Study of Surface Finishing using Abrasive Flow Machining

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Abstract— Abrasive Flow Machining (AFM) is an effective way to polish unsymmetrical surfaces and interior structure of parts, which are difficult to reach by conventional machining. The material to be machined may be cylindrical or any complex shape. Various process parameters are Material Removal Rate, Machining Time, and Abrasive Mesh size that affects the performance of AFM. The key components of AFM process are the machine, tooling and abrasive medium. AFM is capable to produce surface finish (Ra) as good as 0.05 µm, deburr holes as small as 0.2 mm and radius edges from 0.025 mm to 1.5mm. AFM has wide range of applications in industries such as aerospace, medical, electronics, automotive, precision dies and moulds as a part of their manufacturing activities. For better surface integrity, texture and its performance, continuous developments are taking place for modifying the existing AFM process technology and AFM machine configuration.

Key words: Abrasive flow machining, Material removal rate; Surface roughness, Surface Finish

I. INTRODUCTION

Abrasive Flow Machining (AFM) was developed by Extrude Hone Corporation, USA in 1960s as a method to deburr, polish, and radius difficult to reach surfaces like intricate geometries and edges by flowing an abrasive laden viscoelastic polymer over them. AFM is used to deburr, radius and polish difficult to reach surfaces by extruding an abrasive laden polymer medium with very special rheological properties.

Based on the application, three different types of machines have been reported i.e, one way AFM, two way AFM and orbital AFM. Because of simplicity in analysing the physics, analysis of AFM process always refers to two way AFM.

II. WORKING OF TWO WAY AFM

It uses two vertically opposed hydraulic cylinders, which extrude medium back and forth through passage formed by the workpiece and tooling. Abrasion occurs wherever the medium passes through the highly restrictive passage. The key components of AFM process are the machine, tooling and abrasive medium. Process input parameters such as extrusion pressure, number of cycles, grit composition and type, tooling and fixture designs have impact on AFM output responses (such as surface finish and material removal). AFM is capable to produce surface finish (Ra) as good as 0.05 µm, deburr holes as small as 0.2 mm and radius edges from 0.025 mm to 1.5mm.

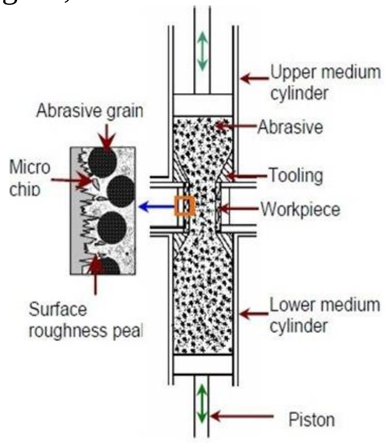


Fig. 1 Principle of material removal mechanism in two-way AFM process

It is widely used finishing process to finish complicated shapes and profiles. The polymer abrasive medium which is used in this process possesses easy flowability, better self-deformability and fine abrading capability. Layer thickness of the material removed is of the order of about 1 to 10 µm. Best surface finish that has been achieved is 50 nm and tolerances are +/- 0.5 µm. In this process tooling plays very important role in finishing of material. In AFM, deburring, radiusing and polishing are performed simultaneously in a single operation in various areas including normally inaccessible areas. It can produce true round radii even on complex edges. AFM reduces surface roughness by 75 to 90 percent on cast and machined surfaces. It can process dozens of holes or multiple passage parts simultaneously with uniform results. Also air cooling holes on a turbine disk and hundreds of holes in a combustion liner can be deburred and radiused in a single operation. AFM maintains flexibility and jobs which require hours of highly skilled hand polishing can be processed in a few minutes; AFM produces uniform, repeatable and predictable results on an impressive range of finishing operations.

III. MAJOR AREAS OF EXPERIMENTAL RESEARCH IN ABRASIVE FLOW MACHINING

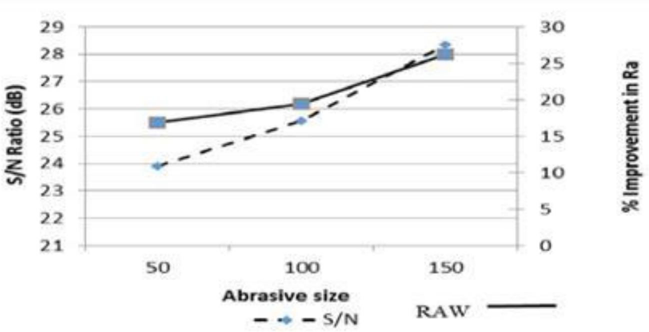
"Ramandeep Singh, R.S. Walia"[1] stated thatabrasive flow machining (AFM) is a relatively new non-traditional micro-machining process developed as a method to debur, radius, polish and remove recast layer of components in a wide range of applications. Material is removed from the work-piece by flowing a semi-solid viscoelastic 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 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 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.

"Ramandeep Singh, R.S. Walia"[2] Limited efforts have been done towards enhancing the productivity of Abrasive Flow Machining (AFM) process with regard to better quality of work piece surface. In recent years, hybrid-machining processes have been developed to improve the efficiency of a process by clubbing the advantages of different machining processes and avoiding limitations. In the present study, the abrasive flow machining was hybridized with the magnetic force for productivity enhancement in terms of material removal (MR). The magnetic force is generate around the full length of the cylindrical work piece by applying DC current to the solenoid, which provides the magnetic force to the abrasive particles normal to the axis of work piece. The various parameters affecting the process are described here and the effect of the key parameters on the performance of process has been studied

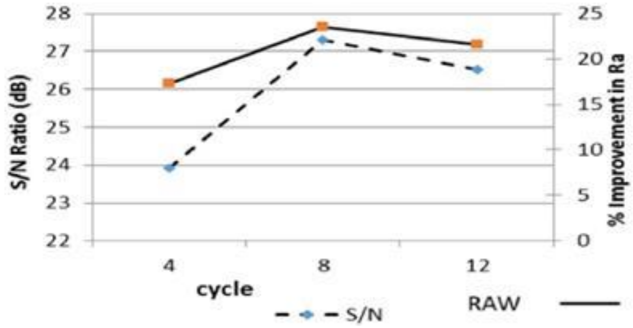
"Jose Cherian" [3] The average percent reduction in surface roughness can be increased by keeping the extrusion pressure, grain mesh number and Abrasive concentration at high levels, while the average force ratio can be increases by keeping extrusion pressure and abrasive concentration at high level and grain mesh number at low level. Also when the force ratio is maximum the percentage reduction in surface roughness is also maximum. The correlation coefficient between average percent reduction in surface roughness and average force ratio is higher as compared to correlations of average percentage reduction in surface roughness with average axial and radial forces.

“Ravi Gupta, Rahul Wandra”[4] carried out experimental investigations notice that centrifugal force improves the efficiency and performance of simple AFM process and also reduces the machining time. The centrifugal force improves the surface quality of work piece. More Improvement in surface quality can be obtained by varying levels of process parameters.

It is possible to increase the efficiency of simply AFM process by using hybrid AFM. The abrasive mesh size has highest contribution followed by rotational speed of CFG rod, number of cycles and abrasive concentrations in both RAW and S/N data towards improvement in surface finish.



Fig, 2 Effect of abrasive size on percentage change in surface roughness



Fig, 3 Effect of Number of Cycle on Percentage Change in Surface Roughness

Jain Rajendra K. et.al [5] demonstrated the effectiveness of using back-propagation neural networks for process modeling and optimization of AFM process. Simulation results showed a good agreement with experimental results for a wide range of machining conditions. The optimization results of the neural network coincide well with the results obtained by GA and hence validate the neural network approach. The possibility of using this neural network model for machined surface quality and MRR prediction for AFM process had been confirmed. Appropriately trained network successfully synthesized optimal input conditions for AFM process. The optimal input conditions maximized the MRR, subject to appropriate process constraints. An important consideration was that process optimization could be performed in the absence of process models and purely by observations of experimental information. The discussed neural network system was fairly general and could be extended to other abrasive processes to improve machining efficiency

“SaadSaeedSiddiqui” [6] 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. 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.

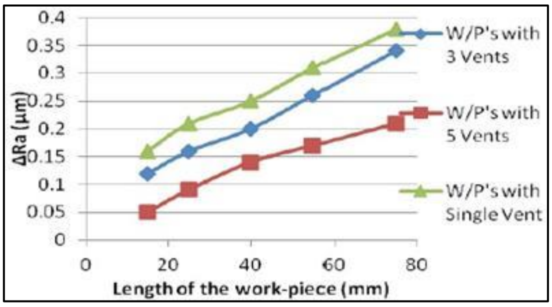


Fig.4 Effect of different vent considerations inwork-pieces of varying lengths on ΔRa

Fig.4 shows the effect of differentvent/passage considerations for media outflow in workpiecesof varying lengths on surface roughness, Ravalue. The change in surface roughness, ΔRa value ishigher in work-pieces having single vent/passage formedia outflow followed by work-pieceshaving multiple vents for media outflow in work-piecesof all lengths, which can be explained by the fact thatwork-piece surfaces having single vent for mediaoutflow offer higher restrictive passage in comparisonwith work-piece surfaces having multiple vents. It canalso be observed that as the length of the work-pieceincreases, the change in surface roughness, ΔRa value also increases because more surface comes in contactwith the abrasive particles

IV. CONCLUSIONS

In this paper, it is concluded that

The Rotational speed of CFG rod is also significant for the present setup and its shows 2.74% improvement in ΔRa at lower rotational speed of 30 rpm the surface finish is the best. A magnetic field has been applied around the work-piece being processed by MFAAFM and an enhanced rate of material removal was achieved.

The average percent reduction in surface roughness can be increased by keeping the extrusion pressure, grain mesh number and Abrasive concentration at high levels, while the average force ratio is able to be increased by keeping extrusion pressure and abrasive concentration at a high level and grain mesh number at a low level

Centrifugal force improves the efficiency and performance of simple AFM process and also reduces the machining time. 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.

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