SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA
Faculty of Materials Science and Technology in Trnava

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Dissertation Thesis Abstract

Influence of cutting edge microgeometry on the selected aspects of machining difficult-to-cut materials

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INTRODUCTION

Attaining and maintaining economic production of machined parts without frequent downtimes in a modern machine shop is notwithstanding a requirement in today's competitive environment in the industry. It is a difficult task, all the more so taking into account the fact that difficult-to-cut materials are becoming more prevalent workpiece materials. One of the most important entries into the machining process are the cutting tools.

Geometry of the cutting tools, along with materials for the cutting tools, was at the forefront of development in the field of metal cutting ever since the metal cutting became a widespread method of manufacturing. However, when considering tool geometry, only the macrogeometry, which encompasses the tool's general observable parameters was developed. Even though the first mentions of tool microgeometry go back almost a century, extensive research in this area only started a couple of decades ago, thanks to the technological developments in other areas. While the importance of the tool's microgeometrical parameters from the standpoint of tool wear has been highlighted by some research institutions, the microgeometry of the tools has not been thoroughly investigated by the tool manufacturers, mostly due to inaccurate edge preparation methods of which most currently do not allow for desired repeatability of the process. Research in this field could be considered to be of an importance if longer tool life and therefore increased productivity of the machining process is to be achieved.

Choosing the right method of cutting edge preparation along with its proper parameters and optimal size and shape of the cutting edge is vital for achieving desired microgeometry and surface quality of the cutting tool, which results in increasing the tool life, especially when machining difficult-to-cut materials. This work aims to carry out an investigation of the influence of the tool's microgeometry when machining difficult-to-cut materials, both at the theoretical and practical level.

1 THEORETICAL ANALYSIS AND CURRENT STATE OF RESEARCH

Since theory is the foundation of any scientific research, it was necessary to investigate both the past and current articles and publications dealing with topics tangential to the focus of the dissertation thesis. If we want to understand the complex issue of tool microgeometry modification, it is important to start with the basics from which the studied issue stems.

1.1 Cutting tool materials

From the standpoint of metal machining, a cutting tool is an instrument used to remove excess material from the workpiece. One of the main characteristics that ensure the possibility of cutting tool carrying out machining operation is its mechanical hardness, as it needs to be higher than the hardness of the material being cut. While hardness might be considered to be a very important material property for cutting tools, it also has a negative influence for the cutting process, as it causes material to be fragile and brittle, which are undesirable properties for machining tools. Very hard cutting materials while being sustainable against permanent shape and geometry changes usually have low fracture strength and are prone to chipping. Cutting tools needs to be not only hard, but it needs to be able to absorb forces and vibrations that are a part of the machining process, without breaking or fracturing. Requirements for the materials used for metal cutting tools are getting ever higher and more difficult to fulfil (Kishawy 2019).

1.2 Microgeometry of the cutting edge

Shape and condition of the cutting edge are one of the most important entry factors in the machining process. In metal cutting operations, high thermal and mechanical loads are taking place on the edge of the cutting tool, resulting in wear and chipping. This in turns affects also the quality of the workpiece surface and accuracy. Extending tool life is a desired need for an economic production with sufficient reliability, as frequent tool changes and replacements negatively impact manufacturing times and disrupt smooth operation of a machine shop (Tonshoff 2013).

Tool geometry can be considered from different scales, there is macro-geometry that describes general spatial dimensions of the tool, cutting angles, chip breakers etc., with the order of magnitude higher than 100 µm. Then there is meso-geometry that deals with cutting edge radius with the order of magnitude ranging from 1 to 100 µm. The smallest order of magnitude below 1 µm is described as tool's micro-geometry (Fulemova 2015).

The meso- and micro-geometries of the tools have not been thoroughly investigated by the tool manufacturers, mostly due to inaccurate edge preparation methods that do not allow for desired repeatability of the process. In the following chapters, we will deal with comprehensive characterization of cutting edge microgeometry (Rech 2006, Dana 2016).

1.2.1 Characterization of the microgeometrical shape of the cutting edge

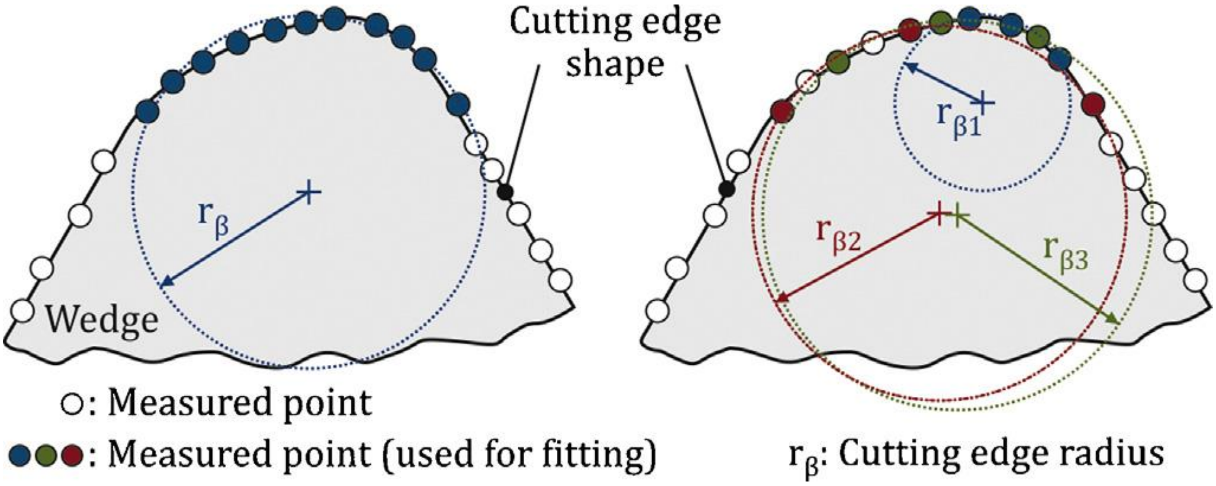
In order to sufficiently define the tools' microgeometry, it is necessary to specify where the cutting edge is located. Even if it may seem that the cutting edge is a two dimensional line from the standpoint of macrogeometry, located on the intersection of rake and flank faces. However, when sufficiently zoomed in, it can be seen that the cutting edge is in fact a curved surface spanning as a transition between the rake face and flank face. Author Denkena uses transition points on the rake and flank faces of the tool to determine where the cutting edge begins and where it ends. The most feasible way of locating these transition points is to create a profile sections of the wedge. Contact conditions of the workpiece material and cutting tool in the chip formation zone can be used as a viable indication of differentiating between micro- and macrogeometry. As tool angles, and therefore rake angle too, are predetermined by the tool's macroscopic form, it is important to observe where the effective rake angle of the wedge starts to differ from the nominal rake angle. This point of difference marks the transition between tool macrogeometry to microgeometry (Denkena 2014).

The intersection of the rake and flank face are usually described in three basic shapes for which terms sharp, rounded and chamfer are used. As it is not possible to produce absolutely sharp cutting edge, when using this term to describe shape of the cutting edge means that the cutting wedge was not prepared by any means and therefore does not have either a chamfer or a rounding (Reilly 2004).

Sharp tools lack edge toughness and stability against mechanical loads because shape of their cutting edge profile is irregular and often chipped, so they perform worse than tools with prepared edges in most metal cutting operations (Bouzakis 2000).

On the other hand, a combination of chamfer and round shape of the cutting edge can be achieved and can be found described. (Heckmann 2010, Vasques 2008) It is possible to make custom shape of the cutting edge tailored to machining a specific material or carrying out specific cutting operation to achieve high tool performance. To generate these custom designs with desired accuracy, detailed characterization of the cutting edge shape and transition points is needed. Various methods for characterizations as well as measurement of the cutting edge shape were developed for this purpose (Terwey 2011).

For rounded edges, a frequently used parameter for characterization is the cutting edge radius. However, the shape of rounded cutting edge is not circular, therefore using radius to describe it is not accurate. Different approaches for characterization of rounded cutting edge based on tactile or optical measurement have been developed (Thiele 2000).



Characterization of the cutting edge by a single radius (Denkena 2012)

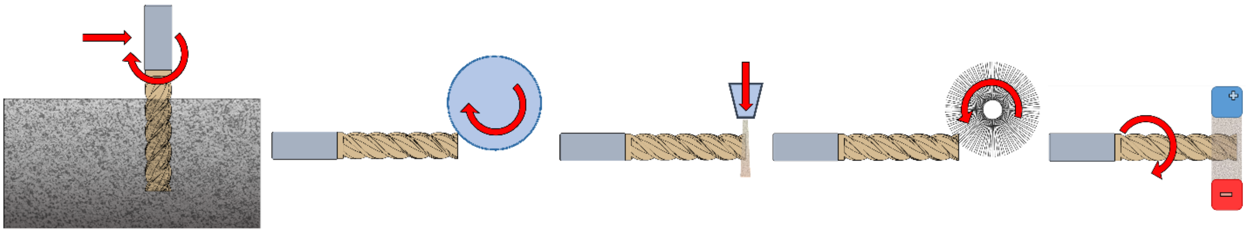
1.3 Methods of edge preparation

There are various different methods utilizing wide range of technologies being used for industrial application for preparing edges and surfaces of cutting tools.

Following in this chapter is updated overview of current cutting edge preparation processes, which builds upon previous categorization made by other authors (Kandráč 2013).

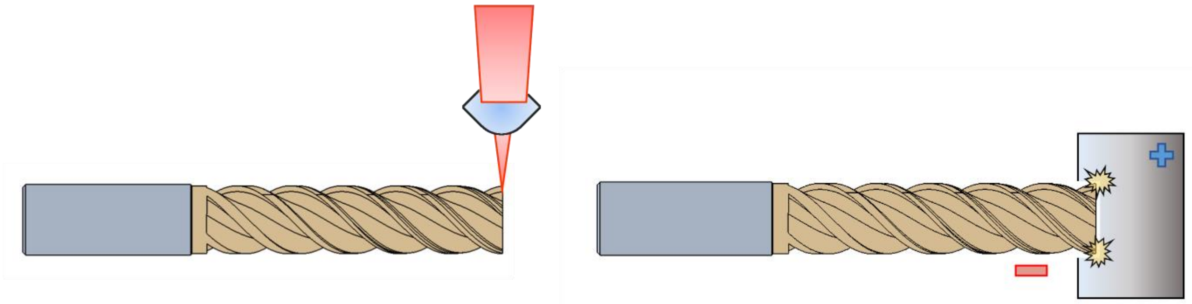
1.3.1 Mechanical edge preparation processes

Methods of edge preparation that belong in this category use various mechanical means to achieve desired edge radius shape. In figures 1 and 2 there are schemes of all the methods described in the work (Vopát 2017).



a) Drag finishing b) Micro-grinding c) Microblasting d) Brushing e) Magnetic polishing

Figure 1 Mechanical edge preparation processes



a) Laser beam machining b) Electro-erosion

Figure 2 Thermal edge preparation processes

2 THESIS OBJECTIVES

Based on the previous theoretical analysis, as well as the results of the prior research conducted at the faculty, thesis objectives were specified. As the most viable method of gathering the research data was established to be long-term wear tests using various sizes of cutting edge radii while machining two distinct materials using two separate cutting conditions.

Scientific objectives of the research were to determine:

1. ***Influence of the cutting edge radius size on the tool life of uncoated cemented carbide cutting tools.***
2. ***Influence of the cutting edge radius size on the cutting forces during the milling process***
3. ***Influence of the cutting edge radius size on the machined surface roughness.***

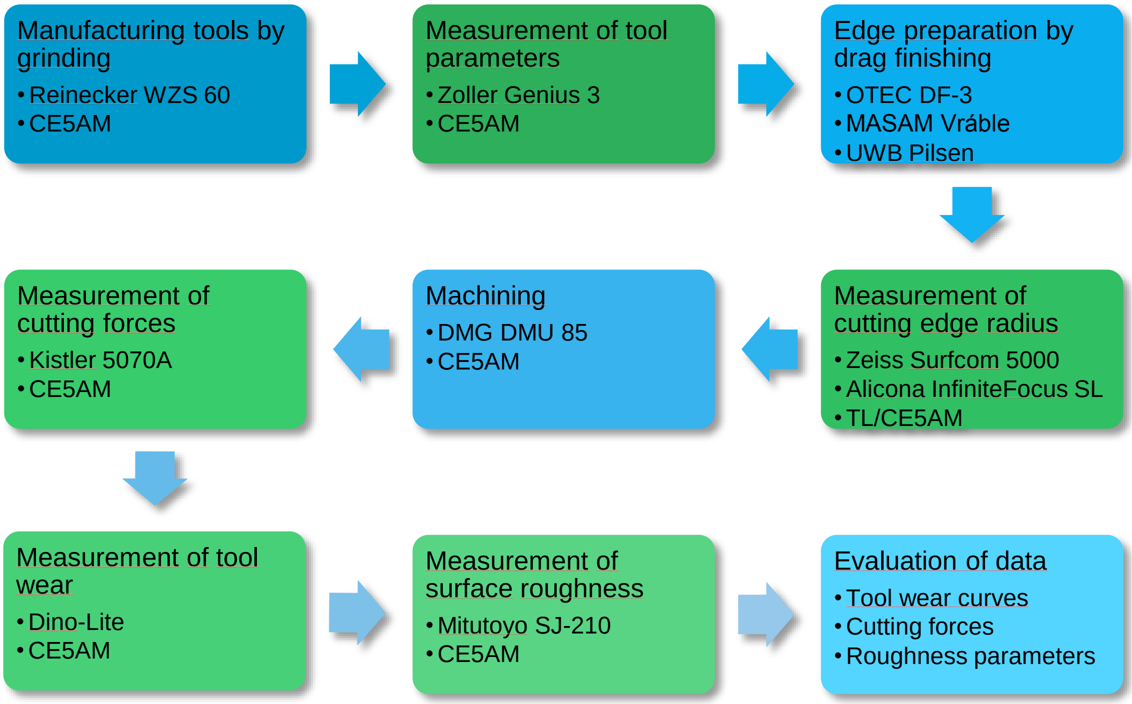
These objectives were to be accomplished on two different materials, both of which fall into difficult-to-cut category. Another objective could therefore be formulated:

4. ***Determine how the cutting edge radius influences aforementioned aspects when machining AISI 316L austenitic stainless steel and Inconel 718 nickel alloy materials.***

Moreover, for both of these materials two distinct cutting parameters meant to represent roughing and finishing conditions were used. Additional objective was stated:

5. ***Determine how the cutting edge radius influences aforementioned aspects when roughing and finishing.***

3 EXPERIMENTAL SETUP



3.1 Cutting tools

In order to carry out long-term wear tests using tools with modified edge microgeometry, uncoated cemented carbide tools with macrogeometry designed for milling stainless steel and nickel superalloys were needed.

Table 1 Tool materials specifications (Ceratizit 2019)

Ceratizit grade	ISO code	Co binder volume [%]	Hardness HV30	Grain size [µ]	Density [kg.m^{-3}]
CTS20D	K20-K40	10	1600	0,5 – < 0,8	14,38
CTS24Z		12	1570		14,10

Solid end cemented carbide mills were manufactured on the Reinecker WZS 60 tool grinding machine in the Centre of Excellence of 5-axis Machining at the Faculty of Materials Science and Technology of Slovak Technical University.

After the mills were manufactured, their macrogeometry as well as microgeometry were measured and compared. ZOLLER Genius 3 universal optical tool measuring machine was used for the purpose of measuring tool macrogeometry to verify if all the needed parameters were manufactured correctly. Microgeometry of the cutting edge after grinding was measured on the CNC measuring station Zeiss Surfcom 5000.

Table 2 Tool parameters

Tool parameter	**Value**	
	T 316	T 718
Maximum depth of cut	20 mm	10 mm
Cutting diameter	10 mm	10 mm
Shank diameter	10 mm	10 mm
Cutting edge count	4	4
Flute helix angle	48°	44°
Main cutting edge setting angle $\varkappa_r$	89°	-
Secondary cutting edge setting angle $\varkappa_r$’	4,15°	-
Corner chamfer length/radius size	0,125x45° mm	0,5 mm

3.2 Edge preparation

Manufactured tools were drag finished in order to round the edges and improve surface quality after grinding. Drag finishing was chosen as a preferred method of edge preparation of the tools for the experiment because of its accessibility in the MASAM Vráble company. Its advantages are high repeatability, ease of use and short time it takes to modify the tools.

Table 3 Measured cutting edge radii size

Cutting edge radius size [µm]		
Expected	Average measured	Standard deviation
5	4.73	0.87
15	13.06	1.54
30	28.90	2.94
45	43.96	2.68

Average size of cutting edge radii after drag finishing was lower than the desired size for all the tools. Cutting edge radius size of the sharp unprepared tools was lower than expected 5 μm as well. It can also be noted that with increasing cutting edge radius size, standard deviation increased, reaching almost 3 μm. This is in part the reason for choosing such a wide range of cutting edge radii, because accuracy and repeatability of the drag finishing process is not yet sufficient for high precision microgeometry modification.

3.3 Machined materials

Two different materials were used for the purpose of the experiment, both of which fall into the difficult-to-cut category due to the chemical composition and mechanical properties of the materials.

Material 1: AISI 316L

Austenitic stainless steel STN 17349/DIN X2CrNiMo17-12-2 (AISI 316L) was used as a machined material for the first part of the experiments.

Material 2: Inconel 718

Nickel based super-alloy ASTM B637/UNS N07718/W.Nr. 2.4668, commonly known as Inconel 718 was used for the second part of the experiment.

3.4 Machining conditions

Table 4 Cutting parameters of the experiment

material	**operation**	**axial depth of cut [mm]**	**radial depth of cut [mm]**	**feed per tooth [mm]**	**cutting speed [m.min^{-1}]**
AISI 316L	roughing	3	3	0,09	190
	finishing	3	0,4	0,03	300
Inconel 718	roughing	3	1,6	0,065	40
	finishing	3	0,4	0,03	65

4 RESULTS AND DISCUSSION

During the machining, three properties were periodically measured in order to sufficiently investigate the influence of the cutting edge radius size – tool wear indicator average flank wear (*VB*) on the side cutting edge, machined surface roughness and cutting forces during machining.

First stop was made after 1,3 cm^3 of material was removed from the workpiece, and after that every 4,1 cm^3 of removed material. Some minor differences remained attributing to the number of cuts in each operation and means of clamping the workpiece to dynamometer by screws in the center.

Cutting edge rounding size was accounted for as initial tool wear before the beginning of machining process, as drag finishing technically causes controlled tool wear.

Values of flank wear measured during the experiment were put into tables and plotted on graphs. Wear was measured on every tooth of the mills in two places – near the tip of the tooth – marked as VB_t and close to the axial cutting depth – marked as VB_3. Average values for each spot on every tooth were calculated and maximum overall value VB_{max} was plotted into graphs. For each material there were three batches of four tools with different cutting edge rounding size. After critical tool wear VB_k = 0,3 mm was reached regardless of its position along the cutting edge, the tool was removed from operational use. In most cases, this value was greatly exceeded. At later stages of the experiment it was deemed that this criterion was initially set to a needlessly high value, as the tool wear curves presented later in this chapter indicate that failure region of the tool wear curve starts to occur sooner, at around *VB* = 0,15 mm.

4.1 Tool wear

Comparison of average volume of removed material for all sets of tools used in the experiments is plotted in following figures. It can be observed that the deviation labels for roughing operation have wider range because of the lower stability of the machining when using roughing conditions compared to finishing.

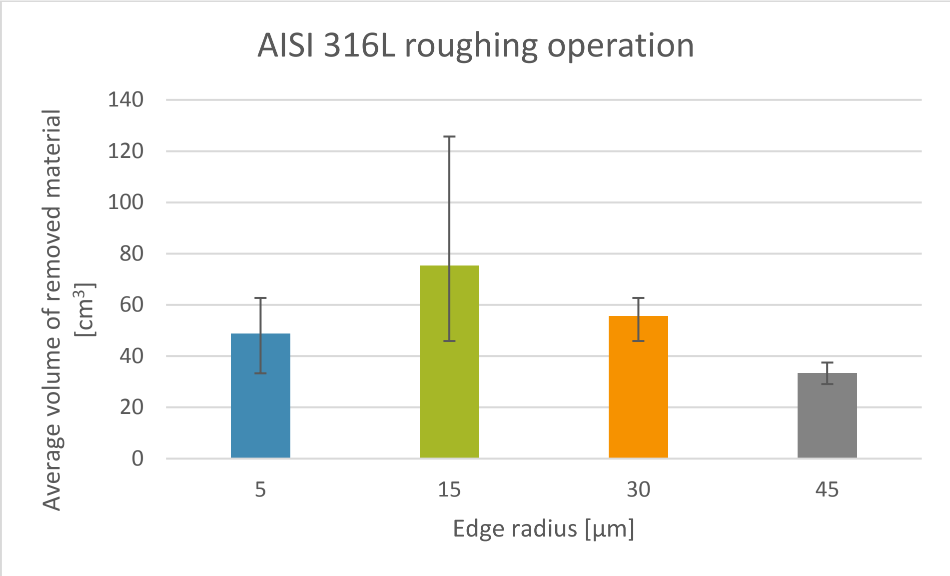


Figure 3 Comparison of tool life when roughing AISI 316L

It can be seen from Figure 80 that on average the tool with cutting edge rounding radius size of 15 µm has achieved the longest tools life out of four tested tools. However, taking into the account considerably higher values of deviations and considering differing wear curves, the tool with cutting edge rounding of 30 µm is to an extent comparable to the one with cutting edge rounding size of 15 µm.

Range of values of removed material volume was quite wide because of lower stability of the process when machining with conditions representing roughing operation.

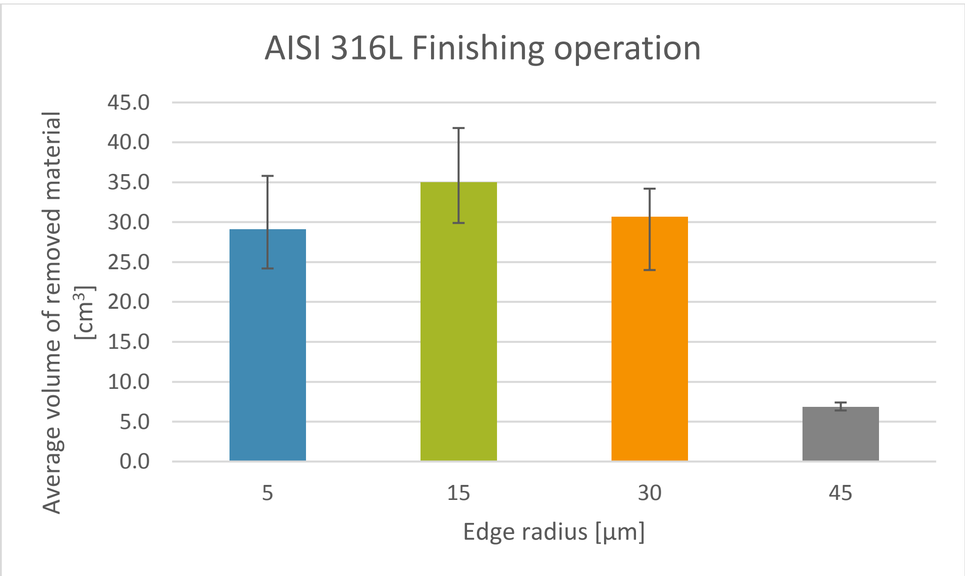


Figure 4 Comparison of tool life when finishing AISI 316L

The best average volume of removed material and therefore the longest tool life was achieved by the tool with cutting edge rounding size of 15 μm. Deviations of results for finishing operation were smaller most likely due to higher stability of the process. However, the differences between the tool lifetimes are also smaller.

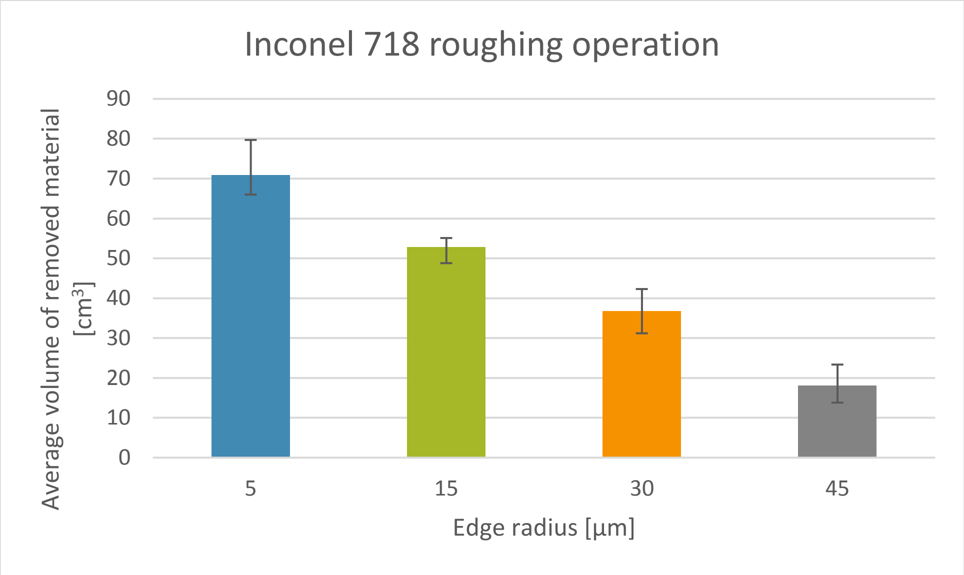


Figure 5 Comparison of tool life when roughing Inconel 718

Comparison of the average volume of removed material by each tool in the approximate moment when tool wear reached the set criterion of VB_k = 0.3 mm, as shown in figure 82, indicates that in the case of machining Inconel 718 alloy with the aforementioned cutting conditions, cutting edge preparation to 15 μm or more does not improve tool lifetime.

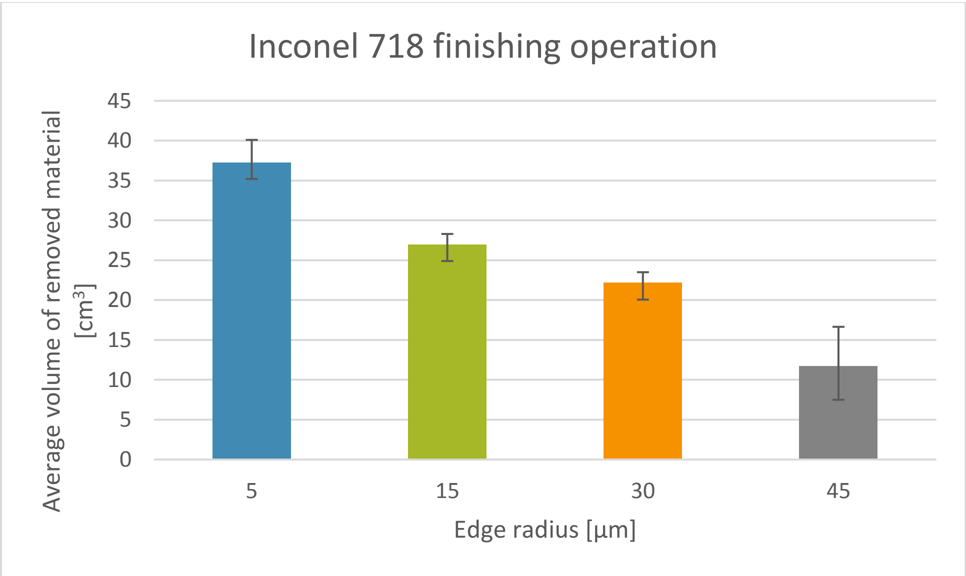


Figure 6 Comparison of tool life when finishing Inconel 718

Finishing operation of Inconel 718 material did not show substantially different results than the roughing operation. Average volume of removed material is decreasing with increasing cutting edge radius size.

Average tool life of all three cutting tool sets with modified microgeometry was compared to the unprepared sharp tool and increase or decrease was stated in percentages for better readability.

Table 5 Average tool life comparison

Material	Operation	Cutting edge rounding size [µm]		
		15	30	45
AISI 316L	Roughing	↑↑↑ +55%	↑↑ +14%	↓↓ -32%
	Finishing	↑↑ +20%	↑ +5%	↓↓↓ -76%
Inconel 718	Roughing	↓↓ -25%	↓↓↓ -48%	↓↓↓ -75%
	Finishing	↓↓ -28%	↓↓ -40%	↓↓↓ -69%

It is apparent that for AISI 316L austenitic stainless steel material, preparation of cutting edges resulted in increase of tool life for tools with cutting edges radius size of 15 and 30 µm compared to sharp unprepared cutting tool. For the tool with cutting edge radius of 45 µm, there was substantial decrease of tool life, which was to an extent expected result, since such a large rounding of the cutting edge is not commonly used for this type of material.

For Inconel 718 super-alloy, there was considerable decrease of tool life for all tools with modified cutting edges. Taking into consideration that the original tool from the manufacturer had cutting edge rounding smaller than 15 µm, it is not a surprising result, however it could be important to note that such a marginal increase in cutting edge radius size influenced the tool life in considerably negative way, highlighting the significance of accurate cutting edge microgeometry modification.

4.2 Cutting forces

In order to compare the values of measured cutting forces, it was deemed appropriate to consider average values of *Fx* component at the beginning of the machining process when the cutting edge radius was intact and at the end of the tool run when tool wear was nearing the set value of VB_k. *Fx* component of the cutting forces was chosen because it reached values by the order of magnitude higher than the *Fy* component, therefore it can be assumed that the tangential cutting force is represented by these measured values. This comparison is composed of average values for all three sets of the tested tools for the roughing operation and can be seen plotted in figure 83.

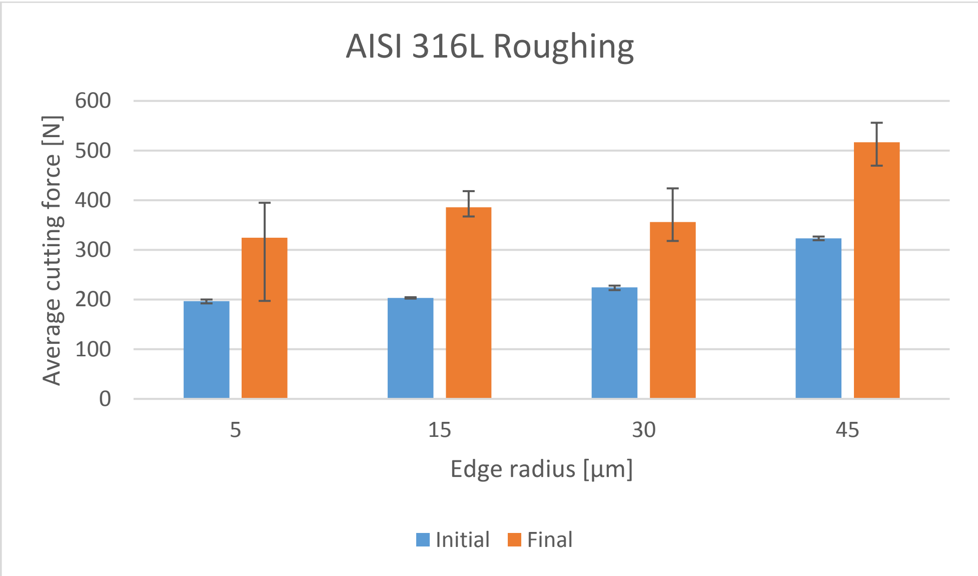


Figure 7 Cutting forces comparison for AISI 316L roughing

While the initial value of the cutting force component *Fx* increased in a non-linear fashion with the increase of cutting edge rounding size, final values by the end of the machining were lowest for the sharp unprepared tool. It is to be expected that at the beginning of the machining, cutting forces will always be the lowest for the sharp tool, however by the end of the machining, cutting forces are influenced by the value of flank wear on the tool. Taking into the account deviations plotted in the graph, tool with cutting edge rounding of 15 µm did not considerably exceed the values of average cutting force component *Fx* compared to the sharp tool, even though it achieved significant increase in tool life.

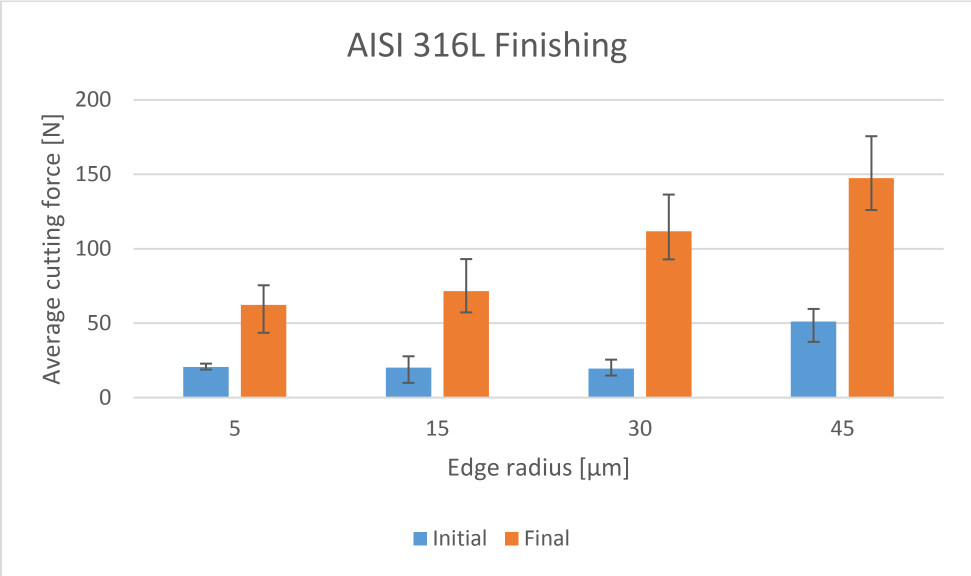


Figure 8 Cutting forces comparison for AISI 316L finishing

For the finishing operation the initial cutting forces were similar to the roughing operation in the sense that tools with cutting edge radius up to 30 µm were reaching comparable values of the cutting forces. The overall scale of the average cutting force values is however much lower, which is caused by the difference in cutting parameters compared to roughing operation. Values of average cutting force by the end of the tool life are again comparable between sharp tool and the tool with cutting edge radius of 15 µm, this indicates that when it comes to the cutting forces there is no disadvantage of cutting edge modification of this size.

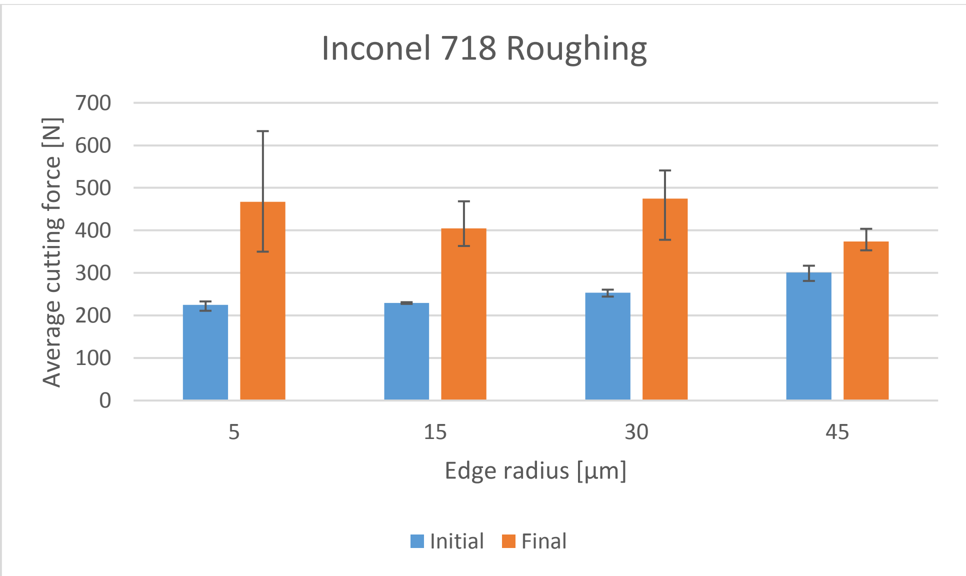


Figure 9 Cutting forces comparison for Inconel 718 roughing

For the Inconel 718 material, initial values of the cutting forces for the sharp unprepared tool and the tool with cutting edge radius of 15 µm were comparable in value for the roughing operation. With increasing cutting edge radius, initial cutting forces increased as well. As far as final achieved cutting forces go, it is interesting to note that the highest values were recorded for the sharp cutting tool, even though it achieved the best result when it comes to tool wear. Tool with the cutting edge rounding of 45 µm which achieved the shortest tool life seems to have achieved the lowest final cutting force value. This disparity is most likely caused by the changes that occur on the cutting edge of the tool when machining Inconel 718, as the biggest changes on it occur for the sharp tool.

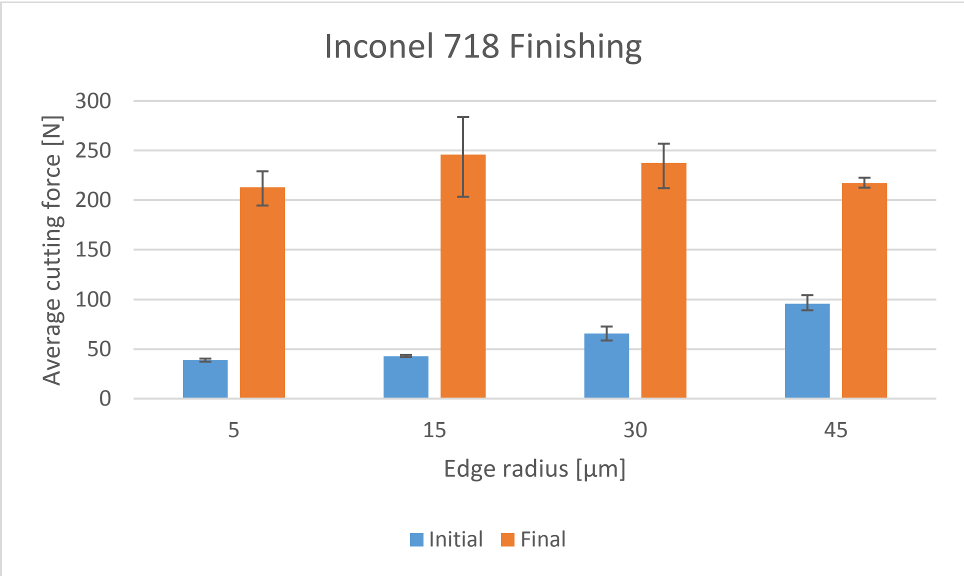


Figure 10 Cutting forces comparison for Inconel 718 finishing

Observing the plotted data for the cutting forces when machining Inconel 718 with cutting parameters constituting finishing operation, it can be seen that initial cutting forces values were the lowest for the sharp tool. Same non-linear increase with the size of the cutting edge radius as in the previous plots can be observed. This corresponds with the achieved tool wear on unprepared tool.

4.3 Machined surface roughness

Quality of the machined surface was evaluated by using the measured *Ra* parameter in the same fashion as with aforementioned cutting forces, taking into the account initial values as well as values by the end of the machining when the tools were approaching set value of VB_k.

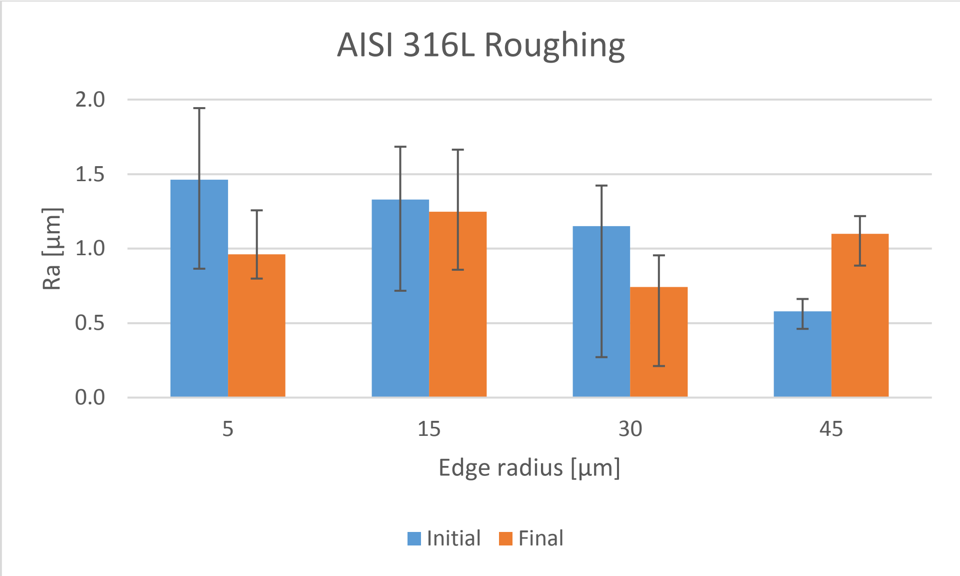


Figure 11 Roughness parameter Ra comparison for AISI 316L roughing

When roughing AISI 316L material, initial roughness values were decreasing with increasing cutting edge radius size. It is most likely a result of the cutting edge pressing into and swiping the surface of the machined material. Final values of the roughness are lower than the initial ones for all the tools with the exception of the tool with cutting edge radius of 45 µm. Drawing a conclusion that increasing cutting edge radius positively affects the quality of machined surface is tempting, however this finding is unsupported by the rest of the results of the measured roughness values. This result for one machining operation of one material could have been caused by a multitude of other factors influencing outcome of the machining process, such as cutting parameters.

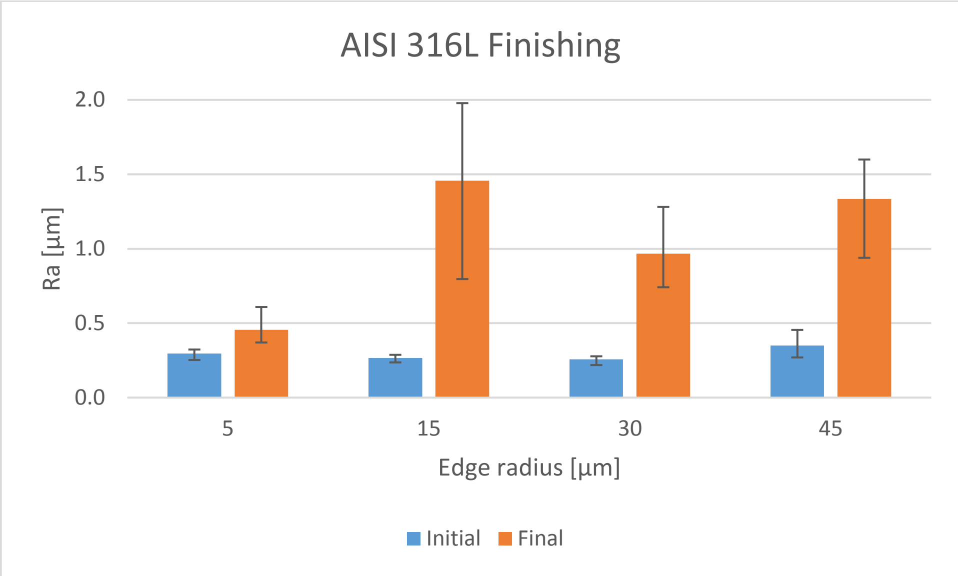


Figure 12 Roughness parameter Ra comparison for AISI 316L finishing

Initial values of machined surface roughness were comparably low for all the tools at the beginning of finishing operation. This is most likely the result of cutting parameters rather than the cutting edge radius. Final values of the roughness are higher than the initial values, unlike in the previous operation. Tool with the cutting edge radius of 15 µm achieved the highest value of final roughness of machined surface which does not correspond with either the tool life or measured cutting forces for this tool. However, it fits with the final values of machined surface roughness for the roughing operation.

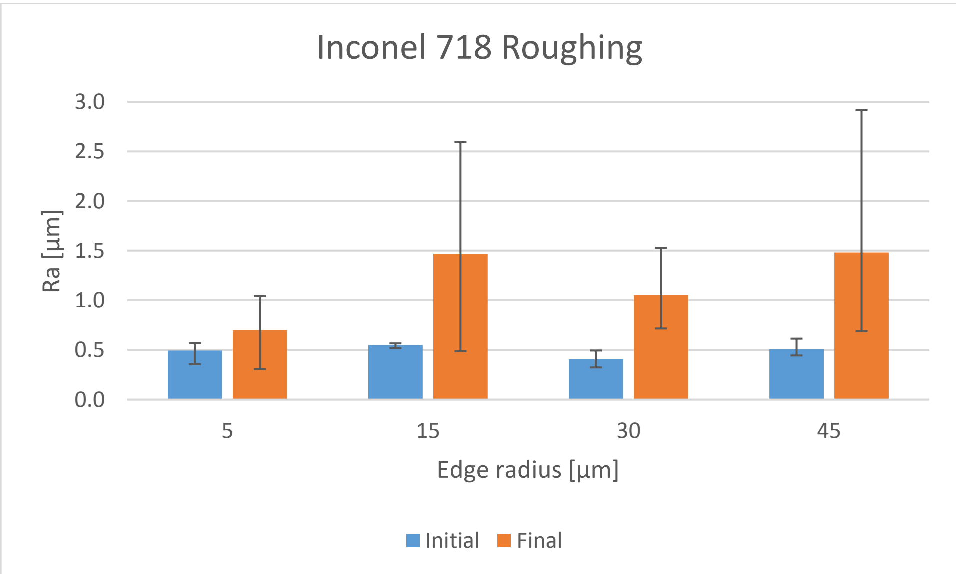


Figure 13 Roughness parameter Ra comparison for Inconel 718 roughing

Initial roughness values of *Ra* for the roughing operation when machining Inconel 718 were not substantially different in relation to the cutting edge radius size. Final values of the *Ra* parameter are the lowest for the sharp tool, which corresponds with the measured tool wear for this tool. Highest value of machined surface roughness was recorded for the tool with cutting edge radius size of 15 µm, which seems to be forming a recurring pattern when comparing it with results for AISI 316L material.

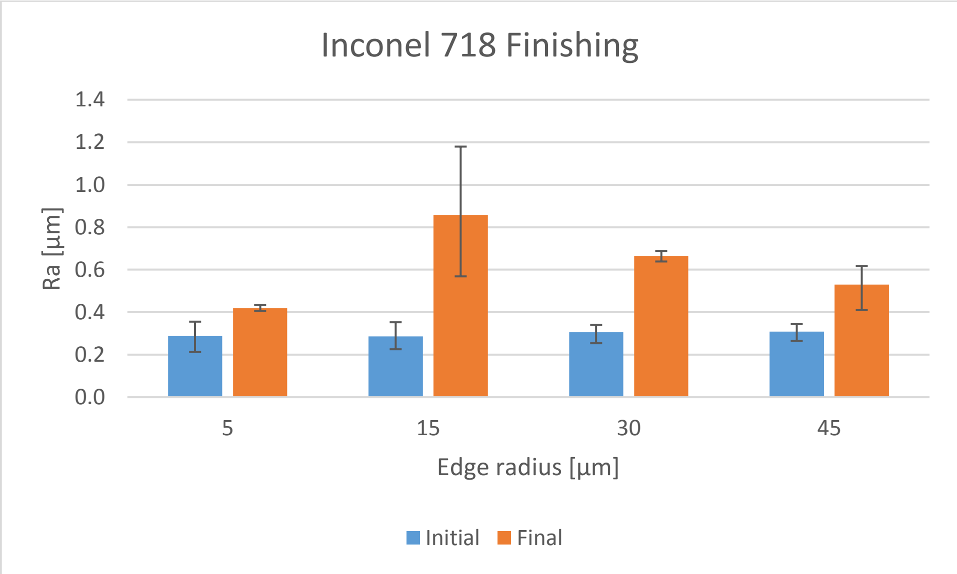


Figure 14 Roughness parameter Ra comparison for Inconel 718 finishing

Machined surface roughness value Ra for the finishing operation when machining Inconel 718 was the lowest for the sharp unprepared tool both at the beginning and at the end of the machining process. This aligns with the results of best tool life for this tool when machining Inconel 718. The highest value of Ra was once again achieved by the tool with cutting edge radius size of 15 µm. It is unclear why this particular size of cutting edge rounding would influence machined surface roughness in a negative way. Examining the machined surface more in detail as part of future experiments could provide explanation to this observation.

4.4 Future research

Recommendations for the future research regarding topic of this work are following:

- Considering the negative results achieved by the tools with modified microgeometry when machining Inconel 718 in regard to the tool life, it is recommended to use tools with cutting edge rounding in the range of 8 to 10 μm.
- Similar experiment as is described in the work could be extended to include coated tools, as it would create an interesting comparison to the results of the uncoated tools.
- Extensive analysis of the machined surface could be conducted in order to understand the impact of cutting edge microgeometry modification on certain aspects of the surface quality.
- Tools with cutting edge prepared using different methods than drag finishing, such as brushing or electrolytic honing could be tested as well, in order to separate the influence of the cutting edge radius size from the residual effect of the technology used to achieve it.

4.5 Contributions of the research

Scientific

- Determination of dependencies of cutting edge radius size on tool life, cutting forces and surface roughness.
- Basis for further research into the influence of edge preparation on tool life of cutting tools and coating adhesion to substrate.
- Further research into the edge preparation using the results of dissertation thesis for the solution of research projects at the Faculty of Materials Science and Technology in Trnava.
- Patented fixtures for testing of cutting tools and measurement of cutting forces.

Pedagogical

- Practical demonstrations of the experiments for students.
- Results of dissertation thesis, especially influence of cutting edge radius size on the tool life, can be used in teaching the subject of "Theory of Machining", focusing on the dependence of cutting edge radius sizes on tool life for specific materials.
- Results of the dissertation thesis can be used and expanded upon in other dissertation theses.
- Design of experiment and methodology of solution experiment can be used in the bachelor and master theses.
- Use of process of experimental tool life determination for the bachelor and master theses.

Applicable in the industry

- Determination of viable milling and drilling parameters for AISI 316L and Inconel 718.
- Determination of importance of cutting edge rounding when machining AISI 316L and Inconel 718.

CONCLUSION

In the work, a theoretical foundation based on an overview of the current state of the cutting edge microgeometry research is presented. Materials for cutting tools are briefly described, followed by the topic of cutting edge microgeometry, its definition, measurement and impact on the machining process. Various means of modifying the cutting edge geometry are also described, as well as the results of experiments executed by other researchers and institutions.

Research methodology described in the third chapter was at first drafted based on the literature survey and further refined after preliminary experiments produced relevant data. Alongside troubleshooting research methodology by practical tests, objectives of the research were also formulated. Main objective of the work was to determine the influence of cutting edge radius size of uncoated cemented carbide mills on three aspects of the machining process - tool wear, cutting forces and machined surface roughness. All of the objectives were investigated by the method of long term wear tests where three sets of tools with four different cutting edge rounding were used to machine two distinct materials, each with roughing and finishing cutting conditions. Results were evaluated for each material separately, however some conclusions can be drawn from the comparison of the similarities across the materials.

For the first machined material – austenitic stainless steel AISI 316L, the tool with cutting edge rounding size of 15 μm was observed to have the best performance out of the tested tools, however the difference of tool lifetime compared to the tool with cutting edge rounding size of 30 μm was marginal. Unprepared tool with sharp cutting edge with edge rounding size of 5 μm also performed comparably to aforementioned tools during some of the testing runs, especially for the roughing operation. Higher values of deviation from the mean were observed for the roughing operation compared to the finishing operation, most likely attributing to the lower stability of the process when machining with cutting parameters for roughing. Experiment results of finishing operation achieved lower values of deviation, therefore better repeatability of the process.

For the second machined material – nickel alloy Inconel 718, all of the tools with modified microgeometry performed with worse results compared to the sharp unprepared tools. This was observed for both roughing and finishing operations.

Interpreting the gathered data and drawing conclusions, it needs to be stated that the character of all milling operations was side milling, all of the tools were uncoated and the method of tool microgeometry modification was drag finishing. It is entirely plausible to assume that changing any of these conditions could produce different results when it comes to the evaluating the influence of cutting edge radius size on the machining of difficult-to-cut materials.

Depending on the machined material and cutting operation, it would be reco mmended to reconsider the need to modify microgeometry of cutting tools from an economical perspective, as it is an extra step in the process of tool manufacturing that increases time and financial expenses required to produce the tools. In the case of austenitic stainless steel, extending tool lifetime by up to 55% as a result of modifying the microgeometry should be sufficient incentive for the undertaking. On the contrary, for Inconel 718 it would seem that the most economical approach would be to disregard tool microgeometry modification completely, as it does not seem to have any positive influence on extension of tool life when machining this super-alloy material.

Another outcome of the experiments was that while in some cases cutting tool microgeometry modification can extend the tool life, it only does so up to a certain value of cutting edge radius. Having larger radius of the cutting edge than 30 μm resulted in considerably worse performance of the tools compared to both unprepared tools as well as the tools with smaller cutting edge radius, especially considering that drag finishing process of these tools took longer than tools with smaller edge radii.

The only observed aspect of the experiments which does not seem to be influenced at all by the cutting edge radius size was the machined surface roughness, which was fluctuating regardless of the tool or machining operation. However, the overall values of the roughness parameters were not excessively high and only started to rise when tool wear increased as well. This result can be most likely explained by the well devised cutting parameters based on the initial experiments.

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AEC	Scientific works in foreign peer-reviewed scientific proceedings, monographies	2
AFC	Published papers at foreign scientific conferences	10
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