Optimization of process parameter for maximizing Material removal rate in turning of EN8 (45C8) material on CNC Lathe machine using Taguchi method

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Abstract - In today's era of mass manufacturing, MRR (material removal rate) is of primary concern using CNC (computer numerical controlled) machines. In this paper Taguchi method has been employed with L9 Orthogonal Array for three parameters RPM, Feed and Depth of cut. For each of these parameters three different levels have been identified and used to perform the turning operation for the maximization of material removal rate on 2D CNC lathe. The material selected for machining was EN 8 Bright bar with carbide cutting tool. The MRR is observed as the objective to develop the combination of optimum cutting parameters. This research proposes an optimization approach using orthogonal array(L9) for the maximizing MRR and the result from this study confirms the same. This study also produced a predictive equation for Determining MRR with a given set of parameters in CNC turning operation. Thus, with the proposed optimal parameters it is possible to increase the efficiency of machining process and decrease production cost in an automated manufacturing environment.

Key Words: *Material removal rate(MRR),CNC Lathe, Turning operation, Design of experiments (DOE),Orthogonal array(L9) Taguchi method, S/N ratio.*

1.INTRODUCTON

Today, CNC machining has grown to be an indispensible part of machining industry. The accuracy, precision achieved through CNC could not be achieved by the conventional manufacturing machines. But still there is a room for errors in a CNC machine and it basically depends on the skill and experience of the worker to get the dimensions right.[1] Metal cutting is one of the most important processes and broadly used manufacturing processes in mechanical industries [2] the material removal rate (MRR) was considered for the present work as the factor directly affects the cost of machining . The machining parameters namely cutting speed, feed rate and depth of cut were considered. The objective was to find the optimized set of values for maximizing the MRR using Taguchi method. In order to find the optimized set of input parameters and also to identify the effect of each towards a particular output, researchers have been trying for years together. Meng [3] tried to calculate optimum cutting condition for turning operation using a machining theory. Researchers [4-7] have tried to optimize the machining parameters using various methods like Genetic Algorithm, simulated annealing method, Multi-Objective Evolutionary Algorithm etc. The Taguchi method emphasizes over the selection of the most optimal solution (i.e. MRR) over the set of given inputs (i.e. cutting speed, feed rate and depth of cut) with a reduced cost and increased quality. The optimal solution so obtained is least affected by any outside disturbances like the noise or any other environmental conditions [10] Thus, the modern day approach to find the optimal output over a set of given input can be easily carried out by the use of Taguchi method rather than using any other conventional methods. This method has a wide scope of use varying from the agricultural field to medical field and various fields of Engineering sciences. It has been used by many agricultural scientists to evaluate the production of their crops based on the different sets of inputs like the waterfall level, fertility of the land, types of seeds used and many other factors. It is also used by the weather department in forecasting of the various environmental conditions. And, in the field of Science and Engineering, it is used for obtaining optimal results based on the various engineering inputs. Thus, the Taguchi approach has a wide variety of applications in the different fields because of its easiness and optimized results [11] However, even being having a lot of advantages , it suffers from a major disadvantage that the results obtained are only relative to the levels selected and do not exactly indicate the effect of entire range of each parameter on the performance characteristic value. They also do not test the output for all the combinations of input variables as the combination selected here is limited. Moreover, major disadvantage of the Taguchi method is that it is not a dynamic process i.e. it is not concerned with those variables which discretely or continuously change their values from time to time. Thus, it deals with mostly the static variables i.e. variables whose values are not time dependent. Moreover, it deals with designing of the quality rather than improving the quality. Because of this, they are applied in the industries at the early stages only [12] However, despite of all these disadvantages, it is used widely in the different areas very effectively. To reduce the error while using an increased number of inputs, the orthogonal matrix of Taguchi can be used, which is selected as per the requirements of the person. In this work L9 Orthogonal Array was used to obtain optimized economical results. The Taguchi method for the Design of Experiments also emphasizes over the use of Loss function, which is the deviation from the desired value of the quality characteristics. Based on these Loss functions, the S/N ratio for each experimental set is evaluated and accordingly the optimal results are derived. Minitab software is then used for the results and finally, the confirmations results are obtained between the experimental values and the determined values.

2. TAGUCHI METHOD

Basically, traditional experimental design procedures are too complex and not easy to use. A large number of experimental works have to be carried out when the number of the process parameters increases with their levels. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments. The greatest advantage of this method is to save the effort in performing Experiments: to save the experimental time, to reduce the cost, and to find out significant factors fast. Taguchi robust design method is a most powerful tool for the design of a high-quality system. He considered three steps in a process's and product's development: system design, parameter design, and tolerance design. In system design, the engineer uses scientific and engineering principles to determine the fundamental configuration. In the parameter design step, the specific values for system parameters are determined. Tolerance design is used to determine the best tolerances for the parameters[14]

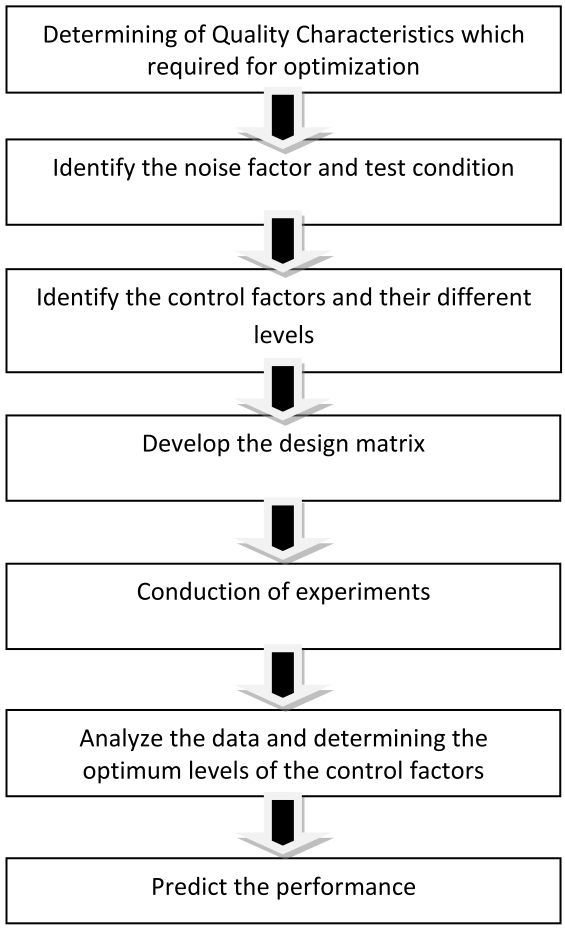


FIG. Flow chart of Taguchi method [14]

Taguchi method is a powerful design of experiments (DOE) tool for optimization of engineering processes, in which the concept of S/N ratio is used for the improvement of quality.

3. EXPERIMENTAL DETAILS

The experiments are performed on CNC lathe MCL 12 selected. The tool and material selected were carbide tool and mild steel EN8 Bright bar respectively. Three process parameters, as, Cutting speed (A), Feed rate (B) and Depth of cut (C) were considered in the study. Equally spaced three levels within the operating range of the input parameters were selected for each of the process parameters. Based on Taguchi method, an L9 orthogonal array (OA) which has 9 different experiments at three levels was developed. Table3.1 shows the design factors along with their levels.

Table3.1 Parameters and Their Levels for Experiment

S.No	Parameter	L1	L2	L3
1	Cutting speed(A)	600	900	1200
2	Feed Rate(B)	0.15	0.20	0.25
3	Depth of Cut(C)	0.1	0.2	0.3

Table3.2 Orthogonal Array[L9]

Experiment no	Level 1	Level 2	Level 3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Larger is better S/N =-10 log [1/n (Σ1/yi2)]

Table 3.3 Experimental values

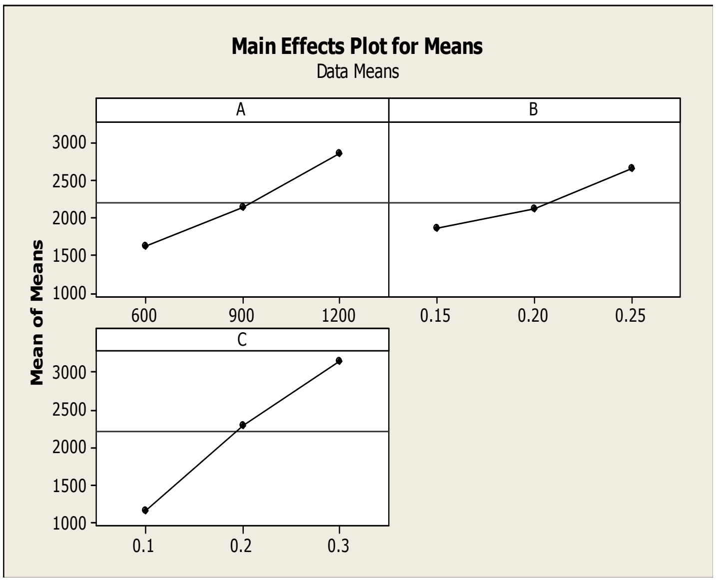
Exp no.	A(RPM)	B(mm/rev)	C(mm)	MRR (mm^3/min)	S/N Ratio
1	600	0.15	0.1	562.659	55.004905
2	600	0.20	0.2	1492.88	63.480498
3	600	0.25	0.3	2785.02	68.896566
4	900	0.15	0.2	1679.49	64.503548
5	900	0.20	0.3	3342.02	70.480180
6	900	0.25	0.1	1406.64	62.963659
7	1200	0.15	0.3	3342.02	70.480210
8	1200	0.20	0.1	1500.42	63.524256
9	1200	0.25	0.2	3732.21	71.439321

Table3.4 Mean response table for material removal rate(MRR)

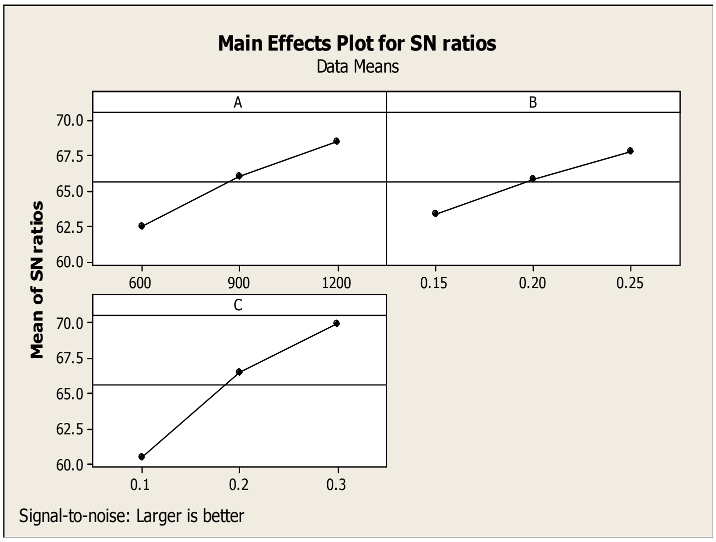
S.No	Parameter	L1	L2	L3
1	Cutting speed(A)	1613.51	2142.71	2858.21
2	Feed Rate(B)	3722.77	2111.773	2641.29
3	Depth of Cut(C)	1156.57	2301.52	3156.35

Table 3.5 S/N ratio table for material removal rate(MRR)

S.No	Parameter	L1	L2	L3
1	Cutting speed(A)	62.46	65.98	68.48
2	Feed Rate(B)	63.32	65.82	67.76
3	Depth of Cut(C)	60.49	66.47	69.95



Graph 1: means of Responce



Graph 2: Means of S/N ratio

4. Development Mathematical Modeling

Regression analysis is performed to find out the relationship between factors and Material removal rate. In conducting regression analysis, it is assumed that factors and the response are linearly related to each other. A multiple regression technique was used to formulate the Cutting speed, feed rate and depth of cut to the Material removal rate. The response function representing the material removal rate can be expressed as: Material removal rate = f (Cutting speed, feed rate and depth of cut). This equation can also be written as:

The regression equation is
MRR = - 3222 + 2.07 A + 7799 B + 9999 C

Predictor	Coef	SE Coef	T-factor	P-factor
Constant	-3221.8	791.7	-4.07	0.010
A	2.0745	0.4845	4.28	0.008
B	7799	2907	2.68	0.044
C	9999	1454	6.88	0.001

S = 356.043 R-Sq = 93.6% R-Sq(adj) = 89.7%

5. Response Graphs for Means

5.1 Level [3] for cutting speed A3 = 2858.21mm^3/min indicated as the optimum situation in terms of Material removal rate(MRR) values.

5.2 Level [1] for feed rate B1 = 3722.77mm^3/min indicated as the optimum situation in terms of material removal rate(MRR) values.

5.3 Level [3] for depth of cut C1 = 3156.35 mm^3/min indicated as the optimum situation in terms of material removal rate (MRR)values.

6. CONCLUSIONS AND SCOPE OF FUTURE WORK

For main effects depth of cut and Cutting speed have significant effect on the Material removal rate. Whereas cutting speed have increasing effect on MRR. This is consistent with the conclusions from the study of other investigators.

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