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Linear Regression and Anova Modelling Tool When Turning of EN 24 / EN 31 Alloy Steel

Deepak.P[1], B.R. Narendra Babu[2], Dr. K. Chandrashekara[3]
[1]M.Tech, Department of Mechanical Engineering, Vidya Vikas Institute of Engineering and Technology, Mysore – 570 028.
[2]Associate Professor, Department of Mechanical Engineering, Vidya Vikas Institute of Engineering and Technology, Mysore – 570 028.
[3]Professor, Department of Mechanical Engineering, Sri Jaya Chamarajendra College of Engineering, Mysore – 570 006.

ABSTRACT
In any machining process, apart from obtaining the accurate dimensions, achieving a good surface quality and maximized metal removal are also of utmost importance. A machining process involves many process parameters which directly or indirectly influence the surface roughness and metal removal rate of the product in common. Surface roughness and metal removal in turning process are varied due to various parameters like feed, speed and depth of cut are important ones. Extensive study has been conducted in the past to optimize the process parameters in any machining process to have the best product. Current investigation on turning process is a Linear Regression Methodology (LRM) applied on the most effective process parameters i.e. feed, cutting speed and depth of cut while machining alloy steels as the two types of work pieces with HSS cutting tool in dry environment. The main effects (independent parameters), quadratic effects (square of the independent variables), and interaction effects of the variables have been considered separately to build best subset of the model. Four levels of the feed, four levels of speed, four levels of the depth of cut, two different types of work materials have been used to generate readings in a single set. After obtaining the data from the experiments, LR is calculated using the existing formulae. To analyze the data set, statistical tool ANOVA has been used to reduce the manipulation and help to arrive at proper improvement plan of the manufacturing process & techniques. A comparison between the observed and predicted data was made, which shows a close relationship.
Keywords: Linear Regression Methodology (LRM), Turning, ANOVA.

I. INTRODUCTION

Steel is an alloy of iron and carbon or other alloying elements. When the alloying element is carbon, the steel is referred to as carbon steel. Carbon steels are classified by the percentage of carbon in “points” or hundredths of 1 percent they contain. The term hardened steel is often used for medium or high carbon steel that has been given the heat treatments of quenching followed by tempering. The quenching results in the formation of metastable martensite, different medias are selected for getting different structures, the fraction of which is reduced the desired amount during tempering. This is the most common state for finished articles such as machine tools and machine parts. In contrast, the same steel composition in annealed state will be softer as required for forming and machining.

Depending on the temperature and composition of the steel, it can be hardened or softened. In order to make steel harder, it must be heated to very high temperatures. The final result of exactly how hard the steel will be depends on the amount of carbon present in the metal. Only steel that is high in carbon can be hardened and tempered. If a metal does not contain the necessary quantity of carbon, then its crystalline structure cannot be broken, and therefore the physical makeup of the steel cannot be altered.

EN 24 is a high quality, high tensile, medium-carbon low-alloy steel. It combines high tensile strength, shock resistance, good ductility and resistance to wear. Properties of EN 24 steel, like low specific heat, and tendency to strain-harden and diffuse between tool and work material, give rise to certain problems in its machining such as large cutting forces, high cutting-tool temperatures, poor surface finish and built-up-edge formation.

Applications: Highly stressed components of large cross section for aircraft, automotive & general enginery application such as propeller shafts, connecting rods, gear shafts, crane shafts & landing gear components, heavy forging, such as rotor shafts & discs.

EN 31 is a high carbon alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance.

Applications: For roller bearing components such as brakes, cylindrical, conical & needle rollers.

II. TURNING PROCESS PARAMETERS

To identify the parameters those affects the machining performance (in terms of cutting forces, MRR) and the quality of the components machined by turning a preliminary study was conducted. The parameters for machining can be classified as follow:

1. *Machine based parameters*: These are spindle speed, feed rate, depth of cut and cutting tool.

2. *Coolant based parameters*: These are the supply of coolant, type of coolant.

3. *Workpiece based parameters*: These are the workpiece geometry, dia. of workpiece, chemical composition of the workpiece material.

4. *Cutting tool base parameter*: These are the material to tool, shape of tool, nose radius of tool.

III. EXPERIMENTAL INVESTIGATION

Experiments were performed by turning EN 24 and EN 31 using HSS tool in lathe tool dynamometer. Experiments were conducted by varying the cutting speed, feed rate and depth of cut. The cutting operation was interrupted at regular intervals and the dynamometer is capable of measuring feed force (F_x), cutting force (F_y) and thrust force (F_z) which occurs during turning operations.

3.1 The chemical composition and microstructure study of EN 24 and EN 31 alloy steels

Chemical composition and microstructure of the alloy steels of samples (EN 24 and EN 31 samples) is presented in Table.1 and figure 1,2,3&4.

Table 1. Chemical composition of the used samples

Material	Elements							
	C %	Si %	Mn %	P %	S %	Cr (%)	Mo (%)	Ni (%)
EN 24	0.39	0.31	0.62	0.03	0.02	1.01	0.21	0.18
EN 31	1.01	0.20	0.33	0.02	0.01	1.36	0	0

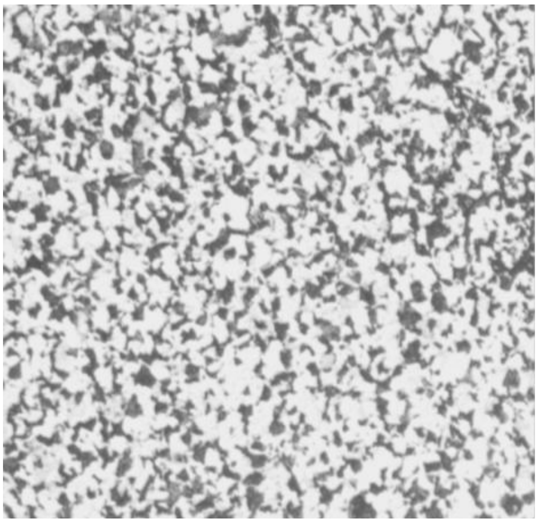

Figure1.100x nital

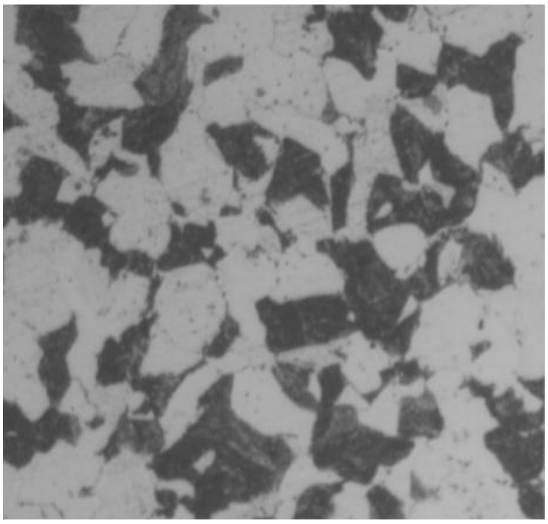

Figure2.500x nital

Figure 1 and 2 represents microstructure of EN 24 alloy steel. Microstructure consists of uniformly distributed Ferrite and Pearlite.

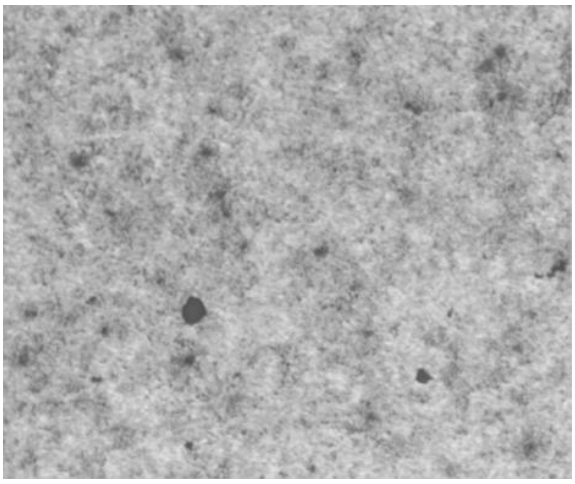
Figure 3.100x nital

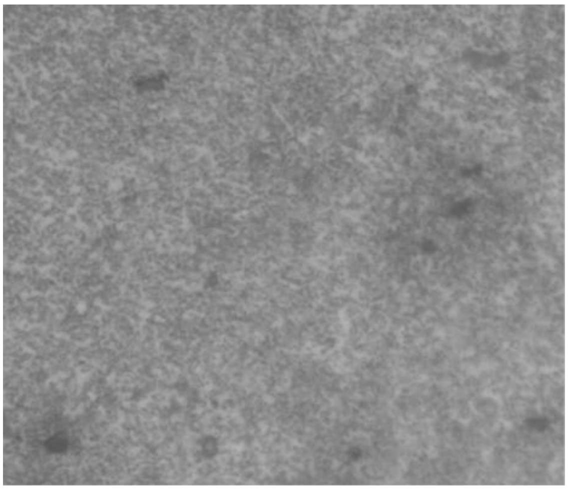
Figure4.500x nital

Figure 3 and 4 represents microstructure of EN 31 alloy steel. Microstructure consists of uniformly distributed Fine Tempered Martensite with 10% Ferrite

1.2 TESTING

Mechanical properties investigations were carried out in the testing laboratory.

a. Tensile test was made by TUE-C-1000 of the testing equipment with loading range 0 to 35 kN.
b. Brinell hardness test was made by B-3000 of the testing equipment with the tungsten ball indenter of a diameter 10 mm pressed into the surface of specimens under the load 3000kg.
c. The microstructure of the specimens was made by optical metallurgical microscope NIKON Epiphot 200.

Experiments were performed by turning EN 24 and EN 31 using HSS tool in lathe tool dynamometer. Experiments were conducted by varying the cutting speed, feed rate and depth of cut. The cutting operation was interrupted at regular intervals and the dynamometer is capable of measuring feed force (F_x), cutting force (F_y) and thrust force (F_z) which occurs during turning operations.

The experimental data obtained was used to estimate forces in turning by applying analysis methods like Linear Regression Analysis and ANOVA used to check the adequacy of the model developed. The estimates of feed, cutting and thrust forces obtained by Linear Regression Analysis were compared with the measured value.

IV. RESULTS AND DISCUSSION

4.1. Constant Depth of Cut

Table 2. Constant depth of cut

Sl.No	*Depth of Cut d,mm*	*Speed N, rpm*	*Feed Force Fx, N*	*Cutting Force Fy, N*	*Thrust Force Fz, N*
1	1.2	360	9	31	16
2	1.2	500	8	34	18
3	1.2	840	13	48	25
4	1.2	1400	8	30	16

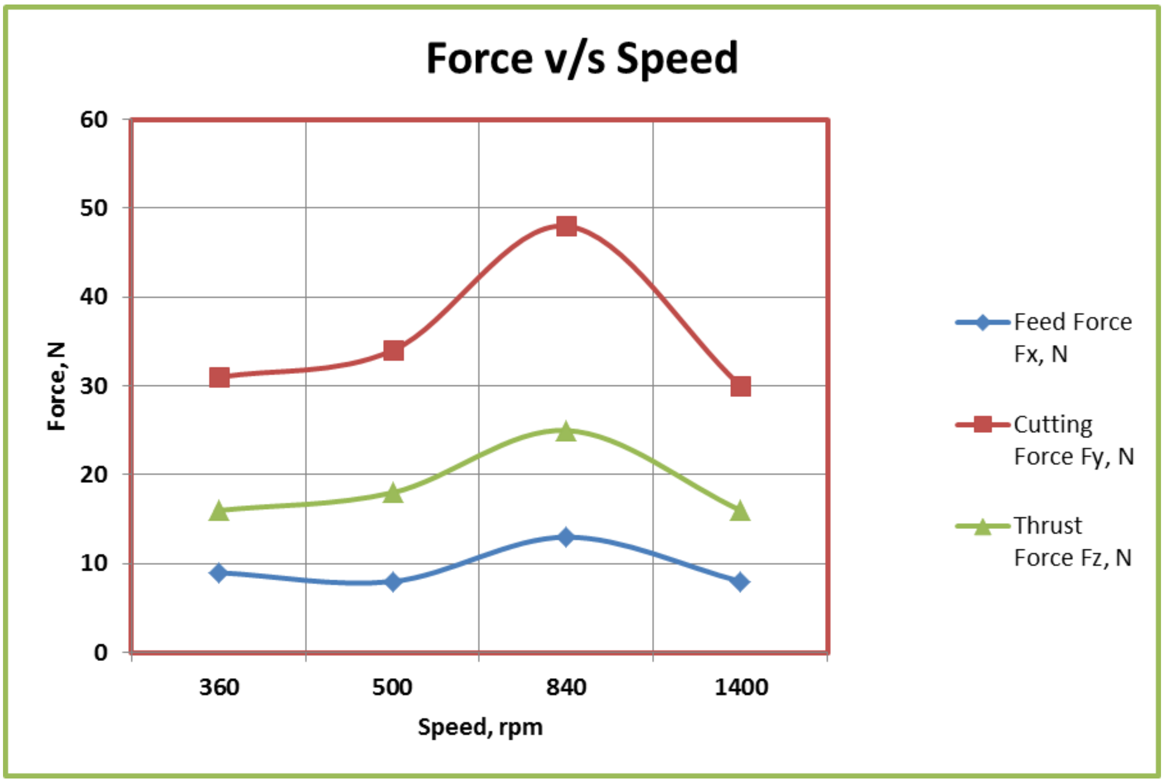

Figure5. Force v/s Speed curve for constant depth of cut

4.1.1 LRA Test Results for Feed Force, F_x HSS Tool

Table 3 LRA Test Results for Feed Force, F_x HSS Tool

Regression Statistics	
Multiple R	0.027227884
R Square	0.000741358
Adjusted R Square	-0.498887963
Standard Error	2.914395042
Observations	4

Table 4 ANOVA Test Results for Feed Force, F_x HSS Tool

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.012603081	0.012603081	0.001483815	0.972772116
Residual	2	16.98739692	8.49369846		
Total	3	17			

Table 5 Variable Test Results for Feed Force, F_x HSS Tool

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	9.6085	3.17192	3.029	0.093	-4.03914	23.2562	-4.03914	23.2562
X Variable	-0.00014	0.003635	-0.038	0.972	-0.01578	0.015502	-0.01578	0.015502

Table 6 Residual Output and Probability output Test Results for Feed Force, F_x HSS Tool

RESIDUAL OUTPUT			
Observation	***Predicted Y***	***Residuals***	***Standard Residuals***
1	9.5581	-0.5581	-0.2345
2	9.5385	-1.5385	-0.6465
3	9.4908	3.5091	1.4746
4	9.4124	-1.4124	-0.5935

PROBABILITY OUTPUT	
Percentile	***Y***
12.5	8
37.5	8
62.5	9
87.5	13

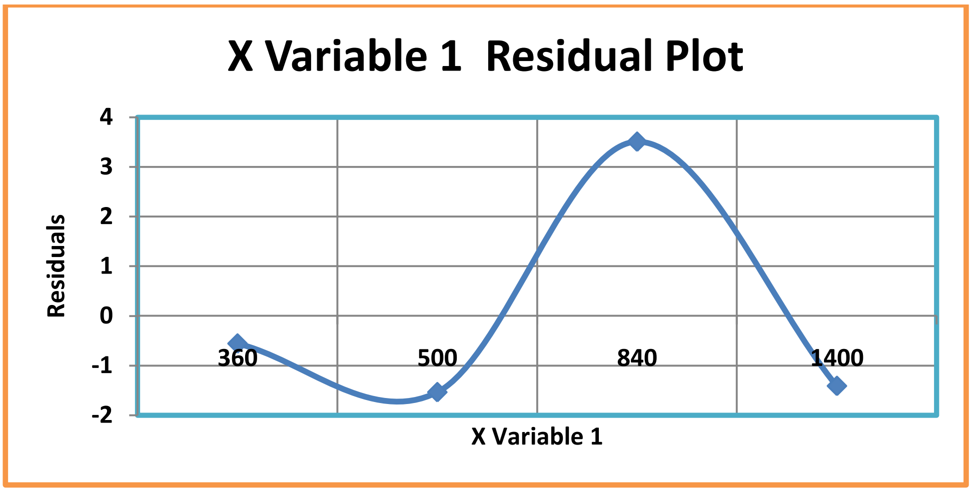

Figure6. Residual Plot for Feed Force, F_x HSS Tool

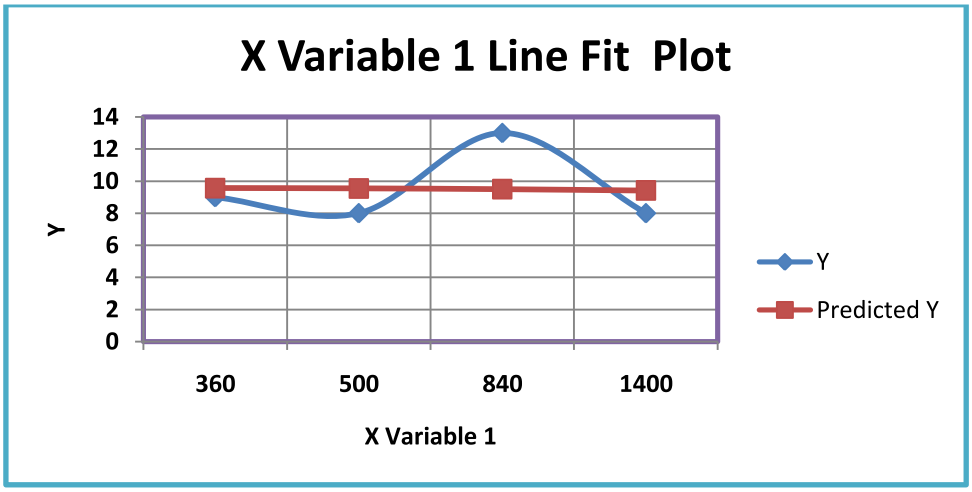

Figure7. Line Fit Plot for Feed Force, F_x HSS Tool

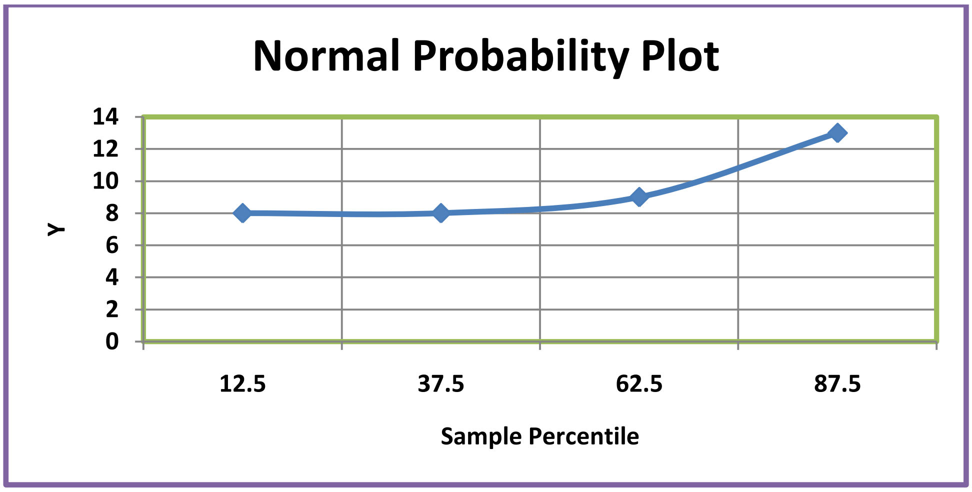

Figure8. Normal Probability Plot for Feed Force, F_x HSS Tool

V. CONCLUSION

- The effect on surface roughness of machining parameters such as cutting speed, feed, and depth of cut while turning EN 24 alloy steel was discovered.
- Using experimental data, a simple linear regression model was developed that proved to be effective in optimizing the cutting conditions in turning operations.
- The surface roughness is mainly influenced by the feed rate. With an increase in feed rate, the surface roughness also increases considerably. The cutting speed and the depth of cut are less significant for surface roughness than the feed rate.
- From the ANOVA analysis, the parameter that has the most significant effect on surface roughness is the feed rate. Cutting speed has the next most significant effect, and finally, the depth of cut has the least significant effect on surface roughness.
- From a line fit plot it is clear that there is a close relationship between the observed and predicted value.
- A comparison between the observed and predicted data was made, which shows the close relationship.

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