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TURNING OF AISI 304 AUSTENITIC STAINLESS STEEL

Cebeli ÖZEK, Ahmet HASÇALIK, Ulaş ÇAYDAŞ*, Faruk KARACA, Engin ÜNAL

University of Firat, Technical Education Faculty, Department of Manufacturing, ELAZIG

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ABSTRACT

This paper presents an experimental investigation of the machining characteristics of AISI 304 austenitic stainless steel in turning process. During experiments, parameters such as cutting speed, feed rate and depth of cut were changed to explore their effect on the surface roughness, tool flank wear and tool – chip interface temperature. Chip forms were determined. Taking into consideration the experimental results, it is found that with increasing cutting speed, tool – chip interface temperature and tool flank wear were decreased. Surface roughness got better with decreasing feed rate and depth of cut.
Keywords: Surface roughness, AISI 304 austenitic stainless steel, process parameters.

AISI 304 OSTENİTİK PASLANMAZ ÇELİĞİN TORNALANMASI

ÖZET

Bu çalışmada, AISI 304 ostenitik paslanmaz çeliğinin tornalama işleminde işlenebilirlik karakteristikleri deneysel olarak araştırılmıştır. Deneylerde, kesme hızı, ilerleme miktarı, talaş derinliği gibi parametreler değiştirilerek, parametrelerin yüzey pürüzlülüğü, takım yanak aşınması ve takım-talaş ara yüzey sıcaklığına olan etkileri incelenmiştir. Deneyler neticesinde, kesme hızının artmasıyla, takım-talaş ara yüzey sıcaklığının ve takım yanak aşınmasının azaldığı; ilerleme miktarı ve talaş derinliğinin azalmasıyla yüzey pürüzlülüğünün iyileştiği belirlenmiştir.
Anahtar Sözcükler: Yüzey pürüzlülüğü, AISI 304 ostenitik paslanmaz çelik, işlem parametreleri.

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1. INTRODUCTION

The AISI 300 series of austenitic stainless steels represent the largest group of steels in use of total [1]. However these steels have very high corrosion resistance, it is more difficult to machine these materials because of their low heat conductivity, built – up edge tendency and high work hardening properties than carbon and low alloy steels [2,3]. Poor surface finish and high tool wear are the common problems [1].

In metal cutting operations, temperature develops at the chip – tool interface due to the plastic deformation developed at the primary shear plane and friction at the tool – chip interface. This temperature rise effects the tool wear and its life, and surface integrity of material. The heat

*Sorumlu Yazar/Corresponding Autor: e-mail/e-ileti: ucaydas@firat.edu.tr, tel: (0424) 237 00 00 / 4227

generated and temperature are also connected the use of process parameters and thermo physical properties of workpiece and tool materials, including the heat thermal conductivity, thermal diffusivity and heat transfer coefficient [4]. So it is important to choose the correct parameters for satisfy the increasing demands of sophisticated component performance, longevity and reliability.

Little work has been carried on the determination of optimum machining parameters when machining austenitic stainless steels [5]. In this study, parameters such as cutting speed, feed rate and depth of cut were changed to explore their effects on the temperature rise at the tool – chip interface, surface roughness and tool flank wear.

2. EXPERIMENTAL PROCEDURE

The composition of AISI 304 austenitic stainless steel used in experiments is given Table 1. Specimens were prepared with 25 mm in diameter and 175 mm length. The tests were performed on a CNC lathe (20kW and 3500 rpm). Coolant wasn't used. WC ISO P10 cemented carbide tool was used. Temperature developed at the tool – chip interface was measured an infrared thermometer which have 0 – 870 °C and ±1 °C sensitive. The infrared thermometer was clamped on the turret as a rigid tool holder (Fig 1). Average surface roughness (R_a) was measured using Mitutoyo Surftest SJ – 201 portable device. In experiments, different settings of cutting speed, feed rate and depth of cut were used (Table 2). Different combinations of these machining parameters were tested using factorial experimental design method. The tool flank wear was measured using a Stereo Zoom Microscope.

Table 1. Chemical composition of specimens tested (wt. %)

C	Si	Mn	Cr	Mo	Ni	P	S	Fe
0.033	0.480	1.324	19.500	0.313	7.370	0.037	0.005	balance

Table 2. Parameters of the setting

Input parameters	*Level 1*	*Level 2*	*Level 3*
Cutting speed (m/min)	100	150	200
Feed rate (mm/rev)	0.1	0.2	0.4
Depth of cut (mm)	0.5	1	2

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1. Temperature Measurement

Fig. 2 shows the interface temperature values that obtained with infrared thermometer when machining AISI 304 austenitic stainless steel, related to the cutting speed and feed rate parameters with a depth of cut 1 mm. It is experimentally found that the hottest point on the flank face is 230 °C at the cutting speed of 100 m/min and feed rate of 0.4 mm/rev conditions. With increasing the cutting speed, the interface temperature decreased. The exploration of this phenomenon is, most of the heat generated in machining is removed from the cutting zone by the chip [6]. So the chip speed flow in the cutting zone tending to increase with cutting speed, leading to a greater heat evacuation [7].

Taking into consideration of the temperature as a function of friction, the contact length decreased with increasing cutting speed [8]. An increasing value of feed rate leads to an augmentation of the cutting and feed forces [7]. However, the energy consumption is higher and the temperature rise increasing.

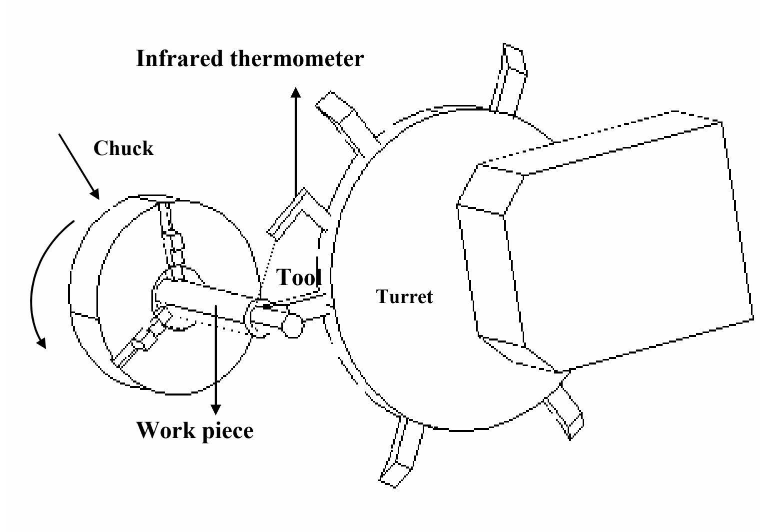

Figure 1. Experimental setup

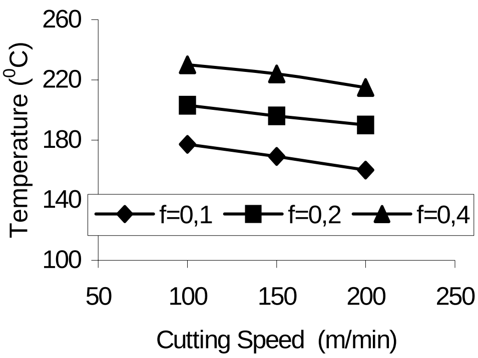

Figure 2. Effects of cutting speed and feed rate on the interface temperature

3.2. The Influence Of Machining Parameters On Tool Flank Wear And Surface Roughness

The values of tool flank wear can be seen in Fig. 3. With increasing the cutting speed, tool flank wear was decreased. Due to the austenitic stainless steel AISI 304 have low thermal conductivity; this material can not evacuate the heat rapidly. So at the lower cutting speed, the tool performance is seen very poor. Korkut et. al [5] also indicated the poor tool performance at the lower cutting speed because of the longer contact time on the rake face as the chips moved slowly when compared to the higher cutting speeds. In the same paper, the authors have also reported that the the tool flank wear has increased at the 210 m/min. So for the tool life's importance when machining AISI 304, cutting speed should not be over 200 m/min.

The effects of cutting speed and feed rate on the surface roughness at 1 mm constant depth of cut were given in Fig. 4. The lowest average surface roughness got obtained 0.1 mm/rev feed rate and 150 m/min cutting speed conditions. This is because the higher feed rates lead to the greater elastic relaxation after machining [9]. Similar observation has been reported by Tekiner et al. [10] and decreasing the feed rate, less vibration was observed and surface roughness got better due to the decrease of power consumption.

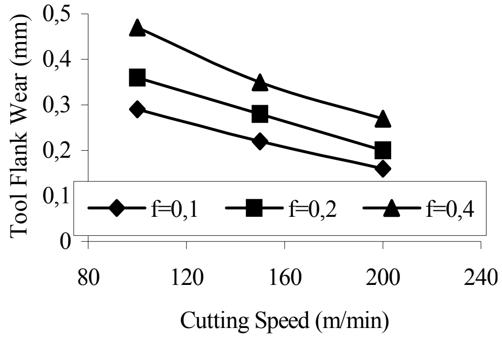

Figure 3. Effects of cutting speed and feed rate on the tool flank wear

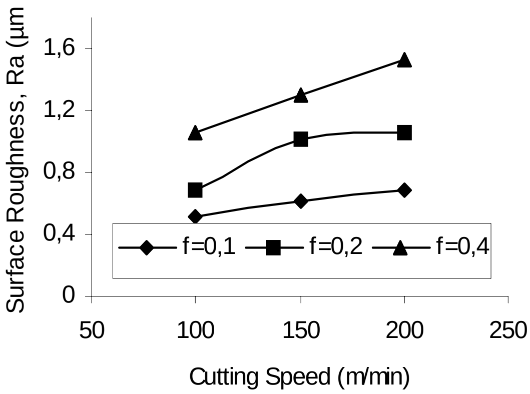

Figure 4. Effects of cutting speed and feed rate on the surface roughness

3.3. Chip Formation

Fig.5 shows typical chip forms at different cutting speed and feed rate conditions. At 100 m/min cutting speed, the chips' curl radii were found 0.75 – 1 mm and thickness of 0.3 mm. With increasing cutting speed up to 150 m/min, curl radii raised to 2 – 2.5 mm and 0.6 mm thickness. Finally, at the highest cutting speed 200 m/min, the chip curl radii and chip thickness were found 3 –3.5 and 0.75 mm respectively.

At the lowest cutting speed 100 m/min the chips were in a color close to yellow. Higher cutting speeds lead to brittle chip color [5].

Figure 5. Typical chip forms (a; 100m/min, b; 150 m/min, c; 200 m/min cutting speed, feed rate 0.2 mm/rev and 2 mm depth of cut)

4. CONCLUSIONS

In this experimental study, the effect of turning parameters such as cutting speed, feed rate and depth of cut on machining characteristics of AISI 304 steel was investigated. Summarizing the main features of the results, the following conclusions may be drawn.

1. The highest tool – chip interface temperature was measured 356 °C at 100 m/min cutting speed, 0.2 mm/rev and 2mm depth of cut conditions. The most effective parameter on the temperature rise was found depth of cut.
2. The surface roughness increased when the depth of cut and feed rate were increased while the cutting speed have an inverse influence.
3. At the lowest cutting speed of 100 m/min, the chips' colors were found yellow because of the highest temperature value evaluated. With increasing cutting speed chip curl radius increased and chip thickness decreased gradually.

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