Optimization of abrasive flow finishing process parameters for two dimensional mixture models using CFD simulation

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Abstract A rapid development in engineering and technology demands a high accuracy as well as high precision in the development of the fragile components. Improvement in the surface quality of the finished products is a quite challenges issue in the finishing operation in the industries related to the field of automobile applications, aerospace applications and biomedical applications etc using abrasive flow finishing (AFF). Viscosity of media, number of particles, size of abrasive particles, and extrusion pressure are the governing parameters that affect the surface finish during abrasive flow finishing operation. To perform the operation with all governing parameters with optimized conditions in a very short time are difficult to accomplish because the operation requires a high precision in surface finish. To calculate the optimized parameters, a computer fluid dynamics (CFD) simulation was employed. Present research focus on development of 2D model and analysis of flow, calculation of forces, and material removal prediction were performed and compared with the available experimental data.

Keywords: Ansys Fluent, Surface finish, simulation, abrasive flow finishing

Introduction

The new name of AFF process is known as extrude honing or deburring(Schrader et al.2000; Kumar et al.2016). Generally it is used for the internal parts of the components to be finished and it is designate by passing a abrasive in the form of fluid through a workpiece (Rhoades 1991). AFF generally used for the smoothening of the rough surfaces and remove unwanted material in the form of burrs, polishing the surface in the mirror form and can be used as material removal process (Rhoades 1998). The big advantage of AFF process over grinding process includes the capability of interior finishing, finishing of slots and very narrow cavities (Rhodes 1998; Jain 2010).

The erosion of the workpiece is generally result of the fluid form nature of the abrasive (Jain 2008; Jain 2009). In AFF process, the abrasive in fluid form is forced with the help of hydraulic cylinder assembly into the rough surfaces of workpiece and perform the task of finishing resulting in the mirror shape like smooth surface. The principle of working of AFF process based on Bernoulli’s theorem which stated as the fluid restriction in the area of workpiece resulting in the highest amount of material removal because of increase in pressure intensity.
Finally, the uniform finish is achieved by the pressure exerted by the fluid near the contacting rough surface. The evaluation of fluid characteristics of abrasive particles in AFF process also results in the smooth surface of the part to be finished by Davies et al. 1996.

The computational fluid dynamics method of simulation is well known method to overcome the defects and deficiencies occurs in the other traditional methods of analysis theoretically and by experimentally. It can be found from the various research gaps that the several parameters which affect mostly the AFF process cannot be studied feasibly through procedures by experimentally. So, CFD is a better approach to study the governing parameters which affects the AFF process. In the present work, a 2D model was developed for the CFD simulation to determine the MRR using a mixture laminar flow approach at different extrusion pressure.

**CFD Modeling and Analysis**

**Modeling of work piece**

A 2D model with meshing of work piece having cylindrical geometry is created using ansys fluent design modeler as shown below. A continuous supply of abrasive media consisting of viscoelastic polymers along the uneven surfaces of the workpiece regulated. For simulation and modeling purpose each particle can be assumed to be continuous phase. A solid phase is considered for the CFD simulation in the design parameter because of the tiny and farinose particles of abrasive. For the optimal solution this 2D model is divided 10862 finite elements.
Simulation parameters

For the CFD simulation pressure-based model and steady-state formulations with double precision is specified in the general setting and multiphase mixtures flow with 2 phases is used. When the fluid is flowing in a closed chamber and flow is in parallel layers then laminar or turbulent flow is specified depending on the velocity of flow. In AFM velocity of flow is very less so laminar flow is used for the simulation.

In this work first we analyze the work piece at some extrusion pressure without rotating the wall of work piece and then analyze by rotating the wall of work piece with the same extrusion pressure with no wall slip condition.

Results discussion

The results achieved from the simulation mainly consist of effect of velocity, dynamic pressure and wall shear. The main aim of wall shear values to calculate the MRR. The theoretical results of MRR were compared with that of the results obtained experimentally.

The flow outputs of velocity contours and dynamic pressure contours are shown in the fig 3 and fig 4. Generally, in this paper the flow velocity at the same extrusion pressure simulations is performed one by the rotation of the wall of the work piece and second for without rotating the wall. It is very much clear from the fig 3 and from fig 4 that by rotating the wall of work piece value of Dynamic pressure and flow Velocity increases Similarly, the value of wall shear also increases.
Fig 3: Dynamic pressure contour

Fig 4: Velocity Contours
Fig 5: Wall shear stress

Table (1): Values of Maximum velocity, dynamic pressure and wall shear

<table>
<thead>
<tr>
<th></th>
<th>Without Rotation of wall</th>
<th>With Rotation of wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Velocity</td>
<td>0.1084</td>
<td>0.1152</td>
</tr>
<tr>
<td>Dynamic Pressure</td>
<td>0.516</td>
<td>0.08126</td>
</tr>
<tr>
<td>Wall shear</td>
<td>0.11</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Conclusions

There Abrasive Flow Finishing process is mainly affected by the various controlling parameters including extrusion pressure, number of cycles, volume fraction, size of abrasive particles and abrasive media viscosity. It can be concluded that when the extrusion pressure are taken into consideration as the controlling factor, the main factors which mainly considered are velocity and shear stress at the wall of workpiece. The wall stress value at the workpiece of increasing rate helps in increasing the MRR. The velocity gradient also increased with the increased in the extrusion pressure, which ultimately helps in increasing the value of stock removal per unit time. One more interesting fact also found that as the value of extrusion pressure reached maximum, the effects of dynamic pressure become negligible.

So it can be easily interpreted from the table by rotating the work piece at the same Extrusion pressure the value of Dynamic Pressure and wall Shear increases therefore valve for material removal rate also increases and better surface finish is obtained.

References


