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Investigation of the Effects of the Parametric Variations in Turning Process of En31 Alloy

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ABSTRACT : The objective of the paper is to obtain an optimal setting of turning process parameters -cutting speed, feed, depth of cut, cutting tool and cutting fluid which may result in optimizing the thrust force and feed force encountered during machining of EN31 alloy. *EN31* is a high carbon alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance, but is usually known to create major challenges during its machining. Turning is the process known for its capabilities in providing machining efficiency in terms of higher machining rate low tool wear apart from reasonably good surface quality. The study was aimed to investigate the effect of several input parameters of turning operation (cutting tool, cutting oil, cutting speed, feed and depth of cut) on the different response parameters such as *thrust force* and *feed force* in turning process on EN31. The result showed that the response variables were strongly influenced by the input parameters. The experiments were performed on conventional lathe machine. Taguchi's robust design methodology has been used for statistical planning of the experiments. Experiments were conducted on conventional lathe machine in a completely random manner to minimize the effect of noise factors present while turning EN31 under different experimental conditions. Two type of tools and three types of coolant were used with three different values of machining parameters (speed, feed and depth of cut).

I. INTRODUCTION

Even though the machine tool industry in India has made tremendous progress, the metal cutting industries continue to suffer from a major drawback of not running the machine tools at their optimum operating condition. The problem of arriving at the optimum levels of the process parameters has attracted the attention of the researchers and practicing engineers for a very long time [9]. It has long been recognized that conditions during cutting, such as feed rate, cutting speed and depth of cut, should be selected to optimize the economics of machining operations,

as assessed by productivity, total manufacturing cost per component or some other suitable criterion. The need for selecting and implementing optimal machining conditions and the most suitable cutting tool has been felt over the last few decades [1]. Turning is the primary operation in most of the production processes in the industry, surface finish of turned components has greater influence on the quality of the product. Surface finish in turning has been found to be influenced in varying amounts by a number of factors such as feed rate, work material characteristics, cutting speed, depth of cut, cutting time, tool nose radius and tool cutting edge angles, stability of machine tool and workpiece setup, chatter, and use of cutting fluids[5]. Some research work has been reported in this regard for various work materials such as A1S1 P20, ferrite stainless steel, grade A1S1 12L14, SCM 440 alloy steel and super alloy Inconel 718 etc. However there is a critical need for exploring these issues for EN31 for which almost no work has been reported.

In this paper Taguchi's DOE approach is used to analyze the effect of turning process parameters -cutting tool, cutting fluid ,cutting speed, feed and depth of cut, while machining EN31 steel and to obtain an optimal setting of these parameters that may result in optimizing thrust and feed force.

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 and cause and effect diagram was drawn (Fig. 1).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.

The parameters selected for this study based on the availability of these parameters on the machine were - Cutting Tool, Cutting Fluid, Spindle Speed, Feed and Depth of Cut.

Five factors with different number of levels were selected for this experimentation. The first factor has two levels while other four factors have three levels. The level for each factor was selected in high of trends of cutting force.

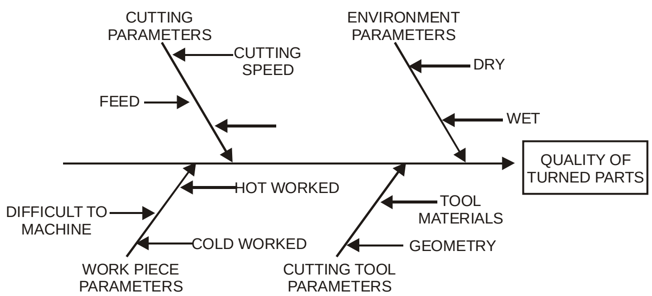

Fig.1. Cause effect diagram

Table 1. Nomenclature of Parameters of lathe machine.

Control Factor	Symbol
Cutting Tool	Factor A
Cutting Fluid	Factor B
Spindle Speed	Factor C
Feed	Factor D
Depth of Cut	Factor E

Table 2. Levels for various control factors.

S.No.	Factor	Levels	Level 1	Level 2	Level 3	Unit
A.	Cutting Tool	2	HSS	Carbide	—	—
B.	Cutting Fluid (coolant)	3	Servo	Soluble	Dry	—
C.	Spindle Speed	3	420	325	192	Rpm
D.	Feed	3	0.2	0.1	0.05	mm/rev
E.	Depth of Cut	3	1.0	0.6	0.32	Mm

III. SELECTION OF ORTHOGONAL ARRAY

Taguchi’s robust design of experiments (DOE) methodology was too used to plan the experiments statistically. Before finalizing a particular orthogonal array for the purpose of designing the experiments, the following two things must be established [7].

1. The number of levels for the parameters of interest.
2. The number of parameters and interactions of interest.

In the present investigation, five different process parameters have been selected as already discussed. The cutting tool has two levels whereas all other parameters i.e. spindle speed, depth of cut, feed and cutting fluid have three levels. As per requirements of the study, L18 array (in standard form) was selected for the present investigation. For the present investigation, cutting tool has two levels whereas all other parameters have three levels, hence for cutting tool the DOF is 1 whereas for all other factors DOF is 2 for each factor. Therefore total DOF in the present investigation are:

Total degree of freedom = $(1 \times 1) + (4 \times 2) = 9$

Hence L18 orthogonal array (having 17 DOF) can be adopted for planning of the experimentation, based on the computation of degree of freedom.

Analysis of Variance : The percentage contribution of various process parameters on selected performance characteristics can be estimated by performing analysis of variance test (ANOVA). Thus, information about how significant the effect of each controlled parameter is on the quality characteristics of interest can be obtained. The ANOVA for mean and SN data have been performed to identify the significant parameters to quantify their effect on performance characteristics. The most favorable condition of performance parameter has been established by analyzing response curves of SN ratio associated with raw data.

Evaluation of S/N Ratio : The S/N ratio is obtained using Taguchi's methodology. Here the term "signal" represents the desirable value (mean) and the" noise" represent the undesirable value (std. deviation). Thus, the S/N ratio represents the amount of variation present in the performance characteristic. Here the desirable objective is to optimize the response variable. Hence, *smaller the better type S/N ratio was applied for transforming the raw data for cutting forces as smaller value of cutting force is desirable*.

IV. EXPERIMENT, ANALYSIS AND DISCUSSION

EN31 alloy steel rods of 20mm diameter and 100mm length were turned on a centre lathe machine. The spindle speed for the lathe machine ranges from the 42 rpm to the 2040 rpm. The depth of cut ranges from 0.2 mm to 4.8 mm and the range of feed on the machine is from 0.05 mm/rev to 0.8 mm/rev. The control unit consists of the levers to set the spindle speed and feed for the various combinations for experimentation. Cutting fluid is supplied to the cutting fluid unit with the help of electric motor. The storage capacity of the fluid tank is 20 liters. The cutting fluid is supplied at constant rate. It was filtered by the filters provided on the tank. The tool used for the turning was of HSS and Carbide. The size of the shank for both the tool is 12.70mm x 52.40 mm. The carbide bit was used with the shank. The range for the dynamometer varies from the 0000 the 2000 kg for the thrust force, 000 to 900 kg for feed and radial forces.

In order to study the significance of the parameters in affecting the thrust force and feed force, analysis of variance (ANOVA) was performed. The pooled ANOVA of the raw data (tool life) is given in Table 4 and Table 6 for thrust and feed force respectively. The analysis of results shows that input parameter setting of cutting tool as carbide, cutting condition as dry, spindle speed at 230 rpm, feed at 0.25 mm/rev and depth of cut at 0.3 mm has given the optimum results for the thrust force and input parameter setting of cutting tool as HSS, cutting fluid as soluble oil, spindle speed at 230 rpm, feed at 0.25 mm/rev and depth of cut at 0.3 mm have been given the optimum results for the feed force when EN31 was turned on lathe.

V. CONCLUSION

1. The percentage contribution of feed rate towards the variation in the thrust force is 32.19 % and depth of cut is 29.31 %. The percentage contribution 0f cutting tool is 6.15 % and the spindle speed is 4.57 %. The cutting contributes 0.22 % with regard to thrust force.
2. The percentage contribution of depth of cut towards the variations of feed force is 20.61 %. The percentage contribution of cutting oil is 15.67 % and feed rate is 10.69 %. The spindle speed contribute 7.22 % where as cutting tools contributes 0.12 %with regard to feed force.

Table 3. Test data summary for thrust force.

Exp. No	Thrust force (kg.)			Thrust force means (kg.)	Thrust force S/N ratio (dB)
	R1	R2	R3		
1	157	138	137	144	-43.18
2	86	78	88	84	-38.49
3	3	6	3	4	-12.55
4	160	147	137	148	-43.42
5	127	12	122	87	-41.80
6	98	85	84	89	-39.01
7	130	148	82	120	-41.81
8	90	105	90	95	-39.57
9	136	97	136	123	-41.89
10	22	12	20	18	-25.34
11	227	187	216	210	-46.47
12	57	45	123	75	-38.32
13	23	19	21	21	-26.47
14	88	82	76	82	-38.29
15	96	90	114	100	-40.04
16	49	31	58	46	-33.50
17	45	42	42	43	-32.67
18	98	105	103	102	.40.17
Average				88.38889	-36.83
Maximum	227	187	216	210	-12.55
Minimum	3	6	3	4	-46.47

Table 4. ANOVA results for Thrust force (raw data)

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% conribution
A	1	9048	9048	9048	9.84	0.003*	6.15
B	2	329	329	165	0.18	0.837	0.22
C	2	6725	6725	3363	3.66	0.034*	4.57
D	2	47314	47314	23657	25.72	0.000*	32.19
E	2	43080	43080	21540	23.42	0.000*	29.31
ERROR	44	40473	40473	920			
TOTAL	53	146971					

S = 13.9726 R- Sq = 61.76% R= Sq (adj) - 53.93%

Order of significance: 1. Feed rate, Depth of cut 2. Cutting oil, 3.spindle speed significant at 5 % level

Table 5. Test Data Summary for Feed Force

Exp. No	Thrust force (kg.)			Thrust force means (kg.)	Thrust force S/N ratio (dB)
	R1	R2	R3		
1	178	155	162	165	–44.36
2	86	70	78	78	–37.90
3	3	2	4	3	–9.85
4	153	149	133	145	–43.24
5	143	135	136	138	–42.80
6	80	76	78	78	–37.84
7	225	198	237	220	–46.87
8	115	102	89	102	–40.21
9	63	47	79	63	–36.16
10	96	62	73	77	–37.87
11	609	532	551	564	–55.04
12	245	243	202	230	–47.26
13	5	6	7	6	–15.64
14	68	66	46	60	–35.68
15	32	25	24	27	–28.70
16	45	43	41	43	–32.67
17	14	13	12	13	–20.65
18	59	55	54	56	–34.97
Average.				114.8333	–35.98
Maximum	609	532	551	564	–9.85
Minimum	3	2	4	3	–55.04

Table 6. ANOVA results for feed force (raw data).

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% conribution
A	1	1076	1076	1076	0.12	0.734	0.12
B	2	138424	138424	69212	7.52	0.002*	15.67
C	2	62040	62040	31020	3.37	0.043*	07.02
D	2	94428	94428	47214	5.13	0.010*	10.69
E	2	182047	182047	91023	9.89	0.000*	20.61
ERROR	44	405026	405026	9205			
TOTAL	53	883041					

S = 95.9434 R-Sq = 54.13%R- Sq (adj) = 44.75%

Order of significance: 1. Depth of cut 2. Cutting oil 3. Feed rate 4. Spindle speed significant at 5 % level

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