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WEAR OF CUTTING TOOL WITH EXCEL GEOMETRY IN TURNING PROCESS OF HARDENED STEEL

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Abstract

This paper deals with hard turning using a cutting tool with Xcel geometry. This is one of the new geometries, and there is not any information about Xcel wear in comparison to the conventional geometry. It is already known from cutting tools producers that using the Xcel geometry leads to higher quality of machined surface, perticularly surface roughness. It is possible to achieve more than 4 times lower Ra and Rz values after turning than after using conventional geometry with radius. The workpiece material was 100Cr6 hardened steel with hardness of 60 ± 1 HRC. The machine used for the experiment was a lathe with counter spindle DMG CTX alpha 500, which is located in the Centre of Excellence of 5–axis Machining at the Faculty of Materials Science and Technology in Trnava. The cutting tools made by CBN were obtained from Sandvik COROMANT Company.
The aim of this paper is to investigate the cutting tool wear in hard turning process by the Xcel cutting tool geometry.

Key words

Hard turning, Xcel geometry, conventional geometry, cutting tool wear

INTRODUCTION

Hard turning started to develop at the beginning of the nineties. The reason was the availability of new tool materials and the capability of designing a turning machine that was rigid, stable and accurate enough to successfully finish hard turning. The result of the development has made finish hard turning a viable alternative to grinding, as an accurate finishing operation (1).

Hard turning is defined as a process of single point cutting of part pieces that have hardness values over 45 HRC. Typically, however, hard turned part pieces have the hardness in the range of 58-68 HRC. The approach to machining the hardened steel depends on the degree of hardness and its depth (if case hardened). The hard turning process is quite similar to the conventional “soft” turning, so that the introduction of this process into the normal factory environment can happen with relatively small operational changes. Hard turning is best accomplished with cutting inserts made of either CBN (Cubic Boron Nitride), Cermet or Ceramics. Since hard turning is single point cutting, a significant benefit of this process is the capability to produce contours and to generate complex forms with the inherent motion capability of modern machine tools. The high quality hard turning applications do require a properly configured machine tool and the appropriate tooling. For many applications, CBN tooling will be the dominant choice. However, Ceramics and Cermet also have use in this process (2).

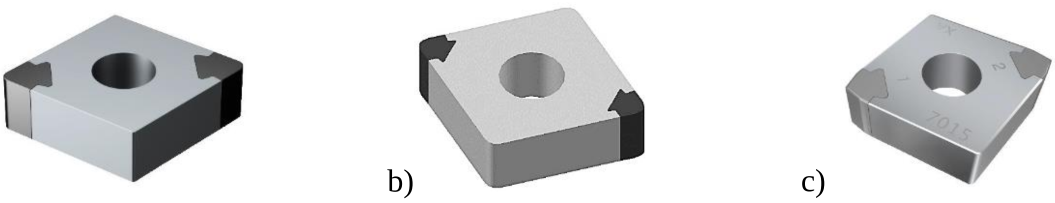
There is a necessity of very hard cutting materials because of the hardness of machined materials, which is higher than 40 HRC. The cutting materials with higher hardness are for example Cermet, Ceramics, Cubic Boron Nitride (CBN) or Diamond. CBN was also used in this experimental research.

Cubic Boron Nitride (CBN). If the hardness ranges between 50-68 HRC and the depth of hardness is greater than the depth of material to be removed, then Cubic Boron Nitride (CBN) is the best material. CBN will give good tool life and wear properties. Surface finishes of 11-15 micro-inches can be achieved and maintained. ISO inserts are available with multiple grades to suit different machining requirements. Insert hardness and therefore also wear rate are traded for toughness and ability to withstand shock loading from interrupted cuts, (i.e., keyways).

Ceramics. Ceramics in hardened steel turning have applications and are very economically priced compared to other types of tool materials. The nature of the material necessitates the use of blunt edge geometry, which inevitably increases cutting forces and reduces surface finish potential.

Natural and Synthetic Diamonds. Natural diamond and synthetic diamond are the least preferred options for operations involving machining of hardened steel. They have high costs per edge, and poor reliability in terms of interrupted cuts and wear mode. Brazing cannot always be guaranteed and re-grinding is not always possible. Diamond also interacts chemically with steels and can cause failure (2).

The cutting tool geometry has a big influence on the surface quality. There are fundamental geometries of cutting tools with radius, wiper geometry and the latest Xcel geometry (Fig. 1).



a) b) c)

Fig. 1 *Cutting tool geometries – a) conventional (radius) geometry, b) Wiper [3], c) Xcel (4)*

Wiper geometry is typical for its prolonged minor cutting edge. It leads to better surface quality. Xcel geometry benefits into higher feeds and achievement of the very high surface quality. The difference of this geometry is in the shape of the cutting edge – there is no characteristic tip on this insert, which shape is copied into the workpiece surface. The cutting tool comes to the contact with the machined surface with skewed edge. It leads to the lower surface roughness values. But there is no information about the cutting tool wear with this progressive geometry.

MATERIAL AND EXPERIMENTAL INVESTIGATION

The machined material was 100Cr6 hardened steel (STN 14109) with Rockwell hardness of 60 ± 1 HRC. The workpiece was a tube with length of 125 mm, internal diameter of 38 mm and external diameter of 48 mm. It was fixed as shown in Fig. 2.

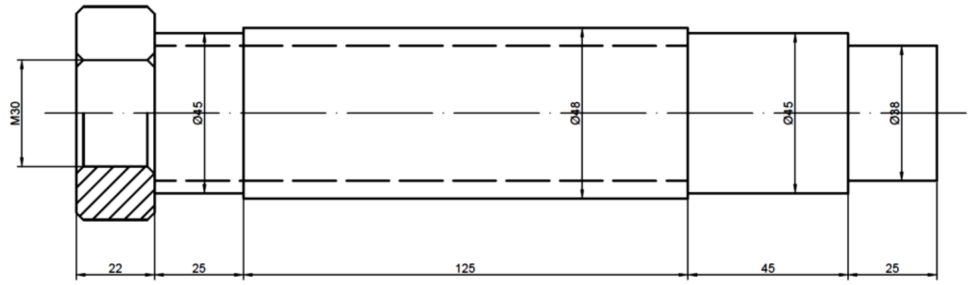


Fig. 2 *Workpiece with the fixture*

The lathe with DMG CTX alpha 500 counter spindle, which is located in Centre of Excellence of 5–axis Machining at the Faculty of Materials Science and Technology in Trnava was used for the machining process. The workpiece was fixed in the main spindle and in the counter spindle as well (Fig. 3).

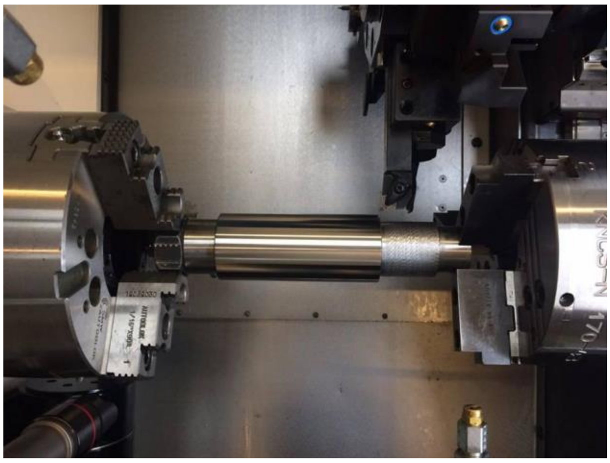


Fig. 3 *Workpiece fixed in the lathe*

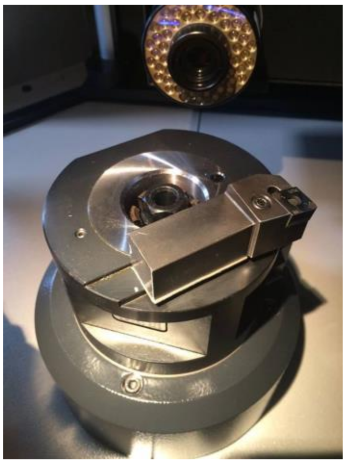
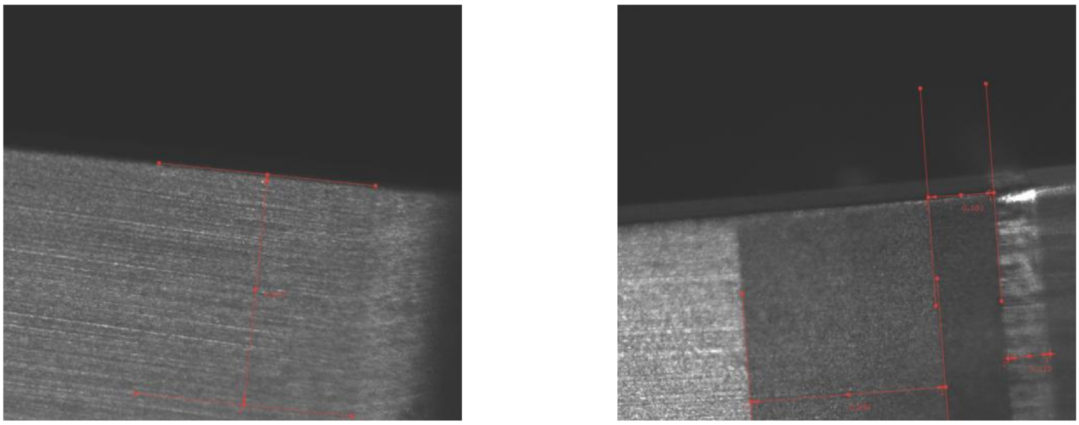


Fig. 4 *Cutting insert holder in the measuring device Zoller Genius 3s*

Cutting tool used for this experiment was of Sandvik Coromant Company. The exact type of conventional geometry was CNGA120408S01018A 7025 and Xcel geometry CNGX1204L025-18AXA 7025. The cutting tool wear was measured after machining the workpiece according to the predetermined intervals. Zoller Genius 3s device was used for the measurements. The cutting insert holder was placed in the measuring machine to ensure standard measuring position (Fig. 4).

Cutting conditions were selected according to the recommendations of the producer:
- v_c = 125 m. min^{-1}, f = 0.2 mm, a_p = 0.1 mm.

The experimental research started with machining by using conventional geometry. Fig. 5 shows the initial (as-received) state of the studied inserts.

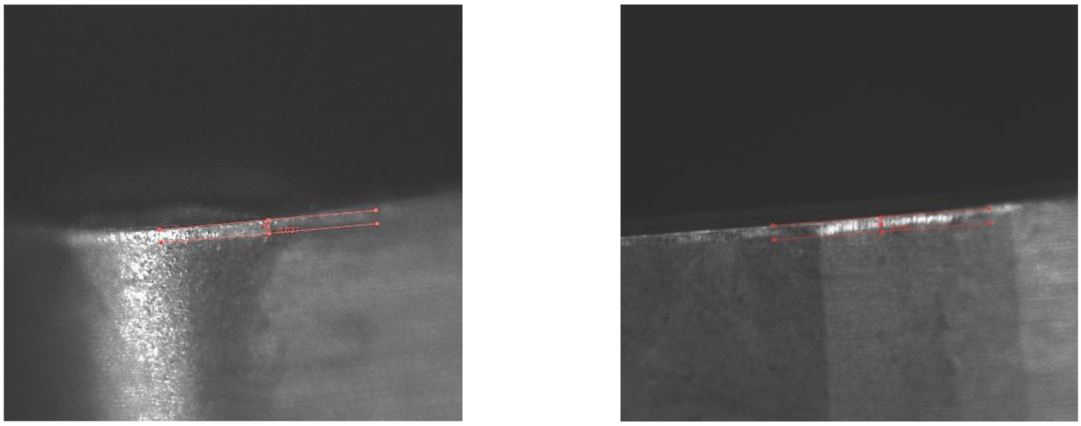


a) Cutting tool wear VB = 0 mm *b) Cutting tool wear VB = 0 mm*

Magnification 200x

Fig. 5 *Conventional (a) and Xcel geometry before machining*

Fig. 6 shows the worn cutting tool inserts after the machining of the workpiece length (125 mm) one time.

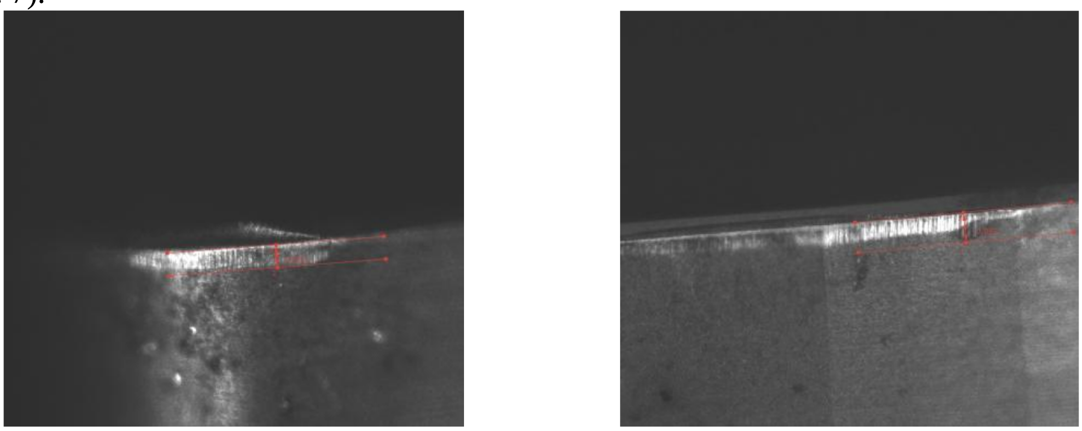


a) Cutting tool wear VB = 0,02 mm *b) Cutting tool wear VB = 0,02 mm*

Magnification 200x

Fig. 6 *Conventional (a) and Xcel geometry (b) after 1 length machining (0.859 min)*

The same VB value 0.02 mm was measured for the inserts with conventional and Xcel geometry, as can be seen in Fig. 6. Other images were acquired after 3 times length machining. It was 2.56 min of contact of the cutting tool insert with machined surface (Fig. 7).

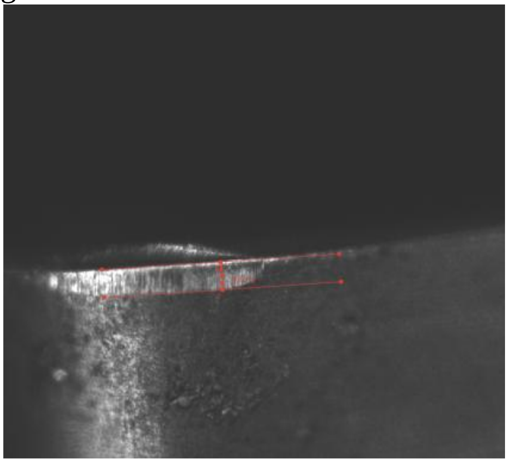


a) Cutting tool wear VB = 0.06 mm *b) Cutting tool wear VB = 0.085 mm*

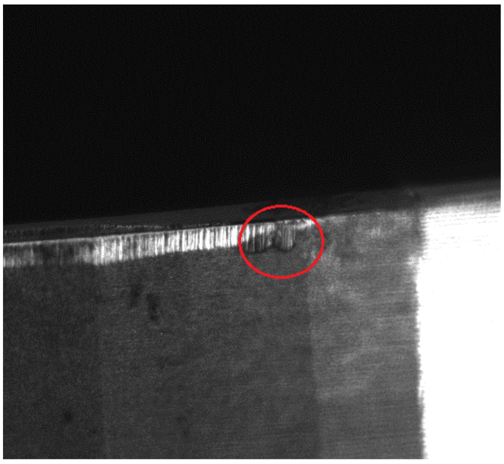
Magnification 200x

Fig. 7 *Conventional (a) and Xcel geometry (b) after 3 lengths machining (2.56 min)*

The cutting tool with Xcel geometry has higher wear value of 0,025 mm. This value was achieved very fast from the beginning of the machining process. However, this value was stabilized as shown in Fig. 8. Pictures were obtained after 5x machining of the workpiece length.



a) Cutting tool wear VB = 0,07 mm

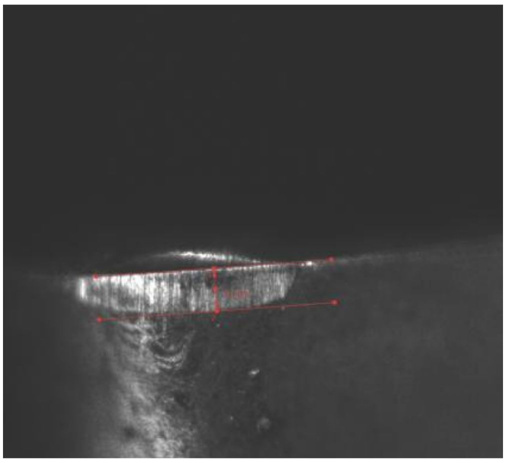


b) Cutting tool wear VB = 0,086 mm

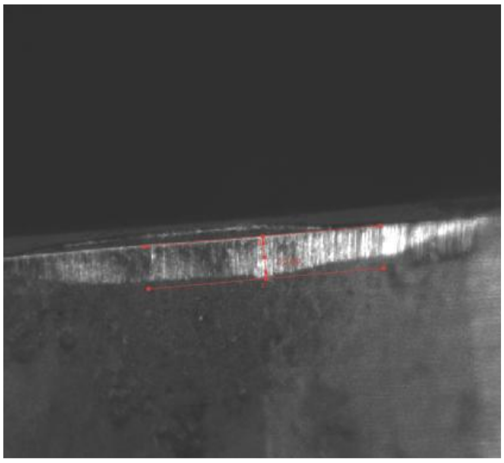
Magnification 200x

Fig. 8 *Conventional (a) and Xcel geometry (b) after 7 lengths machining (4,25 min)*

The previous Figure shows that the cutting tool wear of Xcel geometry did not increase significantly. However, there is difference in the location of the cutting tool wear in comparison to the conventional geometry, which has increased the wear values in the same place. On the other hand, the wear of Xcel geometry moved to the right side of the minor cutting edge (in the circle). Next step was the machining of other 3 lengths of the workpiece using both geometries. The cutting tool wear values after 6.75 min of machining are not significantly increased (for conventional geometry – 0.09 mm and Xcel geometry – 0.,094 mm). Another wear measurement was made after 11 lengths machining (Fig. 9).



a) Cutting tool wear VB = 0,11mm

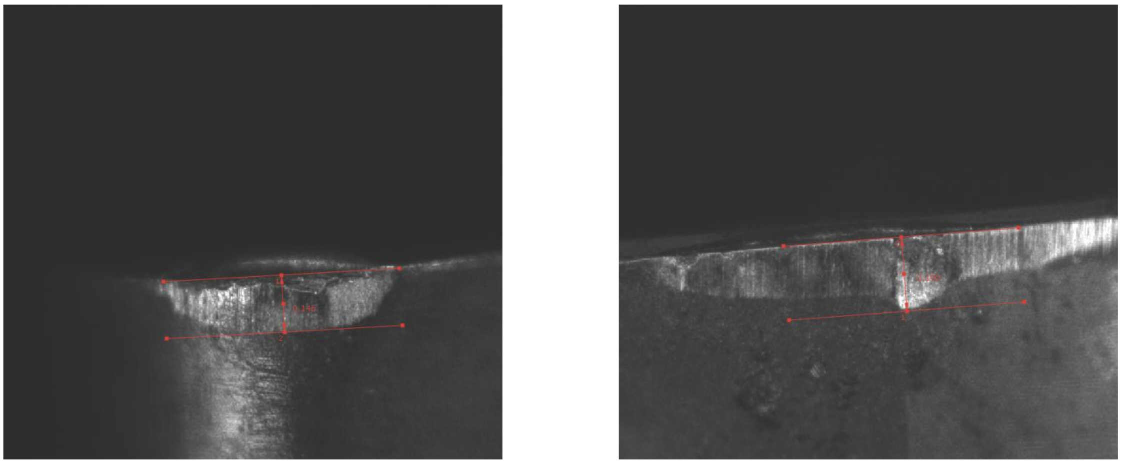


b) Cutting tool wear VB = 0,109 mm

Magnification 200x

Fig. 9 *Conventional (a) and Xcel geometry (b) after 11 lengths machining (9.23 min)*

Eleven workpiece lengths machining means 9.23 min contact of the cutting tool with machined workpiece. As seen in Figure 9, the cutting tool wear for both cutting tools with different geometries has similar value. Other images and measurements of the wear were made after 16 lengths machining (13.3 min). The wear values achieved after this machining time were 0.13 mm for conventional geometry and 0.135 mm for Xcel geometry. The wear of Xcel geometry takes bigger area than the conventional wear, as seen in Fig. 10.

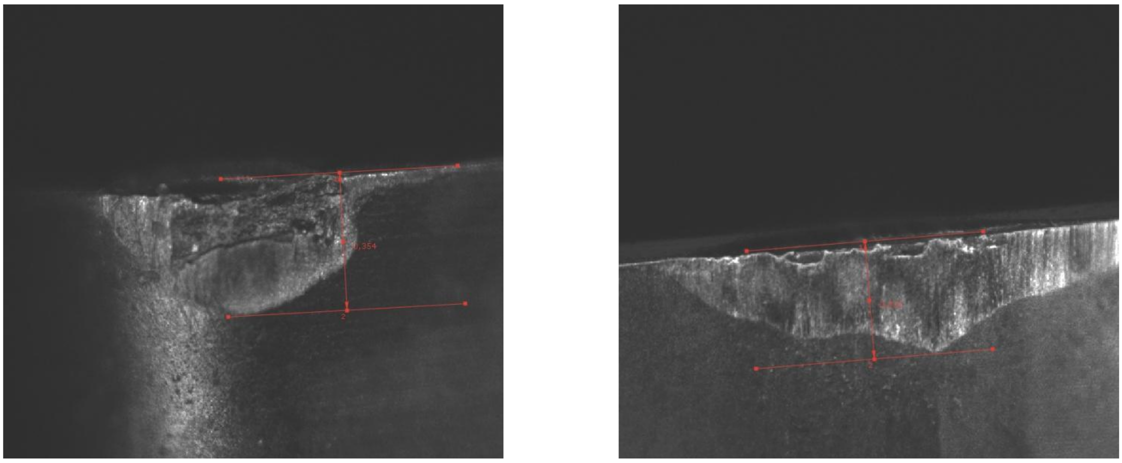


a) Cutting tool wear VB = 0.146 mm *b) Cutting tool wear VB = 0.19 mm*

Magnification 200x

Fig. 10 *Conventional (a) and Xcel geometry (b) after 20 lengths machining (16.5 min)*

The next measurement of the cutting tool wear of both geometries was performed after 21.2 minutes of use – it was 26 workpiece lengths machining. Conventional geometry achieved wear of 0.222 mm and Xcel geometries achieved the wear of 0.246 mm. The flank wear criterion was established as 0.35 mm. This value has not been achieved yet. The machining process continued as before, but the cutting tool wear measurements were performed more often. The next measurement made after other 4.6 min of machining showed that the cutting tool wear of conventional geometry achieved the value of 0.249 mm and Xcel geometry of 0.272 mm. Thus the flank wear criterion was achieved sooner in the case of the tool with the conventional geometry (Fig. 11).

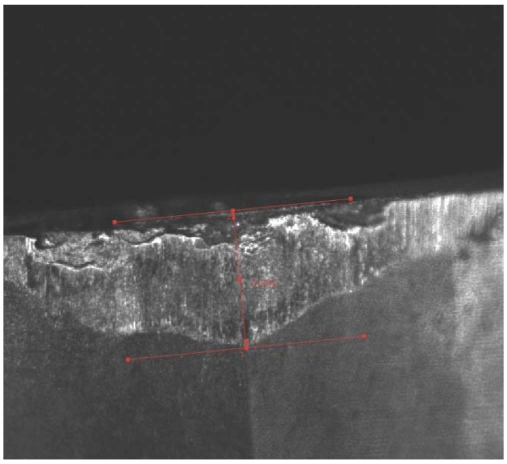


a) Cutting tool wear VB = 0.354mm *b) Cutting tool wear VB = 0.302 mm*

Magnification 200x

Fig. 11 *Conventional (a) and Xcel geometry (b) after 35 lengths machining (28 min)*

The cutting tool insert with conventional geometry was already broken, but it was still possible to use Xcel geometry. Therefore, the next machining was performed using only Xcel geometry.



Cutting tool wear VB = 0.353mm
Magnification 200x
***Fig. 12** Xcel geometry after 42 lengths machining (33.2 min)*

The flank wear criterion (VB_k = 0.35 mm) was achieved after 42 lengths machining, that means 33.2 minutes of machining (Fig. 12).

CONCLUSION

This experimental research dealt with the issues of differently shaped cutting tools wear in hard turning process. The conventional and Xcel geometries were used. The cutting tool wear of both geometries was increasing with time (as known from theoretical knowledge) and the shape of the curve is seen in Fig. 13.

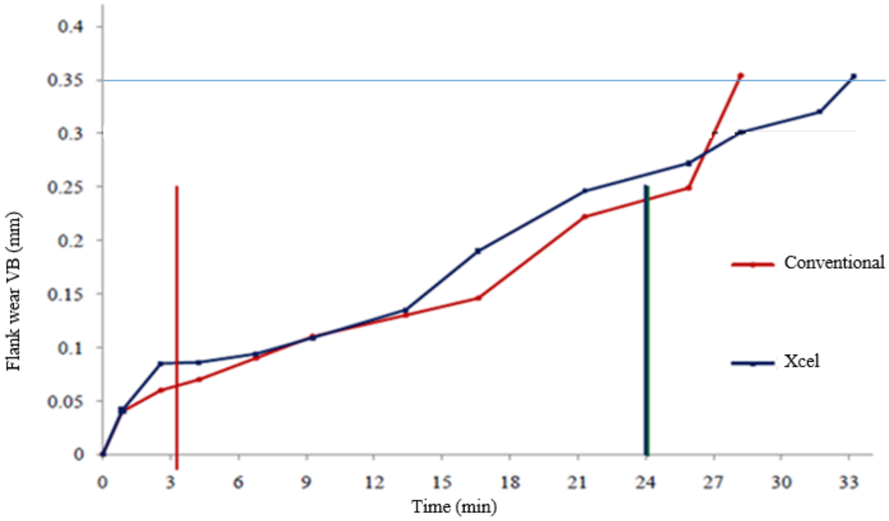


***Fig. 13** Dependence of flank wear in relation to cutting time*

In this experiment, the life of the cutting tool with Xcel geometry (33.2 minutes) was 5 minutes longer than the life of the cutting tool with conventional geometry (28.2 minutes). Another advantage of the use of cutting tool with Xcel geometry in the hard turning process was confirmed.

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