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Identification Of The Optimal Parameters For Minimizing Surface Roughness For Alloy Steel On Aerospace Fasteners Using Design Of Experiments

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Abstract- *In manufacturing industry, the current trend is to adopt six- sigma, which is about improving process in all the aspects of production. By applying various Industrial Engineering tools, the process of any industry can be improved or optimized. Surface roughness of a fastener plays a crucial role in providing a good surface finish. Controlling the surface roughness value to an optimum level would ensure minimum surface defects. In a machining set up various factors would affect product quality characteristics. Surface roughness can be affected by various process parameters and material characteristics. To understand and analyze the effect of various factors an experimental study would be needed.*
Design of experiments provides a scientific pathway to identify and analyze the crucial factors which affects the response variables (Surface roughness). To conduct the experiment, few factors were chosen which includes Speed, feed and depth of cut with two levels and the experiment was carried out using DOE principle, such as Randomization and Replication. Various types of response variables such as Average surface roughness, face average for surface roughness, surface roughness range and standard deviation for surface roughness for alloy steel were obtained to analyze the significant effects. The choice of these response variables were based on understanding the effects on mean as well as variability of surface roughness.

Keywords- *Surface Roughness, Speed, feed, depth of cut, 2-level design (2^k design), Design Of Experiments, ANOVA*

I. INTRODUCTION

The aim of the paper is to reduce the defects and defectives in the production line and minimizing surface roughness using Industrial engineering tools and techniques. Surface roughness of a material has a direct impact on surface finish quality and hence surface defects. The lower the surface roughness value the better would be the surface finish quality. In aerospace, the surface finish plays a crucial role and becomes important quality characteristic, therefore a need of minimal or zero defects. Generally during production, most likely material used is Titanium alloy. Because of its various applications, but use of alloy steel can reduce the cost in the production and it acts as replacement.

Surface roughness for titanium alloy is less in comparison to alloy steel. The surface roughness is dependent on various factors, such as speed, feed and depth of cut. To analyse and identify which combination gives better result, design of experiment approach is used.

Machining was carried out using CNC machine and material used was Alloy steel (AISI-304). To machine, Alloy steels were used with 6mm diameter and 10 mm length as shown in the figure.

Figure 1. Work piece

The chemical composition of Alloy steel AISI-304 is summarized shown in the table 1. All the work from initial preparation of work piece to final machining experiment was done at ABC Company.

Table 1. Chemical composition of AISI-304, % wt

Elements	C	Si	Mn	S	P	Cr	Ni	Mo
Wt(%)	0.368	0.155	0.684	0.023	0.023	1.600	1.598	0.284

II. LITERATURE REVIEW

There have been various literatures on and carried inn analysing the effects of various machining factors on material such as titanium, alloy steel.

Mohammed T. Hayajneh et al. [9], carried out a set of experimental design to understand the surface quality for End-Milling Process. Their objective was to know the effects of spindle speed, cutting feed rate and depth of cut on the surface roughness and to build a multiple regression model.

Er. Manpreet Singh et al. [16] carried out literature review on different type of material to be machined. Their study showcase the importance of machining parameters like Speed Feed Depth of cut Nose radius plays a vital role in Surface Roughness.

Navneet Khanna, J P Davim [15] studied the effect of control factors i.e. cutting speed, feed rate and cutting tool temperature using taguchi technique. The output of their study was to suggesting Aerospace industry to use titanium alloys which has superior strength.

Goutam Devaraya Revankara et al. [8] carried out their study on Titanium alloy (Ti–6Al–4V) and Polycrystalline Diamond Tool using different factors such as speed feed and depth of cut. The aim of their study was to know the effect of these parameters on surface roughness and hardness. The study tells, the smaller the roughness, better hardness is achieved.

III. EXPERIMENTAL DESIGN

A 2^3 design was considered with factors and levels as shown in Table 2. The response variables considered are shown in Table 3.

Table 2. Process control parameters and their levels

Parameters	**Units**	**Level 1**	**Level 2**
Speed	Rpm	2300	3700
Feed	mm/rev	O4	O6
Depth of cut	mm	0.2	0.3

3.1 Experimental procedure

The turning, Outer diameter(OD) and part off operations were carried out in CNC machine at ABC Company. The CNC machine is equipped with AC variable speed spindle motor up to 4000 rpm and regular industrial power was used for present experimental work. The cutting tool used was Carbide tool and inserts.

Figure 2. Photo of CNC machine

3.2 Response values

The response values were taken using **Surface Roughness Tester** in Advance Material science lab at MSRIT, Bangalore. Surface Roughness can be measured in µm and the cut off length is 0.25mm and 2.5mm. If we place the specimen below the tester, it automatically calculates the surface roughness of it. To check the repeatability, the readings were collected for many trials. The figure3 shows the surface testing machine.

Figure 3. Surface roughness testing machine

The response variables are tested as follows

3.2.1 Average surface roughness: In this within a part five data point's average were collected to check the variability within a part.
3.2.2 Face Average for surface roughness: In this the face of the specimen was measured with two data point and then average of it was considered to check the variability within a part.

3.2.3 Surface roughness Range: In this the range was considered to know the variation within a part.
3.2.4 Standard deviation for surface roughness: In this the lateral side of the specimen's five data points were measured to check the variation across the part.

After collecting the responses, the data was input in run order sheet and using Minitab software, then accordingly data was analyses using Minitab software package. Table 4 shows the run orders and response values. The experiment was run for 32 runs (2^^{3} * 4 Replicates) based on randomization for which the details have been provided in Table 4.

Table 3. Response variables

Response Average for SR	Range for SR	Std Dev for SR	Face Avg for SR
1.92	0.21	0.1110416	1.625
0.27	0.07	0.0311121	0.705
1.966	1.43	0.6641762	1.06
1.84	1.06	0.4168933	0.54
1.674	0.73	0.2834255	0.775
0.29	0.09	0.034641	0.39
1.74	1.2	0.5015425	1.38
1.112	0.72	0.3100025	1.045
1.102	0.27	0.1082589	1.065
1.94	0.98	0.3807887	0.775
1.566	0.9	0.3445898	1.815
1.785	0.91	0.4195899	0.6
2.029	1.39	0.5767582	1.73
1.188	1.26	0.5755172	0.7
2.094	0.36	0.1361249	2.03
2.031	0.99	0.4278434	2.21
1.425	0.58	0.2788727	1.16
1.589	2.11	0.8685412	1.595
1.885	1.05	0.4519071	1.425
2.6	1.81	0.7012537	0.39

2.12	0.5	0.2085186	2.31
1.356	0.65	0.2541653	1.005
1.6	0.98	0.3614139	1.08
1.224	1.15	0.4385544	0.465
1.272	0.98	0.4585521	1.23
2.541	2.42	0.9236548	2.105
0.308	0.14	0.0506952	1.025
1.66	0.48	0.244806	0.715
1.852	1.14	0.5124579	0.86
1.612	0.84	0.3627947	0.545
1.542	0.72	0.2651488	1.14
1.788	1.23	0.4541246	0.485

Table 4. Run orders

StdOrder	Run Order	Speed	Feed	Depth of cut	ResponseAverage	Range	Std Dev	Face Avg
31	1	3700	O6	0.2	1.92	0.21	0.1110416	1.625
14	2	3700	O4	0.3	0.27	0.07	0.0311121	0.705
5	3	3700	O4	0.2	1.966	1.43	0.6641762	1.06
17	4	2300	O4	0.2	1.84	1.06	0.4168933	0.54
12	5	2300	O6	0.3	1.674	0.73	0.2834255	0.775
25	6	2300	O4	0.2	0.29	0.09	0.034641	0.39
20	7	2300	O6	0.3	1.74	1.2	0.5015425	1.38
9	8	2300	O4	0.2	1.112	0.72	0.3100025	1.045
3	9	2300	O6	0.2	1.102	0.27	0.1082589	1.065
27	10	2300	O6	0.2	1.94	0.98	0.3807887	0.775
16	11	3700	O6	0.3	1.566	0.9	0.3445898	1.815
19	12	2300	O6	0.2	1.785	0.91	0.4195899	0.6
1	13	2300	O4	0.2	2.029	1.39	0.5767582	1.73
21	14	3700	O4	0.2	1.188	1.26	0.5755172	0.7
2	15	2300	O4	0.3	2.094	0.36	0.1361249	2.03
18	16	2300	O4	0.3	2.031	0.99	0.4278434	2.21
26	17	2300	O4	0.3	1.425	0.58	0.2788727	1.16
10	18	2300	O4	0.3	1.589	2.11	0.8685412	1.595
24	19	3700	O6	0.3	1.885	1.05	0.4519071	1.425
11	20	2300	O6	0.2	2.6	1.81	0.7012537	0.39
30	21	3700	O4	0.3	2.12	0.5	0.2085186	2.31
22	22	3700	O4	0.3	1.356	0.65	0.2541653	1.005
4	23	2300	O6	0.3	1.6	0.98	0.3614139	1.08
29	24	3700	O4	0.2	1.224	1.15	0.4385544	0.465
7	25	3700	O6	0.2	1.272	0.98	0.4585521	1.23
28	26	2300	O6	0.3	2.541	2.42	0.9236548	2.105
15	27	3700	O6	0.2	0.308	0.14	0.0506952	1.025
8	28	3700	O6	0.3	1.66	0.48	0.244806	0.715

6	29	3700	O4	0.3	1.852	1.14	0.5124579	0.86
13	30	3700	O4	0.2	1.612	0.84	0.3627947	0.545
23	31	3700	O6	0.2	1.542	0.72	0.2651488	1.14
32	32	3700	O6	0.3	1.788	1.23	0.4541246	0.485

IV. RESULTS

4.1 Main effects plot of average surface roughness for alloy steel

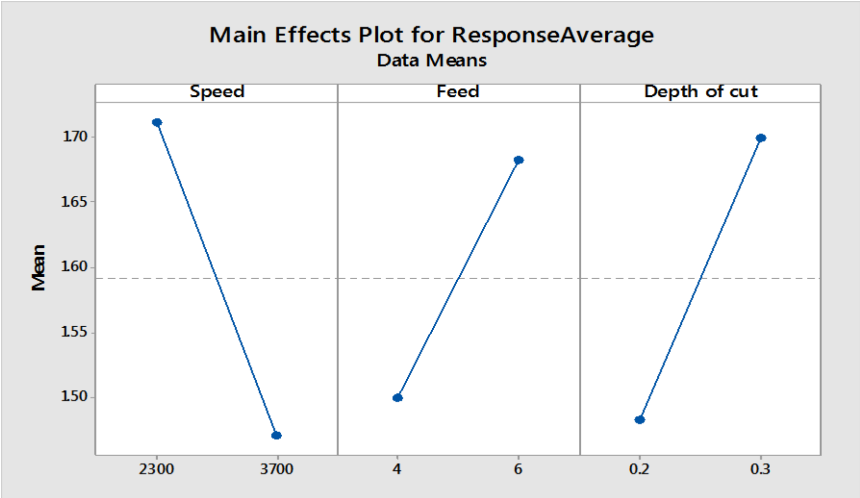
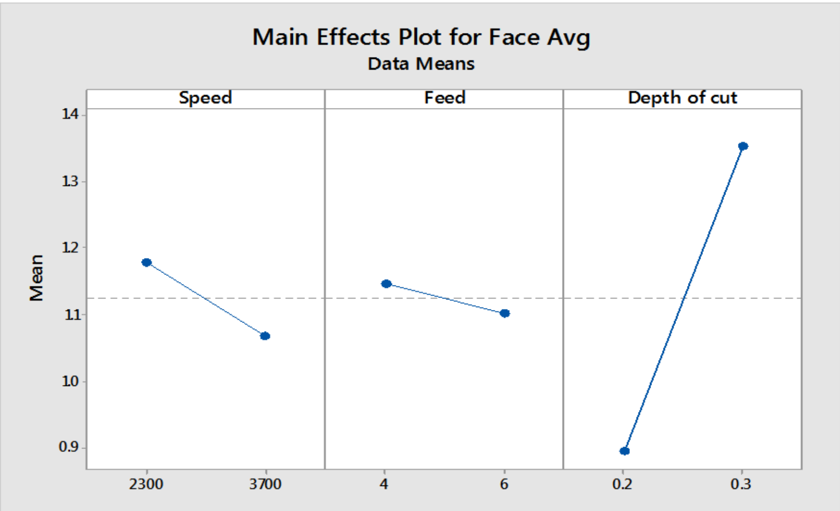


Figure 4. Main effects plot of average surface roughness for alloy steel

It is seen from the main effects plot of Average surface roughness of Alloy steel that, there is a minimal change from 1.7 to 1.5, when speed is changed from 2300 rpm to 3700 rpm this shows that speed plays an insignificant role in Surface roughness average value. Likewise the changes are insignificant for feed and depth of cut.

4.2 Main effects plot for face average of surface roughness for alloy steel



Figuure 5. Main effects plot for face average of surface roughness for alloy steel

It is seen from the main effects plot of Face average of Surface roughness for Alloy steel, that there is change in depth of cut as it varies from 0.9 to 1.4. When depth of cut is changed from 0.2mm tto 0.3mm. This shows that depth of cut plays a significant role in face average for surfacce roughness. Likewie the changes are insignificcant for feed and speed.

4.3 Main effects plot of surface roughness range for alloy steel

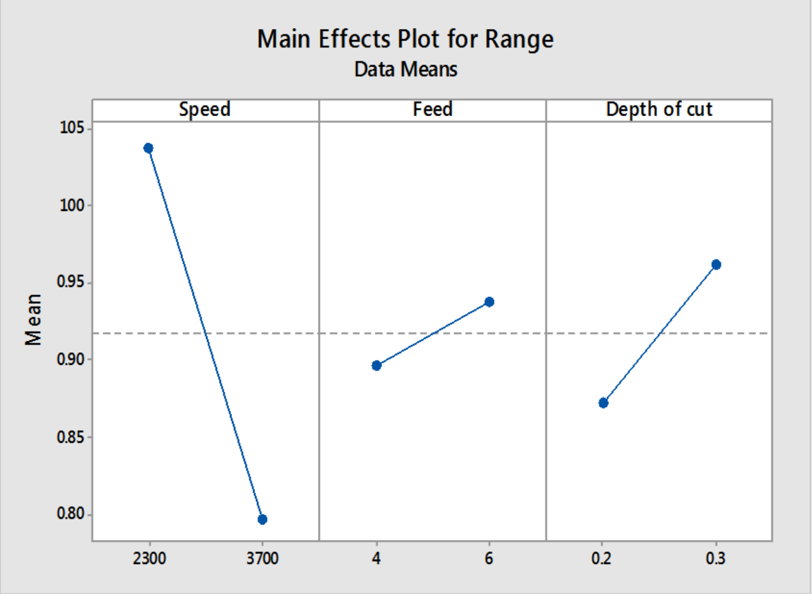


Figure 6. Main effects plot of surface roughness range for alloy steel

It is seen from the main effects plot of Surface roughness range for Alloy steel that, there is a minimal change from 0.8 to 1.05, when speed is changed from 2300 rpm to 3700 rpm this shows that speed plays an insignificant role in Surface roughness for range. Likewise the changes are insignificant for feed and depth of cut.

4.4 Main effects plot of sstandard deviation for surface roughness for alloy steel

Figure 7. Main effects plot of standard deviation for surface roughness of alloy steel

It is seen from the main effects plot of Standard deviation for Surface roughness of Alloy steel that there is minimal change from 0.33 to .42, when speed is changed from 2300 rpm tto 3700 rpm. This shows that speed plays an insignificant role in Standard deviation for surfacce roughness. Likewie the changes are insignificcant for feed and depth of cut.

4.5 Interaction plot for average surface roughness for alloy steel

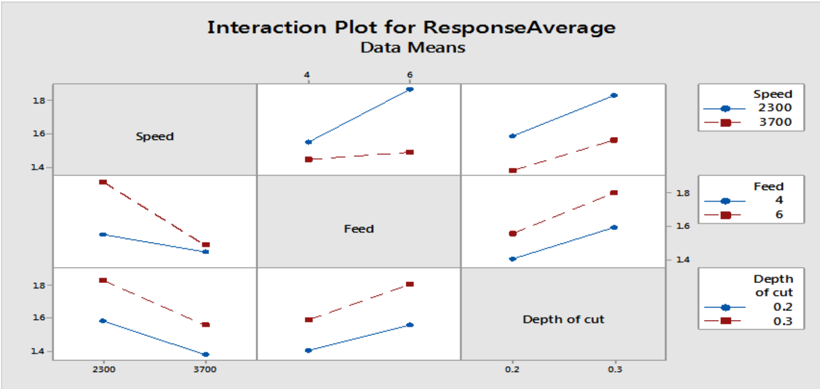


Figure 8. Interaction plot for average surface roughness for alloy steel

It is seen from the plot that the lines are parallel. Hence there is no lines are intersecting between any of the combinations. This indicates that there is no interaction effect between them.

4.6 Interaction plot for face Average of surface roughness for alloy steel

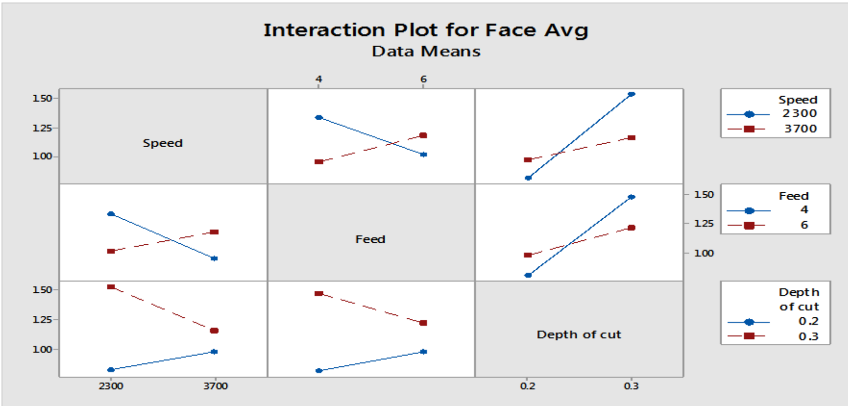


Figure 9. Interaction plot for face average of surface roughness for alloy steel

It is seen from the plot that the lines are completely intersecting between speed and feed, speed amd depth of cut, feed and depth of cut. This indicates an interaction effect between them, however the interaction effect is insignificant between Speed and feed because of low contrast value. But the contrast value between depth and feed, depth cut and speed is little bit more. So the interaction effect beween them is significant.

4.7 Interaction plot for range of surface roughness for alloy steel

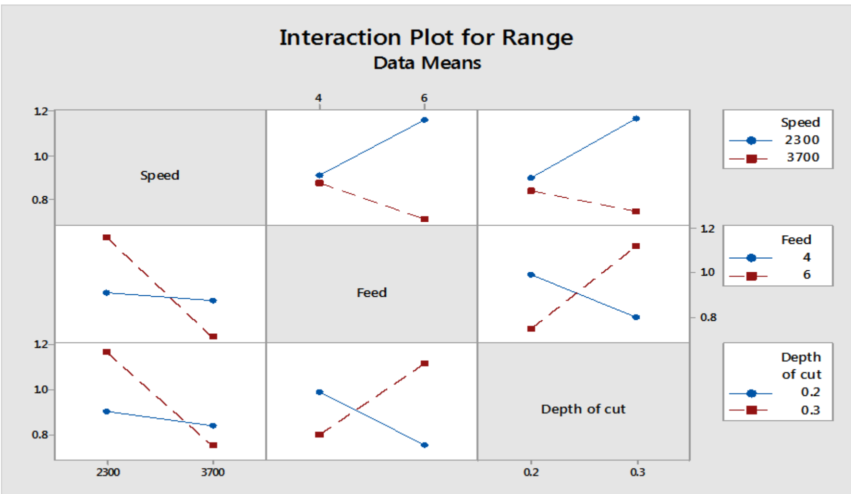


Figure 10. Interaction plot for range of surface roughness for alloy steel

It is seen from the plot that the lines are completely intersecting between speed and feed, speed amd depth of cut, feed and depth of cut. This indicates an interaction effect between them, however the interaction effect is insignificant because of low contrast value.

4.8 Interaction plot for standard deviation of surface roughness for alloy steel

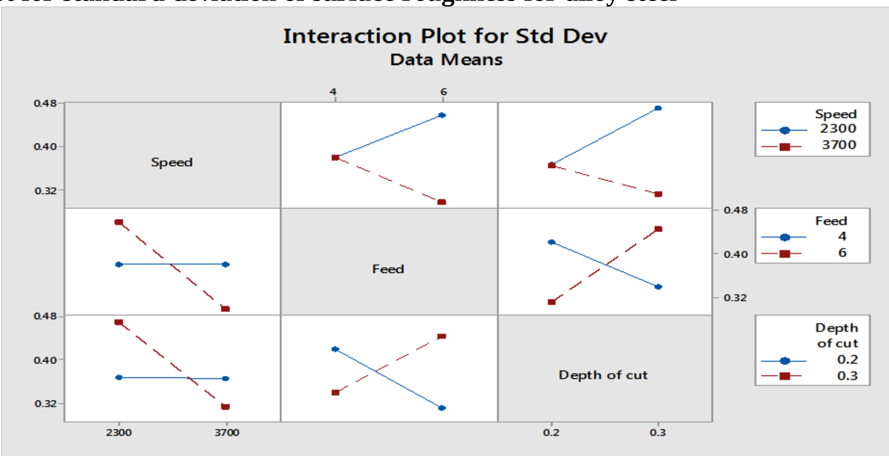


Figure 11. Interaction plot for standard deviation of surface roughness for alloy steel

It is seen from the plot that the lines are completely intersecting between speed and feed, speed amd depth of cut, feed and depth of cut. This indicates an interaction effect between them, however the interaction effect is insignificant because of low contrast value.

4.9 Analysis of variance (ANOVA)

The main purpose of the analysis of variance (ANOVA) is the application of a statistical method to identify the effects of individual parameters and their significance for the response variable. Results from ANOVA can determine very clearly the impact of each of parameters on the process results at desired confidence level.

4.10 ANOVA for average surface roughness for alloy steel

Table 5. ANOVA for Averrage of surface roughness for Alloy steel

General Factorial Regression: ResponseAverage versus Speed, Feed, Depth of cut

Factor Information

Factor	Levels	Values
Speed	2	2300, 3700
Feed	2	4, 6
Depth of cut	2	0.2, 0.3

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	1.77606	0.253723	0.78	0.610
Linear	3	1.10803	0.369343	1.14	0.354
Speed	1	0.46634	0.466337	1.44	0.243
Feed	1	0.26736	0.267363	0.82	0.373
Depth of cut	1	0.37433	0.374329	1.15	0.294
2-Way Interactions	3	0.17078	0.056927	0.18	0.912
Speed*Feed	1	0.15387	0.153874	0.47	0.498
Speed*Depth of cut	1	0.00881	0.008811	0.03	0.871
Feed*Depth of cut	1	0.00810	0.008096	0.02	0.876
3-Way Interactions	1	0.49725	0.497254	1.53	0.228
Speed*Feed*Depth of cut	1	0.49725	0.497254	1.53	0.228
Error	24	7.79781	0.324909		
Total	31	9.57388			

The above table shows that the p-value for linera model,2-way interaction and for 3-way interaction is greater than 0.05. There for it infers that all the factors for all the combination of interacction are insignificnt.

4.11 ANOVA for range of surface roughness for alloy steel

Table 6. ANOVA for range of surface roughness for alloy steel

General Factorial Regression: Range versus Speed, Feed, Depth of cut

Factor Information

Factor	Levels	Values
Speed	2	2300, 3700
Feed	2	4, 6
Depth of cut	2	0.2, 0.3

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	2.12782	0.30397	1.01	0.447
Linear	3	0.54113	0.18038	0.60	0.620
Speed	1	0.46320	0.46320	1.54	0.226
Feed	1	0.01403	0.01403	0.05	0.831
Depth of cut	1	0.06390	0.06390	0.21	0.648
2-Way Interactions	3	1.23598	0.41199	1.37	0.275
Speed*Feed	1	0.34653	0.34653	1.16	0.293
Speed*Depth of cut	1	0.25383	0.25383	0.85	0.367
Feed*Depth of cut	1	0.63563	0.63563	2.12	0.158
3-Way Interactions	1	0.35070	0.35070	1.17	0.290
Speed*Feed*Depth of cut	1	0.35070	0.35070	1.17	0.290
Error	24	7.19622	0.29984		
Total	31	9.32405			

The above table shows that the p-value for linear model, 2-way interaction and for 3-way interaction is greater than 0.05. There for it infers that all the factors for all the combination of interacction are insignificnt.

4.12 ANOVA for face average of surface roughness for alloy steel

Table 7. ANOVA for face averrage of surface roughness for alloy steel

General Factorial Regression: Face Avg versus Speed, Feed, Depth of cut

Factor Information

Factor	Levels	Values
Speed	2	2300, 3700
Feed	2	4, 6
Depth of cut	2	0.2, 0.3

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	3.44070	0.49153	1.91	0.111
Linear	3	1.79203	0.59734	2.33	0.100
Speed	1	0.09680	0.09680	0.38	0.545
Feed	1	0.01620	0.01620	0.06	0.804
Depth of cut	1	1.67903	1.67903	6.54	0.017
2-Way Interactions	3	1.53467	0.51156	1.99	0.142
Speed*Feed	1	0.58861	0.58861	2.29	0.143
Speed*Depth of cut	1	0.56978	0.56978	2.22	0.149
Feed*Depth of cut	1	0.37628	0.37628	1.47	0.238
3-Way Interactions	1	0.11400	0.11400	0.44	0.512
Speed*Feed*Depth of cut	1	0.11400	0.11400	0.44	0.512
Error	24	6.16159	0.25673		
Total	31	9.60229			

The above table shows that the p-value for linear model, 2-way interaction and for 3-way interaction is greater than 0.05.But in the linear model, the p-value for factor depth of cut is 0.017 which is less than 0.05. there for it alone plays a significant role as dpth of cut changees from 0.2mm to 0.3mm.

4.13 ANOVA for sstandard deviation of surface roughness for alloy steel

Table 8. ANOVA for standard deviation of surface roughness for alloy steel

General Factorial Regression: Std Dev versus Speed, Feed, Depth of cut

Factor Information

Factor	Levels	Values
Speed	2	2300, 3700
Feed	2	4, 6
Depth of cut	2	0.2, 0.3

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	0.32974	0.047106	0.96	0.483
Linear	3	0.05818	0.019395	0.39	0.758
Speed	1	0.05293	0.052930	1.08	0.310
Feed	1	0.00004	0.000041	0.00	0.977
Depth of cut	1	0.00521	0.005213	0.11	0.748
2-Way Interactions	3	0.19573	0.065243	1.33	0.289
Speed*Feed	1	0.05254	0.052543	1.07	0.312
Speed*Depth of cut	1	0.04946	0.049458	1.00	0.326
Feed*Depth of cut	1	0.09373	0.093727	1.90	0.180
3-Way Interactions	1	0.07583	0.075828	1.54	0.227
Speed*Feed*Depth of cut	1	0.07583	0.075828	1.54	0.227
Error	24	1.18135	0.049223		
Total	31	1.51108			

The above table shows that the p-value for linear model,2-way interaction and for 3-way interaction is greater than 0.05. There for it infers that all the factors for all the combination of interacction are insignificnt.

V. CONCLUSION

The important conclusions drawn from the present work are summarized as follows:

1. ANOVA table for face average of surface roughness for Alloy steel shows that Depth of cut alone plays a significant role, since its p-value is less than 0.05.
2. Even the main effects plot shows that the depth of cut plays the significant role in face average of surface roughness for Alloy steel.
3. The best process of optimal parameters are as shown
   a. Depth of cut with 0.2mm, Speed with 3700rpm and feed with O4mm/rev.
   b. Depth of cut with 0.2mm, Speed with constant with o4mm/rev.

REFERENCES

[1] Design and analysis of Experiments, Douglas C. Montgomery, 5th edition
[2] Other cause of fasteners, Carrie Menendez, failure metallurgist SMT&I, USA
[3] Adan Valles, Jaime Sanchez, Salvador Noriega, and Berenice Gómez Nuñez Implementation of Six Sigma in a Manufacturing ProcessInternational Journal of Industrial Engineering, 16(3), 171-181, 2009.
[4] Tanvir Ahmed, Raj Narayan Acharjee, MD.Abdur Rahim, Noman Sikder, Taslima Akther, Mohd. Rifat Khan, MD.Fazle Rabbi, Anup Saha An Application of Pareto Analysis and Cause-Effect Diagram for Minimizing Defect Percentage in Sewing Section of a Garment Factory, Vol. 3, Issue. 6, Nov - Dec. 2013 pp-3700-3715
[5] Dr. Rajeshkumar U. Sambhe: Six Sigma practice for quality improvement. Volume 4, Issue 4 (Nov-Dec. 2012), PP 26-42
[6] Mohit Taneja, Arpan Manchanda: Six Sigma an Approach to Improve Productivity in Manufacturing Industry, Volume 5 Number 6- Nov, 2013
[7] Text book of Applied Statistics and Probability for Engineers by Douglas C. Montgomery, George C. Runger, 3rd edition.
[8] Goutam Devaraya Revankara, Raviraj Shettyb, Shrikantha Srinivas Raoc, Vinayak Neelakanth Gaitonded "Analysis of Surface Roughness and Hardness in Titanium Alloy Machining with Polycrystalline Diamond Tool under Different Lubricating Modes",
[9] Mohammed T. Hayajneh , Montasser S. Tahat b, Joachim Bluhm: A Study of the Effects of Machining Parameters on the Surface Roughness in the End-Milling Process, Volume 1, Number 1, Sep. 2007 ISSN 1995-6665 Pages 1 – 5.

[10] Rodrigues L.L.R, Kantharaj A.N, Kantharaj B, Freitas W. R. C. And Murthy B.R.N: Effect of Cutting Parameters on Surface Roughness and Cutting Force in Turning Mild Steel, Vol. 1(10), 19-26, October (2012).

[11] B.Tulasiramarao,Dr.K.Srinivas, Dr. P Ram Reddy, A.Raveendra, Dr.B.V.R.Ravi Kumar: Experimental Study On The Effect Of Cutting Parameters On Surface Finish Obtained In Cnc Turning Operation, Vol. 2, Issue 9, September 2013

[12] Pragnesh. R. Patel, Prof. V. A. Patel: Effect of machining parameters on Surface roughness and Power consumption for 6063 Al alloy TiC Composites (MMCs) , Vol. 2, Issue 4, July-August 2012, pp.295-300.

[13] Mehmet Alper, İlhan ASİLTÜRK: Effects of Cutting Tool Parameters on Surface Roughness, Volume 4, Issue 8 (August 2015), PP.15-22.

[14] Rahul kumar, Kiran Dhull: To study the influence of milling parameters onn material removal rate of AISI H13 by ANOVA, Volume 2, Issue 2, Feb-206

[15] Navneet khanna, J.P. Davin: Design of experiments application machining in titanium alloys for aerospace structural components.

[16] Er. Manpreet Singh: Literature review on different type of materials