RESEARCH ARTICLE OPEN ACCESS

Parametric Optimization of Surface Roughness & Material Remove Rate of AISI D2 Steel For Turning

Hitesh Patel*, Jigar Patel**, Chandresh Patel***
* PG Fellow,
** Assistant Professor
*** Assistant Professor
Department of Mechanical Engineering, S.P.B.Patel Engineering College, Mehsana, Gujarat.

ABSTRACT
In order to produce any product with desired quality by machining, proper selection of process parameters is essential. This can be accomplished by Full Factorial method. The aim of the present work is to investigate the effect of process parameter on surface finish and material removal rate (MRR) to obtain the optimal setting of these process parameters and the analysis of variance is also used to analysis the influence of cutting parameters during machining. In this work AISI D2 steel work pieces are turned on conventional all gear lathe by using carbide tool. In the present work, Design of Experiment (DOE) with full factorial design has been explored to produce 27 specimens on AISI D2 Steel by straight turning operation MRR will be calculated from MRR equation. Collected data related to surface roughness have been utilized for optimization. ANOVA analysis gives the percentage contribution of each process parameter. Cutting speed is the most effective parameter which affects surface roughness in straight turning operation. Feed rate and depth of cut are most effective on material removal rate for turning operations. Grey relational analysis is used for finding out the optimal condition for surface roughness and material removal rate for straight turning operation. Grey relational analysis give the better surface finish at low speed, low feed rate and high depth of cut.
Keywords - Full Factorial Method, Machining Parameters, Surface Roughness, Material Removal Rate (MRR), ANOVA Analysis

I. INTRODUCTION

Turning is a machining process in which a cutting tool, typically a non-rotary toolbit, describes a helical tool path by moving more or less linearly while the workpiece rotates. Many articles addressed experimental and theoretical optimization processes discussed during dissertation work. Some of them given here. M. Kaladhar et al.[1] (2011) investigate the effects of process parameters on surface finish and material removal rate (MRR) to obtain the optimal setting of these process parameters on AISI 304 steel. The Analysis Of Variance (ANOVA) is also used to analyze the influence of cutting parameters during machining. The results revealed that the feed and nose radius is the most significant process parameters on work piece surface roughness. However, the depth of cut and feed are the significant factors on MRR. Muammer Nalbant et al. [2] investigate the effects of machining of AISI 1030 steel (i.e. orthogonal cutting) uncoated, PVD- and CVD-coated cemented carbide insert with different feed rates, cutting speeds by keeping depth of cuts constant without using cooling liquids has been accomplished. Anil Gupta et al. [3] presents the application of Taguchi method with logical fuzzy reasoning for multiple output optimization of high speed CNC turning of AISI P-20 tool steel using TiN coated tungsten carbide coatings. B FNIDE et al. [4] investigate the application of response surface methodology for determining statistical models of cutting forces in hard turning of AISI H11 hot work tool steel. The feed rate influences tangential cutting force more than radial and axial forces. The cutting speed affects radial force more than tangential and axial forces. From above discussion we found that how these parameters affect in turning processes .In our project we use AISI D2 tool steel which also known as HCHC tool steel. The chemical composition of AISI D2 tool steel is given in below Table 1.

Table 1. Chemical Composition of AISI D2 Steel

Carbon	1.55%
Silicon	0.30%
Manganese	0.35%
Chromium	12.00% 12.00%
Molybdenum	0.75%
Vanadium	0.90%

AISI D2 is recommended for tools requiring very high wear resistance, combined with moderate toughness (shock-resistance).AISI D2can be supplied in various finishes, including the hot-rolled, pre-machined and fine machined condition

II. Design of Experiment

Design of experiments was developed in the early 1920s by Sir Ronald Fisher at the Rothamsted Agriculture field Research Station in London, England. His initial experiments were concerned with determining the effect of various fertilizers on different plots of land. The final condition of the crop was not only dependent on the fertilizer but also on the number of other factors (such as underlying soil condition, moisture content of the soil, etc.) of each of the respective plots. Fishers used DOE which could differentiate the effect of fertilizer and the effect of other factors. Since that time the DOE has been widely accepted in agricultural as well as Engineering Science. Design of experiments has become an important methodology that maximizes the knowledge gained from experimental data by using a smart positioning of points in the space. This methodology provides a strong tool to design and analyze experiments; it eliminates redundant observations and reduces the time and resources to make experiments.

We have used factorial design, and used full factorial design. For a full factorial design, if the numbers of levels are same then the possible design N is

$$N = L^m$$

Where, L = number of levels for each factor, and m= number of factors.

Table 2 Factors and their levels in CNC straight turning

Factor	Level		
	Level 1	Level 2	Level 3
Cutting Speed (m/min)	49	66	103
Feed Rate (mm/rev)	0.107	0.215	0.313
D.O.C (mm)	1	1.5	2

From the above table according to design of experiments with full factorial design total numbers of experiments to be performed are 27.

III. Experimental set up

In order to achieve the goal of this experimental work the cutting tests were carried out in a conventional heavy duty lathe. The lathe turning centre has 2.2 kw spindle motor power and a maximal machining diameter of 165mm, maximal spindle speed of 938 rpm, spindle speed range 25 to 938 rpm and maximal turning length 350mm.

Table 3 Data obtained from experimental work for surface roughness

Sr No.	Cutting Speed	Feed Rate	Depth of Cut	Surface roughness	MRR
	m/min	mm/r	mm	µm.	mm^3/min
1	49	0.107	1	0.9	61.50
2	49	0.107	1.5	0.75	92.25
3	49	0.107	2	0.44	122.99
4	49	0.215	1	1.15	123.56
5	49	0.215	1.5	0.93	185.34
6	49	0.215	2	0.67	247.13
7	49	0.313	1	0.53	179.88
8	49	0.313	1.5	0.90	269.83
9	49	0.313	2	0.45	359.77
10	66	0.107	1	0.97	81.92
11	66	0.107	1.5	0.97	122.88
12	66	0.107	2	0.8	163.84
13	66	0.215	1	0.71	164.61
14	66	0.215	1.5	0.54	246.91
15	66	0.215	2	0.63	329.22
16	66	0.313	1	0.59	239.64
17	66	0.313	1.5	0.73	359.46
18	66	0.313	2	0.70	479.30
19	103	0.107	1	1.5	127.45
20	103	0.107	1.5	1.9	191.18
21	103	0.107	2	1.62	254.91
22	103	0.215	1	1.3	256.11
23	103	0.215	1.5	1.5	384.16
24	103	0.215	2	1.52	512.22
25	103	0.313	1	1.34	372.84
26	103	0.313	1.5	1.4	559.27
27	103	0.313	2	1.66	745.69

IV. Anova Analysis

The percentage contribution of Cutting Speed is 79.80%, Feed Rate is 2.90%, and D.O.C is 1.54%. Parametric analysis is carried out for the quality of the sample. i.e. Surface Roughness. This parametric analysis (ANOVA) shows the percentage contribution of parameters individually as shown in Table 4

Table 4: PERCENTAGE CONTRIBUTION OF PROCESS PARAMETER FOR SURFACE ROUGHNESS

Source of Variation	DOF	Sum of Squares S	Variance (Mean Square)	Variance Ratio F	Percentage Contribution P
Factor A	2	3.692	1.846	5.0938	79.80%
Factor B	2	0.134	0.06731	1.8573	2.90%
Factor C	2	0.071	0.03562	0.9828	1.54%
Error (O)	20	0.73	0.03624	1	15.76%
Total	26	4.63	1.98517	8.9339	100%

Main Effect Plots for ANOVA

The analysis is made with the help of a software package MINITAB 16. The main effect plots are shown in Fig. 1 and Fig. 2 These show the variation of individual response with the three parameters i.e. cutting speed, feed, and depth of cut separately. In the plots, the x-axis indicates the value of each process parameter at three level and y-axis the response value. Horizontal line indicates the mean value of the response. The main effects plots are used to determine the optimal design conditions to obtain the optimum surface finish.

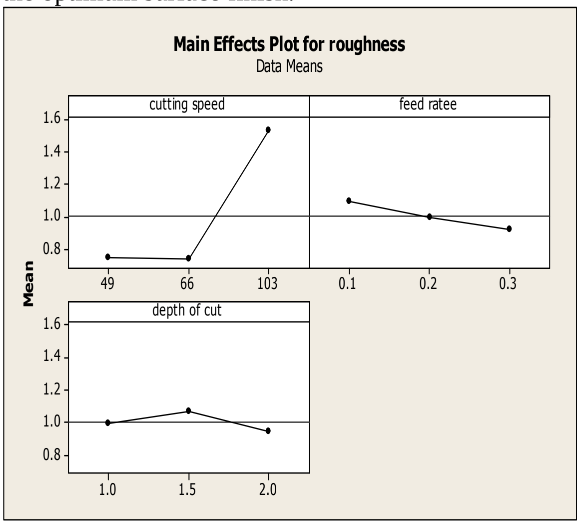

Fig. 1 Main Effect Plot For Surface Roughness

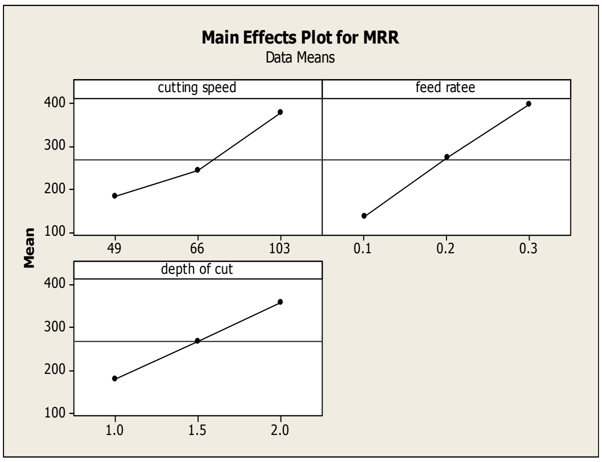

Fig. 2 Main Effect Plot For MRR

V. GRAY RELATIONAL ANALYSIS

In grey relational generation, the normalized data corresponding to Lower-the-Better (LB) criterion can be expressed as:

$$Xi(k) = \frac{\max yi\ (k) - yi\,(k)}{\max yi\,(k) - \min yi\,(k)}$$

For Higher-the-Better (HB) criterion, the normalized data can be expressed as:

$$Xi(k) = \frac{yi\,(k) - \min yi\ (k)}{\max yi\,(k) - \min yi\,(k)}$$

Where xi (k) is the value after the grey relational generation, min $yi\ (k)$is the smallest value of $yi\ (k)$for the kth response, and max $yi\ (k)$is the largest value of $yi\ (k)$for the kth response. An ideal sequence is x0 (k) for the responses.

However, if there is ‘‘a specific target value’’, then the original sequence is normalized using,

$$Xi\ (k) = 1 - \frac{|yi\ (k) - OB|}{\max\{\max yi\ (k) - OB, OB - \min yi\ (k)\}}$$

Table 5. Grey relational analysis

Source	DOF	Sum of Square SS	Adj SS	Adj MS	V.R	P
Cutting speed	2	0.373796	0.373796	0.186898	51.19	0.000
Feed rate	2	0.057886	0.057886	0.028943	7.93	0.003
Depth of cut	2	0.024836	0.024836	0.012418	3.40	0.054
Error	20	0.073028	0.073028	0.003651		
Total	26	0.529545				
S = 0.0604269 R-Sq = 86.21% R-Sq(adj) = 82.07%						

Table 6. ANOVA for grey relational grade

Sr No.	GRC of SR	GRC of MRR	GRG	Grade No.
1	0.6134	1	0.8067	4
2	0.7020	0.9174	0.8097	3
3	1	0.8476	0.9238	1
4	0.5069	0.8445	0.6757	14
5	0.5984	0.7342	0.6663	15
6	0.7605	0.6483	0.7044	12
7	0.8903	0.7429	0.8166	2
8	0.6134	0.6215	0.6175	18
9	0.9866	0.5342	0.7604	7
10	0.5794	0.9437	0.7616	6
11	0.5794	0.8479	0.7137	11
12	0.6697	0.7697	0.7197	10
13	0.7300	0.7684	0.7492	8
14	0.8795	0.6485	0.7640	5
15	0.7935	0.5609	0.6772	13
16	0.8296	0.6575	0.7436	9
17	0.7157	0.5346	0.6252	16
18	0.7374	0.4502	0.5938	19
19	0.4078	0.8384	0.6231	17
20	0.3333	0.7252	0.5293	21
21	0.3822	0.6388	0.5105	22
22	0.4591	0.6374	0.5483	20
23	0.4078	0.5146	0.4612	24
24	0.4033	0.4316	0.4175	26
25	0.4487	0.5236	0.4862	23
26	0.4320	0.4073	0.4197	25
27	0.3744	0.3333	0.3539	27

VI. CONCLUSION

In this dissertation work, various cutting parameters like, cutting speed, feed and depth of cut have been evaluated to investigate their influence on surface roughness and material removal rate. Based on the result obtained, it can be concluded as follows:

SURFACE ROUGHNESS:

- Cutting speed, feed rate and depth of cut significantly effects on surface roughness.
- Cutting speed is found the most significant effect on surface roughness. Increase in Cutting speed value of surface roughness is increase.
- Feed rate is found to have effect on surface roughness. Increase in Feed rate, value of surface roughness is decrease.
- Depth of cut is found to have effect on surface roughness. Increase in depth of cut value of surface roughness is increase.
- The optimal combination of low feed rate and low depth of cut with high cutting speed is beneficial for reducing machining force so surface roughness is decrease when high cutting speed, low feed rate and low depth of cut.
- The percentage contribution of cutting speed is 79.80 %, feed of 2.90 % and depth of cut of 1.54 % on surface roughness for straight turning operation.

MATERIAL REMOVAL RATE:

- The volume of material removed can be achieved better when machining was done at high depth of cut and high feed rate.
- Feed and Depth of cut are found the most significant effect on material removal rate.
- Increase in feed and depth of cut, value of material removal rate is increase. The percentage contribution of cutting speed is 25.92 %, feed of 43.91 % and depth of cut of 20.59 % on material removal rate for straight turning operation.

REFERENCES

[1] M. Kaladhar, K. Venkata Subbaiah, Ch. Srinivasa Rao. "*Determination of Optimum Process Parameters during turning of AISI 304 Austenitic Stainless Steels using Taguchi method and ANOVA*" International Journal of Lean Thinking Volume 3, Issue 1 (June 2012) pp.1-19.

[2] Muammer Nalbant, Hasan Gokkaya, Ihsan Toktas, Gokhan Sur. "*The experimental investigation of the effects of uncoated, PVD- and CVD-coated cemented carbide inserts and cutting parameters on surface roughness in CNC turning and its prediction using artificial neural networks*" Robotics and Computer-Integrated Manufacturing 25 (2009) pp.211–223.

[3] Anil Gupta, Hari Singh, Aman Aggarwal. "*Taguchi-fuzzy multi output optimization (MOO) in high speed CNC turning of AISI P-*

20 tool steel" Expert Systems with Applications 38 (2011) pp.6822–6828.

[4] B Fnides, M A Yallese, T Mabrouki, J F Rigal. "*Application of response surface methodology for determining cutting force model in turning hardened AISI H11 hot work tool steel*" Sadhana Vol. 36, Part 1 (2011) pp.109–123.

[5] Sukumar, Poornima. "*Optimization of machining parameters in CNC turning of martensitic stainless steel using RSM and GA*" International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.2, (Apr. 2012) pp.539-542.

[6] Yansong Guo, Jef Loenders, Joost Duflou, Bert Lauwers. "*Optimization of energy consumption and surface quality in finish turning*" Procedia CIRP 1 (2012) pp.529 – 534.

[7] Gaurav Bartarya, S.K.Choudhury. "*Effect of cutting parameters on cutting force and surface roughness during finish hard turning AISI52100 grade steel"* Procedia CIRP 1 (2012) pp.674 – 679.

[8] Suleiman Abdulkareem, Usman Jibrin Rumah, Apasi Adaokoma. "*Optimizing Machining Parameters during Turning Process*" International Journal of Integrated Engineering, Vol. 3 No. 1 (2011) pp.23-27.

[9] R A Mahdavinejad, S Saeedy. "*Investigation of the influential parameters of machining of AISI 304 stainless steel*" Sadhana Vol. 36, Part 6 (2011) pp.963–970.

[10] Pragnesh. R. Patel, Prof. V. A. Patel. "*Effect of machining parameters on Surface roughness and Power consumption for 6063 Al alloy TiC Composites (MMCs)*" International Journal of Engineering Research and Applications Vol. 2 (2012) pp.295-300.

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