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INFLUENCE OF THE MICROGEOMETRY ON THE DRILLING PROCESS IN INCONEL 718

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Abstract: *The process of cutting different material is getting difficult due the good mechanical properties of the new material. According to the evolution of the aeronautical and automotive industry, the materials had to be improved in order to keep the tendency. In parallel, it was necessary to improve the properties of the cutting tools that process this material. Four major directions are intended to be studied in case of the work tools: base material, coating, geometry and microgeometry. The researches have shown that all have a great importance in determining the best durability of the work tool. The article is trying to emphasize the role of the microgeometry in processing the Inconel 718. The material presents difficult cutting properties due to its mechanical and physical properties. One of the machining results is durability, the surface quality and on this criterion will be evaluated the best microgeometry used in drilling the Inconel 718*

Key words: *Drill, K Factor, cutting edge, microgeometry, wear.*

1. INTRODUCTION

Due to the fact that it has some very good mechanical properties, the processing of Inconel 718 is very difficult and also the durability of the cutting tools is low. It's used in various industries, especially in the aeronautics industry. That stimulates the researchers to focus on developing new tools that can achieve a suitable durability. This means that the work tool has to have optimal properties in all four variables: base material, coating, geometry and microgeometry. In paper [1, 2] are presented the effects cutting parameters and cutting edge preparation for machining Inconel 718. One of the processes that the researchers focused on was the drilling process. In various works the durability of the cutting tools was studied, but also the roughness of the machined surfaces on different type of materials. During the drilling process the quality of the hole depends on the type of the drill: macrogeometry, microgeometry, material of the drill, but also on the material of the workpiece. One of the studies was by Biermann et al., which was focused on drills with a diameter of 8.5 mm on drilling the 42CrMo4. In this study the authors has used drills with different microgeometry. They used K-factors 0.6, 1 and 1.4, with $\bar{S}$~35μm. The smallest roundness deviation of the hole appears at drills with a K-factor 1, while the biggest at drills with K-factor 1.4. Regarding the average surface roughness Ra can be observed that the smallest value is obtained with work tools that have symmetrical microgeometry (K=1), smallest cutting speed and biggest feed rate or biggest cutting speed and smallest feed rate. Other cutting parameters that were between these two produced worse surface quality [3]. Another study was made by Beer et al., where he chooses two different types of drills with 6.8 diameters for drilling in Inconel 718. They choose a standard drill from the Guhring Company and the second drill was a modification from a standard drill. Authors changed the flank face of the drill, creating a groove near to the cutting edge. With this modification they obtained better results with the new geometry of the drill on tool life and roughness. Regarding to the tool life, the new geometry seems to have a real improvement, increasing the tool life with approximately 30%.

The influence of the new geometry on the roundness deviation is small. Looking to the average surface roughness it seems that the extreme values are smaller in case of the modified tool [4]. Paper [5] presents a study with different macrogeometry of drills from different suppliers to bore in Inconel 718. The test from [5] shows which macrogeometry has a better tool life and the influence on the surface roughness. In paper [6] is presented the roughness of the machined surface in 42CrMo4 material on the milling process with different K-factors. Authors concluded that the lower the K-factor is, the better the surface quality can be achieved. Another paper where the surface roughness was studied is [7], where authors used different drill macrogeometry. There are also different papers where machining of Inconel 718 was studied [8, 9, 10, 11, 12, 13, 14].

This paper studied the influence of the K-factor in drilling process of Inconel 718 material. Authors studied the tool life but also the roughness evolution of the hole. In this experiment were used drills with 6.8 diameters and length 4xD. The K factor was chosen to have values of 0.5, 1 and 1.4.

2. MICROGEOMETRY

Cutting tools can have different macrogeometry or microgeometry. The microgeometry of the cutting edge can be divided in chamfer or rounding form. The rounded cutting edge is characterized by the radius rβ when it presents a symmetrical edge and by Sα and Sγ for asymmetrical microgeometry. The parameters Sα and Sγ are determined by the intersection point between the flank and rake face and the tangents from where the rounding begins as it can be observed in fig. 1.

K-factor is defined by the relation:

$$K = \frac{S_\gamma}{S_\alpha}. \qquad (1)$$

[15]

r_β – radius of the cutting edge

S_α - cutting edge segment on the flank face

S_γ - cutting edge segment on the rake face

$\bar{S}$ - average cutting edge rounding

Δr - profile flattening

φ - apex angle

When K>1 the cutting edge has the tendency to the rake face and when K<1 has the tendency to the flank face [16]. Microgeometry can be prepared with different process: mechanical thermic and chemical [17, 18, 19]. In the industry, the most used cutting edge preparation is the mechanical ones due to its precision and reduced time.

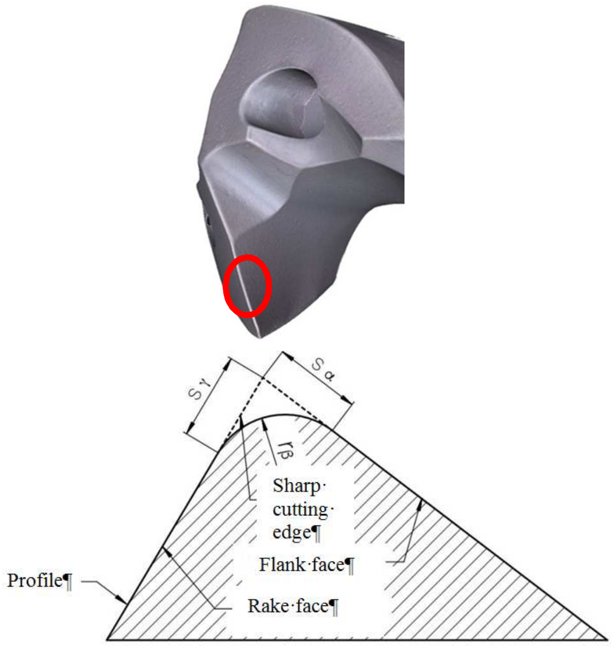


Fig. 1. Microgeometry of the cutting edge.

3. EXPERIMENTAL DATES

For this experiments were used rectangular boards from Inconel 718. In order not to have influence coming from the cutting material, all the material was prepared in the same batch.

As in case of the cutting material, all the drills are made from the same carbide in the same batch and also the cutting zone has the same macrogeometry. For the microgeometry of the drills was followed to be the same condition for surface treatment and polishing process for all K-factors. For the cutting edge preparation was followed to change as few parameters as possible. After the drills were prepared and polished, they were coated and the microgeometry was measured. In this paper were used K≈0.5, K≈1and K≈1.4 and the radius r_β was prepared as in the manufacturing drawing. From the 27 prepared drills, for the experiments were used 9 drills. The criteria of choosing the 9 drills, was the value of the K-factor to be close to the nominal value and the radius r_β which were measured with an optical microscope. Another criterion was the surface quality and last but not the least the surface integrity that was inspected on electronic microscope. After the coating, the rake face of the drills was measured to determine the surface roughness. Fig. 2 presents the roughness surface of the rake face for the 6.8 mm drills, results being according with DIN 4287.

It can be observed a similarity between the values of the drills with K≈0.5 and the drills with symmetrical microgeometry and the highest values are obtain for drills with K≈1.4. The explanation of these results is that drills with K≈1.4 are more surface treated on the rake face then the other two type of microgeometry.

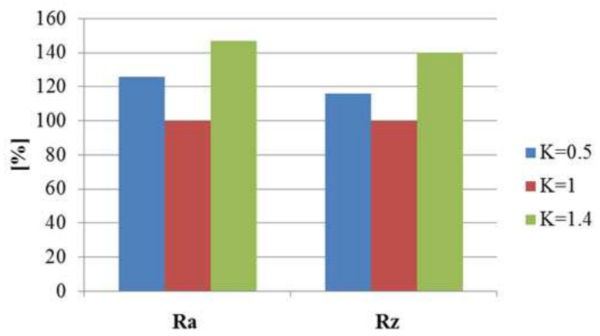
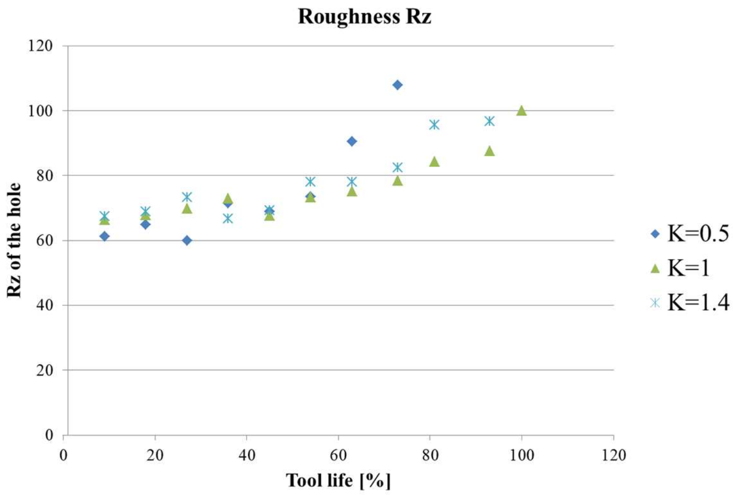


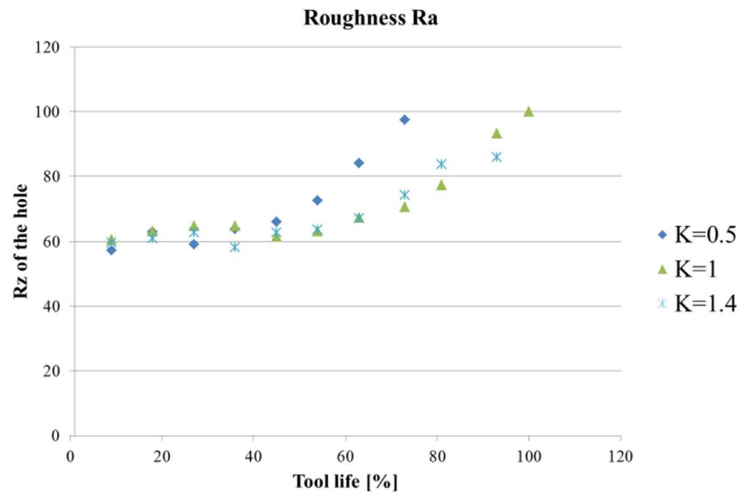
Fig. 2. Roughness surface of the rake face.

In fig. 3 it can be observed the influence of the microgeometry on the roughness Rz and Ra of the holes in relationship with the tool life. For each K-factor were studied three drills and in the graph from fig 3 is represented the mean value of the Ra and Rz. All the values are in percentage and all the values are reported to the standard microgeometry that is considered heaving a K factor equal to 1. The maximum tool life and roughness of the hole for the standard drill were considered with 100%. The surface roughness was measured at predetermined intervals. In fig. 3 a) can be noticed that until 50% of the tool life, all the roughness values are approximately the same. After the half of the total tool life, the roughness Rz tends to increase for drills with K≈0.5. That means that the tool wear begins to increase and that's the main reason for lower surface quality when are utilized drills with K≈0.5. Between drills with K≈1 and K≈1.4 the differences are not highlighted. At the end of the tool life, the results are representative for the tools with K≈0.5, but for the other two K≈1 and K≈1.4 the differences are not significant. The study can be compared with the study made by Biermann in [3] where it was studied the influence of the process parameters.

Fig. 3 b) shows that the surface roughness Ra has the same evolution like Rz with the difference that at the end of the experiments better surfaces is obtained with drills with K-factor 1.4, but these drills have lower tool life than the standard drills.



a) Roughness Rz



b) Roughness Ra

Fig. 3. Surface roughness of the hole.

As a conclusion regarding the surface quality and tool life is that the K factor equal to 1 can achieve the highest tool life but a bigger K factor is increasing the surface quality without drastically reducing the tool life. This means that in case of a mass production can be given a nominal value of K factor of 1.2.

Fig. 4 presents the cutting edge at the end of the tool life with similarities for all three K factors: built-up edge on the flank face. At the beginning of the experiments there was not so obvious, but drilling more holes this phenomena could be seeing.

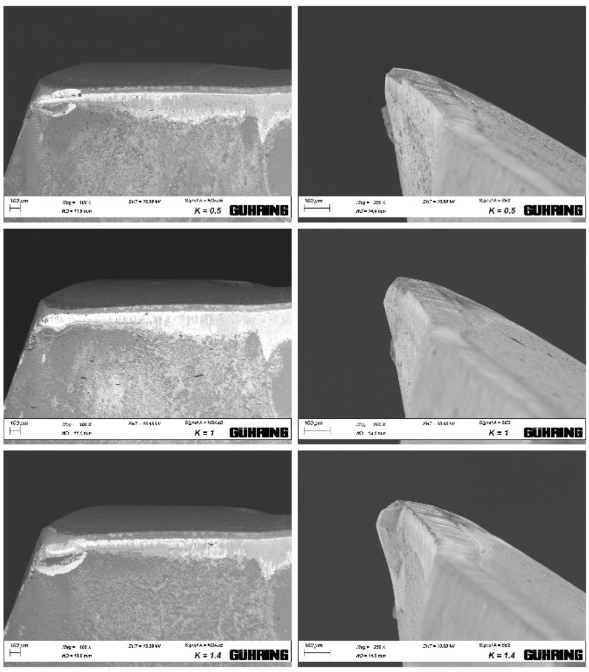
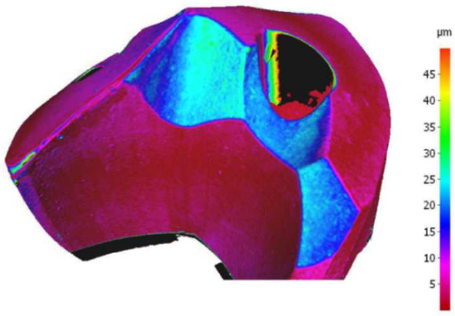


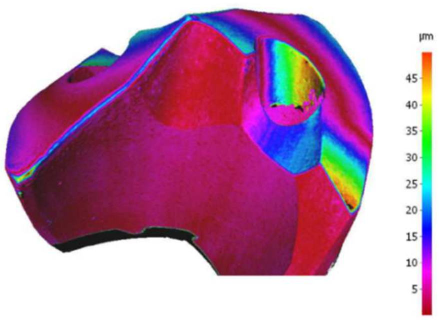
Fig. 4. Overview of the cutting edge at the end of experiments.

At the beginning of the process, the phenomena couldn’t be observed, but it appeared after a few meters of process and it wars accentuated after the coating was gone from the work tool. There are also different studies where was discuss the problem of adhering material on the cutting tools when Inconel 718 is machined [5, 20]. Looking particular on each photo in fig. 4 with K≈0.5 appears a broken cutting edge near to the corner of the cutting edge. On the secondary edge appears also material deposition meaning that the geometry of the edge is modified. When the geometry of the “false edge” causes enough stress on the work tool, the material will be removed. The bounder between the work tool and material deposition is not defined in this case, so the breaking plane will appear randomly also in the material of the work tool. The main wearing mechanism is first the abrasion that is removing the coating. The coating of the work tool prevents the adhesion of the workpiece material. After the coating is removed, the adhesion is starting to act in the wearing process. Drills that were not broken, present edge cracks on the corner. Another aspect is that the material depositions on the rake face increase from the corner to the chisel edge, after that will decrease to the point thinning. Same aspects of the cutting edge appear on drills with symmetrical microgeometry-K≈1 and with K≈1.4, the difference are that the broken edge is bigger than in case of K≈0.5.

To have a better behavior of the corner of the drill could be make different geometry only in that part of the drill, like for the flank face.
Another analysis of this paper is “the 3D scanning of the drills”. After the experiments end they were again scanned 3D and compare to drills before the experiments start. This analysis can emphasize the wear of the work tool during the entire process or the material deposition after a period. The surface scanning equipment facilitates this analysis. In fig. 5 can be observed how the wear is more pronounced on the corner of the drills.



a) K≈0.5



b) K≈1

c) K≈1.4

Fig. 5. Comparison of the 3D scanned drills.

On the flank face the wear is not so notable; also on drills with K≈1.4 it can be noticed that near the cutting edge the wear is more pronounced as in the other two cases, meaning that the tool life for this drills is smaller than in other cases, but looking on fig. 4 it’s not the case. That could mean that the wear is bigger only near to the cutting edge on a small part of the flank face and in rest could be more uniform than in in case of K≈1 and K≈0.5. This phenomenon appears when the material is compacted under the force under the flank face.

4. CONCLUSION

After this experiments the authors could say that the in case of quality of the rake face the surface roughness is better for drills with K≤1, because the surface of the rake face of the drill is treated more intensively. Looking at the surface roughness of the machined material and tool life of the tool, we could say there is not obvious difference between the results the studied microgeometry, but some remarks could be made like better quality of the surface of the hole is obtained with drills that have K-factor ≥1. Also in all three cases on the flank faces appear material deposition and all the corner of the drill break up or are tending to break up. The problem could be solved by changing the cutting parameters, coating material, or improving the geometry of the drill.

5. ACKNOWLEDGMENT

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Influența microgeometriei în procesul de burghiere a materialului Inconel 718

Procesul de așchiere a diferitelor materiale, devine din ce în ce mai dificil din cauza bunelor proprietăți mecanice ale noilor materiale.Potrivit evoluției industriei aeronautice și auto, a fost necesară îmbunătățirea materialelor pentru a ține pasul cu cerințele din aceste industrii. În paralel, a fost necesară și optimizarea proprietăților sculelor așchietoare care prelucrează aceste materiale. Se intenționează a se studia patru direcții majore în cazul sculelor așchietoare: materialul de bază, acoperirea, geometria și microgeometria. Studiile au arătat că toate acestea au o mare importanță în determinarea durabilității optime a sculelor. Acest articolul încearcă să sublinieze rolul microgeometriei în procesarea materialului Inconel 718. Acest material prezintă dificultăți în a fi așchiat datorită proprietăților sale mecanice și fizice. În cazul acestui material, durabilitatea și calitatea suprafeței reprezintă criteriul după care va fi evaluată cea mai bună microgeometrie pentru a burghiere a materialul Inconel 718.

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