

Surface Finishing using Abrasive Flow Machining: A Review

Jitender Panchal¹, Sushil Mittal², Harmesh Kansal³

¹Research Scholar, Department of Mechanical Engineering, HCTM, Kaithal

²Assistant professor, Department of Mechanical Engineering, HCTM, Kaithal

³Associate Professor, Dept of Mechanical Engineering, UIET, Panjab University Chandigarh

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 objective of this paper is to study the effects of process parameter related to it such as material removal rate, surface finishing etc.

KEYWORDS: Abrasive flow machining, Material Removal Rate, Surface finishing.

1. INTRODUCTION: ABRASIVE FLOW MACHINING

Limited efforts have been done towards enhancing the productivity of AFM process with look upon to superior quality of work piece surface. AFM process has a greater potential of being used to deburr, radius, polish and remove recast layer of component. Basically there are three types of AFM processes. One way, Two way and Orbital AFM. Commonly we use two way AFM. In two way AFM process consist of two cylinder stocks, one from the lower cylinder pumping an Abrasive laden medium throughout and one from the upper cylinder makes up one process. The polymer abrasive medium which is used in this process possesses trouble-free flow ability, better nature deformability and excellent abrading capacity. For the finishing of the components which have complex unsymmetrical shape/profile, holes and undercut, a need is being felt to expand finishing operations which can produce parts with superior quality performance and higher productivity. AFM is one of such method. The various parameters affecting the process are described here and the effect of the key parameters on the performance of process has been studied. Material Removal Rate and Surface Finish are the two major output parameters.

2. LITERATURE SURVEY

Fletcher et al. [1] studied the relationship between medium rheological properties and the AFM process. Shear rate of the polymer increases when it passes through the restriction (or reduced cross sectional area). Capillary rheometer is used to find the relationship between wall shear stress and shear rate for medium viscosity of polyborosiloxane medium. They concluded that coefficient of viscosity decreases but shear stress increases as shear rate increases. Variation of wall shear stress with time is also studied. They also concluded that greater finishing action could be achieved as a result of longer piston stroke durations, due to higher wall shear stress generated.

Jain and Jain [2] proposed a generalized back propagation neural network model and a second network which parallelizes the augmented Lagrange multiplier (ALM) algorithm. The model determines optimal finishing parameters by minimizing a performance index subject to appropriate operating constraints.

Sarah et al. [3] presented a neural network model as an off-line controller for AFM of automotive engine manifold to predict when the AFM process should be stopped to achieve the required airflow rate through manifold body.

Ramandeep Singh et al.[4] 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 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 viscoelastic 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.

Szulczynski, Hubert et al. [5] Abrasive flow machining (AFM) is a process for the production of excellent surface qualities of inner profiles that are difficult to access and outside edges, as well as for deburring and edge rounding. The grinding medium used in AFM consists of a polymer fluid, the so-called base, in which the abrasive grains are bound. The grinding medium is pressed along the contours at a defined pressure and temperature. Depending on the respective machining task, different specifications of media are used. The description of process-related material removal mechanisms requires the knowledge of material removal mechanisms in AFM. Based on findings in flow mechanism, analyses have been made on material removal mechanisms. The objective of the investigations at the Institute for Machine Tools and Factory Management - IWF in Berlin is to trace correlations capable of influencing the work result. Jose Cherain et al. [6] Abrasive flow machining (AFM) process is a non-traditional finishing process used for polishing and radius difficult to reach surfaces by the abrading action of the abrasives. The material to be machined is taken in the form of a cylinder. The abrasives are taken in the work piece and rotated at high RPM. AFM can be used to produce high surface finish. Various process parameters are abrasive size, Machining time, Hardness of abrasives and speed of abrasives. The experimental result reveals that the efficiency of the process strongly linked to the mechanical properties of the machined material and machining time. This technique offers good surface finish without affecting closest geometrical tolerances of materials.

R.S. Walia et al. [7] 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.

M. Ravi Sankar et al. [8] Abrasive Flow Machining (AFM) was developed in 1960s as a method to deburr, polish, and radius difficult to reach surfaces like intricate geometries and edges by flowing a abrasive laden viscoelastic polymer over them. 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 analyzing the physics, analysis of AFM process always refers to 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. 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. To overcome some of the draw backs such as low finishing rate and inability to correct the form geometry, researchers have proposed various versions of AFM machines abbreviated as M-AFM, DBGAFF, CFAAFM, spiral polishing and R-AFF.

3. EXPERIMENTAL DESIGN

The photograph shows an assembly drawing of the table-top set-up for an AFM process. The machine has two cylinders each i.e. hydraulic and media. The medium is extruded, hydraulically or mechanically, from the filled chamber to empty chamber via the restricted passageway through or past the work piece surface to be abraded. Typically, the medium is extruded back and forth between the fixed chambers for the desired number of cycles [9]. The cylindrical work pieces are placed in the work holder. When extrusion pressure is applied to the medium by the piston two types of forces are generated i.e. Radial and Axial forces. The medium used for experimental is silly putty. The initial positions of these pistons will decided the media volume. To and fro media movements are controlled by the hydraulic cylinders connected to the control unit. A flange is used for clamping the fixture between the media cylinder as shown in fig.-1



Figure 1 Flange which is used for clamping the fixture between the media cylinder

3.1 Procedure

The experiments were performed by AFM technique conducted on cylindrical work-piece. The abrasives used in the media are silicon carbide. The mixture of media is mixed with the abrasive particles of particular mesh size in a definite proportion to achieve the desired percentage concentration of abrasive particles by weight. Before performing the real experiments, the intermediate 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 significant variables are identified the number of cycles, extrusion pressure, abrasive mesh size, work piece material and are kept constant which is explained below. Values of variable parameters and of constant parameters are given in the table-1. All experiments were conducted on work piece surfaces comprising of cylindrical part. Material removal and surface roughness values were output responses calculated as performance indicators in each case. [10]

3.2 Experimental Materials

The Die Steel (D3,O1) as a work-piece material is used. The hollow space to be machined in the work piece which is prepared by drilling operation and then followed by boring operation for necessary size i.e. Dimensions 10 mm internal diameter , 15 mm external diameter and 25 mm length. Sectional view of a test work piece is shown in fig. - 2. The internal cylindrical surface was finished by AFM process. The media formulation used for this study consisted a silicon based polymer, hydraulic oil and abrasive grains. The Abrasive called Silicon Carbide. Each work-piece was machined for a preset number of cycles. The work-piece was taken out from the setup and cleaned with acetone before any measurement is taken.

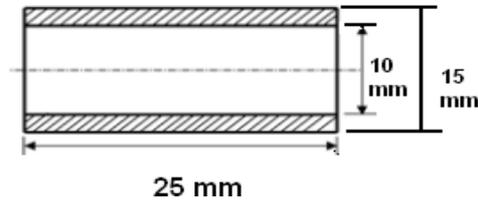


Figure 2 Sectional view of a test work piece

3.3 Fixture

The fixture is made up of Nylon with certain hole to hold the work piece having dimensions are shown in the sectional view of the given design as shown in fig-3



Figure 3 Sectional view of Given Design Fixture

4. EXPERIMENTAL CONDITIONS

The special effects of machining parameters related with AFM on machining characteristics were widely investigated in this study. Moreover, the important parameters and the most favorable combination levels of machining parameters were determined.

5. PROCESS PARAMETERS

The selected parameters and their rang for the detailed experiments as shown in the Table-1

Table 1: Selected Process Parameters and their Range

S.NO.	Process Parameter	Range	Unit
1	Extrusion Pressure	200-700	N/mm ²
2	Number Cycles	50-150	No
3	Abrasive Particle Size	100-200	Micron
4	Work Piece Material	Die Steel Grade (O1+D3)	No

6. CONCLUSION

It is generally applied to finish complex shapes for better surface roughness values and tight tolerances. It is possible to increase the performance of conventional AFM by providing additional motion to the media. But the major shortcoming of this process is slow finishing rate. So continuous efforts are being made to increase finishing rate, improve surface texture and to some extent to improve MRR. If higher the Extrusion pressure and speed of the piston higher will be the material removal rate and surface finish.

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AUTHOR



Jitender Panchal received the B.Tech degree in Mechanical Engineering from Ambala College of Engineering And Applied Research in 2010, and currently in Thesis Work of his masters and for the accomplishment of dissertation work this paper has been carried out.