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INCREASING OF THE CUTTING POWER AT INSERTS FOR APPLICATION IN THE AREA OF POWER INDUSTRY

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Abstract

This article deals with the influence of cutting edge preparation on tool life, cutting forces and the roughness of machined surface. The cutting edge preparation was done on the inserts with wiper geometry which are used during machining of dividing plane at a steam turbine casing. This cutting inserts were prepared by the technology of drag finishing on the edge radius 5, 10 and 15μm. The workpiece material was ferritic – martensitic steel with the content of 9%Mo and 1%Cr and the material of cutting inserts was submicron sintered carbide. There was used only one cutting insert in the milling cutter.

Key words: *edge radius, milling, tool life, roughness, forces*

1. INTRODUCTION

During machining there are high local pressures between the tool and the workpiece, high temperatures, cutting forces, etc. The cutting temperature, which is generated during cutting process, exposes the cutting tool to extreme thermal conditions. Heat, which is also generated by chip formation and by the friction on the rake face during high speed cutting, is adverse effect. This adverse effect can influence the tool life. At both discontinuous and continuous cut the cutting forces act unstable that is caused by small and very hard elements in the workpiece microstructure. That is why there are very strict requirements on the cutting material. The example of requirements is following: high hardness at elevated temperature, high fracture toughness, resistivity to tool wear and high strength. The user expects from the tool productive machining and very low tool wear. These requirements are possible to realize by better design of the cutting tool, new substrates, new deposited thin layers, etc [Biermann & Terwey 2008]. The design of cutting tool is possible to improve in the area of either macro-geometry (tool profile, reshaping, angles, etc.) or micro-geometry. Micro-geometry of cutting tool is influenced to a certain extent by the cutting material and the deposited thin layer, which influences the roughness of machined surface and also the edge radius. For the cutting edge preparation there are used different methods, for example: brushing, drag finishing, mirco-blasting dry, micro-blasting wet, magnet finishing, honing by hand, laser, etc. Most of these methods are based on the principle of abrasive elements effect. The effect is transmitted by suitable process media. The process media can be: air, paste, a fibre, a magnet, etc [Bouzakis 2009]. The required edge radius is created by the combination of speed and the duration of abrasive movement or the workpiece. The aim of cutting edge preparation is:

- increasing the strength of the cutting edge
- increasing the tool life
- to reduce the internal stress of the coating
- to reduce the risk of edge chipping
- the preparation of the tool for deposition (smoother surface)

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- to create the defined shape and size of the cutting edge

Why is it necessary to prepare cutting edges? In the Fig.1 there is shown the difference between a sharp tool and a tool with prepared edge. On the left side there is the sharp cutting edge which was created by grinding the rake face and the flank of the tool. The cutting edge has defined edge radius because we are not able to produce perfectly sharp tool. The roughness on the tool edge is higher and the surface of this tool may have defects. The defects can be:

- micro – defects: they arise during grinding process and they are also caused by manipulation among each step of production process. These defects can be seen both before and after coating.
- burrs: they are caused by the grinding process. Burrs can roll up over the cutting edge during the cutting process and they can destroy it. Definitely necessity for coating is the tool without burrs.

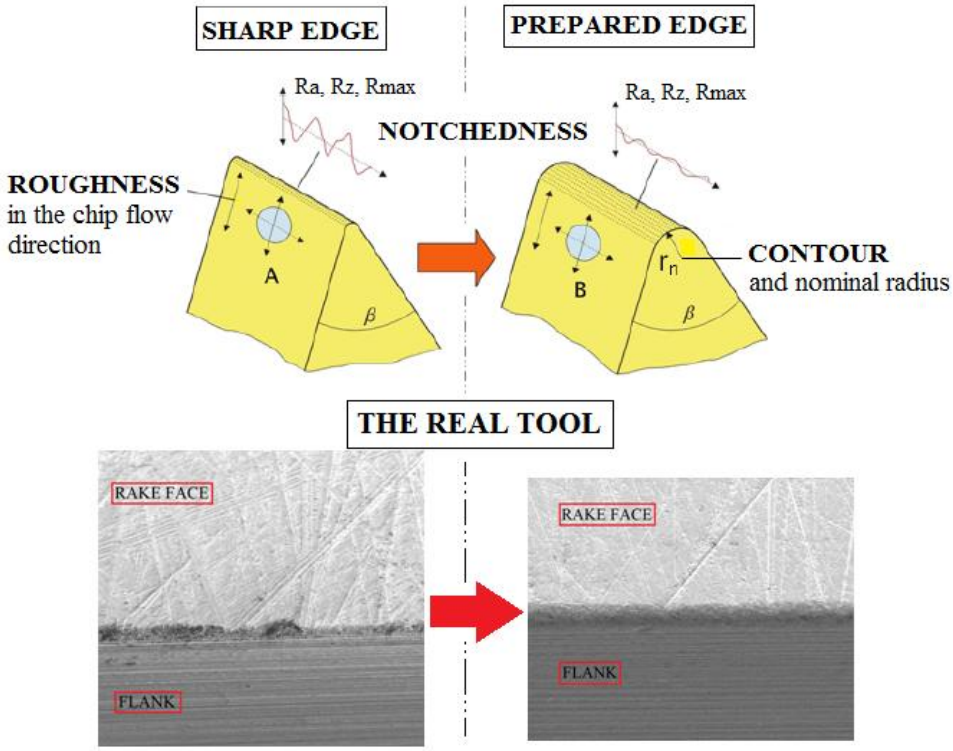


Fig. 1: Characterization of cutting edge preparation [Rodriguez 2009]

The cutting edge preparation can influence:

- cutting forces/gyroscopic moment
- cutting forces
- tool wear – tool life
- chip formation
- quality of machined surface
- accuracy of machining

- adhesion of deposited thin layer, etc.

At a production process of a cutting tool it is necessary to follow the influence of inter-process preparation and also the influence of tool process technologies because right these factors have essential influence on the success of coated thin layer and the tool life. The production process of a tool can be seen in the Fig.2 [Buechel 2007].



Fig. 2: Manufacturing process for precision tools [Byrne, Dornfeld & Denkena 2003]

1.1 Definition of the wiper geometry and the cutting edge micro-geometry

The wiper geometry is special type of cutting tool geometry which is suitable for both turning and milling operations. The theoretical Rt surface roughness value can be determined with the radius, tool cutting-edge angle on the minor cutting edge and the feed rates on hand. For better quality of finished surface is necessary to use either lower feet rates or higher edge radius. The next way is to use the tool with wiper geometry. In the Fig. 3 there is shown the principle of standard and wiper geometry (all values in the Fig.3 are in micrometer). The required surface can be also calculated very precisely in advance.

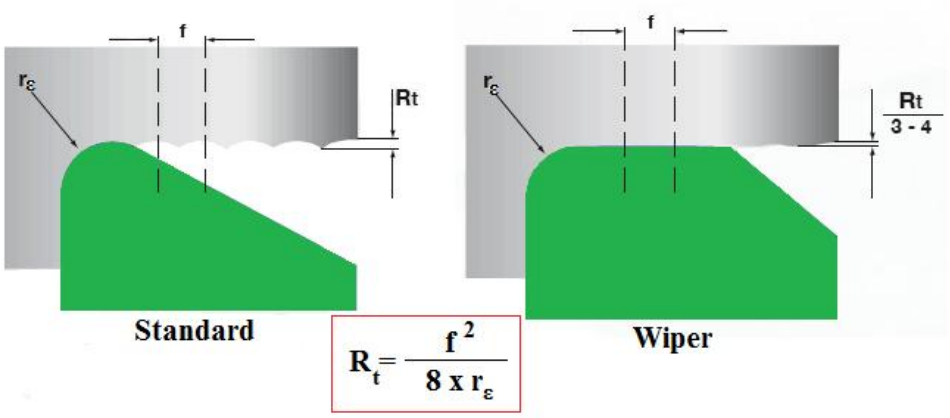


Fig. 3: Comparison of standard and wiper geometry [*Wiper geometry and surface finish* 2012]

For the evaluation of the cutting edge micro-geometry it is necessary to use consistent specifications. The cutting edge is defined by:

- cutting edge radius r_β
- parameters: Δr, φ, Sα and Sγ
- $K = \frac{S_\gamma}{S_\alpha}$

These parameters can be seen in the Fig. 4. K is defined to describe the symmetry of the contour generated by the cutting edge rounding process. If K=1, the micro-geometry is symmetrical. While

K > 1 indicates a slope towards the rake face and K < 1 describes a slope towards the flank [Denkena, Lucas & Bassett 2011; Otec 2006].

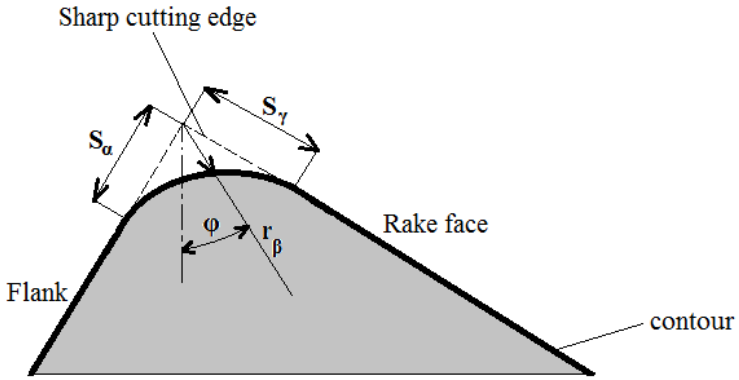


Fig. 4: Characterization of the cutting edge micro-geometry

2. EXPERIMENTAL SETUP

The whole experiments were done on the three-axial vertical machining center MCV 750A. Workpiece, which was fixed on the work-table of the machining center, was machined by a milling cutter with diameter 80mm. External cooling was running. The milling cutter was fitted with the one sub-micron sintered carbide tangential indexable insert without chip breaker (YDA323L101). Only one indexable insert was used because it was necessary to remove the influence of insert´s dimensional inaccuracy or the milling cutter on machined surface. During machining there was measured: tool wear, cutting forces and roughness of machined surface. The following main criteria were determined:

- maximal tool wear $VB_n/KB = 0.2mm$
- roughness of machined surface $Ra < 0.8\mu m$
- volume of removed material $B \geq 60cm^3$

The cutting conditions and technical data are shown in the Tab.1. There is also the photo of the milling cutter, the indexable insert and the machining centre.

2.1 Cutting edge preparation

The cutting edge of the indexable insert was prepared on the edge radius 5, 10 and 15µm by the technology of drag finishing. During this preparation the indexable insert is dragged in a circular motion at high speed through a container filled with grinding or polishing media. The high-speed motion creates high contact pressures between the workpieces and the media, producing perfect results in a very short time in the form of high-precision rounding of the edges or a high-lustre finish. The process media for drag finishing was composition walnut granulate with SiC [http://www.otec.de/en/drag-finishing-units.html].

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Milling type:	Climb milling, outer cooling	Machine tool:	**MCV 750 A** Producer Kovosvit a.s. Sezimovo Ústí
Axial depth of cut a_p [mm]:	0.02		
Cutting speed v_c [m/min]:	$v_c = 200$	Measurement system:	Three-component piezoelectric dynamometer **KISTLER 9255 A**
Feed rate f_z [mm/tooth]:	$f_z = 4.5$		
Spindle speed: [ot/min]	n = 796		**Alicona InfiniteFocus** – optical measurement system, surface metrology and form measurement
Radial width of cut a_e [mm]:	$a_e = 50$		
Criterial value of tool wear:	$VB_n = 0.2$mm KB = 0.2mm		Device for measuring roughness **Marsurf M300**
Workpiece:	EN ISO X12CrMoVNbN9-1 (185 ÷ 260HB)		Microscope **MULTICHECK PC** 500 (zoom 10x, 30x, 75x a 150x)
Tool:	Milling cutter Ingersoll , ø80mm, possibility to fix 4 inserts		

Tab. 1: Technical and cutting conditions

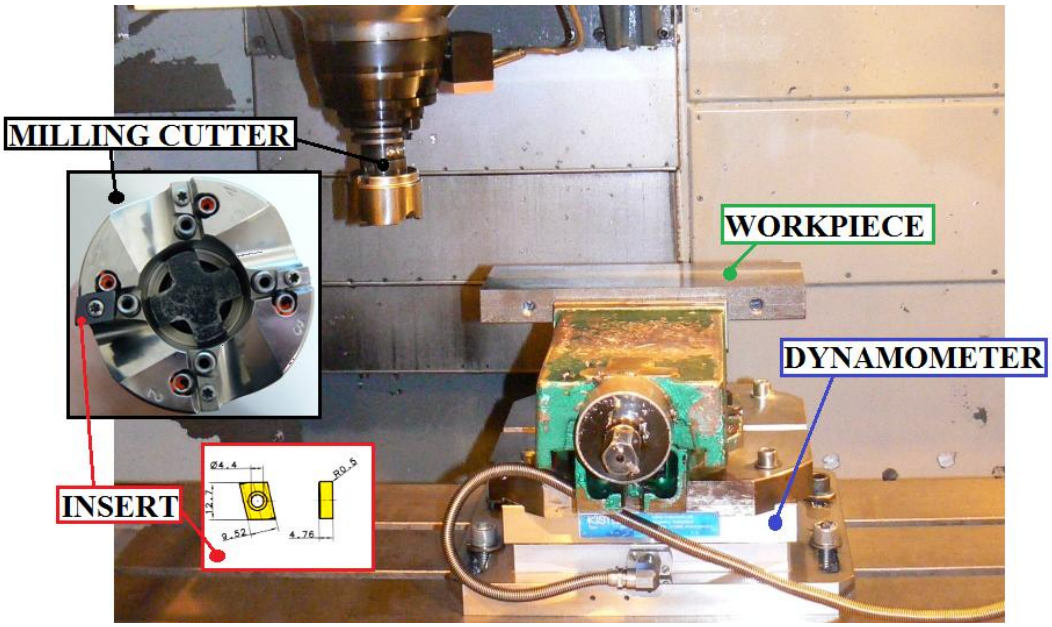
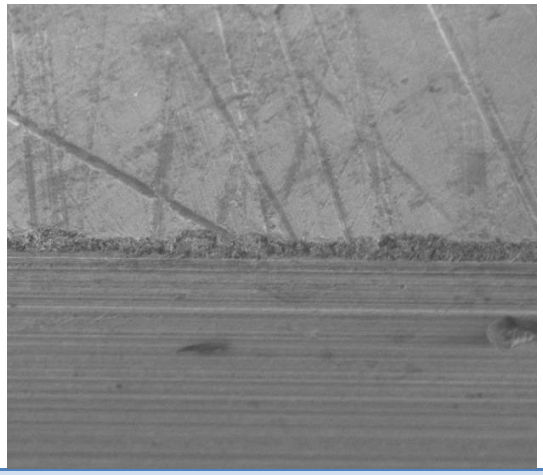
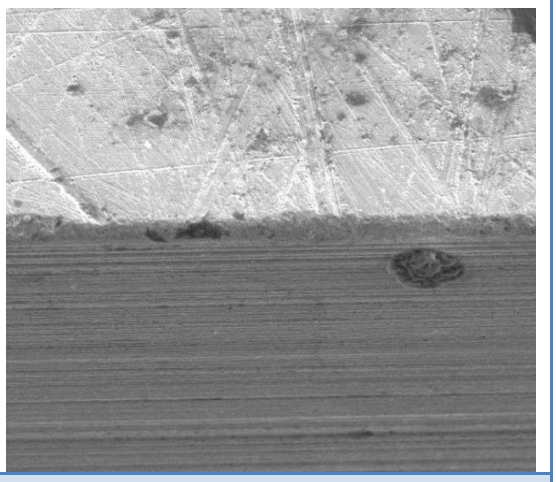
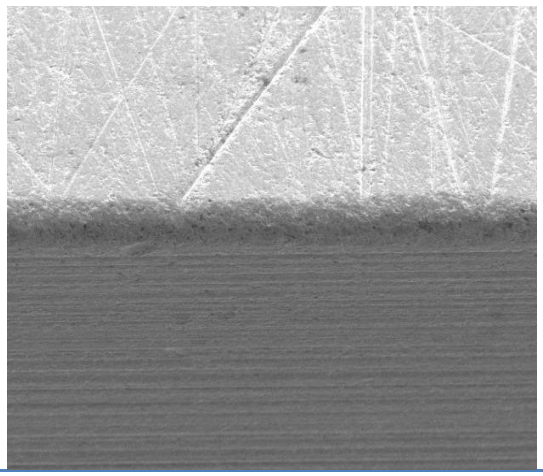
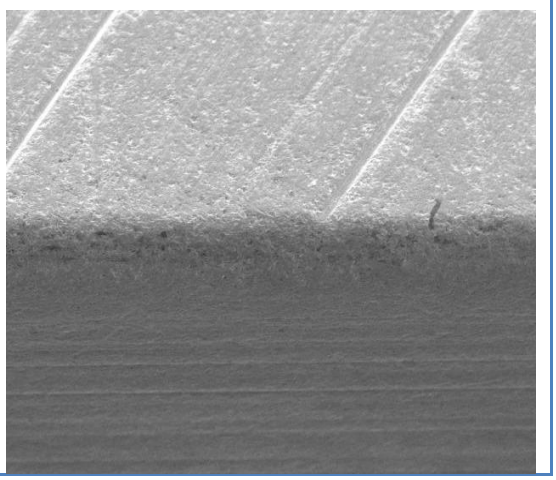


Fig. 5: Description of the workspace

Edge radius	
grinded edge	**r_β = 5µm (K = 1)**
	
r_β = 10µm (K = 1)	**r_β = 15µm (K = 1)**
	

Tab. 2: The photos of prepared tools – zoom 500x

The pictures in the Tab. 2 were captured by the scanning electron microscope and the edge radius was measured on the Alicona Infinite Focus.

3. EXPERIMENTAL RESULTS

The experimental results will be mentioned in this chapter. Experiments were twice repeated; when the difference among measured results was higher than 10percent we repeated experiment twice again.

3.1 Tool life

There is shown the influence of the edge radius on the tool life in the Fig. 6. During experimental machining tool wear on the rake face and on the flank was measured. When the tools wear either rake face or flank reached/crossed the criterial value the experiment was stopped. The experiment was also stopped when the volume of removed material reached 60cm^3. This value is important because this

experiment is based on real machining. The dividing plane of the body steam casing is machined by this type of indexable insert. The one cutting edge must remove at least 60cm^3. The Fig. 6 shows very important information, that with increasing edge radius the tool life is also increasing. There is not the tool which was "only" grinded in the Fig.6. The tool life of grinded tool was very low, lower than the tool life of the tool with edge radius 5µm. The information in the scientific articles speaks about the most suitable edge radius which is about 20 ÷ 25µm. We could not prepare the edge radius higher than 20µm, because the depth of cut is equal 20µm! So here can be confirmed hypothesis: increasing edge radius (in the interval 5 ÷ 15µm) means increasing tool life. It is done by compact and smooth surface of the cutting edge; the cutting edge has higher strength and it is without defects (see in the Tab.2). The tool wear was in the form of chipping cutting edge parts for the edge radius r_β =5 and 10µm and in the form of uniform tool wear for the edge radius r_β =15µm. The tool wear was measured on the rake face and on the flank, but in the Fig. 6 is analysed on the tool wear on the flank. It is done because the tool wear on the flank influences the roughness of machined surface more than the tool wear on the rake face.

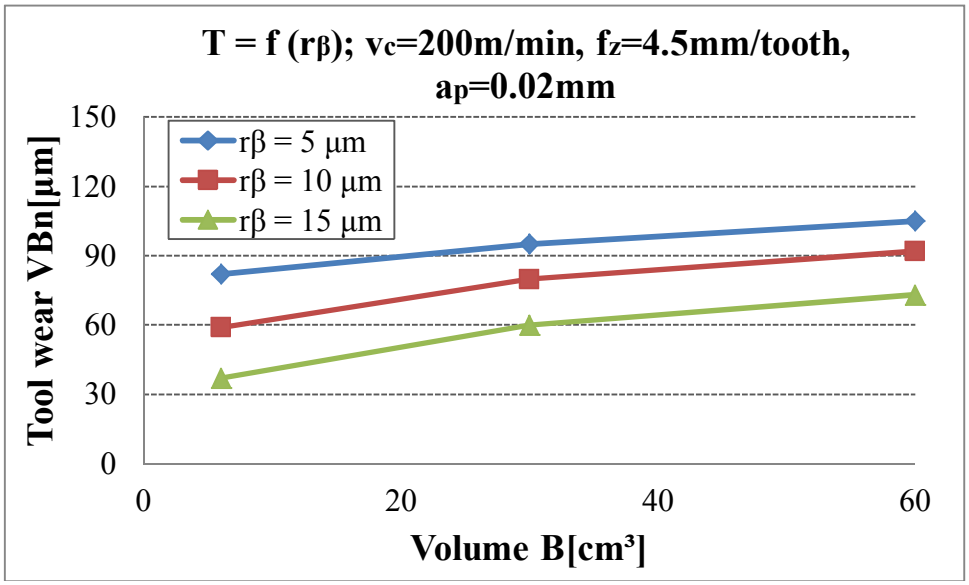


Fig. 6: Influence of the edge radius on the tool life

3.2 Roughness of machined surface

The roughness of machined surface is also very important because it must not be higher than Ra = 0.8µm; this value is written in the design documentation. The next parameter is difference of machined surface roughness at the beginning and at the end of machining. It is not so suitable if the difference of machined surface roughness is high because it means problems with accuracy of machined surface, assembly problems and possibility of accidental cutting edge damage which can influence integrity of machined surface. The influence of the edge radius on the roughness of machined surface can be seen in the Fig.7. The lowest roughness of machined surface is reached with the edge radius r_β = 15µm, because this tool is the most stable during machining. This tool has the lowest tool wear, no defect on the cutting edge and the roughness of machined surface is the same both the beginning and the end of machining. Roughness of machined surface for the edge radius r_β = 5 and 10µm is decreasing and from the volume of removed material 30cm^3 is the same. It can be explained as an incising (there is forming a cutting edge on the new tool).

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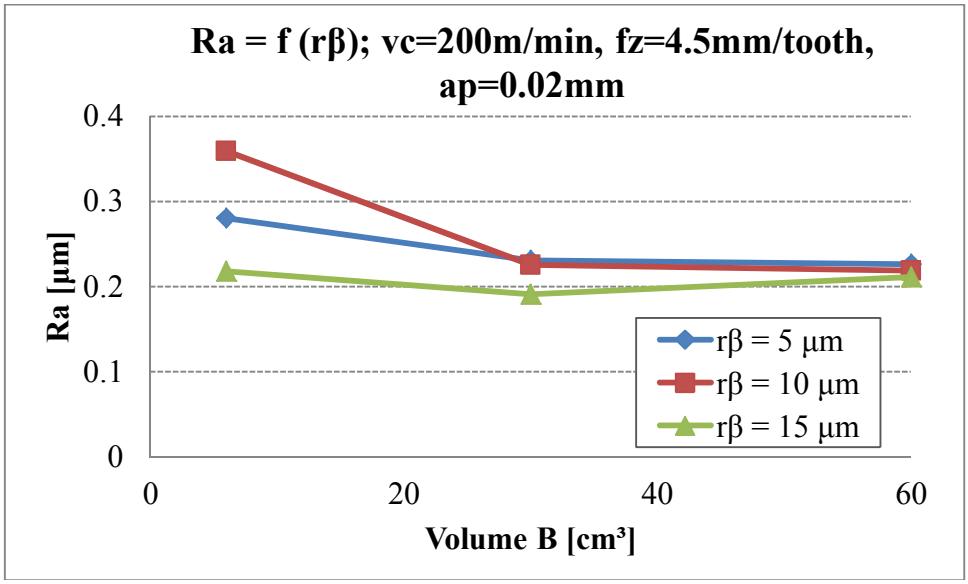


Fig. 7: Influence of the edge radius on the roughness of machined surface

3.3 Force load

During machining process there were also measured components of cutting forces Fx, Fy and Fz. In the Fig.8 there is influence of the edge radius on the total force load (a diagram on the left side) and component of cutting force Fz (a diagram on the right side). The total force load was calculated from:

$$F = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

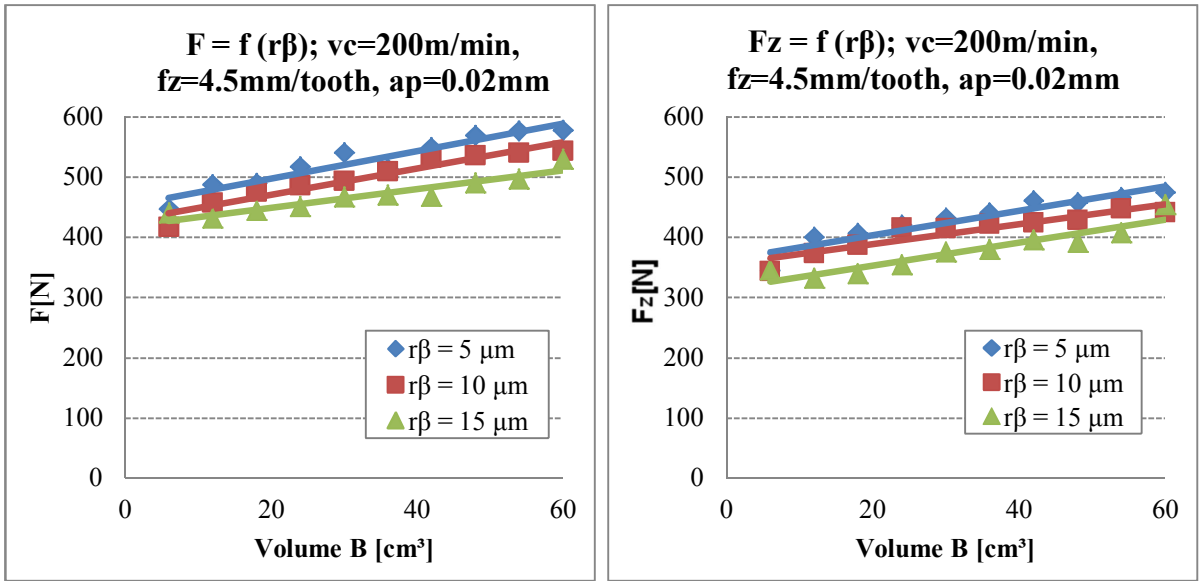


Fig. 8: Influence of the edge radius on the total force load (on the left side) and on the component of cutting force Fz (on the right side)

Cutting forces are increasing with the volume of removed material (with increasing tool wear). The lower edge radius, the higher total force load and the component of cutting force Fz. This result is very interesting, because it should be to the contrary (the lower edge radius, the lower cutting forces). The tool with edge radius 5µm is sharper than the tool with edge radius 15µm. Sharper tool should generate lower cutting forces because this tool easier enters to the material, but when we look in the Fig. 6 we can see the answer to this matter. After removing the volume 6cm^3 the tool wear of the tool with edge radius 5µm is almost 0.085mm and the tool wear on the tool with edge radius 15µm is around 0.035mm so the tool wear is responsible for higher cutting forces for the tool with lower edge radius.

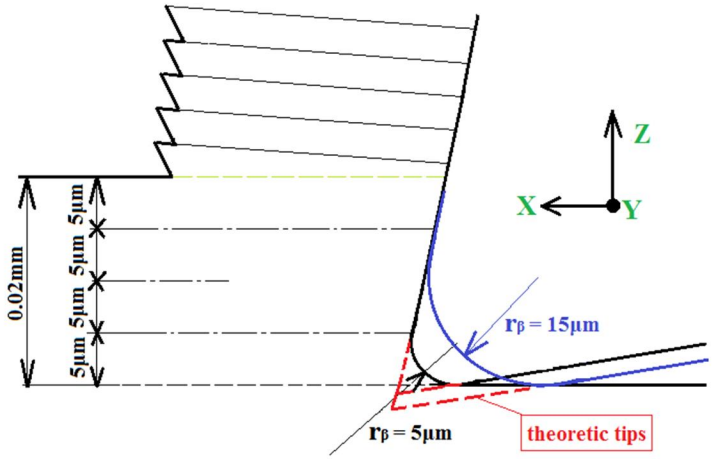


Fig. 9: Comparison of the edge radius 5 and 15µm

4. CONCLUSION

This article was focused on the influence of the edge geometry on the tool life, roughness of machined surface and the cutting forces during finishing machining of ferritic-martensitic stainless steel which is used for cast of body steam casing. The described technology is used for machining dividing plane where the depth of cut is 0.02mm, so it means that the edge radius cannot be higher than 20µm. Sub-micron sintered carbide indexable insert, which was only grinded on the functional surfaces, was prepared by the technology of drag finishing on the edge radius 5, 10 and 15µm. The cutting conditions was experimental determined (the extensive experiment went before this experiment) on the v_c = 200m/min, f_z = 4.5mm/tooth, climb milling and external cooling. The results were clear and they were with theoretical hypotheses that the best edge radius is 15µm (from the tested interval 5 ÷15µm). The tool with the edge radius 15µm reached the highest tool life, the lowest roughness of machined surface and the lowest force load in comparison to the tools with edge radius 5 and 10µm. The roughness of machined surface and the force load is in connection with the tool wear. The tool wear on this tool was uniform. The other tools were worn by chipping of cutting edge. So the recommendation for using indexable inserts with wiper geometry on this specific machining process is following: v_c = 200m/min, f_z = 4.5mm/tooth, a_p = 0.02mm, r_β = 20µm, climb milling and external cooling.

5. ACKNOWLEDGEMENTS

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