Evaluation of multiple responces using Taguchi method for Hard Turning of HE30(AA6082)

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ABSTRACT

Hard Turning is an established process in industries for the finish machining of a wide range of hardened work pieces. This process is used for machining of part pieces that have hardness values over 45 HRc. Aluminium alloy HE30 (AA6082) is material of medium strength alloy possess good hardness and excellent corrosion resistance.

In the present work, an experimentation has been made while hard turning of Aluminium Alloy HE30 (6082) material to discover the impact of process parameters, for example, speed (N), feed (f) and cutting apparatus material on the execution estimates specifically material removal rate (MRR), surface roughness (SR). Further ideal mixes of the parameters are gotten to yield maximum material removal rate, least surface roughness, independently utilizing by and overall evaluation criteria technique (OEC). In the wake of dissecting the outcomes it was seen that the speed (cutting rate) has most huge impact though feed and cutting toll material has less noteworthy impact on the execution measures. Experiments are designed and conducted as per Taguchi L9 orthogonal array (OA). Analysis of variance (ANOVA) was also performed to identify the level of significance of each process parameter. Optimal combination of the process parameters is obtained by OEC considering each performance measures as multiple objectives. Further confirmation experiments are conducted at optimal parametric setting. Further experimental values are compared with predicted values.

Key words: Hard Turning, Taguchi Method, Material Removal Rate, Surface Roughness, Overall Evaluation Criteria (OEC), ANOVA.

I. INTRODUCTION

Hard turning is a machining process to turn materials having hardness values over 45HRc. The significance of speed, feed and depth of cut on cutting force and surface roughness while working with tool made of ceramic with an Al_2O_3+TiC matrix (KY1615)and the work material of AISI 1050 steel (hardness of 484 HV) have studied.

Dr. C. J. Rao [1]. M.kaladhar [2], have explored the impacts of process parameters speed, feed, depth of cut and nose range on surface complete and material expulsion rate amid turning of AISI 304 Austenitic Stainless Steels utilizing Taguchi technique. Hamdi Aouici [3], carried out experimentation on the effects of feed rate, cutting speed, work piece hardness and depth of cut on surface roughness and cutting force components in the hard turning. AISI H11 steel subjected to hardening to (40; 45 and 50) HRC, Performed machining using cubic boron nitride (CBN 7020 from Sandvik Company) which is essentially made of 57% CBN and 35% TiCN. J.S.Senthil kumaar [4] have investigated single pass complete the process of turning and facing in dry slicing condition so as to explore the execution and concentrate the wear system of uncoated carbide apparatuses on Inconel 718.H. Yanda [5] have researched the impact of feed rate, cutting rate and profundity of cut on material expulsion rate, surface roughness and device life in traditional turning of ductile cast iron FCD700 grade utilizing Tin coated cutting tool in dry condition. Anderson P. Paiva [6] have presented an alternative hybrid approach, combining response surface methodology (RSM) and principal component analysis (PCA) to optimize multiple correlated responses in a turning process. Ihsan Korkut [7] have investigated the influence of cutting rate on tool wear and surface roughness when turning an AISI 304 austenitic stainless steel using cemented carbide cutting tools. Tian-Syung LAN [8], experimented with four parameters (speed, feed rate, cutting depth, tool nose runoff) with three levels (high, medium and low) were considered to optimize the surface roughness for finish turning. Muammer Nalbant [9], have modelled regression analysis and neural network-based models for the estimation of surface roughness were compared for various cutting conditions in turning. The present work aims to investigate the effect of process parameters such as speed (N), feed (f) and cutting tool material on the performance measures namely material removal rate (MRR), surface roughness (SR) while hard turning of Aluminium alloy HE30 (AA6082) material.

II. DESIGN OF EXPERIMENTS, PROCEDURE AND SETUP

The objective of conducting experiments is to investigate the effect of process parameters such as speed, feed and cutting tool material on performance measures of hard turning of work material Aluminium alloy HE30. The properties work material and its chemical composition are shown in Table1 and Table2 respectively.

Physical property	Value
Density	2.70 g/cm³
Melting Point	555 °C
Thermal Expansion	24 $x10^{-6}$ /K
Modulus of Elasticity	70 GPa
Thermal Conductivity	180 W/mºK
Electrical Resistivity	0.038 $x10^{-6}$ Ω .m
Proof Stress	240 Min MPa
Tensile Strength	295 Min MPa
Rockwell Hardness	46 HRC

Table1: Properties of AA6082 (HE30) material

Table2: Chemical composition of AA6082

Chemical Element	% Percent
Manganese (Mn)	0.40 - 1.00
Iron (Fe)	0.0 - 0.50
Magnesium (Mg)	0.60 - 1.20
Silicon (Si)	0.70 - 1.30
Copper (Cu)	0.0 - 0.10
Zinc (Zn)	0.0 - 0.20
Titanium (Ti)	0.0 - 0.10
Chromium (Cr)	0.0 - 0.25
Other (Each)	0.0 - 0.05
Others (Total)	0.0 - 0.15
Aluminium (Al)	Balance

Three levels of each factor are selected in this case. Trial experiments are conducted using one factor-at-a-time approach to select range. The range and corresponding levels of the selected process parameters under the present study are shown in Table3

Table3: Process parameters and corresponding levels

	FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
1	SPEED (RPM)	100	700	1300
2	FEED(MM/REV)	0.2	0.3	0.4
3	TOOL MATERIAL	CARBIDE	HSS	CERAMICS

The experiments are conducted as per the L_9 (3^4) OA shown in Table4. Each experiment is repeated two times to minimize the experimental errors. The average of two trials is taken for further analysis and measurements. The experimental results of MRR and SR are further transformed into Average standard values. The "Larger -the-better" for MRR and "Smaller-the-better" for SR are selected for obtaining machining performance.

After calculation of Average standard values, the effect of each machining parameter at different levels is separated. The mean Average standard values for each process parameter at each level was calculated by averaging the average standard values for the experiments at the same level for that particular parameter. Mean of means response tables and mean of means graphs for MRR, SR are prepared by using QUALITEK-4 software. The analysis of variance (ANOVA) is used to determine which parameter significantly affects the performance measures. All the experiments were conducted on CNC Lathe machine model Jaguar. The experiments were conducted by changing parameters speed, feed and cutting tool material. Depth of cut has been kept constant for all the experiments. The experimental set up is shown in Figure1. Further experimental conditions are presented in Table5

Figure1: Experimental set up

Table5: Experimental conditions

Material	Aluminum Alloy HE30 (6082)
Machining Length	45 mm
Depth of Cut	0.4 mm
Coolant	Water
Machine	CNC Lathe

Material removal rate (MRR) and surface roughness (SR) are chosen to evaluate machining performance. A digital weighing balance (citizen) having capacity up to 300 grams with a resolution of 0.1gmswas used for weighing the work pieces. Surface roughness (Ra) of the machined work pieces is measured using MITUTOYO SJ210 SURF TEST surface roughness tester. Roughness measurements are carried out in the transverse direction on machined surface with sampling length of 0.8 mm and were repeated three times and average values are calculated.

III. Results and Discussions

Table6: Experimental data of performance characteristics MRR, SR

Exp. No.	Speed, N (rpm)	Feed Rate, f (mm/rev)	Cutting Tool Material, TM	MRR (gm/min)	SR (µm)
1	100	0.2	CARBIDE	3.8008	1.472
2	100	0.3	HSS	6.3919	2.544
3	100	0.4	CERAMICS	7.7730	4.760
4	700	0.2	HSS	8.2583	1.758
5	700	0.3	CERAMICS	14.6779	3.819
6	700	0.4	CARBIDE	15.1642	4.523
7	1300	0.2	CERAMICS	47.3200	5.523
8	1300	0.3	CARBIDE	48.2900	7.279
9	1300	0.4	HSS	51.3200	8.246

According to the qualitek-4 software inner array design, collected appropriate responses are MRR (gm/min) and SR (µm). These responses were subjected to Overall Evaluation Criteria which gives multiple objective optimum combinations.

A. Overall Evaluation Criteria

An overall evaluation criterion (OEC) Process used to optimise the multiple responses and gives the single optimum combination value. OEC technique takes the relative weightages of responses according to the weightages of multiple responses entire data will be analyzed.

In the criteria description MRR and Surface Roughness worst and best values entered and quality characteristics of individual responses were given as above and Relative weightages of responses are also given as for MRR it is 60% and for Surface roughness it is 40%. These Relative weightages indicates the process priorities. At end total relative weightages must be equal to 100%. For each trail condition MRR and Surface roughness are aligned to Single Quality characteristics and normalised with respected to relative weightages as per equation1

$$OEC = \left[\frac{M - M_W}{M_B - M_W}\right] \times W_T + \left[1 - \frac{S - S_B}{S_W - S_B}\right] \times W_T \quad \text{QC= All the cases ---------------} \quad (1)$$

Table7: Overall Evaluation Criteria

S.n	Description	Worst	Best	QC	Weightage
1	Material Removal Rate(M)	3.8008	51.32	Bigger the better	60
2	Surface roughness(S)	8.246	1.472	Smaller the better	40

As per experimentation responses from Table.6 the least MRR value is 3.808gm/min considered as the worst whereas 51.32gm/min was best. For surface roughness highest value 8.246µm is the worst and 1.472 µm. Grand value calculated as per above formulae and obtained results are plotted below. For the 7 trail experiment obtain the bigger value that is 71.02.

B. Main Effects of Parameters

Table8. Main effects of Process Parameters

Factors	Level1	Level2	Level3	Δ	Rank
Speed	34.18	39.986	64.299	30.119	1
Feed	51.593	46.229	40.643	10.951	2
Cutting tool material	46.07	46.899	45.496	1.403	3

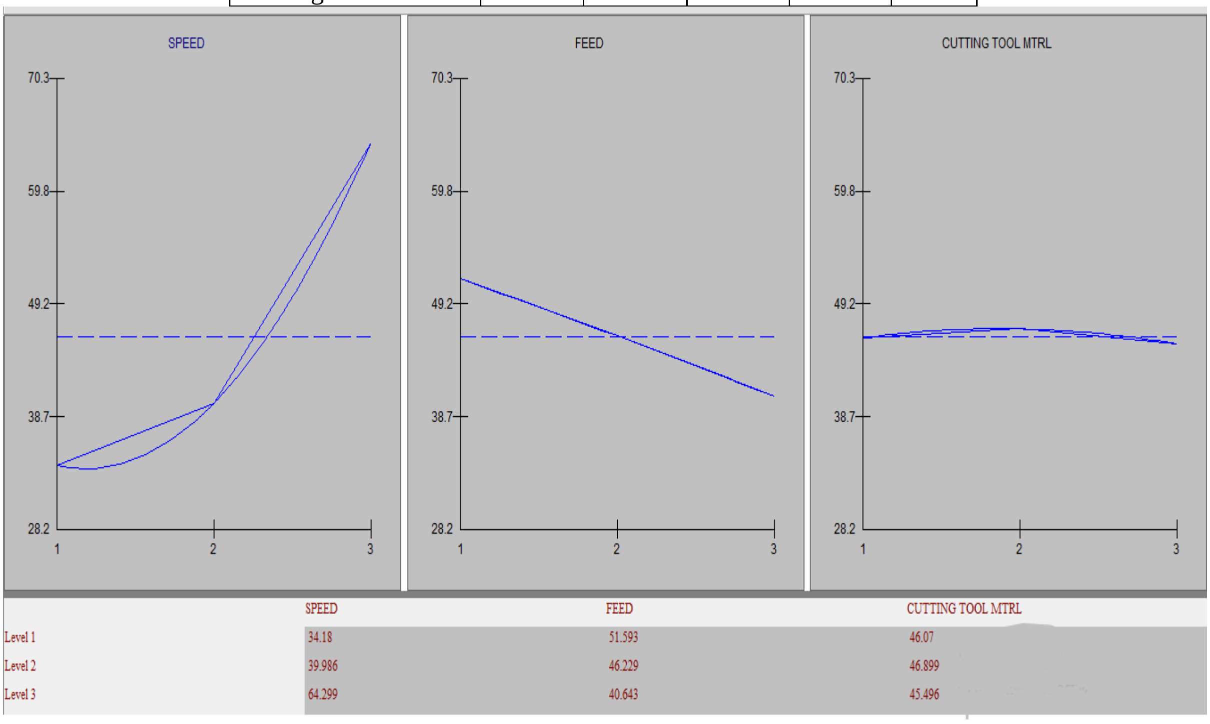

Fig2: multiple plots for process parameters

Main effect are depicting that speed at level 3, feed at level 1 and cutting tool material at level 2 gave the optimum value.

C. ANOVA (Analysis of variance)

Table9: Analysis of variance

S.No	Factors	DOF	Sum of Squares	Variance	F-Ratio	Pure Sum	Percent
1	Speed	2	1,532.068	766.034	52.165	1,502.699	86.148
2	Feed	2	179.879	89.939	6.124	150.509	8.628
3	Cutting tool material	2	2.98	1.493	0.101	0.000	0.000

Table9 is clearly showing that the percentage of contribution and F-ratios, in the hard turning experiments the speed and feed process parameters gave the high percentage contribution but comparing in between speed and feed, speed percentage contribution is 86.124 and feed percentage of contribution is 8.628, but interestingly percentage of contribution of cutting tool material is negligible. From the F-ratio also it is clear that speed factor is more significant comparing to feed and cutting tool materials.

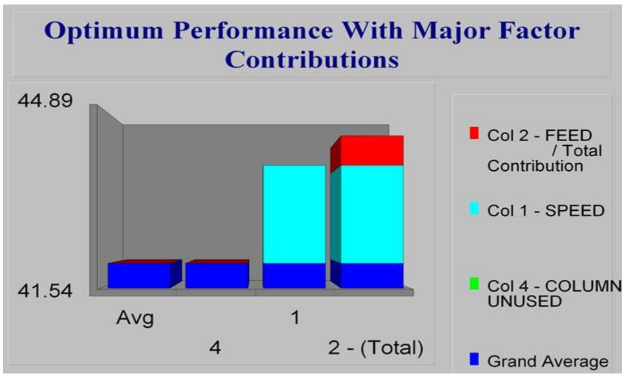

Fig5: Optimum performance with Major Factor Contributions

Fig2 clearly showing that for an optimum condition, the amount of contribution from the factors speed and feed high when to cutting tool material.

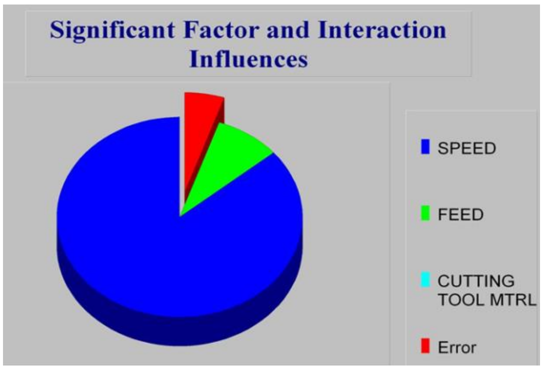

Fig3: Significant factor and interaction influences

From the above Fig3 the major significant factor shown as speed and after that feed and also an error influencing the process due to uncontrollable noise factors. Optimum condition and performance obtained as shown in following table10.

Table10: optimum condition and performance

S.No	factors	Level Description	Level	Contribution
1	SPEED	1300	3	18.144
2	FEED	0.2	1	5.437
3	CUTTING TOOL MATERIAL	HSS	2	0.744

Total contribution from all factors	24.324
Current grand average of performance	46.155
Expected result as optimum condition	70.480

From table10 it is showing that the optimum combination as speed 1300rpm, feed 0.2 mm/rev, cutting tool material is HSS. This combination is not existed in L9 OA. Confirmation experiment is conducted to verify the result obtained optimum combination.

IV. CONFIRMATION EXPERIMENTS

The confirmation experiments are conducted during hard turning of aluminium alloy HE30 (6082) at optimal parametric settings. Table10 shows optimal combination of parameters for maximum material removal rate (MRR) and surface roughness (SR). Further predicted values are compared with experimental results and the deviation is calculated as percentage error using equation (4). The percentage error calculated for all the cases is below 5%.

	Optimal process parameters		% error
	Expected Result	Experiment Result	
OEC	70.480	73.0437	3.509817

As per the pervious data results MRR (gm/min) is 51.32 and Surface roughness (µm) is 1.472 but for optimum condition showed that speed 1300rpm, feed 0.2mm/rev, cutting tool material HSS, whereas HSS cutting tool Exhibits very high roughness more than 8 µm. By the confirmation test the obtained values are MRR is 57.32gm/min, SR is 7.32 µm which are the best values compare to previous values.

V. CONCLUSIONS

Hard turning of aluminium alloy HE30 (6082) material is subjected to the experimental investigations. After analysis the final conclusions are:

1. Material removal rate and surface roughness increases with increasing in speed and also feed. However feed has a less effect on the MRR. The cutting tool material has least effect on the MRR, SR, but at the end HSS tool material exhibited more MRR and SR.
2. The significant effect of input parameters such as cutting speed, feed and cutting tool material on MRR is as follows. The cutting speed has most significant effect on the MRR, feed has less significant effect and the cutting tool material has no significant effect on MRR. However speed has most significant effect on MRR, SR.
3. Overall Evaluation Criteria gave the optimum combination of process parameters 1300rpm, 0.2mm/rev, HSS (speed, feed, and cutting tool material), which is not present in previous nine experiments.
4. Optimum combination obtained is subjected to confirmation test, from those process parameters the resulted values of MRR and SR (57.32 gm/min and 7.32µm) are better than previous values of MRR and SR (51.32gm/min and 8.246 µm). Also obtained value of surface roughness is true and Best compare to earlier values.
5. From OEC experimentation it has been concluded that the significance and Major contribution gained from Speed then Feed. Also least contribution from cutting tool material.

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