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The Study of Physical Properties & Analysis of Machining Parameters of EN25 Steel In-Situ Condition & Post Heat Treatment Conditions

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***Abstract :** This paper is related to a comparative study based on various observations on properties of EN 25 steel through a range of testsin as supplied condition and after heat treatment keeping in view the basics of material science that Structure-Property- Processing- Performance- Social need is the ultimate criterion for designing any product. In this study samples for various testing are prepared & conducted a series of tests like microstructure analysis, tensile test, impact test, hardness test, etc. in as supplied condition. Heat treatment is taken up by elevating these samples to its austenizing temperature and cooling it in different ways, samples are again prepared and carried out same series of tests. From the observations of their physical properties from those experiments, a comparative chart is prepared which shows enhancement in properties and performance of those materials after heat treatment. Machining parameters play an important role here. It includes the variation of machining input parameters speed, feed, depth of cut to observe material removal rate and surface roughness using samples of various hardness. The relative study of machining performances on the basis of metallurgicalproperties are prepared by the help of statistical tools i.e. L_9 Orthogonal Array, ANOVA etc.*
***Keywords :** steel, EN25, heat treatment, mechanical properties, machining performance, L_9 Orthogonal Array.*

I. INTRODUCTION

Steel is everywhere in our daily lives from buildings and vehicles to the tin can that conserves food safely for months or years. It is the world's most important engineering material. Nonetheless producing steel is extremely energy intensive. However, once produced, steel can be used again and again. With a global recovery rate of more than 70%, steel is the most recycled material on the planet.

Steel is an iron alloy containing carbon from as low as 0.03 percent (as in ingot steel) to 2 percent by weight , and varying amounts of other elements (mainly chromium, manganese, molybdenum, nickel, and silicon) depending on its end use.

Generally in commercial production of steel, carbon is maximized at under 1% in steels because above this percentage material can cause brittleness as carbon content is the main hardening element in steels. As a result difficulty in machining will increase correspondingly. In modern industry the goal is to manufacture low cost, high quality products in short time. Automated and semi-automated machine tools are employed as they are capable of achieving high accuracy with minimum processing time. In this study a lathe operation is used to measure the machining performance on EN25 in different conditions.

II. LITERATURE REVIEW

Steels used in different practical and industrial uses are standardized and described by the different standards. **[1] [2] [3]** Classification, application and different chemical compositions of steels in compliance with their structure, property, processes and performance gives rise to the different grades of steels, which are very common in their daily practical uses.

A. Singaravel, T. Selvaraj [4]

Department of Production Engineering, National Institute of Technology, Tiruchirapalli, have experimented to seek optimum machining parameters are determined in turning operation of EN25 steel with coated carbide tools using combined technique for order preference by similarity to ideal solution (TOPSIS) and Hierachy process (AHP) method

B. Singaravel et.al. [5]

Department of Production Engineering, National Institute of Technology, Tiruchirapalli, have done an experimental analysis to estimate an optimum machining parameters using Taguchi based concept coupled with Principal Component Analysis (PCA) on turning of EN25 steel with CVD and PVD coated carbide tools. This study describes the minimization of surface roughness, cutting forces and maximization of material removal rate (MRR) and optimized by S/N ratio and analyzed by Analysis of variance (ANOVA's). Finally implemented a result based on percentage of contribution of the machining parameters on the machining performance of EN25 steel.

C. Mr. Raktim Saha [6]

Department of Mechanical Engineering, SDET- Brainware Group of Institutions, Kolkata, has done a comparative study based on various observation on properties of EN9 and EN19 steels in as supplied condition and after heat treatment. In this study firstly samples of various tests are prepared from both types of steels. After that those samples undergo a series of tests like microstructure test, tensile test, torsion test, impact test, hardness test, etc. in as supplied condition. Then heat treatment is done by elevating these samples to its austenizing temperature and cooling it in different ways. After that those samples again undergoes same series of tests. From the observations of their physical properties from those experiments a comparative chart is prepared which shows some enhancement in properties and performance of those materials after heat treatment. Further about the performances of EN9 & EN19 steels both types of treated and untreated samples are prepared for machining. The criteria for performance check is based on two machining process characteristics: material removal rate, surface roughness. In this experiment definite sets of Speed, Feed, and Depth of Cuts are selected. The observation charts are made on the concepts of Design of Experiments. After that all the material undergoes the same series of machining. The analysis and optimization on the performance is done on the basis of observations of machining parameters.

III. WORKING MATERIAL

This grade EN25 is 2.5% nickel chromium molybdenum specification usually supplied hardened and tempered suitable for ranges 90-160 kg/mm^2. EN25 steel is readily machinable and combines a good high tensile steel strength with shock resistance, ductility and wear resistance. It is widely used engineering steel with reasonably good impact properties at low temperatures, whilst this is also suitable for a variety of elevated temperature applications.

TABLE : I Chemical Composition Of En 25 Steel

Chemical Composition of EN 25 as per BS: 970 (Specified)								
	C	Si	Mn	P	S	Mo	Cr	Ni
Min	0.27	0.10	0.50	-	-	0.40	0.50	2.30
Max	0.35	0.35	0.70	0.045	0.050	0.70	0.80	2.80

Composition of EN 25 sample selected (as per BS: 970)							
C	Si	Mn	P	S	Mo	Cr	Ni
0.30%	0.22%	0.59%	0.038%	0.040%	0.51%	0.67%	2.62%

IV. METHODOLOGY

The present research has gone through two different phase of work i.e. a metallurgical part, a machining part. For the test to be performed the work material is divided into three groups. In the metallurgical phase a part of EN25 is kept in as supplied annealed condition, a part of it is normalised (air cooled), and the rest part is hardened (water quenched).

TABLE : II HARDNESS TESTING RESULTS

Condition	Hardness Value
EN25 steel in supplied condition (Annealed condition)	18 HRC
EN25 steel normalized condition (at 880ºC)	33 HRC
EN25 steel is hardened(at 860ºC) and tempered (at 250ºC) condition	41 HRC

After getting the desired hardness as a parameter, the machining performance test of EN25 is carried out by turning the test pieces in a manual lathe with a carbide insert. The design of experiment is done with Taguchi L_9 orthogonal array in which 4 factors (hardness, speed, feed, depth of cut) with 3 levels of each is selected.

TABLE : III L_9 ARRAY

L_9 array:				
No of Obs.	A	B	C	D
1)	1	1	1	1
2)	1	2	2	2
3)	1	3	3	3
4)	2	1	2	3
5)	2	2	3	1
6)	2	3	1	2
7)	3	1	3	2
8)	3	2	1	3
9)	3	3	2	1

V. SAMPLE PREPARATION

Three cylindrical pieces of 20mm length are cut from each of the three conditioned EN25 to make nine samples required for the L_9 array observations. Turning , facing and external threading is done on each piece for the purpose of the easy mounting during operation.

Fig 1: Sample preparation for machining performance test

TABLE : IV INPUT PARAMETERS IN MACHINING PERFORMANCE TEST

Sl. No.	Hardness (HRC)	Speed (rpm)	Feed(mm/rev)	Depth Of Cut (mm)
1	18	455	0.090	0.3
2	33	315	0.133	0.7
3	41	215	0.250	0.95

Observation of Performance in Machining Performance Test : MRR, Surface Roughness .

VI. EXPERIMENTAL READINGS

TABLE : V ARRAY OF MACHINING PERFORMANCE TEST

No. of Obs.	Speed (rpm)	Feed (mm/rev)	Depth Of Cut (mm)	Hardness(HRC)	MRR(cm^3/sec)	Ra(μ)
1	455	0.090	0.3	18	0.01232	2.546
2	455	0.133	0.7	33	0.04233	5.926
3	455	0.250	0.95	41	0.07909	12.012
4	315	0.090	0.7	41	0.03888	8.792
5	315	0.133	0.95	18	0.01968	2.705
6	315	0.250	0.3	33	0.02383	12.166
7	215	0.090	0.95	33	0.01800	6.459
8	215	0.133	0.3	41	0.00902	6.591
9	215	0.250	0.7	18	0.04009	10.444

VII. COMPUTING OUTPUT FACTORS ON MACHINING

Material Removal Rate: It can be calculated from the formula given below:

$$\text{MRR} = \frac{Initial\ volume - Final\ volume}{Time}$$

$$= \frac{\left\{\left(\frac{\pi}{4} \times D^2 \times L\right) - \left(\frac{\pi}{4} \times d^2 \times L\right)\right\}}{Time}$$

Where, D= Initial diameter of work piece

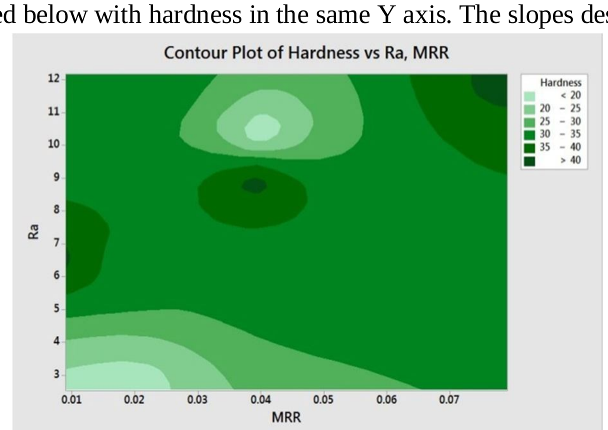
d= Final diameter after machining

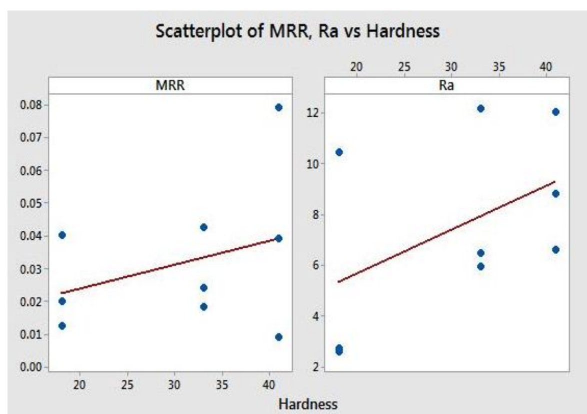
L= Sample length of workpiece

Surface Roughness: The Surface Roughness (Ra) is calculated with a Talysurf Apparatus. Makers: Mitutoyo

VIII. DATA ANALYSIS

To serve the purpose of data analysis Minitab 17 is used. A contour plot of Hardness vs. MRR, Ra is represented below. From the plot it is found that surface roughness varies more with hardness than MRR. For further surety of the above statement a graph is plotted below with hardness in the same Y axis. The slopes describes that Ra varies more with hardness than MRR.

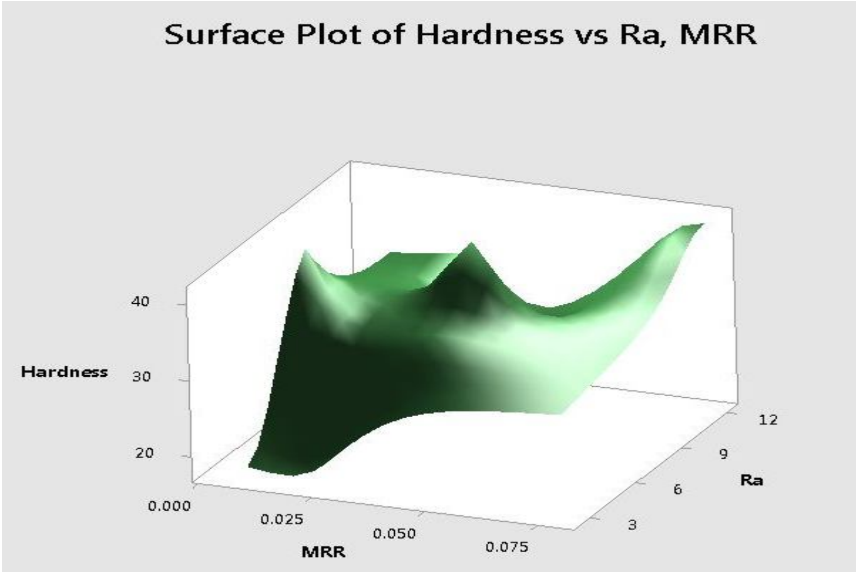




Contour Plot: From the contour plot of Hardness vs. Ra, MRR it can be concluded that Ra and MRR has an increasing nature with increasing Hardness. But from the graph it is also observed that there are two optimum points for maximum and minimum hardness at Ra value 9 and 11 respectively and MRR value 0.04.

Scatter Plot: The increasing nature of MRR and Ra with the change of Hardness paves the way for better machining conditions. In comparison between MRR and Ra the influence of Hardness on Ra values is more than that of MRR.

From Contour and scatter plots the response surface has been interpreted by a 3D surface plot which interprets the result as stated in contour and surface plot.



A. General Linear Model: MRR versus Speed, Feed, D.O.C, Hardness

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Speed	Fixed	3	215, 315, 455
Feed	Fixed	3	0.090, 0.133, 0.250
D.O.C	Fixed	3	0.30, 0.70, 0.95
Hardness	Fixed	3	18, 33, 41

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed	2	0.000812	0.000406	*	*
Feed	2	0.001181	0.000591	*	*
D.O.C	2	0.001216	0.000608	*	*
Hardness	2	0.000555	0.000277	*	*
Error	0	*	*		
Total	8	0.003764			

Regression Equation

MRR = -0.0733 + 0.000094 Speed + 0.1646 Feed + 0.0392 D.O.C + 0.000728 Hardness

B. General Linear Model: Ra versus Speed, Feed, D.O.C, Hardness

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Speed	Fixed	3	215, 315, 455
Feed	Fixed	3	0.090, 0.133, 0.250
D.O.C	Fixed	3	0.30, 0.70, 0.95
Hardness	Fixed	3	18, 33, 41

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed	2	2.133	1.066	*	*
Feed	2	74.008	37.004	*	*
D.O.C	2	3.422	1.711	*	*
Hardness	2	24.823	12.412	*	*
Error	0	*	*		
Total	8	104.385			

Regression Equation

Ra = -2.70 - 0.00440 Speed + 39.31 Feed + 0.24 D.O.C + 0.1731 Hardness

C. Computation of sum of squares and percentage contribution

Calculation of sum of square for MRR (Ref. TABLE : V)

$\mu = (0.01232+0.04233+0.07909+0.03888+0.01968+0.02383+0.01800+0.00902+0.04009)/9$

$= 0.031471$

Adj. SS $= (0.031471-0.01232)^2+(0.031471-0.04233)^2+(0.031471-0.07909)^2+(0.031471-0.03888)^2 + (0.031471-0.01968)^2+ (0.031471-0.02383)^2+(0.031471-0.01800)^2+(0.031471-0.00902)^2 + (0.031471-0.04009)^2$

Or, Adj. SS = 0.003764

Percentage of Contribution :

1) Speed : (0.000812/0.003764)*100% = 21.57%
2) Feed : (0.001181/0.003764) *100% = 31.38%
3) Depth of cut : (0.001216/0.003764) *100% = 32.31%
4) Hardness : (0.000555/0.003764) *100% = 14.74%

Calculation of sum of square for MRR (Ref. TABLE : V)

$\mu = (2.546+5.926+12.012+8.792+2.705+12.166+6.459+6.591+10.444)/9$

$= 7.5156$

Adj. SS $= (7.5156 - 2.546)^2 + (7.5156 - 5.926)^2 +(7.5156 - 12.012)^2 +(7.5156 -8.792)^2 + (7.5156 -2.705)^2 +(7.5156 -12.166)^2 +(7.5156 – B\ 6.459)^2 +(7.5156 - 6.591)^2 +(7.5156 - 10.444)^2$

Or, Adj. SS= 104.385

Percentage of Contribution:

5) Speed : (2.133/104.385)*100% = 2.05%
6) Feed : (74.008/104.385)*100% = 70.89%
7) Depth of cut : (3.422/104.385)*100% =3.28%
8) Hardness : (24.823/104.385)*100% = 23.78%

Table: vipercentage of contribution of speed-feed-d.o.c.-hardness on machining performance

	Speed	*Feed*	*D.O.C.*	*Hardness*
MRR	21.57	31.38	32.31	14.74
Rank	3	2	1	4
Ra	2.05	70.89	3.28	23.78
Rank	4	1	3	2

IX. CONCLUSION

It is found from the results that the machining parameters are more influential than mechanical properties for variance in output. In present study D.O.C plays major role followed by feed and speed for achieving higher material removal rate. It is also stated that for achieving an optimum material removal rate, D.O.C. has to keep in the moderate level, taking speed at lower level and feed at higher level or vice versa.

It can also be said that the machining through suitable adjustments of various parameters did not have much effect on the final roughness & waviness of the product simple due to improved method of manufacture and resultant properties.

X. FUTURE SOPE OF THE PRESENT WORK

Being specific for an alloy steel like EN25 following area are still to be explored:

To evaluate the influence of mechanical properties, separate machining tests are to be conducted before and after each of the heat treatment according to the L_9 array of the design of experiments.

The process is to be optimized.

XI. ACKNOWLEDGEMENT

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