Optimization of turning Parameters for IC 4140 Alloy Steel on Lathe Machine

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Abstract: The main objective of the proposed work is to determine the influence of controllable parameters on machining Characteristics of IC 4140 Alloy Steel and to achieve the optimum parameters for sustainable and efficient turning. Understanding the consequences of tool materials together with higher cutting speeds on the formation of residual stresses controllable cutting parameters such as cutting speed, feed rate, and depth of cut were selected at a different level for experimentations in accordance with the Taguchi L9 Orthogonal array method using cutting tool as Tungsten carbide tip tool. An extensive study is done on the resulting Material removal rate, tool wear and chip formation. The results obtained from (MINI TAB) ANOVA software is analyzed and finally, the optimized parameters are obtained for efficient machining of IC 4140 Alloy Steel.

I. INTRODUCTION

Machining is one of the manufacturing processes in which the dimensions, shape or surface properties of machined parts are changed by removing the excess material. The turning process is carried out on a lathe machine. The three primary factors in any basic turning operation are cutting speed, feed, and depth of cut. Other factors which further influences the machining are type of material and tool geometry. Process parameters are of great significance to control the machining performances. The Material removal rate is affected by process parameters in order to better surface finish, high accuracy, long tool life. It is necessary to choose the most important thing process parameters. IC 4140 alloy steel is having better characteristics and properties. The use of IC 4140 alloy steel in such destructive environments ensures that it up holds high corrosion resistance. High fatigue resistance, withstand them at high mechanical and thermal shock, creeps, and erosion at elevated temperature. In Aerospace engines IC 4140 alloy steel is normally used for manufacturing of gas turbine blades, which operates at very high temperature and pressure. IC 4140 alloy steel retains high toughness and strength over a wide temperature range, striking for high temperature applications where other aluminum and steel alloys would get soften. But on other hand IC 4140 alloy steel offers serious challenge as a work material during turning machining due to their exceptional combined properties such as high temperature strength and toughness, hardness and chemical wear and creep resistance. Although these properties are attractive for design requirements, they create a bigger challenge to manufacturing engineers due to high temperatures and stresses generation during machining. There are two main problems in machining of IC 4140 alloy steel less tool life due to the work hardening and abrasion properties of the IC 4140 alloy steel metallurgical and surface damages to the work piece due to very high cutting pressure and temperature, which also contributes towards work hardening, surface tearing, and deformation.

II. LITERATURE SURVEY

S. Christopher Ezhil Singh1, D.Rajeev2, C.Sankar3, D. Dinakaran4, S. Ajitha Priyadarsini5, in the year of 2020, Minimizing MRR during turning of AISI 4140 steel with the selected process parameters by optimization The process parameters on response parameters of AISI 4140 steel alloy during turning. The BBD was used to examine the PP to obtain the optimum result. The ANOVA and the 2D & 3D plots indicate that the most influencing parameter affecting MRR was CS, and the remaining two factors (feed rate and DoC influencing less compared to that CS. The optimum solution for MRR during turning occurs at CS of 60, the feed of 0.060, DoC of 0.267322 is 1.00138 cc/min. Mohd Shadab Siddique1, Mohammad Nehal Akhtar2, Mohammad Wajahat Iqbal3, Nizam Beg4, Mohd Ziaul Haq5, Turning parameter Optimization for Material Removal Rate of AISI 4140 Alloy steel by Taguchi method in the year of 2017, machining of the AISI 4140 Alloy steel with the help of coated carbide insert of TNMG 432 PD M400 C7 CVD Al2O3 is performed. Analysis of the Material removal rate is done experimentally with specific input values of feed, depth of cut and speed and gradually the optimal condition is found out the multilayer coated carbide inserts have performed well and provide us with an optimal operating condition for Material removal rate at a combination of speed of 2100 rpm, feed of 0.3 mm/rev and depth of 0.6 mm. From response table Mean analysis of MRR. The most effecting factors on MRR is feed followed by DOC. From response table Signal to noise ratio analysis of MRR. The most effecting factors on MRR is feed followed by DOC. From the regression equation the output parameters can be optimized for any machine with different combination of input parameters.

III. EXPERIMENTAL SETUP

Turning operations were carried out on lathe Machine. This lathe is provided with a high quality feed mechanism which maintains the set feed accurately. To examine the influence of machining parameters on process meters, experiments are carried out on IC 4140 Alloy steel (of length 50mm and diameter of 12mm) using carbide tip tool inserts (Insert: SNMG 120408; Grade: TS2500). Preliminary experiments were carried out to fix the limits of cutting speed for different cutting tool materials based on the available data for machining IC 4140 Alloy Steel from hand books and literature. The Cutting conditions selected for the experiments are shown in the table 1. According to Taguchi's full factorial Design of Experiments an L9 Orthogonal Array was selected, Where number of factors are 3 (Cutting speed, Feed and Depth of cut) number of levels of each factor is 3 and number of experiments to be conducted are 9. The experiments were performed on Lathe machine. Various input parameters varied during the experimentation are cutting speed, feed rate and depth of cut.

Table 1: L9 Orthogonal array and cutting parameter

CONDITION \ COLUMN	L_9		
	1	2	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

	Level		
Control Factors	I	II	III
Cutting speed	40	90	140
Feed rate	20	30	40
Depth of cut	0.2	0.3	0.4

The effects of these input parameters are studied on MRR; following steps were followed in the cutting operation:

• The work piece was made horizontal with the help of dial indicator.

• The work piece is facing at one side and made a centre hole with drill bit.

• The experiment was made for cutting operation of the work piece and a profile of different depth of cuts of 0.2, 0.3, 0.4 mm and turning lengths of 20, 30, 40 mm.

Figure 1: Experimental setup

For the present experimental work three process parameters each at three levels have been decided. It is desirable to have minimum three levels of process parameters to reflect the true behavior of output parameters under study. The L9 orthogonal array with all values selected for the experimental run is shown in table. There are 9 parameter combinations that need to be tested. Each parameter combination is tested for replications for effective error reduction and for accurate S/N ratio. The levels of the individual process parameters / factors are given in and show L9 Orthogonal Array of Process Parameter.

Table 2: Material composition

Components	Mo	C	Mn	Si	P	S	Cr	Fe
Percentage (%)	0.2	0.4	0.9	0.5	0.04 Max	0.04 Max	0.9	Bal

Table 3: Work piece properties

Work specimens	IC 4140 Alloy Steel
Hardness	27 HRC
Size	12 x 50 mm
Density	7.85 g/cm³
Young's modulus	190-210 Gpa
Workpiece holder	3 Jaw Chuck

3.2. Minitab 16

MINITAB 16 is a computer program designed to perform basic and advanced statistical functions. It combines the user-friendliness of Microsoft Excel with the ability to perform complex statistical analysis. The Figure – 2 shows the MINITAB 16 work sheet with the Taguchi design selected for the design. MINITAB 16 calculates response tables and generates main effects and interaction plots for Signal-to-noise rations (S/N ratios) vs. the control factors.

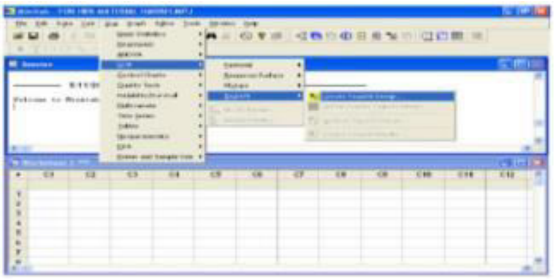

Figure 2: The MINITAB 16 Work Sheet With The Taguchi Design

IV. EXPERIMENTAL PROCEDURE

The major problem with the turning process is setting the parameters for different materials for different thickness. The different values of the parameters set for machining some material for the same work piece will give different values of accuracy. So it not possible to randomly select the parameters, which give the wrong values of the performance measures. But the machine operator may choose some good parameters based on his experience on that machine, which may give better output. Every operator will choose different parameters which may or may not give the good responses. The objective of any company is to give good products to the customer so that it should not damage or lose its function thereby avoiding the loss to the customer.

Table 4: L9 orthogonal array (model/Assigned values)

S. No	Cutting Speed	Depth Of Cut	Feed Rate
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

S. No	Cutting Speed	Depth Of Cut	Feed Rate
1	40	0.20	20
2	40	0.30	30
3	40	0.40	40
4	90	0.20	30
5	90	0.30	40
6	90	0.40	20
7	140	0.20	40
8	140	0.30	20
9	140	0.40	30

V. RESULTS AND DISCUSSIONS

The statistical analysis of variance is to determine which design parameters significantly effects of MRR. Based on the ANOVA the relative importance of machining parameters MRR is investigated and machining parameters in table 4 shows the result of the ANOVA analysis of MRR. An analysis of variance (ANOVA) table is commonly used to summarize the tests performed. The ANOVA is applied to test adequacy of the developed models. The purpose of the ANOVA is to investigate which parameters significantly affect the response characteristics. The test for significance of the regression model and the test for significance on individual model coefficients are performed. Table 5 shows ANOVA for MRR of the IC 4140 Alloy Steel. The purpose of ANOVA to find the process parameters which affect the performance characteristic. It is observed that the depth of cut has insignificant effect on MRR.

5.1. Material Removal Rate

MRR is the rate at which the material is removed the work piece. The MRR is defined as the ratio of the difference in weight of the work piece before and after machining to the machining time. MRR is the rate at which the material is removed the work piece.. The MRR is defined as the ratio of the difference in weight of the work piece before and after machining to the machining time. Metal removing rate (mm3/sec), Turning is most common process in whole manufacturing, for turning process the lathe is selected. Material

Specification. Ø12mm and length 50mm.

Table 5: L9 orthogonal array (calculated values)

Run	CUTTING SPEED (rpm)	FEED (mm/rev)	DEPTH OF CUT (mm)	MACHINING TIME (seconds)	MRR (mm^3/Min)
1	40	20	0.20	12	386.534
2	40	30	0.30	20	568.41
3	40	40	0.40	24	766.78
4	90	30	0.20	13	523.769
5	90	40	0.30	17	798.008
6	90	20	0.40	08	1134.177
7	140	40	0.20	13	675.1
8	140	20	0.30	06	1144.137
9	140	30	0.40	08	1622.17

5.2 Analysis of Experimental Data using Taguchi

The data obtained after measuring the response variables were tabulated and discussed in the previous sections. In this section, obtained data has been analyzed based on Taguchi analysis using MINITAB 16 software.

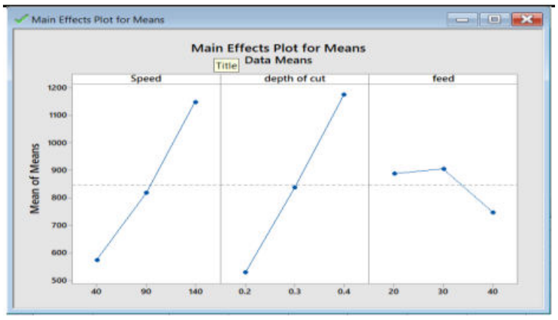

Figure 3: Mean vs Mean graph

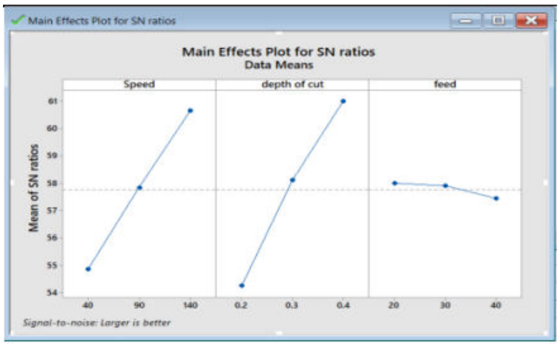

Figure 4: Graph for signal to noise ratios

VI. CONCLUSIONS AND FUTURE WORK

Based on the results and discussion the following conclusions are drawn. It is observed that the effect of feed is maximum MRR followed by cutting speed and depth of cut has least effect on MRR. The optimum parameters are cutting speed 140 rpm, feed rate 30 mm/rev and depth of cut 0.4 mm. The parameters are ranked as 2, 1, 3 for cutting speed, depth of cut and feed rate. The developed regression equation is used to predict the MRR with 4.6% error. The developed regression equation is used to predict the MRR with 95.40% accuracy. The maximum % of contribution in feed rate is 4.60%, cutting speed is about 40.93%, Depth of cut is about 51.97% and also error is 4.6% are obtained by ANOVA calculations.

The work can be extended by considering the other parameters like different tool materials, conditions and by changing tool angle, Tool flank wear etc., The work may be continued for machining various materials for finding optimal combinations of parameters and also by varying the work materials to find out the best material of the work. During the experiment, some noise factors were ignored like temperature, vibrations etc., which can be included. The present work is carried out on Lathe Machine. The experiment can also be conducted using fully automatic CNC machine.

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