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***Research paper***

# Modeling of the Cutting Edge Rounding Influence on the Tool Life in Processing A Gear Wheel by the Power Skiving Method

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**Abstract**

Modeling of the shaping by a milling cutter is made while forming the internal gear teeth of the driven gear wheel. The estimate of the cutting edge rounding influence on the tool life taking into account the wear-resistant coating. The effects of radii of 10 μm, 15 μm, 20 μm, 25 μm are simulated. At the edge radius of 10 μm, the coating layer is rapidly collapses. At a radius of 15 μm, the highest tool life is obtained. At the more high radii, the tools durability is decreases. A practical experiment was carried out on a cupped skiving cutter with AlTiCN-coating (PVD). Processed steel 41CrAlMo7 with hardness 241-287HB. The simulation results were confirmed, the highest tools lifetime at a radius of 16.13 microns for 60 parts. As a result, for this type of processing and for this coating type of the cutting tool, the most optimal cutting edge rounding can be considered as the value of 15-18 μm. It can be concluded that, perhaps, a more sharp edge from 10 to 15 μm can be a positive effect on tools lifetime, in the case of uniform rounding over the entire cutter edge of the tools tooth (on the top and side tooth profile).

***Keywords*** Modeling of shaping, the cutting edges rounding, tool durability, tools lifetime, skiving.

## 1. Introduction

For the machining of "Driven gear" part (Fig. 1) is used a cupped skiving cutter with parameters: diameter 135mm, the module m=3,5. The gears material is steel 41CrAlMo7 with a hardness of 241-287HB. Attention should be paid to the internal groove that separates the splines, which creates additional impact loads.

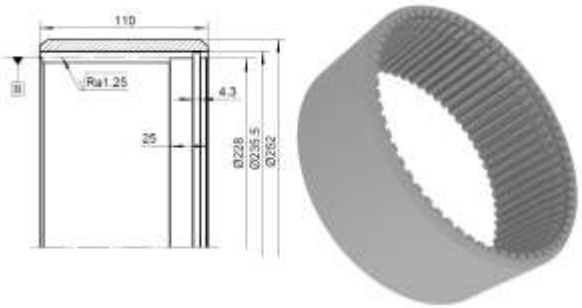



**Fig.1**: Sketch and model of the « Driven gear » part

In order to reduce the cost of production, the tool is re-sharpening at the factory. To increase the tools lifetime is used AlTiCN-coating (PVD). In this case, the durability of the reconditioned tool is lower than the new one from the supplier.

It is required to increase the tools lifetime, without changing the basic characteristics of the gear cutter geometry. One of these parameters can be considered rounding the cutting edge, which directly affects the tools lifetime during machining. In articles [1] and [2], the influence of the position of roundness on the rake face and flank of the cutting edge on the life cycle of the mill was studied. Thus, the study [3], [4], [5] showed that the greatest tools lifetime was fixed at a symmetrical roundness position $S\alpha = S\gamma = 30 \pm 5$ μm, with a rounding radius of 25 μm ± 5 μm. As the object of investigation, a cutter d25mm with carbide plates ADGT 080308R-F56 was considered. Cutting data: speed vc=230 m/min, feed per tooth fz=0.2 mm with cutting depth ap=0.15mm for steel 42CrMo4-QT. The influence of the cutting edge rounding on the conditions of the cutting process is considered in [3], [4], [6], [7].

Thus, the purpose of the article to consider the influence of the cutting edge rounding on the tools lifetime of the cupped skiving cutter with AlTiCN-coating when machining a gear from 41CrAlMo7 steel with a hardness of 241-287HB. Cutting speed 80m/min, average feed per tooth 0.25mm.

## 2. Methods.

For a preliminary analysis of the influence of the cutting edge rounding on tools lifetime, modeling was performed in the ANSYS environment [8]. It was simulated the formation of edge chipping/breakage according to the wear of the PVD-coating [9], [10]. Simulation serves to pre-obtain the optimum the cutting edge rounding of the tool but does not give an exact value of the tools lifetime.

To confirm the simulation results, practical experiments were carried out to determine the dependence of the tools lifetime on cutting edge rounding. The reconditioned tool before of the PVD-coating was as a basis. The cutting edge was machining by wet blast cleaning system with a blasting medium of ceramic balls 50-

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120μm. The radius rounding was reached by the compressed air pressure value and the machining duration. Taking into account the geometrical characteristics of the tools teeth, it was found out experimentally that the radius of rounding at the top of the tooth is formed by 60-90% greater than in the side profile and bottom of the teeth. The first parameter is taken for analysis.

In the mass production cutting edge can be prepared by the various blasting cleaning systems (dry or wet), on the drag finishing or stream finishing machines. In practice, it is rather difficult to precisely adjust the roundness parameters Sα and Sγ [11], so we need to operate with an approximate rounding value [12], [13]. It should be noted that the effect of the rounding size of the cutting edges is valid not only for carbide tools, but also for tools made of high-speed steel.

## 3. Results and Discussion.

For a preliminary analysis of the effect of the cutting edge radius on the tools lifetime, a simulation was performed. It was simulated the formation of edge chipping/breakage according to the wear of the PVD-coating. The result of the simulation is shown in Fig. 2. The horizontal axis is cutting edge radius value of the tool. The vertical axis is some tools lifetime value on conditional scale. Here it can be inferred that maximum tools lifetime value is possible, between from 10 to 20μm, and practical experiments should be carried out in this range of tool edge rounding.

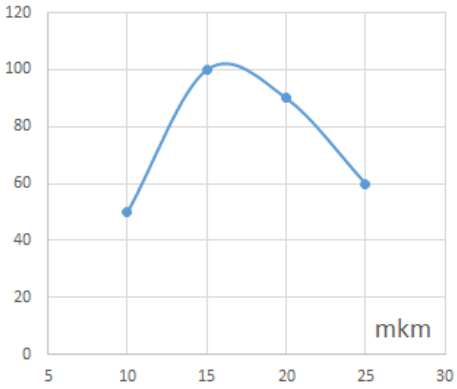



**Fig. 2:** The simulated dependence graph of tools lifetime versus the cutting edge rounding value

We will prepare the experiment. As a tool for experimenting, the cupped skiving cutter with AlTiCN-coating. Cutting speed 80m/min, average feed per tooth 0.25mm. The tool has been reconditioned. Before the coating process, cutting edge was machining by wet blast cleaning system with a blasting medium of ceramic balls 50-120μm. The radius rounding was reached by the compressed air pressure value and the machining duration. For comparison of tools lifetime, the cutting edge rounding was chosen: 10, 15, 20, 25μm. The results of processing the tool are shown in Fig. 3,4,5.

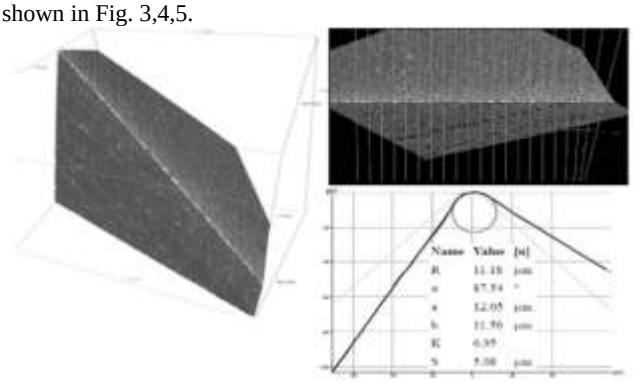


**Fig. 3:** The cutting edge rounding result is 10 μm (in fact R = 11.18)

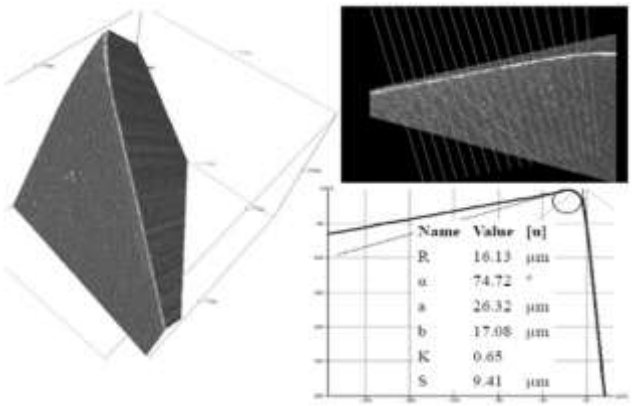



**Fig. 4**: The cutting edge rounding result is 15 μm (in fact R = 16.13)

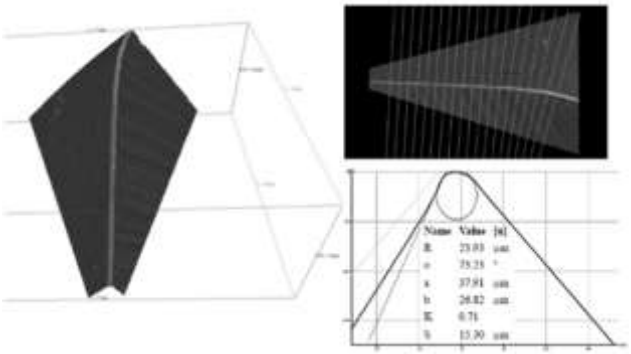


**Fig. 5**: The cutting edge rounding result is 15 μm 25 μm (in fact R = 23.93)

Each of tools was used for machining a "Driven gear" part (Figure 1) from 41CrAlMo7 steel with a hardness of 241-287HB by the PowerSkiving method. The results of the tests are shown in Table 1.

**Table 1:** Test result of a tool with a different rounding radius

| Test variant | R rounding, μm | Tool life, pcs |
|---|---|---|
| A | 11.18 | 24 |
| B | 16.13 | 60 |
| C | 20.12 | 51 |
| D | 23.93 | 36 |

The criterion for completing the tests was: an extreme increase in the load on the spindle or the occurrence of extraneous noise (this indicates the presence of chips or wear more than 0.3 mm usually), or the achievement of the number of parts for forced tool change (60 pcs.)
Visual analysis the nature of wear is shown in Fig. 6, 7.




**Fig.6:** Wear of cutting edge with initial rounding radius R=11.18 μm (left image), R=20.12μm (right image)

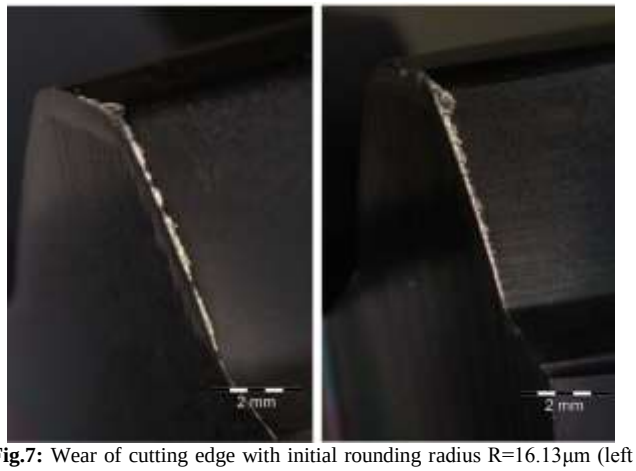



**Fig.7:** Wear of cutting edge with initial rounding radius R=16.13μm (left image), R=23.93μm (right image)

For the case A "R=11.18μm" - increased wear along the profile of the tooth, is associated with insufficient machining of this surface. That is, getting edge rounding radius of 10-12μm on the top of the tooth, this radius was practically absent on the side profile, up to the presence of burrs remaining after the re-sharpening (grinding along the front surface). This drawback affected the quality of the applied AlTiCN-coating and led to premature wear. The top of the tooth remained undamaged practically.

The tool in the case D "R=23.93μm" proved to be least satisfactory, because vibration appeared at the machining on the32nd part, and wear after the 36th part was more than 0.4mm. In addition, a burrs was observed at the output of the gear splines, which indicates the deformation (extrusion) of the metal during machining, rather than the normal cutting process.

## 4. Conclusion

As a result, for this machining type, the most optimal cutting edge radius of rounding can be considered as 15-18μm. Also, in conclusion, we would like to note that, perhaps, a more sharp edge (10-15μm) can have a positive effect on tools lifetime, in the case of uniform rounding over the entire cutter edge of the tools tooth (on the top and side tooth profile)

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