Article

Latest Trends in Abrasive Flow Machining Process

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Abstract

Abrasive flow machining (AFM) was developed by Extrude Hone Corporation in 1960s as a technique of deburring, polishing, radiusing and to exclude recast film in various applications. In this technique, an abrasive laden media (viscoelastic) under pre-define pressure was used for abrading the internal and external surface. The effect of key parameters such as grit size and type, total number of cycles, abrasive mesh size, extrusion pressure, design of work piece holding device and proper tooling have influence the outcome parameters such as material abrasion and surface finishing. AFM has quickly spread out into automobile, pharmaceutical, chemical, production, defence, space and aeronautics industry. In AFM process, usually the material removal rate is very slow. So the researchers have to develop the hybrid abrasive flow machining process integrated with other non-traditional machining process to reduce the drawback such as low abrasion rate, low finishing rate and failure to accurate the form geometry, researchers have suggested several types of hybrid abrasive flow machining process abbreviated as MAAFM, UFP, DBG-AFF, HLX-AFM, ECA2FM and MRAFF.

Keywords: Abrasive flow machining, Abrasive mesh size, Extrusion pressure, Material removal rate, Non-traditional machining process

Introduction

Conventional finishing process are the most time and labour intensive, needs to address to high demands of the perfection and obstacles in the area of manufacturing process. With the occurrence of industrial revolution, automation of many industrial processes, market competition, industries constantly endeavoured for the best quality and competitive pricing with more intricate, miniaturized and convoluted design with the best suited materials for component. To achieve the higher level of dimensional tolerances and surface finish on the internal surfaces of dies, nozzles and other components, the Abrasive Flow Machining (AFM) Process alone or in combination with other hybrid non-traditional processes finds the suitable application. Abrasive flow machining (AFM) is a non-conventional machining method also named as extrude honing and abrasive flow deburring.[1-3] Abrasive flow machining (AFM) process was developed by Extrude Hone Corporation in 1960s. McCarty RW developed this honing process by mode of extrusion, for the purpose of abrading the internal surface to remove the burrs.[4] Przyklenk K executed parametric study of abrasive flow machining (AFM) under different working conditions.[5]

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Loveless TR et al. examined the effect of different machining process parameters to achieve the quality of work surface produced by abrasive flow machining (AFM).[6] Wang AC et al. conducted the study on rheological properties of abrasive media in AFM and observed the effect of process parameters of used abrasive laden media in the Abrasive flow machining (AFM).[7] Jain VK et al. developed finite element model for analyzing stresses and forces developed during flow of media in AFM process.[8]

Classification of AFM Machine

AFM Machine is categorized into three types according to ways of movement of Abrasive Laden Media.

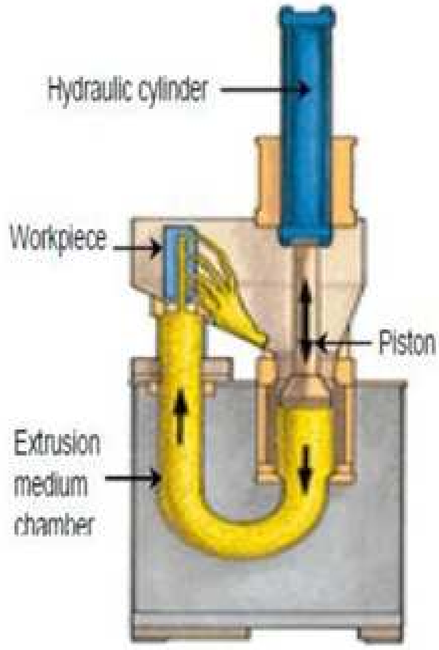

Figure 1.One Way AFM[2]

One-way AFM Process

In One way AFM, extrude abrasive media unidirectional across the inner surface of the work piece with the help of piston cylinder arrangement shown in Fig. 1.

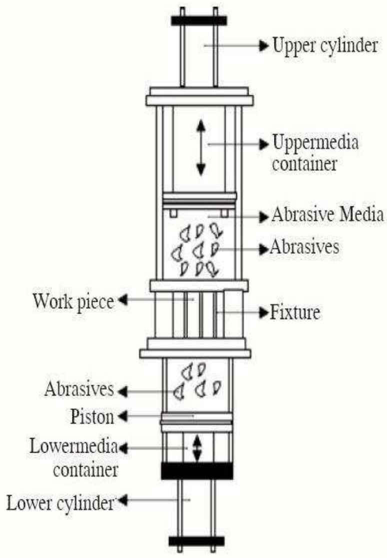

Figure 2.Two Way AFM[5]

Two-way AFM

In this process, abrasive laden media is injected into lower cylinder. The work piece is placed between cylinder and work piece holder. After properly placing the work piece; an abrasive laden media is pushed upward in to the work piece by lower piston. After that the process, upper piston pushes the media downward in to the work piece shown in Fig. 2. This upward and downward extrusion of AFM media complete an AFM cycle. The machining cycles are repeated till the desired finishing is obtained.[9]

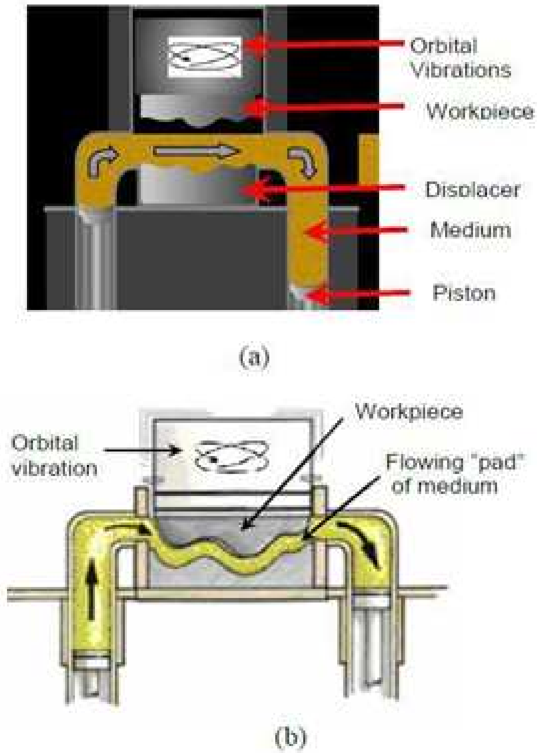

Figure 3.Orbital AFM - Before and After Finishing[2]

Orbital AFM

Very less orbital vibrations are used to the work-piece to produce very fine finishing shown in Fig. 3. It also reduces polishing costs and labour cost and also helps to increase productivity.[4]

Abrasive Laden Media

The abrasive particles of silicon carbide, aluminium oxide, boron carbide and diamond are commonly used as cutting edges in the abrading medium of non-Newtonian liquid polymer and additives. The consternation of abrasive, media of flow and viscosity can be varied. The flow ability and rheological properties of media are controlled by different gels or additives.

Major areas of Experimental Research in AFM Process

A lot of field experimental work and analytical research has been conducted on Abrasive Flow Machining (AFM) process since 1960's. The effect of various AFM process parameters like concentration of abrasive, number of cycles, extrusion pressure, abrasive mesh size, volume flow media on material removal and surface finish was studied by many researchers.[1,3,7,8,11,18] Jain VK et al. developed finite element model for analyzing the stresses and forces developed during flow of media through a cylindrical work piece in AFM. It also analyzes the material removal by abrasive media from work piece for estimation of a material removal rate and surface finish during the AFM process.[8,27] The present literature review is mainly focused on the field of Hybrid Abrasive Flow Machining Processes. It is well known that the material removal in the basic AFM process is very low and to enhance the machining ability of AFM, the various researchers have clubbed AFM with other modern machining processes in order to club the advantages of the two processes.[15] The recent trends in the development of various Hybrid Abrasive Flow Machining Processes have been described as follows:

Magnetic Assisted Abrasive Flow Machining (MAAFM)

Singh and Shan (2002) developed MAAFM process for the purpose to increase to the material removal rate (MRR) and enhancement in surface roughness of component by polymer base abrasive laden media mixed with ferromagnetic abrasive particles in AFM process. In this new hybrid technique, the two poles are enclosed by coil aligned in that way to deliver strong magnetic field in AFM process, it was reported that application of magnetic field with AFM process, enhanced the number of vibrant dynamic grains involved in cutting action.

With the application of the magnetic field, the carbonyl particles make chains and enhance the viscosity of the media, which results in the increase in the dynamic force on the abrasives and thus more cutting. It was also reported that the magnetic field is more effective at lower extrusion pressure. The application of providing magnetic field to AFM results in the increase of material removal rate (MRR) and better surface finish in terms of quality.[10]

Patil V, Ashtekar J enforced magnetic force in the development of flexible magnetic brush, which provided comparatively more cutting forces on the metal surface, thus more polish on the surface.[11]

Ultrasonic Flow Polishing (UFP)

Jones and Hull (1998) developed Ultrasonic Flow Polishing (UFP) by integrating AFM with ultrasonic Machining. In UFP, Abrasive medium within slurry was vibrating with the tool, which was attached to piezoelectric transducer for providing vibrations for the purpose of mirror like image of tooltip on the surface of work piece. Malik and Pandey (2010) also developed Ultrasonic Assisted Magnetic Abrasive Finishing (UAMAF) process by combining two non-traditional processes of USM and MAF to improve the surface finish a work-piece within short period. On the hardened steel work piece, the value obtained by UAMAF for surface roughness was as low as 22 nm within 80 seconds. A 65 percent improvement was recorded by selecting the ideal parameters in UAMAF in terms of surface finish.[13] Gudipadu V et al. used Ultrasonic Assisted Abrasive Flow Machining (UAFM) process for the purpose of finish of such parts which have very intricate geometries.[13] The surface characteristics of intricate geometries got glassy texture due to increase in the density of active dynamic abrasive grains in the given time.[14]

Drill Bit Guided Abrasive Flow Finishing (DBG-AFF)

Sankar MR et al. proposed Drill Bit-Guided Abrasive Flow Finishing (DBG-AFF) process to improve the efficiency of AFM process in terms of surface finish and material removal rate.[15] The Tooling is a major difference between DBG-AFF process and AFM Machines. In DBG-AFF Process twine slot fixture plates were used to keep the drill bit co-axial within the finishing zone. In DBG-AFF process the annular slug gets separated into two parts during the extrusion and at the outlet these two divisions re-associate, resulting in greater intermixing of media.

This use of a twist drill produced more centrifugal forces on the cutting abrasive grains that were in the CFG rotating rods. Self-deformability of Abrasive Laden media is not only reason of abrasive intermixing, but also drill bit being exerted a pressure on the media for intermixing. Thus material removal rate of work piece and surface finish is better in terms of quality.[20]

Helical Abrasive Flow Machining (HLX-AFM)

Brar BS et al. developed Helical Abrasive Flow Machining (HLX-AFM) by placing a co-axial stationary drill bit inside the hollow work piece to increase the performance of simple AFM process.[16] Due to the use of stationary drill bit, no extra power drive was needed so its experimental setup was simple and robust in infrastructure. The abrasive laden media passes through a circular space between work-piece and drill-bit. It was recorded 78.89% contribution of drill bit in the total machining process and it increased the material removal by a factor of 2.66 than the basic Abrasive Flow Machining (AFM) process and 70.53% contribution of drill-bit in percentage improvement in ΔRa was observed.[21,22]

Brar BS et al. further modified the Helical AFM process and employed three different helical helical profiles and observed that the finishing performance of 3-start profile is 15% better than the standard helical drill-bit with no increase in the operating pressures.[23] Kumar R et al. extended this study by employing this process for the machining of ductile materials and employed a three start helical profile rod in place of the drill-bit.[19] The three start profile was employed for the finishing of mild steel, brass and gun metal and more material removal was observed for the brass work-pieces. It was recorded that the extrusion pressure has 20.43% contribution, number of cycle has 26.9% contribution and the material type has the most contribution of 29.57% for response parameter of MR.[24]

Electro-Chemical Assisted Abrasive Flow (ECA2FM)

Dabrowski L et al. investigated with Electro-chemical Assisted Abrasive Flow (ECAFM) for fine finishing of flat surfaces.[25,26] Brar BS et al. modified the process for the finishing of internal prismatic/cylindrical surfaces and developed Electro-Chemical Aided Abrasive Flow Machining (ECA2FM) process for internal holes and recesses and named this as ECA2FM process.[12] Nylon Fixture was used to hold the conducting cylindrical work piece made as an anode and coaxial Copper electrode made as Cathode inside the work-piece.

This electrolytic action results in the abrading of material from the work-piece surface and it results in the softening of the surface. The associated mechanical impact of the abrasive particles results in better surface finish and higher material removal rate. This process is very suitable for thin and delicate parts because electrochemical action can be operated at low pressure.[27-29]

Magneto-rheological Abrasive Flow Finishing (MRAFF)

Sidpara A, Jain VK developed Magneto-rheological Abrasive flow finishing (MRAFF) by integration of magneto-rheological finishing with AFM.[25] MR fluid is used for Nano-finishing of complicated parts and external finish of ocular lenses where the force is regulated by external means. MRAFF technique delivers the better control over rheological properties of abrasive laden magneto-rheological media. It was recorded that in nil magnetic field situations no progress in surface finish was observed and more finishing was observed at increased magnetic field.[31,32]

AFM Applications

Abrasive flow machine is mainly utilized for the finishing of complex internal geometries. From the initial surface roughness of 0.7-7 micron range, the AFM process is capable to enhance the surface smoothness up to 10 times. Surface finish generated by AFM is 50 nm with tolerance limit of ±0.005 mm. AFM has quickly spread out into automobile, pharmaceutical, chemical, production, defence, space and aeronautics industry. Abrasive flow machining is utilized for finishing of nozzle of gas welding torch and extrusion dies. The fatigue strength of spokes, spillways, fins and disks are enhanced by AFM process. Air inlet moulds and heads of two-stroke and four-stroke engines are finished by AFM process.[1-3]

Conclusions

In AFM process, an abrasive laden media (semi solid) is used for abrading the internal and external surfaces. Abrasive laden media extrudes under pre-define pressure across the surface, which is to be finished with help of hydraulic actuators. Due to mechanical impact of abrasive particles on the work-pieces surface, the material is abraded from the surface. The recent work represented here is an overview of developments of AFM and future research directions. AFM is mostly used to finish complex shapes for better surface finish and tight tolerances. But the main drawback of this process is low finishing rate. So the continuous efforts are being made to increase finishing rate and to improve MRR. Different researchers have proposed various types of AFM machines abbreviated as MAAFM, UFP, DBG-AFF, HLX-AFM, ECA2FM and MRAFF etc. So, this process is successfully applied to finish the surface finish and MRR for externally as well as internally simultaneously. There is a further more scope of improvement in the field of AFM.

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