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Optimization of Process Parameters of Aluminium Alloy Material While Machining in High Speed Lathe Machine in Wet Condition by Using Grey-Taguchi

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ABSTRACT

In today's rapidly changing scenario in manufacturing industries, applications of optimization techniques in metal cutting processes is essential for a manufacturing unit to respond effectively to severe competitiveness and increasing demand of quality product in the market. The main objective of this study is to know under what parametric setting Cutting force and surface roughness is to be reduce in order to improve Surface finish and increase the tool life by changing the machining parameters of turning process. In this work, an attempt has been made to solve the correlated multiple criteria optimization problem of turning process by considering three different process parameters viz. Spindle Speed, feed and depth of cut. Grey Relational Analysis has been adopted to convert multiple objectives of the optimization problem into a single objective function, denoted as Grey Relational Grade. The overall Grey Relational Grade has been optimized by using Taguchi method. Analysis of variance (ANOVA) has been conducted for Grey relational grade (G R G) to find the optimal process parameters. Signal to Noise (S/N) Ratio has been found for GRG to find the optimal levels of the process parameters. Finally a conformation test has been made and the results have been plotted.

Keywords: Turning, Optimization, Grey-Taguchi and ANOVA

1.0 INTRODUCTION

Many engineers and researchers in industries and academicians face the difficulty in understanding the role of optimization in engineering design. Optimization is an esoteric technique used only in mathematics and operation research related activities. In most engineering design activities the design objective could be simply to minimize the cost of production. An optimization algorithm is a procedure which is executed iteratively by comparing various solutions till the optimum or a satisfactory solution is found. Md. Maksudul Islam et al. [1] applied the parameter design in the optimization of metal removal rate of ASTM A48 grey cast iron in turning operation. ANOVA is required to know the contribution of each factors and their quantitative percentage during operation. To get the accurate percentage of contribution L27 orthogonal array is used in ANOVA analysis whereas for Taguchi's method L9 orthogonal array is used. K. G. Nikam et al. [2] found that the highest surface finish (lowest Ra) is obtained at a cutting speed of 200 m/min, feed rate of 0.2 mm/revolutions and a depth of cut of 0.5mm.The results of ANOVA for surface roughness show that feed rate is most significant parameter which affects the surface finish than other cutting parameters. Vikas B. Magdum et al. [3] This study used for optimization and evaluation of machining parameters for turning on EN8 steel on Lathe machine. This study investigates the use of tool materials and process parameters for machining forces for selected parameter range and estimation of optimum performance characteristics. Suha K. Shihab [14] concluded that cutting force components are influenced principally by the depth of cut, while the effect of both cutting speed and feed rate is small. On the other hand, the depth of cut has the most significant effect on the MRR; the cutting speed has less significant effect whereas feed rate has the lowest effect.

2. EXPERIMENTAL SET UP

2.1 MATERIAL SELECTION: - **MATERIAL:-ALLOY**

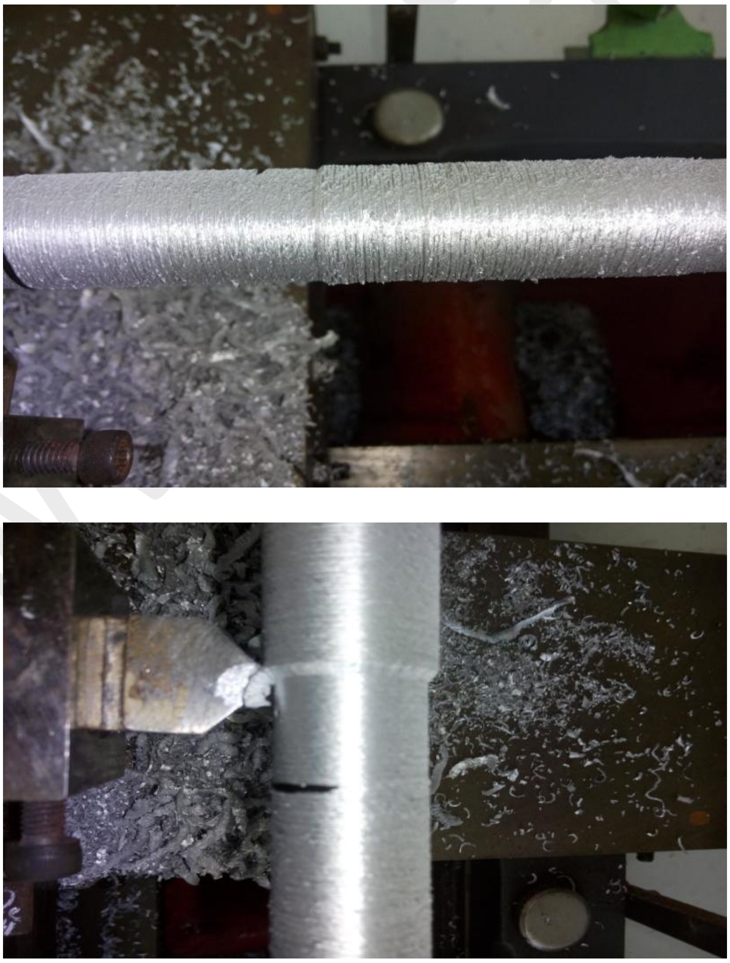

Figure 1. Shows various surfaces (alloy) at various cutting condition

2.2 SURFACE ROUGHNESS:

Surface roughness, often shortened to roughness, is a measure of the texture of a surface. It is measured by an instrument called Surface roughness Tester.

Figure 2. Shows surface roughness tester

2.3 HIGH SPEED LATHE MACHINE:

It consists of 8 spindle speeds ranging from 70 R.P.M, 116, 186, 269, 315, 525, 842, and 1250. Each speed consists of 4 different feeds.

Figure.3 Shows High Speed Lathe Machine (MGL-54)

2.4 TOOL DYNAMOMETER:

It is a device used to measure the force exerted by tool to the work piece. We are measuring three types of forces (Fx, Fy, Fz). Fx=Feed force, Fy=Thrust force, Fz=cutting force

Figure.4 Shows tool dynamometer set up

2.5 MACHINING PARAMETERS:

In this investigation, for implementation of the concept of Design of Experiments; Speed, Feed and Depth of Cut are taken as input parameters and their levels are shown in table 1. Thrust force (F_y), Feed force (F_x) and Cutting force (F_z) being the output parameters.

Condition	Speed(RPM)	Feed(mm/rev)	Depth of Cut(mm)
High(+1)	315	0.690	1.5
Medium(0)	269	0.380	1.0
Low(-1)	186	0.094	0.5

Table.1 cutting parameters and their levels

Exp No	INPUT PARAMETERS			OUTPUT PARAMETERS Force				Surface roughness (Ra)
	Speed	Feed	Depth of Cut	Cutting Force(Fz)in Kgf	Feed Force(Fx) in Kgf	Thrust Force(Fy) in Kgf	Resultant Force in Kgf (Actual)	
1	186	.094	0.5	7.14	3.59	6.5	10.30	6.65
2	186	0.380	1.0	34.90	12.24	35.10	50.98	7.023
3	186	0.690	1.5	137.1	45.65	114.2	184.17	8.432
4	269	0.094	1.0	10.89	5.28	12.61	17.47	5.432
5	269	0.380	1.5	108.3	45.33	83.62	114.13	5.896
6	269	0.690	0.5	39.08	11.5	37.38	55.28	6.587
7	315	0.094	1.5	62.65	28.5	37.7	78.47	3.963
8	315	0.380	0.5	27.65	9.65	27.65	38.36	4.217
9	315	0.690	1.0	70.48	22.52	62.29	96.71	4.754

Table 2. Shows experimental design matrix, Cutting force& Ra value for ALLOY.

3.0 OPTIMIZATION USING GREY RELATIONAL ANALYSIS COUPLED WITH TAGUCHI METHOD

Taguchi method makes use of a special design of orthogonal array (OA) to examine the quality characteristics through a minimal number of experiments (D.C Montgomery, 1997). The success of Taguchi methods is partly a consequence of experimentation being tailored to the application. The Grey system theory is mainly utilized to study uncertainties in system models, analyze relations between systems establish models and make forecasts and decisions. Multi-objective optimization problem is converted into single objective optimization problem using Grey Relational Analysis. The Grey Relational Analysis coupled with Taguchi method is adopted to optimize the process parameters of turning operation. The experimental results are first normalized to convert the experimental data to grey relational coefficients. The Turning process parameters and three materials are optimized using Grey – Taguchi to get the minimum cutting force and surface roughness. Taguchi method is a powerful tool in quality optimization for manufacturing process.

3.1 Methodology used in Grey Relational Analysis:

- Getting experimental data: The experimental value for the four output responses are tabulated and are taken to optimization.
- Normalization of experimental data: As the desired objective is to minimise cutting force and surface roughness, hence the experimental data is normalized by using the smaller -the-better (S.B) criterion the normalized data can be expressed below.

$$x_i(y) = \frac{y_i(k) - \min y_i(k)}{\max y_i(k) - \min y_i(k)}$$

Here $x_i(k)$ is the value after the grey relational generation, min y_i (k) is the smallest value of y_i (k) for the k^{th} response, and max $y_i(k)$ is the largest value of $y_i(k)$ for the k^{th} response .

- Calculation of quality loss Estimates: An ideal sequence is x_0 (k) for the responses. The quality loss for each i^{th} trial is estimated as $x_0(k) - x_i(k)$.
- Calculation of Grey Relational Coefficients: The purpose of grey relational grade is to reveal the degrees of relation between the sequences say, [$x_0(k)$ and $x_i(k)$,i=1, 2,3.......,16]. The grey relational coefficient x_i (k) can be calculated as

$$\zeta_i(k) = \frac{\Delta_{\min} + \psi\Delta_{\max}}{\Delta_{0i} + \psi\Delta_{\max}}$$

- Then we have to find out Grey relational grade by using formula:

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n} \zeta_i(k)$$

Where n =number of process responses.

Exp No	INPUT PARAMETERS			OUTPUT PARAMETERS Force				Normalisation value	Taguchi loss(Δi)	Grey relational co-efficient E_i (k)
	Speed	Feed	Depth of Cut	Cutting Force(Fz) in Kgf	Feed Force(Fx) in Kgf	Thrust Force(Fy) in Kgf	Resultant Force in Kgf (Actual)			
1	186	.094	0.5	7.14	3.59	6.5	10.30	1	0	1
2	186	0.380	1.0	34.90	12.24	35.10	50.98	0.76	0.24	0.67
3	186	0.690	1.5	137.1	45.65	114.2	184.17	0	1	0.33
4	269	0.094	1.0	10.89	5.28	12.61	17.47	0.95	0.05	0.90
5	269	0.380	1.5	108.3	45.33	83.62	114.13	0.40	0.60	0.45
6	269	0.690	0.5	39.08	11.5	37.38	55.28	0.74	0.26	0.65
7	315	0.094	1.5	62.65	28.5	37.7	78.47	0.6	0.4	0.55
8	315	0.380	0.5	27.65	9.65	27.65	38.36	0.83	0.17	0.74
9	315	0.690	1.0	70.48	22.52	62.29	96.71	0.50	0.50	0.5

Table 3. Shows the normalised value, Taguchi loss and grey relational co-efficient for cutting force.

Exp No	INPUT PARAMETERS			OUTPUT PARAMETERS SURFACE ROUGHNESS	Normalization value	Taguchi loss(Δi)	Grey relational co-efficient E_i (k)
	Speed	Feed	Depth of Cut	RA VALUE			

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1	186	.094	.5	6.65	0.39	0.61	0.45
2	186	0.380	1.0	7.023	0.315	0.685	0.42
3	186	0.690	1.5	8.432	0	1	0.33
4	269	0.094	1.0	5.432	0.67	0.33	0.60
5	269	0.380	1.5	5.896	0.56	0.44	0.53
6	269	0.690	0.5	6.587	0.41	0.59	0.45
7	315	0.094	1.5	3.963	1	0	1
8	315	0.380	0.5	4.217	0.94	0.06	0.89
9	315	0.690	1.0	4.754	0.82	0.18	0.73

Table 4. Shows the normalised value, Taguchi loss and grey relational co-efficient for Surface Roughness.

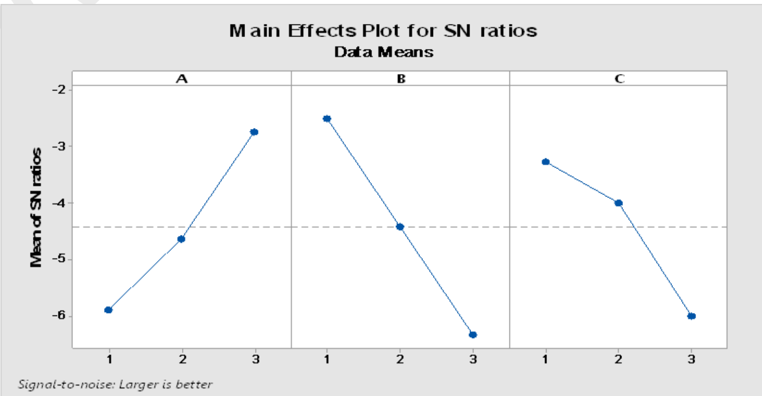
No of	Grey relational co-	Grey relational co-	Grey relational
1	1	0.45	0.725
2	0.67	0.42	0.545
3	0.33	0.33	0.33
4	0.90	0.60	0.75
5	0.45	0.53	0.49
6	0.65	0.45	0.55
7	0.55	1	0.775
8	0.74	0.89	0.815
9	0.5	0.73	0.615

Table 5. Shows Grey relational grade (Y_i)

4 RESULT AND DISCUSSION:

Exp No	INPUT PARAMETERS			Grey relational grade(Y_i)	S/N Ratio	Mean
	Speed	Feed	Depth of Cut			
1	186	.094	0.5	0.725	-2.79324	0.725
2	186	0.380	1.0	0.545	-5.27207	0.545
3	186	0.690	1.5	0.33	-9.62972	0.33
4	269	0.094	1.0	0.75	-2.49877	0.75
5	269	0.380	1.5	0.49	-6.19608	0.49
6	269	0.690	0.5	0.55	-5.19275	0.55
7	315	0.094	1.5	0.775	-2.21397	0.775
8	315	0.380	0.5	0.815	-1.77685	0.815
9	315	0.690	1.0	0.615	-4.22250	0.615

Table 6. Shows SN ratio and mean obtained from MINI TAB Software



Graph-1 shows the main effect for SN ratios.

Taguchi Analysis: grey relational grade versus A, B, C

Response Table for Signal to Noise Ratios

Larger is better

Level	A	B	C
1	-5.898	-2.502	-3.254
2	-4.629	-4.415	-3.998
3	-2.738	-6.348	-6.013
Delta	3.161	3.846	2.759
Rank	2	1	3

Linear Model Analysis: SN ratios versus A, B, C

Estimated Model Coefficients for SN ratios

Term	Coef	SE Coef	T	P
Constant	-4.42177	0.1184	-37.358	0.001
A 1	-1.47657	0.1674	-8.821	0.013
A 2	-0.20743	0.1674	-1.239	0.341
B 1	1.91978	0.1674	11.469	0.008
B 2	0.00677	0.1674	0.040	0.971
C 1	1.16749	0.1674	6.975	0.020
C 2	0.42399	0.1674	2.533	0.127

S = 0.3551   R-Sq = 99.5%   R-Sq(adj) = 98.0%

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	15.1775	15.1775	7.5887	60.19	0.016
B	2	22.1916	22.1916	11.0958	88.00	0.011
C	2	12.2269	12.2269	6.1134	48.49	0.020
Residual Error	2	0.2522	0.2522	0.1261		
Total	8	49.8481				

The optimal factor setting becomes, Speed=315 rpm feed=0.094 mm/rev, Depth of cut=0.5 mm obtained in the grey- Taguchi method. The variation of S/N ratio with overall grey relation grade for four parameters i.e speed (A), feed (B), depth of cut (C).The parametric setting we are achieving as 3-1-1(i.e Speed at 3 level, Feed at 1 level and Depth of cut at 1 level.).Under this parametric setting we are achieving a low surface roughness and the cutting force was minimum.

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5. CONCLUSIONS

In the above study, the use of GRA-based hybrid Taguchi method has been proposed and adopted for the solution of multi-objective optimization in a turning process. Application of GRA can eliminate multi co linearity of the output responses and transform these correlated responses into uncorrelated quality indices called Grey Relational Grade. Absence of correlation between the responses is the basic assumption for applying Taguchi optimization technique. It can be recommended that the GRA based hybrid Taguchi method is good, for example, in the case of (chemical and pharmaceutical) industries when there are hundreds of response variables.

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