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INVESTIGATION TO EFFECTS OF CUTTING PARAMETER ON TOOL WEAR, TOOL LIFE AND MACHINABILITY IN MACHINING OPERATION

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Abstract— In this study, it is aimed to investigate the surface roughness of cutting tools during the machining of AISI 304 stainless steels, the life of cutting tools and the cutting forces that occur during cutting and machining. The main features of stainless steels are: high corrosion resistance, ductility and high tensile strength. Stainless steels contain elements such as chromium, nickel and molybdenum which affect the machinability in the negative direction; therefore it is very difficult to process stainless steels. This work was carried out using covered cutting tools. The work was carried out at different cutting depths and different feed rates without the use of cooling liquid. The life and wear mechanisms of cutting tools, cutting forces and surface roughness were investigated in relation to cutting parameters.

Key Words— Machinability, stainless steel, tool wear, tool life, cutting depth, feed rate, AISI 304.

1 INTRODUCTION

Today's market economy has become global. The ability of producers to sustain their assets depends on their ability to meet the demands of customers as soon as possible and in good quality. In this sense, machinability is an important point. Until this time, this area has been an important research area and has increased by its daily attractiveness. The work done plays a vital role in the development of both the materials and the equipment required to carry out these tasks.

Because of their economical efficiency and their mechanical properties, the application areas of steels are considerably wider. In this sense, determining the machinability properties of steels is very important.

In this study, the machinability of AISI 304 stainless steels was investigated. The work was carried out at constant cutting speed, at two different cutting depths and feed rates. The work was carried out on a lathe without using cooling liquid (green cutting). In the study, cutting forces, surface roughness, tool wear and tool life were investigated. With the obtained data, if necessary, it is aimed to create an alternative resource for the producers. A lot of academic work has been carried out in the field of workability of materials as much as daily. Ozcelik B. et al. used environmentally friendly cooling liquids in their work. Newly developed oils based on herbal oils have been chosen as cooling fluids. Two different cutting fluids, semi-synthetic and mineral, were used in the study. In the study using AISI 304L stainless steel, the effects of cooling liquids on the machinability of the material were compared. The results obtained were compared with the data obtained under dry cutting conditions. The surface roughness, cutting and progressive forces and tool wear were taken as comparison parameters. The work was carried out on a lathe. The study concluded that canola-based cooling fluid exhibited 8% better performance than the other cooling fluid(Ozcelik, Kuram et al. 2011). Saketi S. et al. examined the wear of the tool during the turning of 316L stainless steels. In the study, Cermet carbide tools with CVD and PVD coating were used as cutting tools. The cutting tools obtained at the end of the study were examined by high resolution electron scanning microscope and X-ray spectroscopy. At the end of the study, it was determined that high abrasion occurred on the cutting tool chip surface. It has been determined that wear in both cutting tools is irregularly on the cutting surfaces of the cutting tools. In addition, crater wear from cutting tools during machining has been investigated(Saketi, Östby et al. 2016). Cetin M. H. et al. found that newly developed herbal cooling liquids are less harmful for health. In their study, 6 different herbal cooling liquids were used. Four of the cooling liquids used were obtained from sunflower and canola plants; The other two are commercial (synthetic and mineral-based) cooling fluids. Taguchi's L18 method was applied in the study(Cetin, Ozcelik et al. 2011). Korkut I. Et al. aimed to find the optimum cutting speed value for the processing of AISI 304 stainless steels in their work. Three different cutting speed data were used in the study. The work was carried out using a cementitic carbide cutting tool. The effect of cutting speed on surface roughness and tool wear has been investigated. At the end of the study, it was observed that both tool wear and surface roughness decreased with increasing cutting speed(Korkut, Kasap et al. 2004). Tekiner Z. Et al. aimed to find the cutting conditions and cutting parameters most suitable for the machining of AISI 304 stainless steels in their work. The AISI 304 stainless steel material used for this purpose is 300 mm in length and 20 mm in diameter. The work was carried out on a CNC lathe. The work was carried out at constant cutting depth but at different cutting speeds and different feed rates. The optimum cutting speed and feed rate are intended to be determined according to the data of tool wear, cutting tool tip accumulation, chip form and finished surface roughness data. At the end of the study, the most suitable cutting parameters are given; 165 m / min cutting speed, and 0.25 mm / g, respectively(Tekıner and Yeşılyurt 2004). Elbah M.et al. examined the effect of cutting tools on surface roughness in the processing of cured AISI 4140 stainless steels in their work. For this purpose, cutting tools with two different geometry features of the same material were used. The study was carried out in accordance with Taguchi's L27 design and the data obtained were checked using the ANOVA analysis method and RSM surface roughness determination method. At the end of the study, it was determined that the feed rate and cutting depth data are effective in reducing significant surface roughness(Elbah, Yallese et al. 2013). Debnath S. et al. have investigated the effects of different grades of cooling fluid and cutting parameters on surface roughness and tool wear. The study was carried out with a TiCN + Al2O3 + TiN plated tool on a CNC lathe using mild steel. The parameter that affects the roughness of the surface roughly is the rate of progression; but the most effective parameters for tool wear are cutting speed and cutting depth. It has been stated that optimum cutting parameters can be achieved in working with high cutting speed, medium cutting depth and low feed rate (Debnath, Reddy et al. 2016). Xavior M. A. et al. have studied the effect of cooling fluid usage on surface roughness and tool wear in the machining of AISI 304 stainless steels. In the study, coconut oil and 2 different cooling liquids were compared. It has been stated that the use of cooling fluid in the work reduces surface roughness and tool wear. Coconut oil has been reported to provide better surface roughness and less tool wear than the other two cooling fluids used(Xavior and Adithan 2009). Wagh S.S. et al. have examined the machinability of AISI 304 stainless steels in their work. A PVD plated carbide tool was used in the study. During operation, shear force and surface roughness and cutting temperature are measured. It has been reported that cutting force and surface roughness increase with the increase in working rate(Wagh, Kulkarni et al. 2013). Bh V. et al. investigated the machinability of AISI D3 hardened steel materials in their work. The work was carried out using a ceramic cutting tool without the use of cooling liquid. The effects of cutting parameters such as cutting speed, feed rate and cutting depth on tool wear and surface roughness were investigated. Three different cutting speeds, 3 cutting depths and 3 different feed rates are used in the study. In the study, it was stated that the most important parameter on tool wear is cutting depth(Varaprasad.Bh, Rao.Ch et al. 2014). Correa J. G. et al. Examined the mechanism of wear in CVD coated carbide tools in the turning of S41000 and S 41426 stainless steels. The amount of cutting edge wear was examined by electron scanning microscopy (SEM) after each run. At the end of the study; It has been determined that tool life is shorter when machining of super-martensitic stainless steels at high speed and high cutting depths than martensitic stainless steels. In martensitic stainless steels, it has been determined that the tool wear mechanism is in the abrasion and attrition mechanism in abrasion and diffusional super-martensitic stainless steels (Corrêa, Schroeter et al. 2017). Nayak S. K. studied the effects of cutting parameters such as cutting speed, feed rate and cutting depth on cutting process of AISI 304 stainless steels during machining. Uncoated cementitic carbide tool was used in the study. Each of the cutting parameters was worked on 3 different values and the L27 orthogonal array design was applied. The material loss rate, shear force and surface roughness data are measured in the work. In addition, the study was replicated using the Gray method and 88.78% compliance was found between the two studies(Nayak, Patro et al. 2014). Parro J. et al. [2006] performed experiments using two X5CrMnN1818 materials with different amounts of nitrogen in their contents. Experiments were carried out using two different materials with 0.91% and 0.57% nitrogen content. Tool life and surface roughness are measured in experiments carried out at constant cutting depth, feed rate and cutting speed. Tool life in experiments using stainless steel containing 0.91% nitrogen in 30 min. Tool life in experiments using stainless steel with 0.57% nitrogen content 10 min. . It has been determined that as the cutting speed increases, the tool life in both materials decreases (Paro J. 2008). Tekaslan Ö. et al. examined the effect of cutting parameters on surface roughness in the machining of AISI 304 stainless steels. The relationship between feed rate and surface roughness was determined. It is stated that as the feed rate increases, the surface roughness increases. Similarly, as the cutting depth increases, the surface roughness increases. However, increasing the cutting speed by a certain amount reduces the surface roughness. It is also stated that the surface roughness increases as the cutting tool wear occurs (Tekaslan Ö. 2008). Ciftci has studied the machinability of AISI 304 quality austenitic stainless steel materials. The study was carried out at four different cutting speeds, constant feed rate and chip depth without the use of cooling fluid. Coated cementitious carbide tool was used in the study. Cutting force and surface roughness were measured during operation. The type and mechanism of wear on the cutting tool was investigated using scanning electron microscopy (SEM). It has been found that the cutting speed has a significant effect on the surface roughness. With increasing cutting speed, the surface roughness decreased and reached a minimum value(Ciftci 2006).

2. DETAILS EXPERIMENTAL

In the processing experiments, AISI 304 stainless steel samples were used with a diameter of 110 mm and a length of 350 mm. The chemical content of AISI 304 stainless steels is given in Table 1. In order to facilitate the connection of the lathe to the test specimens, the pre-drilling operation was first applied and then the spot drill was opened from one side.

Table 1. AISI 304 Chemical Content Table

AISI	C %	Si %	Mn %	Cr %	Mo %	Cu %	Ni %	Co %	P %	S %	N %
304	0.01	0.5	1,7	18,4	0,4	0,4	8,1	0,1	0,02	0,02	0,08

Tool holders and cutting tools

A tool holder with code number A25T TWLNR / L 08 was selected in accordance with the CNC lathe used in the machining tests. The tool holder used was chosen as the appropriate geometry cutting tool. In machining tests, TaeguTec T-Tinox carbide series TT9125 cutting tool with CVD coating was used. Cutting tool ISO notation WNMG 080408 MP.

Test Parameters

In this study, the working parameters of AISI 304 stainless steels were evaluated in accordance with the literature. This work, which examines the machinability of austenitic stainless steels, has been carried out at constant feed rate, depth of cut and different cutting speeds. The experimental parameters in which the studies are performed are given in Table 2.
Table 2. Experimental processing parameters

Cutting speed	Feed	Depth of cut
V (m/min)	f (mm/rev)	a (mm)
100 225	0,35 0,35	1 1

Figure 2. Dynamometer device

Table 3. Technical specifications of the dynamometer

Force interval(kN)	-5...10
Response(N)	< 0,01
Precision (pC/N)	-7,5
Linearity	% FSO
Hysteresis	% 0,5 FSO
Natural frequency (kHz)	3,5
Operating temperature(°C)	0…70
Capacitance (pF)	220
Insulationresistance(Ω) (20 °C)	> 1013
Earthinginsulation(Ω)	108
Protectionclass	IP 67

Figure 3. Surface roughness device

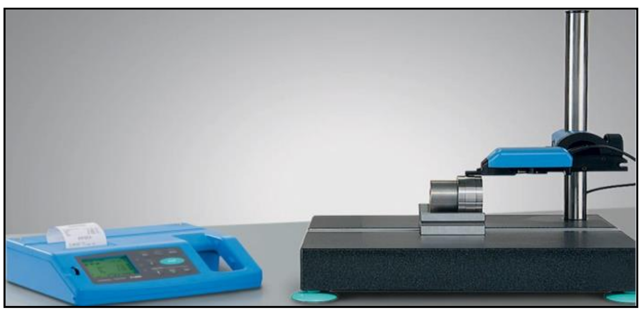

Table 4. Technical specifications of surface roughness device

Model	T 1000
Scanspeed (mm/s)	0.05-3.0
Measurementranges (µm)	0.01-80
Profile resolution (µm)	0.04-320
Filter	Gauss
Samplinglength	1.25-4.0-12.5
Measuringlength (mm)	0.08-0.25-0.8-2.5-8.0
Measuredparameters	Ra, Rz, Rmax

RESULTS AND DISCUSSION

Assessment of tool life and wear

Figure 4 shows the effect of the change in depth of cut and cutting depth on the tool life in experiments using teTT9215 coated cutting tool. Experiments were carried out by using the TT9215 cutting tool to determine the cutting depth of 1 mm. The test was terminated when the cutting tool free surface wear value reached 0.3 mm, in accordance with the standards [9].The cutting rake face wear value reached 0.45 mm at the end of 45 tests. The experiment tests were carried out for 300.54 min. When the experiments were carried out, the cutting speed was determined as cutting speed 100 m/min, feed rate 0.35 mm/rev, cutting depth 1 mm.

Cutting depth of 2 mm using TT9215 cutting tool was determined as the upper limit of the free surface wear value in the machining tests and 0.3 mm wear value was obtained as the machining test result. The total elapsed time for 12 machining runs is 37.39 min. Cutting speed cutting speed 100 m/min, feed rate 0.35 mm/rev, cutting depth 2 mm were determined in the machining experiments performed.
With cutting depth from 1 mm to 2 mm, the tool life is reduced by 30%. This decrease in the cutting tool can be attributed to the increased area of the cutting area. As the cutting area increases, the forces generated during the removal of the material from the material are increasing. Increased forces cause the tool to wear more easily and reduce tool life.
Increased cutting depth increases tool wear and reduces tool life. When the cutting depth is high, the tool life reaches its minimum value.
Figure 4 also shows the relationship between feed rate and tool life. The cutting rake face wear value reached 0.45 mm at the end of 45 tests. The experiment tests were carried out for 300.54 min. When the experiments were carried out, the cutting speed was determined as cutting speed 100 m/min, feed rate 0.1 mm/rev, cutting depth 1 mm.
Feed rate of 0.35 mm/rev using TT9215 cutting tool was determined as the upper limit of the free surface wear value in the machining tests and 0.3 mm wear value was obtained as the machining test result. The total elapsed time for 12 machining runs is 37.39 min. Cutting speed cutting speed 100 m/min, feed rate 0.35 mm/rev, cutting depth 1 mm were determined in the machining experiments performed.
With feed rate from 0.1 mm/rev to 0.35 mm/rev, the tool life is reduced by 30%. This decrease in the cutting tool can be attributed to the increase in the feed rate is thought to be the increased heat in the cutting zone. It is thought that with the increased heat, the tool is easier to deform and the tool life is decreasing.
Wear of the cutting tool and formation of agglomerate mouth have adversely affected the surface roughness.
In the tests performed, the cutting force is increased in proportion to the amount of tool wear during the machining operations.

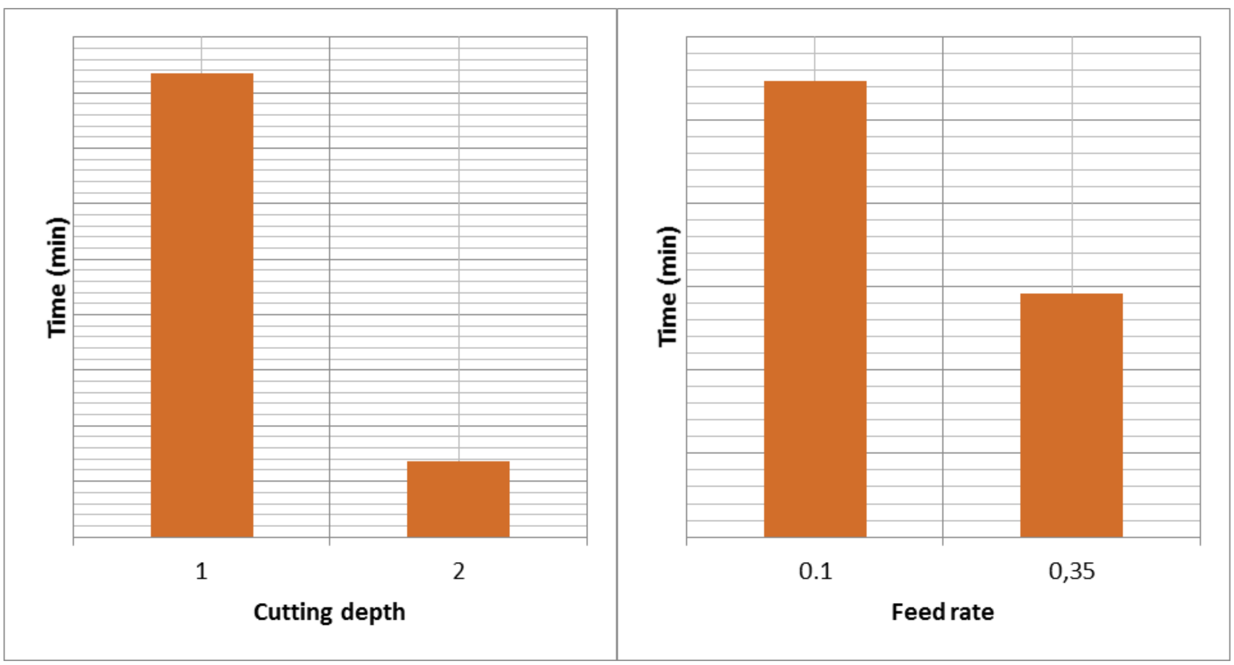

Figure 4. Cutting depth - tool life, feed rate – tool life.

<u>Surface roughness evaluation</u>
As the depth of cut increased, the surface roughness increased by 64%. Figure 5 shows the effect of the change in depth of cut and feed rate on the surface roughness in experiments using teTT9215 coated cutting tool. As a consequence of this decrease in surface roughness of AISI 304 stainless steel samples due to increased cutting depth, is considered to be an increase in shear forces due to increased cutting depth.
The surface roughness increases by 82% with increasing the feed rate. The increase in the surface roughness is given in figure 5. The reason for the increase in surface roughness data, obtained from the work surface of the workpiece with the increased feed rate, is the increase in shear forces with increasing feed rate.

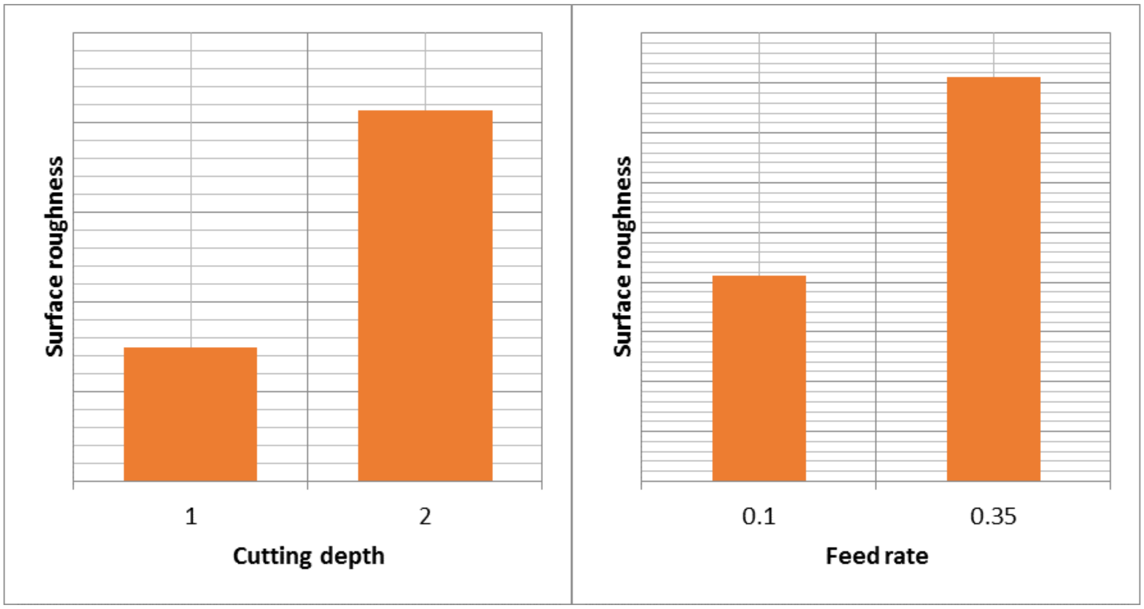

Figure 5. Cutting depth – surface rughness, feed rate – surface rughness.

Shear force evaluation

Fx, Fy, Fz of the cutting force components increased by 6%, 37%, 40%, respectively, with increasing the feed rate. This change in the shear force components with the change in the feed rate is given in Figure 6. With the increase in the rate of progress, the reason for this change, is the increase of the cutting area.

Fx, Fy, and Fz of the cutting force components increased by 59%, 25%, 49%, respectively, as the cutting depth increased. This change in shear force components with shear depth change is given in Figure 6. This change due to the cutting force is caused by the increase of the connection area (chip section) between the cutting tool and the workpiece during the cutting operation.

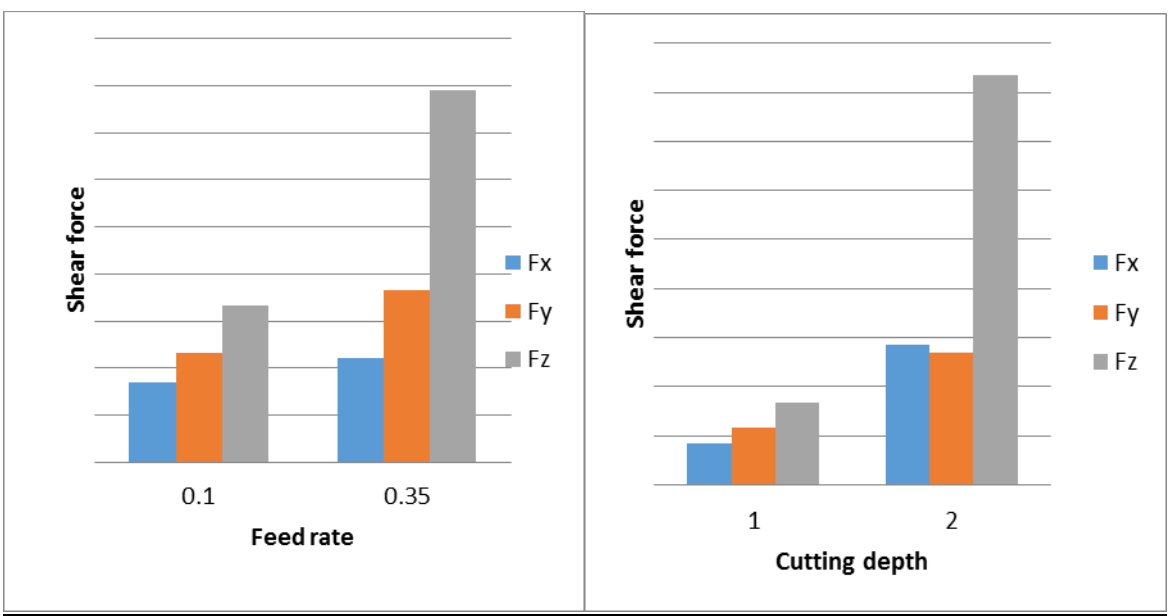

Figure 6. Cutting depth – shear force, feed rate – shear force.

Feed rate and cutting tool wear mechanism

The tool wear images obtained at a cutting speed of 100 m/min, a feed rate of 0.1 mm/rev and a cutting depth of 2 mm is shown in

Figure 7 and a cutting speed of 100 m/min, a feed rate of 0.35 mm/rev and a cutting depth of 2 mm is shown in Figure 8. Crater wear on the chip surface is more effective than other types of wear, with the feed rate increasing. In addition, the cutting tool wear is accelerated with the increase in the feed rate. When the feed rate is 0.1 mm/rev, the wear value used in the standard reaches 46.17 min and reaches 25.87 min in wear value when the feed rate is 0.35 mm/rev.

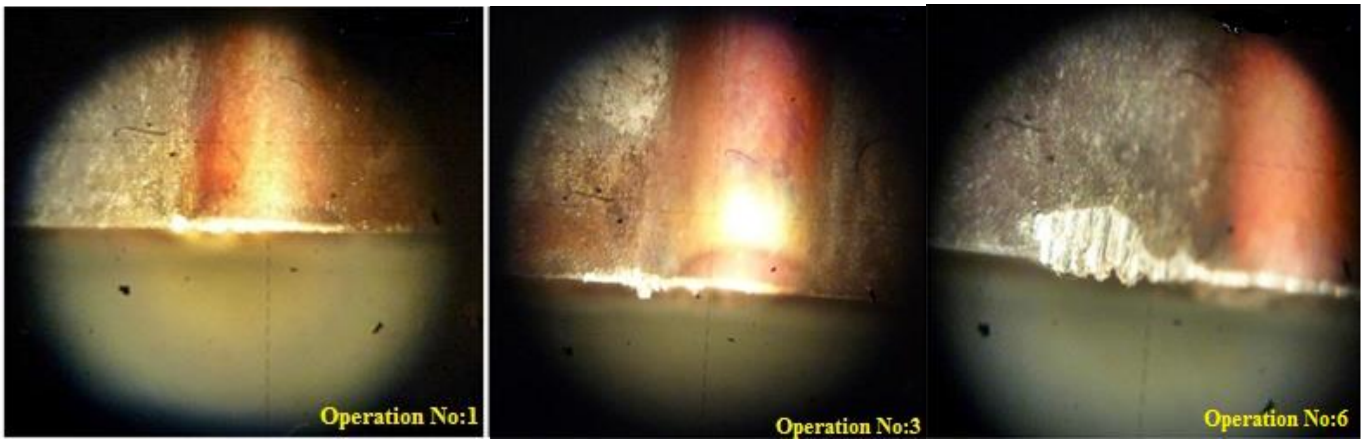

Figure7. Cutting tool wear mechanisms

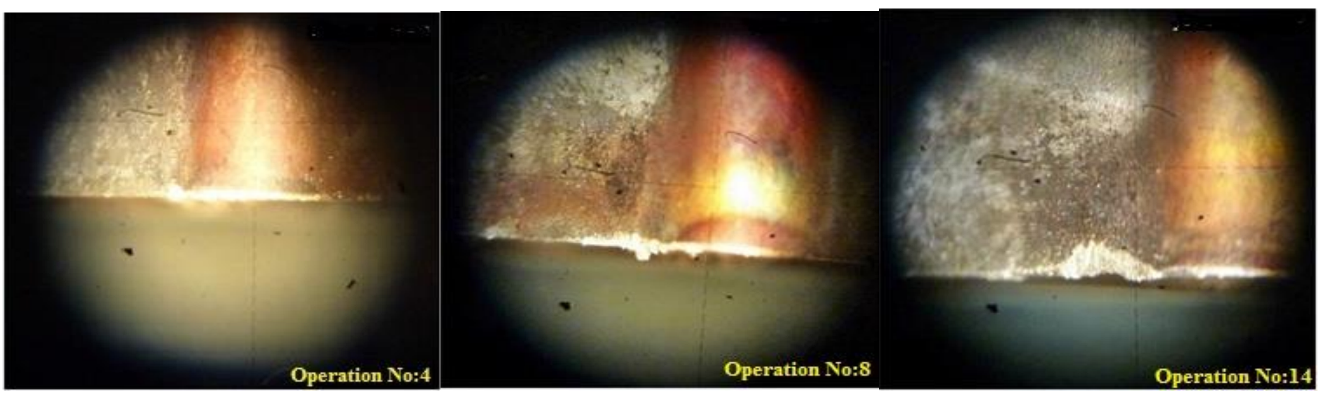

Figure8. Cutting tool wear mechanisms

Cutting depth and cutting tool wear mechanism

The tool wear images obtained with a cutting speed of 100 m/min, a feed rate of 0.35 mm/rev and a cutting depth of 1 mm is shown in Figure 9 and a cutting speed of 100 m/min, a feed rate of 0.35 mm/rev and a cutting depth of 2 mm is shown in Figure 10. Crater wear, which occurs on the surface of the tool chip with the increase in cutting depth, has come earlier in value to the value of the standard tool wear. When working with a cutting depth of 2 mm, the wear value used in the standard is 28.87 min, the cutting depth is 1mm and the wear value used in the standard is 41.63 min.

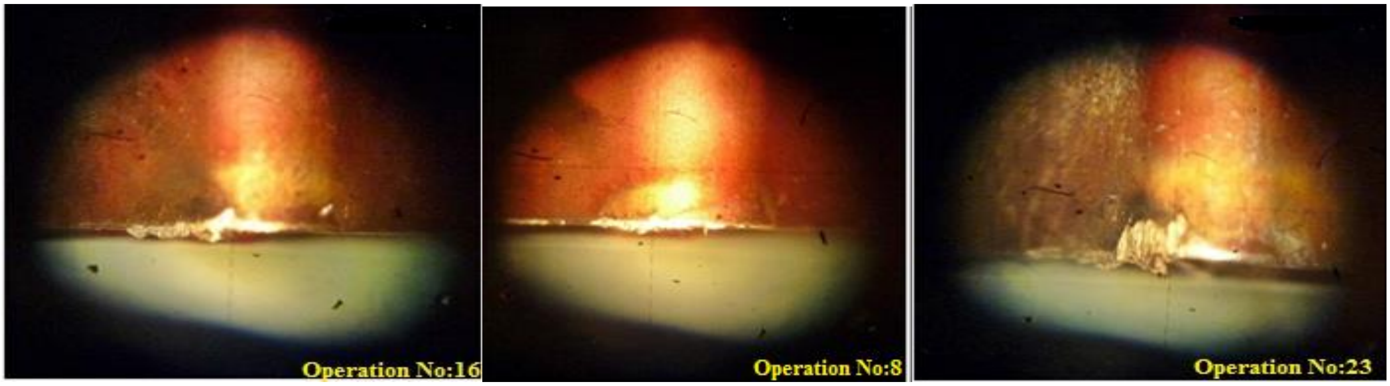

Figure 9. Cutting tool wear mechanisms

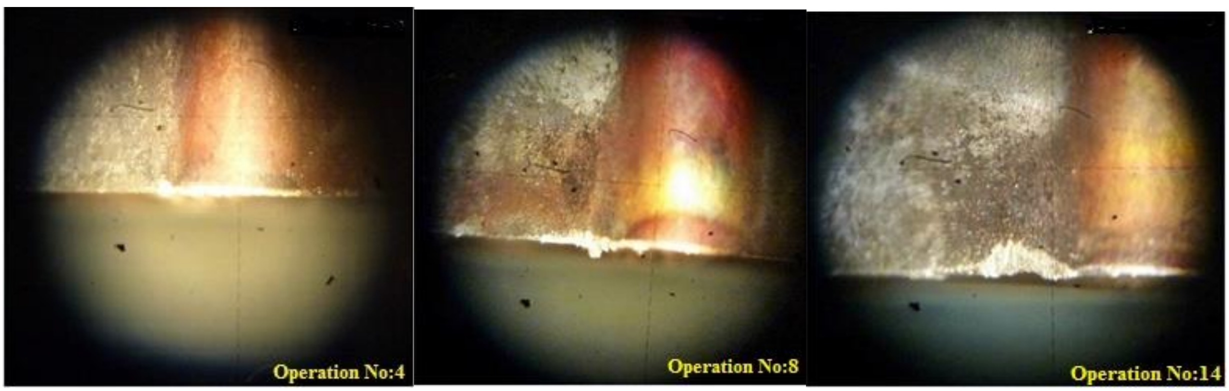

Figure 10. Cutting tool wear mechanisms

CONCLUSIONS

In this study, the machinability of AISI 304 austenitic stainless steels at constant cutting depth and feed rate on CNC lathe was investigated in terms of shear strength, surface roughness and cutting tool wear parameters.
Feed rate were determined as 2 different values (f=0.1, 0.35 mm/rev), cutting depth were determined as 2 different values (a=0.10, 0.35 mm), constant cutting speeds (V=100 mm/min) in the machining experiments performed. TT9215 used as cutting tool. The wear value was measured after each machining test performed and the experiment was terminated when this value reached 0.30 mm.
The following conclusions are reached in the obtained data:
• The increase in the feed rate has increased all three components of the cutting force. Similarly, the increase in depth of cut increases all three components of cutting force.
• The increase in feed rate and depth of cut has a similar effect to surface roughness. Both parameters increase the surface roughness value of the workpiece.
• Both the progression rate and the depth of cut increase, negatively impacting tool life. With both parameter increases, tool life is reduced.
• With increasing feed rate and depth of cut, the wear type of the cutting tool has not changed and the crater wear has occurred on the tool chip surface.

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