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Optimization of the Feed Force and Cutting Force in Turning Operation of EN-8 Steel

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Abstract- In this research experiment, the Taguchi method is applied to optimize the feed force and cutting force in turning of EN 8 steel. The input process parameters for this investigations are feed, spindle speed and depth of cut. The experiments were completed According to the Taguchi's L9 orthogonal array. ANOVA (general linear model) and signal to noise ratio are applied to optimize the process parameter. For both (feed force and cutting force) Depth of cut has most dominating effect on feed force subsequently followed by feed and spindle speed.

Index Terms- Taguchi method, Feed force, Cutting Force, Orthogonal array(L9) ,Optimization, ANOVA

1. INTRODUCTION

Turning is the process whereby a single point cutting tool is moved parallel to the surface of rotating workpiece in which certain depth of cut and feed is provided to the cutting tool to penetrate in the workpiece to cause the removal of material with the help of friction force. It can be done manually, using a traditional form of lathe, which requires continuous supervision by the operator. There are three principal forces in oblique turning and these are cutting force , feed force and radial force. Out of these forces cutting force is the largest force and radial force is the smallest .In orthogonal turning radial force becomes zero. EN-8 steel is used in many applications such as axle, shaft, Fasteners and gears due to their strength to weight ratio and high hardness. The EN8 steel is greatly influenced by different parameters such as feed, cutting speed and depth of cut.

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2. LITERATURE REVIEW

Ghosh et al (2009); investigated that the chipping and adhesion are the main cause of the wear. L18 orthogonal array was used and input process parameters were cutting speed , feed, depth of cut and length of cut. Dogra et al(2016) investigated by using L 9 orthogonal array that the speed is the most important parameter to reduce the toll tip wear. Ramamurthy et al (2009); optimized the supply of minimum quality lubrication in high speed turning of super alloy Inconel 718 for sustainable development. During machining wears progress rapidly because of high cutting temperature and strong adhesion between tool and workpiece material resulting from their low conductivity and high reactivity. so large amount of cutting fluid is flushed into the cutting zone to facilitate the heat transfer from cutting zone. Obtained results showed that minimum quantity lubrication under pulse jet mode proved to be effective.

Feng et al (2001); investigated that the depth of cut does not impact the surface roughness in the experiment range, It could be used to improve productivity if it would not worsen the microstructure of surface of the material and geometric and dimensional accuracy. In addition to speed, nose radius, work material and feed, the tool point angle also has a dominating impact on the surface roughness. Manna et al (2004); found the surface roughness model in a turning operation considering the effect of the depth of cut and feed on the motion geometry of the turning process. This model concluded that the feed rate and depth of cut is significant factors for the surface roughness while the effect of cutting speed is insignificant. Singh et al (2006); reported the optimization of process parameters for turning EN24 steel rod, using speed, depth of cut and feed as controlled factors and feed force as output variable through Taguchi approach. Ozel at el (2005); conducted an investigation using steel work rod, spindle speed, cutting tool and workpiece length material control input parameters, and surface roughness as response parameter. Results shows the surface roughness is significantly affected by spindle speed, the effect of cutting tool material is less significant and , small workpiece length resulted in better surface roughness.

Singh et al (2005); elaborated various optimization techniques for the machining of workpiece. In this he attempted to made literature on optimizing machining parameters in turning . Various conventional techniques were used for optimization include geometric programming, geometric plus linear programming, goal programming, dynamic programming etc. The latest technique for optimization includes, genetic algorithm, scatter search technique, fuzzy logic, response surface methodology and Taguchi technique.

Singh et al (2008); conducted an experiment on optimum setting input parameters (feed, depth of cut and speed). The tool life of TiC coated carbide inserts while turning En24 steel (0.4 % C). The results were indicating that the selected process parameters significantly affect the mean and variance of the tool life of the carbide inserts. Hasan et al (2008); analyzed the surface roughness produced by turning process on hard martensitic stainless steel by cubic boron nitride cutting tool. The work piece material was hard AISI 440C martensitic stainless steel. The experiments were designed using various input parameters like cutting speed, depth of cut and feed rate. Lowest value of surface roughness was produced at cutting speed of 225 m/min while the feed rate of 0.125 mm/rev and 0.50 mm depth of cut. However, moderate cutting speed of 175 m/min under feed rate of .0125 mm/rev and depth of cut 0.05 mm is an ideal operating parameter taking flank wear in the account.

3. EXPERIMENTAL SETUP

Turning Operation has been done on lathe HMT NH22 available at central workshop at u.i.e.t Kanpur. The work material selected for the study was EN 8 which was in the form of cylindrical bar with a diameter of 60 mm and length of 300mm.
Turning operation was performed by using insert holder with insert CNMG120404-PF-4015. In the present investigation experiment consists of turning of EN 8 on a lathe machine. Three process parameters along with their 3 levels are given below.

Table 1. Process parameters and their levels

Factors	Unit	Level-1	Level-2	Level-3
Speed	Rpm	325	420	550
Feed	mm/rev	0.1	0.2	0.28
DOC	mm	0.5	0.7	0.9

4. RESULT DISCUSSION AND ANALYSIS

It can be observed from table 4 that depth of cut, feed and speed are the significant factors for feed force. The percentage contribution of depth of cut is 57.89 %which is most significant factor. Feed 26.82% and speed 14.68 % so these are less significant factors. According to the value of S/N ratio the S/N response have been found to highest for those factor levels that corresponds to highest average response. Hence these factor levels termed as optimum for point of view of S/N response as well as average response. As S/N response takes into account both the magnitude as well as variation in a response, the factor level that corresponds to highest S/N ratio are termed as optimum. As shown in figure 1,During turning operation speed vs feed force clearly depicts that when the spindle speed increases from 325 rpm to 425 rpm, the feed force would be decreased in this region due to thermal softening was dominating in compare to strain hardening and from 420 rpm to 550 rpm the feed force increases due to increment in speed.in this region the heat dissipation rate is enhanced so the strain hardening phenomena was dominating over to thermal softening. For feed vs feed force diagram and depth of cut vs feed force shows that higher value of feed and depth of cut the feed force also increased due to increment of friction force and increment of material removal rate.

Table 2. Experimental results with L9 Orthogonal array

Exp no.	Speed (rpm)	Feed (mm/rev)	D.o.c	Feed force	Cutting force
1	325	0.10	0.5	13.5	17
2	325	0.20	0.7	36	24.5
3	325	0.28	0.9	40	26.5
4	420	0.10	0.7	23.5	24.5
5	420	0.20	0.9	31	16.5
6	420	0.28	0.5	19.5	10.5
7	550	0.10	0.9	31	34
8	550	0.20	0.5	12	11
9	550	0.28	0.7	39	23.5

It can be observed from table that depth of cut, feed and speed are the significant factors for cutting force. The percentage contribution of depth of cut is 70.37 %which is most significant factor. Feed 16.43 % and speed 13.06 % so these are less significant factors. As shown in figure 3,During turning operation speed vs cutting force clearly depicts that when the spindle speed increases from 325 rpm to 425 rpm, the cutting force would be decreased in this region due to thermal softening was dominating in compare to strain hardening and from 420 rpm to 550 rpm the cutting force increases due to increment in speed. In this region the heat dissipation rate is enhanced so the strain hardening phenomena was dominating over to thermal softening. For feed vs cutting force diagram the value of cutting force, from 0.1 mm/rev to 0.2 mm/rev is decreased and from .02mm/ rev to 0.28 mm/rev the value of cutting force is increased and depth of cut vs feed force shows that when the value of depth of cut was increased , the cutting force also increased due to high material removal rate.

Table3. Response for Means for feed force

Level	Speed	Feed	Depth of cut
1	29.83	22.67	15.00
2	24.67	26.33	32.83
3	27.33	32.83	34.00
Delta	5.17	10.17	19.00
Rank	3	2	1

Table 4. Analysis of Variance for feed force

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-value	P-value
Rpm	2	188.39	14.68%	188.929	94.464	24.29	0.040
Feed	2	345.07	26.82%	345.069	172.535	44.37	0.022
D.o.c	2	744.77	57.89%	744.77	372.387	95.76	0.010
Error	2	7.78	0.60%	7.777	3.889		
Total	8	1286.55	100.00%				

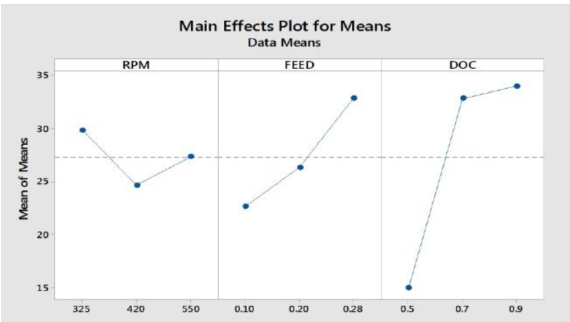

Fig. 1.Effect of process parameters on feed force

Table 5.Response for Signal to Noise Ratios for feed force (smaller is better)

Level	Speed	FEED	Depth of cut
1	-28.59	-26.62	-23.33
2	-27.68	-27.51	-30.12
3	-27.74	-29.89	-30.57
Delta	0.91	3.27	7.23
Rank	3	2	1

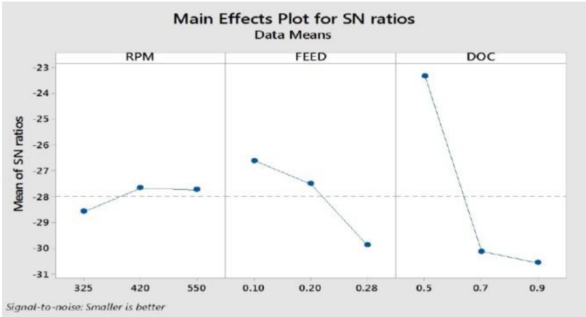

Fig. 2. Effect of process parameters on feed force

Table 6. Response for Means for cutting force

Level	Speed	FEED	Depth of cut
1	22.67	25.17	12.83
2	17.17	17.33	24.17
3	22.83	20.17	25.67
Delta	5.67	7.83	12.83
Rank	3	2	1

Table 7. Analysis of Variance for cutting force

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-value	P-value
RPM	2	0.001292	13.06%	0.001292	0.000646	96.02	0.010
FEED	2	0.001626	16.43%	0.001626	0.000813	120.80	0.008
DOC	2	0.006960	70.37%	0.006960	0.003480	517.20	0.002
Error	2	0.000013	0.14%	0.000013	0.000007		
Total	8	0.009891	100%				

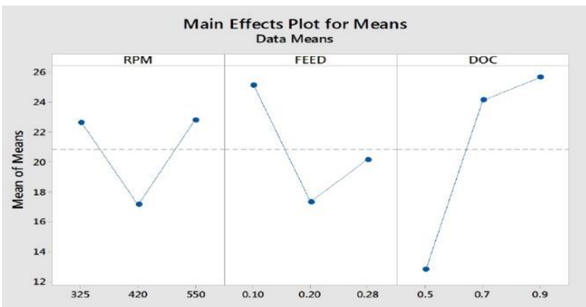

Fig. 3. Effect of process parameters on cutting force

Table 8.Response for Signal to Noise Ratios for cutting force (smaller is better)

Level	Speed	FEED	Depth of cut
1	-26.95	-27.67	-21.95
2	-24.19	-24.32	-27.66
3	-26.29	-25.44	-27.81
Delta	2.77	3.35	5.86
Rank	3	2	1

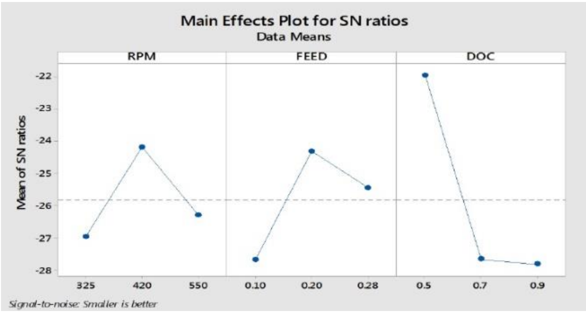

Fig. 4. Effect of process parameters on cutting force

5. CONCLUSION

Machining of EN 8 STEEL is important because it is used in axle, gear etc.. so machining parameters optimization plays a very important role for fabrication of component using EN 8 steel.

Effect of depth of cut is the most significant factor on feed force in turning operation of EN 8 steel. It has 57.89% contribution which is highest in compare to other input process parameters. Effect of feed is significant factor on feed force in turning operation of EN 8 steel. It has 26.82% contribution. Effect of speed is significant factor on feed force in turning of EN8 steel. It has 14.68% contribution.

Effect of depth of cut is the most significant factor on cutting force in turning operation of EN 8 steel. It has 70.37 % contribution which is highest in compare to other input process parameters. Effect of feed is significant factor on feed force in turning operation of EN 8 steel. It has 16.43 % contribution. Effect of speed is significant factor on feed force in turning of EN8 steel. It has 13.06 % contribution.

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