Abstract: In abrasive flow machining (AFM), an abrasive mixture and a polymer of special rheological properties is forced through a restricting medium. This results the abrasive mixture and the polymer to act as a self-forming tool which precisely removes the material of the work piece and improves the surface finish. It is capable of machining areas, which are difficult to reach by conventional machining and can be used to machine and improve surface finish of internal parts of intricate shapes. The work piece hardness, abrasive size, abrasive hardness, extrusion pressure and properties of carrier are the important process parameters that affect the performance of AFM. The objective of the present paper is to study the effect of process variables on surface finish and material removal.

Keywords— Abrasive flow machining, Material removal, Silly Putty, soft materials, Surface finish.

I. INTRODUCTION

Manufacturing process demands approximately 15% of the total manufacturing cost for finishing operations. When the surface roughness value is less than one micron, the cost of surface finishing operation again increases sharply. AFM is developed as a method to improve the surface finish of components have complicated irregular shape/profile, rough internal surface, cavity and undercut. It is also capable of improving the productivity and performance of the components. AFM process has a greater potential to deburr, radius, polish and remove recast layer of components in a wide range of applications.

AFM was developed by Extrude Hone Corporation; USA in 1960s. The abrasion ability of abrasive media is governed by many factors, especially by grain size, abrasive concentration, extrusion pressure and hardness of work piece material. In order to analyze the influence of such parameters and other AFM conditions upon material removal and surface finish many experimental investigations were conducted and formed models for the same [1-2]. Experimental investigations [3-5] discuss the effect of process parameters such as extrusion pressure, number of cycles, viscosity, abrasive concentration and grain size on the process performance parameters, such as surface finish and material removal during AFM.

II. PROCESS MODELLING AND OPTIMIZATION

Williams and Rajurkar [6] used the full factorial design for experimentation and studied the effect of medium viscosity and extrusion pressure on material removal rate and surface finish. Jain and Adsul [7] reported that initial surface roughness and hardness of the work piece are important parameters affecting the material removal rate in AFM. Loveless [8] studied the effect of viscosity of media on surface finish. They found that viscosity is the only parameter which significantly affects the surface finish. They found the relationship between initial surface finish and percentage improvement in surface finish is non-linear. Singh and Shan [9] applied a magnetic field around the work piece and observed that the presence of magnetic field significantly improves the surface finish and material removal. This improvement is mainly due to the increased concentration of abrasive at the machining surface. The objective of the present paper is to analyze the effect of extrusion pressure, grain size, abrasive concentration on material removal and surface finish.

Williams and Rajurkar [6] developed a stochastic model of AFM generated surfaces by Data Dependent systems (DDS) methodology. They have estimated the ratio of surface roughness peak height (Rz) to the centerline average surface roughness value (Ra) by DDS methodology and found to be between 1.4 and 2.2 micrometers for the AFM process. It was established in their research that AFM finished surface profiles possess two distinct wavelengths, a large wavelength, that corresponds to the main path of the abrasive while the small wavelength is associated with the cutting edges. Good agreement is found between the primary frequency ranges obtained in the DDS modeling and those derived from spectral analysis function. It is found that these frequency bands are related to different material removal modes in AFM. Consequently, the mechanism of material removal is considered to consist of ploughing responsible for the creation of characteristic flow lines and micro cutting. They proposed an expression for estimating the abrasive grain wear and the number of active grains (Cd). The estimated value of Cd can be used as a cutting life criterion for abrasives.
For small number of cycles, its value should remain fairly stable but with more and more processing, the abrasive particles may fracture and thereby increasing the Cd value. The downturn of Cd value indicates that the medium has been absorbed too much abrasives and needs replacement. Jain et al.[10] also carried out simulation of finished surface profiles and material removed considering the interaction of abrasive grain with work piece material.

Rajeshwar et al.[11] proposed a mathematical simulation model to determine the characteristics of the medium flow during finishing and its experimental verification was carried out. This model was developed using constitutive equations of Maxwell model, considering the medium characteristics as non-Newtonian flow. They reported that a linear relationship exists between shear stress acting on the surface and the layer thickness of material removed.

III. EXPERIMENTAL AFM SET-UP

The fig.1 shows the abrasive flow machining set up. AFM works on the principle of back and forth flow of a compound against the work piece. This leads to the improvement in the surface finish of the work piece. The compound used here is an abrasive (SiC) mixed with silly putty. Work piece is placed inside the work holding device and the dynamometer is placed in between the two opposite piston cylinder arrangement. The surfaces and edges of the work piece are finished by the flowing medium across the work piece to be finished. The tooling, also called as fixture arrangement, holds the work piece in position and directs the abrasive medium to the appropriate areas of the work piece that is to be machined.

When extrusion pressure is applied to the medium by the piston two types of forces are generated, axial and radial. A two component dynamometer is used to measure these forces. The medium used for experimentation is natural rubber.

IV. EXPERIMENTAL RESULTS.

It seems to indicate that for surface finish to improve the extrusion pressure must be at a higher level. At lower level of extrusion pressure, low abrasive concentration level and smaller grain size, the surface finish value diminishes. Also low extrusion pressure and larger grains seem to provide uneven distribution of grains resulting in significant variation in the surface finish. The improved surface finish can be achieved only through an optimum combination of three parameters-extrusion pressure, grain mesh number and abrasive concentration.

<table>
<thead>
<tr>
<th>Model term</th>
<th>Effect estimate</th>
<th>Sum of squares</th>
<th>Percent contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A'</td>
<td>9.820</td>
<td>192.865</td>
<td>8.45</td>
</tr>
<tr>
<td>B'</td>
<td>12.65</td>
<td>320.298</td>
<td>14.03</td>
</tr>
<tr>
<td>C'</td>
<td>24.787</td>
<td>1228.840</td>
<td>53.85</td>
</tr>
<tr>
<td>A'B'</td>
<td>0.022</td>
<td>0.001</td>
<td>0.000043</td>
</tr>
<tr>
<td>A'C'</td>
<td>1.672</td>
<td>5.595</td>
<td>0.245</td>
</tr>
<tr>
<td>B'C'</td>
<td>16.037</td>
<td>514.403</td>
<td>22.54</td>
</tr>
<tr>
<td>A'B'C'</td>
<td>3.157</td>
<td>19.94</td>
<td>0.873</td>
</tr>
</tbody>
</table>

The main effects of extrusion pressure (A'), grain mesh number (B') and abrasive concentration (C') and their interaction on average percentage reduction in surface roughness are given in Table1. All the three factors must be kept high to maximize the average percentage reduction in surface roughness.

The interaction effects are shown in the Table1. The interactions A'B', A'C' and B'C' are plotted in fig2, fig3 and fig4. It is seen that figure2 and fig3 are almost parallel. Hence there is no interaction effect between A'&B' and A'&C'. Their percentage contribution is also insignificant.
Larger interspacing between the grains will lead to reduction in medium stiffness. These will cause high variability in percent reduction in Ra with larger grains. At high extrusion pressure and high grain mesh number more grains will be present in a unit area causing reduced interspacing and increased stiffness of the medium. The net result of these will be low variability in percent reduction in Ra. At Low abrasive concentration, less grain will come in contact with the work piece causing low variation in percent reduction Ra.

The figures 8 to 10 show the variance of interaction between A’B’ and A’C’ and B’C’. It is clear that A’ and B’ are highly interactive. Fig 9 shows the interaction effect of B’C’ on the variance of percent reduction in Ra.

4.1 Effect of Main Process Variables

Main effects plot for variance of percentage reduction in Ra are plotted in fig (5) to fig(7)
Also from experiments it is clear that when the force ratio is maximum, the percentage reduction in surface roughness is also maximum. The correlation coefficient between average percent reduction in surface roughness and average force ratio are higher as compared to correlations of average percentage reduction in surface roughness with average axial and radial forces.

REFERENCES


