Influence of the cutting edge microgeometry in drilling operation of 42CrMo4 and X5CrNi18-10

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Abstract. It's known that the durability of the cutting tool is influenced by the cutting parameters. In the recent years, scientists turn their research efforts to demonstrate that the microgeometry have an important role in determining the durability of the cutting tools. The processes studied most are milling and turning, but few researches have been done on the drilling operation. In this paper is presented the influence of 6.8 mm diameter drills with three values of the K-factor, but the same radius of the cutting edge and same macrogeometry. To obtain the desired microgeometry of the drills, two preparing technologies of the cutting edge were used. Drills were tested in two types of materials: X5CrNi18-10 (1.4301) and 42CrMo4 (1.7225). The main goal of this paper is to observe the influence of the microgeometry in the drilling process namely the durability and wear evolution.

1 Introduction

Different sectors in the automotive and aeronautics industry have begun to use materials that have improved physical properties compared to the previous ones. This improvement of the materials requires also an improvement of the tools in several directions, such as: basic material, coating, macro and microgeometry of the tool. By improving these aspects of the cutting tools, the aim is to obtain better surfaces, tool life, and productivity.

In the papers [1, 2] the cutting edges are divided into different categories: rounded edge - single radius, trumpet form, and waterfall; sharp edge; chamfered edge - chamfer, protective chamfer (land) and double chamfer; and the last category is a combination edge - chamfer and rounded cutting edge. There are studies which show the influence of the K factor, specifically focusing on the subject of variable microgeometry. In case of [3], drills with 8.5 mm in diameter were utilized, using different microgeometries (K factors with values of 0.6, 1 and 1.4). According to the study conducted by Biermann in the paper [3], the feed forces drop at the same rate with an increase of the K factor. Moreover, in terms of the torsion moment, the lowest moment of torsion appears at K=1, and of the highest moment of torsion appears at K=0.6. In terms of wear, VB (wear on the flank face) drops at

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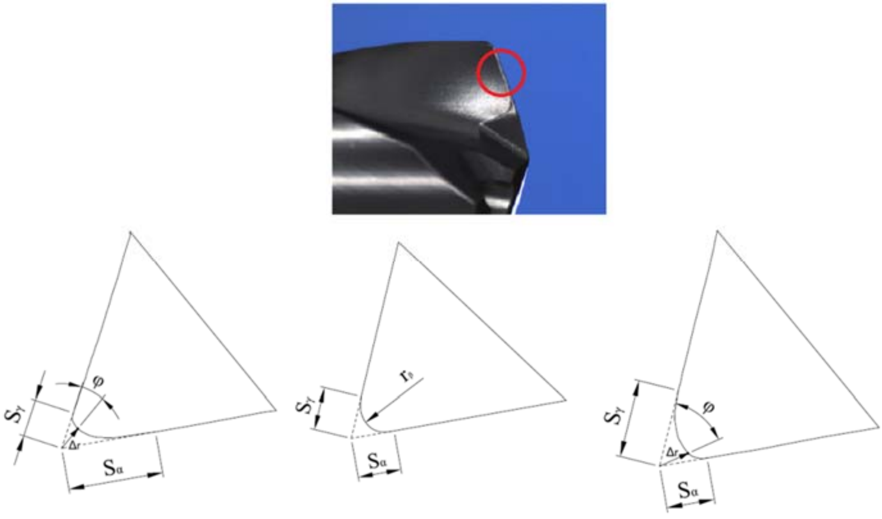
the same rate with the increase of the K factor. There are also studies about the microgeometry of the cutting tools in other fields, such as milling and turning. An excellent study testing more K factors is in the paper [4], where a milling cutter with the K-factors 0.5, 0.6, 1, 1.6, and 2 was utilized. The minimum tool wear VB were caused using the K factors K=0.5 and K=0.6, and the maximum tool wear were caused by using K=1.6 and K=2. Following this research, the tools produced the best results when inserts with a K factor less than 1 were used. Other studies for the milling process are in the papers [3, 5]. For the turning process, the only tested K-factors are 0.5, 1 and 2 [6, 7]. Regarding passive force, F_p, and feed force, F_f, it has been found that the smallest forces are recorded from the inserts with an sharp edge and also with an chamfered edge. In case of the inserts where different K factors are used, it has been determined that when the K factors decrease, the forces increase. The main cutting force, F_c, is influenced mostly by a plate that has a factor of K=0.5 and K=1. The smallest tool wear is found from the insert with a single chamfer that has followed from the sharp edge.

2 Objectives of the paper

The article focuses on K factor's influence on drill-type tools with 6.8 mm diameter (5xD), because they are used for achievement of cutting thread M8x1.25, in 42CrMo4 and X5CrNi18-10 materials. The K factors utilized in this study are: 0.5, 1 and 1.4 and they have the same macrogeometry. Only one type of coating was used for all the drills, in order to have a minimum of factors that can influence the results.

3 Definition of the cutting edge microgeometry

The cutting edge rounding r_β is not enough to characterize the shape of the cutting edge [8]. With the help of K, S_α, S_γ, φ, and Δr factors, the cutting edge is completely defined [8]. The distance between the intersection point of the flank and rake face tangents, as well as the point of detachment of the respective tangent from the cutting edge profile, defines the parameters S_α and S_γ. The relation $K=S_\gamma/S_\alpha$ determines the tendency of the edge to the flank face (K<1) or to the rake face (K>1) [8].



K<1 K=1 K>1

Fig. 1. Types of microgeometries.

It can be distinguishing three types of K-factors which can be seen in Figure 1, namely $K<1$ describes slope toward the flank face, $K=1$ shows a symmetrical edge and $K>1$ indicates a slope towards the rake face.

Asymmetric edges are characterized by the following parameters: S_γ, S_α and K. Average rounding cutting edges are defined by size $\bar{S}=(S_\gamma+S_\alpha)/2$ [8]. Δr quantifies the edge sharpness; a low Δr denotes a sharp edge, while a high Δr means that the radius resembles a chamfer. The angle φ between the rake face and Δr describes the localization of the highest point of the edge [9].

Other parameters are: 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

4 Experimental dates

4.1 The machined material

42CrMo4 material is utilized for the construction of components that need increased hardness and strength in the automotive and aeronautics industries, but also in the construction of axes and shafts and other parts which need these characteristics. Because of the material's good thermal conductivity, the heat produced in the cutting area spreads well throughout the tool, chips and the processed material. Although the machining process does not produce a very high heat quantity, the plastic deformation increases the chip hardness that causes a high abrasion wear on the cutting tool, resulting in low durability.

X5CrNi18-10 has good chipping performance, the cutting depth has to be large, but the feed has to be minor in order to prevent the hardening of material. Because of the austenitic material's low thermal conductivity it results in a heath concentration in the cutting edge.

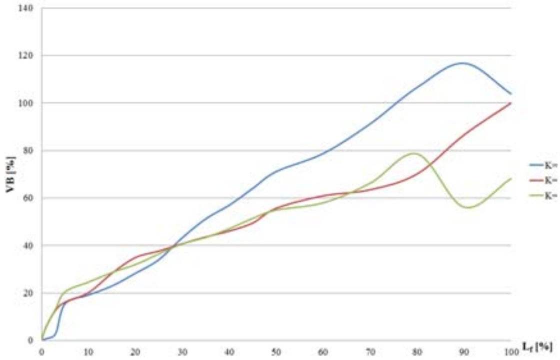
The wear of the drills was measured for each one of the tools, for both cutting edges on previously established intervals. There were used three drills for each K-factor. In addition, thorough documentation has been created, that means on specific intervals the drills wear were studied using an electronic microscope. By utilizing this method, it was possible to notice the evolution of the cutting edge during the experiments.

4.2 Determining the drill wear

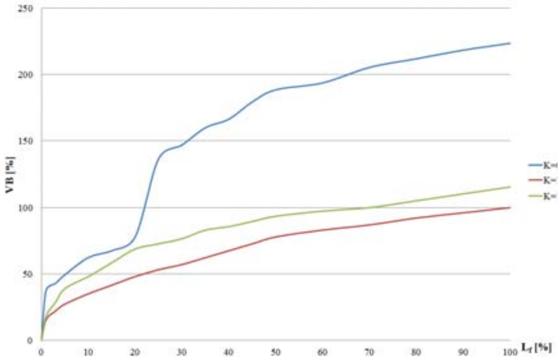
The wear (VB) of the tool is evaluated after DIN ISO 3685. All the tests made in this research have been stopped after reaching the maximum wear level or after reaching the maximum tool life (Lf) given by the producer. For each K-factors of each material were used three drills. The drill with the symmetric microgeometry (K=1) was the reference drill, and the maximum wear and tool life of this were noted with 100%, that's means that the VB and Lf are scaled values. Those wear levels are represented in Fig 2. The wear of the drills with factors K=0.5 (orientated to the flank face) and K=1.4 (orientated to the rake face) has been reported to the drill with factor K=1.

In Figure 2a) for the 42CrMo4 material, can be observed that the wear of the three microgeometries is almost the same until the point of 30% of the entire tool life. The wear for the drill with a K factor 0.5 increase in comparison to the wear of the drills with symmetric microgeometry and K=1.4. At approximately 70% of the total durability, the drills with tendency of the edge to the flank face have a wear which is 50% bigger than those with a symmetric microgeometry. This can be explained by the fact that the drills with K=0.5 have been sandblasted more on the flank face, so the wear appears more on the flank face. Wear of the drills with tendency of the edge to the flank face is bigger than that of the drills with symmetrical microgemetry and drills tendency of the edge to the rake face. Thus, it can't be said that the wear will be smaller if the K factor increases like mentioned in [3].

Drills with factor K=0.5 drives to a flat or even a concave form. These new shape brings the material separation point closer to the flank face of the material, meaning that the height of the deformed material left behind the work tool is smaller than the one left by the new tool. The geometry is changing during the entire tool life and this drives to the need of a research that concerns the variation of the geometry.



a) 42CrMo4



b) X5CrNi18-10

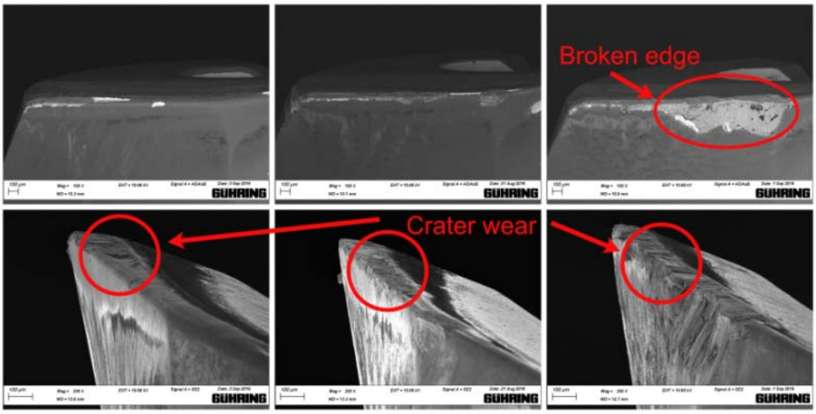
Fig. 2. Drill wear in different materials.

With the wear being reported on the road made by the tool in the X5CrNi18-10 material (Figure2 b)), can be noticed even from the beginning how the drills with a factor K=1 and K=1.4 have almost the same wear, this fact being valuable until the end of the experiment. For the drills with a factor K=0.5, the wear is much bigger than in the last two cases.

In the first part of the tool life the difference of the wear between the drills with tendency of the edge to the flank face and the other two microgeometries is constant and after 20% of tool life, the wear grows again, being reported to drills with symmetrical microgeometry and with tendency of the edge to the rake face. Starting after the first quarter, the slope of the drills with factor K=0.5 becomes less steep than in the beginning. At the end of the experiment, the wear of the drills with a factor K<1 is doubled than in the case of the drills with a factor K equal to or bigger than 1. A good conclusion regarding the durability, due to the insignificant differences between the three types of drills, since all the drills have been stopped before breaking.

5 Wear analysis using an electronic microscope

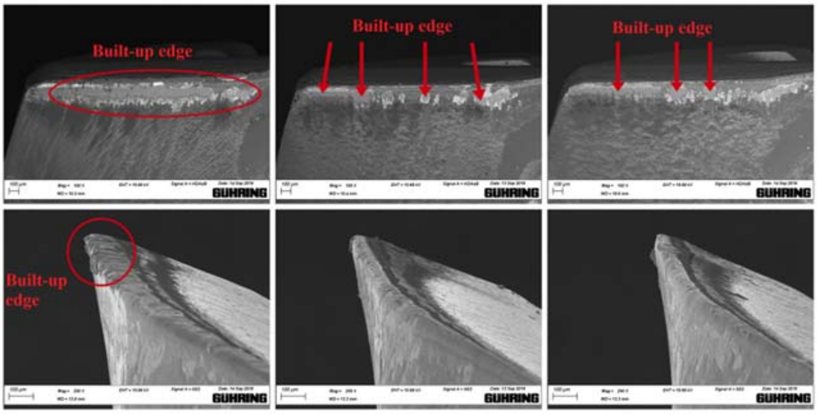
Figure 3 and Figure 4 have been made at the end of the experiment, to see the wear level of the drills. In the case of the 42CrMo4 material, in Figure 3, can be observed the built-up edge in the crater situated on the flank face. This can be explained by the fact that the 42CrMo4 material has increase hardness, and the cutting material is settled under the action of the cutting force under the flank face. From these photos, it can be noticed how in the case of the drill with a factor K=0.5, the crater is bigger than in the other two cases. As mentioned before, in Figure 2, the biggest craters, or the biggest material adhesion, appear in the case of the drills where the surface has been exposed for a longer period to the sandblasting process. Figure 3c) shows that in the case of the drill with factor K=1.4, the cutting edge is chipped. This can be explained by the fact that on the rake face there is a much larger built-up edge than in the other cases. Only a certain amount of material can be attached to the cutting edge, once the volume exceeds a critical value, it separates from the cutting edge. There is always the phenomenon of pinching the edge when removing the built-up edge, a phenomenon that leads to the chipping of the cutting edge.



a) K=0.5 b) K=1 c) K=1.4

Fig. 3. Overview of the drill in material 42CrMo4.

Using X5CrNi18-10 (Figure 4) material, it can be notice a different effect (compared to the 42CrMo4 material), concerning the wear, on the cutting edge.



a) K=0.5 b) K=1 c) K=1.4

Fig. 4. Overview of the drill in material X5CrNi18-10.

On the flank face, the craters don’t occur anymore as in Figure 3. This can be explained by the fact that the hardness of this material does not affect the drill as much as the 42CrMo4 material does. In the case of drills with a factor K=0.5, can be observed how on the flank face, built-up edge takes place - same phenomena as for 42CrMo4 material. On the rake face for drill with tendency of the edge to the rake face, there is a much bigger built-up edge, uniform across the length of the surface. These built-up edge appear more rapidly than in the case of drills with tendency of the edge to the flank face and drills with symmetrical microgeometry. For the drills with the factors K=0.5 and K=1, this built-up edge on the rake face is not uniform, but it is more visible in the middle of the rake face and in the chisel edge zone.

6 Conclusions

As a conclusion the optimal microgeometry for cutting these materials is the symmetrical edge. The symmetrical microgeometry has the advantage of lower chipping forces and less wear, respectively the aspect of drills with symmetrical microgeometry is better than asymmetrical microgeometries.

The more material flows under the flank face, the more stressed under compression is the cutting edge. On a bigger K factor (1.0 and 1.4) the quantity of material that flows under the flank face tends to reduce resulting that the level on wear on the faces is depending on the K factor. As expected, the tendency on the rake face is reversed. The most material tends to adheres on the rake face for K factor 1.4 and decreases to the drills with tendency of the edge to the flank face. A symmetric cutting edge lean to small adhesion on the flank and rake face, but does not have a big influence on the wear, like asymmetric microgeometry. For K=0.5 the separation point is bigger than K factors 1 and 1.4. The quantity of the material that flows under the flank face in case of K=0.5 is larger than K=1 and K=1.4. That means the friction for K factor smaller than 1 is bigger; resulting more pronounced wear than in others two cases.

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