OPTIMIZATION OF PROCESS PARAMETERS IN MACHINING OF ALUMINIUM

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ABSTRACT

Producing the requisite shape or surface quality is the main purpose of machining. The manufacturing parameters are to be selected based on the requirement of geometry and surface finish. This paper focuses on optimization of parameters during machining to obtain the required surface finish. In this paper the effects of varying speed, feed, and depth of cut are studied. The influence of the machining parameters are analyzed using Taguchi optimization method. L9 orthogonal array is built considering the three parameters and three levels for each parameter, corresponding to the nine experimental tests. The influence of the parameters on the output are studied.

KEYWORDS: *Machining, Surface Finish, Optimization, Orthogonal Array, Taguchi Method*

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1. INTRODUCTION

Machining operations are used to produce shapes or surface characteristics for a product. Some common conventional machining operations are turning, boring, drilling, reaming, milling, and tapping. Conditions for machining operations were chosen based on geometry and surface finish requirements rather than profit when costs were comparatively low on labor, resource, machines, and tools [1].

The goal of the industry has always been the manufacturing of low-cost and high-quality products in a short time. Modern industries try to enhance these characteristics. To achieve a high cutting performance, the industry needs to operate close to the optimal cutting parameters [2].

The primary tooling concerns when machining aluminum are minimizing the tendency of aluminum to stick to the tool cutting edges; ensuring there is good chip evacuation from the cutting edges ensuring there is good chip evacuation from the cutting edge; and ensuring the core strength of the tool is sufficient to withstand the cutting forces without breaking [3].

When machining aluminum, one of the major failure modes of cutting tools is the material being machined adheres to the tool cutting edge. This condition rapidly degrades the cutting ability of the tool. The built-up edge that is generated by the adhering aluminum dulls the tool so it can no longer cut through the material. Tool material selection and tool coating selection are the two primary techniques used by tool designers to reduce the occurrence of the built-up edge [4].

HMT lathe machines combine all those features that are expected in heavy duty production lathes. Some of these features include great efficiency and high-end sliding, surfacing and screw cutting operation. These lathe

machines are easy to operate and install.

As lightweight metals are widely used, aluminum machining parts are becoming a choice of many industries. The material and geometric parameters of the tool have an important influence on the cutting force and cutting heat. The correct selection of the tool is essential to improve dimensional stability[6].

Cutting forces are generally low and because aluminum is a good conductor of heat and since most aluminum alloys melt at temperatures between 500 and 600 °C, cutting temperatures and tool wear rates are also low. When cut under proper conditions with sharp tools, aluminum alloys acquire fine finishes through turning, drilling and milling, minimizing the necessity for grinding and polishing operations. Aluminum is commonly machined with high-speed steel, diamond and carbide tooling; silicon nitride-based ceramic tools are generally not used with aluminum because of the high solubility of silicon in aluminum. The major machinability concerned with aluminum alloys include tool life, chip characteristics, chip disposal and surface finish [5].

2. METHODOLOGY

Systematic methodology has been adopted to conduct experiments and collect output data. Experiments are planned to conduct in accordance with matrices of face centered central composite design (CCD). Three replicates for each experimental run are considered and conducted in random order without bias. The machining has been carried out on aluminum of 30 mm diameter up to the length of 50 mm. Material removal rate, surface roughness, axial force, Radial force and feed force have been measured on each sample and the average values of three replicates are used for statistical analysis. Furthermore, randomly the input variables are varied between their operating levels and experiments are conducted.

The HMT Lathe with dynamometer on which the turning operation is carried is represented in the figure 1.

Figure 1: Lathe with Tool Dynamometer

The interfacing unit of the lathe tool dynamometer is shown in figure 2 and 3

Figure 2: Interfacing Transfer Unit

Figure 3: Lathe Tool Dynamometer PC Interfacing Setup

Experiments are carried out by using the L9 orthogonal array which is generated from the following three variables at three levels represented in table 1.

Table 1: Input Machining Parameters and their Operating Levels

Sl. No.	Cutting Parameters	Units	Levels		
			Low	Medium	High
1	Speed	(rpm)	88	114	192
2	Feed	(mm/rev)	0.2	0.4	0.8
3	Depth of cut	(mm)	0.5	1	1.5

The specimens after machining are shown in figure 4.

Figure 4: Specimens after Machining

The forces during turning are measured using the dynamometer and using the interface the graphs are obtained from the PC monitor. The three forces variation during turning are shown if figure 5 to figure 13.

Figure 5: Graph Generated using PC Tool Dynamometer for Specimen 1

Figure 6: Graph Generated using PC Tool Dynamometer for Specimen 2

Figure 7: Graph Generated using PC Tool Dynamometer for Specimen 3

Figure 8: Graph Generated using PC Tool Dynamometer for Specimen 4

Figure 9: Graph Generated using PC Tool Dynamometer for Specimen 5

Figure 10: Graph Generated using PC Tool Dynamometer for Specimen 6

Figure 11: Graph Generated using PC Tool Dynamometer for Specimen 7

Figure 12: Graph Generated using PC Tool Dynamometer for Specimen 8

Figure 13: Graph Generated using PC Tool Dynamometer for Specimen 9

The surface roughness is measured using Surftest SJ-210, the details are shown in figure 14.

It includes

1. Display and transverse unit
2. Calibration standard
3. printer
4. Pick-up and diamond stylus
5. DP-1VR

Equipment Name: SurfTest SJ-210
Figure 14: Surface Roughness Tester

The specifications are listed in the table 2.

Table 2: Specifications of surfTest SJ-210

Measuring Range	350 μ m (-200 μ m to +150 μ m)
Digital Filter Gauss	2CR75,PC75
Customize setting Sampling Length	0.08mm,0.25mm,0.8mm,2.5mm,8mm.
No. of sampling (L)	1-10
Roughness Standards	DIN EN ISO,VDA,JIS,ANSI
Analysis Graphs	BAC, ADC.
Profile Roughness	Profile (R),R-Motif,DF-profile and more
Parameters	Ra,Rq, Rz, Ry, Rp, Rv, Rt, R3z, Rsk, Rku, Rc, RPc, RSm, Rmax, Rz1max, S, HSC, RzJIS, Rppi, R Δ a, R Δ q, Rlr, Rmr, Rmr(c), R δ c, Rk, Rpk, Rvk, Mr1, A1, A2, Vo, λ a, λ q, Lo, Rpm, tp, Htp, R, Rx, AR,W, AW, Wx, Wte
Cut Off length	λ c : 0,08 mm, 0,25mm,0,8 mm, 2,5 mm, 8mm, λ s : 2,5 μ m, 8 μ m
Stylus Diamond Tip	Skid radius 40mm
Power	Battery or Mains (optional)
Mass	1.7kg

The specimens which are machined on the HMT Lathe NH22 are tested on the surfTest SJ-210 tester for determination of surface roughness. As the number of specimens are more in number. The results obtained are tabulated in

the Result data Sheet according to the respective specimen. The images related to the measurement of surface finish are shown in figure 15.

Figure 15: Sample for surface finish Measurement

3. RESULTS

The material removal rate is calculated and the data obtained is presented in the table 3.

Table 3: Material Removal Rate (mm³/min)

Specimen no	Speed(rpm)	Feed(mm/rev)	Depth of cut(mm)	MRR (mm ³ /min)
1	88	0.2	0.5	8.8
2	88	0.4	1.0	17.6
3	88	0.8	1.5	26.4
4	114	0.2	1.0	45.6
5	114	0.4	1.5	68.4
6	114	0.8	0.5	22.8
7	192	0.2	1.5	230.4
8	192	0.4	0.5	76.8
9	192	0.8	1.0	153.6

Taguchi Analysis: MRR (mm^3/min) versus Speed(rpm), Feed(mm/rev), Depth of cut(mm) is shown in figure 16

Figure 16: Variation of MRR

The forces measured during the turning operation are represented in the form of graph. The maximum force for each iteration is obtained and represented in table 4.

Table 4: Maximum Force Obtained during Machining

SPECIMEN NO	CUTTING FORCE	FEED FORCE	AXIAL FORCE
1	46	31	16
2	34	23	13
3	50	26	16
4	41	21	21
5	75	38	27
6	29	17	18
7	67	32	32
8	36	0	22
9	32	17	74

The Taguchi design is analyzed for forces and the graph is shown below in figure 17 and 18.

Figure 17: Cutting Forces Mean Graph

Figure 18: Cutting Forces S/N Graph

Response Table for Means

	Speed(rpm)	Feed(mm/rev)	Depth of cut(mm)
Level			
1	28.33	34.11	23.89
2	31.89	29.78	30.67
3	34.67	31.00	40.33
Delta	6.33	4.33	16.44
Rank	2	3	1

Response Table for Signal to Noise RatiosNominal is best ($10 \times \log_{10}(\bar{Y}^2/s^2)$)

	Speed(rpm)	Feed(mm/rev)	Depth of cut(mm)
Level			
1	6.041	6.863	5.656
2	7.691	4.284	5.789
3	3.363	5.948	5.650
Delta	4.329	2.578	0.140
Rank	1	2	3

The roughness average, Ten point mean roughness and Root Mean Square Roughness measured are represented in the table 5.

Table 5: Surface Roughness

Specimen No.	Roughness Average R(a)	Ten-Point Mean Roughness R(z)	Root Mean Square Roughness R(q)
1	9.080	37.222	10.648
2	3.297	13.725	3.839
3	8.548	34.262	9.930
4	8.661	40.403	10.605
5	6.023	29.424	7.256
6	2.915	3.712	14.859
7	3.629	16.914	4.346
8	11.137	50.447	13.934
9	11.377	54.874	14.461

Response Table for Signal to Noise Ratios

Nominal is best ($10 \times \log_{10}(\bar{Y}^2/s^2)$)

	Level	Speed(rpm)	Feed(mm/rev)	Depth of cut(mm)
1		1.5840	1.1546	1.1304
2		0.7507	1.1144	1.1112
3		1.0001	1.0658	1.0933
Delta		0.8334	0.0888	0.0371
Rank		1	2	3

Response Table for Means

	Level	Speed(rpm)	Feed(mm/rev)	Depth of cut(mm)
1		14.51	15.72	17.11
2		13.76	15.45	17.92
3		20.12	17.22	13.37
Delta		6.36	1.76	4.55
Rank		1	3	2

The Taguchi design is analyzed for surface finish and the graph is shown below in figure 19 to 21

Figure 19: Roughness Average Graph **Figure 20: Ten Point Mean Roughness Average Graph**

Figure 21: Root Mean Square Roughness Graph

4. CONCLUSIONS

From the data analyzed it is clear that the MRR increases with increase in speed, feed, and depth of cut.

The forces are mainly influenced by depth of cut, the second influencing parameter being speed and the least influencing parameter is feed.

The surface finish is mainly influenced by speed, the second influencing parameter being feed and the least influencing parameter is depth of cut.

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