1.15 μm for the gear with 17 teeth. These differences result from the working of the tooth form from the first gear. In 3D profiling the a_p parameter was 0.2 mm, what can be seen in the roughness profile (Fig. 4a). It is repeated by Rz parameters, 10.04 μm for the first gear and 5.18 μm for the second gear.

Assuming ideal conditions of manufacturing process, it is possible to calculate the shape errors which are created because of tool's movement along the axis. The CAD software was used for this purpose. The value of deviations from involute's ideal profile can be noticed in Figure 5. Modelling the milling cutter profile on the gear

Table 1. The results of gears roughness measurements

Parameter	Measurement along the tooth line		Measurement along tooth profile	
	Ra [µm]	Rz [µm]	Ra [µm]	Rz [µm]
Gear 15 teeth	0.87	4.15	1.94	10.04
Gear 17 teeth	0.51	3.08	1.16	5.18

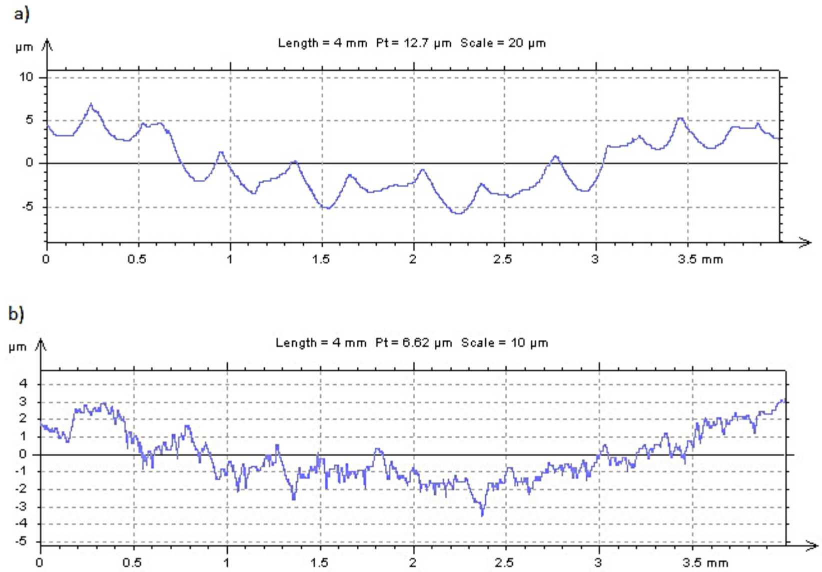

Fig. 3. The roughness profiles measured along the tooth line: a) 15-teeth gear, b) 17-teeth gear

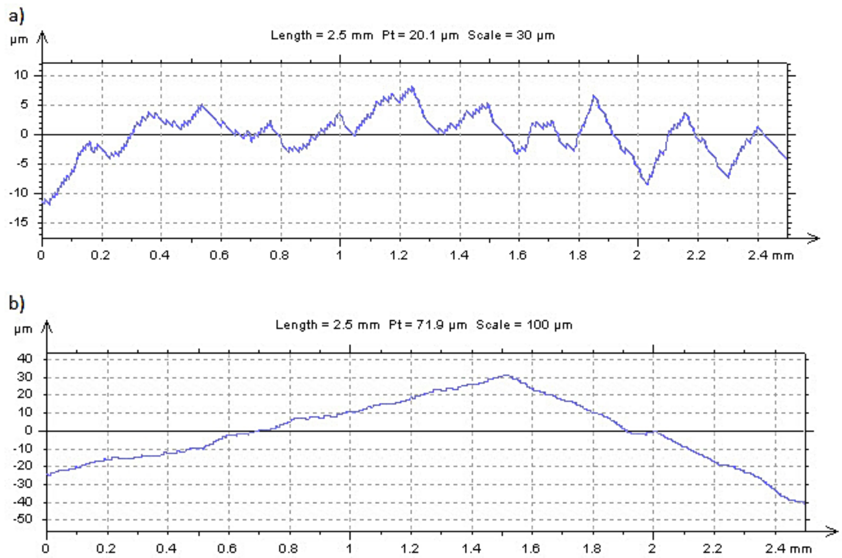

Fig. 4. The roughness profiles measured along the tooth profile: a) 15-teeth gear, b) 17-teeth gear

during the working process is needed to see the value, as it is shown in Figure 5. The results of deviation values (3 µm) are presented.

The value can be calculated from the formula (1):

$$\delta_z = \frac{f^2}{4 \cdot D} \qquad (1)$$

where: δ_z – the deviation of profile,
f – the value of the milling cutter dip,
D – the milling cutter diameter.

Substituting $f = 0.2$ mm and $D = 3$ mm for the above formula, the value of deviation amounts $\delta_z = 3.33$ µm.

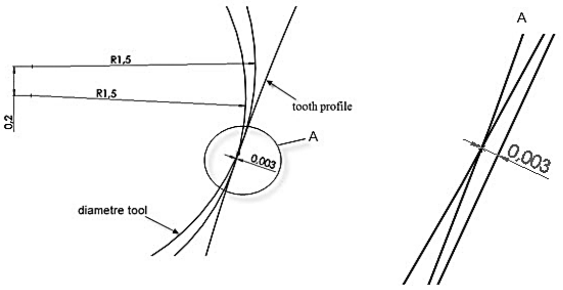

Fig. 5. The milling cutter profile during the manufacturing process and its deviation (in millimeters)

The results from the 15-teeth gear measurements and calculation are shown in the Table 2.

The difference between roughness parameters values and real deviations values from physical concomitants during the manufacturing are presented.

Table 2. The profile deviation values of gear 15 teeth

Parameter Rz (μm)	Deviation values (μm)	Values on CAD (μm)
10.04	3.33	3.00

CONCLUSION

The described gear machining methods can be applied to the unit production due to the fact that they are not very efficient, comparing to the traditional methods. The gear can be manufactured without using special tools by using the CAD/CAM software and the universal CNC machine tool.

As a result of the research, it was stated that the difference in roughness values along the tooth line is slight. However, the roughness difference which arose from the measurement along the tooth profile can be reduced by decrease depth of cut but it is connected with longer time of the gear machining.

Obtaining more precise teeth is the advantage of making the gear from the model generated in the CAD/CAM software in comparison to the gear generating method because there is no need to use additional tool– an index head, which was used during the gear manufacturing by 3D profiling method.

Comparing the results, it can be stated that the difference between the obtained roughnesses and deviations' values come from the factors functioning during the machining, i.e. vibrations, machine inaccuracy, tool's wear, cutting forces, etc.

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