International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-1, October 2012

Application of Taguchi Method for Optimizing Turning Process by the effects of Machining Parameters

Krishankant, Jatin Taneja, Mohit Bector, Rajesh Kumar

Abstract- This paper reports on an optimization of turning process by the effects of machining parameters applying Taguchi methods to improve the quality of manufactured goods, and engineering development of designs for studying variation. EN24 steel is used as the work piece material for carrying out the experimentation to optimize the Material Removal Rate. The bars used are of diameter 44mm and length 60mm. There are three machining parameters i.e. Spindle speed, Feed rate, Depth of cut. Different experiments are done by varying one parameter and keeping other two fixed so maximum value of each parameter was obtained. Operating range is found by experimenting with top spindle speed and taking the lower levels of other parameters. Taguchi orthogonal array is designed with three levels of turning parameters with the help of software Minitab 15. In the first run nine experiments are performed and material removal rate (MRR) is calculated. When experiments are repeated in second run adain MRR is calculated. Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The metal removal rate was considered as the quality characteristic with the concept of "the larger-the-better". The S/N ratio for the larger-the-better Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration with the help of software Minitab 15. The MRR values measured from the experiments and their optimum value for maximum material removal rate. Every day scientists are developing new materials and for each new material, we need economical and efficient machining. It is also predicted that Taguchi method is a good method for optimization of various machining parameters as it reduces the number of experiments. From the literature survey,it can be seen that there is no work done on EN24 steel. So in this project the turning of EN24 steel is done in order to optimize the turning process parameters for maximizing the material removal rate.

Keywords : Taguchi Method, Machining Parameters, Turning Process, EN24 Steel, Software Minitab15

I. INTRODUCTION

Turning is a form of machining or a material removal process which is used to create rotational parts by cutting away unwanted material as shown in Fig. 1.1. The turning process requires a turning machine or lathe, work piece, fixture, and cutting tool. The work piece is a piece of re-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is also secured in the machine. The cutting tool feeds into the rotating work piece and cuts away material in the form of small chips to create the desire shape.

Manuscript published on 30 October 2012.
* Correspondence Author (s)
Krishankant , Faculty of Mechanical Engineering ,Galaxy Global Group of Institutions,Dinarpur ,Ambala,India.
Jatin Taneja , Faculty of Mechanical Engineering ,Galaxy Global Group of Institutions,Dinarpur ,Ambala,India.
Mohit Bector, Faculty of Mechanical Engineering ,Galaxy Global Group of Institutions,Dinarpur ,Ambala,India.
Rajesh Kumar, Faculty of Mechanical Engineering ,Kurukshetra Institute Of Technology & Management ,India.

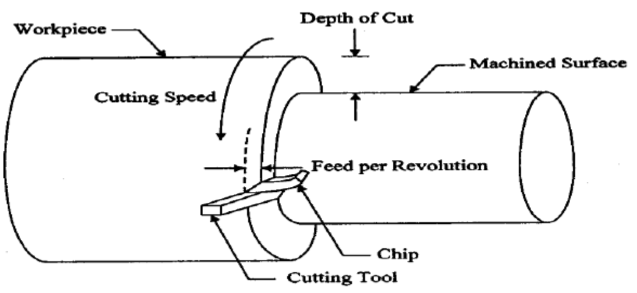


Fig. 1.1 Turning Process

In turning, the speed and motion of the cutting tool is specified through several parameters. These parameters are selected for each operation based upon the workpiece material, tool material, tool size, and more. Turning parameters that can affect the processes are:

a) Cutting speed - The speed of the work piece surface relative to the edge of the cutting tool during a cut, measured in surface feet per minute (SFM).

b) Spindle speed - The rotational speed of the spindle and the work piece in revolutions per minute (RPM). The spindle speed is equal to the cutting speed divided by the circumference of the work piece where the cut is being made. In order to maintain a constant cutting speed, the spindle speed must vary based on the diameter of the cut. If the spindle speed is held constant, then the cutting speed will vary.

c) Feed rate - The speed of the cutting tool's movement relative to the work piece as the tool makes a cut. The feed rate is measured in mm per revolution.

d) Depth of cut - The depth of the tool along the radius of the work piece as it makes a cut, as in a turning or boring operation. A large depth of cut will require a low feed rate, or else it will result in a high load on the tool and reduce the tool life. Therefore, a feature is often machined in several steps as the tool moves over at the depth of cut.

The Taguchi method is a well-known technique that provides a systematic and efficient methodology for process optimization and this is a powerful tool for the design of high quality systems. Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. This is an engineering methodology for obtaining product and process condition, which are minimally sensitive to the various causes of variation, and which produce high-quality products with low development and manufacturing costs. Signal to noise ratio and orthogonal array are two major tools used in robu design.

*Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)*

The S/N ratio characteristics can be divided into three categories when the characteristic is continuous

a) Nominal is the best

b) Smaller the better

c) Larger is better characteristics.

For the maximum material removal rate, the solution is "Larger is better" and S/N ratio is determined according to the following equation:

$$S/N = -10log_{10}\{\frac{1}{n}\sum\frac{1}{y^2}\}$$

Where, S/N = Signal to Noise Ratio,

n = No. of Measurements,

y = Measured Value

The influence of each control factor can be more clearly presented with response graphs. Optimal cutting conditions of control factors can be very easily determined from S/N response graphs, too. Parameters design is the key step in Taguchi method to achieve reliable results without increasing the experimental costs.

EN24T is most suitable for the manufacture of parts such as heavy-duty axles and shafts, gears, bolts and studs. EN24T is capable of retaining good impact values at low temperatures hence it is frequently specified for harsh offshore applications such as hydraulic bolt tensionless and ship borne mechanical handling equipment. EN24 is usually supplied in the finally heat treated condition (quenched and tempered to "T" properties) up to a limiting ruling section of 250mm, which is superior to grades 605M36, 708M40 or 709M40. EN24 is a very popular grade of through-hardening alloy steel, which is readily machinable in the "T" condition. EN24T can be further surface-hardened typically to 58-60 HRC by induction or nitride processes, producing components with enhanced wear resistance. EN24 sections larger than 250mm may still be available in the quenched and tempered condition, but it should be noted that a fall-off in mechanical properties may be apparent approaching the centre of the bar. It is therefore recommended that larger sizes are supplied in the annealed (softened) condition, and that quenching and tempering is carried out after initial stock removal. This should achieve better mechanical properties towards the core.

Experiment Set UP / WORK UNDERTAKEN

The experimental setup used for conducting the experiments by using single point cutting tool on Lathe

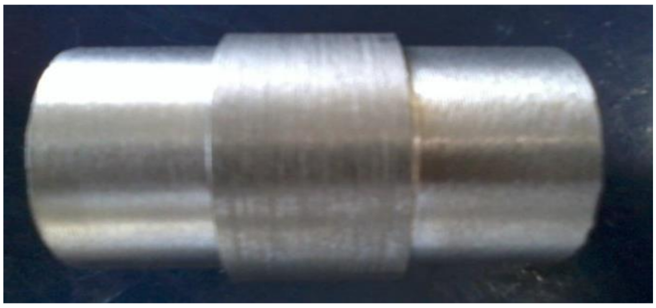
Cutting tool:-

The tool is single point cutting tool made of high speed steel. It is grinded after each experiment and the same tool geometry is maintained by using the Bevel Protector Combination Set. The tool used is of MIRANDA, S-400 as

S No	Angle	Value
1	Side Rack Angle	7^0
2	Back Rake Angle	9^0
3	Side Cutting Edge Angle	13^0
4	End Cutting Edge Angle	12^0
5	Side Relief Angle	6^0
6	End Relief Angle	8^0

Workpiece Material :-

EN24 steel is used as the workpiece material for carrying out the experimentation to optimize the Material Removal Rate. The bars used are of diameter 44mm and length 60mm.



Chemical Composition of EN24

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

S No	Metal	Range
1	Carbon	0.36-0.44%
2	Silicon	0.10-0.35%
3	Manganese	0.45-0.70%
4	Sulphur	0.040%
5	Phosphorus	0.035%
6	Chromium	1.00-1.40%
7	Molybdenum	0.20-0.35%
8	Nickel	1.30-1.70%

Mechanical Properties of EN24 Steel

S No	Mechanical Property	Range
1	Max Stress	850-1000 N/mm^2
2	Yield Stress	680 N/mm^2
3	Yield Stress	650 N/mm^2
4	Elongation	13%
5	Impact KCV	50 Joules
7	Hardness	248-302 Brinell

Material Removal Rate (MRR) Measurement From the initial and final weight of job MRR is calculated and the relation is given below:

MRR = (Initial Wt - Final Wt)/Time Taken

MRR is calculated for both set of experiment. Considering one set correct S/N ratio is calculated from MINITAB 15 software.

Taguchi Orthogonal Array

If there is an experiment having 3 factors which have three values, then total number of experiment is 27. Then results of all experiment will give 100 accurate results. In comparison to above method the Taguchi orthogonal array make list of nine experiments in a particular order which cover all factors. Those nine experiments will give 99.96% accurate result.

By using this method number of experiments reduced to 9 instead of 27 with almost same accuracy.

1.1 Available Spindle Step :-

Total there are six spindle speeds three are in forward gear and three are in back gear. There values are given in Table 3.4

Spindle Speed	Forward gear(rpm)	Back Gear(rpm)
1	216	40
2	347	60
3	536	95

1.2 Available Feed Rate :-

There are two levers which can be engaged in the combination of A-D, B-D, A-C, B-C to get desired feed rate. The feed rates available on the lathe machine are given .

1.3 Working Level of Process Parameters :-

Experiments are performed to find the working levels of parameters. The levels are observed in experiments are shown below Table :-

Feed Rate

Gear No	A-D (mm/rev)	B-D (mm/rev)	A-C (mm/rev)	B-C (mm/rev)
1	0.085	0.165	0.338	0.675
2	0.090	0.180	0.360	0.713
3	0.098	0.195	0.388	0.775
4	0.105	0.210	0.418	0.825
5	0.115	0.228	0.458	0.913
6	0.125	0.250	0.500	1.013
7	0.143	0.280	0.563	1.100
8	0.158	0.315	0.623	1.250

Process Parameter

Level	Spindle Speed(rpm)	Feed Rate(mm/rev)	Depth of Cut(mm)
1	216	0.388	0.9
2	347	0.418	1.0
3	536	0.458	1.1

1.5 Design of Experiment :-

Taguchi's designs aimed to allow greater understanding of variation than did many of the traditional designs. Taguchi contended that conventional sampling is inadequate here as there is no way of obtaining a random sample of future conditions. Taguchi proposed

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

extending each experiment with an "outer array" or orthogonal array should simulate the random environment in which the experiment would function.

Design of Experiment

S No	Spindle Speed(rpm)	Feed Rate(mm/rev)	Depth of Cut(mm)
1	216	0.388	1.1
2	216	0.418	1
3	216	0.458	0.9
4	347	0.388	1
5	347	0.418	0.9
6	347	0.458	1.1
7	536	0.388	0.9
8	536	0.418	1.1
9	536	0.458	1

1.6 Experimentation :-

The whole experimentation is divided into different steps. All the steps are discussed in detail below:

1.6.1 **Preparation of Job**

After doing initial turning on workpiece the diameter is reduced to 47mm. Workpiece is cut into equal part of length 60mm and measured initial weight of all jobs.

1.6.2 Maximum Limits of Operating Parameters

There are three machining parameters i.e. Spindle speed, Feed rate, Depth of cut. Different experiments are done by varying one parameter and keeping other two fixed so maximum value of each parameter was obtained. Operating range is found by experimenting with top spindle speed and taking the lower levels of other parameters. A combination of all three parameters is found beyond which tool or job fails.

1.6.3 Taguchi Orthogonal Array

Taguchi orthogonal array is designed with three levels of turning parameters with the help of software Minitab 15.

Taguchi Orthogonal Array

JOB NO.	Spindle Speed(rpm)	Feed Rate(mm/rev)	Depth of Cut(mm)
1	1	1	3
2	1	2	2
3	1	3	1
4	2	1	2
5	2	2	1
6	2	3	3
12	3	1	1
8	3	2	3
9	3	3	2

1.6.4 Experiment Performed :-

Experiments are performed according to the selected design of experiment as shown in Table. Machining time is noted by stopwatch and measured final weight of all jobs. Material removal rate (MRR) is calculated by using relation

MRR = (Initial Wt – Final Wt)/ Machining Time

1.6.5 Second Set of Experiment

All the above steps are repeated to perform next set of experiment.

1.6.6 Observation

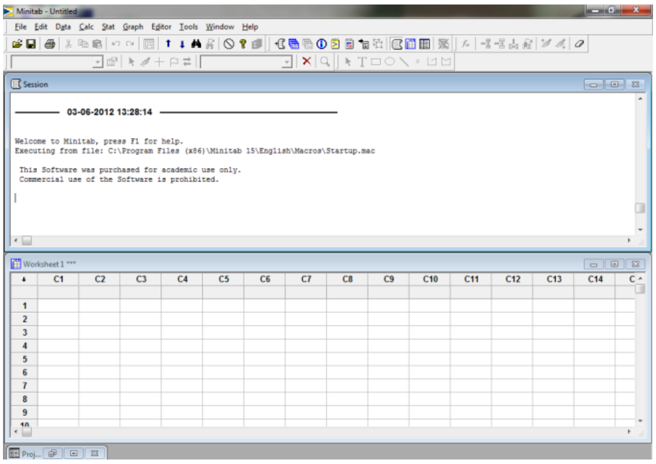
In the first run nine experiments are performed and material removal rate (MRR) is calculated. When experiments are repeated in second run adain MRR is calculated. The observation tables are given below.

Observation of First Run

Spindle Speed (N, RPM)	Feed Rate (mm/rev)	Depth of Cut (mm)	Time (Sec)	Initial Weight (g)	Final Weight (g)	Diff. of Weight (g)	MRR 1 (g/sec)
216	0.388	1.1	16	737	714	23	1.44
216	0.418	1	15	757	738	19	1.27
216	0.458	0.9	11.8	762	744	18	1.53
347	0.388	1	9.98	762	740	22	2.20
347	0.418	0.9	9	758	740	18	2.00
347	0.458	1.1	8	784	766	18	2.25
536	0.388	0.9	7.1	753	746	7	0.99
536	0.418	1.1	7.1	758	742	16	2.25
536	0.458	1	6.41	727	716	11	1.72

Observation of Second Run

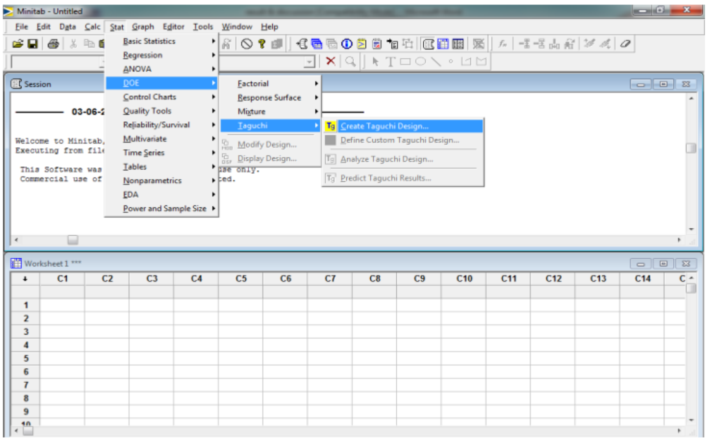
Spindle Speed (N, RPM)	Feed Rate (mm/rev)	Depth of Cut (mm)	Time (Sec)	Final Weight (g)	Initial Weight (g)	Diff. of Weight (g)	MRR 2 (g/sec)
216	0.388	1.1	15.66	692	714	22	1.40
216	0.418	1	15.41	718	738	20	1.30
216	0.458	0.9	11.71	726	744	18	1.54
347	0.388	1	10	714	736	22	2.20
347	0.418	0.9	8.75	722	740	18	2.06
347	0.458	1.1	8.13	748	766	18	2.21
536	0.388	0.9	6.1	740	746	6	0.98
536	0.418	1.1	6.54	728	742	14	2.14
536	0.458	1	6.39	704	716	12	1.88



1.6.7 Design of Orthogonal Array :-

First Taguchi Orthogonal Array is designed in Minitab15 to calculate S/N ratio and Means which steps is given below:

Create Taguchi Design is selected as shown in figure . Then a window of Taguchi design is opened.



RESULTS & DISCUSSION

Calculations :-

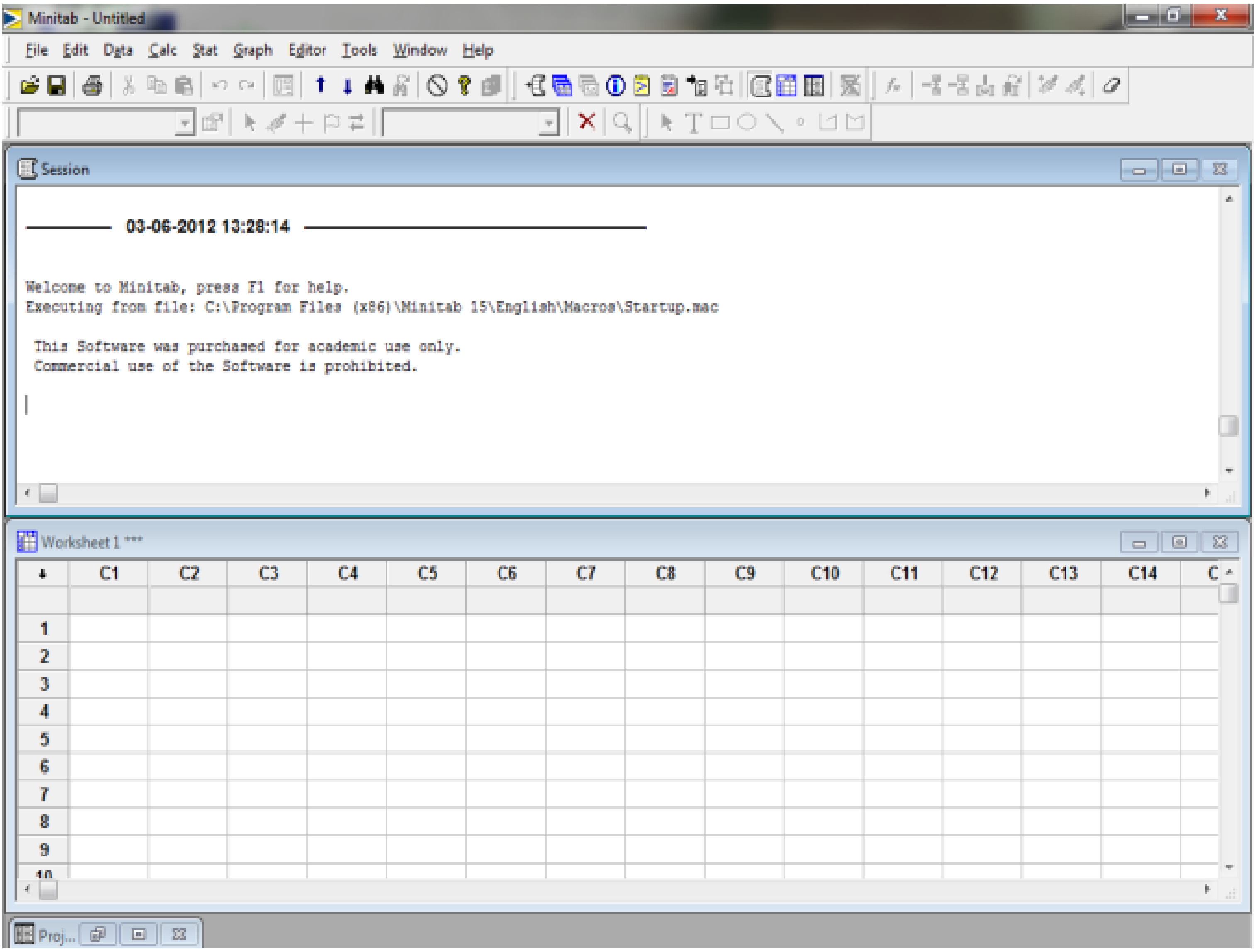
After finding all the observation as given in Table 3.10 and 3.11, S/N ratio and Means are calculated and various graph for analysis is drawn by using Minitab 15 software. The S/N ratio

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

for MRR is calculated on Minitab 15 Software using Taguchi Method. The steps used are as follows:

Starting Minitab 15 :-

To start Minitab, click shortcut of Minitab on Desktop of computer. A window is opened in computer as shown in Figure :-

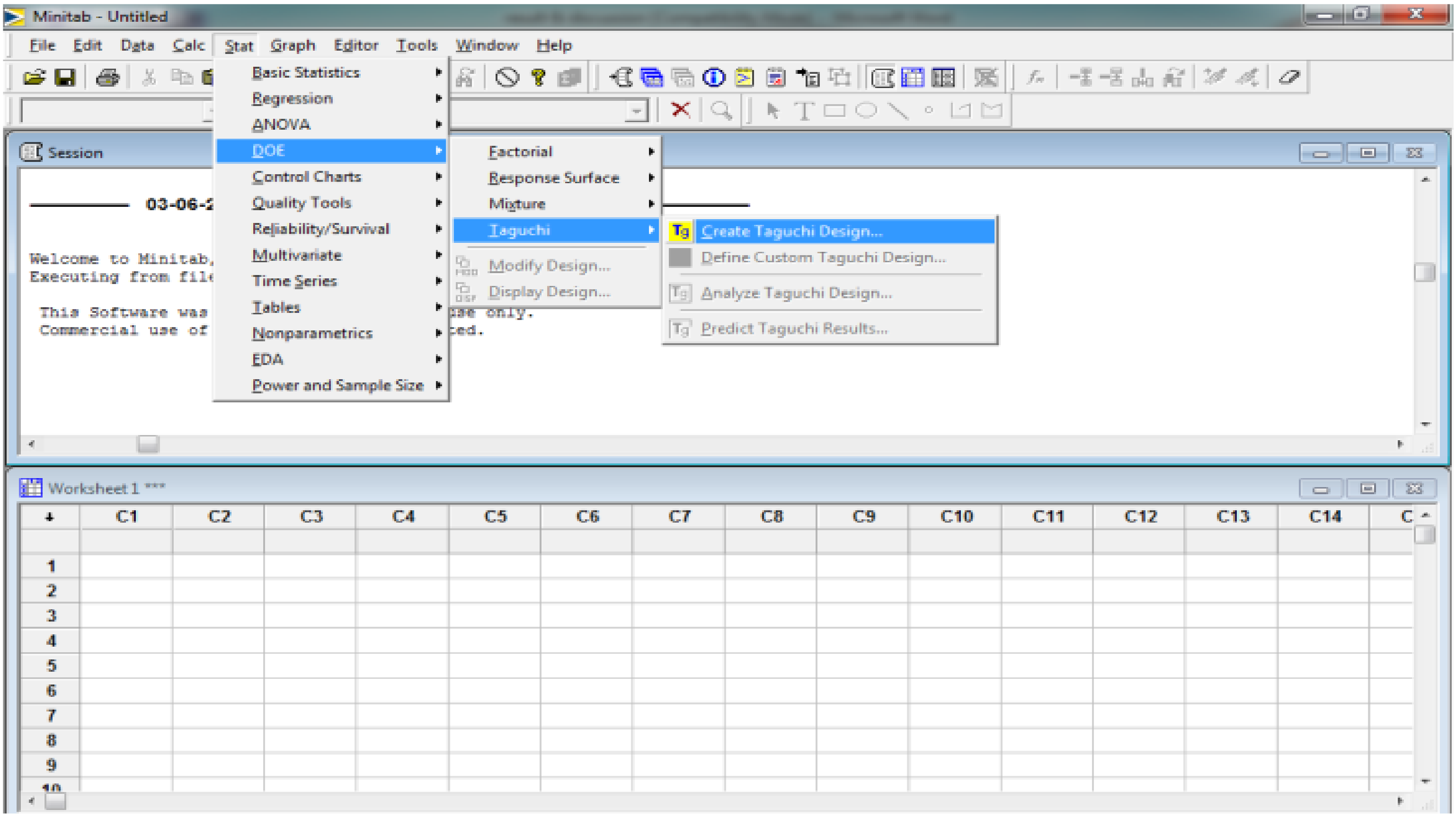


Minitab Software

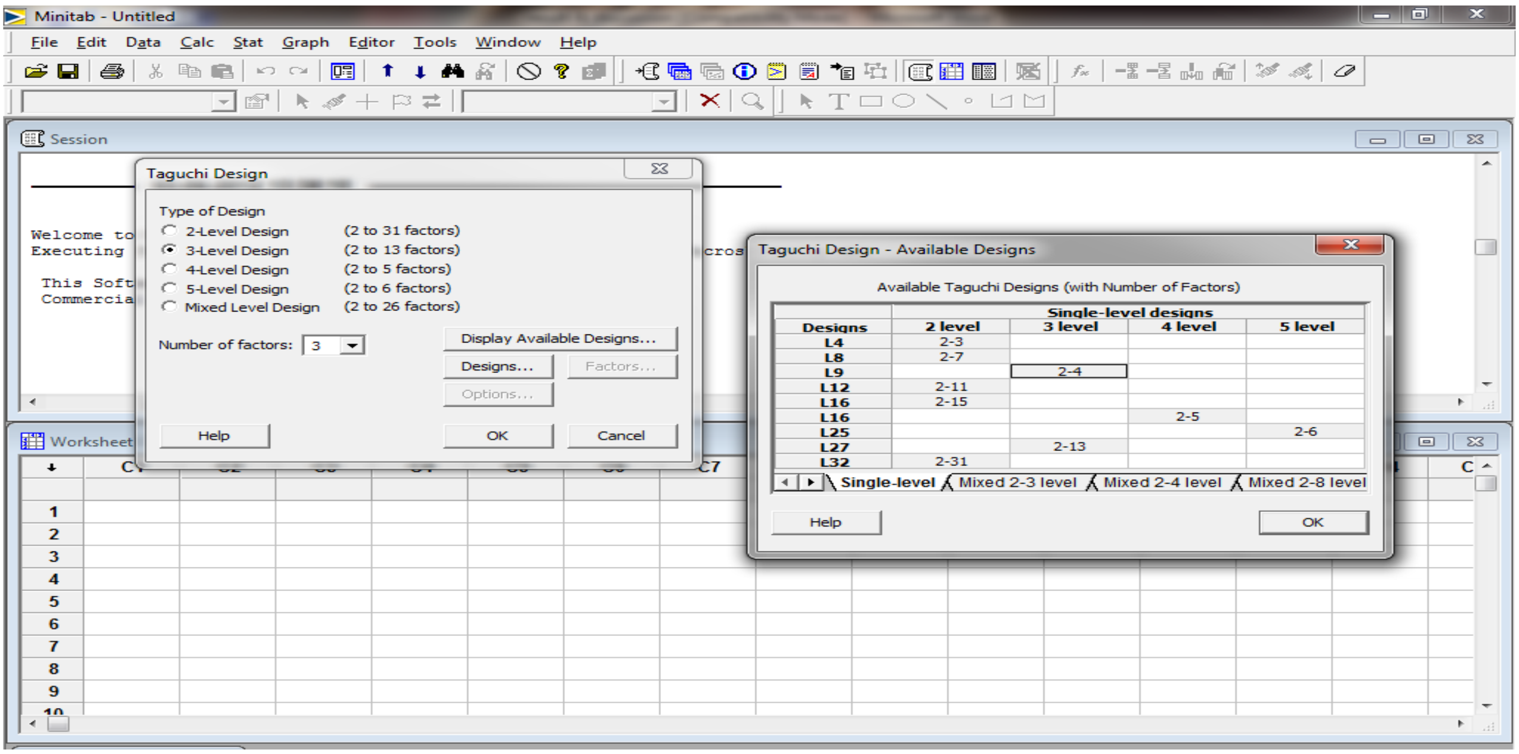
Design of Orthogonal Array

First Taguchi Orthogonal Array is designed in Minitab15 to calculate S/N ratio and Means which steps is given below:

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-1, October 2012

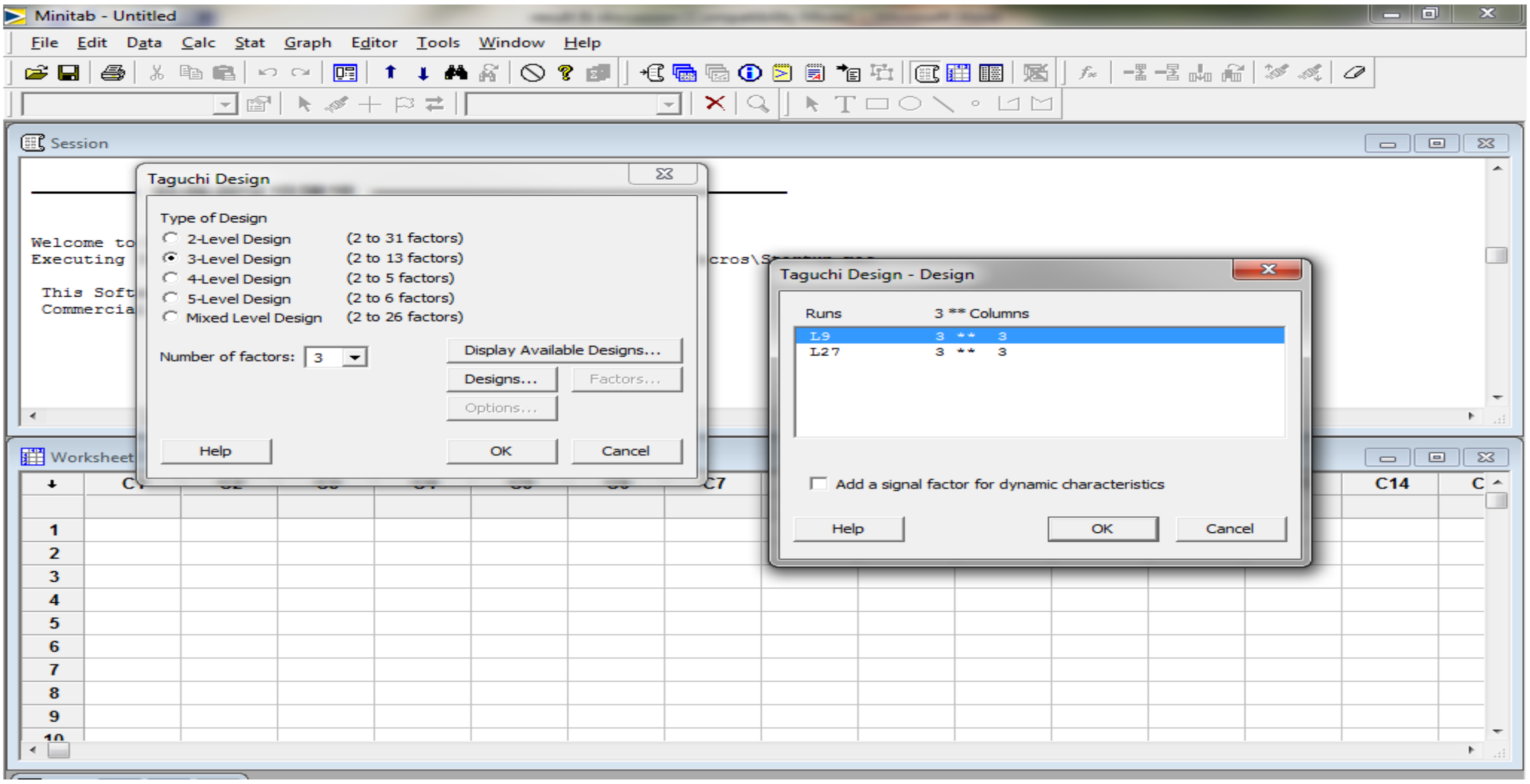


Create Taguchi Design



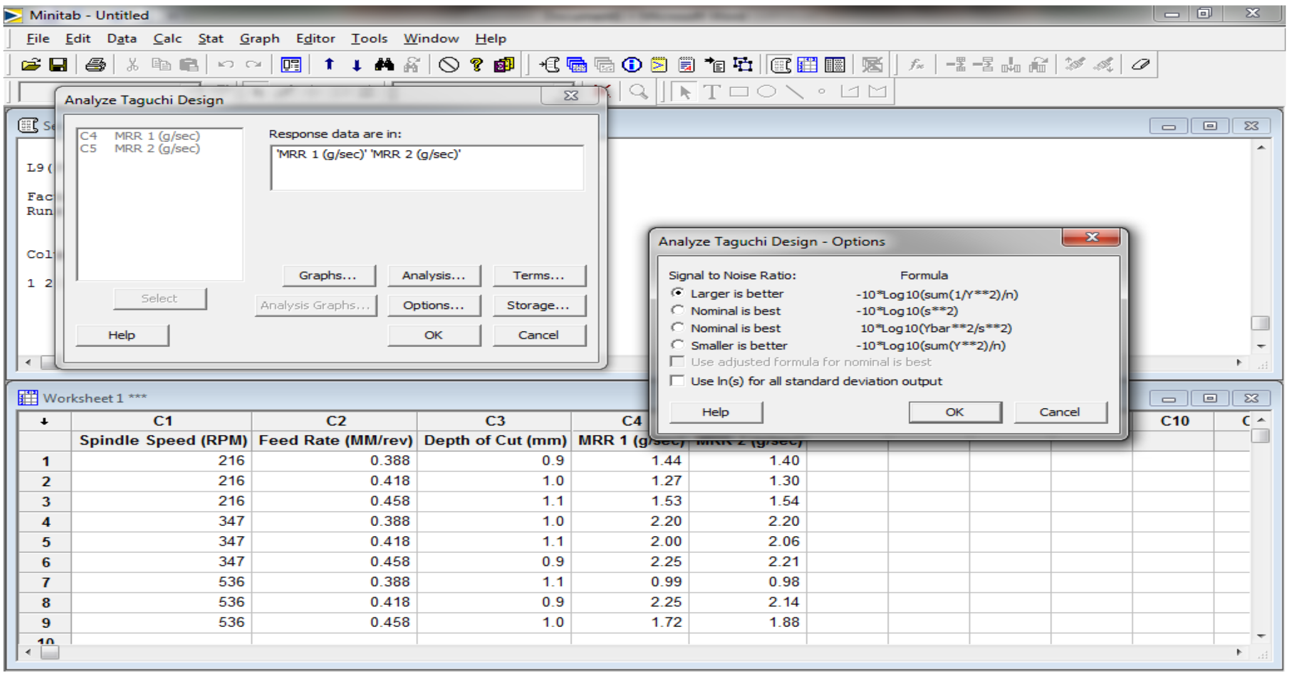
Selection of Available Design

Click on Design and select L9. Then click on ok as shown below :-



Selection of Taguchi Design

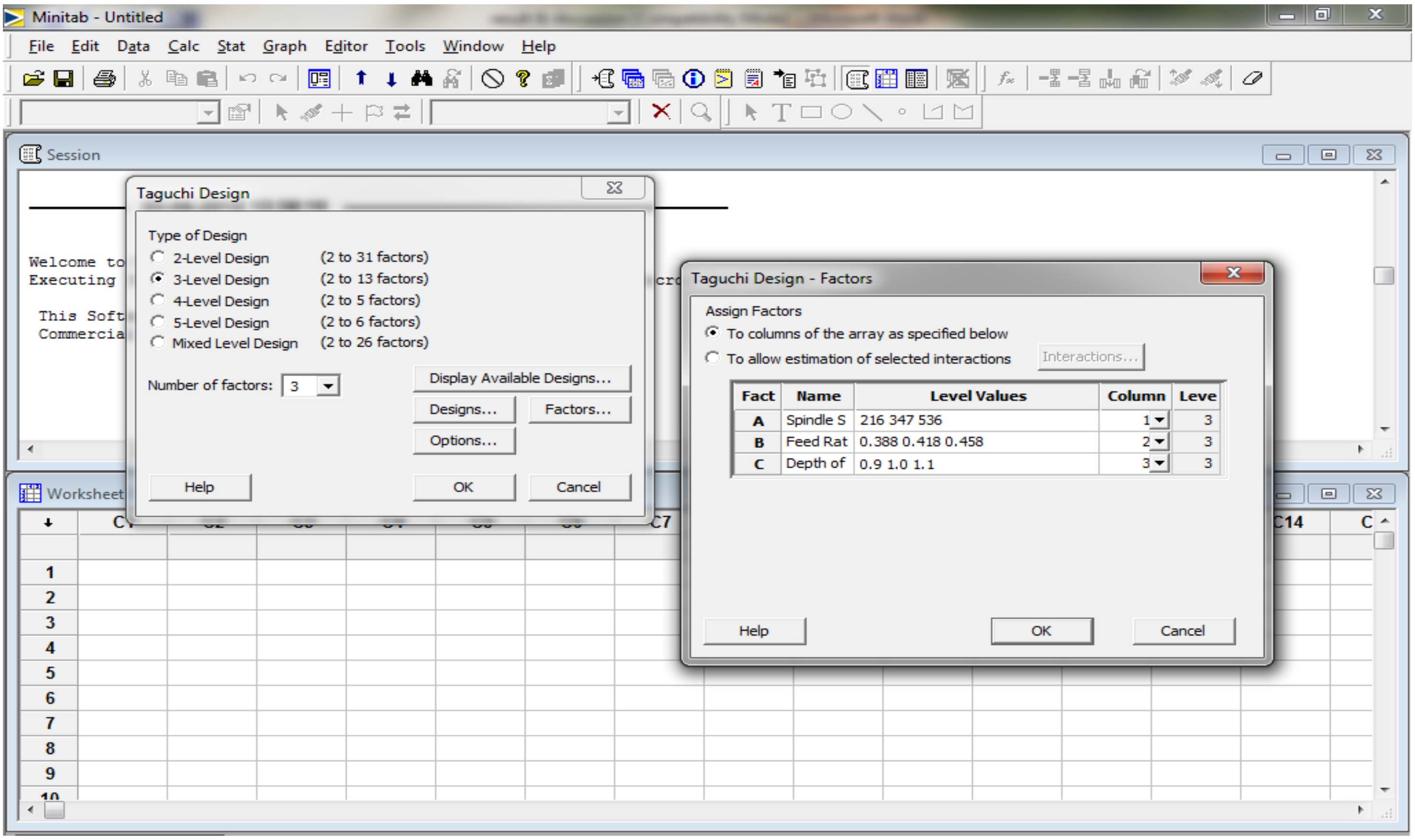
Click on *Factors* and write name of factors and levels of factors at desired place. Then press *ok* as shown in



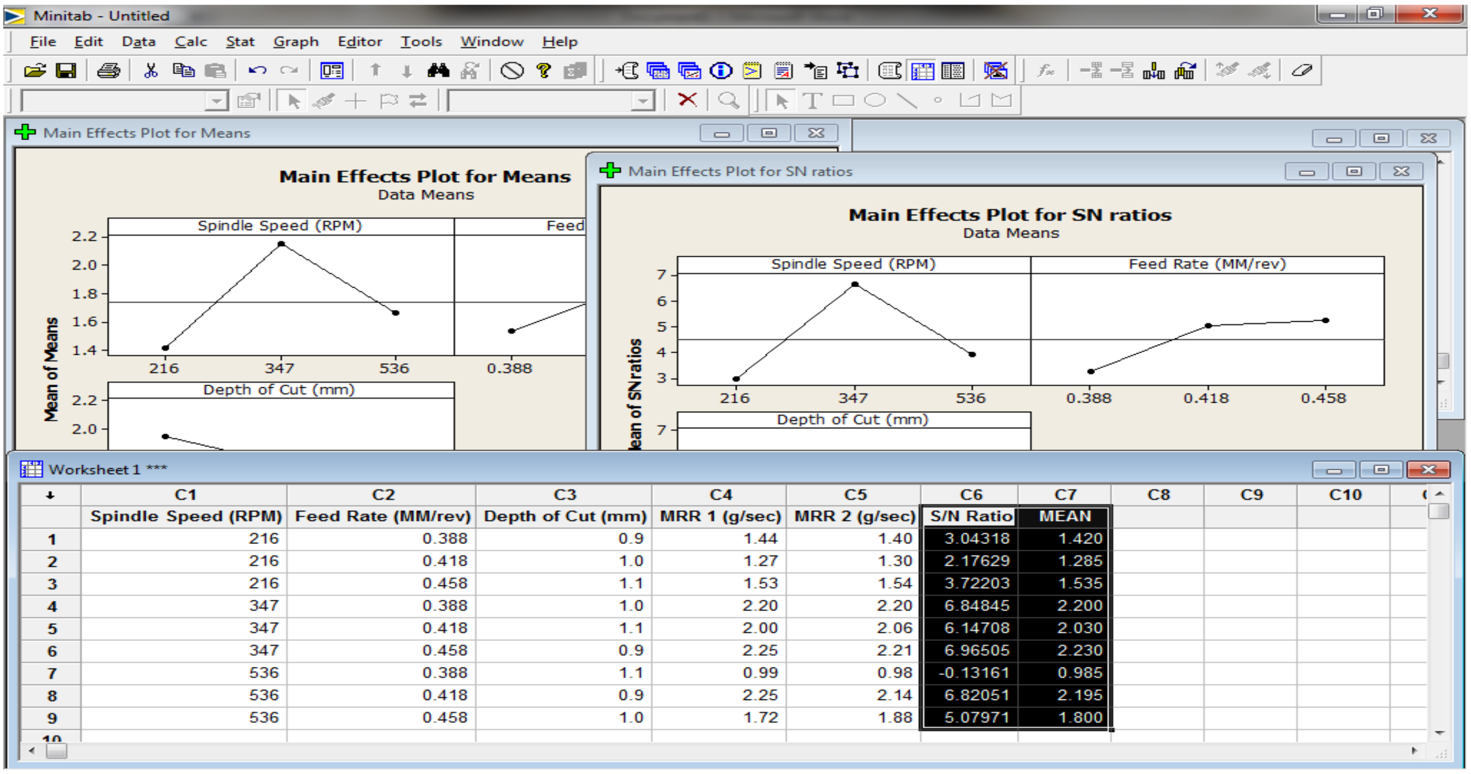
Analyses Taguchi Design-Option

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-1, October 2012



Finally press *ok* in window analyses Taguchi design. Graphs and S/N ratio is generated as shown in :-



Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Results

Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The metal removal rate was considered as the quality characteristic with the concept of "the larger-the-better".

The S/N ratio for the larger-the-better is:

$$S/N = -10 log_{10}\{\frac{1}{n}\sum\frac{1}{y^2}\}$$

Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration Eqn. 4.1 with the help of software Minitab 15. The MRR values measured from the experiments and their corresponding S/N ratio values are listed in Table

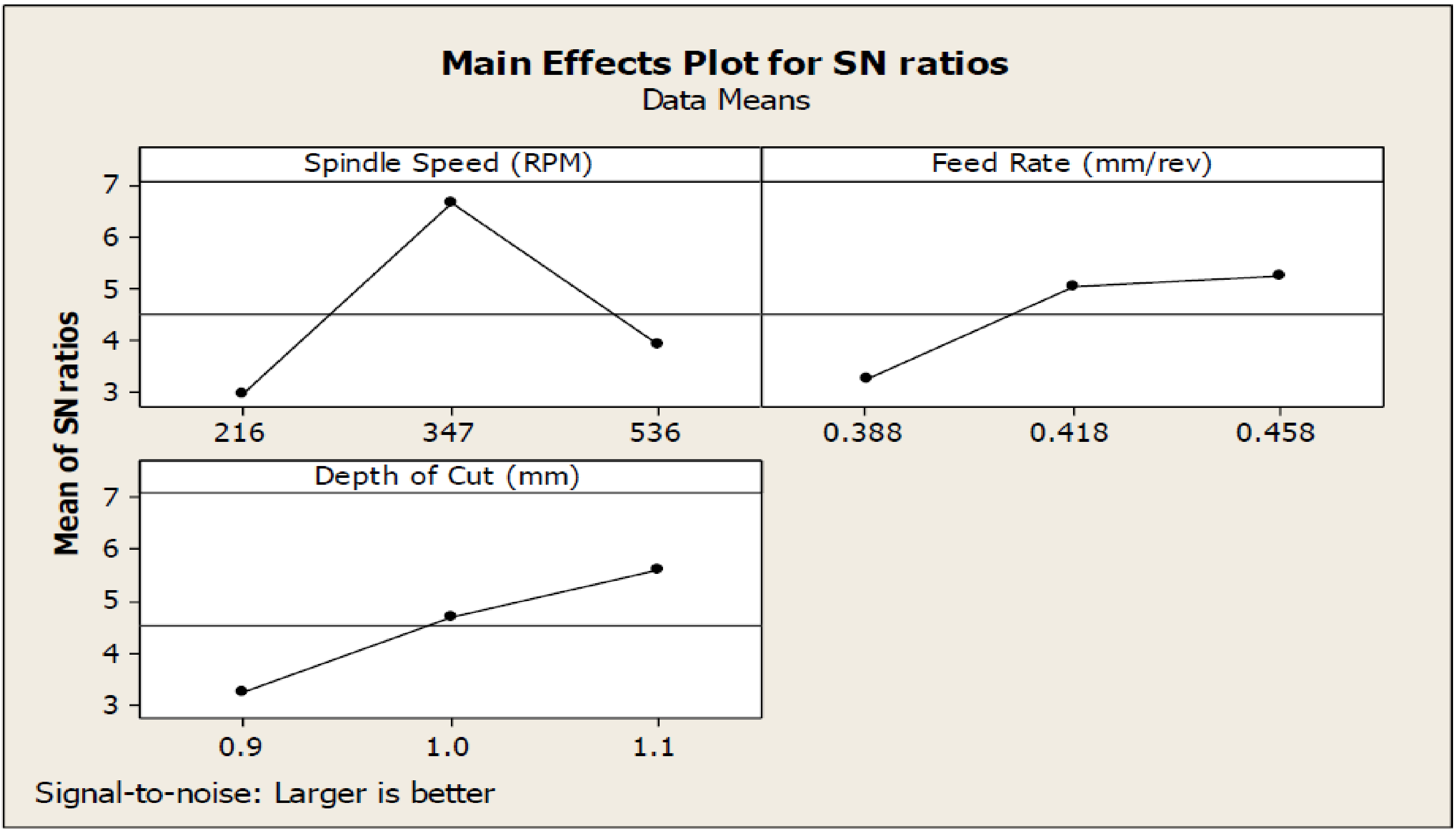
Experimental Result and Corresponding S/N Ratio

S. No	Spindle speed, *N* (RPM)	Feed rate, *f* (mm/rev)	Depth of Cut, *d* (mm)	MRR 1 (g/sec)	MRR 2 (g/sec)	S/N Ratio
1	216	0.388	1.1	1.43	1.41	3.05
2	216	0.418	1	1.27	1.3	2.16
3	216	0.458	0.9	1.53	1.54	3.70
4	347	0.388	1	2.20	2.2	6.86
5	347	0.418	0.9	2	2.06	6.14
6	347	0.458	1.1	2.25	2.21	6.97
7	536	0.388	0.9	0.98	0.98	-0.13
8	536	0.418	1.1	2.25	2.14	6.83
9	536	0.458	1	1.72	1.88	5.06

Analysis and Discussion

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)



Effect of Turning Parameters on Material Removal Rate for S/N Ratio

Spindle Speed :-

The effect of parameters spindle speed on the metal removal rate values is shown above figure for S/N ratio. Its effect is increasing with increase in spindle speed upto 347 RPM beyond that it is decreasing. So the optimum spindle speed is level 2 i.e. 347 RPM.

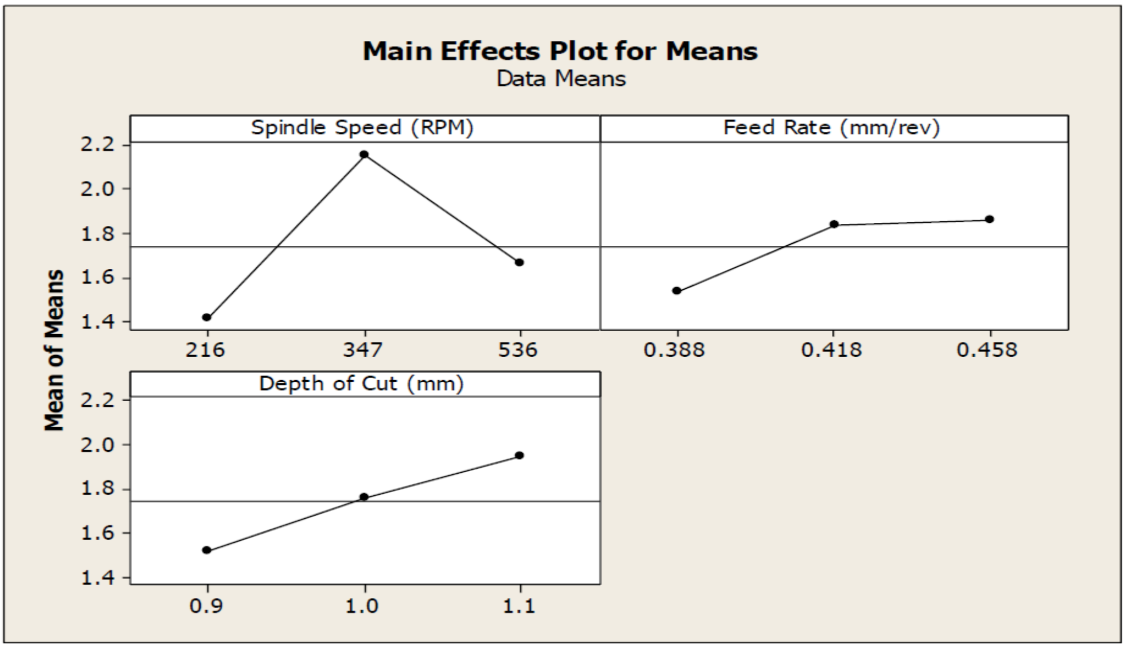
Feed Rate :-

The effect of parameters feed rate on the metal removal rate values is shown above figure S/N ratio. Its effect is increasing with increase in feed rate. So the optimum feed rate is level 3 i.e. 0.458 mm/rev.

Depth of Cut :-

The effect of parameters depth of cut on the metal removal rate values is shown above figure for S/N ratio. Its effect is increasing with increase in depth of cut. So the optimum depth of cut is level 3 i.e. 0.458 mm/rev.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)



Effect of Turning Parameters on Material Removal Rate for Means

References:

[1] Nishant Kumar (2008), "Optimizing The Cutting Parameters Using Taguchi Method To Reduce The Cutting Tool Vibration" Thesis (2008)

[2] Umesh Khandey, "Optimization Of Surface Roughness, Material Removal Rate And Cutting Tool Flank Wear In Turning Using Extended Taguchi Approach"

[3] Sijo M.T and Biju.N (2010), "Taguchi Method for Optimization of Cutting Parameters in Turning Operations" Proc. of. Int. Conf.on Advances in Mechanical Engineering 2010.

[4] Dhavamani and Alwarsamy (2011), "Optimization of Cutting Parameters of Composite Materials using Genetic Algorithm" European Journal of Scientific Research ISSN 1450-216X Vol.63 No.2 (2011), pp.279-285.

[5] Yigit et al. (2011), "Multi-Objective Optimization of the Cutting Forces in Turning Operations Using the Grey-Based Taguchi Method" ISSN 1580-2949.

[6] Kamal, Anish and M.P.Garg (2012), "Experimental investigation of Material removal rate in CNC turning using Taguchi method"International Journal of Engineering Research and Applications (IJERA) Vol. 2, Issue 2,Mar-Apr 2012, pp.1581-1590

[7] Rama and Padmanabhan. G (2012), "Application of Taguchi methods and ANOVA in optimization of process parameters for metal removal rate in electrochemical machining of Al/5%SiC composites" International Journal of Engineering Research and Applications (IJERA) Vol. 2, Issue 3, May-Jun 2012, pp. 192-197

[8] Ballal, Inamdar and Patil P.V. (2012), "Application Of Taguchi Method For Design Of Experiments In Turning Gray Cast Iron " International Journal of Engineering Research and Applications (IJERA) Vol. 2, Issue 3, May-Jun 2012, pp.1391-1397 36

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)