Optimization of Turning Parameters on 45C8 Steel Cylindrical Rods Using Grey-Taguchi Methodology

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Abstract: *In this research, the experiments were performed by using a material specimen of 45C8 to know the effect of different machining parameters on tool wear. The main aim of every manufacturing industry to reduces the wastage of time, material, machinery services, labor cast, etc..In Every production industry, the most important process's turning operation on the round bars, cylindrical bars and conical type of bars. The main aim of this works to find out minimum surface roughness and maxima material removal rate. The most important input parameter are speed, feed, and depth of cut. In This experimental retrospection for turning operations is done on a CNC lathe. Taguchi-Grey Relational Analysis is adopted to convert the multiple objectives of the optimization problem into the single objective. Turning operations are performed based on the orthogonal array with L9 for 45C8 carbon steel. The experimental results are analyses using ANOVA techniques. ANOVA mainly explained at the percentage of the conurbation. Grey relation is to find out the combined optimal response values.*

Keywords: *45C8, Turning Parameters, Taguchi, DOE, S/N Ratio, ANOVA.*

I. INTRODUCTION

The recent developments in science and technology have put tremendous demands on manufacturing industries. The present work includes 45C8 carbon steel. Finding many more applications such as shaft, axle, gears and Fasteners due to their high hardness, strength to weight ratio. Optimums machining input parameters of turning operations are more influenced by concern along with the manufacturing environment. The 45C8 carbon steel. With different parameters such as spindle speed, feed rate and depth of cut are more influenced by response parameters. It is normally supplied in the cold drawn or as-rolled condition. Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material.

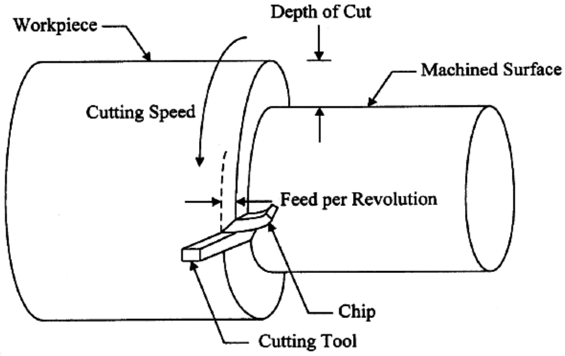

Fig1: Turning operation

The turning process requires a turning machine or lathe, work piece, fixture, and cutting tool. The work piece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The Lathe is a machine tool used to remove unwanted material from a given workpiece to get the desired shape. It is generally used for machining cylindrical work-pieces. Cutting operations in this lathe involved a lot of manual labour and consumed a large amount of time. Turning operation mainly effective sources are speed, feed, depth of cut, toll wearing and tall tip radius those are main effects on the material removal rate and surface roughness The Taguchi's system is the standardized approach, for deciding the best creation of information and to deliver the result of component influences. Taguchi was able to determine the control variables and levels.

II. LITERATURE SURVEY

Literature study is required to understand the correct objective of the project work. The post research work gives the better idea and clear contains of cognition .it helps us to reach to a particular destination. The goal is “Optimization of the turning process parameters using Taguchi Method”. Taguchi Method provides a systematic & efficient methodology for the design optimization of the cutting parameter with for less effect than would be required for the most optimization technology

Ashish Bhateja ,Jyoti Bhardwaj, Maninder singh,and sandeepkumar[1]

The first objective of this paper is selection of cutting tool and work piece material and their geometry, selection of various process parameters and their levels and after section experimental L9orthogonal array on minitab16 software. Conducted the experiments and next measures the response variables are surfaces roughness and material removal rate .by using the taguchi method to calculate the best optimal cutting parameters. Analysis of variance is to find out parentage of contribution which parameter is most significant

Quazi TZ, Partik more, Vipul sonawane [2]

In this paper an attempt is made to review the literature on optimization of machining parameters in turning processes by using taguchi method the setting of turning parameters are determined by using taguchi method next selecting work pieces material and selection of levels next conducting the experimental process after to find out the response variable values are tool wear and machining process time next calculation of signal to noise ratio

Yigit kazancoglu, Ugur esme Melih Bayramglu,Onur Guven , Sueda Ozgun[3]

They investigated the multi-objective optimization of the turning process for an optimal parametric combination to yield the minimum cutting and surfaces roughness and the maximum material removal rate by using the combination of the grey analysis and taguchi method. first selection of input parameters cutting speed feed rate and depth of cut next selected levels after to formation of L9 orthogonal array . to find the output parameters are measured final conclude the best optimal values

Aasheet kumar , Gaurav Chaudhary and Manish kalra[4]

This paper explained at most effect turning input operation are find out the best optimal response values by using on taguchi method . Those are selected best orthogonal array L27 next conducted the experimental and the find out surface roughness was most affected by cutting speed .the impact of feed rate was somewhat smaller on the influence of depth of cut was least pronounced. By using the ANOVA to fine out the how much percentage of speed, feed rate and depth of cut are calculate

S.K. Madhavi, D.sreeraramu, M.venkatesh [5]

The main objective of this study is to improve toughness and hardness of the of engineering material by changing the machine parameters of turning process by applying the taguchi method the quality of manufactured goods. Grey relational analysis is mainly use of the multi objective parameters in to single objective parameter. After find out the grey relational grade (GRD).the applying taguchi technique to take the response variable into the (GRD) to find the optimal input variables in this paper L9 orthogonal array will be selected, next to find out the normalization of the output response next it will be find out the grey relational coefficient and average of two variables GRC .next fined the final order formation of raking the best optimal response is first rank

III. METHODOLOGY

Taguchi method this is most impotent statistical optimization technology. He is Japanese engineer who has been active in the improvement of japans industrial product and process since in the 1940s many Japanese firms achieved great success by applying his methodology. During 1983 taguchi associated with the top most company’s and institutes of USA (ford motor company, XEROX)

Process of optimization

Process of optimization can be defined as the method of finding the conditions that will be given the maximum or minimum vales of response. To determine the controllable factors that will affect the desired response .To minimizes the effect of uncontrollable or noise factors. To determine the optimum combinations of controllable factors that will given the best values of the desired response. Multi-response where a balance is to be achieved between a numbers of desired responses

Two of the most commonly used techniques of the process optimization are:

1) Taguchi experimental design
2) Response surface methodology

Experimental designs there are two types:

1) Full factorial design: The total number of experimental are required to run all possible combinations of all the levels for each of the factors
2) Fractional factorial design: A portion of total combinations. If orthogonality is maintained the fractional factorial matrices be call as orthogonal array.

Robust experimental design

The fundamental principle of robust design is to improve the quality of product by minimizing the effect of the causes of variation without eliminating the causes. This is achieved by optimizing the product and process design to make the performance minimally sensitive to the various causes of variation. Robust design methodology serves as an amplifier. it enable an engineer to generate required information needed for decision-making with much less experimental effort. It is critical to obtain dependent information about the process parameter so that any changes during manufacturing and customer use are avoided. this is achieved by employing signal to noise (SN) portion to measure quality and orthogonal array to study many design parameters simultaneously. The applications of robust-design are not limited to engineering filed; the technology has been successfully employed for "profit planning in business and cash flow optimization". Robost design methodology offers continuous improvement of product quality, performance, cost, and engineering productivity.

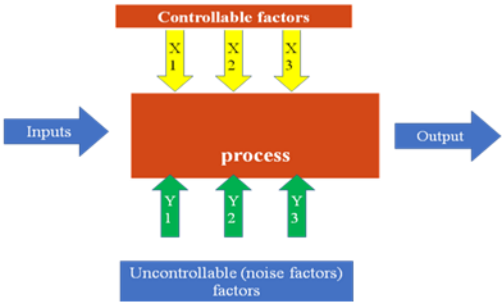

Fig 2 General model of process or system

Orthogonal Array

Columns of the array are mutually orthogonal .it means that for any pair of columns, all combinations of factors levels occur and they occur an equal number of times. This is called a balancing property and it implies orthogonal array. The number of rows of an orthogonal array represents the number of experiments. The number of columns of an array represents the maximum number of factors that can be studied using that array. Taguchi has tabulated 18 basic orthogonal array that are called standard orthogonal array depending up on the number of factors and their levels it is generally possible to select one of these for specific requirements.

Orthogonal array selection rules

Taguchi developed orthogonal arrays to identify factors influence without less of accuracy.

For two levels

Number of factors	Orthogonal array
2 to 3	L_4
4 to 7	L_8
8 to 11	L_{12}
12 to	L_{16}

For three levels

Number of factors	Orthogonal array
2 to 4	L_9
5 to 7	L_{27}

1) **Signal to noise ratio**

A signal to noise ratio is measure of robustness, which can be used to identify the control settings that minimize the effect of noise on the response .signal to noise ratio for each combination of control factors levels in the design. Choose from different signal to noise ratios depending on the goal of our experiment

Small is better

The Signal-To-Noise ratio for the Smaller-The-Better is: S/N =-10*log (sum of the mean square of the response.

$$S/N = -10\log_{10}\left(\frac{\sum y^2}{n}\right)............................(a)$$

2) ***High is better***

The S/N equation for the Nominal-The-Best is:

S/N = 10 * log (sum of the square of the mean divided by the variance)

$$S/N = -10\log_{10}\left(\frac{1}{n}\sum\frac{1}{y^2}\right)...........................(b)$$

3) Nominal is better

The Signal-To-Noise the bigger-the-better is:

S/N = -10*log (mean square of the inverse of the response)

$$S/N = 10\log_{10}\left(\frac{y^2}{s^2}\right)................................(C)$$

Taguchi-Grey Relation Analysis

Grey theory was proposed by Dr.Deng which includes Grey relation analysis and grey modeling. Grey relation analysis is used to determine the relationship between machining parameters and machining performance.

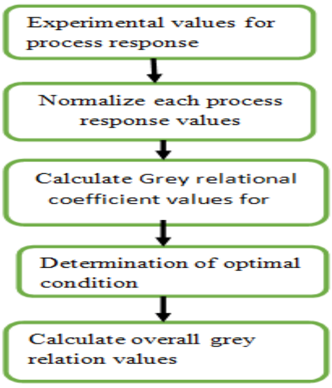

Fig: 3 Procedure of the grey – taguchi technique

Grey relation analysis is suitable for solving problems with the complicated interrelationship between multiple factors and variables grey relation analysis is solves multi-attribute decision-making problems by combing the entire range of performance attribute values being considered for every alternative into a single decision-making problem. Grey relation analysis requires fewer data and can analyze many factors that can overcome the disadvantages of statistical method

Multi Response Optimization Using Grey Relational Analysis

There are three step are their

Step 1: normalization of the experiment

The first step in grey –taguchi analysis in the normalization of the the experimental result of the MRR and surface roughness. Each response value is normalized in the range of 0 to 1. For normalization of MRR "High-the better" (equation 1) criterion and for normalization of surfaces roughness (SR) "Lower is better" (equation 2) criterion used.

$$Zij = \frac{Yij - max(Yij)}{max(Yij) - min(Yij)} \quad (1)$$

$$Zij = \frac{max(Yij) - Yij}{max(Yij) - min(Yij)} \quad (2)$$

Where,

Z_{ij} = value after the normalization data /Grey relational generation value

Min (Y_{ij}) = smallest value of the all response values

Max (Y_{ij}) = largest value of the all response values

Step 2: Grey relational coefficient

After normalization the result of MRR and surface roughness, the nest step in the calculation to the grey relational coefficient values for MRR and SR. To express the relation between actual and ideal (it means value is 1) experimental values

Grey relational coefficient (∈) can be calculated by using equation (3)

$$GCij = \frac{\Delta min - \epsilon\Delta max}{\Delta ij - \epsilon\Delta max} \quad (3)$$

where

GCij = grey relational coefficient for the i th experiment and j th response

Δij = absolute difference between Yoj and Yij

Yoj = optimum performance value or the ideal normalized value of jth response

Yij = the ith normalized value of the j th response dependent variable

Δmin = minimum value of Δ

Δmax = maximum value of Δ

∈ = distinguishing coefficient and its value can be taken between 0and 1

Step 3: Grey relational grade and order

In this step calculation of multi objective response is converted into single objective .first average the grey coefficient values and next find the ranking at each order .High value of grey relational grade indicate the best value, so high value grade value gives the highest order

Grey relational grade

$$GRG = \frac{1}{N}\sum GCij \qquad (4)$$

Where

N = Number of responses

GCij = Grey relation coefficient

IV. EXPERIMENTAL SET UP

a. Material properties

Most of the mechanical components are made up of 45C8 carbon steel material. This material mostly used for machine tools, bigger gears, bolts, lead screws feed rods shafts and rocks.

Elements	Composition %	Element	Composition %
Carbon	0.42-0.50	Chromium	0.25max
Silicon	0.10-0.35	Molybdenum	0.05max
Manganese	0.60-0.90	Vanadium	0.05max
Phosphorous	0.035max	Copper	0.35max
Sulfur	0.035 max	Nickel	0.25max

Table: 1 chemical composition of 45C8 material

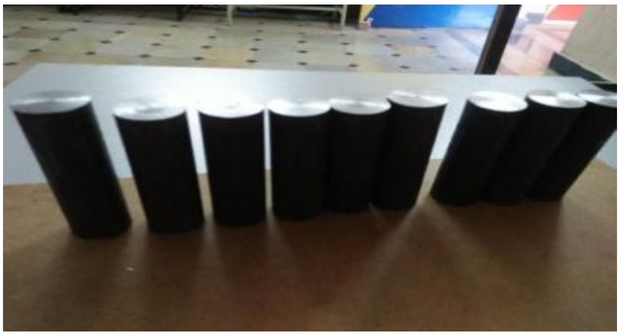

Fig4: 45C8 carbon steel material before machining

Mechanical properties of 45C8

Property	Value
Density	7.85 g /cc
Melting point	1300ºC
Modulus of elasticity	190-210 Gpa
Thermal conductivity	49.8 W/mk
Thermal expansion	11*10-6/K

Table: 2 Mechanical properties

b. CNC Turning machine

Today's most of the industries are using the CNC machines this mainly reduces errors and do a good quality of products it can be produced and also reduces the labor expenses. It can take a less machining time

Fig :5 CNC machine

Specifications of Siemens 828D basic T lathe machine

Speculations of lathe	Values
Length bed	2275 mm
Height	1620 mm
Breadth	1640 mm
Max swing over bed	480 mm
Max swing over the carriage	260 mm
Max turning length	262 mm
Spindle speed	4500-6000 rpm
Tailstock sleeve	MT-4
Power required	19KV

Table: 3 specification of Siemens 828Dbasic T lathe machine

c. Tungsten carbide insert

This is a single point cutting tool. Its combination of carbon and tungsten allay.

Fig: 6 Tungsten carbide insert

Chemical composition of tungsten carbide inserts

Material	Composition %
Carbon	0.5%
Cobalt	10%
Molybdenum	6%
Chromium	2.5%
Tungsten	81%

Table: 4 Chemical composition of tungsten carbide insert

d. Surface roughness tester

This most important for measuring the roughness of the finished product .it is more important inaccuracy by tolerance .if tolerance is high, the surface roughness of the workpiece is not good condition. While producing the product, the most important parameter to continue the process is surface finishing for any type of shapes

Specifications

Model	SJ 201
Range of measurements	0-360 µm
Stylus type	SJ 310
Least count	0.02µm

Table: 5 specifications of surface roughness tester

Fig 7: surface roughness measuring instrument

V. EXPERIMENTAL DESIGN

Optimization of process parameters in turning of 45C8 by using taguchi method

There are various responses considered during turning of 45C8 material; all of those responses optimized by using taguchi method. Taguchi method is best technique to select the best parameters combination for to get best minimized and maximized responses values .taguchi method applied separately for each individual response output. The response output considered for the taguchi optimization study is minimum surface roughness and maximum material removal rate. The process parameters with three levels of spindle speed, feed rate and depth of cut are used for the optimization.

S.NO	Process parameters	Level 1	Level 2	Level 3
1	Spindle speed(rpm)	1200	1600	2000
2	Feed (mm/rev	0.1	0.2	0.3
3	Depth of cut(mm)	0.5	1.0	1.5

Table: process parameters

Orthogonal array (OA)

Orthogonal array allows for the maximum number of main effects to be estimated in an orthogonal array manner, with minimum number of runs used in the study as presented in table

Experimental runs	Spindle speed	Feed rate	Depth of cut
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

Table6: basic L9 orthogonal array

VI. EXPERIMENTAL RESULT

The turning experiment performed on 48C8 carbon steel rod for optimize the process parameters for the responses material removal rate and surface roughness. The experimental result displayed in the table

Exp no	Speed	feed	Depth of cut	Ra (μm)	MRR (mm^3/sec)
1	1200	0.1	0.5	2.01	78.53
2	1200	0.2	1.0	2.36	314.15
3	1200	0.3	1.5	1.75	706.85
4	1600	0.1	1.0	3.22	209.43
5	1600	0.2	1.5	1.70	661.65
6	1600	0.3	1.0	2.54	314.15
7	2000	0.1	1.5	2.89	392.69
8	2000	0.2	0. 5	3.33	261.79
9	2000	0.3	1.0	2.74	785.39

Table7: Experimental result of45C8 carbon steel

Fig8: 45C8 carbon steel material after experiment

The optimization study performed by using Minitab 18.1 software. Signal to noise ratio (SN ratio) values for45C8 carbon steel material are displayed in below table

Exp no	Speed	feed	Depth of cut	Ra SNRA	MRR SNRA
1	1200	0.1	0.5	-6.06	97.90
2	1200	0.2	1.0	-7.45	49.90
3	1200	0.3	1.5	-4.86	56.98
4	1600	0.1	1.0	-10.15	46.42

5	1600	0.2	1.5	-4.60	56.41
6	1600	0.3	1.0	-8.09	49.94
7	2000	0.1	1.5	-9.21	51.88
8	2000	0.2	0. 5	-10.31	48.35
9	2000	0.3	1.0	-8.75	57.90

Table8: signal to noise ratio for 45C8 carbon steel

Fig show the effect of spindle speed, feed rate and depth of cut on signal to noise ratio of the surface roughness. From the Fig: it is investigated that signal to noise ratio is lower at high speed, low feed rate and medium depth of cut. The optimal test condition for obtaining for lower surface roughness is speed at third level (2000 rpm), feed rate at first level (0.1) and depth of cut at first level (0.5)

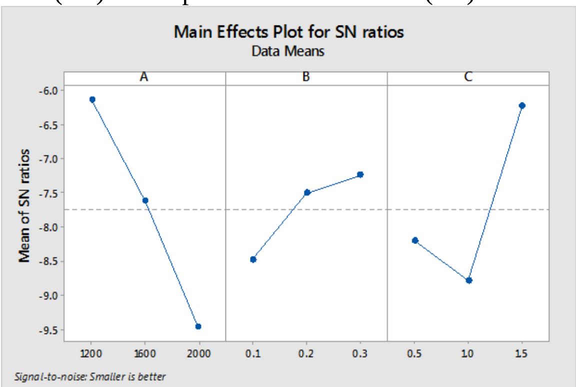

Fig: 8 Effective of process parameters on Ra for45C8

Level	Speed	Feed	Depth of cut
1	-6.128	-8.480	-8.203
2	-7.621	-7.505	-8.790
3	-9.474	-7.237	-6.229
Delta	3.347	1.242	2.561
Rank	1	3	2
Optimal S/N ratio	Speed -3	Feed rate -1	Depth of cut -2

Table: 9 Response table for S/N ratio of Ra for 45C8

Fig: show the effect of spindle speed, feed rate and depth of cut on signal to noise ratio of the material removal rate (MRR). From the Fig: it is investigated that signal to noise ratio is high at high speed, high feed rate and high depth of cut. The optimal test condition for obtaining for high material removal rate is speed at third level (2000 rpm), feed rate at first level (0.3) and depth of cut at first level (1.5)

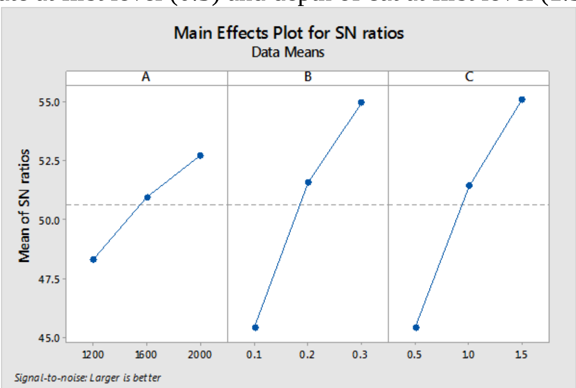

Fig: 9 Effective of process parameters on MRR for45C8

Level	Speed	Feed	Depth of cut
1	48.28	45.40	45.40
2	50.93	51.57	51.42
3	52.71	54.94	55.09
Delta	4.44	9.54	9.68
Rank	3	2	1
Optimal S/N ratio	Speed -3	Feed rate -3	Depth of cut -3

Table: 10 Response table for S/N ratio of MRR for 45C8

Multi response optimization by using grey relational analysis

Taguchi method is very efficient in optimizing single response, but it is not suited for optimizing multiple responses. Grey relation analysis can solve above maintained problem, in this method a grey relation grade is used for to get the best solution in multiple response .grey relational analysis applied on the responses surface roughness and material removal rate

Grey relational analysis for 45C8 carbon steel

In the grey relational analysis normalization is done for all the response output, there are two normalization equations (1 and 2) performing normalization like lower and high the better

Exp no	Speed	Feed	Depth of cut	Ra	MRR
1	1200	0.1	0.5	0.806	0.000
2	1200	0.2	1.0	0.587	0.333
3	1200	0.3	1.5	0.968	0.888
4	1600	0.1	1.0	0.050	0.185
5	1600	0.2	1.5	1.000	0.824
6	1600	0.3	1.0	0.475	0.333
7	2000	0.1	1.5	0.256	0.444
8	2000	0.2	0. 5	0.000	0.259
9	2000	0.3	1.0	0.350	1.000

Table: 11 Normalization values for 45C8

Grey relational coefficient for 45C8 carbon steel

Grey relation coefficient value are calculated by using equation (3)

Exp no	Speed	Feed	Depth of cut	Ra	MRR
1	1200	0.1	0.5	0.721	0.333
2	1200	0.2	1.0	0.548	0.429
3	1200	0.3	1.5	0.941	0.818
4	1600	0.1	1.0	0.345	0.380
5	1600	0.2	1.5	1.000	0.741
6	1600	0.3	1.0	0.488	0.429
7	2000	0.1	1.5	0.402	0.474
8	2000	0.2	0. 5	0.333	0.403
9	2000	0.3	1.0	0.435	1.000

Table: 12 Grey relational coefficient values for45C8

Below table Display the grey relational grades, which are used for to identify the best process parameter combination for for obtaining best multiple response results. Grey relational grade (GRG) is calculated by using equation (4)

Exp no	Speed	Feed	Depth of cut	GRG	Order /rank
1	1200	0.1	0.5	0.527	4
2	1200	0.2	1.0	0.488	5
3	1200	0.3	1.5	0.879	1
4	1600	0.1	1.0	0.362	9
5	1600	0.2	1.5	0.870	2
6	1600	0.3	1.0	0.458	6
7	2000	0.1	1.5	0.437	7
8	2000	0.2	0. 5	0.368	8
9	2000	0.3	1.0	0.717	3

Table: 13 grey relational grade and order/ rank for 45C8

The higher grey relational grade relational grade is achieved for trail 3; so that best multi response results are achieved by using trail 3.The best values for the surface roughness and material removal rate are obtained by using trial 3

The mean of the grey relational grade at different levels is displayed table

Level	Speed	Feed	Depth of cut
1	-4.301	-7.183	-7.007
2	-5.599	-5.371	-5.975
3	-6.246	-3.591	-3.164
Delta	1.945	3.391	3.843
Rank	3	2	1
Optimal S/N ratio	Speed -3	Feed r -2	Depth of cut -3

Table: 14 Response table for grey relational grade

From table, it is found that the difference between maximum GRG and minimum GRG for cutting speed is very low and rank 3 is given to the cutting speed, based on this it is decided that cutting speed is having least significance on the multiple responses

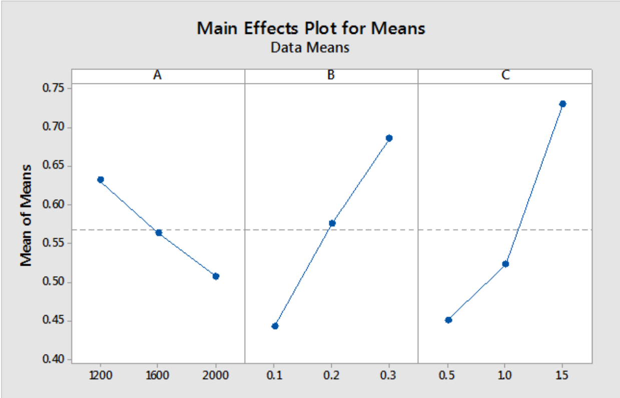

Fig: 10 Main effective plots mean for GRG

It is the observed that the higher GRG is achieved for the process parameters combination speed feed depth of cut and this combination gives the optimal result for the responses Ra and MRR

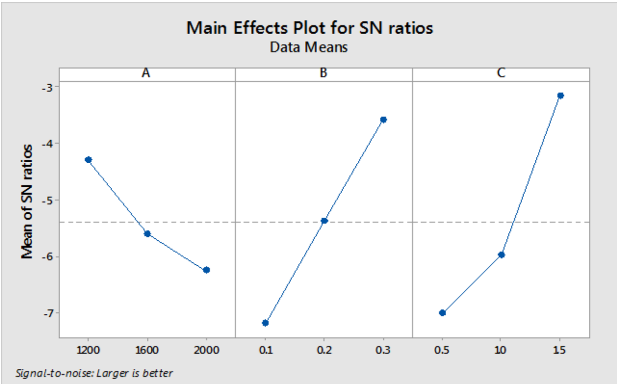

Fig: 11 Main effect plots for Grey relational grade (S/N Ratio)

As grade implies "higher the better" type response, it can be seen from the main effect plots that the third level of spindle speed, the first level of federate and the first level of depth of cut provides the highest value of grade. The S/N ratio plot a suggests the optimal condition i.e. the first level of speed, third level of feed rate and third level of depth of cut as the best optimal condition for obtaining maximum MRR and minimum SR in turning the process

ANOVA (analysis of variance)

Source	DF	Seq SS	Adj SS	Adj MS	P	F	% of contribution
Speed	2	10.88	10.88	5.44	0.27	0.78	15.45
Feed	2	22.34	22.34	12.17	0.90	0.52	34.55
Depth of cut	2	33.73	33.73	16.86	1.10	0.47	47.88
Residual error	2	1.48	1.48	0.74			2.12
Total	8	70.44					

Table: 15 Analysis of variance of GRG

ANOVA table was obtained by performing the Analysis of variance (ANOVA) in the Minitab17 tool. ANOVA was used to find out the percentage contribution of each control factor over GRG. This analysis is carried out for a significance level of α=0.05, i.e. for a confidence level of 95%. Sources with a P-value less than 0.05 were considered to have a statistically significant contribution to the performance measures. And the higher

F-ratio shows more effect and more contribution of the input parameter over MRR. The ratio between the mean square factors to the mean square errors is called F-ratio.

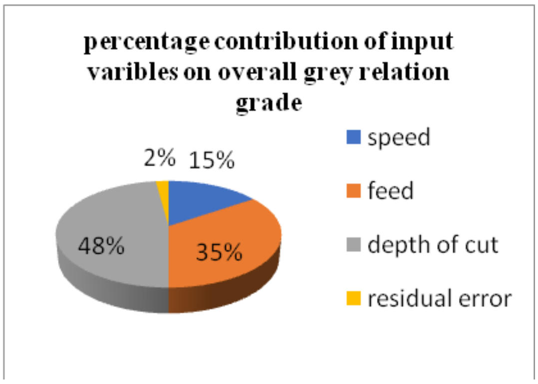

Fig: 12 percentage of contribution

VII. RESULT

The experimental investigation data is normalized and a grey relational grade is obtained. it is kept the maximum value i.e. higher the better .the value is subjected to ANOVA test which provides to the percentage of contribution of the input parameters. The optimization values are obtained from the main effective plots diagram .from the response tables the input parameters are ranked to determine which input variables affect more on the output response. So the following result is obtained after the test was completed.

Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)	Surface roughness (μm)	Material removal rate (mm^3/min)
1200	0.3	1.5	1.83	706.85

Table: 16 Final optimum response values

VIII. CONCUSSION

In this paper effects of turning parameters on surface roughness and material removal rate of 45C 8 carbon steel using tungsten carbide insert was investigated .experimentation is doing as per taguchi L9 orthogonal array. Optimal combination of machining parameters and their levels for minimum surface roughness and maximum material removal rate are obtain and significance of the machining parameters is determine using ANOVA based on the result of the present study the following conclusion are given

1) Turning robust design is successfully used for the optimizing turning parameters on45C8 carbon steel
2) Optimal combination of machining parameters for surface roughness and material removal rate fined at spindle speed 1200 rpm , feed rate 0.3 mm/ rev and depth of cut 1.5mm
3) Depth of cut contributes maximum (48%) , followed by spindle speed (15%) and feed rate at (35%) to the minimum surface roughness and maximum material removal rate

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