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Effect of Cutting Speed During Turning of Low Carbon Steel on Mechanical Properties and Surface Roughness

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Abstract. The purpose of this paper is to study the cutting speed effect on mechanical and surface roughness (Ra) of XC18 steel. Scanning electron microscopy, hardness and roughness tests were used. We have found that the cutting speed affects the surface layer of a workpiece, induces hardening of the surface, and increases the surface roughness.

Introduction

Turning is one of the major manufacturing processes used to produce mechanical parts. Surface finish of the machined parts is one of the important criteria by which the success of a machining operation is judged [1]. Due to the increasing demand of higher precision components for its functional aspect, surface roughness of a machined part plays an important role in the modern manufacturing process [2].

Good surface finish is necessary to prevent premature fatigue failure; to improve corrosion resistance; to reduce friction, wear, and noise; and finally to improve product life. Therefore, achieving the required surface finish is critical to the success of many machining operations [3]. Consequently, the poor selection of the process parameters may cause excessive tool wear and increased work surface roughness. It is well known that the final geometry of surface roughness is influenced by various machining conditions such as spindle speed, feed rate and depth of cut.

However, hard turning can introduce modifications within the surface layer of a workpiece. These modifications are metallurgical transformations as a result of intense, localized and rapid thermo-mechanical loading. The surface layer can show an extremely different structure from the bulk material due to the white layer formation that appears white in colour under an optical microscope after polishing and etching or featureless in a scanning electron microscope [4]. It is referred to as untempered martensite [5] and characterized by an increase in hardness than the bulk material [4-6].

The aim of this study is to present the influence of cutting speed by turning process on mechanical behavior of the surface and surface roughness of low carbon steel in order to optimise the cutting speed.

The selected work materials was low carbon steel (XC18) in the forms of bars. The work piece material was received as 500 mm length bar having 50 mm diameter machined by Triangular Carbide Tool. The machining tests were conducted on precision turning machine.

Fig. 1 shows the experimental machining system (left) and the work piece (right) used in the experiments.

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

During machining tests, a 0,6 mm fine depth of cut and four cutting speeds were used (340, 560, 840, and 1100 tours /min).

The surface roughness was measured using ZEISS SURFCOM 1400D-3DF (Fig.2). For each specimen, 3 roughness profiles were recorded perpendicular to the grooves. The scanning length profile length was 6 mm. The surface roughness amplitude (Ra) was computed.

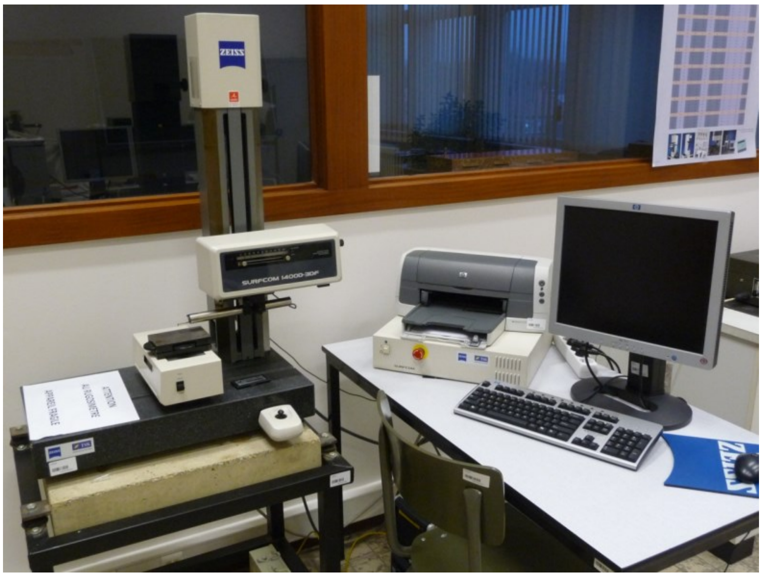

Fig. 2 Photographic view of the surface roughness tester.

The cross-section of each specimen (Fig.3) was prepared for microscopic analysis using metallographic techniques. The specimens were carefully sectioned, polished and etched using a 2 % Nital solution for approximately 12 s. The micrographic analyses of cross-sections were then carried out using scanning electron microscope (Philips SEM505). The hardness profile evolution from the surface to the core of the machined steel is measured by Knoop hardness.

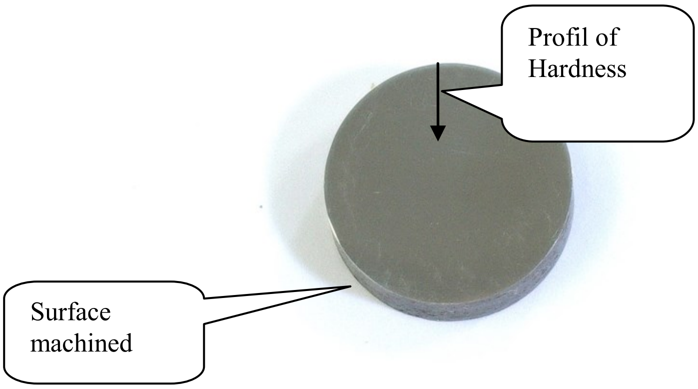

Figure 3 : Specimen of machined XC18 steel.

Results and Discussion

Microstructural Evolution. Typical microstructure of non machined original metal is presented in figure 4 which is largely composed of equiaxed ferrite grains having an average diameter of 20µm. Small regions of pearlite (α-Fe + Fe3C) are present in the base metal microstructure at grain boundaries edges and corners.

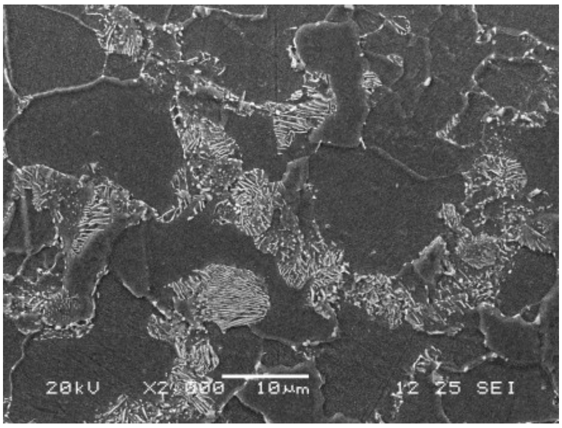

Figure 4 : Microstructure of low carbon steel (AISI 1055)

The microstructures of machined material were inspected with a SEM. There was a clear evolution in microstructure of surface layer after increasing cutting speed (Fig.5). The white layer (1µm width) was observed at the surface wich confirmed previous work [4]. The mechanism of white layer formation is attributed to severe plastic deformation, which produces a homogenous structure or one with a very fine grain size ,and/or rapid heating and quenching, which results in phase transformation [5-7]. Consequently, hard turning can introduce modifications within the surface layer of a workpiece. An increase in cutting speed implies an increase in local temperature near the cutting tip.

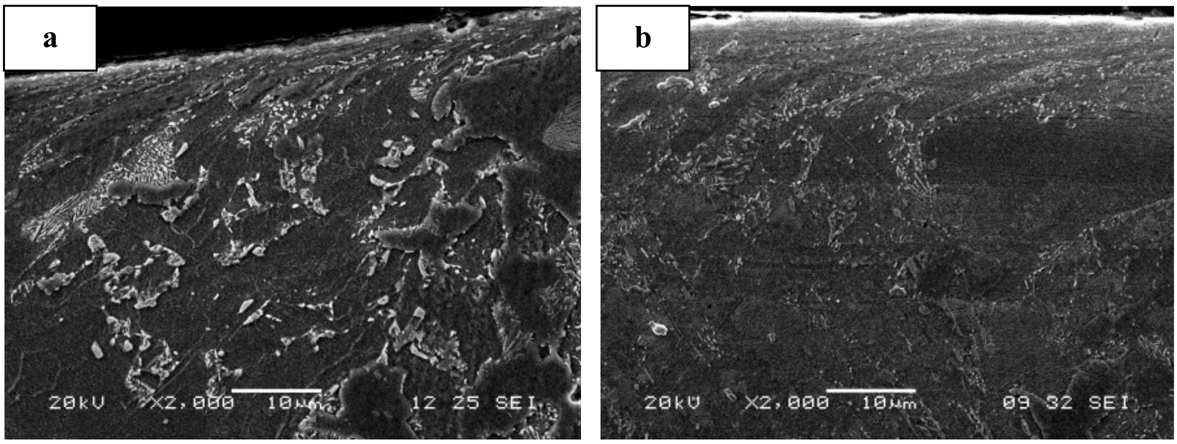

Figure 5 : Microstructures of the cross-section of low carbon steel after two cutting speeds by hard turning : (a) V2 = 560 and (b) V4 1100

Hardness Profile Variation. Figure 6 presents the effect of cutting speed on hardness profile evolution from the surface to the core of the machined steel. The highest hardness value (2000) is obtained for the highest cutting speed. It has been reported that if high temperatures are reached at the surface and heat penetration is lower, it would be more probable the martensite transformation in quenching, favouring the formation of compressive transformation stresses [8].

However, the hardness values for the other lower cutting speed were approximatively equal but the hardness curve obtained after cutting speed V3 is slightly higher than V1 and V2. .

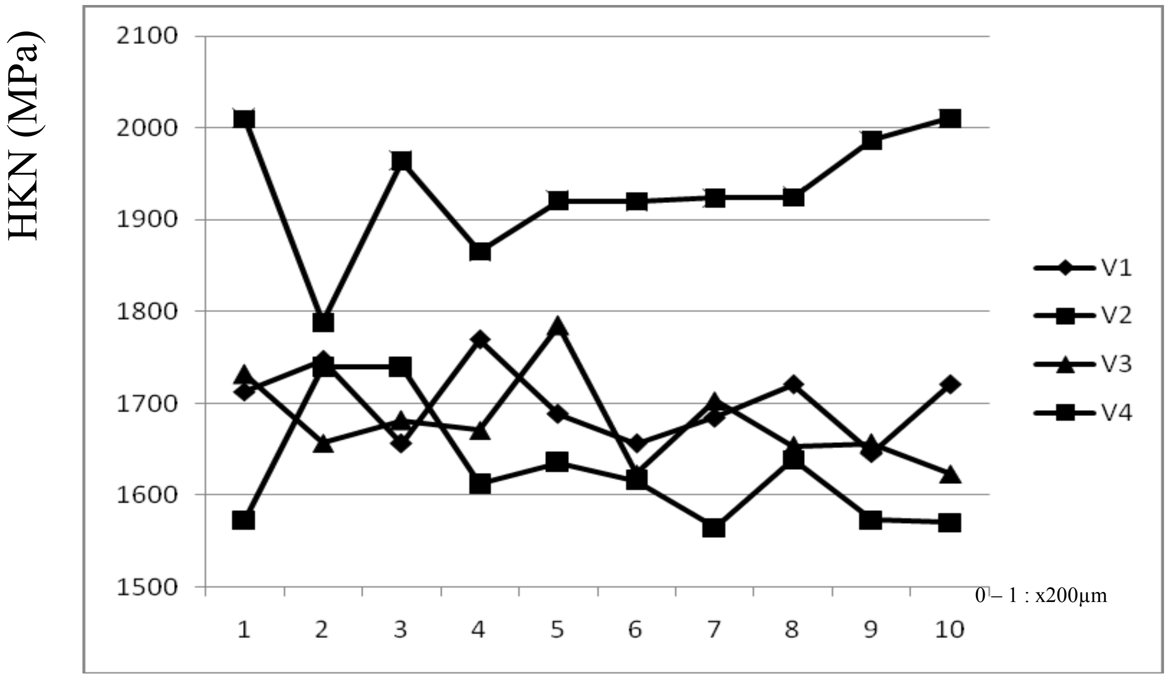

Figure 6 : Knoop hardness evolution curves from the surface to the core of low carbon steel after different cutting speed by hard turning.

Surface Roughness Measurement. It is known that the surface roughness represents the random and repetitive deviations of a surface profile from the nominal surface. The figure 7 shows cutting speed Vs surface roughness having cutting speeds (340, 560, 840, and 1100 tours /min) . At low cutting speed of 340, the surface roughness obtained was 8 (27 micron). The cutting speed 840 (225 m/min) produced the highest value of surface roughness 16, but up this cutting speed the surface roughness decreases. From this study of effect of cutting speed on surface roughness of low carbon steels it may be concluded that the better surface finish may be achieved by turning carbon alloy steels at low cutting speeds. It was found that the surface finish in turning is influenced by several factors such as feed, work material characteristics, workpiece hardness, coolants, cutting speed, depth of cut, tool nose radius and tool cutting edge angles [9-10]. For example, Suresh et al [11] , has been found that the surface roughness decreases sharply with increase in cutting speed for a given value of feed rate. However, Thiele and Melkote [12] and Capello et al. [13] have also observed an increase in surface roughness with cutting speed.

We deduce that many parameters can influence the surface roughness. The increase in cutting speed improves the machined surface quality. If the speed is higher than 350 m/min, the curves related to surface roughness take ascending forms because of the vibrations related to high speeds

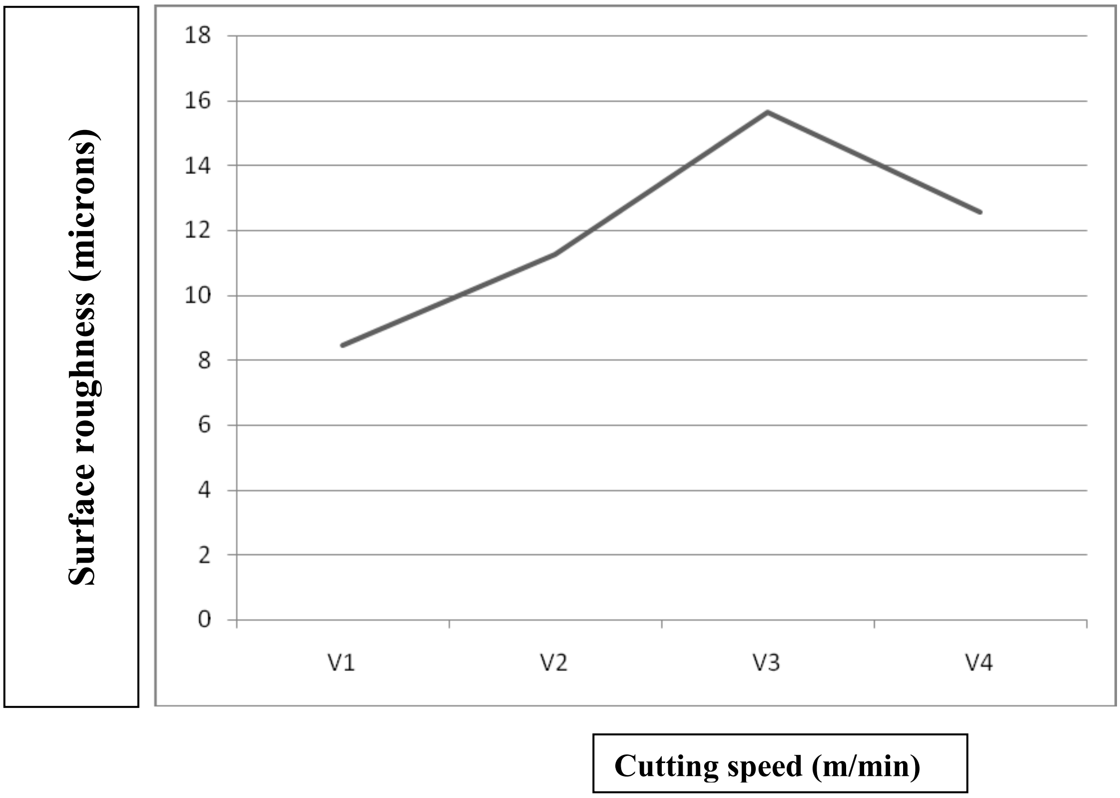

Fig. 7. Surface roughness vs. cutting speed by turning of low steel

Conclusion

In summary, the effect of cutting speed by turning process on low carbon steel was studied by using scanning electron microscopy, roughness and microhardness meausurements. From this investigation, width of surface layer affected by machining was determined. Metallurgical transformations within this layer induces hardening phenomenon. In general, surface roughness depends on cutting speed.

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