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Magnetic Field assisted Abrasive Flow Machine based Surface Super Finishing

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Abstract: Now a day, need of compact and efficient design of any product with good strength has increased. This requires hard materials like carbide and ceramics for achieving better service life. Conventional machining processes when applied to these newer materials are uneconomical, Produce poor degree of surface finish and accuracy, Produce some stress, highly insufficient. It is impossible to achieve good and desired surface finish in compact, complex, intricate shapes, profiles, curved splines etc, where conventional machine tool faces difficulties during machining and consumes much time. It experience same problem with micro/nano finishing like small size diameters use in fuel injector etc. Abrasive flow machining (AFM) is relatively new process among non-conventional machining processes. Low material removal rate happens to be one serious limitation of almost all processes. Magneto abrasive flow machining is a new development in AFM. With the use of uniform magnetic field around the work piece in abrasive flow machining, we can increase the material removal rate as well as the surface finish.

Keywords: Abrasive slurry, Magnetic Abrasive Flow Machine (MAFM), Material Removal Rate (MRR)

I. INTRODUCTION

Magneto abrasive flow machining (MAFM) is a new technique in machining. These processes can be classified as hybrid machining processes (HMP) _ a recent concept in the advancement of non conventional machining. The reasons for developing a hybrid machining process is to make use of combined or mutually enhanced advantages and to avoid or reduce some of the adverse effects the constituent processes produce when they are individually applied. The present paper reports the preliminary results of an on-going research project being conducted with the aim of exploring techniques for improving material removal rate (MRR) in AFM. One such technique uses a magnetic field around the work piece during machining. Magnetic fields introduce such a machining force toward machining in magnetic abrasive finishing (MAF), used for micro machining and finishing of components, particularly circular profile.

II. PROBLEM DEFINITION

Magneto Abrasive flow machining (MAFM) is one of the latest non-conventional machining processes, which possesses excellent capabilities for finish-machining of inaccessible regions of a component. It has been successfully employed for deburring, radiusing, and removing recast layers of precision components. High levels of surface finish and sufficiently close tolerances have been achieved for a wide range of components. In MAFM, a semi-solid medium consisting of a polymer-based carrier and abrasives with ferromagnetic particles in a typical proportion is extruded under pressure through or across the surfaces to be machined. The abrasion takes place between surface and abrasive results in material removal in form of small chip particle which mix with slurry and work as tool. A special fixture is generally required to create restrictive passage or to direct the medium to the desired locations in the work piece. This report discusses the possible improvement in surface roughness and material removal rate by applying a magnetic field around the work piece in AFM. Relationships are developed between the material removal rate and the percentage improvement in surface roughness of steel component when finish-machined by this process.

III. OVERVIEW

Abrasive flow machining (AFM) is a non-traditional machining process that was developed in the USA in the 1960s. This provides improvement in surface roughness and material removal rate, polish intricate geometries. The process has found applications in a wide range of fields such as aerospace, defence, and surgical and tool manufacturing industries. Extrusion pressure, flow volume, grit size, number of cycles, media, and work piece configuration are the principal machining parameters that control the surface finish characteristics. Recently there has been a trend to create hybrid processes. This has opened up new vistas for finishing difficult to machine materials with complicated shapes which would have been otherwise impossible. These processes are emerging as major technological infrastructure for precision, micro, and nano scale engineering. This review provides an insight into the

fundamental and applied research in the area and creates a better understanding of this finishing process, with the objective of helping in the selection of optimum machining parameters for the finishing of varied work pieces in practice. The various limitations of Abrasive Flow Machining are overcome like:

1. Low finishing rate.
2. Low MRR.
3. Bad surface texture.
4. Uneconomical.

IV. EXPERIMENTAL SETUP

An experimental set-up is designed and fabricated as shown in fig.1. The machine has two actuators. These actuators can be hydraulic or pneumatic operated with the use of a synchronize circuit. The circuit contains a direction control valve which is push button operated, controls the flow of pressurized fluid and results in the desired motion of the cylinder piston. Tooling in the vacant chamber is used to store abrasive slurry, and it is made up from nylon material as it is not affected by abrasive particles. This abrasive slurry flows from lower tooling to upper tooling and then vice versa, making one cycle of machining. The fixture is designed in such a way that it is inbuilt in tooling and helps to hold the work piece in the right position. An electromagnet is used to provide a uniform magnetic field around the specimen by using a DC supply, and it also facilitates the cut-off of magnetic flux after machining is carried out. The electromagnet contains a number of poles which are well fitted around the specimen that keeps a minimum distance from the center of flow. The machine structure contains a base stand, strut, and steel plates that hold the whole machine in position.

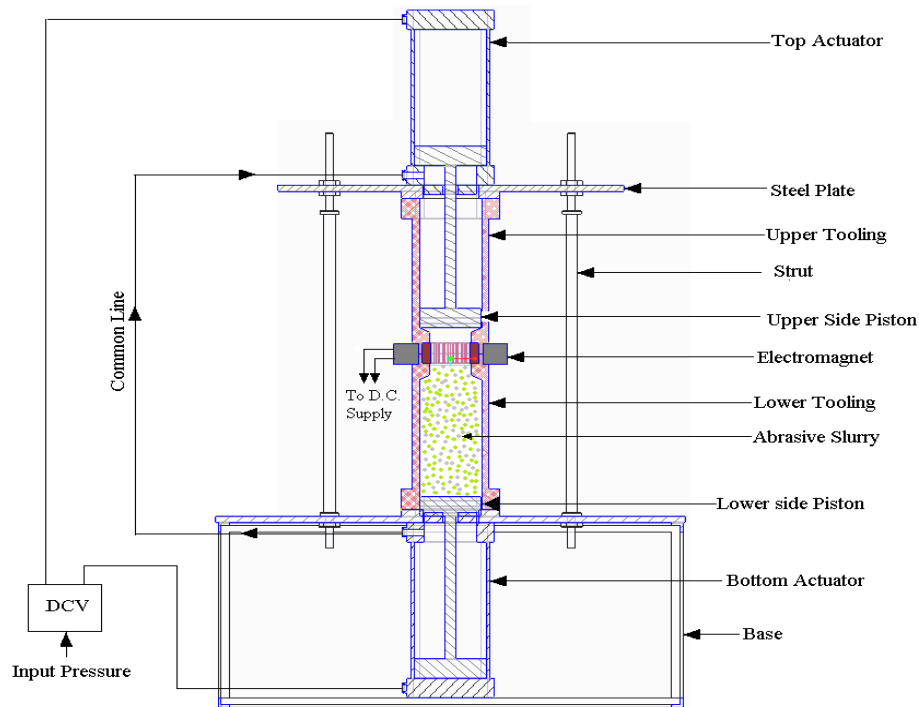


Fig. 1 : Experimental Setup

A. Specimen

The work specimen used in this test is a dog clutch containing splines (tooth) on its internal surface. The dog clutch is made from alloy steel having specified dimensions as shown in Fig.1

Dimension : - D_o - 75mm, D_i (mean) - 53.5 mm, L - 26mm

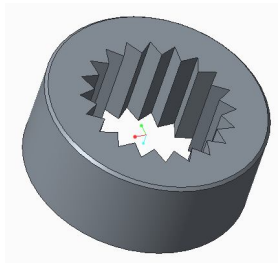


Fig. 2 : Specimen

B. Electromagnet

The electromagnet was design and assembled for its location around the work piece. The electromagnet is created by manufacturing core. Core is made from number of silicon steel strip placing one on one called as stamping. Core is design in such a way that it creates number of poles around the work-piece. It consists of 24 poles that are surrounded by coils which contain 108 numbers of turns. Gauge of wire in electromagnetic coil is 28. It is positioned in such a way that it can provide the maximum magnetic field near the entire internal surface of the work piece.



Fig. 3 : Electromagnet

TABLE I
SPECIFICATION OF ELECTROMAGNET

Pole and yoke material	Silicon Steel
Coil Copper wire	0.32 mm, 108 turns
Power supply	0 – 220 V, 0 – 4A
Maximum flux density	1 – 2 Tesla

C. Flow Media

Flow media is in state of semi solid fluid. It is mixture abrasive such as aluminium oxide and silicon carbide followed by binding agent like oil, hydrocarbon gel, Silicon based polymer etc, which conforms the fluidity of abrasive slurry. This mixture contain 43 % (by weight) of ferromagnetic material, 42% Al₂O₃ and 15% Si₂O₃. In ferromagnetic materials we can use iron powder, granules of Fe etc.



Fig. 4 : Flow Media

V. PROCESS PARAMETERS

TABLE III
INDEPENDENT PARAMETERS

Sr. No	Process Parameters	Range	Unit
1	Extrusion Pressure	20 - 30	Bar
2	Abrasive carrier concentration	70-30	% by weight
3	Viscosity of Media	490	Pa-s
4	Media flow Rate	618	cm ³ /min

TABLE IIIII
CONSTANT PARAMETERS

S. No	Process Parameters	Range	Unit
1	Abrasive Particle size (mesh size)	60-65	Micron
2	Processing Time	5	Min
3	Temperature of Media	35±2	°C
4	Initial surface roughness	3.04	µm

TABLE IVV
PROCESS RESPONSE

Sr. No.	Process Parameters	Range	Unit
1	Surface Finish (improvement)	72.72	%
2	Material Removal	0.2	gm (per cycle)

VI. WORKING PRINCIPLE

The abrasive slurry which is in semi solid fluid form flows through work piece. This abrasive particle is force to flow by piston cylinder by applying the pressure. Due to this, velocity of abrasive particle increases by converting potential energy into kinetic energy. When the magnetic field is applied around work piece the ferromagnetic material present in abrasive slurry get struck along with abrasive to the work-piece. Due to pressure of piston it get rubbed on surface of work-piece which results in micro-chipping, causes surface finishing. This process is carried until desire surface is required. Hence by application of magnetic field the abrasive slurry sticks to the surface and increases MRR in short span of time. After desire result power supply is switched off, magnetic field is vanished hence abrasive left the surface. In this way surface finishing is done.

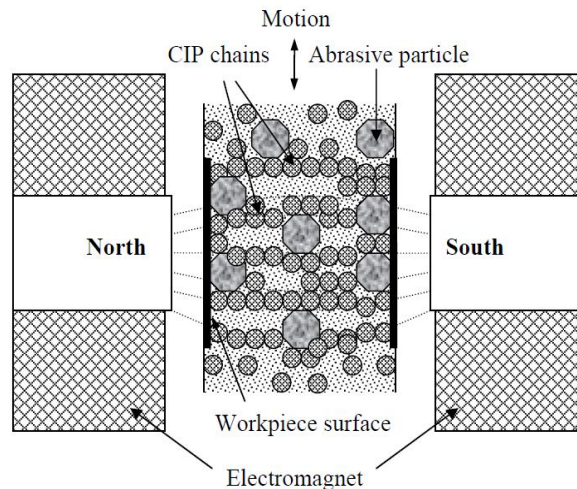


Fig. 5: Principle of Abrasion

VII. COMPARISON

TABLE VV PROCESS COMPARISON

Parameters	AFM	MAFM
Machining Time (per work piece)	5 min (for 30 Cycle)	3 min (for 30 cycle)
Setup Time	2-3 min	2-3 min
Surface finish (Ra value in μm)	0.05-1.0	3.0-5.0
Material removal Rate	0.008-0.010 mm	0.020-0.030 mm
Productivity	Lower as compare to MAFM	Higher
Accuracy	Higher	Higher

VIII. ADVANTAGES

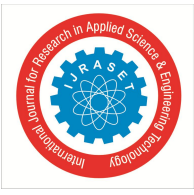
- A. MAFM increases material removal rate and surface finish as compared to AFM.
- B. It effective on all material such as hard and high strength material like ceramics and carbide.
- C. It produce high degree of surface finish and accuracy and highly efficient over conventional process.
- D. Higher MRR as compare to AFM.
- E. Machining time reduce as compare to AFM and other conventional machining process.

IX. LIMITATIONS

- A. Abrasive material tends to get embedded if the work material is ductile.
- B. Heat generated by electromagnet may change the property of flow media.
- C. Initial cost of machine is more as compare to AFM.

X. APPLICATIONS

- A. *MAFM in Automotive industry*
 - 1) Enhanced uniformity and surface quality of finished components.
 - 2) Increased engine performance.
 - 3) Increased flow velocity and volume.
 - 4) Improved fuel economy and reduced emissions.
 - 5) Extended work piece life by reducing wear and stress surfaces.
- B. *MAFM in Aerospace industry*
 - 1) Improved surface quality.
 - 2) Enhanced high cycle fatigue strength.
 - 3) Optimized combustion and hydraulics.
 - 4) Increased airflow.
 - 5) Extended component life.
- C. *MAFM in Medicine industry*
 - 1) Eliminate the surface imperfections where dangerous contaminates can reside.
 - 2) Improved functionality, durability and reliability of medical components.
 - 3) Enhanced uniformity and cleanliness of surfaces.
 - 4) Extended component life.
- D. *MAFM in Dies and Moulds industry*
 - 1) Reduced production costs.
 - 2) Increased production throughput.
 - 3) Enhanced surface uniformity, finish and cleanliness.
 - 4) Improved die performance and extend life of dies and mould.



XI. CONCLUSION

- A. The magnetic field has been developed around the work piece and removes the material by friction of flow media on the work piece.
- B. This can help to reduce the manufacturing operation per cycle compared to AFM. This is a continuous process as the combination of magnetic field and flow media interacted toward the work piece and removal of material takes place.
- C. The media flow is semi viscous form, they cannot affect on work piece as it pass through it continuous motion of flow.

XII. FUTURE SCOPE

Electromagnet generates lot of heat which changes flow media properties. Any can redesign electromagnet or can provide cooling jacket to it.

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