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Experimental Study on the High Speed Machining of Hardened Steel

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Abstract

In the present paper, experimental study is made to investigate the effect of cutting parameters on surface roughness in dry high speed milling of hardened tool steel using two cutting tools (diameter of 20 and 40 mm). The cutting parameters considered include cutting speed and feed per tooth. Experiments are conducted in up-cut and down-cut milling. Based on the experimental data, the effect of tool diameter on the surface roughness is analyzed. The good surface roughness can be achieved in high speed machining of examined steel but rapidly tool wear is observed.

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Keywords: high speed machining; hardened steel; cutting parameters; surface roughness

1. Introduction

High speed machining is an advanced manufacturing technology with a great future potential [1]. Since, there is no unique definition of high speed machining because it is defined differently from the different authors. One definition is that the process “involves machining at considerably higher cutting speeds and feed rates than those used in conventional machining", however, it is most commonly used to describe milling at high rotational speeds. The process has been adapted to a wide range of applications. One of the more recent applications of high speed machining is in the manufacture of moulds and dies from hardened tool steels [2, 3, 4]. The significance for high speed machining and especially high speed milling in production has increased since new machines and tools enable the possibility to reduce process time on one hand and to improve surface quality on the other hand [5].The surface

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quality is one of the most specified customer requirements and the major indicator of surface quality on machined parts is surface roughness. The surface roughness is mainly a result of various controllable or uncontrollable process parameters and it is harder to attain and track than physical dimensions are. A considerable number of studies have researched the effects of the cutting speed, feed, depth of cut, nose radius and other factors on the surface roughness [6, 7, 8, 9]. Thus, it is necessary to have a deeper knowledge about the optimum operation conditions, which will permit us to assure a good surface roughness. An experimental approach is taken this study. First, the experimental setup is introduced. Then, the effect of cutting parameters on surface roughness in high speed face milling of hardened steel is explained.

2. Experimental setup

In order to achieve the stated objective, the experiments are carried out using hardened tool steel to investigate the effect of cutting parameters on surface roughness. Experiments are conducted on the Faculty of Mechanical Engineering in Sarajevo. Fig. 1 shows the experimental machining system (left) and the work piece (right) used in the experiments. Experimental machining system is constructed by the adaptation of the stiff universal milling-drilling machine, by building modern high speed components which have primary characteristics: flexibility, high productivity and modularity. The process of the machining system set-up was accompanied by a number of expert and non-standard practices as well as investigations regarding the rigidity and vibrations that played an important role in the selection of the mounting. During implementation of the experimental investigations the two milling tools with exchangeable inserts of hard metal used as the cutting tool, manufacturer SANDVIK Coromant. The cutting tools are clamped to the motor spindle HSM by a tool interface HSK 40E, and it is produced in Technical office of Sandvik Coromant in Germany by submission of the authors of this study. Experimental investigations conducted in high speed face milling, with the following parameters:

- *Tool diameter of 20 mm*: cutting speed from 500 to 1500 m/min and feed per tooth from 0,05 mm to 0,15 mm. Depth of milling and width of milling are 0,30 mm and 12 mm, respectively.
- *Tool diameter of 40 mm*: cutting speed from 750 to 3000 m/min and feed per tooth from 0,05 mm to 0,15 mm. Depth of milling and width of milling are 0,30 mm and 24 mm, respectively.

Cutting tests carried out under dry machining conditions. A new cutting edge for each machining experiment is used. For measuring of surface roughness, the modern device Perthometer Concpet is used. The material used for experiments was the hardened tool steel X37CrMoV5-1(~51 HRC).

Fig.1.The experimental machining system used in the experiments and the workpiece.

3. Results and discussion

The effect of cutting speed on surface roughness during high speed down-cut and up-cut face milling of the hardened steel using two cutting tools (diameter 20 and 40 mm) are done in Fig. 2, 3, and 4.

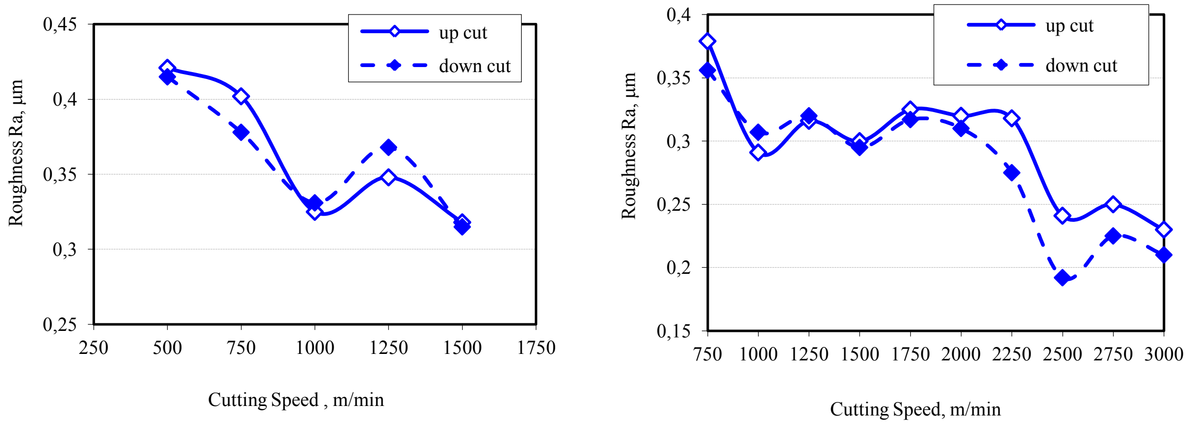

Fig.2. The surface roughness at the feed per tooth of 0,05 mm: tool diameter of 20 mm (left) and tool diameter of 40 mm (right).

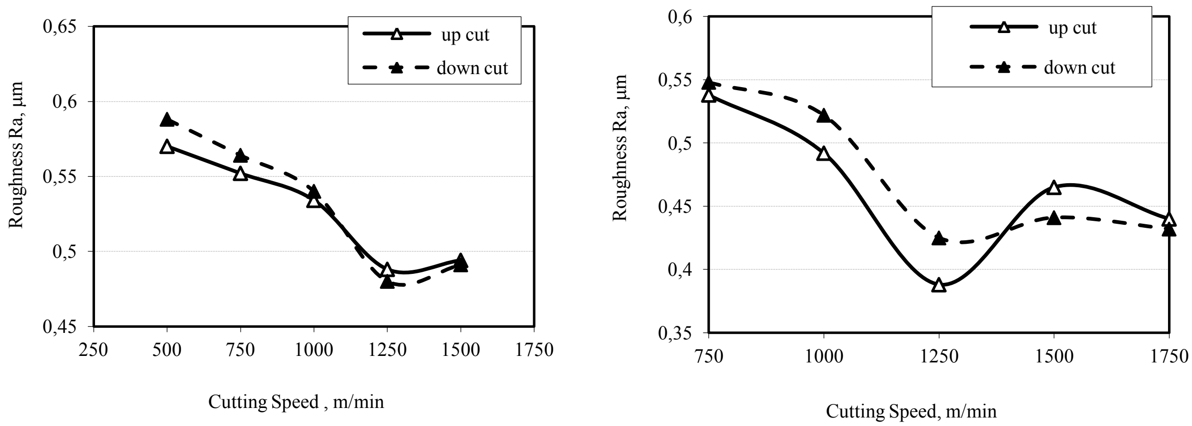

Fig.3. The surface roughness at the feed per tooth of 0,10 mm: tool diameter of 20 mm (left) and tool diameter of 40 mm (right).

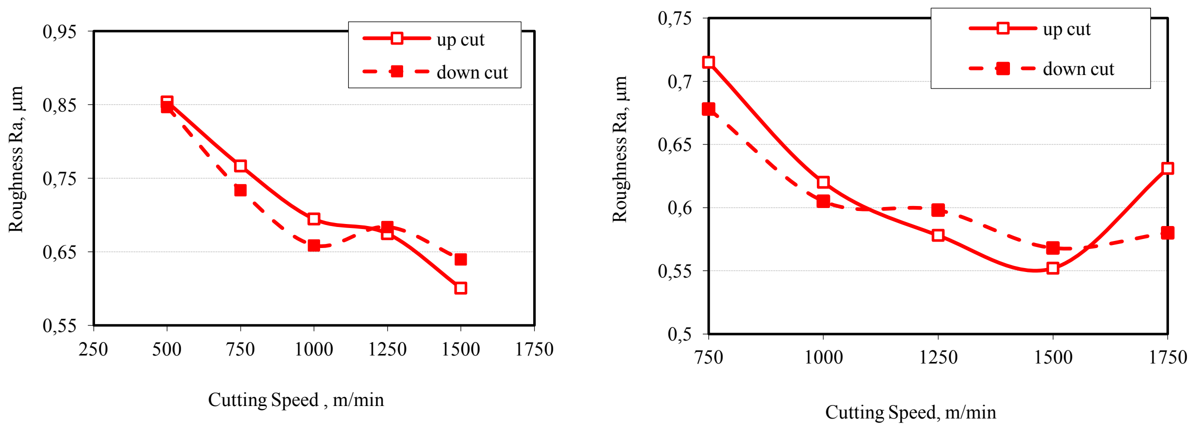

Fig.4. The surface roughness at the feed per tooth of 0,15 mm: tool diameter of 20 mm (left) and tool diameter of 40 mm (right).

In Fig. 2, 3 and 4 can be seen that the surface roughness decreases by the increase of cutting speed in high speed milling of the examined steel. At the feed per tooth of 0,05 mm, see Fig. 2 – right side, the surface roughness slightly changes in the domain of cutting speeds from 1000 m/min to 2250 m/min. The decrease of surface roughness can be observed when the cutting speed higher than 2250 m/min. Important to note that during the execution of experiments, rapidly the tool wear was observed with the increase of cutting speed. On this occasion, it is necessary to give an explanation on the diagrams (at the right side) in Fig. 3 and Fig.4, when the tool diameter of 40 mm was used. At the feed per tooth of 0,10 mm and 0,15 mm, the machining of the examined steel was not possible at the cutting speeds higher than 1750 mm, due to rapid tool wear and impossibility to obtain valid results. With economical point of view, it is recommended to use "lower" cutting speed during machining of the examined material.

The effect of feed per tooth and the tool diameter on the surface roughness in high speed up-cut face milling of the examined steel is done in Fig. 5.

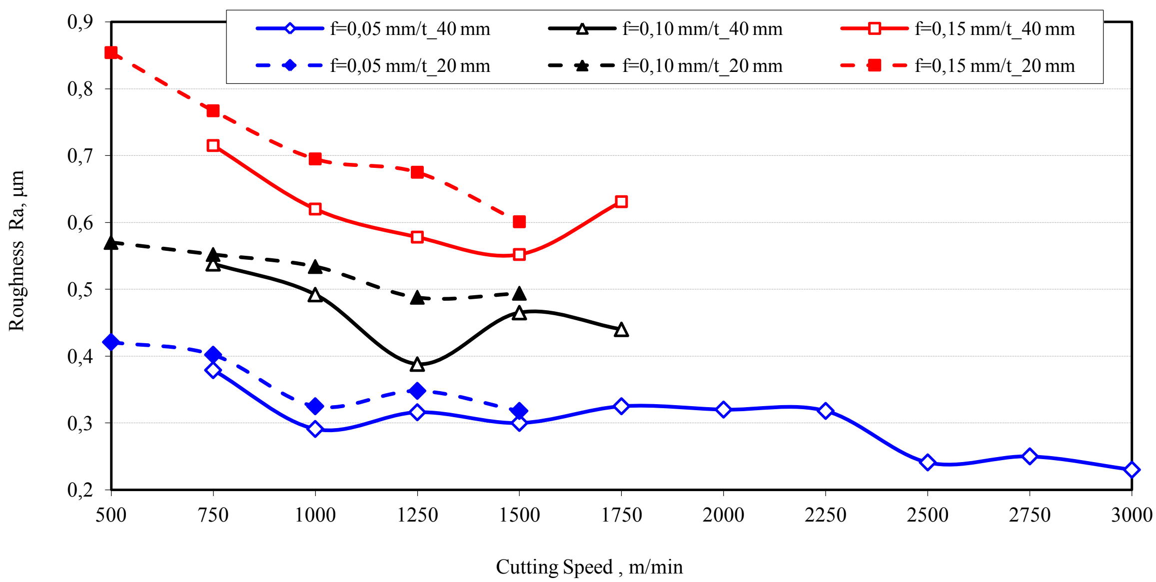

Fig.5. The effect of feed per tooth and the tool diameter on the surface roughness in high speed up-cut milling.

Fig.5 shows that the feed per tooth has deeply effect on the surface roughness during high speed machining. The surface roughness increases by the increase of feed per tooth. Also can be observed that better surface roughness is achieved when used tool diameter of 40 mm.

During high speed machining of the examined steel, the lowest roughness is obtained at the following machining parameters: tool diameter of 40 mm, down-cut milling, cutting speed of 2500 m/min, feed per tooth of 0,05 mm, milling depth of 0,10 mm and milling width of 24 mm. The value of roughness parameter: R_a=0,192 µm.

4. Conclusion

Due of comprehensive experimental research, detailed theoretical investigations and performed analysis, it is possible extract followed conclusions:

- The surface roughness decreases with the increase of cutting speed in high speed milling of hardened steel.
- The feed per tooth has deeply effect on the surface roughness in high speed machining. The surface roughness increases by the increase of feed per tooth.
- The better surface roughness is achieved when used the tool with larger diameter.

- Also, it can be concluded that milling direction (down-cut and up-cut) has no effect on surface roughness.
- Due to rapid tool wear, the hardened steel was not possible to machining at the cutting speed higher than of 1750 mm/min and the feed per tooth higher than of 0.10 mm. The lower feed per tooth and the lower cutting speed, it is recommended in machining of the examined material.
- By machining system VBS, which is located on Faculty of Mechanical Engineering in Sarajevo, it has been gained excellent conditions for research of phenomena inherent during ultra high speed milling.

The effect of tool geometry and tool material on the surface quality in high speed machining of hardened steel, it is recommended to further experimental study. The required surface roughness in high speed milling can be achieved, but it is very important to select the optimal cutting conditions.

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