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Pressure Variation in Abrasive Flow Machining: Modelling and Simulation

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Abstract : *The improvement of manufacturing techniques has led to the development of new finishing techniques and abrasive flow machining has emerged as a potential tool in the field of surface finish. Abrasive flow Machining is a potential method for achieving surface finish up to Nano level. The requirement of improved surface finish has increased with the advancement of technologies which has led to the development various hybrids of abrasive flow machining. Over the year several research and experiment have been performed in this field with different parameters optimized with optimum techniques. The selection of proper viscoelastic fluid with suitable mixture of abrasive is a major requirement and thus there is a need for proper modelling and analysis of the process which is a major research gap in the process. This paper includes solid modelling of the process and simulation on Ansys Fluent module and analyse the pressure variation on the workpiece and its effect on material removal.*

Keywords: *viscoelastic, Hybrids, Nano Finishing, Material removal.*

1. INTRODUCTION

Abrasive flow machining is a Nano finishing technique generally used for internal and hard to reach surfaces and complex geometries of hollow workpiece. The Process involves the abrasion of abrasive particles on the wall of the workpiece when the mixture of polymer, gel and abrasive are allowed to flow in a constrained passage [1]. The Machining process is obtained by continuous reciprocation of the mixture under the suitable pressure difference which can be achieved by various configurations thus on this basis these are of three categories ie One-way AFM [2], two-way [3] and orbital AFM [4]. These classifications have been done on the basis of motion of the fluid in the setup of which two-way AFM are most common technique. AFM process finds its application in wide areas which includes finishing and removal of thermal recast layer formed in Micro channels (MEMS) during the machining by EDM [5]. AFM process find its application in Miniaturized parts like fuel injectors, micro filters, ink-jet printer nozzles, micro pumps which contains micro bores of diameter smaller than 500 um in various sensors apart from that AFM is used for polishing microbores in metal of abut 400 and 500 um sizes [6]. AFM process finds its major application in finishing of industrial components like Bevel gears [7]. AFM process is successively applicable for machining of nonlinear tube runner which finds its application in military and civil areas [8]. Jung et al. [9] uses AFM for studying the quality of Direct Injection (DI) diesel engine fuel injector nozzles Xu et al. [10] uses AFM for the finishing of Helical Gears. Kenda et al. [11] uses AFM on the gear injection mould made of tool steel and commented on its successful implementation. Application of AFM has also been stated in finishing of hydraulic components (nitro alloy collar and brass convergent divergent nozzle) [12,13]. Apart from that the major area of application of abrasive flow machining is machining of bio-medical components which includes Knee joint implant [15]. A new hybrid of abrasive Flow machining, Rotational-Magneto Rheological Abrasive Flow Finishing (R-MRAFF) is developed for finishing of freeform component similar to knee joint implant to Nanometres level [16] hence there was a need for the development of new Hybrids of Abrasive Flow Machining which would enhance the material removal and provides a better surface finish. The various hybrids of AFM developed so far are Magnetic force assisted AFM process [17], Centrifugal force assisted AFM [18,19,20,21], ultrasonic AFM [22,23], Drill bit assisted AFM [24], Rotational AFM [25,26], Electrochemical assisted AFM [27,28], Helical AFM [29,30,31], Centrifugal magnetic force assisted AFM [32], Hybrid electrochemical and centrifugal force assisted abrasive flow machining [33]. Some of the application of abrasive flow Machining process is depicted in figure 1.

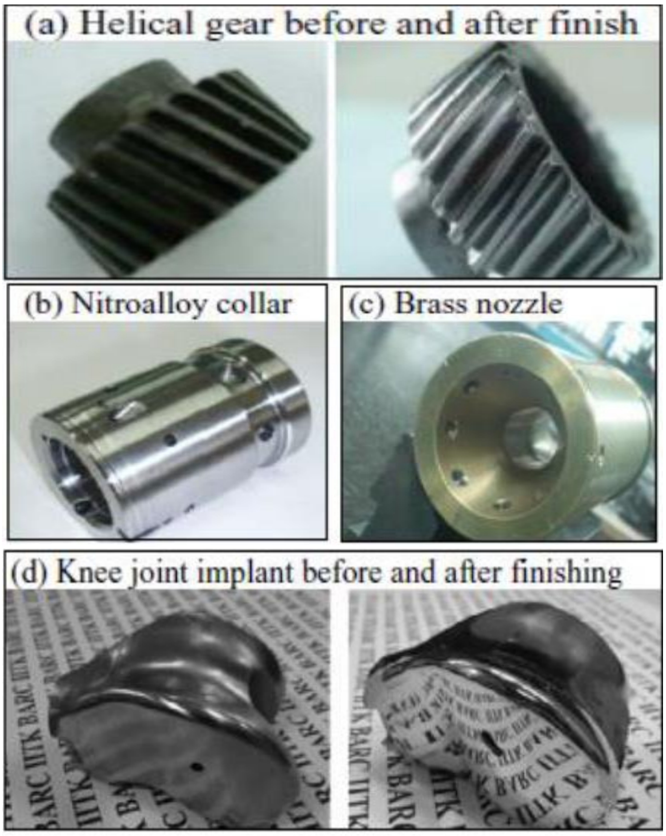

Fig.1 application of Abrasive Flow Machining [34]

2. EXPERIMENTAL SETUP

The major research gap in the field of abrasive flow machining is solid modelling and its software analysis thus to cover that Ansys Fluent software is used. The initial step in the process was creating a geometry which consist of three major parts the brass workpiece, the alumina abrasive and the polymer media which is taken as Polyborosiloxine as it can be treated as the economic viscoelastic fluid used in this process. The initial setup was made using Creo parametric 3.0 and was then imported to Ansys. Figure 2 represents the geometry of the experiment in Ansys modeller.

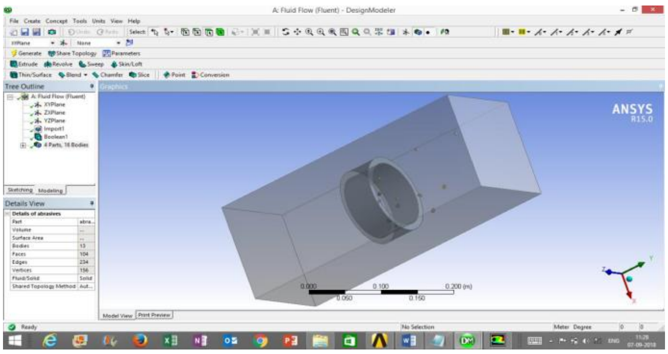

Fig.2 Initial geometry in Ansys fluent

The above figure (2) shows the required parts which are being consider in the analysis which are Fluid Domain which covers the hollow workpiece and contains abrasives scatter inside the media. The next step in this analysis was to give the name selections for providing the boundary conditions and for this purpose 5 name selections were given inlet, outlet, Fluid Domain, workpiece and the abrasives. once the name selection was done, messing of the setup was done to start the analysis of the system.

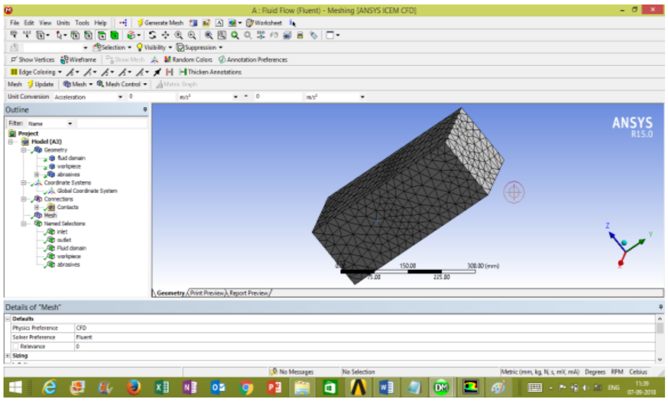

Fig. 3 Messing of Fluid Domain

The detail of mesh for the simulations is shown in the Table 1. Which tells about the total elements and nodes involved in the simulation.

Table 1

Domain	Nodes	Elements
Abrasives	234	52
Fluid domain	1803	8194
workpiece	176	69
All Domain	2213	8315

Once the messing was done the next steps was the initialization of fluent set up. Fig 5 shows fluent setup report in which double precision serial and 3D simulation was taken on.

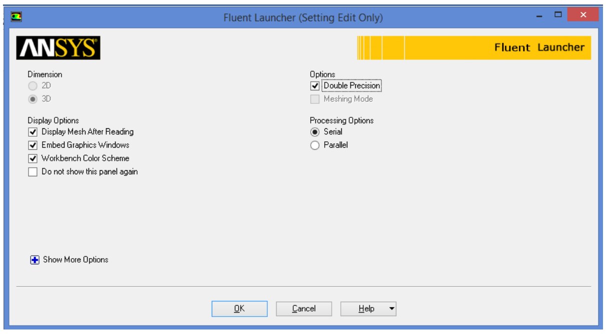

Fig.5 Initial setup

Once the set up initiate we select the pressure-based simulation with energy equation on and laminar viscous model after going through the initial condition we select the materials for our simulation which are listed in table 2 which talk about the material, type, density, Viscosity, Density, thermal conductivity and specific heat.

Table 2

Material	Type	Density (Kg/M3)	Viscosity (Kg/ M-S)	Thermal Conductivity (W/ M-K)	Specific Heat (J/Kg -K)
Polyborosiloxine	Fluid	1219	0.789	0.22	20.25
Brass	solid	8300	109	401	
Alumina abrasives	solid	3950	12	451	

After assigning the material to the workpiece Boundary conditions were applied to the various name selections which was done before messing and table 3 shows various boundary conditions along with name.

Table 3

Sr no.	Name	Boundary condition
1	Inlet	Pressure inlet with inlet pressure 40 MPa
2	Fluid	Stationary fluid at room at temperature 300 K
3	Workpiece	Stationary workpiece at Room Temperature 300 K
4	Outlet	Pressure Outlet with outlet Pressure 20 MPa

After applying the boundary conditions solution was initialized with Hybrid initialization and the setup was allowed to run for 100 iterations and it converged successfully. The graph of conversion with respect to the X,Y and Z velocity and continuity equation is shown by figure 6.

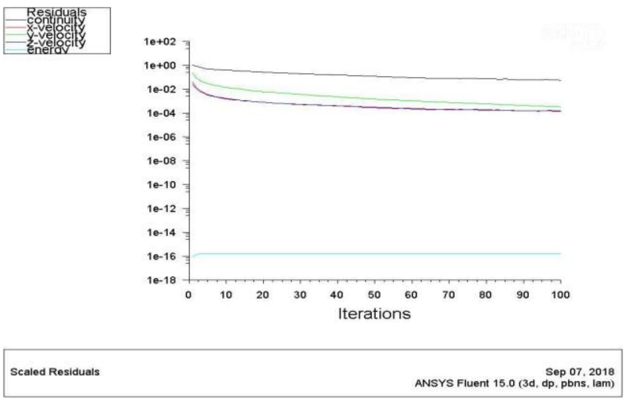

Fig. 6 Conversion graph

3. RESULT AND DISCUSSION

After its conversion the pressure effect on the workpiece was observed and following results were obtained which is shown by Figure 7. The maximum pressure shown after the analysis is 26.2455 MPa and the minimum Pressure obtained after the analysis is 10.4519 MPa which is an optimum for machining the brass workpiece at the pressure range of 40 MPa to 20 MPa.

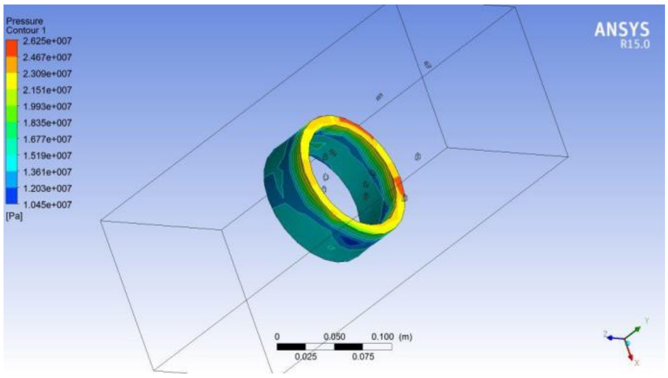

Fig. 7 Effect of Pressure variation on the workpiece

The fluid was allowed to reciprocate from the inlet to outlet by applying the pressure difference of 20 MPa so there is a Forced Flow of fluid is there which is represented by the stream line graph obtained after successful simulation. Figure 8 shows the streamline variation of the Polymer media. Thus, Abrasive Flow Machining is a major tool in finishing of hollow work surfaces and there is a scope of further modelling and simulation in this field.

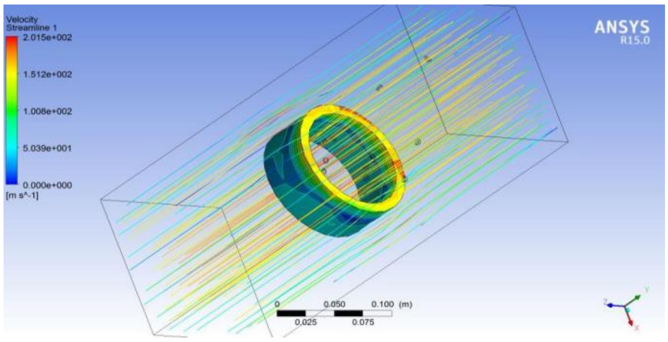

Fig.8. streamline variation of Polymer Media

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