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Experimental Investigations in Abrasive Laden Organic Media for Abrasive Flow Machining Process

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Abstract: A self-deformable abrasive media is used in the Abrasive Flow Machining (AFM) process to fine-finish the workpiece. Long processing times, expensive equipment, and high preparation costs are all involved in the development of polymer and rubber-based abrasive media. The processing and disposal of these abrasive media endangers both human health and the environment. As a result, alternative abrasive media that are both economical and environmentally friendly are required. In the present work, attempt has been made to develop low cost and environmental friendly abrasive laden organic media in which Guar Gum, Xanthan Gum and Bees Wax used as the constituents to develop hydrogel. Finally, the abrasives were incorporated into the hydrogel to create abrasive media. The performance of developed abrasive media was evaluated by finishing Brass workpiece on the amount of material removed (MR) and percentage improvement in surface roughness (% Δ*Ra*) has been discussed.

Keywords: Abrasive Flow Machining (AFM), Guar Gum, Xanthan Gum, Bees Wax.

INTRODUCTION:

The need for high accuracy and high efficiency machining of difficult-to-machine materials is increasing the importance of abrasive finishing technologies. Final machining operations are the most labor-intensive and uncontrollable aspect of precision part manufacturing. The cost of surface finish increases sharply for a roughness value of less than one micron. In order to fulfill the requirement of better surface finish and to work on complex geometries, Abrasive flow machining is gaining importance day by day. In abrasive flow machining an abrasive laden media is used which contains polymer, abrasive and gel or liquid synthesizer in required proportion and generally abrasive-to-media proportion of 1:1 is taken. Then the media under set pressure is extruded across the surface to be finished. The media is capable to deform easily so it can go through any desired shape and size of passage. Abrasive laden media act as grinding tool for finishing the work piece surface. The work-piece is placed between two opposing cylinders i.e. upper cylinder and lower cylinder. These cylinders are placed in opposite direction and are hydraulically operated. Lower cylinder is filled with abrasive laden media of required volume and the media is passed through the work-piece to upper cylinder with required pressure. After this the process is reversed and media through the work-piece is extruded back to the lower cylinder.

LITERATURE SURVEY:

A lot of work has been done in the field of Abrasive Flow Machining since 1960's. First of all researchers has done work to optimize the Basic AFM and its parameters so that its efficiency can be increased. Apart of many benefits of AFM it has some demerits like material removal rate is very less in AFM process and time to achieve required surface finish is longer., So to improve the efficiency the AFM has been hybridized with other processes. Now researchers take keen interest to develop a new alternative AFM media which is cost effective and environment friendly. In this research main focus is on developing suitable organic media so detailed literature survey on media used is given below:

Dixit et al. (2021) develop a low-cost hydrogel-based abrasive media containing Xanthan Gum (XG) as the primary constituent and as cross linking and thickening agents, Locust Bean Gum (LBG) and Fumed Silica (FS) were added. The performance of developed abrasive media was evaluated by finishing copper workpieces with it. The effect of extrusion pressure, cycle number, and abrasive mesh size on material removed (MR) and percentage improvement in surface roughness ((% ΔRa) has been discussed.

Wei et al. (2019) proposed guar gum hydrogel based media with shear-thickening property. When compared to styrene-butadiene rubber-based media (traditional shear-thinning AFM media), guar gum hydrogel-based media produces a better finished surface under shear-thickening conditions. Material removal rate for AISI316 stainless steel in the experiment using this new media increases from 69 mg/h to 351 mg/h as shear rate increases from shear-thinning phase to shear-thickening phase, and surface roughness in terms of Ra decreases from 120.12 nm to 6.48 nm.

Dull et al. (2018) made an attempt in the direction of developing new media based on viscoelastic carrier. Different polymer media viz. styrene butadiene rubber, nitrile and natural rubber based media has been developed and experimentation has been performed on abrasive flow machine to calculate material removal rate and improvement in surface roughness. It was found that material removal first increases, reaches maximum at pressure of 22 bar and then decrease with increase in pressure and the same effect is shown in case of increase of number of cycles.

Prajwal et al. (2018) tried abrasive flow finishing of FDM printed parts using an environment friendly media which can be disposed after use without harming the environment. New media is developed by adding additives like marble powder and fuller's earth as base and Waste Vegetable Oil used is derived from Millettiapinnata tree seed used as additives known as Karanja oil. Silicon Carbide, Alumina or diamond, Cubic boron nitrate (CBN) are the commonly used abrasive particles. It was found from TGA test the stability of the media over a temperature of 200^0 C and FTIR analysis revealed alkanes, esters; amines are more dominating in media.

Kishan et al. (2016) developed low cost alternative media consisting of base polymer, SiC abrasive and liquid synthesizer. In the various media viscosity grades of abrasive mixed polymer, 11 to 27 percent liquid synthesizer was added. The apparent viscosity of the developed media was determined at various abrasive concentrations, temperatures, and abrasive mesh size. Following rheological investigation, it was discovered that media viscosity increases with abrasive concentration and decreases with abrasive mesh size, percentage of liquid synthesizer, and temperature. After machining, polymer abrasive gel does not adhere to the work piece.

Mali et al. (2014) Alternative polymer abrasive gel (PAG) media for AFM were synthesized and compared with commercial media (streamer), and it was discovered that PAG media can withstand up to 100^oC and that alkenes and esters groups dominate in PAG, providing elastic nature to the media.

Rajesha et al. (2010) create new media Natural polymers, primarily from the Easter group. The newly developed media was mixed with Naphthenic-based processing oil to maintain the desired viscosity, and it was discovered that the newly developed media could withstand temperatures of up to 70^0 C without changing its properties.

AFM Fixture and Setup:

AFM fixture is made of nylon. The nylon fixture will be placed in between the media cylinders and will hold the work piece.

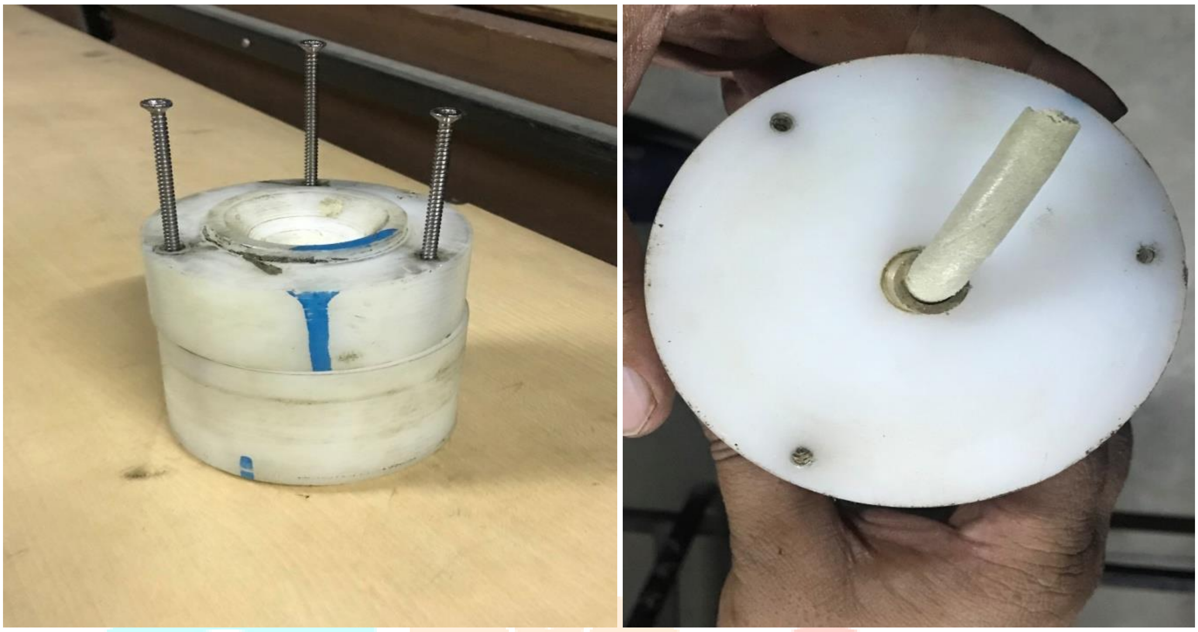

Figure 1: Nylon Fixture

The assembly of the AFM setup consists of the frame, hydraulic actuators, hydraulic power pack, hydraulic controls, media cylinders, AFM fixture. The Four pillars hold the top and bottom main plates. The hydraulic actuators have been fixed in these plates. The two media cylinders are held in between with the help of suitable clamps. DCV is used to operate the cylinders in upward and downward motion and Rotary valve in power pack is used to get back the cylinders in original position

Figure 2: Assembly of AFM Set Up

EXPERIMENTAL DESIGN:

The Experimental design was according to One-factor-at-a-time approach. This method consists of varying one factor at a time while all others factors held constant. The main process parameter for the present experimentation is Abrasive Laden Organic Media, the other parameters f the experimentation have been kept constant. The output parameters taken are Material Removal Rate (MR in mg) and Percentage Improvement in Surface Roughness (**%ΔRa**). The material removal signifies the amount of material that has been removed from a work piece in a specified number of cycles. Material Removal is calculated by using:

Material Removal (MR) = (Initial Weight- Final Weight) * 1000 (mg)

And Percentage Improvement in Surface Roughness is calculated by using:

Surface Roughness Improvement (%ΔRa) = $\frac{Initial\ Ra - Final\ Ra}{Initial\ Ra} * 100.$

For the present experimentation the work piece material taken is Brass. The cylindrical hole has been machined in the test work piece by drilling Operation. Initial surface roughness of the specimens is in the range of 1.34 to 1.54 µm. The work piece is hollow cylindrical piece with internal diameter 10mm, outer diameter 12mm and Length 16mm. The abrasive used is Aluminium Oxide.

During the experimentation, the abrasive laden organic Media is extruded through the hollow cylindrical Work- piece. In present experimentation media has been extruded for eight cycles. The experiments, process parameters shown in Table 1 to study the effect of only one factor of Abrasive Laden Organic Media on the output parameter of Material Removal and Table 2 shows the effect of only one factor of Abrasive Laden Organic Media on the output parameter of Percentage Improvement in Surface Roughness (**%ΔRa**). .

Table 1: Process Parameters and Experimental Results for

Material Removal in the One-factor-at-a-time Approach

MEAN DATA OF MATERIAL REMOVAL (MR)				
Exp No.	**Work piece Number**	**Response for Material Removal, MR (in mg)**		
		Abrasive Laden Media	**M1**	**Mean MR**
1	17	Guar Gum	1.2	1.425
2	23	Guar Gum	1	
3	22	Guar Gum	1.7	
4	26	Guar Gum	1.8	
MEAN DATA OF MATERIAL REMOVAL (MR)				
Exp No.	**Work piece Number**	**Response for Material Removal, MR (in mg)**		
		Abrasive Laden Media	**M2**	**Mean MR**
5	10	Xanthan Gum	1.5	3.97
6	19	Xanthan Gum	8.6	
7	5	Xanthan Gum	1.3	
8	29	Xanthan Gum	4.5	

MEAN DATA OF MATERIAL REMOVAL (MR)				
Exp No.	**Work piece Number**	**Response for Material Removal, MR (in mg)**		
		Abrasive Laden Media	**M3**	**Mean MR**
9	16	Bees Wax	3.1	15
10	9	Bees Wax	12.1	
11	20	Bees Wax	25.9	
12	31	Bees Wax	18.9	

Table 2: Process Parameters and Experimental Results for

Percentage Improvement in Surface Roughness in the One-factor-at-a-time Approach

Mean of % Improvement in ΔRa				
Exp No.	**Work piece Number**	**Response for % Improvement in ΔRa**		
		Abrasive Laden Media	**R1**	**Mean of % Improvement in ΔRa**
1	17	Guar Gum	33.5	26.93
2	23	Guar Gum	24.62	
3	22	Guar Gum	17.03	
4	26	Guar Gum	32.59	
Mean of % Improvement in ΔRa				
Exp No.	**Work piece Number**	**Response for % Improvement in ΔRa**		
		Abrasive Laden Media	**R2**	**Mean of % Improvement in ΔRa**
5	10	Xanthan Gum	7.14	9.59
6	19	Xanthan Gum	8.2	
7	5	Xanthan Gum	11.5	
8	29	Xanthan Gum	11.53	
Mean of % Improvement in ΔRa				
Exp No.	**Work piece Number**	**Response for % Improvement in ΔRa**		
		Abrasive Laden Media	**R3**	**Mean of % Improvement in ΔRa**
9	16	Bees Wax	18.36	21.77
10	9	Bees Wax	34.32	
11	20	Bees Wax	13.63	
12	31	Bees Wax	20.8	

ANALYSIS AND DISCUSSION:

Material Removal

The main effects for the process parameter, abrasive laden organic media are determined based on the average of the raw response data. The main effect for the abrasive laden organic media v/s Material Removal is shown in Figure 3. The analysis of Variance (ANOVA) is performed to analyze the significance of the abrasive laden organic Media (Table 3).

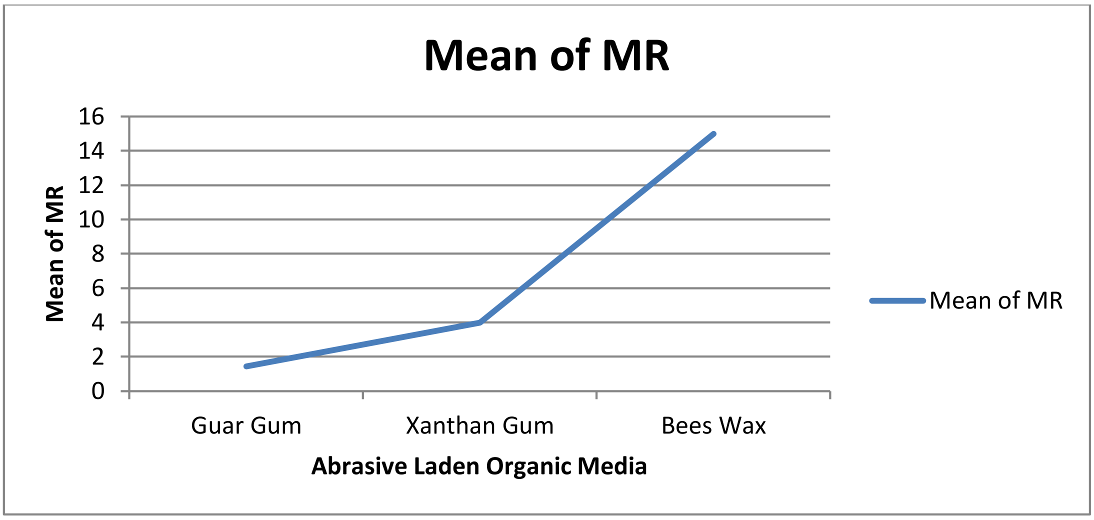

Figure 3: Main Effects of Abrasive Laden Organic Media on Material Removal

The main effects for the material removal for the process parameter of Abrasive laden organic Media shows material removed by Guar Gum is least and material removed by Bees Wax is maximum among all organic Medias.

Table 3: ANOVA (Material Removal)

SOURCE	DOF	Sum of Squares (SS)	Mean Squares (V)	F-Ratio
Abrasive Laden Media Type (Treatment)	3-1=2	421.67	210.83	210.83/35.41 = 5.95*
Error	9	318.7	35.41	--------
Total	12-1=11	740.37	-------	----------

*Significant at 95% confidence Level

$F_{critical\ (2,9,0.05)} = 3.982$

Percentage Improvement in Surface Roughness

The main effects for the process parameter, abrasive laden organic media are determined based on the average of the raw response data. The main effect for the abrasive laden organic media v/s Percentage Improvement in Surface Roughness is shown in Figure 6. The analysis of Variance (ANOVA) is performed to analyze the significance of the abrasive laden organic Media (Table 4).

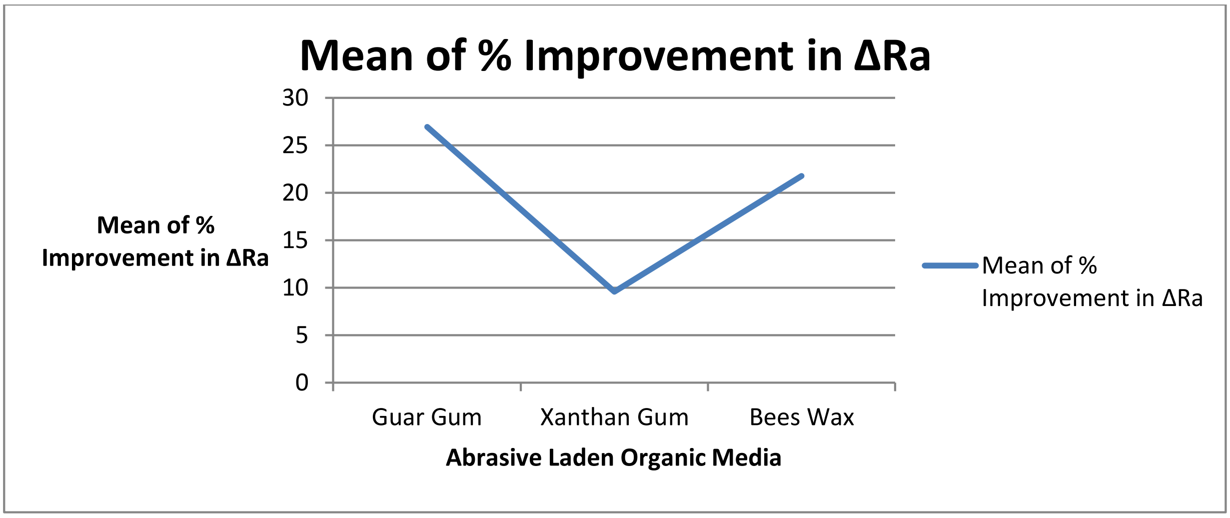

Figure 4: Main Effects of Abrasive Laden Organic Media on % Improvement in ΔRa

The main effects for the Percentage Improvement in Surface Roughness for the process parameter of Abrasive laden organic Media shows Percentage Improvement in Surface Roughness is maximum by Guar Gum and minimum by Xanthan Gum.

Table 4: ANOVA (Percentage Improvement in Surface Roughness)

SOURCE	DOF	Sum of Squares (SS)	Mean Squares (V)	F-Ratio
Abrasive Laden Media Type (Treatment)	3-1=2	634.43	317.21	317.21/17.46= 18.16*
Error	9	157.2	17.46	--------
Total	12-1=11	791.63	--------	----------

*Significant at 95% confidence Level

$F_{critical\ (2,9,0.05)} = 3.982$

CONCLUSION:

The important conclusions of this research work are:

- Guar Gum media perform satisfactorily in Abrasive Flow Machining Process than other media used.
- Material removed by Guar Gum is least and material removed by Bees Wax is maximum among all organic Medias.
- Percentage Improvement in Surface Roughness is maximum by Guar Gum and minimum by Xanthan Gum.

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