Some Studies on machining of 304 austenitic stainless steel

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Abstract- **Austenitic stainless steel (304) cannot be hardened through heat treatment. Such steel can be hardened by cold working. Cold working to this steel can enhance a wide range of mechanical properties. This material shows lower thermal conductivity. This steel is used for production of chemical and food processing equipment as well as for machinery parts which are applied in corrosive environment. Machinability of this material is affected because of its unique weldability characteristics. Present steel was machined on a lathe using coated carbide tool at different machining parameters. Chip reduction coefficient and von Mises stress were determined at different machining conditions. Generated von Mises stress was found to be higher at lower speed because of built up edge (BUE) formation. SEM examination of the chip showed the effect of BUE at this cutting condition.**

Key words Austenitic stainless steel, cold working, chip reduction coefficient, von Mises stress

I. INTRODUCTION

Machining is deformation-based process. Machining chip is basically a deformed part of the work material. Therefore, entire machinability study can be performed by emphasizing on deformation behaviour of a material . Chip reduction coefficient (Ϛ) can be considered as a measure of plastic deformation of a material. Material properties namely strain hardening exponent(n) and strength coefficient(K) can also be considered as factors that effectively influence the process of chip formation. Present machinability study is performed by employing Ϛ , n and K for assessment of machining responses. Literature on the machinability assessment following the present approach is scarce.

R.A. Mahdavinejad and S. Saeedy [1] indicated that the process parameters of cutting speed and feed rate have significant effects on the quality of turning of stainless steel 304. Tool flank wear is closely related to the cutting speed so that it decreases significantly by increasing the cutting speed up to 175 m/min. The main reason for flank wear is the lack of efficient heat removal due to the low conductivity of SS 304 alloy, the shape and size of the chips formed. They observed that the surface roughness is mostly affected by the feed rate. They also found that the surface finish can be improved by decreasing the feed rate and increasing the cutting speed. At higher speeds and lower feed rates , built up edge decreases causing decreased cutting forces and machine vibrations. The application of cutting fluid results in longer tool life compared to dry cutting. They observed that the optimum condition of cutting speed (175 m/min) and feed rate (0.2 mm/rev) exhibited superior turning properties when cutting fluid was used.

M.A Xavier [2] performed machining of 304 austenitic stainless steel on CNC lathe using alumina inserts. He studied the effect of feed and speed on surface roughness and temperature generation . He also studied the effect of machining time on flank wear. He found that maximum tool life time (36.3Min) can be attainable at a cutting speed of 100 m/min.

M. Ay [3] conducted machining work on CNC lathe taking 304L stainless steel as work material type. He used Kennametal PVD coated tool insert for machining of this material. He considered speed, feed and corner radius as input machining parameters and surface roughness, cutting force and surface hardness as response parameters. Subsequently, he optimized the cutting process by using Grey based Taguchi method. He found that feed value of 0.1mm/rev, depth of cut value of 0.4 mm and corner radius value of 0.8mm are the selected cutting conditions for optimal response on surface roughness and cutting force.

II. EXPERIMENTAL PROCEDURE

Work piece specification for the present machinability study:

Work piece type: 304 austenitic stainless steel

Length : 28 (cm)

Diameter: 6 (cm)

Tungaloy made carbide insert (SNMG 120404 TMT 9125) with ASBNL and 20*20 M12 tool holder was used for the turning operation

Engine lathe was used to carry out the dry turning operation on 304 austenitic stainless steel. Available speed range was between 630 rpm to 198 rpm. Available feed range was between 0.373mm/rev to 0.41 mm/rev. Table 1 below shows the input parameter domain following which the experiments were carried out.

TABLE I: VALUES OF VARIOUS MACHINING PARAMETERS

Sl. No.	1	2	3	4	5	6	7	8	9
R.P.M.	250	630	250	400	400	630	250	400	630
Feed (mm/rev)	0.1	0.2	0.2	0.29	0.1	0.29	0.29	0.2	0.1
D.O.C. (mm)	0.5	0.5	1	0.5	1	1	2	2	2

III. THEORY

*1.*Chip Thickness t_2, $t_2 = \frac{W}{\rho w l}$ (1)

Where,
t_2= Chip thickness
W=Weight of the chip in grams
ρ=Density of the work material in g/cm^3 (assumed to be unchanged during chip formation)
w=Width of the chip in mm

l=Length of the chip in mm
Weight of the chip is evaluated by using the weighing balance.
Width of the chip w, $w = \frac{d}{\cos(90-\phi)}$ (2)

Where,
d=Depth of cut in mm
ϕ=Principal cutting edge angle in degree

2 Uncut chip thickness t_1, $t_1 = f * \sin\phi$ (3)

Where,
t_1=Uncut chip thickness in mm
f=Feed in mm/rev

3Chip reduction coefficient ζ, $\zeta = \frac{t_2}{t_1}$ (4)

4 Shear angle β_0, $\tan\beta_0 = \frac{\cos\gamma_0}{\zeta - \sin\gamma_0}$ (5)

Where,
γ_0= Rake angle in degree

5 von Mises Stress σ_v, $\sigma_v = 1.74K(\ln\zeta)^n$ (6)

IV. RESULTS AND DISCUSSION

"n" and" K "were calculated by using the plot of true stress vs true strain on the log- log graph paper. The values of these true strain and true stress were calculated by using the results of tensile test. Specimen was prepared according to the ASTM E-13 standard.

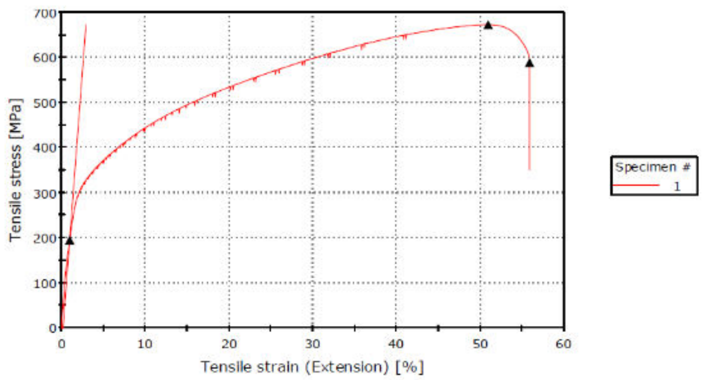


Fig. 1. Stress vs strain graph for the sample material.

From the results of tensile test (Fig. 1), true stress and true strain were evaluated at different points between the ultimate stress point and yield point. These results were then plotted on log-log graph paper(Fig. 2). From this log-log graph paper plot, values of n and K were evaluated.

n: slope of the straight line

K: Point where the straight line intersects the true stress axis at the numerical value of 1 on the true strain axis.

True stress and True strain are calculated by equations 7 and 8 respectively.

True stress, $\sigma_t = \sigma\ (1+\epsilon)$ (7)

True strain, $\epsilon_t = \ln\ (1+\epsilon)$ (8)

Where, σ = Stress at different point on stress - strain curve

ϵ = Strain at different point on stress - strain curve

Values of" n" and "K" came out to be 0.18 and 1400 and power law equation (9) was established from the true stress vs true strain graph as

$$\sigma = 1400\varepsilon^{0.18}$$

(9)

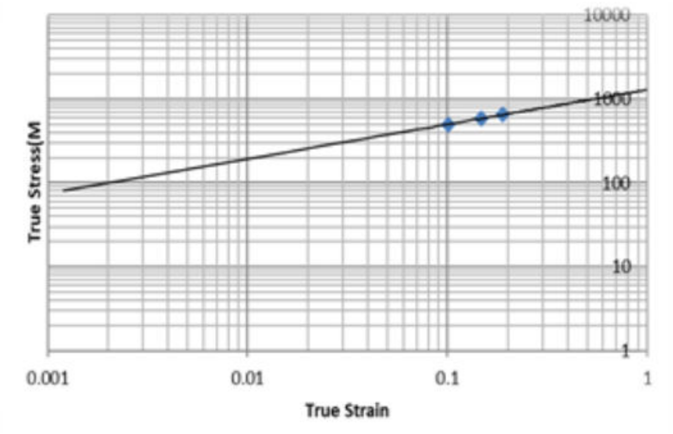


Fig. 2 True stress vs true strain on log-log graph paper

TABLE II: CALCULATED VALUES OF MACHINING RESPONSE PARAMETERS

Sl. No.	C.R. C.	Shear angle (Degree)	Von-Mises Stress (MPa)
1	2.14	23.89	2319.03
2	1.414	33.21	2012.97
3	1.161	38.14	1730.88
4	1.125	38.96	1657.57

5	1.084	39.91	1549.32
6	1.045	40.86	1388.44
7	1.031	41.20	1303.64
8	1.068	40.29	1494.12
9	1.125	38.96	1658.02

V. SEM IMAGES AND DISCUSSION

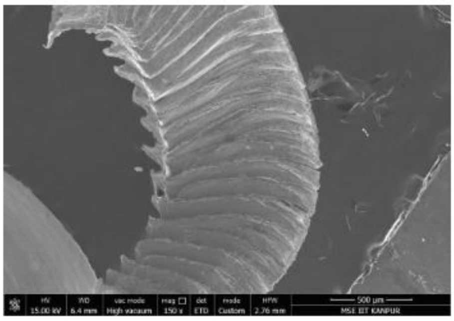


Fig. 3 SEM image of top surface at higher cutting parameters (630rpm, 0.2mm/rev, 0.5mm) X250

At higher cutting parameters (Fig. 3) chips are formed through saw tooth mechanism. Several microfolds are seen in the chip top surface. Because of poor thermal conductivity of the material, developed heat at the primary deformation zone (PDZ) cannot get dissipated and the accumulated heat promotes saw tooth chip formation through adiabatic shear displacement method.

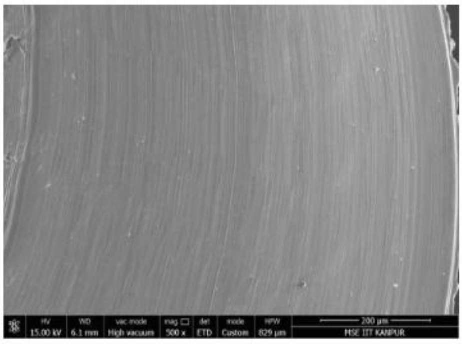


Fig. 4 SEM image of bottom surface at higher cutting parameters (630rpm,0.2mm/rev,0.5mm) X500

Chip under surface (fig. 4) shows chip formation mode through shear sliding only and Indicates better cutting action. 304 austenitic stainless steel is reluctant to transform. This particular feature of 304 austenitic stainless steel makes it enabled to be machined without any induced transformational stress within it. BUE cannot exist because of fast moving chip at higher cutting speed

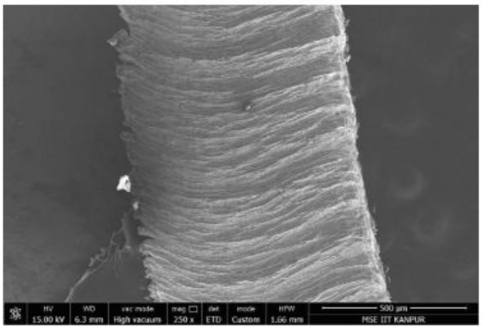
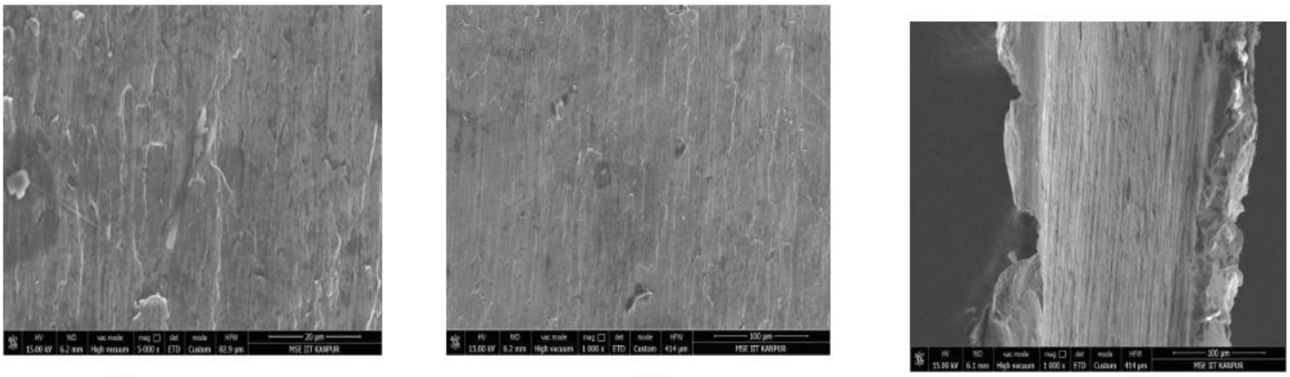


Fig 5 SEM image of top surface at lower cutting parameters (250rpm, 0.1mm/rev, 0.5mm) X250

At lower cutting parameters (fig. 5), chips are formed by cutting action in irregular mode.

At this cutting condition, proper cutting action is inhibited because of BUE formation. BUE on the tool faces forms through contact welding and impairs the cutting process. Material at the BUE undergoes work hardening and such BUE takes part in cutting action resulting improper machining. SEM image of the chip under surface indicates chip formation process through side flow, cracking and fracturing from BUE(fig. 6a , b and c).This finding is in conformity with the maximum CRC value (2.14) and von Mises stress (2319 MPa) that are attainable at lowest cutting parameter condition in the present parameters domain (Table I, Table II). Whereas, at other experimental conditions, such higher values of CRC and von Mises stress were not attainable. This clearly indicates that the cutting process was adverse at lowest cutting parameter condition mainly due to BUE formation. Surface finish of the machined item at this cutting condition will be highly affected through plastic flow, cracking etc.



(a) X5000 (b) X1000 (c) X100

Fig. 6 SEM images of bottom surface at lower cutting parameters (250rpm.0.1mm/rev, 0.5mm)

VI. CONCLUSION

1 Machinability of 304 austenitic stainless steel is impaired owing to BUE formation at lowest cutting speed. Both austenite retention and higher work hardening features of this material favour formation of BUE through contact welding.
2 High speed machining with appropriate tool can be recommended for machining of 304 austenitic stainless steel.

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