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EXPERIMENTS WITH DIFFERENT ORGANIC MEDIA IN ABRASIVE FLOW MACHINING

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Abstract
In the present scenario of fine finishing abrasive flow machining is a process to polish internal surface of specimen and radius difficult to reach surfaces.Media flows under pressure to and fro from the workpiece (brass) in between the nylon fixture .In our research we are using two way abrasive flow machining. Using the Taguchi method, the main parameters of Media type, Grit Size and Number of Cycles have been optimized for the better signal-to-noise ratio for the quality characteristics of material removed (MR) and the percentage improvement in the surface finish (ΔR_a) respectively. Taguchi's experimental design based on L_9 orthogonal array has been taken for the experimentation and on the basis of maximum Signal-to-Noise (S/N) ratio, the optimal parameters have been selected leading to the robust AFM setup

Keywords:
Abrasive aluminium oxide, Abrasive Flow Machining, Types of Media

I. Introduction

In the world of manufacturing and machining, the quest for superior precision and surface quality has always been paramount. One technology that has emerged as a comfortable solution to achieve such results is Abrasive Flow Machining (AFM). We are discussing to explore the fundamentals, process, applications, and advantages of AFM in the realm of material finishing. Fundamentals of Abrasive Flow Machining: Abrasive Flow Machining, also known as extrude honing or extrude deburring, is a non-traditional machining process that involves the removal of material through the controlled flow of abrasive media. Unlike conventional machining techniques that rely on rigid tools, AFM employs a viscoelastic media, usually consisting of a polymer base with abrasive particles suspended within it. The media is forced through the workpiece's internal passages, thus achieving precise material removal and surface enhancement.Process of Abrasive Flow Machining: The AFM process consists of several key steps. First, a workpiece, typically made of metal, is prepared by identifying the areas that require finishing. These areas could have rough surfaces, unwanted burrs, or internal passages with insufficient dimensions. Next, the workpiece is clamped in a fixture that allows the flow of the abrasive media through the desired channels. The fixture is designed in a way that enables easy access to the areas that require finishing.Once the fixture is ready, the viscoelastic abrasive media is injected into the workpiece. High-pressure pumps are used to create the required force to drive the media through the passages. The abrasive particles in the media flow along with the polymer base, exerting a controlled cutting action on the surfaces they come into contact with. This results in the removal of material and the desired surface finish. The process continues until the desired quality and precision are achieved AFM finds application in Medical industry,Die and mould industryIt was initially developed in the 1960s for aerospace applications but has since found applications in various industries, including automotive, marine, and medical.The Taguchi method, also known as Taguchi's robust design methodology, is a statistical approach developed by Dr. Genichi Taguchi, a Japanese engineer and statistician. It is widely used in the field of quality engineering to improve the quality and reliability of products and processes. The Taguchi method emphasizes the use of orthogonal arrays in designing experiments. Orthogonal arrays ensure that all possible combinations of input variables are tested equally, allowing for efficient identification of the most influential factors and their optimal levels. This helps to reduce the number of experiments required while providing meaningful results.The array forces all experimenters to design almost identical experiments [19, 20].In the present investigation the feasibility and reliability of the developed AFM have been investigated. For this experimentation the essential AFM parameters such as Media type, abrasives grit size, and number of cycles have been selected. The quality characteristics under the consideration are material removal (MR) and the percentage improvement in the surface finish (Ra).

2. Experimental materials

In the present investigation a hollow cylindrical work piece of brass (yellow brass :65 % Cu,35%Zn having BHN hardness 156). The inner surface of the workpiece has been prepared by drilling operation. Initial surface roughness of the specimens is in the range of (2.20-2.9) microns. Workpiece is a hollow cylindrical piece with I.D.10 mm, O.D.13.8 mm and length 16 mm.for abrading the material of brass. During the experimentation, abrasive laden media is extruded through the hollow cylindrical workpiece. The work piece is held in the setup with the help of designed nylon fixtures

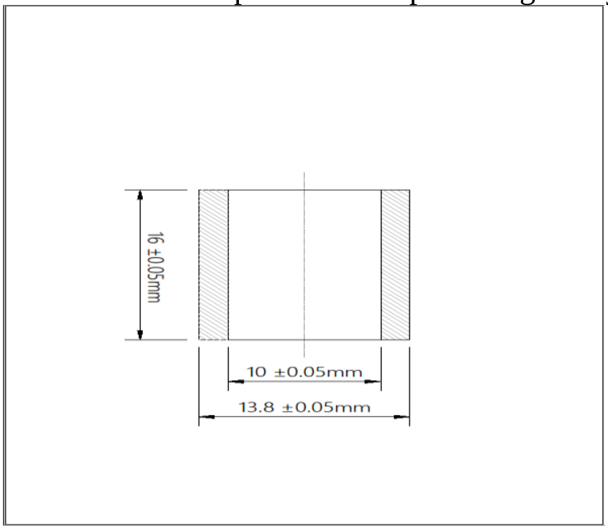

Fig.1 Specimen of length 16 mm and O.D =13.8mm,I.D=10mm,made of brass

2.1 Equipment and Procedure

The designed setup has highest extrusion pressure of 25N/mm². Media is pushed by two actuators which are connected to two media cylinders, media passes from one media cylinder to another media cylinder through the workpiece. When this stroke is complete reverse stroke occurs and both upward and downward stroke complete one cycle. The stroke length is permanent value of 100 mm and media volume has been taken as 310 cc. Media cylinder I.D 63 mm. when media passes through the work-piece, it aim the finishing of inner surface of the work-piece. The internal cylindrical surface of the work piece is finished by the abrasion process, when the abrasives laden media extrudes through this. Each workpiece was machined for a predetermined number of cycles. The workpieces were measured by a precision electronic balance (CX220) with 0.1mg resolution before and after each experiment to calculate the material removal. The measurement of surface roughness(avg of three values) employed a precision profilometer (Mitutoyo SJ-201) to evaluate the quality of the machined surface

Fig. 2 Developed AFM setup at (ycoe)

Experimental conditions

The effects of machining parameters associated with AFM on machining characteristics were extensively investigated in this study. Moreover, the significant parameters and the optimal combination levels of machining parameters were determined.

Process parameters

The machining parameters, such as Media (M), Abrasive Grit Size (G) and Number of cycles (N) were varied to determine their effects on the machining characteristics material removal (MR) and %age improvement in surface finish. The experiments were designed to study the effect of these on response characteristics of AFM process.Table 1.shows the various levels of process parameters, and values of other fixed parameters.

Table 1- Process Variables and their Values at Different levels

Symbol	Process Parameters	Unit	Level 1	Level 2	Level 3
M	Media	-	Guar-Gum	Locust Bean Gum	Agar-Agar
G	Grit Size	Number	100	150	200
N	Number of Cycles	Number	3	6	9
Polymer-to-Gel Ratio: 1:1, Work-piece material: Brass, Abrasive type: Al_2O_3, Grit Size: 100,150,200. Media Flow Volume: 310 cm^3, Reduction Ratio: 0.97, Temperature: 32 $\pm$ 2°C, Initial Surface Roughness of Work-piece: 2.2 -2.9 micron					

2.3 Response parameters

The effect of selected process parameters was studied on the following response characteristics of AFM process:

Percentage Improvement in Surface Roughness (ΔRa): The average of R_a value was calculated and the percentage improvement in roughness was estimated as:

ΔRa= (Initial Roughness-Roughness after machining)x 100/Initial Roughness

Material Removal in mg (MR): The material removal signifies the amount of material that has been removed from a specimen in a specified number of process cycles. It was estimated by calculating the difference between initial weight of the specimen and final weight of the specimen after processing at a specified set of conditions by AFM.

Experimental design based on Taguchi Method The experimental design was according to an orthogonal array (OA) based on the Taguchi method as the total degrees of freedom associated with the three parameters at three levels each (without interaction) is 7, which is less than 8, total degrees of freedom of L_9 OA. The L_9 orthogonal array had three columns and 9 rows, thus, there are three machining parameters can be apportioned to the columns and the rows designate nine experiments with various combination levels of the machining parameters. In this investigation only three parameters were considered. Three observed values of MR and Percentage improvement in surface finish (ΔR_a) were examined. The levels of each machining parameter were set according to the L_9 orthogonal array, based on the Taguchi method. Moreover, the significant machining parameters associated with MR and % Improvement in (ΔR_a)were determined by ANOVA based on S/N ratio.

Experimentation

Experiments were conducted according to the test conditions specified by the L_9 OA (Table 2.) Each experiment was repeated three times in each of the trial conditions. Thus, twenty seven work-pieces were selected having initial surface in close range of (2.2-2.9 micron). In each of the trial conditions and for every replication, the percentage improvement in surface roughness and material removal were measured. The data is listed in Table 2.

2.4 Analysis and Discussions

Analysis by Taguchi Method

The experiments were planned by using the parametric approach of the Taguchi's Method. The response characteristic data is given in Table 2. The standard method to analyze the data based on S/N ratio, as suggested by Taguchi, is worked out. The average values of the S/N Ratio of the quality/response characteristics for each parameter at different levels are calculated from experimental data. Both the response parameters viz. material removal and %age improvement in surface finish, are of "higher the better" type of machining quality characteristics, hence the S/N ratio for these types of responses is given below.

$$\left(S/N\right)_{HB} = -10 \log\left(MSD_{HB}\right)$$

where

$$MSD_{HB} = \frac{1}{R}\sum_{j=1}^{R}\left(1/y_j^2\right)$$

R = Number of repetitions

y_j = Response value

The main effects of process parameters for S/N Ratio for each response are plotted by calculating the average values of response characteristics for each parameter at level one, level two and level three (M1,M2, M3). The analysis of variance (ANOVA) of S/N Ratio data is performed to identify the significant parameters and to quantify their effect on the response characteristics.1 means Guar-Gum,2 means Locoust Bean Gum,3 means Agar-Agar for media type;Abrasive aluminium oxide grit size of 100,150,200 are taken ;Number of cycles 3,6,9 are taken

2.5 Effect on Material Removal(MR)

Type of media Agar Agar gives more material removal than locust bean gum and guar gum

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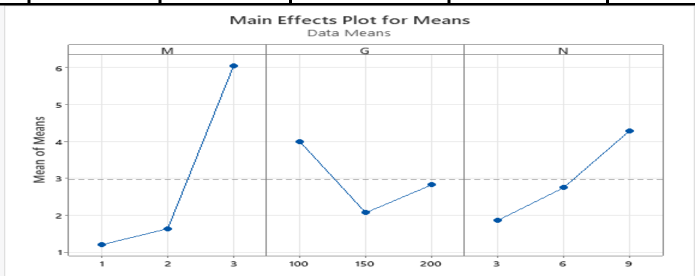
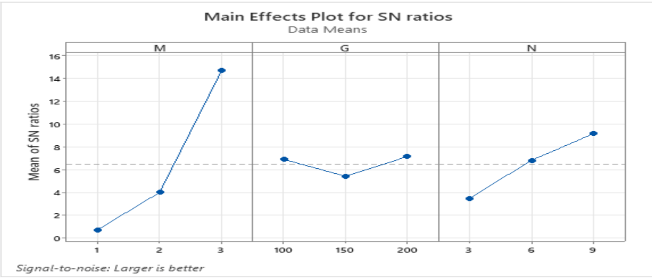
Grit size Aluminiun oxide abrasive of Grit size 200 gives better material removal than Grit size 100 and 150

Number of cycles it is clearly shown in figure as number of cycles increases from 3 to 9 the material removal increase .more number of cycles means more abrasion action and higher material removal

Table. 2 S/N ratio of material removal

Exp. No.	1	2	3	Responses for Material Removal MR			
	M	G	N	R1	R2	R3	S/N Ratio
1	1	1	1	0.8	0.7	0.6	-3.27
2	1	2	2	1.1	1.2	1.4	1.69
3	1	3	3	1.2	2.1	1.7	3.74
4	2	1	2	2.1	1.7	1.4	4.42
5	2	2	3	1.8	1.6	1.5	4.18
6	2	3	1	1.3	1.4	1.9	3.37
7	3	1	3	9.4	8.6	10.7	19.5
8	3	2	1	3.7	2.9	3.4	10.3
9	3	3	2	4.6	5.3	5.9	14.2





Response **Table 3** for Means for material removal

Level	Media	Grit	N
1	1.2	4	1.856
2	1.633	2.067	2.744
3	6.056	2.822	4.289
Delta	4.856	1.933	2.433
Rank	1	3	2

Table 4 ANOVA (S/N Ratio of material removal)

SOURCE	SS	DOF	V	P	F-Ratio	Pooling
Media	321.25	2	160. 6	82.2	21.29	YES(SIGNIFICANT)
Grit Size	5.28	2	2.64	1.35	0.34	NO
Number of Cycles	48.77	2	24.3853	12.4	3.23	NO
ERROR	30.16	4	7.54	3.86		

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T	390.39	8		100		
* Significant at 95 % confidence level, $F_{critical}$ = 19						
SS – Sum of Squares, DOF – Degree of Freedom, V – Variance, SS' – Pure Sum of Squares						

The percentage contribution of media is 82.2%,Grit size is 1.35% and Number of cycles 12.4% .Media is the most significant parameter

2.6 Effect on Percentage Improvement in Surface Roughness

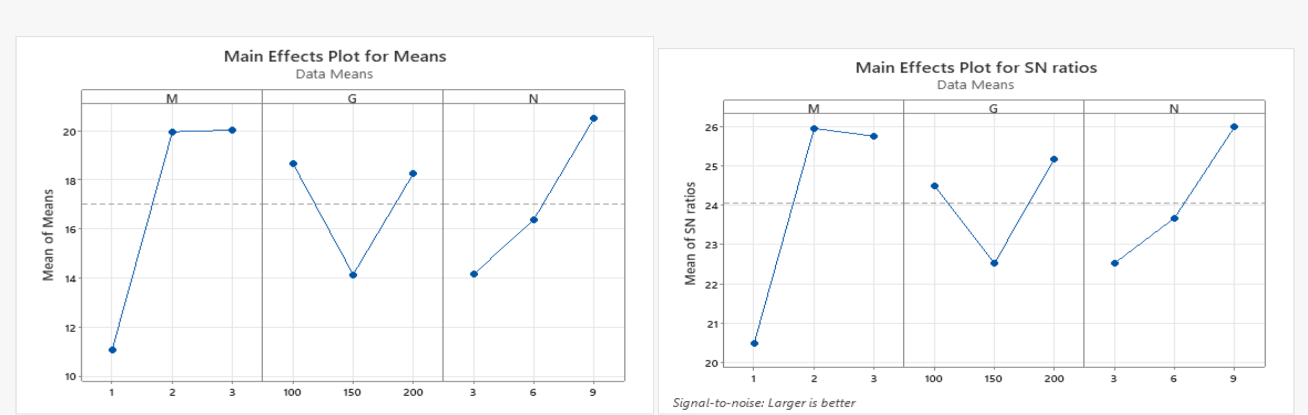
Type of media locust bean gum gives more % improvement in surface roughness than Agar Agar and guar gum

Grit size Aluminiun oxide abrasive of Grit size 200 gives better % improvement in surface roughness than Grit size 100 and 150

Number of cycles it is visible in figure as number of cycles increases from 3 to 9 the % improvement in surface roughness increases i.e more finish at 9(no. of cycles) Data is analysed by minitab software

Exp. No.	1	2	3	% improvement in surface roughness			
	M	G	N	R1	R2	R3	S/N Ratio
1	1	1	1	8.52	8.21	8.86	18.60
2	1	2	2	8.57	8.36	9.51	18.86
3	1	3	3	14.83	15.44	17.46	23.97
4	2	1	2	20.52	20.51	22.15	26.45
5	2	2	3	17.37	21.8	18.58	25.57
6	2	3	1	20.33	19.38	19	25.82
7	3	1	3	25.28	27.11	26.85	28.42
8	3	2	1	14.12	13.76	15.25	23.12
9	3	3	2	18.53	19.8	19.59	25.70

Table 5 S/N ratio of % improvement in surface roughness



Response **Table 6 f**or Means of % improvement in surface roughness

Level	M	G	N
1	11.08	18.67	14.16
2	19.96	14.15	16.39
3	20.03	18.26	20.52
Delta	8.95	4.52	6.37
Rank	1	3	2

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Table 7 ANOVA(S/N Data OF % Improvement in Surface Roughness)

SOURCE	SS	DOF	V	P	F-Ratio	Pooling
Media	57.73	2	28.86	63.8	21.58	YES (SIGNIFICANT)
Grit Size	11.33	2	5.67	12.52	4.23	NO(SIGNIFICANT)
No. of Cycles	18.74	2	9.37	20.71	7.006	NO(SIGNIFICANT)
ERROR	5.34	4	2.66	2.95		
T	90.48	8		100		

* Significant at 95 % confidence level, $F_{critical}$ = 19
SS – Sum of Squares, DOF – Degree of Freedom, V – Variance, SS' – Pure Sum of Squares

The percentage contribution of media is 63.8%,Grit size is 12.52% and Number of cycles 20.71% .Media is the most significant parameter

3. Conclusion

The optimum values of the response characteristic along with their respective confidence intervals have been predicted using the Taguchi approach [19, 20,22].using Minitab software .As observed the optimum values for maximum Material Removal are **$M_3G_3N_3$** according to S/N data Agar Agar media with abrasive size 200 and number of cycles 9 is better for material removal and for maximum percentage improvement in ΔR_a are **$M_2G_3N_3$** according to S/N data.locust bean gum with grit size 200 and number of cycles 9 is better for % improvement in surface roughness

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