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MACHINABILITY OF EN 24 STEEL (817M40)

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Abstract– EN24 steel is medium carbon steel containing high strength steel alloy, and the grade is a nickel-chromium-molybdenum combination (34CrNiMo6). The En 24 steel has good shock and impact resistance as well as wear and abrasion resistance in the hardened condition. The steel properties offer good ductility in the annealed condition, allowing it to be bent or formed. Fusion and resistance welding is also possible with this steel. It is often utilized where other alloy steels do not have the hardenability to give the strength required. For highly stressed parts it is an excellent choice. It provides a good combination of high tensile strength, with good ductility and wear resistance characteristics. EN24 is most acceptable for the production of parts such as heavy-duty axles and shafts, gears, bolts, studs and it is capable of retaining good impact values at low temperatures. The paper presents the experimental study on machinability of the EN24 steel. During experimentation, chemical vapour deposition (CVD) coated carbide tool was used. The input parameters are speed, feed and depth of cuts and chip reduction coefficient, material removal rate (MRR) and Von Mises stress are the output responses. The input parameters were assigned with code and arranged in 3^3 factorial design, according to the Design of Experiment (DOE). Strain hardening exponent and strength coefficient are the material properties that were evaluated from the true stress-true strain curve and with the use of these properties corresponding Von Mises stress was calculated, and further analysis was done. From the study, it showed that high cutting speed is the favourable condition for machining with EN24 steel.
Keywords- Machinability; Chip thickness; Strain hardening; Von Mises stress;

1. INTRODUCTION

Steel plays a vital role in the field of manufacturing industries and in today's ruthless market where material, time, quality, processes are the primary factors that contribute towards the profit incurred to the industries.To design any mechanical component made out of steel, it is essential to know about the environment in which the component has to work. For maintaining the required conditions, the steel needs to be alloyed, and heat treated followed by some other processes.

The present work is designed at for experimental investigation of the Von Mises stresses generated during dry turning of EN24 steel. The work emphasizes the chip formation process which was the result of the input process parameters applied while machining. Chip formation and its thickness showed the extent of severe plastic deformation of the material. Von Mises stress was generated when the material was subjected to plastic deformation. It was generated at the flow zone during the process of chip formation. The Von Mises stress was estimated by considering material properties such as Strength coefficient 'K' and strain hardening exponent 'n' and the chip reduction coefficient 'ξ'. It was difficult to measure the chip thickness directly because the chips formed during the experiment were of irregular shaped , curl and twisted. To overcome this problem, length and weight of the chip was measured . The weight of the chip takes care of the inaccuracies occurred for the determination of the cut chip thickness. The SEM(Scanning Electron Microscope) examination of the chips was done, and further investigation was carried out.

2. LITERATURE REVIEW

R. Kumar et al.[1] applied the Taguchi Method which owned the responsibility to optimize the machining parameters during machining of EN 24 alloy steel. Speed, feed, depth of cut, nose radius, cutting environment (wet and dry) are the process parameters considered to optimize surface roughness, and material removal rate and experimental investigation has been done with TiN coated cutting tools. The results showed that speed 1500 (rpm), feed 0.12 (mm/rev.), depth of cut 1mm and nose radius at 1.2mm are the appropriate best input parameters setting.

M. Adinarayana et al.[2] performed the experiments for Dry turning operation with EN 24 alloy steel by the use of PVD coated tool insert and conventional lathe (PSG A141). The tests were carried out for a 500 mm length of work material. The results showed the optimality conditions as speed: 740rpm, feed: 0.09 mm/rev, and depth of cut: 0.10 mm. The contribution of different process parameters on response variables has been established by using the ANOVA technique.

Krishankant et al.[3] conducted the experiments on the lathe using single point cutting method . The tool is a single point cutting tool made of high-speed steel. It is ground after each experiment, and the same tool geometry is maintained by using the Bevel Protector Combination Set. The tool used was of MIRANDA, S-400 and they investigated on the optimization of the turning process with respect to the input machining parameters applying Taguchi methods. EN24 steel was used as the workpiece material for carrying out the experimentation to optimize the Material Removal Rate.

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3. EXPERIMENTAL ANALYSIS

In the present work, EN24 steel was selected as work material type, and the assessment on machinability was done on the basis of Von Mises stress generated and the mechanism of chip formation during machining. The dimension of the work material is of 110 mm diameter and 400 mm length. CVD (Chemical Vapour Deposition) coated (3 to 16 µm thick) carbide grades consisting of cemented carbide substrate TiCN tool insert Tungaloy made is used for turning. The coating over the tool insert improves the hot hardness and oxidation resistance property of the tool, thus making the tool chemically stable which increases the tool life and efficiency of machining.

Table 1, Chemical composition of EN24 steel

%Fe	%C	%Mn	%Si	%P	%Cr	%Mo	%Ni	%Al	%S
Balanced	0.398	0.582	0.206	0.029	1.04	0.246	1.36	0.0235	0.0164

The central lathe was used for turning operation on the workpiece. The lathe is gear driven provided with the spindle speed range of 45 rpm to 1000 rpm and feed range of 0.06mm/rev to 1.72 mm/rev.

Tool Used

Holder specification: ASBNR 25*25 M12-A

Carbide inserts Specification: SNMG 120404 TM T9125

Selection of process parameters

The input process parameters were selected based on the values available on the lathe.

Table 2, Input Process Parameters used for machining.

Factors	Level 1	Level 2	Level 3
Coding	-1	0	1
Speed (m/min)	36	60	100
Feed (mm/rev)	0.49	0.63	0.86
DOC (mm)	0.67	1	1.5

Table 2 describes the codes for each input process parameters. Based on 3^3 factorial design, 27 different combinations of the machining parameters were used for the experimentation.

Table 3, 3^3 factorial design showing the input parameters for machining

S.No.	Velocity Code	Feed Code	DOC Code	V (m/min.)	f (mm/rev)	d (mm)
1	-1	-1	-1	36	0.49	0.67
2	-1	-1	0	36	0.49	1
3	-1	-1	1	36	0.49	1.5
4	-1	0	-1	36	0.63	0.67
5	-1	0	0	36	0.63	1
6	-1	0	1	36	0.63	1.5
7	-1	1	-1	36	0.86	0.67
8	-1	1	0	36	0.86	1
9	-1	1	1	36	0.86	1.5
10	0	-1	-1	60	0.49	0.67
11	0	-1	0	60	0.49	1
12	0	-1	1	60	0.49	1.5
13	0	0	-1	60	0.63	0.67
14	0	0	0	60	0.63	1
15	0	0	1	60	0.63	1.5
16	0	1	-1	60	0.86	0.67
17	0	1	0	60	0.86	1
18	0	1	1	60	0.86	1.5

19	1	-1	-1	100	0.49	0.67
20	1	-1	0	100	0.49	1
21	1	-1	1	100	0.49	1.5
22	1	0	-1	100	0.63	0.67
23	1	0	0	100	0.63	1
24	1	0	1	100	0.63	1.5
25	1	1	-1	100	0.86	0.67
26	1	1	0	100	0.86	1
27	1	1	1	100	0.86	1.5

After mounting the work material on the lathe, turning operation was carried out for 30 seconds for each experiment. From the machining experiments, 27 different types of chips were collected.

Fig. 1. EN24 Steel mounted on the lathe.

4. THEORY AND RESULT

After performing 27 different experiments, from each experimental sample, one chip was selected, and it's length, and weight were measured. After the measurement, cut chip thickness, chip reduction coefficient and Von Mises stress are calculated from the theoretical relations that are shown below:

$$Cut\ chip\ thickness\ t_2 = \frac{W}{\rho w l}$$

Where,
W = Weight of a chip (gm)
ρ = Density of the steel (0.008 gm/mm3)
l = Length of a chip (mm)
w = width of a chip (mm)

$$width\ of\ a\ chip\ w = \frac{d}{\cos(90 - \Theta)}$$

Where,
d = Depth of cut (mm)
Θ = Principle approach angle (in degree)
Chip reduction coefficient $\xi = \frac{t_2}{t_1}$

Uncut Chip Thickness t1 = f * sin ***Φ***
Where,
f = Feed (mm/rev)
Φ = Principle Cutting edge angle (in degree)

$$Shear\ angle\ \hat{Y} = \frac{\cos\alpha}{\xi - \sin\alpha}$$

Where, α = Rake Angle (in degree)
Von Mises stress $\sigma v = 1.74*K*(\ln\xi)^{n}$ (MPa)

Where,
K = Strength coefficient (MPa)
n = strain hardening exponent
The above mentioned ‘K’ and ‘n’ values were calculated by selecting the points from the true stress-true strain curve and plotting them on log-log graph paper[fig. 3 and fig. 4]. From the work material, ASTM - E8 sample was made, and it was subjected to tensile test by using INSTRON 1195 UTM machine.

Fig. 2(a). ASTM-E8 EN24 steel Specimen before the tensile test.

Fig. 2(b). ASTM-E8 EN24 steel Specimen after the tensile test.

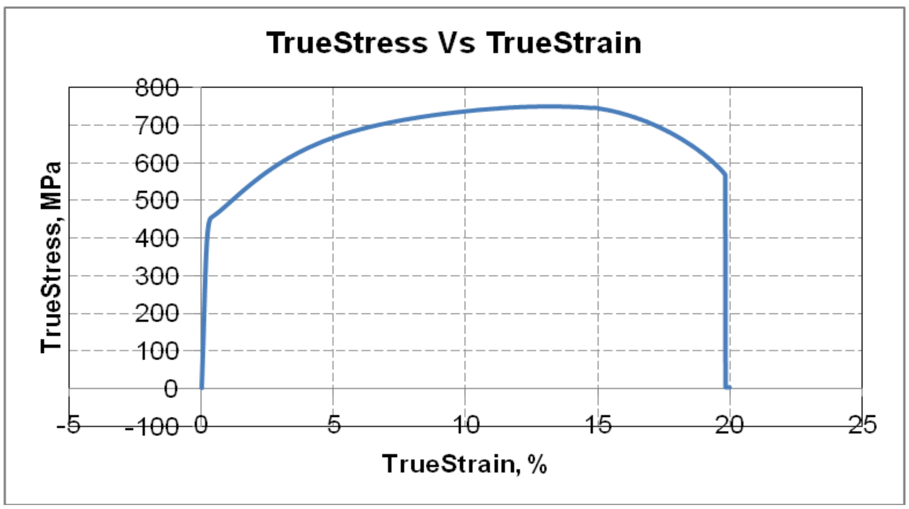


Fig. 3. True stress - True strain curve.

From the result of tensile test, True Stress-True Strain curve was obtained, and points were taken into consideration from the true stress, and true strain graph in between ultimate stress and yield stress and those points were plotted on log-log graph and the obtained line was extrapolated to obtain the values of strain hardening exponent ‘n’ and Strength coefficient ‘K’. Value of ‘K’ is the value of true stress at true strain equals to 1 on a log-log graph.[fig. 3 and fig.4]

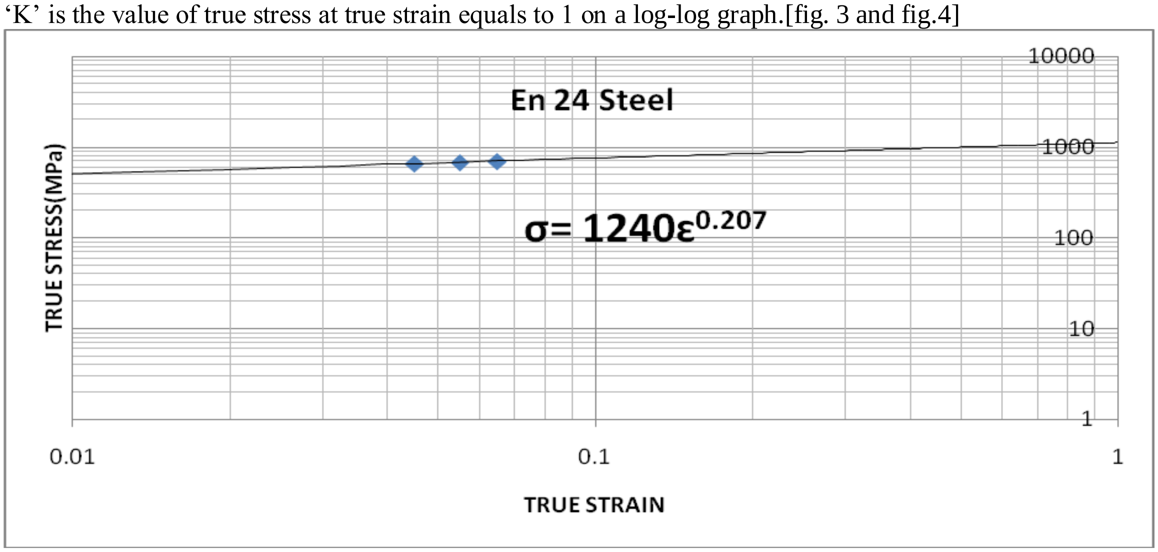


Fig. 4. True stress v/s True strain log-log graph.

After getting the value of 'K' and 'n'
Power equation $\sigma = K\varepsilon^{n}$ was obtained as:-
$\sigma = 1240\varepsilon^{0.207}$

Where,
σ = True Stress (MPa)
ε = True Strain
For total work done, elemental work done was to be evaluated first as shown below:-
Elemental work done We,

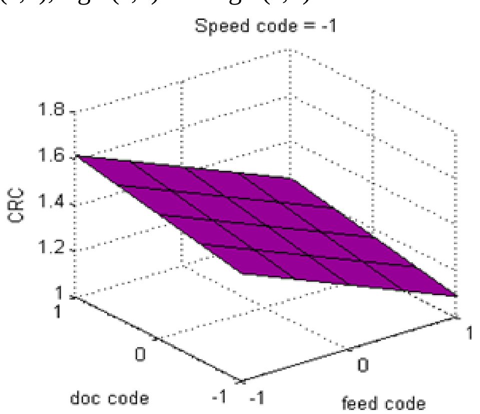
$$W_e = \frac{K(1.15 ln\xi)^{n+1}}{n+1}$$

Total Work done TW,
Tw = We*V*f*d*t (Nm)
Where,
V = Cutting speed (m/min)
f = feed (mm/rev)
d = depth of cut (mm)
t = time (minutes)
The regression equations were generated with the input parameters (speed, feed, depth of cut) for the chip reduction coefficient (bCRC) and Von Mises Stress (bVMS) as machining responses using MINITAB software. The equations are shown below:-

$$bCRC = 2.32+0.112x_1-0.22x_2+0.015x_3-0.45x_1^2+0.0362x_2^2-0.35x_3^2-0.030x_1x_2-0.056x_1x_3-0.161x_2x_3 \quad \text{(eq.a)}$$

$$bVMS = 2106.5+18x_1-87.5x_2+14.5x_3-234x_1^2+33.7x_2^2-170.9x_3^2-50.2x_1x_2-13.9x_1x_3-93.6x_2x_3 . \quad \text{(eq.b)}$$

Where,
x1 = Speed.
x2 = Feed.
x3 = Depth of cut.
The graphs were formed in 3D MATLAB 2013 software from the regression equations. Variation of CRC and Von Mises stress with respect to cutting velocity, feed and depth of cut for high speed, moderate speed and the lowest speed are shown ih .fig.5(a,b), fig.6(a,b) and fig.7(a,b).



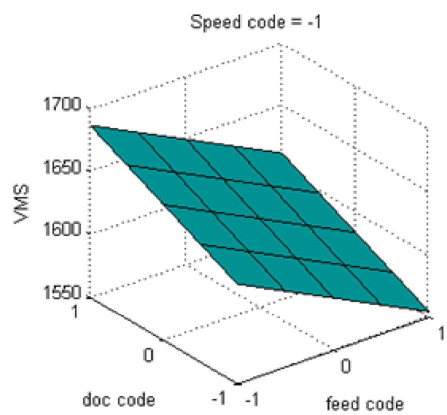


Fig. 5(a). The variation of CRC w.r.t. feed and depth of cut code for speed code -1.
(b).The variation of Von Mises Stress w.r.t. feed and depth of cut code for speed code -1.

From fig. 5 (a) and 5 (b), it is seen that at low speed, both CRC and Von Mises stress decrease with an increase in feed. Strain hardening of the work material and brittleness transition becomes effective with increased feed so as to reduce the value of CRC and Von Mises stress. However, increased depth of cut enhances the value of CRC and Von Mises stress at a lower speed. At lower cutting speed(speed code -1) increased depth of cut causes ductility transition of the work material at the flow zone, due to which the CRC and Von Mises stress increase with an increase in depth of cut. Ductility transition occurs due to thermal softening of the work material at the flow zone. Moreover, because of such happening much cohesive energy develops during the process of chip formation because of which, the Von Mises stress increases significantly at a higher depth of cut condition.

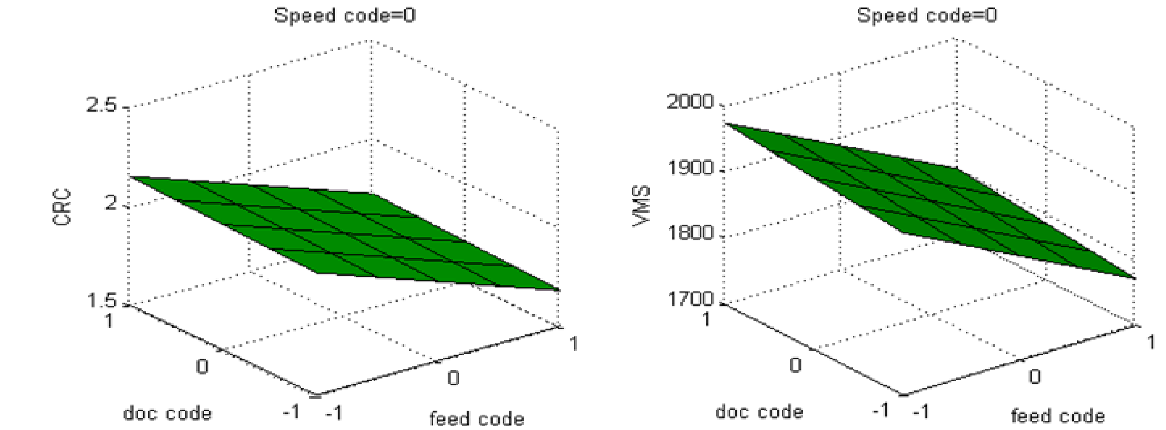


Fig. 6(a). The variation of CRC w.r.t. feed and depth of cut code for speed code 0.
(b). The variation of Von Mises Stress w.r.t. feed and depth of cut code for speed code 0.

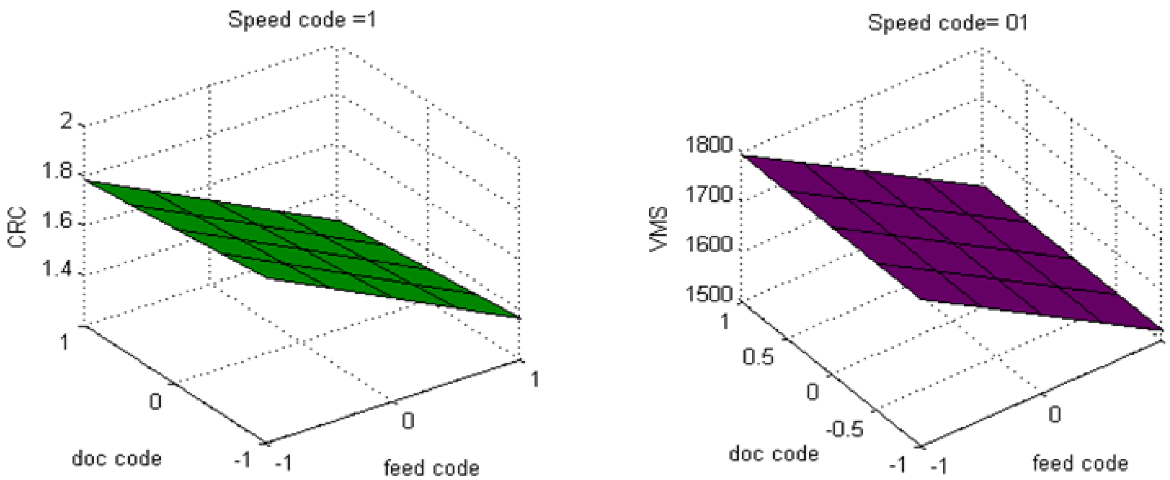


Fig. 7(a). The variation of CRC w.r.t. feed and depth of cut code for speed code 1.
(b). The variation of Von Mises Stress w.r.t. feed and depth of cut code for speed code 1.

Both CRC and Von Mises stress decrease with increase in feed at higher speed (speed code= 0 and 1). However, increased depth of cut has a negligible effect towards CRC and Von Mises stress at higher speeds(speed code= 0 and 1).[fig.6(a,b), fig.7(a,b)]. The thermal softening effect with increased depth of cut counteracts with the strain hardening effect at these cutting condition, for which there is the negligible influence of depth of cut on CRC and Von Mises stress.

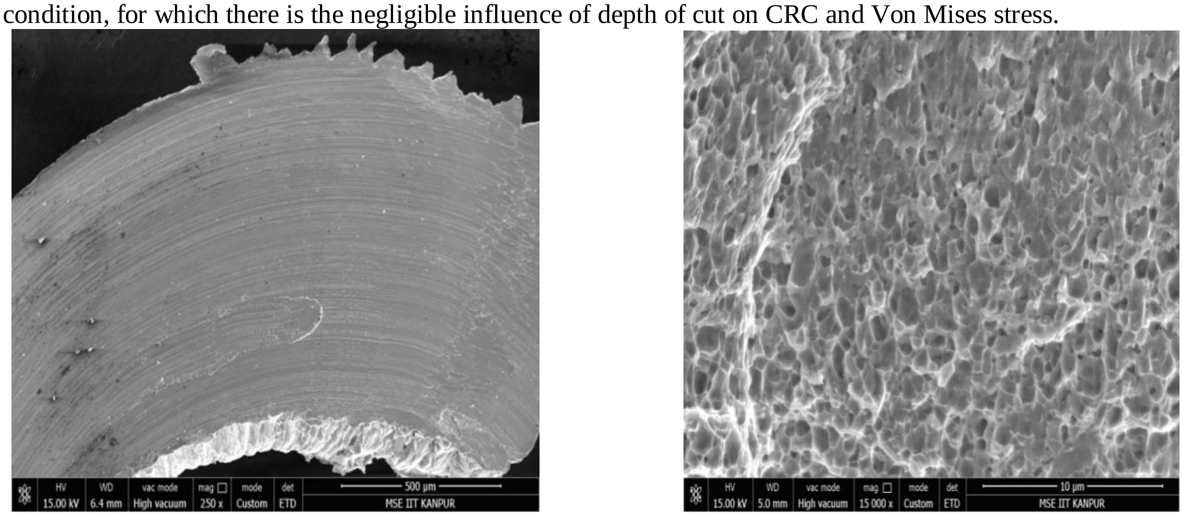
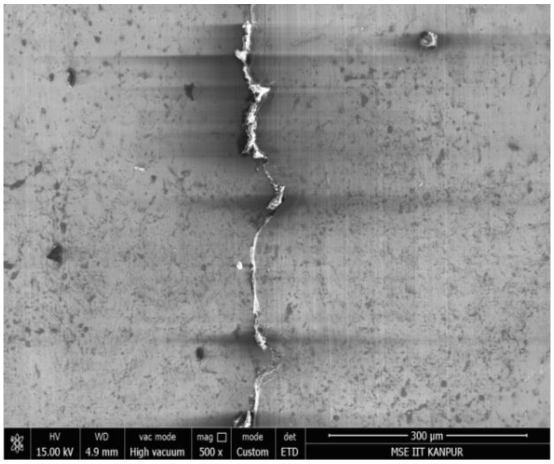


Fig. 8(a). SEM image of a chip under-surface at 250X magnification.
Fig. 8(b). SEM image of the fractured chip at a cross-section at 15000X magnification.



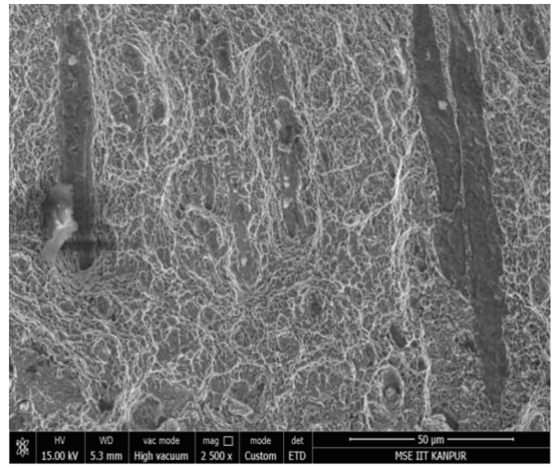


Fig. 9(a). SEM image of chip under surface at 500X magnification.
Fig. 9(b). SEM image of a fractured chip at a cross-section at 2500X magnification.

Fig. 8(a). shows the under-surface of the formed chip obtained at low speed, low feed and low depth of cut condition. It is observed that the process of chip formation has been favoured through the ductile mode during the chip formation process.
Fig. 8(b). shows the fractured surface of the chip indicating numerous dimples formed during chip separation. This clearly illustrates the dominating ductile behaviour of the work material during the process of chip formation.
However, when the chip under-surface(formed at higher speed, higher feed and higher depth of cut condition) was examined under the scanning electron microscope [fig.9(a)], it was observed that the process of chip formation occurred with numerous cracks at the chip under-surface. This clearly shows that the chip formation process is taken place through brittle behaviour of the work material during chip formation. Such brittleness transition of the work material actually takes place through strain hardening of the material. Brittleness transition of the work material is further evident in [fig.9(b)], as it indicates the chip separation occurs through brittle fracture mode.

5. CONCLUSION

EN 24 steel can be machined at higher speed, feed and depth of cut
Chip formation process at a lower speed, feed and depth of cut is dominated by ductile behaviour of the work material.
Chip formation process at high speed, feed and depth of cut is dominated by strain hardening behaviour of the work material.

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7. REFERENCES

[1] Raman Kumar, Jasper Singh Ray and Avnet Singh Virk"Analysis the effects of process parameters in EN24 alloy steel During CNC turning by using madm", International Journal of Innovative Research in Science, Engineering and Technology, vol. 2, 2013, pp. 1131-1145.
[2] M. Adinarayana, G. Prasanthi, G. Krishnaiah, "Multi-Objective Optimization during Turning of EN24 Alloy Steel", Journal of Engineering Research and Applications , vol. 3, 2013, pp. 1193-1198.
[3] Krishankant, J. Taneja, M. Bettor, R. Kumar " Application of Taguchi Method for Optimizing Turning Process by the effects of Machining Parameters",International Journal of engineering and advanced technology (IJEAT), vol. 2,2012, pp. 9-15.