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ANALYSIS OF TOOL WEAR DURING MACHINING OF HARDENED TOOL STEEL

Muhamed Mehmedović, Emir Šarić, Samir Butković,
University of Tuzla, Faculty of Mechanical Engineering
Tuzla, Bosnia and Herzegovina

ABSTRACT
Influence of the machining conditions on tool wear during machining of hardened steel could be observed from the different aspects: work piece properties, machining regimes, cutting tool characteristics, type of applied machining process, and so on. In this paper, cutting tool nose radius and cutting regimes were observed with analysis of their influence on cutting tool wear size, cutting tool wear shape and cutting tool life for machining of hardened Sverker 21 tool steel. Cutting tool nose radius and cutting regimes were observed for three levels, while black ceramic (Al2O3-TiCN) as cutting tool material was used. Analysis of experimental results showed inverse proportion between cutting regimes and cutting tool life, direct proportion between cutting tool nose radius and cutting tool life, as well as abrasive wear as a primary wear mechanism.

Keywords: machining of hardened steel, abrasive tool wear, cutting tool life

1. INTRODUCTION
Machining of hardened material is the process of machining of very hard materials, with hardness range of work pieces 45 - 70 HRC, using cutting tools with defined cutting geometry. Also, the characteristic of the machining of hardened material is using cutting speed in both conventional and high speed areas. These machining processes enable machining of steel hardened work pieces to their final measures, without grinding process. Complexity of conditions that arise during machining of hardened material cause cutting tool wear and cutting tool damage. There are two main cutting tool wear consequences which occur on different cutting tool regions. The first one is so called crater wear which occurs on the rake face, as result of chips sliding along chip-tool interface. The second one is flank wear which occurs on the flank face, as result of friction between side of cutting tool edge or cutting tool nose radius and metal being machined. In this paper, cutting tool nose radius and cutting regimes were observed with analysis of their influence on tool wear and cutting tool life for machining of hardened tool steel. Cutting tool nose radius and cutting regimes were observed for three levels, while black ceramic (Al2O3-TiCN) as cutting tool material was used. The experimental research included the analysis of the cutting tool wear size, cutting tool wear shape and intensity of cutting tool wear, as well as the analysis of the cutting tool life on the basis of cutting tool wear curves designed. Analysis of experimental results showed inverse proportion between cutting regimes and cutting tool life, direct proportion between cutting tool nose radius and cutting tool life, as well as abrasive wear as a primary wear mechanism.

2. EXPERIMENTAL WORK
Experimental wear tests were carried out for longitudinal turning process for dry machining and three levels of cutting regimes. The work piece material used in tool wear experiments was high alloyed tool steel Sverker 21 (X155CrVMo12). Hardness of work piece materials after heat treatment were within the boundaries 55 - 57 HRC, with austenite-martensite microstructure. The cutting tool used in this research was black ceramic CNGA inserts and three different values of cutting tool nose radius, catalogue mark IN22 Al_2O_3-TiCN. Experimental cutting tool flank wear curves, as a function of

cutting time, for three cutting regimes combinations and three different values of cutting tool nose radius 0.4, 0.8 and 1.2, are shown on Figure 1., Figure 2. and Figure 3., respectively.

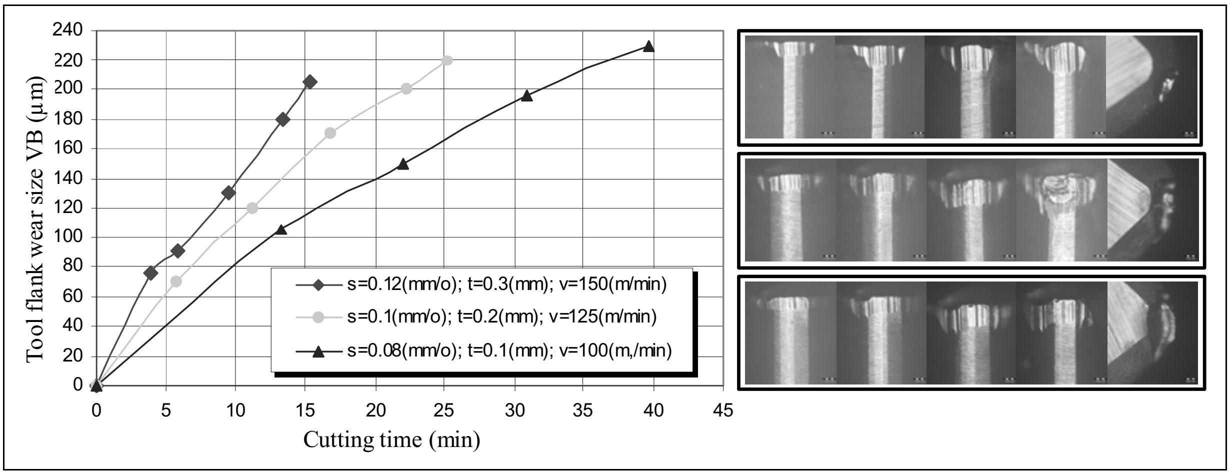

Figure 1. Tool flank wear curves and micrographs of worn cutting tools for tool nose radius 0,4 mm

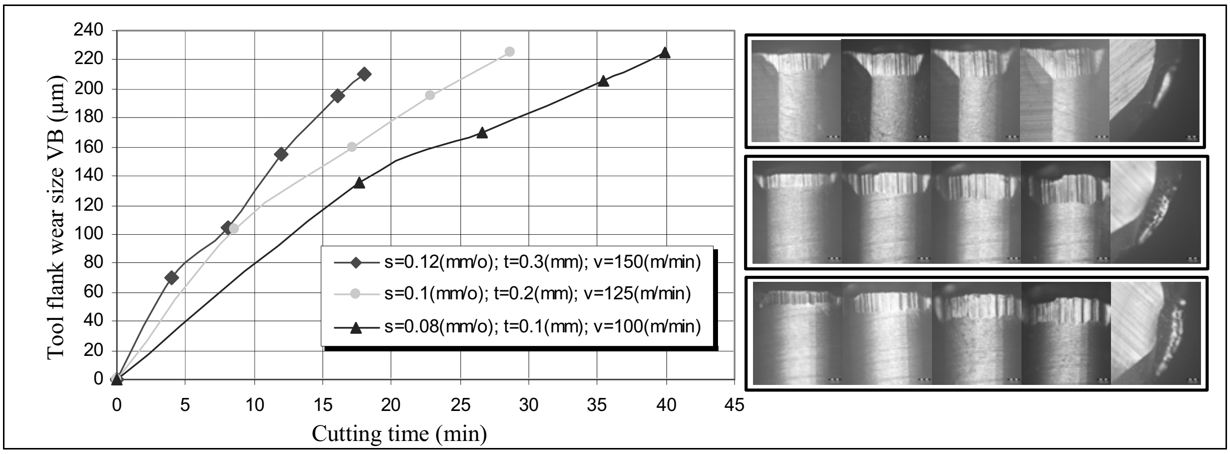

Figure 2. Tool flank wear curves and micrographs of worn cutting tools for tool nose radius 0,8 mm

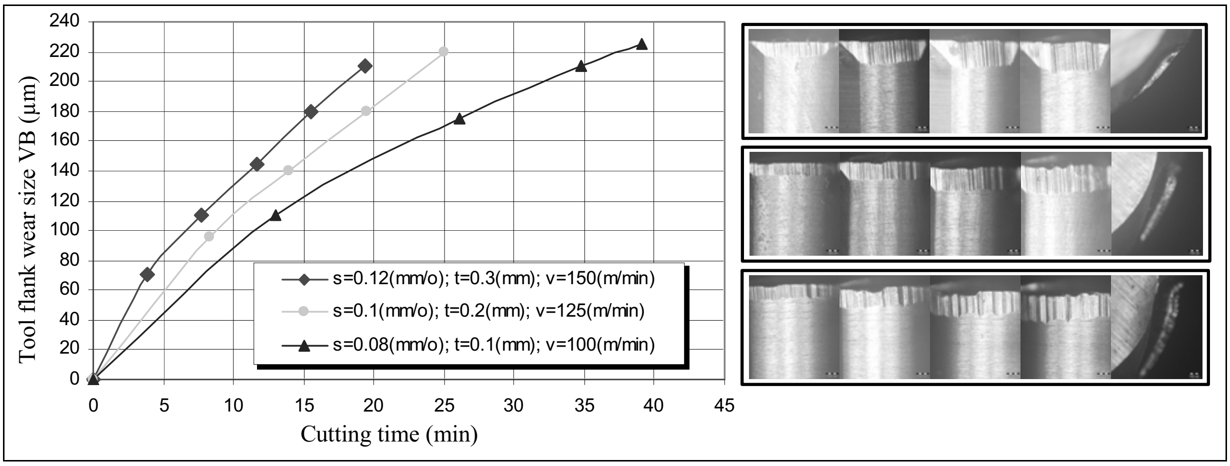

Figure 3. Tool flank wear curves and micrographs of worn cutting tools for tool nose radius 1,2 mm

Micrographs of worn cutting tools, with tool wear regions and clearly visible consequences of tool wear, are shown on the same Figures. Tool flank wear curves had shown some deviations as a result of changes machining regimes during machining processes. Cutting tool flank wear size was within the ranges 210 (µm) - 225 (µm), while the cutting tool life was within the ranges 15 (min) – 40 (min).

In all experimental tests, abrasive cutting tool wear was the dominant tool wear mechanism, while primary and secondary rake tool surfaces as well as main and auxiliary flank tool surface were regions of cutting tool wear.
In the case of more aggressive machining regimes, tool wear manifested through wider tool flank wear size and shorter cutting tool life (cutting tool flank wear curves, Figure 1., Figure 2. and Figure 3.). On the other side, in the case of machining with less aggressive machining regimes, tool wear manifested through increased depth of crater as well as increased width of crater on primary rake tool surface and longer cutting tool life.
Micrographs of worn cutting tools showed widening of crater from primary to secondary rake tool surface, in the case of machining with smaller cutting tool nose radius or machining with more aggressive cutting regimes.

3. RESULTS AND DISCUSSION

Cutting tool life and cutting tool wear intensity during machining of hardened tool steel, for more aggressive machining conditions and three different values of cutting tool nose radius, are analyzed and cutting tool wear curves and cutting tool wear intensity curves as well as micro pictures of worn cutting tool are given on Figure 4.

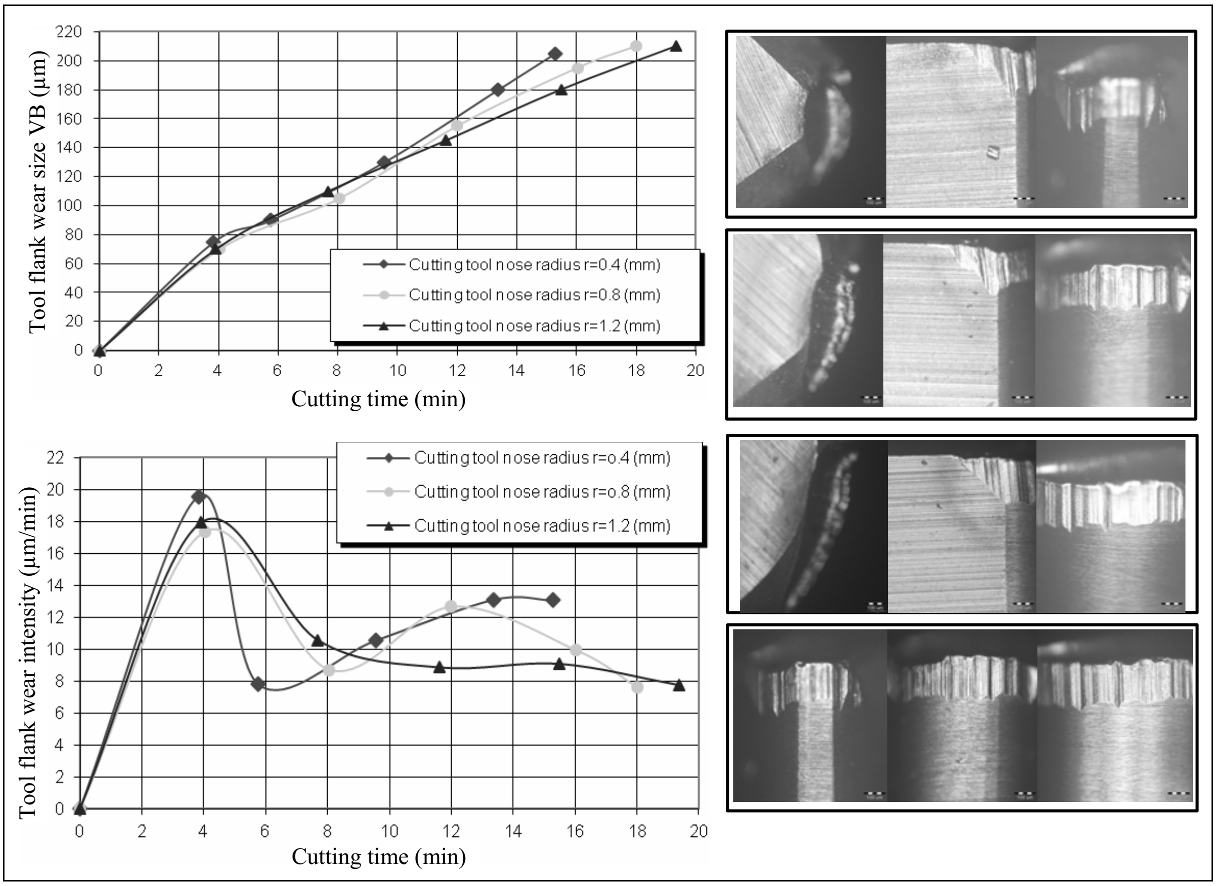

Figure 4. Tool flank wear size and tool flank wear intensity curves for different tool nose radius

As shown in Figure 4., cutting tool wear curves indicate different levels of tool wear size and tool wear intensity depending on tool nose radius, with the local maximum of tool stability when machining with the tool nose radius of 1.2 (mm).
In this case, cutting tool life was the longest. Micro pictures of the worn cutting tools confirm dominant abrasive wear in the region of primary and secondary rake surface as well as in the region of main and auxiliary flank surface, independent of the size of tool nose radius. Shapes of cutting tool wear, in the region of the flank surface, were with significant grooves, as well as with crater in the region of the rake surface.

It can be observed widening of crater from primary to secondary rake tool surface as well as increasing of the crater depth, from micrographs of worn cutting tools, presented in the Figure 4. Intensity of crater propagation from primary to secondary rake tool surface was in inverse proportion with size of cutting tool nose radius.

Crater propagation from primary to secondary rake tool surface indicates increased cutting temperature and increased intensity of tool wear (micrographs on Figure 4.), in this region, which is followed by tool fracture, in the very short time. Traces of increased temperature on secondary rake tool surface are visible on micrographs of worn cutting tools given on Figure 4.

4. CONCLUSION

- In all experimental tests, abrasive cutting tool wear was the dominant tool wear mechanism, while primary and secondary rake tool surfaces as well as main and auxiliary flank tool surface were regions of cutting tool wear.
- Analysis of experimental results showed inverse proportion between flank tool wear size as well as intensity of flank tool wear and values of cutting tool nose radius.
- In the case of machining using smaller values of the tool nose radius, tool wear manifested through increased depth of crater and increased width of crater on primary rake tool surface as well as decreased of cutting tool life.
- In the case of machining using bigger values of the tool nose radius, tool wear manifested through decreased depth of crater and decreased width of crater on primary rake tool surface as well as increased of cutting tool life.
- Analysis of experimental results showed inverse proportion between any of cutting regimes and cutting tool life, as well as abrasive wear as a primary wear mechanism.
- Tool wear size on the flank tool surface as well as crater width and crater depth on the rake tool surface showed direct proportion with cutting speed, depth of cut and feed rates.
- Shapes of cutting tool wear, in the region of the flank surface, were with significant grooves. Also, occurrence of crater in the region of the rake surface can be observed.

5. REFERENCES

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