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A Comparative Analysis of Surface Roughness and Material Removal Rate in Milling Operation of AISI 410 Steel And Aluminium 6061

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ABSTRACT
Surface roughness is an important measure of product quality since it greatly influences the performance of Mechanical parts as well as production cost. Roughness plays an extensive role in demonstrating how the object will interface with the environment. The main purpose of this paper is to analyse the comparative study of Surface Roughness and Material Removal Rate (MRR) of Aluminium 6061and AISI 410 Steel. In the present paper three parameters were taken to check whether quality lies within desired tolerance level. Surface roughness and MRR were taken using three different parameters of CNC machining including spindle speed, feed rate and depth of cut. Optimization of surface roughness of aluminium 6061 and AISI 410 Steel were done using Response Surface Methodology. Response Surface Methodology is an adequate channel in which response variable can be optimized by taking several experimental runs. This paper aims to obtain an optimal setting of three milling parameters by using Carbide cutting tool in end milling operation of AISI 410 steel and Aluminium Alloy 6061 taken as specimen.

Keywords AISI410Steel, Aluminium6061, ANOVA, DOE, RSM

I. INTRODUCTION

Machining Industries in modern trends are mainly focused on the achievement of high quality of products. High quality comes from the factors like dimensional accuracy and Surface finish of the product.[1] Surface texture is mainly concerned with the geometric irregularities of the surface of a material and it is defined in terms of surface roughness, waviness, lay and flaws. Surface roughness consists of the irregularities in the surface texture. [2] Today, in almost every manufacturing industry, manufacturers focus on the quality and Productivity of the product. To increase the production various types of Computer programmed machines have been used in recent years. Different types of computer numerically controlled (CNC) machines have been setup which revolutionized the concept of increasing productivity.[3] One of the most important parameters to determine the quality of product is surface roughness.[4] The mechanism behind the formation of surface roughness in CNC milling process is very dynamic, complicated, and process dependent. There are several parameters which influence the texture and `smoothness of roughness Such as Spindle Speed, Depth of Cut, and Feed Rate etc.[5] Various combination between these parameters are useful to achieve desired surface roughness. Milling process is one of the basic material removal process. This process and its tools are capable of producing different types of shapes with the use of multi-tooth cutting tools. [6] In the milling process, a multi-tooth cutter rotates along various axes with respect to the work piece.[7] Different Applications of the end milling process can be found in almost every industry ranging from small tool maker units to large production industries. The biggest problem, which result from the end milling process, is the finished part surface which does not satisfy product design specifications. A finished part surface might be very rough or of poor dimension accuracy that causes additional machining, thus lowering productivity and increasing the production cost.[8] In order to produce parts of desired quality, proper machining parameters (spindle speed, feed rate, depth of cut, cutter diameter, number of cutting flutes, and tool geometry) must be selected.

Design of experiments (DOE) which is a systematic, approach to engineering problem-solving that applies principles and techniques at the data collection stage to ensure the generation of valid and supportable engineering conclusions. Also all of this is carried out under the constraint of a minimal expenditure of engineering runs, time, and money.[9]Taguchi method which is a technique of Design of experiments can be used for attaining high quality at minimum cost. The quality obtained by means of the optimization of the product or process is found to be cost effective.[10] Response surface methodology (RSM) which is another analysis technique is a collection of mathematical and statistical techniques for empirical model building where the objective is to optimize a response (output variable) which is influenced by several independent variables (input variables).[11] The application of RSM to design optimization is aimed at reducing the cost of expensive analysis methods like finite element method or CFD analysis and their associated numerical noise. Aluminium alloy 6061, a medium to high strength heat-treatable alloy with a very high strength and very good corrosion resistance as well as good weldability is used for the heavy duty structure like Railway coaches, Truck Frames etc. [12] Steels AISI 410 are general-purpose martensitic stainless steels containing 11.5% chromium, which provide good corrosion resistance properties used in manufacturing of Bolts, screws, bushings and nuts and Petroleum fractionating structures [13].

II. Indentations and Equations

In this research work Taguchi method and Response Surface Methodology were used to study the effect of three different process parameters (spindle speed, feed rate and depth of cut) on the surface roughness of the specimen. For the comparative study in the research Aluminium alloy 6061 and AISI 410 Steel were chosen for the specimen material.L9 orthogonal array was used and all the end milling operations were done in Industrial and farm Equipment, Ramnagar on ASM Hydrostatic Machine Model No.- MCV 450 by Carbide cutting tool of diameter 32mm and surface roughness was measured in each run by the Surface Roughness Measurement Device Model no. TR110P.

III. Figures and Tables

3.1 Tables

Table 3.1 Details of the Milling Operation

Factors	**Level 1**	**Level 2**	**Level 3**
Spindle Speed (rpm)	1000	1200	1400
Feed (mm/rev)	150	200	250
Depth of cut	0.2	0.4	0.6

Table 3.2 Results for experimental trial runs for milling operation in AISI 410 Steel

Sr. No.	**Spindle Speed (mm/rev)**	**Feed Rate (rpm)**	**Depth of Cut (mm)**	**Surface Rough-ness (μm)**	**MRR**
01	1000	150	0.2	2.79	0.00478
02	1000	200	0.4	2.09	0.00615
03	1000	250	0.6	2.33	0.00717
04	1200	150	0.4	0.30	0.00975
05	1200	200	0.6	0.39	0.01890
06	1200	250	0.2	0.45	0.00759
07	1400	150	0.6	0.24	0.01980
08	1400	200	0.2	0.30	0.00645
09	1400	250	0.4	0.45	0.01560

Table 3.3 Results for experimental trial run for milling operation in Aluminium 6061

Sr. No.	**Spindle Speed (mm/rev)**	**Feed Rate (rpm)**	**Depth of Cut (mm)**	**Surface Rough-ness (μm)**	**MRR**
01	1000	150	0.2	1.04	0.000042
02	1000	200	0.4	0.95	0.000017
03	1000	250	0.6	0.92	0.000021
04	1200	150	0.4	0.91	0.000028
05	1200	200	0.6	0.61	0.000044
06	1200	250	0.2	0.62	0.000021
07	1400	150	0.6	0.56	0.000043
08	1400	200	0.2	1.05	0.000017
09	1400	250	0.4	0.82	0.000022

Table 3.4 AISI 410 Steel: MRR vs Speed, Feed rate and Depth of cut.

Trial No.	Speed	Feed rate	Depth of cut	MRR	Predictive value	Residual Value
1	1000	150	0.2	0.00478	0.0028828	0.0018972
2	1000	200	0.4	0.00615	0.0067294	-0.0005794
3	1000	250	0.6	0.00717	0.0105761	-0.0034061
4	1200	150	0.4	0.00975	0.0113494	-0.0015994
5	1200	200	0.6	0.01890	0.0151961	0.0037039
6	1200	250	0.2	0.00759	0.0055178	0.0020722
7	1400	150	0.6	0.01980	0.0198161	-0.0000161
8	1400	200	0.2	0.00645	0.0101378	-0.0036878
9	1400	250	0.4	0.01560	0.0139844	0.0016156

Table 3.5 Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	0.000219	0.000073	6.96	0.031
Linear	3	0.000219	0.000073	6.96	0.031
Speed	1	0.000094	0.000094	8.98	0.030
Feed Rate	1	0.000003	0.000003	0.25	0.638
Depth of Cut	1	0.000122	0.000122	11.65	0.019
Error	5	0.000052	0.000010		
Total	8	0.000271			

Table 3.6 AISI 410 Steel: Ra vs Speed, Feed rate and Depth of cut.

Trial No.	Speed	Feed rate	Depth of cut	Ra	Predictive value	Residual Value
1	1000	150	0.2	2.79	2.18778	0.602222
2	1000	200	0.4	2.09	2.07444	0.015556
3	1000	250	0.6	2.33	1.96111	0.368889
4	1200	150	0.4	0.30	1.05444	-0.754444
5	1200	200	0.6	0.39	0.941111	-0.551111
6	1200	250	0.2	0.45	1.11778	-0.667778
7	1400	150	0.6	0.24	-0.07889	0.318889
8	1400	200	0.2	0.30	-0.9778	0.202222
9	1400	250	0.4	0.45	-0.01556	0.465556

Table 3.7 Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	6.50580	2.16860	4.98	0.058
Linear	3	6.50580	2.16860	4.98	0.058
Speed	1	6.44807	6.44807	14.81	0.012
Feed Rate	1	0.00167	0.00167	0.00	0.953
Depth of Cut	1	0.05607	0.05607	0.13	0.734
Error	5	2.17716	0.43543		
Total	8	8.68296			

Table 3.8 Aluminium 6061: Ra vs Speed, Feed rate and Depth of cut.

Trial No.	Speed	Feed rate	Depth of cut	Ra	Predictive value	Residual Value
1	1000	150	0.2	1.04	1.03944	0.0005556
2	1000	200	0.4	0.95	0.911111	0.0388889
3	1000	250	0.6	0.92	0.782778	0.137222
4	1200	150	0.4	0.91	0.856111	0.0538889
5	1200	200	0.6	0.61	0.727778	-0.117778
6	1200	250	0.2	0.62	0.909444	-0.289444
7	1400	150	0.6	0.56	0.672778	-0.112778
8	1400	200	0.2	1.05	0.854444	0.195556
9	1400	250	0.4	0.82	0.726111	0.0938889

Table 3.9 Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	0.106217	0.035406	0.98	0.472
Linear	3	0.106217	0.035406	0.98	0.472
Speed	1	0.038400	0.038400	1.06	0.350
Feed Rate	1	0.003750	0.003750	0.10	0.760
Depth Of Cut	1	0.064067	0.064067	1.77	0.240
Error	5	0.180672	0.036134		
Total	8	0.286889			

Table 3.10 Aluminium 6061: MRR vs Speed, Feed rate and Depth of cut.

Trial No.	Speed	Feed rate	Depth of cut	MRR	Predictive value	Residual Value
1	1000	150	0.2	0.000042	0.0000315	0.0000105
2	1000	200	0.4	0.000017	0.0000280	-0.0000110
3	1000	250	0.6	0.000021	0.0000245	-0.0000035
4	1200	150	0.4	0.000028	0.0000365	-0.0000085
5	1200	200	0.6	0.000044	0.0000330	0.0000110
6	1200	250	0.2	0.000021	0.0000155	0.0000055
7	1400	150	0.6	0.000043	0.0000415	0.0000015
8	1400	200	0.2	0.000017	0.0000240	-0.0000070
9	1400	250	0.4	0.000022	0.0000205	0.0000015

Table 3.11 Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	0.000000	0.000000	1.70	0.281
Linear	3	0.000000	0.000000	1.70	0.281
Speed	1	0.000000	0.000000	0.01	0.939
Feed Rate	1	0.000000	0.000000	3.84	0.107
Depth Of Cut	1	0.000000	0.000000	1.26	0.313
Error	5	0.000000	0.000000		
Total	8	0.000000			

3.2 Graphs

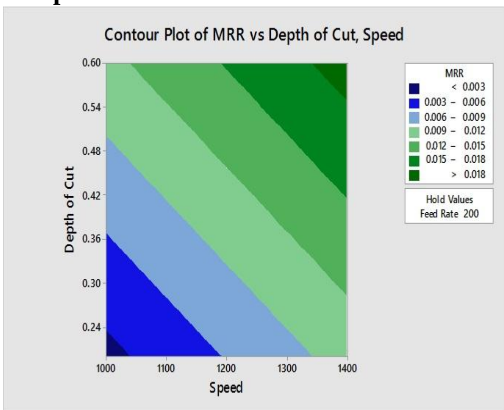

Fig3.1 AISI 410 Steel contour plot, MRR

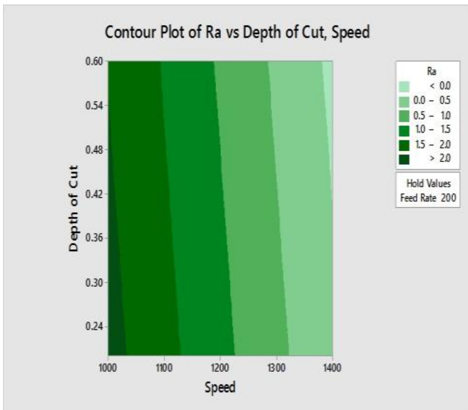

Fig3.2 AISI 410 Steel contour plot, Ra

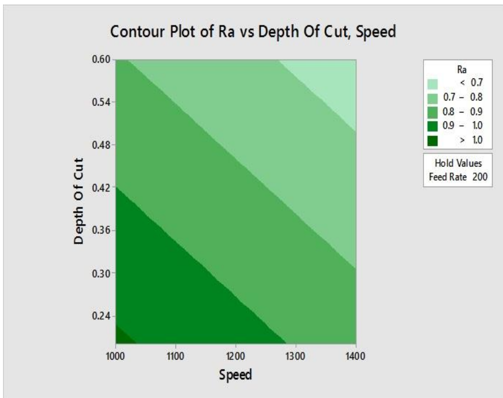

Fig3.3 Aluminium 6061 contour plot, Ra

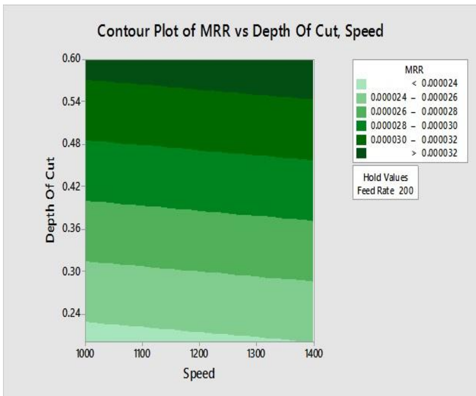

Fig 3.4 Aluminium 6061 contour plot, MRR

IV. Conclusion

According to ANOVA Table 3.5 and Table 3.7 the only significant factor found for the milling operation of AISI Steel 410 was speed whose effect on the surface roughness has to be considered (p-value<0.05). While According to ANOVA Table no. 3.9 and Table no. 3.11 none of the factor was found to be significant for the milling operation of Aluminium 6061 (p-value>0.05).The contour plots showing the graph between speed and depth of cut. For the contour plot of Surface Roughness the area in the light green color means surface is smooth while the dark green color shows the surface is rough. While for the contour plot of MRR the area showing the dark green color shows the maximum MRR while Blue shows the lowest MRR. The smoothest surface and the maximum MRR was found at the speed of 1400 RPM and 0.6 Depth of cut for both AISI 410 Steel and Aluminium 6061.

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