OPTIMIZATION OF OPERATIONAL PARAMETER VALUES OF A JIG BORING PROCESS USING GREY ANALYSIS AND SN RATIO METHOD

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Abstract

Jig boring operation is one of the frequently used machining operation in the field of construction and manufacturing. As this operation is one of the important metal removing operation and frequently used in the field of manufacturing, it is very much required to do this operation with optimum process parameters. In the present study firstly most relevant process parameters for a set of output or target parameters have been identified and then those process parameters have been optimized for the best values of the identified target parameters.

The process parameters or operational parameters which have been identified are like 'Feed Rate (mm/rev)', 'Depth of Cut (mm), Cutting Speed (m/min) and 'Material Property (S_{yt} in MPa). It has been seen by extensive observations that these process or operational parameters effects mostly the target parameters or output parameters like Material Removing Rate (MRR)(gm/sec), Vertical Force (kg force) and Surface Finish (R_a value). To do this optimization work first few level values of the input or operational parameters have been set according to the experimental setup. Then using Taguchi a L9 diagonal array has been set to create nine set of input or operational parameters with different level values to conduct the experiment. After each experiments the output parameter values have been noted. In the next step of this work effect of these machining parameters on the performance of the machining or more especially the process of boring has been examined by doing Grey Analysis on the output parameters. Grey Analysis predicts the optimum effect of all the input parameters on all the output or performance parameters. To examine the effect of input parameters on any particular output parameter Sound/Noise (S/N) analysis has been done.

Keywords: Design of Experiment (DOE), Taguchi Method, Grey Analysis.

INTRODUCTION

Design of Experiment has a very important role in designing any system, any process and a machine. Also DOE plays a deciding role in fine tuning or in optimizing working parameters of any system after its design for smooth running and to obtain optimum performance parameters.A systematic methodology is adopted in DOE to examine the input parameters on the output or performance data generated through an experiment. The designing of the sequence matrix of the input parameters and corresponding output parameters is done in DOE procedures and their analysis is also done in DOE. Different types of analysis can be done with different methodologies in DOE on the basis of experimental data. For example to examine the effect of input parameters on all the output parameters cumulatively we can use Grey Analysis and to know the effect of input parameters on any particular output parameters we can go for Sound/Noise ratio.

TAGUCHI DATA TABLE GENERATION

In the present work an experiment has been done on boring material removing process with work piece of Aluminum, Steel and Brass. To do the experiment in a structured way first the following machining attributes have been considered with three level of parameter values and has been shown in table below.

Table1: Input or Process parameters with levels

Factor	Parameter (Unit)	Level 1	Level 2	Level 3
1	Feed rate (mm/rev)	0.03	0.06	0.09
2	Depth of Cut (mm)	0.4	0.7	1.0
3	Cutting Speed (m/min)	200	800	2000
4	Material Property (S_{yt} in MPa)	Al (225)	Steel (440)	Brass (217)

To optimize the boring machine following mentioned performance parameters have been considered. The performance parameters which have been considered are Vertical Force exerted on the work piece (measured in kg force), Surface Roughness of the bored surface (measured in Ra value) and Material Removing Rate i.e. MRR (measured in gm/sec).

In next step the experimental data matrix has been created with help of Taguchi method using the input parameters or the process parameters and output parameters or the response parameters. Here L9 diagonal array has been considered four attribute and three level for each attribute. The L9 diagonal array has been represented in the table below in Table number 2.

Table 2. L9 Diagonal Array as per Taguchi

Run	Factor 1	Factor2	Factor3	Factor4	Response1	Response 2	Response 3
	Feed Rate	Depth of cut	Speed	Material	MRR	Vertical Force	Surface finish
					gm/sec	Kg Force	Ra
1	1	1	1	1			
2	1	2	2	2			
3	1	3	3	3			
4	2	1	2	3			
5	2	2	3	1			
6	2	3	1	2			
7	3	1	3	2			
8	3	2	1	3			
9	3	3	2	1			

The output parameters have been generated or the response parameters have been generated as per the experiment done according to the set of level combinations of four attributes following Taguchi L9 diagonal matrix mentioned above. The combination of the level values of the input or the process parameters and corresponding output parameters after experiments. These have been depicted below in table 3.

Table 3: Combination of input and output parameters as per Taguchi L9 diagonal array.

Run	Feed Rate	Depth of Cut	Speed	Material	Force	Ra	MMR
1	0.03	0.4	200	225	2.5	1.217	0.011
2	0.03	0.7	800	440	3.5	0.715	0.266
3	0.03	1	2000	217	6.2	0.18	0.59
4	0.06	0.4	800	217	2.9	0.098	0.1975
5	0.06	0.7	2000	225	7	1.248	0.187
6	0.06	1	200	440	19.5	0.601	0.173
7	0.09	0.4	2000	440	4	0.688	0.551
8	0.09	0.7	200	217	5.8	0.177	0.129
9	0.09	1	800	225	2.5	1.689	0.27

EXPERIMENTAL PROCEDURE

Here in this section a detailed procedure has been mentioned regarding experimental methodology by virtue of which experimental data have been generated.

The field data was acquired in Bhilai Steel Plant, machine shop. Machining was conducted on Jig boring machine where normal condition for machine operation
temperature is 20^0C,Limit of Relative dampness of the atmosphere is 55%.

In this experiment work piece specimen size of steel, brass and aluminum plates are 400*70*25 mm. CERATIZIT make S40TI type of cutting tool inserts is used for boring operation.
The following sequential procedure was used to carry out the experiment under dry condition.

1. In order to properly control the depth of cut the internal diameter of the work pieces has been fixed to 25 mm via drilling operation up to plate thickness

2 Boring operations in different material is started with fresh cutting edge. As per orthogonal array L^9 experiment run is conducted and accordingly vertical force is measured.

3 After each pass removed metal chips is collected and weight is done and also surface roughness is measured on roughness meter SJ-201.

4. In each trial, surface roughness, volume of metal removed, time and vertical force is identified.

ANALYSIS OF DATA

To predict the influence of input parameters on output parameters, optimization has been done using Grey Relational Analysis and with Sound/Noise Ratio analysis. Grey Relational Analysis will predict optimum combination of input parameter levels for over all best values of output parameters.

For the Grey analysis we have to first normalize the values of the experimental values as mentioned below.

First step in GRA is to normalize all the experimental data in the range of zero to one. Such normalization is necessary because the range and the unit in one response may vary from the others. If the response is of 'higher-the-better' characteristics, equation for normalizing is as follows:

$$x_i^*(k) = \frac{x_i(k) - \min x_i(k)}{\max x_i - \min x_i(k)} \quad (1)$$

If 'lower-the-better' criterion is to be followed, then the following equation is to be utilized for normalizing the corresponding data:

$$x_i^*(k) = \frac{\max x_i(k) - x_i(k)}{\max x_i - \min x_i(k)} \quad (2)$$

Implementing the above mentioned inequalities or relations we have got the processed data which has been represented below.

Table 4: Normalized values of all the output parameters for each run

Exp. No.	N_Force	N_Ra	N_MMR
1	1.000	0.297	0.000
2	0.941	0.612	0.440
3	0.782	0.948	1.000
4	0.976	1.000	0.322
5	0.735	0.277	0.304
6	0.000	0.684	0.280
7	0.912	0.629	0.933
8	0.806	0.950	0.204
9	1.000	0.000	0.447

Here $x_i*(k)$ and $x_i(k)$ are the normalized data and observed data respectively for ith experiment using kth response.

After normalizing the responses, the next step is to calculate the grey relation coefficient (GRC). GRC is denoted by for kth response. It can be calculated by using equation below.

$$\zeta_i(k) = \frac{\Delta_{\min} + \zeta\Delta_{\max}}{\Delta_i(k) + \zeta\Delta_{\max}} \quad (3)$$

Where, $\Delta_i(k)$ is the absolute value of the difference between and $x^0{}_i(k)$ and $x^*{}_i(k)$ $\Delta_i(k) = |x^*{}_i(k) - x^0{}_i(k)|$. Δ_{max} and Δ_{min} are the global maximum and global minimum values in the different data series, respectively. The distinguishing coefficient lies between 0 and 1, which is to expand or compress the range of GRC, general, ξ= 0.5 is taken.

Table 5: Difference values all the output parameters for each run.

Exp. No.	D_Force	D_Ra	D_MMR
1	0.000	0.703	1.000
2	0.059	0.388	0.560
3	0.218	0.052	0.000
4	0.024	0.000	0.678
5	0.265	0.723	0.696
6	1.000	0.316	0.720
7	0.088	0.371	0.067
8	0.194	0.050	0.796
9	0.000	1.000	0.553

Table 6: Grey relational coefficient and Gradation values.

Exp. No.	GRC_Force	GRC_Ra	GRC_MMR	GRG
1	1.000	0.416	0.333	0.583
2	0.895	0.563	0.472	0.643
3	0.697	0.907	1.000	0.868
4	0.955	1.000	0.424	0.793
5	0.654	0.409	0.418	0.494
6	0.333	0.613	0.410	0.452
7	0.850	0.574	0.881	0.768
8	0.720	0.910	0.386	0.672
9	1.000	0.333	0.475	0.603

Now from the gradation values as mentioned in the column named GRC as per table 6 we can produce response table of Grey Relational Analysis and response table of S/N Ratio Analysis.

RESULT AND DISCUSSION

From the above analysis following response table for Grey Relational Analysis can be created from the Grade values as mentioned in GRC column of Table6. The response table will be as follows.

Table 7: Response table from Grey Relational analysis

Response Table				
Level	A	B	C	D
1	0.698	0.7149	0.5689	0.5598
2	0.5796	0.6029	0.6797	0.6212
3	0.6811	0.6408	0.7099	0.7776
Delta	0.1184	0.1119	0.141	0.2178
Rank	3	4	2	1

So as per ranking of the response the optimum combination of the process parameters are as follows

Table 8: Optimum Combination of Level Values of Input Variables according to Grey Relational Analysis

Parameter	Description with unit	Level
A	Feed rate (mm/rev)	1
B	Depth of Cut (mm)	1
C	Cutting Speed (m/min)	3
D	Material Property (S_{yt} in MPa)	3

The graphical representation of Grey Analysis

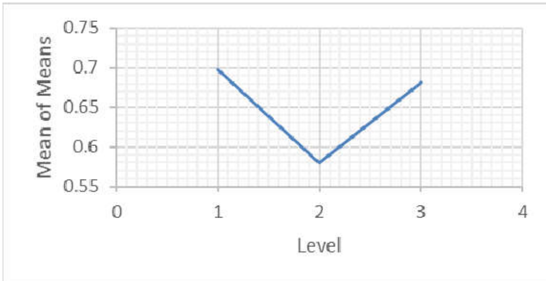

Fig1: Graph of Response Variation of Input Variable 'A' in Grey Relational Analysis

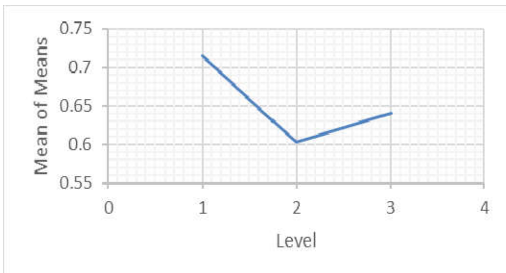

Fig2: Graph of Response Variation of Input Variable 'B' in Grey Relational Analysis

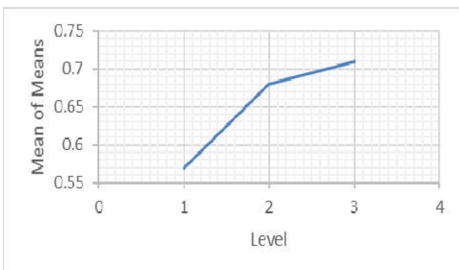

Fig3: Graph of Response Variation of Input Variable 'C' in Grey Relational Analysis

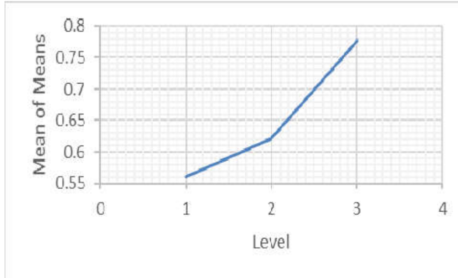

Fig4: Graph of Response Variation of Input Variable 'C' in Grey Relational Analysis

Now the response table to optimize input variables for least value to 'Vertical Force' according to S/N ratio will be.

Table 9: Response table from S/N ratio analysis for minimization of 'Vertical Force'

Response Table				
Level	A	B	C	D
1	-11.563	-9.749	-16.343	-10.94
2	-17.317	-14.351	-9.363	-16.241
3	-11.756	-16.536	-14.93	-13.455
Delta	5.754	6.786	6.98	5.301
Rank	3	2	1	4

So as per ranking of the response the optimum combination of the process parameters are as follows

Table 10: Optimum Combination of Level Values of Input Variables according to response table of S/N ratio analysis on 'Vertical Force' minimization

Parameter	Description with unit	Level
A	Feed rate (mm/rev)	1
B	Depth of Cut (mm)	1
C	Cutting Speed (m/min)	2
D	Material Property (S_{yt} in MPa)	1

The corresponding graphical representation will be

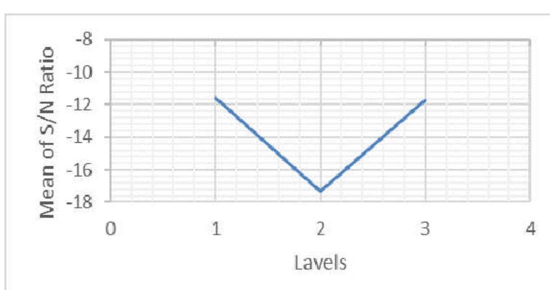

Fig5: Graph of Response Variation of Input Variable 'A' in S/N ratio Analysis regarding 'Vertical Force' minimization

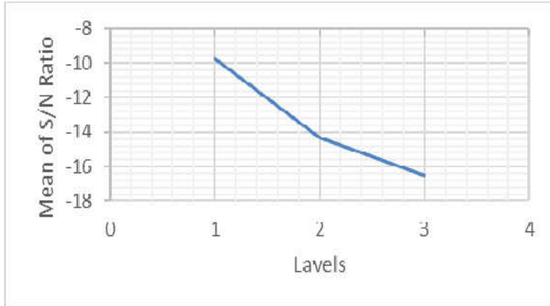

Fig6: Graph of Response Variation of Input Variable 'B' in S/N ratio Analysis regarding 'Vertical Force' minimization

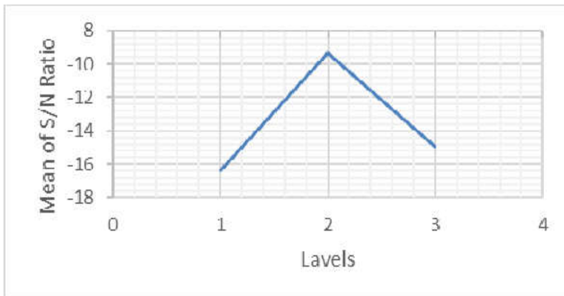

Fig7: Graph of Response Variation of Input Variable 'C' in S/N ratio Analysis regarding 'Vertical Force' minimization

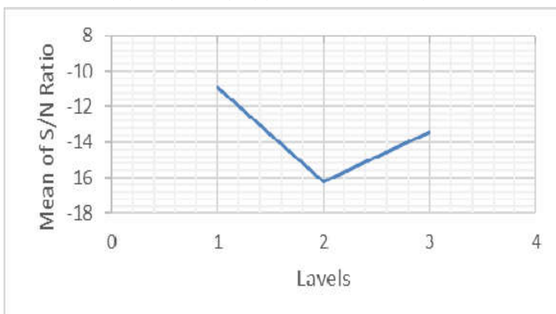

Fig8: Graph of Response Variation of Input Variable 'D' in S/N ratio Analysis regarding 'Vertical Force' minimization

Next the response table to optimize input variables for least value to 'Ra value' according to S/N ratio will be.

Table 11: Response table from S/N ratio analysis for minimization of 'Ra value'

Response Table				
Level	A	B	C	D
1	5.368	7.239	5.919	-2.728
2	7.558	5.343	6.179	3.528
3	4.579	4.921	5.406	16.704
Delta	2.979	2.318	0.773	19.431
Rank	2	3	4	1

So as per ranking of the response the optimum combination of the process parameters are as follows

Table 12: Optimum Combination of Level Values of Input Variables according to response table of S/N ratio analysis on 'Ra value' minimization

Parameter	Description with unit	Level
A	Feed rate (mm/rev)	2
B	Depth of Cut (mm)	1
C	Cutting Speed (m/min)	2
D	Material Property (S_{yt} in MPa)	3

The corresponding graphical representation will be

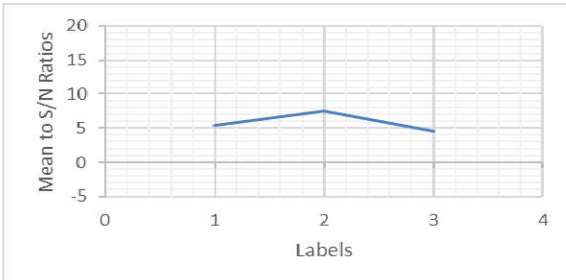

Fig9: Graph of Response Variation of Input Variable 'A' in S/N ratio Analysis regarding 'Ra Value' minimization

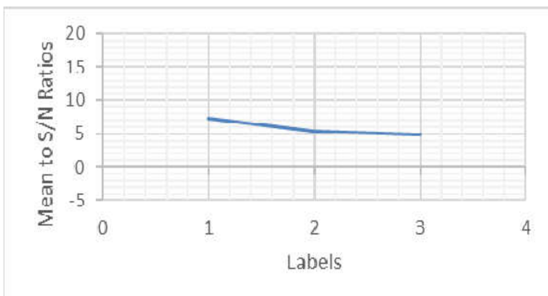

Fig10: Graph of Response Variation of Input Variable 'B' in S/N ratio Analysis regarding 'Ra Value' minimization

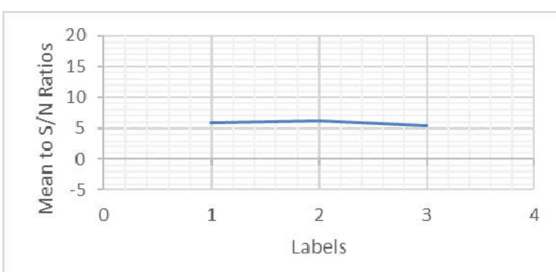

Fig11: Graph of Response Variation of Input Variable 'C' in S/N ratio Analysis regarding 'Ra Value' minimization

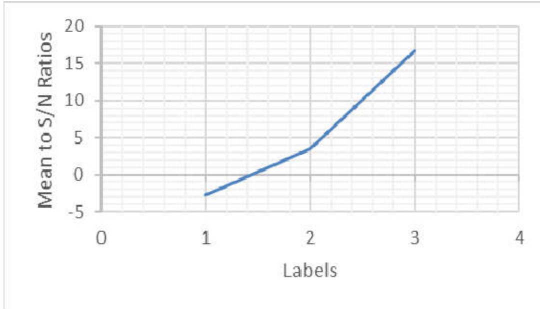

Fig12: Graph of Response Variation of Input Variable 'D' in S/N ratio Analysis regarding 'Ra Value' minimization

Next the response table to optimize input variables for largest value to 'MRR' according to S/N ratio will be.

Table 12: Response table from S/N ratio analysis for maximization of 'MRR'

Response Table				
Level	A	B	C	D
1	-18.419	-19.479	-24.066	-21.703
2	-14.63	-14.618	-12.321	-10.639
3	-11.446	-10.398	-8.108	-12.153
Delta	6.973	9.081	15.959	11.063
Rank	4	3	1	2

So as per ranking of the response the optimum combination of the process parameters are as follows

Table 13: Optimum Combination of Level Values of Input Variables according to response table of S/N ratio analysis on 'MRR' Maximization

Parameter	Description with unit	Level
A	Feed rate (mm/rev)	3
B	Depth of Cut (mm)	3
C	Cutting Speed (m/min)	3
D	Material Property (S_{yt} in MPa)	2

The corresponding graphical representation will be

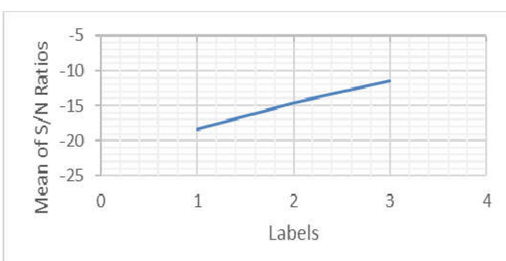

Fig13: Graph of Response Variation of Input Variable 'A' in S/N ratio Analysis regarding 'MRR' maximization

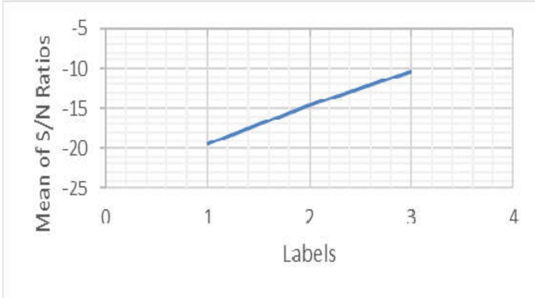

Fig14: Graph of Response Variation of Input Variable 'B' in S/N ratio Analysis regarding 'MRR' maximization

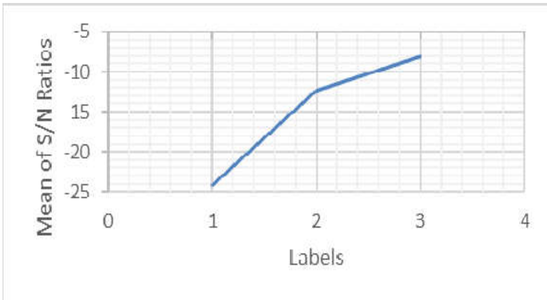

Fig15: Graph of Response Variation of Input Variable 'C' in S/N ratio Analysis regarding 'MRR' maximization

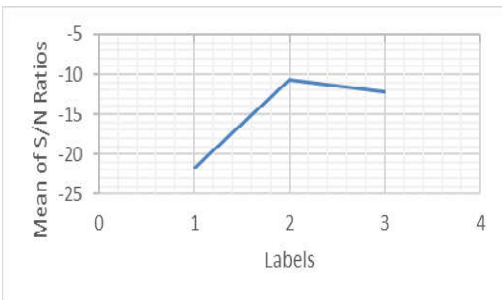

Fig16: Graph of Response Variation of Input Variable 'D' in S/N ratio Analysis regarding 'MRR' maximization

CONCLUSIONS AND FUTURE SCOPE

From the above analysis it is quite clear that a Jig Boring machine can be optimized for overall performance parameters or it can also be optimized for any specific performance parameter. To do the overall optimization Grey Relational analysis is very useful and for the optimization of the input variables regarding to the best value of any particular output variable it has been found that S/N ratio analysis is useful.

When input parameters or the process parameters are optimized for best value of any individual output parameter then it has been noticed that the optimum value of the process parameters are different for different objective parameters.

In future this work can be extended with L29 diagonal matrix where we can do the ANOVA analysis to know the percentage contribution of any particular input parameter on the performance. Also we can do any other mathematical optimization using Genetic Algorithm or Artificial Neural Network or Particle Swarm Optimization (PSO) technique or Ant Colony optimization technique etc after determining the trend of dependency of output parameters on the input parameters using Regration Analysis

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