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MODELLING OF GRANULAR PRESSURE IN ABRASIVE FLOW MACHINING FOR A ROTARY SWAGING DIE

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Abstract: Precision finishing operation has become a major challenge in recent days as it is expensive and requires high skill of the operator. Abrasive flow machining is a new finishing operation which requires less skill and takes little time. The process is dominated by many parameters like abrasive concentration, abrasive mesh size, extrusion pressure, piston velocity and machining time. It is expensive and time consuming to experimentally investigate the effects of all the parameters and to find the optimum one. To overcome the difficulties faced in experiments, CFD approach is applied to study the process parameters and their effects on the material removal and ultimate surface finish. This paper is based on a 3D modelling of flow passage for a rotary swaging die. The flow parameters like granular pressure, wall shear and strain rate were studied to predict the material removed and surface finish. The flow was assumed to be laminar, steady state and granular. The multiphase mixture model was used for the analysis. The simulation results show a significance increase in granular pressure and strain rate with the increase in volume fraction and decrease in skin friction coefficient. The granular pressure is a key parameter to control the surface finish and the material removal rate is affected by strain rate and skin friction coefficient.

Keywords: Abrasive flow machining, mixture model, CFD simulation, granular pressure, skin friction coefficient

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INTRODUCTION

Precision finishing has become an indispensible machining operation for intricate and complex geometries used in aerospace, automobile and chemical industries. The traditional finishing operations failed to achieve the required surface finish in case of these complicated geometries. The abrasive flow machining process is a new precision finishing operation used for finishing up to micron level in case of cylindrical, flat work pieces as well as complex work pieces.

AFM is a process used for deburring, polishing and removal of recast layers produced by EDM process. In the AFM process, a semi-solid viscous media containing abrasive grains in specific proportion is extruded within the work piece surface to be finished [1]. The abrasive media is extruded back and forth within the work piece and media cylinder. The machining is called no-tool finishing operation as no conventional tool is used for cutting except the abrasive particles used for finishing operation[2]. The final surface finish and material removal rate are affected by the controlling parameters of AFM process like extrusion pressure, media concentration, type of abrasive and abrasive sizes [3]. Increase in pressure and viscosity increases the material removal while decreases surface finish [4-6].

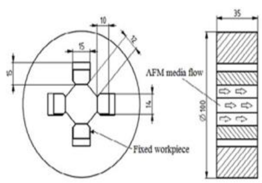
There are numerous parameters that affect the machining process and it is tedious and time consuming to study all the parameters and their effects. The CFD approach to study the abrasive media flow and the parameters affecting AFM like the media concentration, abrasive particle size and volume fraction of abrasives. Theoretical FEM modelling were done previously to predict the media flow, material removal model and surface finish [2,7]. Application of commercial software like FLUENT has made the analytical modelling easier. Recent literature surveys show that the application of FLUENT has predicted the velocities and pressure in AFM process using 2D model [8,9]. In the present work, an analysis of granular pressure has been done using FLUENT at different mesh sizes and volume fraction of abrasive particles. The model considered for the analysis is a 3D model for a rotary swaging die.

GEOMETRICAL MODELLING AND CFD SIMULATION:

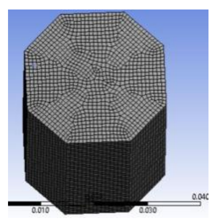
The 3D model of the rotary swaging die was done in ANSYS 15.0 workbench and it was meshed to produce uniform grids. The flow analysis was done by using ANSYS FLUENT. The flow was assumed to be steady state, laminar and the fluid was considered to be incompressible and Newtonian fluid. The fluid was considered to be a two-phase media, the first is the fluid medium and the second phase is the abrasive particles. The multiphase modelling in FLUENT was taken into account as there are two phases under consideration. The mixture model is considered in this case as the model is able to model two phases as well as granular and particle-laden flow.

Mixture model can simulate for n phases and solves momentum, continuity, energy equations and volume fractions of the secondary phase. It is a simpler model to study the solid-liquid flow in comparison to Eulerian multiphase model.

The experimental analysis for a rotary swaging die was done by Kenda et. al [10]. The present paper is based on the CFD simulation and analysis of the same geometry. In the 3D model, the passage for the media flow including the wall of the dies to be finished and the fixture was taken as flow domain. The width of the workpiece is 14mm and the wall to be finished using AFM is of the width 10mm and the length of the whole passage is 35mm. The simulation was done for different volume fractions and different mesh sizes of abrasive particles keeping other parameters constant. The fluid media was assumed to be polyborosiloxane and the abrasive particle is corundum.



(a)



(b)

Fig. 1.(a) Arrangement of work pieces with fixtures by Kenda[10] (b) 3D meshed model for FLUENT analysis of the passage

Fig.1 shows the flow domain for the FLUENT analysis. A part of the geometry around the symmetrical plane was considered for the fluid flow for computational stability.

SIMULATION PARAMETERS:

Workpiece-Aluminium

Density of the Polishing Media- 1219 kg/m^3

Viscosity of media-789 Pa-s

Density of corrundum-3910 kg/m^3

Inlet pressure-5Mpa

Volume fraction values-0.3 (at different diameters)

Mesh size of the abrasive particle-150micron (at different volume fractions)

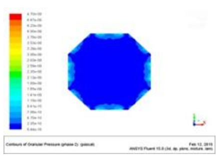
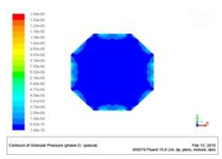
RESULTS AND DISCUSSION:

The parameters affecting the material removal and surface finish in AFM are considered for observation. The velocity, pressure, shear stress and strain rate are the flow parameters those predict the material removal, abrasive actions and surface finish. In a solid-liquid multiphase flow analysis, the pressure examined is practically granular pressure affecting the ablating action. Granular pressure is the pressure applied on the fluidized bed due to particle collision with the wall. The removal of material by the abrasive action is the result of granular pressure. Surface roughness of the final machined surface is affected by granular pressure. Skin friction coefficient and strain rate theoretically determine the deformation produced on the work piece wall.

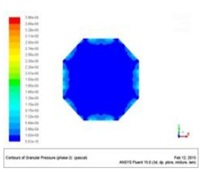
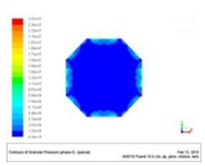
The FLUENT analysis was done for different volume fractions and the variations in different parameters were studied.

Effects on Granular Pressure:

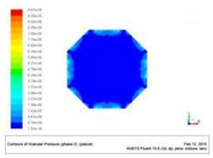
The simulation for granular pressure at different volume fraction is shown in fig.3. The volume fractions selected for the FLUENT analysis are 0.2, 0.25, 0.3, 0.35 and 0.4

(a)Abrasive vf 0.2 (b)Abrasive vf 0.25

(c)Abrasive 0.3 (d)Abrasive vf 0.35



(e)Abrasive vf 0.4

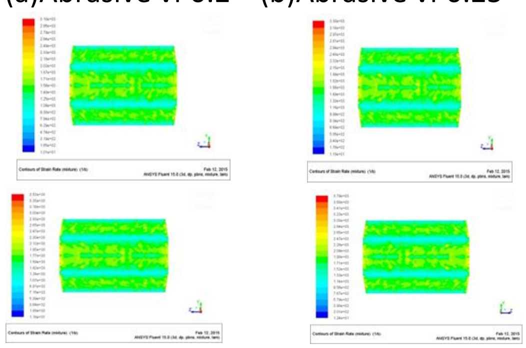
Fig.2. Contours of granular pressure at different volume fractions

Granular pressure was observed to increase with increase in volume fraction of abrasive. The granular pressure is a function of the solid granular phase or the abrasives that affect the material removal. The increase in granular pressure increases the interaction of the granular phase with the continuous fluid media that increases the material removal rate and decreases the surface finish.

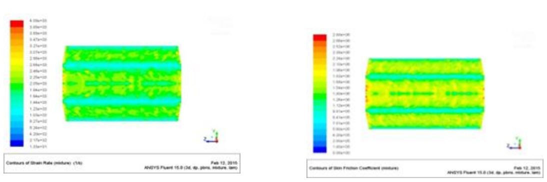
Effects on Strain Rate:

The effects of variation in volume fractions on strain rate are shown in fig. 3.

(a)Abrasive vf 0.2 (b)Abrasive vf 0.25



(c) Abrasive 0.3 (d) Abrasive vf 0.35



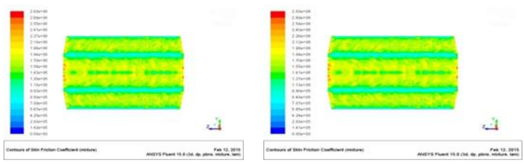
(e)Abrasive vf 0.4(e) Abrasive vf 0.4

Fig.3. Contours of strain rate at different volume fractions

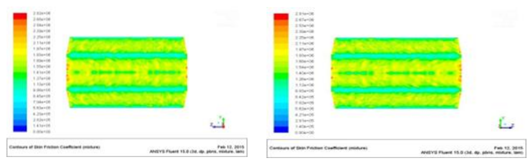
The strain rate from fig. 3 was found to increase with increase in volume fraction of the abrasive particles. The strain rate is proportional to the bulk of stuff removed from the surface. Increase in volume fraction abrasives from 0.2-0.4, the strain rate on the work piece wall as well as the area weighted average strain rate was found to increase.

Effects on Skin Friction Coefficient:

Effects on skin friction coefficient were found at different volume fractions of abrasive particles were found from the following images in fig.4.



(a)Abrasive vf 0.2 (b) Abrasive vf 0.25



(c) Abrasive vf 0.3 (d) Abrasive vf 0.35

Fig.4. Contours of skin friction coefficient at different volume fractions

The contours of skin friction coefficient from fig.4 at different volume fractions show that the increase in volume fraction of the abrasive particles tends to decrease the skin friction coefficient. Increase in volume fraction of the abrasive increases the particle concentration in the suspension fluid. To transport the abrasive particles in fluid medium a part of pressure energy is lost to decrease the velocity as well as skin friction coefficient. This ultimately increases the material removal rate and increasing surface roughness.

CONCLUSIONS

The simulation parameters of CFD were studied at different volume fractions. The granular pressure was found to increase with the increase in concentration of abrasive grains. The pressure due to the granular phase increases thereby increasing the abrasive action. More abrasive action tends to increase the surface roughness of the work piece. The skin friction coefficient was found to decrease with increase in volume fraction of abrasives and the strain rate was found to have the opposite effects. Both of them are found to have effects on material removal. Strain rate was found to have significant effects on material removal at different volume fraction in comparison to skin friction coefficient.

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