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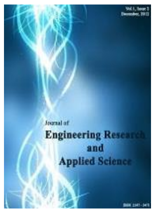

Machinibility of AISI 420 stainless steel depending on cutting speed, tool nose radius and tool coating

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Abstract

This study aims to investigate the machinability of martensitic stainless steel AISI 420. The influence of cutting speed (Vc) and tool nose radius on surface roughness were analyzed and the effect of coating on tool wear was examined. These experimental results gave lots of information about the materials machinability. In this research, AISI 420 experiment materials were turned by computer numerically controlled (CNC) millturn machine with coated carbide tools. The tools had different coatings and nose radius. Surface roughness measured with Lombardore tl70 Alpa perthometer. Tool wears analyzed with Nikon TS2-S-SM microscope. Through the analysis of the results in the present work, the nose radius was identified as the most significant parameter. Surface quality was absolutely better with larger nose radius 0,8 mm than 0,4 mm. Also increasing of the cutting speed had positive effect on surface quality. Microscope analyze results showed that Ti(CN) +Al2O3+TiN coated tools with CVD method had better tool wear resistance than AL2O3+TiCN coated ones.

Keywords: stainless steel; machinability; cutting speed; tool nose radius; surface roughing

1. Introduction

Stainless steels are preferred by many industries like defense, aerospace, automotive etc. for their high corrosion resistance, low thermal conductivity, high strength and high toughness. However some of these specialties causes machinability difficulties. Because of the low thermal conductivity, the chips are formed on the basis of catastrophic failure in narrow shear surfaces [1]. Tool materials, such as CVD-coated (Chemical Vapor Deposition) with hard AL_2O_3 coatings, are often preferred to overcome this problem [2]. Martensitic steels, like AISI 420, are also abrasive and tend to form a built-up edge [3].

In this study, to decrease the built up edge, cutting speed was increased and it had positive effect on surface quality [4]. Surface roughness also decreased as the nose radius increased hence surface finish increased.

Tool wear is a gradual process that occurs with a combination of prime wear modes. It is extremely dependent on the cutting conditions, work piece material, cutting tool type, and tool geometry [5]. The development of coating technology on tool manufacturing industry is getting better day by day. Lower tool wear rate means higher tool life [6].

2. Materials and methods

AISI 420 stainless steel experiment materials were prepared at 300 mm length and 32 mm diameter. Before the experiment, the chemical compassion of the material checked by Oxford Instruments Foundry Master X Line spectral analysis machine (see in fig.1). The results were matched with the AISI 420 standards (see in tab 1.).

The hardness of the work pieces were chosen as 180-220 HB. Mazak I200 Integrex 5 Axis mill turn CNC machine were chosen for the turning operations. Hangsterfer's S500 CF cooling fluid were used in machine at %6 which offered for stainless steels by manufacturer. Cutting tools used from the brand Sandvik model DNMG 11-04-08-PF-4315, DNMG 11-04-04-PF-4325 and from ZCC model DNMG 11-04-08-DF-YBC252, DNMG 11-04-04-DF-YBC252. The tool holder has chosen from the brand Takımsaş PDJNR/.

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Figure 1. Spectral analysis of the work piece

Table 1. Chemical composion of workpiece AISI 420.

Element	Fe	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	V
Value(%)	86,1	0,244	0,422	0,314	0,0085	<0,005	12,5	0,0368	0,113	0,0089	0,007	0,169	0,0062

2.1. The influence of cutting speed on surface roughness

The topic of the first experiment was the influence of cutting speed on surface roughness. Cutting speeds were chosen by tool manufacturers catalog according to ISO 3685. 210-240 and 280 m/min were the cutting speeds with 1mm cutting depth. Sandvik DNMG 11-04-04-PF-4325 and ZCC DNMG 11-04-04-DF-YBC252 were used in this experiment and both of them has 0.4 mm tool nose radius. 5 different work pieces were turned at each cutting speed for each tool. Machined work pieces had cut from 50 mm length and surfaces roughness measured with SM Metrology's Lombardore tl70 Alpa perthometer (See in fig 2.).

Figure 2. SM Metrology's Lombardore tl70 Alpa.

2.2 The influence of tool nose radius on surface roughness

For the second experiment cutting tools used from both Sandvik and ZCC which has 0,4 and 0,8 mm nose radius. Cutting speed was 240 m/min and cutting depth was 1 mm. Three work pieces were machined for each tools and cutted from 50 mm length. To defect the tool wear effect, each work pieces machined with unused surfaces of the tools.

2.3 The influence of tool wear on machinability

Two different brand's cutting tools with different coatings were chosen for this experiment. Sandvik's tools were Ti(CN) +Al2O3 +TiN coated with CVD method and ZCC's tools were coated AL2O3 and TiCN. Five pieces machined with the same cutting surface of tools at 240 m/min cutting speed and 1 mm cutting depth. After the processes tools analyzed with Nikon TS2-S-SM microscope up to 200X zoom (See in fig3)

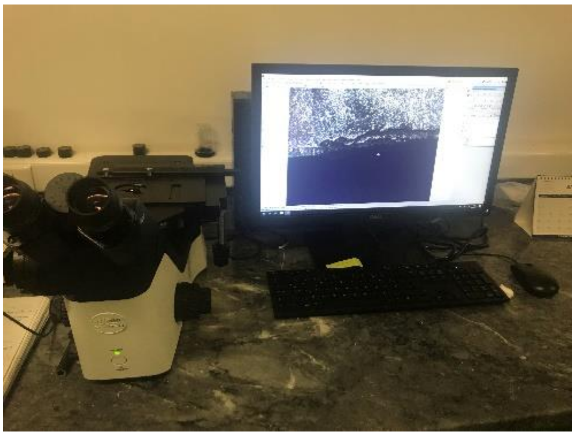

Figure 3. Checking tool wear on Nikon TS2-S-M

3. Results and discussion

The influence of cutting speed on surface roughness is shown in Table 3 and compared in Figure 4. Up to this results, it is clear that the increasing of cutting speed has positive effect on surface roughness. This result is due to the decrease in the built up edge size at higher speed where the influence of the built up edge became negligible [4]. Also higher cutting speed makes the process more stable and the vibration at high cutting speed is less than at lower speed [3].

In second experiment the topic was tool nose radius. four different tools were used in process which have both 0,4 and 0,8 mm nose radius. Cutting speed was 240 m/min and cut depth was 1 mm. According to experimental result (See in tab 2), the surface quality of the materials which turned with 0.8 mm radius tool absolutely better than the materials turned with 0.4 mm nose radius. This result showed that larger nose radius tools are better for using in finishing operations. In third experiment work pieces turned with two different tools with different coatings. As the result, the tool Ti(CN) +Al_2O_3 +TiN coated with CVD method had flank wear that occurs on side of cutting edge as a result of friction between side of cutting edge and metal being machined (see in fig 5). The other one which had coated with AL_2O_3 and TiCN crater wear that occurs as result of chips sliding along chip tool interface and built up edge on cutting tool (see in fig. 6)

.

Table 2. The influence of tool nose radius on surface roughness

Cutting tool	Radius (mm)	Ra_1	Ra_2	Ra_3	Ra_{avg}
ZCC DNMG110408-DF YBC252	0,8	1,43	1,32	1,38	1,38
SANDVIK DNMG 11-04-08-PF-4315	0,8	1,69	1,76	1,54	1,66
ZCC DNMG110404-DF YBC252	0,4	3,19	3,22	3,19	3,20
SANDVIK DNMG 11-04-04-PF-4325	0,4	3,22	3,18	3,29	3,23

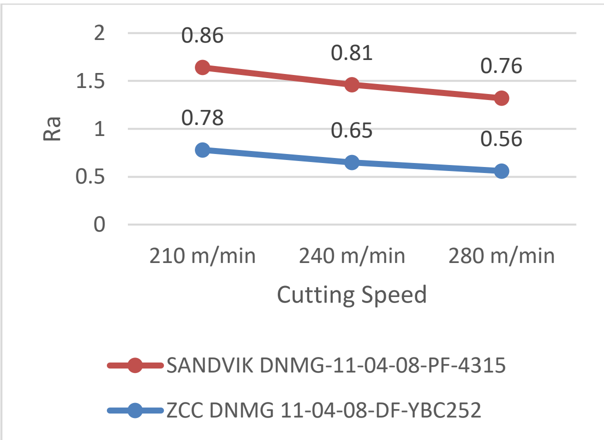

Figure 4. The influence of cutting speed on surface roughness

Table 3. The influence of cutting speed on surface roughness

Cutting Speed	ZCC DNMG 11-04-08-DF-YBC252						SANDVIK DNMG-11-04-08-PF-4315					
	Ra_1	Ra_2	Ra_3	Ra_4	Ra_5	**Ra_{avg}**	Ra_1	Ra_2	Ra_3	Ra_4	Ra_5	**Ra_{avg}**
210 m/min	0,77	0,73	0,72	0,81	0,86	**0,78**	0,86	0,88	0,84	0,86	0,88	**0,86**
240 m/min	0,67	0,65	0,71	0,62	0,59	**0,65**	0,82	0,8	0,83	0,8	0,82	**0,81**
280 m/min	0,58	0,58	0,61	0,49	0,52	**0,56**	0,76	0,78	0,78	0,75	0,71	**0,76**

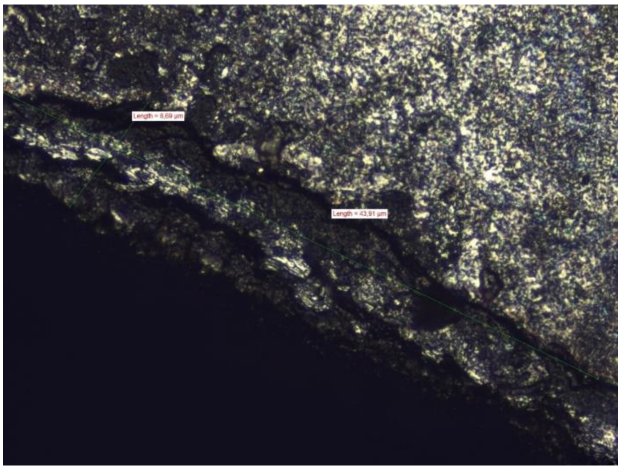

Figure 5. Flank wear on SANDVIK DNMG 11-04-04-PF-4325

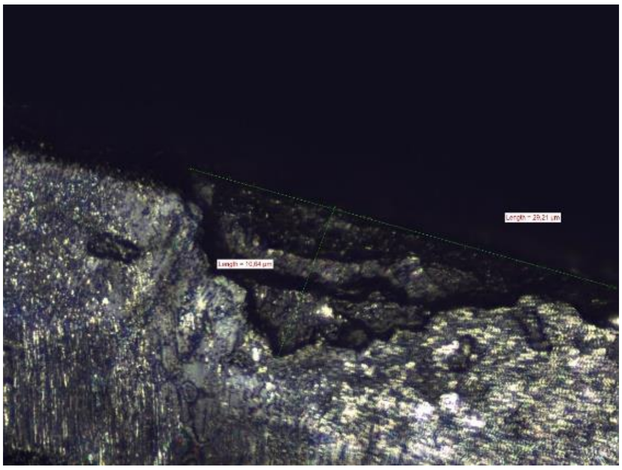

Figure 6. Crater wear on ZCC DNMG110404-DF YBC252

4. Conclusion

From the results obtained in the present work and based on current knowledge of machinability the following conclusions can be derived.

Tool nose radius was the most significant parameter that effects the surface roughness directly. The tools which has larger nose radius could use in finish turning operations. Cutting speed was also very influential parameter on surface roughness. Increasing of the cutting speed means increasing of the surface quality. At last, tool material and coating was one of the critical topic too. The influence of tool material and coating on tool wear was not negligible.

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