Experimental Investigations into Abrasive Flow Machining with an Electrochemical Process Aid

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Abstract: ***Abrasive Flow machining is a precisely controlled and repeated method of material removal which is used to deburr, polish and radius difficult to reach. In Electrochemical aided abrasive flow machining a polymeric electrolyte is added to the prepared media. It is a hybrid process of Electrochemical Machining (ECM) and Abrasive Flow Machining (AFM). The key components of ECA^2FM process are the machine, tooling, voltage regulator and abrasive medium. One serious limitation of this process is its low productivity in terms of rate of improvement in surface roughness. In the present work, the intensified machining action has been observed due to the cooperation between AFM and ECM processes.***

Keyword: AFM (Abrasive Flow Machining), ECM (Electro Chemical Machining), ECA^2FM (Electro-Chemical Aided Abrasive Flow Machining)

1. Introduction

Abrasive Flow Machining (AFM) is purely a mechanical process where chemically inactive and non-corrosive media is used to improve surface finish and edge conditions. The ability of AFM to polish difficult to reach internal passages and bends ensures that it is a crucial part of modern surface finishing [1]. The main abrasives used in AFM are CBN, SiC, AL_2O_3 and polycrystalline diamond. The major element of process includes: machine, tooling and medium. Although the AFM is becoming vital process because its high accuracy and efficient material finishing process, but it has a limitation of longer cycle time to get required material removal of the surface. In the present paper the AFM is hybridized with ECM to enhance material removal rate of the process. Hand polishing or deburring can be impossible to perform on complicated or internal surfaces, In order to overcome these difficulties AFM was developed in 1960. AFM works by the back and forth flow of abrasive media through the work piece which is located in holding fixture. In a typical, two-way flow process abrasive media is passed between two vertically opposed cylinders formed by the work piece and tooling. Lower piston is pre-loaded with abrasive media and then flows towards upper media cylinder through work piece. In a one-way system, the abrasive media flows in only one direction which allows the media to extrude the desire surface.

2. Electrochemical Aided Abrasive Flow Machining

Electro-Chemical Aided Abrasive Flow Machining (ECA^2FM) process employs an axially held cylindrical electrode rod acting as the cathode, work-piece is made anode along with the usual abrasive flow machining. As the medium passes through the space between the stationary cathode rod and work-piece, it results in more machining due to the additional electrolytic machining due to the cutting action of abrasives. In this process, a low voltage DC potential is applied across the electrolyte abrasives laden media flooded gap between a cathode rod and the hollow anodic work-piece for the anodic dissolution, while the abrasives in the media are abrading the work-piece material [2]. The nylon fixture used in ACAFM is provided with two copper electrode in which one acts as cathode connected with rod, while the other acts as anode connected with work piece.

3. Literature Survey

Basic principles of AFM process was investigated experimentally by Rhoades [3-4] and identified its control parameters. He analysed that when the medium is suddenly forced through restrictive passage, its viscosity temporarily rises. Significant material removal is observed only when medium is thickened. A relationship between temperature, number of cycles and pressure drop across the die for the given type of polymer and abrasive concentration was reported by Davies and Fletcher [5]. 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.

Extrusion pressure plays a significant role in material removal rate. Jain and Adsul [6] reported that MRR is high in the first few cycles due to higher initial coarseness of work-piece surface and it starts slightly decreasing in every cycle. The percentage of abrasives in the medium, grain size and viscosity of the base medium are important parameters that influence stock removal and medium velocity. Williams and Rajurkar [7] reported that metal removal and surface finish in AFM are significantly affected by the medium viscosity.

In order to increase material removal rate and surface roughness Hybrid Machining Processes (HMP) are gaining more attention. An example of HMP is the Ultrasonic Flow Polishing (UFP), which is the combination of AFM and USM [8]. A new method of finishing by applying the magnetic field around a component being processed by

AFM and an enhanced rate of material removal was developed by has been achieved Singh and Shan [9]. This process can be applied to finish the component up to nano level surface roughness [10]. In Centrifugal-force-assisted abrasive flow machining process the work piece is surrounded by an attachment specially designed to give necessary rotary motion to CFG rod [11].

Dabrowski experimented with the electrochemically assisted abrasive flow machining (ECA2FM) using polypropylene glycol PPG with NaI salt share and the ethylene glycol PEG with KSCN salt share [12].

4. Experimental Set up and Procedure

The experimental set up consists of two opposite cylinder in which abrading of work piece take place. Firstly the Lower piston is filled with abrasive media, then fixture containing work piece is placed between the cylinder. Fixture is clamped properly between cylinders in order to avoid leakage. Both the electrodes are connected with terminal of DC power source. A scientech DC power supply with voltage range 0-30 V has been used on an already developed basic AFM setup [13] to supply the DC current to the electrodes. Extrusion pressure is applied at lower piston which allows the abrasive media to pass through restricted passage in upward direction. Then extrusion pressure is applied on the upper piston which allows the abrasive media to flow through restricted passage in downward direction. Process is repeated for desired material removal. This extrusion is controlled by a hydraulic system already developed for the basic AFM setup. The internal cylindrical surface of the work-piece is machined by the abrasion process, when the abrasives media extrudes through this. Each work-piece was machined for a predetermined number of cycles. The gap between the cathode rod and the inner surface of the anodic work-piece provides the Electro-Chemical machining process. This process is repeated for desired material removal. The media volume has been taken as 290 cm³, and the stroke length has been kept constant at 100mm.

5. Design, Analysis and Discussions

The experimental design was according to One-factor-at-a-time approach. This method consists of selecting a starting point for each factor and then successively varying each factor over its ranges with the other factors held constant at the baseline level. The main process parameter for the present experimentation is Voltage (V, in volt) the other parameters of the experimentation have been kept constant. The material removal signifies the amount of material that has been removed from a specimen in a specified number of process cycles. It is estimated by calculating the difference between initial weight of the specimen and final weight of the specimen after processing at a specified set of conditions by ECA2FM. For the present investigation, Work-piece material is gun metal. The cylindrical hole has been machined in the test specimen by drilling operation followed by boring to the required size.

Table 1: Experimentation result on material removal rate

Experiment	Run Order	Response for Material Removal, MR (in mg)				
		V	R1	R2	R3	Mean MR
1	1	0	22.31	24.08	23	23.13
2	8	4	24.12	23.55	25.23	24.4
3	2	8	27.31	25.02	26.51	26.28
4	7	12	30.31	27.85	28.9	29.02
5	6	16	32.41	31.33	30.52	31.42
6	5	20	33.24	33.5	33.19	33.31
7	3	25	34.8	37.64	34.42	35.62
8	4	30	38.12	36.9	38.41	37.81

Polymer-to-Gel Ratio: 1:1, Abrasives-to-Media Concentration: 1.25, NaI Salt concentration: 1M (mole/kg), Work-piece material: Gun Metal, Abrasive type: Al_2O_3, Abrasives Grit Size: 600 (13-16 micron), Media Flow Volume: 290 cm^3, Reduction Ratio: 0.95, Extrusion Pressure: 5 MPa, Number of Cycles: 8, Temperature: 32±2°C, Cathode rod diameter: 3.3 mm. R1, R2, R3 represent response value for three repetitions of each trial. The main effects for the process parameter, voltage (V) are determined based on the average of the raw response data. The main effect for the voltage is plotted in the Figure1.

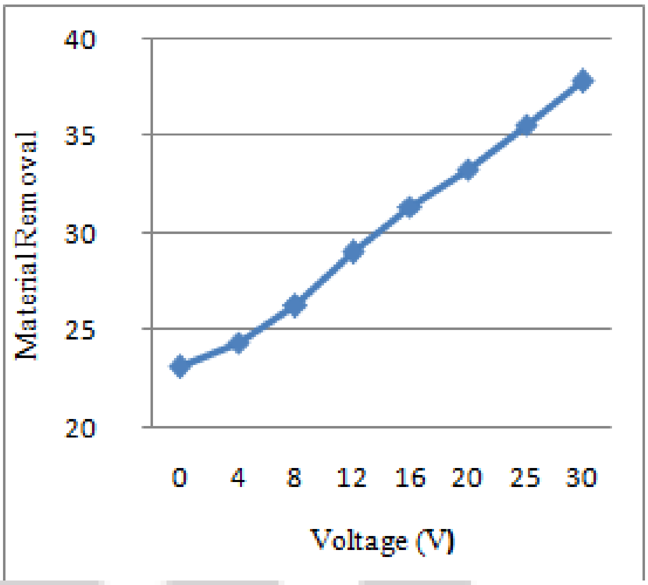

Figure 1: Effect of Voltage on Material Removal

The main effects for the material removal for the process parameter of voltage show that the material removal increases almost linearly with the increase in the. The effect of the voltage was studied from 0-30V. Results are given in Table 1. During the experimentation current of 0.1A amperage was used. The increase in the material removal due to the electrochemical aid in the AFM indicates that the electro-chemical.

6. Conclusion

The important conclusions of this research work are:

- The abrasion of the material is increases due to the addition of electrochemical dissolution with the abrasives cutting in the Abrasive Flow Machining process.
- At higher operating voltages the surfaces are rough due to more material electrolytic dissolution resulting in the deeper scratches on the surface.
- The material removal continuously increases with the increase in the applied voltage.

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