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Fine finishing of glass mold surfaces using low cost Unidirectional Abrasive Flow Machine

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Abstract

Abrasive Flow Machining (AFM) is an innovative finishing method to finish intricate surface with close tolerances by removing micro to nano level material. In this process, material is removed in form of microchip layer by layer by the flow of pressurized semisolid abrasive media over or though the finishing profile. In present work, an industrial component (glass molds) is finished using rheological characterized Polymer abrasive media. A low cost in-house designed and fabricated unidirectional abrasive flow machine is used for finishing experiments. For holding the glass molds, simple tooling and fixture are fabricated using Nylon material. Experimental outcome in terms of improvement in surface roughness have shown that it is an efficient alternative to the hand polishing method used by the glass mold industries. Experimental results show the lowest surface roughness value obtained after finishing is 0.61 µm.

Keywords: Abrasive Flow Machine, extrusion pressure, glass mold, material removal, surface roughness, rheology, viscosity.

1. INTRODUCTION

Improvement in finishing levels of surfaces is broadly classified into traditional finishing i.e. Grinding, honing, polishing and lapping or advance finishing i.e. Abrasive Flow Machining (AFM), Magneto-rheological Finishing (MRF) and Magnetic Float Polishing (MFP). Hand polishing or deburring could also result in inconsistent results, and is impossible to perform on complicated or internal surface [1].To overcome all these difficulties advanced finishing processes are used for finishing intricate shapes and for better surface quality. One of the advance and important finishing process is Abrasive Flow Finishing (AFF) process. In AFM deformable cutting tool known as AFM media is extruded over the surfaces to be finished. During the finishing process a small quantity of material is removed by flowing a abrasive laden viscoelastic media over the surface to be finished. The key components of AFM are the machine, the tooling, types of abrasives, medium composition and process settings [2]. Abrasive flow machining process is used to deburring, polishing and radiusing difficult-to-machine material components having difficult-to reach surfaces such as intricate geometries and edges. By using AFM researchers have achieved high surface finish on complicated surfaces such as fuel injector nozzles and heading dies which directly improved fuel efficiency of the IC engine and die lives respectively.

Abrasive Flow Machining was developed in the 1960's, as a method of smoothing and polishing internal surface, and producing controlled radii. Due to the ability of AFM to process multiple parts simultaneously and finishing inaccessible areas and complex internal passage effectively it is an indispensable finishing tool in industries such as aerospace, medical components, electronics, automotive and precision dies & moulds manufacturing. High end industries are extensively using AFM process as a part of their manufacturing activity. The process can also optimize the flow coefficient for fluid carrying elements. AFM has been applied to the improvement in air and fluid flow for automotive engine components, which was proved as an effective method for lowering emissions as well as increasing performance. On certain components due to improvement in surface consistency cyclic fatigue strength also improved by AFM finishing. Sambharia and Mali [3][4] characterized the developed alternative polymer abrasive gel (PAG) using the Thermogravimatric analysis (TGA) and FTIR technique. They found from TGA analysis that polymer abrasive gel can sustain up to 100 °C temperature. Sambharia et al. [5] study the different alternative for media base and additives available and comparative study in terms of viscosity has been performed on synthesized alternative media using different additives and base. Mali and JaiKishan [6] developed a alternative AFM media (polymer abrasive gel) and study the influence of abrasive concentrations, temperature, abrasive mesh size and percentage of liquid synthesizer on viscosity of the polymer abrasive gel to characterize the rheology of developed alternative AFM media.

In present work, an industrial component (glass molds) is finished using rheological characterized Polymer abrasive media. A low cost in-house designed and fabricated unidirectional abrasive flow machine is used for finishing experiments. For holding the glass molds, simple tooling and fixture are fabricated using Nylon material. Experimental outcome in terms of improvement in surface roughness have shown that it is an efficient alternative to the hand polishing method used by the glass mold industries.

2. EXPERIMENTAL SETUP AND TOOLING DESIGN

Initially, tooling and fixture are designed as shown in Figure 1 (b) using nylon material for the glass mold shown in Figure 1 (a). Nylon tooling is designed for easy mounting of components and provides smooth flow of PAG media to the work piece surface to be finished. Tooling is designed using Autodesk inventor® software. Nylon material is used as raw material and CNC milling machine is used for machining process and fabricated as shown in Figure 1.
The component is fixed in UAFM setup [7], [8], [9] using the developed tooling as shown in Figure 2. During experimentation, process variables are selected as extrusion pressure (12 bar to 32 bar), finishing time (30 minute to 50 minute) and viscosity (50 pa-sec. to 250 pa-sec.). The

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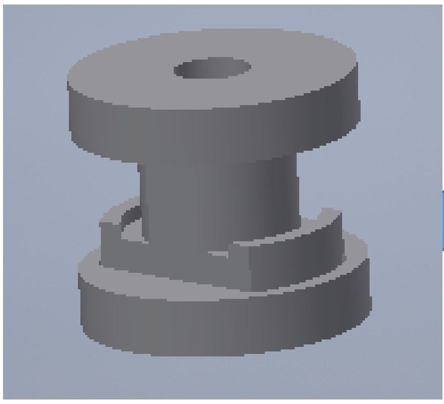


(a) CAD model of designed tooling.

(b) Nylon raw material

(c) CNC milling used for machining the tooling.

(d) Fabricated Tooling for Glass mold.

Figure 1 Steps for tooling design and fabrication

performance variables are improvement in surface roughness (ΔRa in μm) and material removal (mg). Other constant variables are 220 abrasive mesh size and 66% abrasive concentration in PAG media.

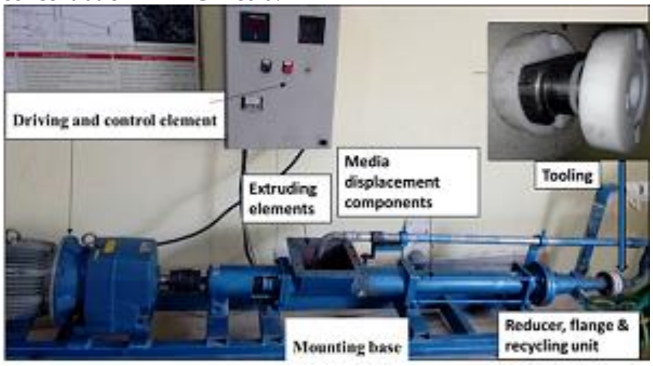


Figure 2 Photograph of UAFM setup with tooling holding the glass mold

3. RHEOLOGICAL STUDY OF PAG MEDIA

After synthesization of alternative AFM media, rheological study were carried out to study the effect of media variables (abrasive concentration, gel percentage and grease percentage) on viscosity of media by varying temperature and shear rate. Based on rheological results, the behavior (Non-Newtonian) of alternative media is identified based on shear stress and shear rate graphs of media synthesized.

During synthesization of alternative AFM media, abrasive mesh size of 320 is used and for gel preparation 2% by weight polysaccharide is used to make solution of gel. The rheological experiment were conducted on atmospheric condition (at 25 °C). The rheological experiment were carried out on Anton Paar make Rotational Rheometer with temperature range (20 °C to 95 °C) and shear rate range (0.01 to 100 sec.-1).

Figure 3. shows the effect of abrasive concentration on viscosity of media when gel concentration (10%, 15%), shear rate (100 sec-1) and temperature (25°C) is kept constant. Results shows that viscosity increases with increased in abrasive concentration of media. It could be due to filling of cavities between polymeric chains of media base compounds results in increasing viscosity of media.

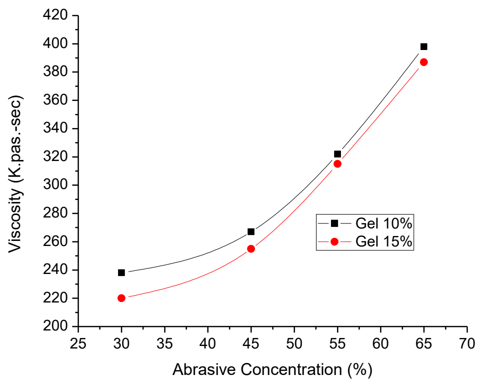


Figure 3. Effect of abrasive concentration on viscosity of media at 10, 15% Gel concentration

Figure. 4 shows the effect of increasing the shear rate (1-100 sec-1) on viscosity of alternative media (Natural Polymer + Gel + Abrasive). The experiment were carried out for media with 45 % abrasive concentration, 15% gel concentration, and constant temperature (25°C). Graph in figure 4. shows the decrease in viscosity of media with increased in shear rate. This shows the shear thinning behavior of non-Newtonian types of fluid. Figure 5 shows the effect of increase in temperature (25-95°C) on viscosity for two alternative media (Natural polymer+gel and Natural polymer+ silicon grease+gel). The experiment were carried out for media with 45 % abrasive concentration, 10 % gel concentration, 5% silicon grease concentration and 100 sec-1 shear rate. The results shows that as the temperature is increased viscosity of media decreases. Also media with silicon grease additive shows constant viscosity graph from 65 to 95 °C. So addition of silicon grease additive with gel gives more thermal stability without losing its properties as compared to other media

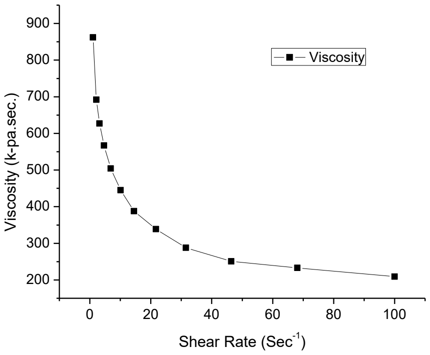


Figure. 4 Effect of shear rate (1-100 sec-1) on viscosity of alternative media

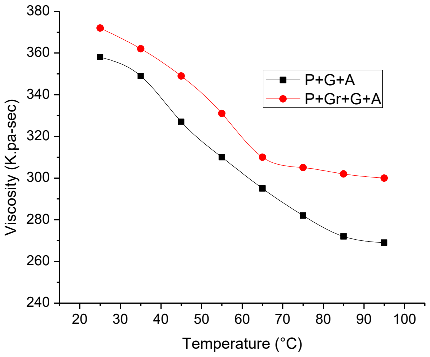


Figure 5. Effect of temperature (25-95°C) on viscosity for two alternative media.

2.1 Results and Discussion

Table 1 and Table 2 results show the lowest surface roughness value obtained after finishing is 0.61 µm and maximum material removal is as high as 4 gm. After finishing glass mold, the maximum improvement in surface roughness (ΔRa) observed was 1.26 µm at 22 bar pressure, 50% abrasive concentration, medium viscosity, and 40 minutes of finishing time.

Table 1

Weight and dimensional changes

	Mold (M1)			Mold (M2)		
	Before finishing	After Finishing	MR Dimension change	Before Finishing	After Finishing	MR Dimension change
Weight	1125gm	1122gm	3 gm	1133 gm	1129 gm	4 gm
Entry id	28.56 mm	28.56 mm	-	28.50 mm	28.57 mm	0.07 mm
Exit id	11.36 mm	11.50 mm	0.14 mm	11.59 mm	11.62 mm	0.03 mm

Table 1

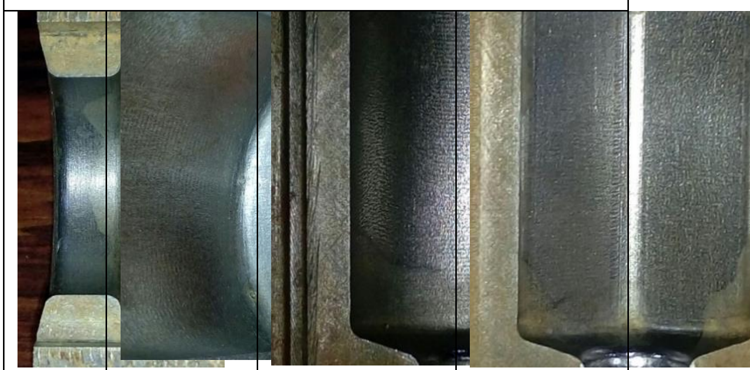
Improvement in surface roughness value for Mold (M1) and Mold (M2)

Finishing parameters	**Mold(M1) Initial Ra and Final Ra**	**Imp. in surface roughness (ΔR_a) for M1**	**Mold (M2) Initial Ra and Final Ra value**	**Imp. in surface roughness (ΔR_a) for M2**
EP 12 bar, 33% Ab. Conc., M vis., FT-40 min.	3.01-2.40 µm	0.61 µm	3.05-2.52µm	0.53 µm
EP 22 bar, 50% ab. Conc., M vis., FT 40 min.	2.40-1.65µm	0.75 µm	2.52-1.52µm	1.0 µm
EP 32 bar, 66% ab. Conc., M vis., FT 40 min.	1.65-0.79µm	0.86 µm	1.52-0.76µm	0.76 µm

Images of glass mold

Figure 6 shows the images of glass mold M1 and Mold M2 before finishing at various locations. After finishing with AFM, at same location the images was recorded and improvement in surface quality can be clearly seen in below images in Figure 7.

Before Finishing



After Finishing

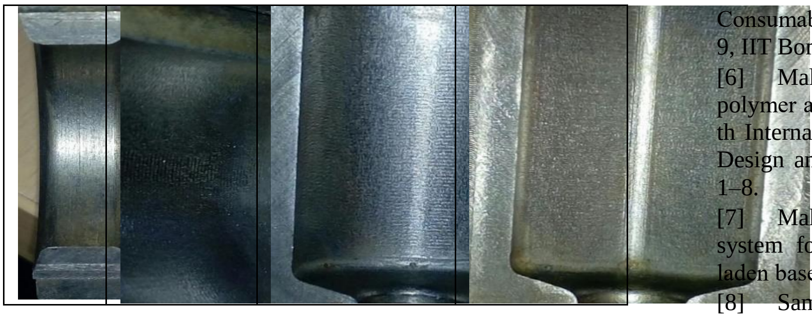


Figure 6 Images of glass mold M1 before AFM and after AFM

7 CONCLUSIONS

In this paper, based on literature review different alternative base and additives were identified to synthesize an alternative to commercially available media. Based on Rheological investigation of different alternative consumables and experimental study following important conclusions have been withdrawn:

- Rheological study shows the effect of media variables (abrasive concentration, gel percentage and silicon grease percentage) on viscosity of media by varying temperature and shear rate.

- Rheology study shows decrease in viscosity of media with increased in shear rate. This shows the shear thinning behavior of non-Newtonian types of fluid.

- Maximum improvement in surface roughness (△Ra) observed was 1.26 µm.

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References

[1] Jain, V. K. “Abrasive-Based Nano-Finishing Techniques: An Overview,” Mach. Sci. Technol., vol. 12, no. 3, pp. 257–294, 2008.

[2] Rhoades, L.J. “Abrasive flow machining : A review,” Manuf. Eng., vol. 75–78, 1988.

[3] Sambharia J. and Mali, H.S. “Characterisation and performance evaluation of developed alternative polymer abrasive gels for abrasive flow finishing process,” Int. J. Precis. Technol., vol. 5, pp. 185–200, 2015.

[4] Sambharia, J., and Mali, H.S.“Characterization and Optimization of Rheological Parameters of Polymer Abrasive Gel for f Abrasive Flow Machining,” Journal of Materials Science and Surface Engineering, vol. 5, no. 3, pp. 549–555, 2017.

[5] Sambharia J., J. Ram, Mali, H.S. “Rheological Investigation and Comparative Study on Synthesized Low Cost Consumables for Abrasive Flow Finishing Processes.”COPEN 9, IIT Bombay, 2015.

[6] Mali, H.S. and Jaikishan, “Developing alternative polymer abrasive gels for abrasive flow finishing process,” in 5 th International & 26 th All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014), 2014, pp. 1–8.

[7] Mali, H.S. Sambharia, J. and J. Kumar, “Design of a system for finishing complicated workpieces using abrasive laden base material,” 201611008902A, 2016.

[8] Sambharia, J., Mali, H.S., V. Garg, “Experimental investigation on unidirectional abrasive flow machining of trim die workpiece,” Mater. Manuf. Process., vol. 0, no. 0, pp. 1–10, 2017.

[9] Sambharia, J. Mali, H.S. “Recent developments in abrasive flow finishing process: A review of current research and future prospects”, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 2017.