Singaporean Journal Scientific Research (SJSR)
ISSN: 2231 - 0061Vol.2, No.2pp.75 - 79

available at:: http://www.iaaet.org/sjsr

Abrasive flow machining performance measures on work-piece surfaces having different vent/passage considerations for media outflow

[1]Saad SaeedSiddiqui, [2]M Hameedullah

1,2Department of Mechanical Engineering, Aligarh Muslim University, Aligarh-202 002, U.P., INDIA
Email ID: sssiddiqui.amu@gmail.com

***Abstract*-Abrasive flow machining (AFM) is a relatively new non-traditional micro-machining process developed as a method to debur, radius, polish and remove recast layer of components in a wide range of applications. Material is removed from the work-piece by flowing a semi-solid visco elastic/plastic abrasive laden medium through or past the work surface to be finished. Components made up of complex passages having surface/areas inaccessible to traditional methods can be finished to high quality and precision by this process.The present work is an attempt to experimentally investigate the effect of different vent/passage considerations for outflow of abrasive laden viscoelasic medium on the performance measures in abrasive flow machining. Cylindrical work-piece surfaces of varying cross-sections & lengths having different vent/passage considerations for outflow of abrasive laden viscoelastic medium have been micro-machined byAFM technique and the process output responses have been measured. Material removal, MR and surface roughness, Ra value are taken as performance measures indicating the output responses. Experiments are performed with significant process parameters, such as concentration of abrasive particles, abrasive mesh size, number of cycles and media flow speed kept as constant on brass as work material. The results suggest that the work-piece surfaces having single vent/passage for media outflow have higher material removal and more improvement in surface roughness in comparison with work-piece surfaces having multiple vents/passages and the performance measures decrease with increase in the number of vents for media outflow.**

***Keywords* – Abrasive Flow Machining, Performance Measures, Material Removal, Surface Roughness.**

1. INTRODUCTION

AFM is an advanced machining process [1] that is used to debur, radius, polish, remove recast layer, and to produce compressive residual stresses. The process is gaining widespread attention due to its ability to produce consistent and predictable results and its wide scope of practical applications; anywhere that the media can be forced to flow represents a practical application of AFM process. In this process, an abrasive laden pliable semi-solid compound is forced to flow across the work-piece surface to be machined. Abrasion occurs wherever the medium passes through the highly restrictive passage.

The key components of AFM process are the machine, tooling, work-piece and abrasive medium. Process input parameters such as extrusion pressure, number of cycles; abrasive grit composition and type, tooling and fixture designs and work-piece geometry have an impact on AFM performance measures, viz. material removal (MR) and surface finish (Ra). The process can debur holes as small as 0.2mm and radius edges from 0.025 to 1.5 mm. Tolerances can be held to ±5μm[2].Rhoades [3-4] experimentally investigated the basic principles of AFM process and identified its control parameters. He observed that when the medium is suddenly forced through restrictive passage, its viscosity temporarily rises. Significant material removal is observed only when medium is thickened.

Jain and Adsul [5] reported that initial surface roughness and hardness of the work-piece affects material removal during AFM process. Material removal and reduction in surface roughness values are reported higher for the case of softer work-piece material as compared to harder materials.Loveless [6] reported that the type of machining operation used to prepare the specimen prior to AFM is important and affects the improvement achieved during finishing.Davies and Fletcher [7] reported a relationship between the number of cycles, temperature and pressure drop across the die for the given type of polymer and abrasive concentration. Increase in temperature results in decrease in medium viscosity. They concluded that rise in temperature is due to a combination of internal shearing of the medium and finishing action of the abrasive grit.Singh and Shan [8] applied magnetic field around the work-piece in AFM and observed that magnetic field significantly affect the material removal and change in surface roughness.

With the application of magnetic field, less number of cycles are required for the higher material removal.Perry [9] reported that abrasion is high where medium velocity is high. An increase in pressure and medium viscosity increases material removal rate while surface finish value (Ra) decreases.Williams and Rajurkar [10] reported that metal removal and surface finish in AFM are significantly affected by the medium viscosity. Jain and Jain [11] also reported that reduction in surface roughness (Ra Value) increases with increase in extrusion pressure and abrasive concentration, but they also observed that reduction in surface roughness (Ra value) is higher with increase in average grain size.William and Rajurkar [12] also reported that extrusion pressure and grain size main effects are significant.Jain and Adsul [13] reported that MRR is high in the first few cycles due to higher initial coarseness of work-piece surface, and thereafter, it starts slightlydecreasing in every cycle.Jain et.al. [14] reported that percentage of abrasives in the medium, grain size and viscosity of the base medium are important parameters that influence stock removal and medium velocity.

Gorana et.al. [15-16] reported that depth of penetration of abrasive particle depends on extrusion pressure, abrasive medium viscosity, and grain size. Due to the combined effect of radial force and axial force, the material is removed in the form of microchip.

It seems that some of the researchers have studied the effects of process parameters like extrusion pressure, abrasive concentration, grain size, number of cycles etc. on the work-piece, viz., surface roughness and material removal. Hardly any information is available in the literature regarding the effect of work-piece profile on the performance measures in abrasive flow machining. The effect of different vent/passage considerations for outflow of abrasive laden viscoelasic medium on the performance measures in abrasive flow machining also remain unexplored.

The present work is an attempt to experimentally investigate the effect of different vent/passage considerations for media outflow on the performance measures in abrasive flow machining. Work-piece surfaces having different number of vents/passages for outflow of abrasive laden viscoelastic medium have been micro-machined by AFM technique and the process output responses have been measured. Material removal, MR and surface roughness, Ra value are taken as performance measures indicating the output responses. Experiments are performed with significant process parameters, such as concentration of abrasive particles, abrasive mesh size, number of cycles and media flow speed kept as constant on brass as work material. The experiments are performed on the simplified table top uni-directional AFM setup developed by the authors. The machined surface roughness is measured using tally surf portable tester and for material removal measurement, an electronic weight balance having accuracy up to 10^{-4}gm has been used. The experimental results are analyzed using multivariable curve-fitting technique.

2. EXPERIMENTAL SETUP AND PROCEDURE

Fig.1 shows an assembly drawing of the table-top setup for an AFM process, designed and fabricated by the authors. The setup is mounted on the work table with the help of steady rests. The configuration is a single cylinder, one-way AFM setup which comprises of single media cylinder, piston, end and mid support plates, work-piece holder with clamp and guiding fixtures, and nozzle to match work-piece profile. The cylindrical work pieces of varying passage geometries, as given in the table1, are placed in the work holder. The setup works as described below.

The mechanical motion/rotation of the lead screw results in the forward translational motion of the piston inside the media cylinder. During this movement, the piston pressurizes the media in the cylinder in a forward direction and extrudes it through the work piece surface. As a result, the abrasive laden media abrades the work-piece placed in the work holder. The forward direction of the piston is reversed mechanically after completing the stroke and the media is refilled in the media cylinder from the media collector during the reverse stroke. This combination of one forward and reverse stroke completes one cycle of the AFM process. The work-pieces are machined for a predetermined number of cycles (Table1). After the machining is over, the work-pieces are taken out from the setup and cleaned with acetone before any measurement is taken. The instrument used to measure surface roughness, Ra value of the finished work-piece, is Tally Surf portable tester. For material removal measurement, an electronic weight balance having accuracy up to 10^{-4}gm has been used.

A. Procedure

The experiments were performed and micro-machining by AFM technique conducted on cylindrical work-piece surfaces of varying cross-sections and lengths having single vent/passage, three vents/passage & five vents/passages for media outflow with brass as work material. For preparing these specimens, the brass section is machined at the predetermined cutting conditions. The other/inner side of the section is milled to get the required passage geometry. From this section, the pieces are cut in the desired size and then filed so as to make them of desirable dimensions.

The media used for the present experimentation is a mixture of 3 of the following readily available and mutually miscible constituents in predetermined amounts, Waxpol Polishing paste, AP-3 Grease & Base Oil.

The abrasives used in the media are silicon carbide. The mixture of media is mixed with the abrasive particles of specified mesh size in a definite proportion to achieve the desired percentage concentration of abrasive particles by weight. Percentage concentration of abrasive by weight is defined as,Percentage concentration of abrasive

$$= \frac{\text{Weight of abrasive particle}}{\text{Weight of abrasive particle} + \text{Weight of polishing paste}} \times 100$$

Before performing the actual experiments, the medium was run for 20-25 cycles with the trial work-piece, so as to get uniform mixing.

Based on the conclusions from the preliminary experiments, four important variables are identified- the number of cycles, abrasive percentage concentration, abrasive mesh size, media flow speed and are kept constant. The experiments are performed according to the plan given in Table 1, which is explained below. Values of variable parameters and of constant parameters are given in this table. All experiments were conducted on work-piece surfaces comprising of cylindrical sections of varying cross-sections and lengths having 1, 3 or 5 vents/passages for media outflow with brass as work material. Material removal and surface roughness values were output responses measured as performance indicators in each case.

Table 1: Plan of experiments

VariablesConstant parameters	
Work-Piece Profile:	Abrasive concentration:
70%1. Single vent for media outflow	Abrasive mesh size:
1802.Three vents for media outflow	Number of cycles: 50
3.Five vents for media outflow	Media flow speed:
700g/min	
Cross-section of each work-piece	
D: 4mm,8mm, 16mm, 32mm,40mmSize/length of each work-piece,	L:
15mm,25mm, 40mm,55mm,75m	

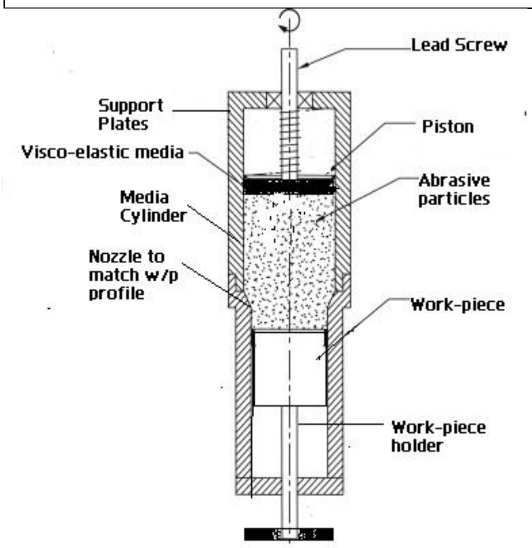

Figure 1 Assembly drawing of the table-top setup for an AFM process

3. RESULTS AND DISCUSSION

During the course of study, work-piece surfaces comprising of cylindrical profiles of varying cross-sections and lengths having different vent/passage considerations for media outflow with brass as work material are micro-machined by AFM process and the significance of vent/passage considerations for media outflow is analyzed by determining the effect of process parameters on material removal and surface roughness.

A. Material Removal

Fig.2 & 3 shows the effect of different vent/passage considerations for media outflow in work-pieces of varying cross sections on Material removal (MR). The material removal is higher in case of work-pieces having single vent/passage for media outflow followed by work-pieces having three & more vents/passages for media outflow in work-pieces of all cross sections. This can be explained as follows. When abrasive laden pliable semi-solid compound is forced to flow through the work-piece surface, abrasion occurs wherever the medium passes through the highly restrictive passage and in the case of work-piece surfaces having single vent for media outflow, the restriction in the passage is higher and the abrasive laden medium moves along the walls thereby resulting in more material removal. Further, as the work-piece cross section increases, it results in lower material removal. Fig.2 also shows that the trend of material removal for different vent/passage considerations is similar, except that the total material removal is higher in the case of work-pieces having

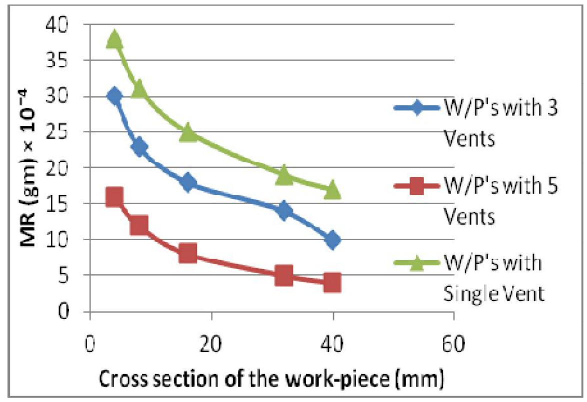

Figure 2. Effect of different vent considerations in work-pieces of varying cross sections on MR

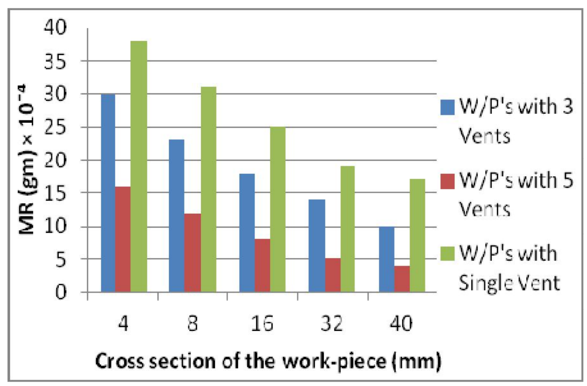

Figure 3. MR in micromachining work-pieces of varying cross sections having different vent considerations

single vent for media outflow because it offers higher restrictive passage compared to work-pieces having multiple vents.

B. Work-piece surfaces of varying lengths having single & multiple vents/passages for media outflow:

Fig.4 & 5 shows the effect of different vent/passage considerations for media outflow in work-pieces of varying lengths on Material removal (MR). The material removal is higher in work-pieces having single vent/passage for media outflow followed by work-pieces having multiple vents for media outflow in work-pieces of all lengths, which can be explained by the fact that work-piece surfaces having single vent for media outflow offer higher restrictive passage in comparison with work-piece surfaces having multiple vents. It can also be observed that as the length of the work-piece increases, MR increases (Fig.4) because more surface comes in contact with the abrasive particles.

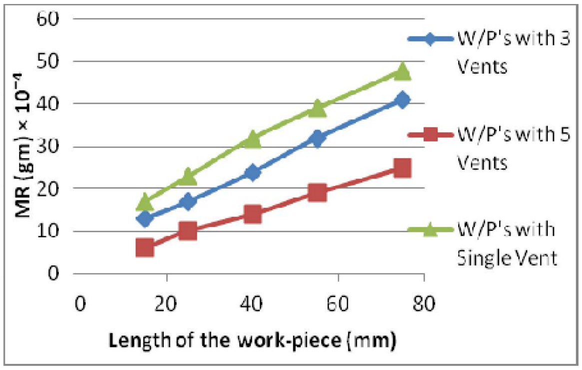

Figure 4. Effect of different vent considerations in work-pieces of varying lengths on MR

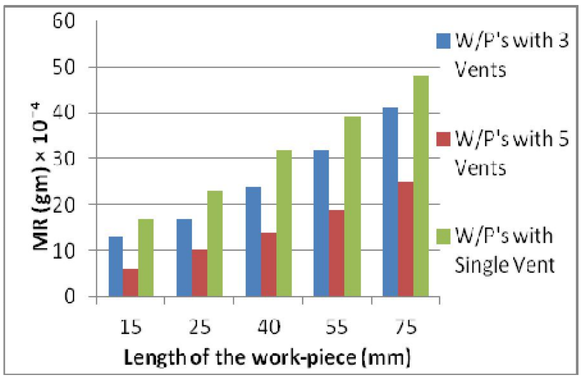

Figure 5. MR in micromachining work-pieces of varying lengths having different vent considerations

C. Surface roughness

The effect of different vent/passage considerations for media outflow on the surface roughness (Ra value) during AFM process is analyzed and the differences between the initial and final Ra values (abbreviated as ΔRa) are reported in this section.

D. Work-piece surfaces of varying cross sections having single & multiple vents/passages for media outflow:

Fig.6 & 7 shows the effect of different vent/passage considerations for media outflow in work-pieces of varying cross sections on the surface roughness, Ra value of the work-pieces. The change in surface roughness, ΔRa value is higher for work-pieces having single vent/passage for media outflow followed by work-pieces having three & more vents/passages for media outflow in work-pieces of all cross sections. This can be explained as follows.

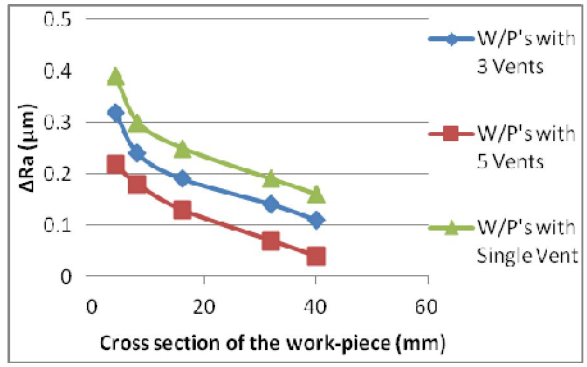

Figure 6. Effect of different vent considerations in work-pieces of varying cross sections on ΔRa

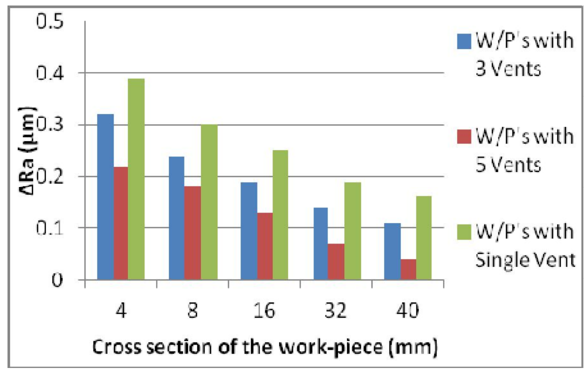

Figure 7. ΔRa in micromachining work-pieces of varying cross sections having different vent considerations

When abrasive laden pliable semi-solid compound is forced to flow through the work-piece surface, abrasion occurs wherever the medium passes through the highly restrictive passage and in the case of work-piece surfaces having single vent for media outflow, the restriction in the passage is higher and the abrasive laden medium moves along the walls thereby resulting in higher ΔRa value. Further, as the work-piece cross section increases, it results in lesser restrictive passage thereby resulting in fewer abrasions and lower ΔRa value.

E. Work-piece surfaces of varying lengths having single & multiple vents/passages for media outflow:

Fig.8 & 9 shows the effect of different vent/passage considerations for media outflow in work-pieces of varying lengths on surface roughness, Ra value. The change in surface roughness, ΔRa value is higher in work-pieces having single vent/passage for media outflow followed by work-pieces

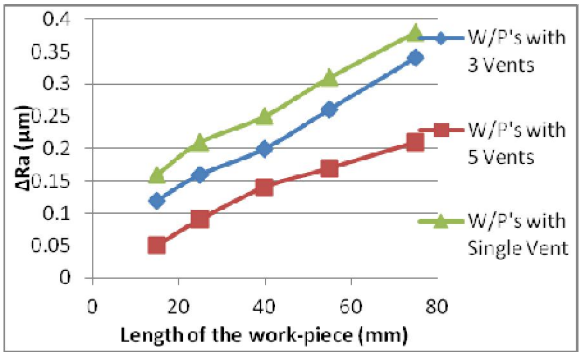

Figure 8. Effect of different vent considerations in work-pieces of varying lengths on ΔRa

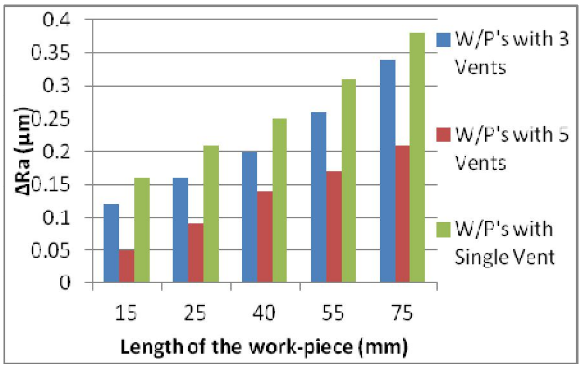

Figure 9. ΔRa in micromachining work-pieces of varying lengths having different vent considerations

having multiple vents for media outflow in work-pieces of all lengths, which can be explained by the fact that work-piece surfaces having single vent for media outflow offer higher restrictive passage in comparison with work-piece surfaces having multiple vents. It can also be observed that as the length of the work-piece increases, the change in surface roughness, ΔRa value also increases because more surface comes in contact with the abrasive particles.

4. CONCLUSIONS

The following conclusions have been derived from the above study:

1. Vent/passage considerations for media outflow in work-piece surface significantly affects performance measures, material removal (MR) and surface roughness (Ra value) in abrasive flow machining.
2. Micro machining work-piece surfaces having single vent/passage for media outflow by abrasive flow machining produced better results in comparison with work-piece surfaces having multiple vents.
3. Work-piece surfaces having single vent/passage for media outflow have higher material removal and more improvement in surface roughness and the performance measures decrease with increase in the number of vents for media outflow.
4. The change in surface roughness, ΔRa increases with the increase in length of the work-piece and decreases with the increase in cross section of the work-piece.
5. As the length of the work-piece increases, material removal increases while the surface roughness value decreases.

REFERENCES

[1] V.K.Jain, Advanced Machining Processes, Allied Publishers, Mumbai
[2] L.J.Rhoades, “Abrasive flow machining with not so silly putty”, Metal Finishing July(1987)27-29
[3] L.J.Rhoades, Abrasive flow machining, Manufacturing Engineering,(1988)pp.75-78
4] L.J.Rhoades, “Abrasive flow machining: A case study”, J.Material Processing Technology,28,(1991), pp.107-116
[5] V.K.Jain, S.G.Adsul, “Experimental investigations into abrasive flow machining(AFM)”, International Journal of Machine Tools and Manufacture, Volume40, Issue 7, May2002
[6] T.R.Loveless, R.E.Willams, K.P.Rajukar, “A study of the effects of abrasive flow finishing on various machined surfaces”, Journal Material Processing Technology, 47(1994),pp.133-151
[7] P.J.Davies, A.J.Fletcher, “The assessment of the rheological characteristics of various polyborosilixane/grit mixtures as utilized in the abrasive flow machining”, Proceedings of Instt. Mech. Engrs.209,(1995),409-418
[8] S.Singh, H.S.Shan, “Development of magneto abrasive flow machining process”, International Journal of Machine Tool & Manufacture 42, (2002), 953-959
[9] W.B.Perry,Non-traditional Conference Proceedings, 1989, pp.121-127
[10] R.E.Williams, K.P.Rajurkar, “Stochastic modeling and analysis of abrasive flow machining”, Transactions of the ASME, Journal of Engineering for Industry 114 (1992) 74-81
[11] R.K.Jain, V.K.Jain, “Simulation of surface generated in abrasive flow machining”, Robotics and Computer Integrated Manufacturing 15 (1999) 403-412
[12] R.E.Williams, K.P.Rajurkar, “Monitoring of abrasive flow machining process using acoustic emission”, S.M. Wu Symposium, vol I, 1994, pp.35-41
[13] V.K.Jain, S.G.Adsul (2000) “Experimental investigations into abrasive flow machining”. Int. J Mach Tools Manuf 40:201-211
[14] V.K.Jain, C. Ranganatha, K.Muralidhar, Evaluation of rheological properties of medium for AFM process. Min Sci Techno 5: 151-170
[15] V.K.Gorana, V.K.Jain, G.K.Lal, “Experimental investigation into cutting forces and active grain density during abrasive flow machining”.Int J Mach Tools Manu 44:201-211 (2004)
[16] V.K.Gorana, V.K.Jain, G.K.Lal, “Forces prediction during material deformation in abrasive flow machining”. Wear 260: 128-139 (2006)