Scientific Journal Impact Factor (SJIF) : 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745 ISSN (PRINT) : 2393 - 8161

Optimization of the material removal rate of EN10250-2 using taguchi method

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Abstract-Purpose: The purpose of this research paper is focused on the analysis of optimum cutting conditions to get maximum material removal rate (MRR) and lowest cutting forces in turning C40 alloy steel by Taguchi method.
Design/Methodology: Experiment was designed using Taguchi method and 9 experiments were designed by this process and experiments conducted. S/N ratio for both cutting forces and MRR calculated with the help of Minitab 17 software.
Findings: Taguchi method has shown that the feed has significant role to play in producing maximum MRR and lowest cutting forces. The depth of cut has lesser role on MRR from the tests and cutting speed has lesser role on cutting forces.
Originality/value: The results obtained by this method will be useful to other researchers for similar type of study.
Keywords: Material Removal Rate (MRR), Taguchi method, Optimization, Dry Turning, Software Minitab17.

I. INTRODUCTION

Turning is one of the most basic fundamental machining processes and it is a form of material removal process which is used to remove the surplus material from the external surface of the workpiece as shown in Fig. 1. The part is rotated while a single point cutting tool is moved parallel to the axis of rotation and cuts away the surplus material in the form of small chips to produce the desired shape of the workpiece. It can be done on the peripheral surface of the part as well as internally. The early material is generally a work piece created by other processes such as forging, casting, drawing, or extrusion.

There are the various parameters which affect the process such as cutting speed, depth of cut, feed rate. These parameters are very useful to specify the speed and motion of the cutting tool. These parameters are selected for each operation based upon the workpiece material, tool size, tool material, and more. Turning parameters that can affect the processes are:

a) Cutting speed – It is measured in surface feet per minute and can be defined as "The speed of the work piece surface relative to the edge of the cutting tool during a cut".

b) Feed rate – It is measured in the terms of mm per revolution and can be defined as "The speed of the cutting tool's movement relative to the work piece as the tool makes a cut".

c) Depth of cut – It is defined as the thickness that is removed by one pass of the cutting tool. 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.

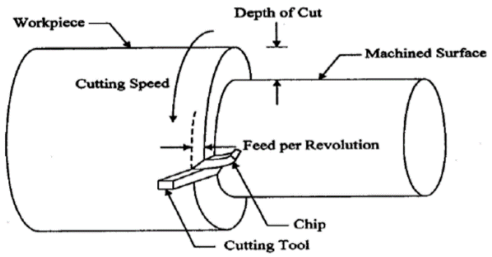

Fig. 1. Turning Process

1.1 Taguchi Method:

Taguchi Method is a well-known powerful and unique technique to improve the quality of the product/process. It is one of the most widely used technique for the optimization purpose. Taguchi method is a more efficient and structured that makes this process relatively simple and differ from the design of experiment (DoE).

Taguchi uses the signal-to-noise ratio rather than the average value to convert the trial result data into a value for the assessment. Taguchi proposed a summary statistic that combines information about the mean and variance into a single performance measure, known as the signal-to-noise (S/N) ratio and can be given as:

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

Where, S/N = Signal to Noise Ratio
n = No. of Measurements
y = Measured Value

II. EXPERIMENTAL DETAILS

2.1 Work Material

The experiment performed with turning of material EN10250-2.
Following tables shows the chemical composition and mechanical properties of selected material:

Table 1. Chemical composition % of grade EN10250-2

Cr+Mo+Ni = Max 0.63							
C	Si	Mn	Ni	P	S	Cr	Mo
0.37-0.44	Max. 0.4	0.5-0.8	Max. 0.4	Max. 0.045	Max. 0.045	Max. 0.4	Max. 0.1

Table 2. Mechanical properties of grade EN10250-2

Quantity	Value	Unit
Young's modulus	200000-200000	MPa
Tensile strength	650-880	MPa
Elongation	8-25	%
Fatigue	275-275	MPa
Yield strength	350-550	MPa

2.2 Cutting tool

The cutting tool used for experimentation with all the standard specification is CCMT 09T308 EN-F43 ISO-HC P35M30 tungsten carbide insert.

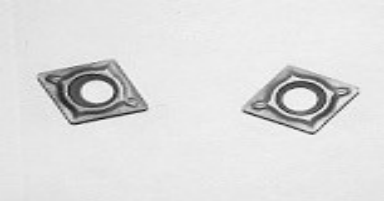

Fig 2. Tungsten carbide insert

2.3 Process Variables and Parameters

In this study, cutting experiments are strategic using statistical three-level full factorial experimental design. Cutting experiments are conducted considering three cutting parameters: Cutting Speed (m/min), Feed rate (mm/rev), Depth of Cut (mm) and Overall 9 experiments were carried out. Following table indicates the values of various parameters used for experiments:

Table 3. Values of Various Parameters used for Experiments

Sr.No	Process Parameter	Low level	Medium level	High level
1.	Speed(rpm)	420	550	715
2.	Feed(mm/rev)	.08	.12	.16
3.	Depth of cut (mm)	.4	.8	1.2

2.5 Response

Material Removal Rate

2.6 Experimentation

The whole experiment is divided into the following steps:

Preparation of job

To prepare the job initially turning is done to make the workpiece of uniform diameter. After doing initial turning on workpiece the diameter is reduced to 32mm. Length of the job is 46.2 cm and nine grooves created at a distance of 20mm to make the nine individual workpiece of length 10mm each on the same job.

Array Selection

Taguchi orthogonal array is selected with three levels of turning parameters with the help of software Minitab 17.

Table 4. Taguchi orthogonal array

Job no.	Speed(rpm)	Feed (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
7	3	1	1
8	3	2	3
9	3	3	2

Experiment Performed

Experiments are conducted according to the selected design of experiment as shown in Table. Machining time is noted by the stopwatch and measured final weight of all the jobs.
Material removal rate (MRR) is calculated by using relation:
MRR = (Initial Wt. – Final Wt.)/ Machining Time

Result and discussion

The complete result from the 9 machining trails for EN10250-2 performed as per the experimental design.

Selection of the optimum level

Irrespective of the classification of the performance characteristics, a greater S/N value resembles to a better performance. Hence the optimal level of the machining parameters is the level with the greatest value.

Table 5. Response Table for Means

Level	Speed(RPM)	Feed(mm/rev)	Depth of cut(mm)
1	0.6721	0.2791	0.7908
2	0.7170	0.7510	0.8607
3	0.9700	1.3290	0.7077
Delta	0.2927	1.0499	0.1530
Rank	2	1	3

Table 6. Response Table for Signal to Noise Ratios

Larger is better			
Level	Speed(RPM)	Feed(mm/rev)	Depth of cut(mm)
1	-5.426	-11.305	-4.236
2	-4.298	-2.628	-3.319
3	-1.839	2.371	-4.007
Delta	3.586	13.676	0.917
Rank	2	1	3

Table 7. Shows the values for 9 experimental setups with the material removal rate.

Speed(rpm)	Feed (mm/rev)	Depth of cut (mm)	Time (sec)	Initial weight(g)	Final weight(g)	Difference of weight(g)	MRR (kg/sec)	S/N ratio	Mean

420	.08	.4	35.1	2478	2471	7	0.1994	-14.0055	01994
420	.12	.8	20.8	2471	2457	14	0.673	-3.4397	0.6730
420	.16	1.2	20.1	2457	2434	23	1.144	1.1685	1.1440
550	.08	.4	17.1	2434	2429	5	0.292	-10.6923	0.2920
550	.12	.8	14.2	2429	2420	9	0.633	-3.9719	0.6330
550	.16	1.2	11.39	2420	2406	14	1.226	1.7698	1.2260
715	.08	.4	20.2	2406	2399	7	0.346	-9.2185	0.3460
715	.12	.8	12.66	2399	2387	12	0.947	-0.4730	0.9470
715	.16	1.2	11.13	2387	2369	18	1.617	4.1742	1.6170

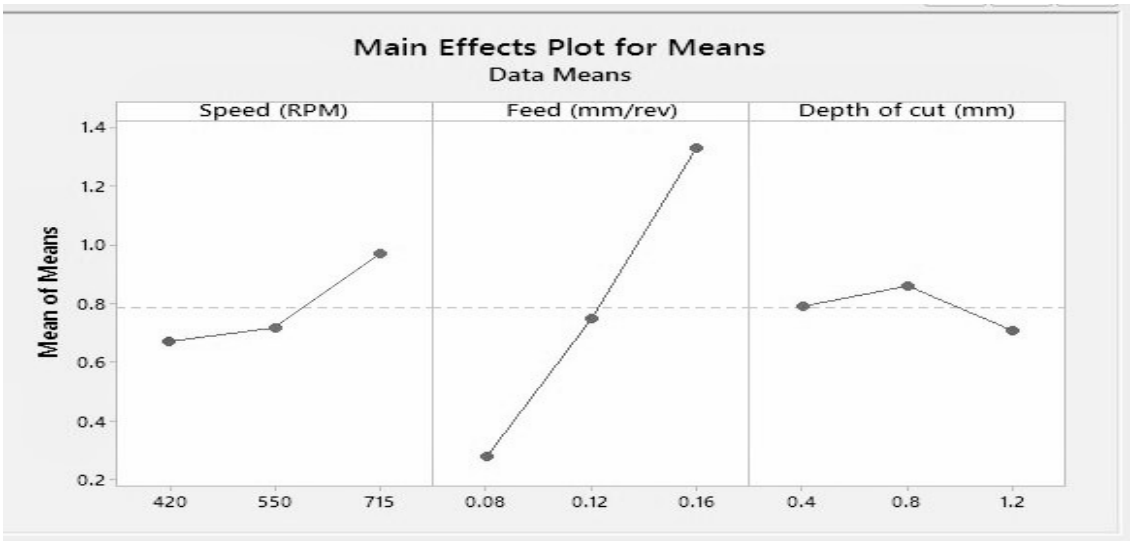

Fig. 3. Effect of Turning Parameters on Material Removal Rate for Means

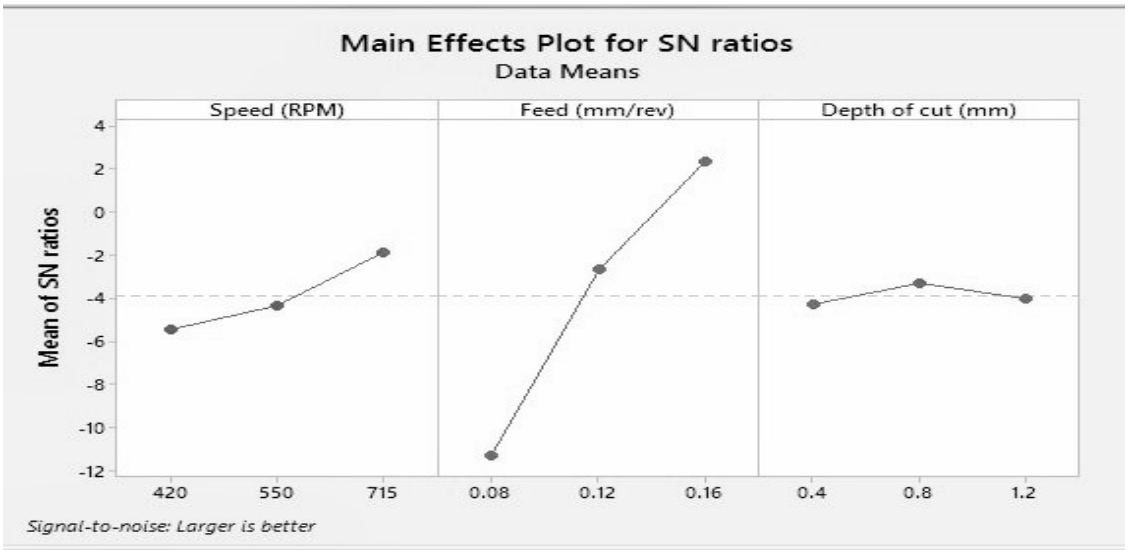

Fig. 4. Effect of Turning Parameters on Material Removal Rate for S/N Ratio

Speed

The consequence of the parameters spindle speed on the metal removal rate is shown in above figure for S/N ratio. Its effect is increasing with increase in speed up to 550 RPM beyond that it is decreasing. So the optimum speed is level 3 i.e. 715 RPM.

Feed Rate

The consequence 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. 0.16 mm/rev.

Depth of Cut

The consequence 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 up to 0.8 mm beyond that it is decreasing. So the optimum depth of cut is level 2 i.e. 0.8 mm.

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