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Modelling and Simulation of Abrasive Flow Machining

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ABSTRACT: With the development of modern manufacturing processes, the demand for finishing has drastically improved. The focus is not on the material removal but on the desired surface texture, which can be achieved by controlled material removal and adequate surface finish. The present paper coins the existence of the conventional Abrasive Flow machining process (AFM) as one of the prominent processes in the field of finishing, which is capable of achieving the surface finish up to the Nano level when clubbed with the adequate hybridisation process. In this account, an effort has been made to analyse the finishing attempt of the abrasive flow machining process by modelling it on ANSYS FLUENT 15 and analysing the effect of pressure variation on the workpiece. The simulation result is validated by the existing literature and found satisfactory for the given pressure range.

Keywords: Abrasive Flow Machining, Manufacturing, Material Removal, Finishing

I. INTRODUCTION

The manufacturing concept is very old, which is significant right from the stone age to the modern manufacturing period. The early man used to hunt their prey with stone, and with time, the stone became pointed and sharpened, and it happened due to the machining as the man learned its application steadily. later on, when man learned the use of bronze, copper and iron, the concept of casting came into the picture, which merely transformed the world. The application of metal and alloy has started affecting the daily life of human beings like weapons, armour ships etc. The two world wars started, and the dependence on manufacturing started, but the concept of finishing did not become popular. However, the concept of abrasive finishing was coined somewhere in 1840 in the US. Still, the conventional finishing processes were more popular, including grinding, Polishing, Burnishing, Buffing, Honing [1] etc. When we talk about grinding, it is a finishing process that results in high accuracy and surface finish. it uses various natural and artificial abrasives such as sandstone (natural silica), natural alumina (emery), diamond and corundum. Also, artificial abrasives like silicon carbide, alumina and cubic boron nitride are used. These abrasives were bonded on the wheel, and the wheel was used to rotate with high rotation making the material removal and providing a high superfinishing process. Although with time, the grinding process has significantly developed to cope with modern times like surface grinding machines, cylindrical grinding machines, and centerless grinding machines. Further, it is classified as the internal centerless grinding the external centerless grinding machine. When we talk about the finishing of the internal surfaces, the concept of the Honing comes into the picture. Honing is a finishing process that is used to finish the internal hole and the external finishing surface. It uses a stick in which the abrasivesare stick and are superimposed on the surface of the workpiece with the help of rotation. the stick can be reciprocated, enhancing the reachability of the stick for the deeper reasons of the hole. the process can be applied on the external surfaces like finishing of gears etc. Lapping is the finishing process in which the powder is sprinkled on the surface to be finished, and a tool called lap, which is made up of the same part opposite to the mating surface, is pressed upon the workpiece and move in the desired motion with the accessing area and thus removing the material and providing the surface finish. The process is generally applied on the gauges, measuring wire, spindles etc. The next process is the Burnishing process, where the steel balls are pressed and moved against the workpiece to get the desired motion so that an appropriate surface finish may be obtained. Burnishing of the shaft is one of the prominent examples of the process. when we talk about polishing and buffing, they are both finishing processes, including in the polishing process. This abrasivesare glued to the wheel's surface. In the burnishing, these abrasives are stick to the outer periphery with the help of a burnishing compound, thus providing a smooth surface finish and the desired result lustre to the workpiece. But all these processes are conventional finishing processes whose range is confined to .25 micrometres only. When we talk about the non-conventional finishing process, the range is extended to the Nanometers. Which includes processes like Magnetic abrasive finishing, Viscoelastic abrasive finishing and the Abrasive Flow Machining process. Although the various hybrids of these processes have evolved, the scope of the superfinishing in hard to reach areas and the complex part of the workpiece has increased. When we talk about machining, there are two important parameters: the relative motion between the workpiece and the tool. The next is that the tool must be harder than the workpiece. The second criterion is generally overcome in the non-conventional machining process as there is no physical contact between the workpiece and the tool. The AFM process involves the reciprocation of the media, which contain abrasive polymers and gels in the constrictive passage to machine the hollow surface of the workpiece [2]. There are various configurations of AFM which are available based on the direction of the motion of the media, which are one way AFM, Two way AFM and the orbital AFM process [3]. The conventional AFM process involves two media cylinders containing the prepared media and a hydraulic cylinder in which the working fluid is maintained. The reciprocation occurs due to the pressure difference between the lower and the upper part. the workpiece whose hollow surface is to be machined is generally kept coaxially with the media cylinder, thus due to the pressure difference, the media is generally passed to and fro and thus machined the internal surface of the workpiece and provides the finish up to the Nano level. With time, various Hybridisation has been developed. Among them, the prominent are Magnetic force assisted Abrasive flow machining process [4], Centrifugal force assisted abrasive flow machining process [5], Ultrasonic Abrasive Flow Machining Process [6], Drill bit guided Abrasive flow machining Process [7], Rotational Abrasive flow machining Process [8], Electrochemical-Assisted AFM [9], Helical AFM [10], Centrifugal -Magnetic Force Assisted Abrasive Flow Machining Process [11], Hybrid Electrochemical and centrifugal Force assisted AFM[12], Thermal Additive Centrifugal Abrasive Flow Machining Process (TACAFM) [13,14,15]. Many researchers work on the modelling of the basic configuration of the AFM. Srinivas et al. [16] modelled the flow parameters of Magnetic abrasive finishing On ANSYS Maxwell and commented about the force exerted by the fluid on the surface of the hollow workpiece. Kumar et al. [17] gave a systematic review of abrasive flow machining. They came out with an effective solution where the researchers highlighted the practical implementation of the abrasive flow machining process. In the modern era, abrasive flow machining is not confined to only machining the internal surface, but many other specific applications can also be achieved from it. Nowadays, with the development of the modern era, the evolution of different hybrids of the process is evolving, and not only that but also the significant improvement in the process is also under their observation. Srinivas et al.[18,19,20] combined the viscoelastic magnetic abrasive finishing process with the abrasive flow machining process setup. The Researchers took a hollow cylindrical workpiece whose internal surface is to be finished. The media made for this purpose used the carbonyl particle, and the permanent magnets were coaxially placed around the workpiece. Thus the effective machining occurs with the result combination of Magnetic effect and conventional AFM. In developing Magnetic force-assisted Abrasive Flow Machining, a hybrid of the Abrasive Flow Machining Process, Bhardwaj et al. [21] uses a 36 mm wind turbine magnet around a hollow workpiece to study its effect on the machining process. Manjunath et al. [22] applied the technique of abrasive flow finishing to improve the surface roughness of the aluminium propeller and highlighted the actual results along with the key points. Basha et al.[23] gave a systematic review highlighting the abrasive flow machining process in the surface finishing of metal matrix composite. Dixit et al. [24] developed Xanthan based gum as a media for abrasive flow machining and analysed its key characteristic using abrasive flow machining.Kumar et al. [25] investigated the internal roundness of the cylinder while experimenting on magnetic-based chemical assisted Abrasive flow machining and highlighted the key points. Mohseni-Mofidi et al.[26] studied the effect of media and modelled it for the magnetic assisted abrasive flow machining process. Sharma [27] Experimented with the rotational magnetorheological abrasive flow finishing process and highlighted the important aspects of the process and its advantage in finishing application. Dixit et al.[28] gave the systematic review of abrasive flow machining and highlighted the key areas and scope of the Abrasive Flow Machining process. It can be observed with today's scenario the problem with pollution is also emerging. The researchers are searching new areas to adjust the primary pollutant of the environment, in that condition, Gupta et al.[29] use fly ash to make the media of abrasive flow machining and analyse its performance for the finishing applications. Seyedi et al. [30]. Worked on the finishing of metal matrix composite using an abrasive flow machining process.The current accounts deal in the pressure computation in the abrasive flow machining process. Figure 1 describes the application of the AFM Process, which mainly includes the hollow workpiece and hard to reach surfaces.

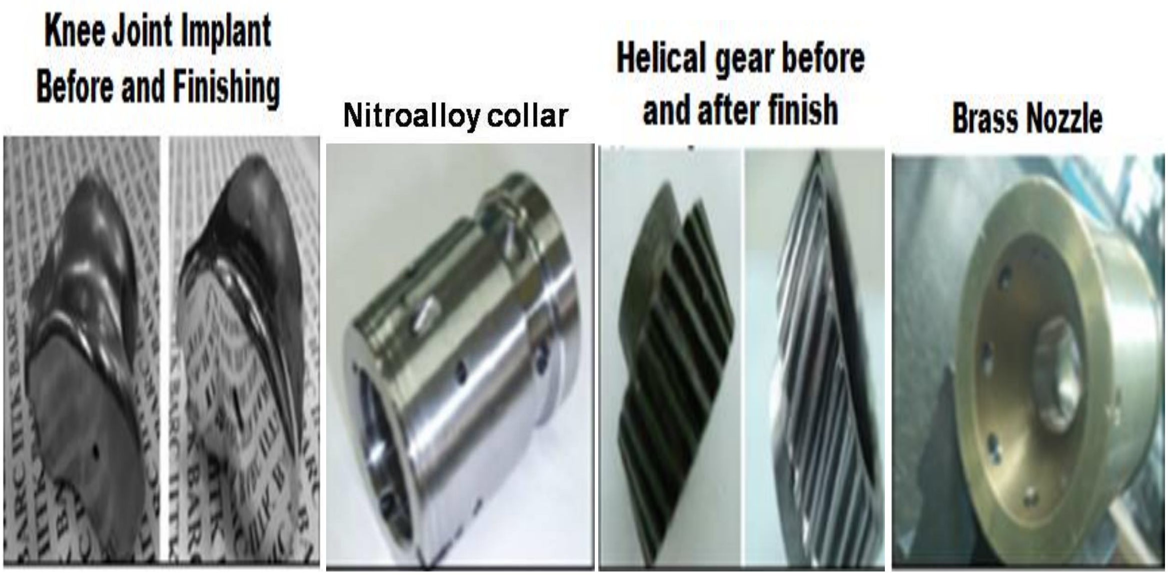

Figure 1 Application of AFM [17]

It is evident from the above figure that the Abrasive flow machining has a vide number of application among which the prominent is the finishing of the intrinsic surface of the gear. Figure 1 shows that the finishing of helical gear, nitro alloy collar and the brass nozzle are easily machined by AFM. Not only in the manufacturing process but also biomedical finishing through the AFM process may be achieved.

II. RESEARCH METHODOLOGY

The researchers developed the Hollow cylinder model of the brass workpiece diameter 10mm and height 10 mm and transferred it to the ANSYS Fluent as IGES files. It is evident that the software analysis of the Abrasive Flow Machining is the prominent area that has not been touched, and the effort is being made to work on it. In this paper, Ansys Fluent software was used to perform simulations and analyses of the AFM process. The media material is taken as polyborosiloxine, the workpiece is brass, and the Alumina workpiece was taken for machining purposes.

The reason for choosing the brass workpiece is that the literature on brass is available as many researchers have experimented on brass and alumina abrasive combinations. The validation of the model is easy using this concept. The initial setup was made using CREO parametric 3.0 and was then imported to ANSYS FLUENT figure 1 depicts the process. The messing of the individual element was done and shown in Figures 3 and 4. The total elements in the mesh were about 3X 103and the shape of the element was majorly tetragonal.

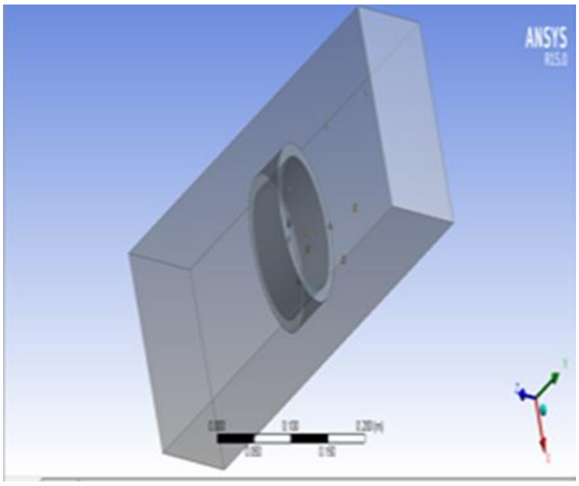

Figure 2 Basic Geometry in ANSYS Workbench

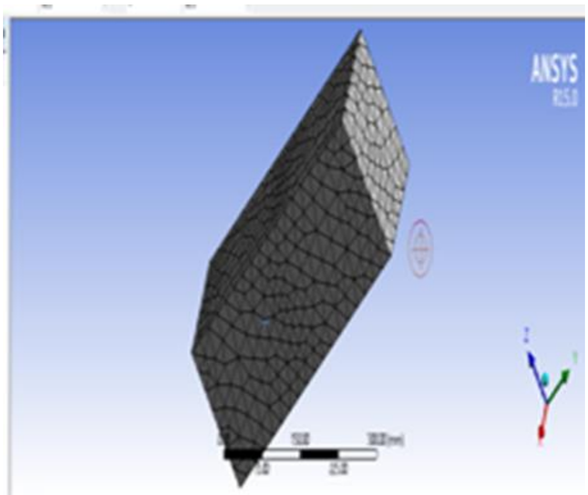

Figure 3 Meshing pf Fluid Domain

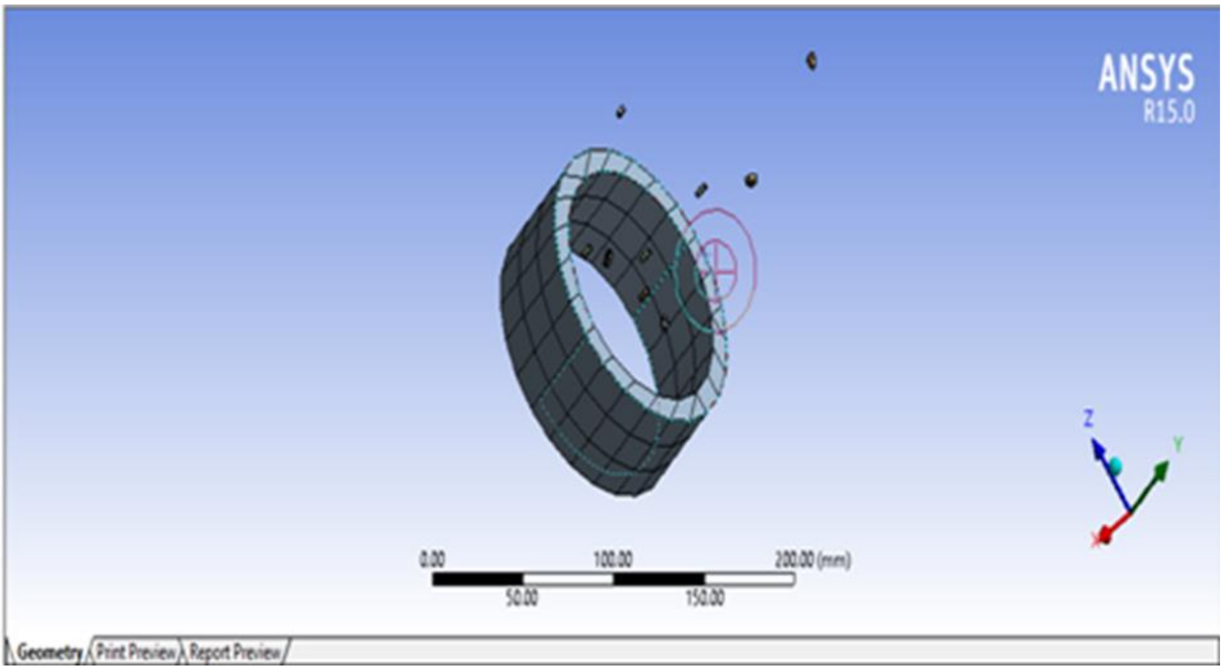

Figure 4 Meshing of Workpiece and Abrasives

The media used for the analysis was polyborosiloxine, which has a density of 1219 kg/m3, and the viscosity is 0.789 Kg/m-s. The thermal conductivity of the fluid is 0.22 W/m-K, and the specific heat of the fluid is 20.25 J/Kg-K. Whereas the abrasive used in the media were alumina, whose properties are density is 3950 kg/m3, thermal conductivity is 12, and the specific heat is 451 J/Kg-K. The workpiece whose surface to be observed is brass, whose properties are density 8300 Kg/m3 thermal conductivity of 109 W/m-K and the specific heat of 401 J/Kg-K. After the setup completion, the boundary conditions were applied with the Pressure at the inlet and outlet surfaces were 40 MPa and 20 MPa, respectively. The fluid is kept stationary with the temperature at 300 K. The inlet and outlet of the liquid were Kept at Pressure based. The simulation was allowed to run for 100 iterations, and a graph was received satisfying the continuity criterion.

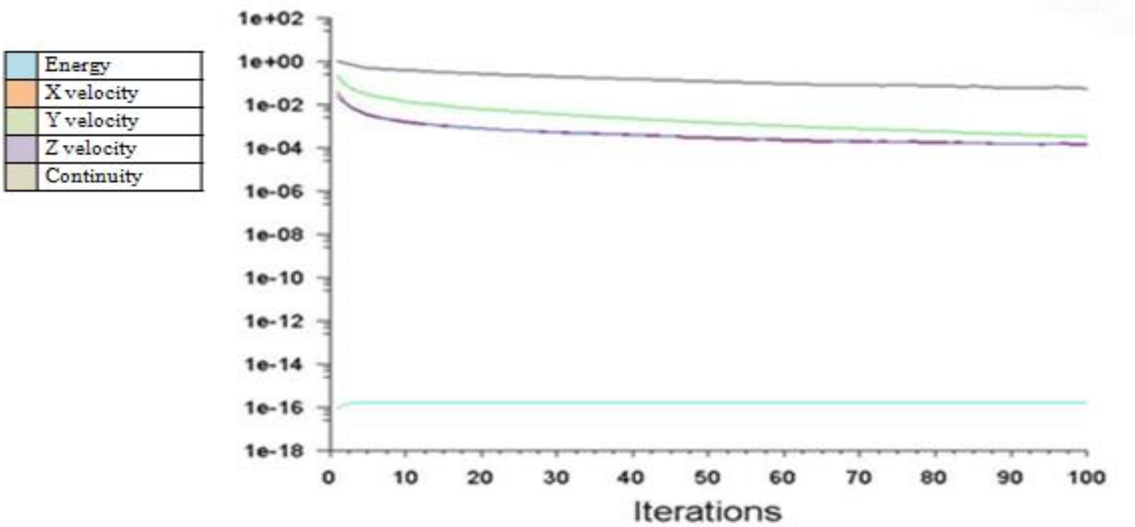

Figure 5 The Conversion Graph

III. RESULT

The maximum pressure value is 26.2455 MPa and that of minimum Pressure is 10.4519 MPa which is an optimum range of 40 MPa to 20 MPa (Fig 6). Figure 7 shows the streamline of fluid flow inside the hollow workpiece.

It can be observed in the figure that the value of Pressure decreases below 20 Mpa at the lower part of the workpiece, through the pressure range is between 40 to 20 Mpa. This happens due to the bell effect. When the fluid enters the neck of the workpiece from the 40 MPa region, the surface area of the workpiece suddenly decreases, resulting in an increase in Pressure at that region. The pressure on the neck is maximum, around 23 MPa. Still, when the fluid moves out of the workpiece, the Pressure outside the workpiece is around 10 MPa as the fluid moves out of the restricted area, which increases the area, and thus the pressure is low. The important point is that there is no backflow as the overall pressure difference is 20 MPa, and the gravity effect also comes into the picture. So due to this constructive passage and Pressure difference, there would be maximum interaction of the media and abrasive with the surface of the workpiece, which results in effective material removal and would give a practical surface finish to the workpiece.

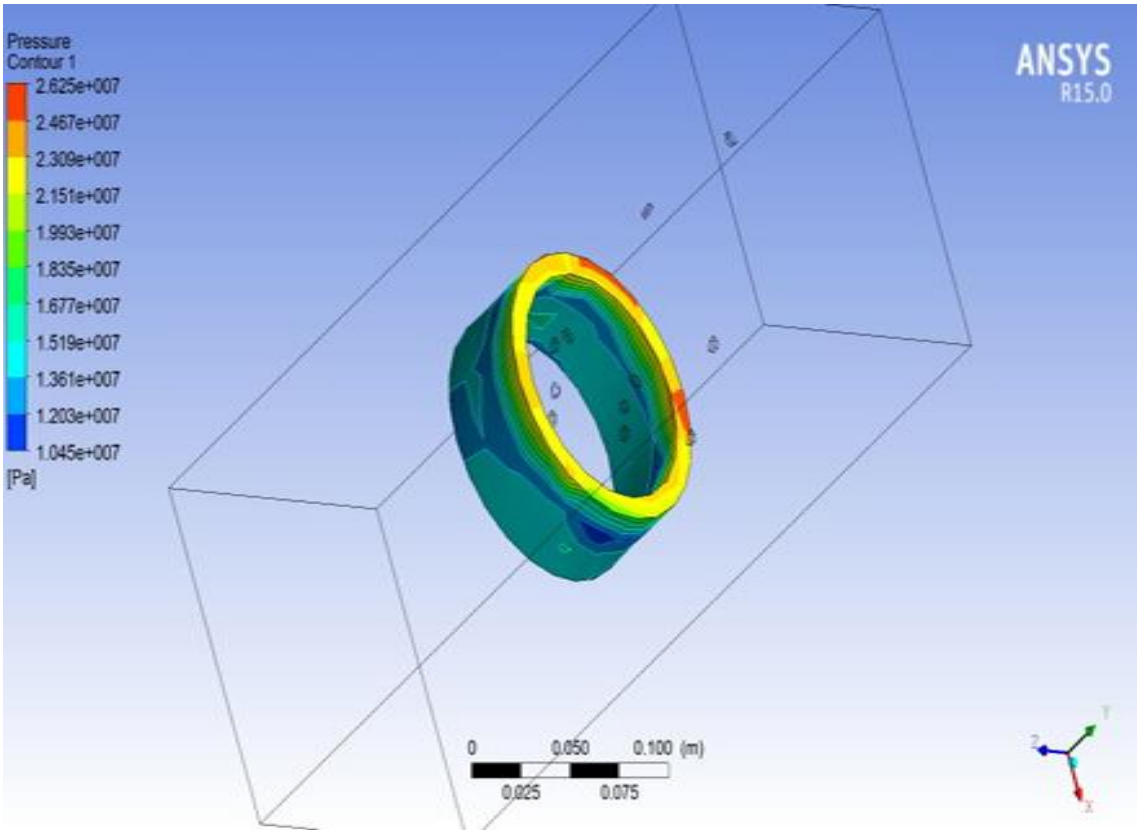

Figure 6 Pressure Variation on Workpiece'

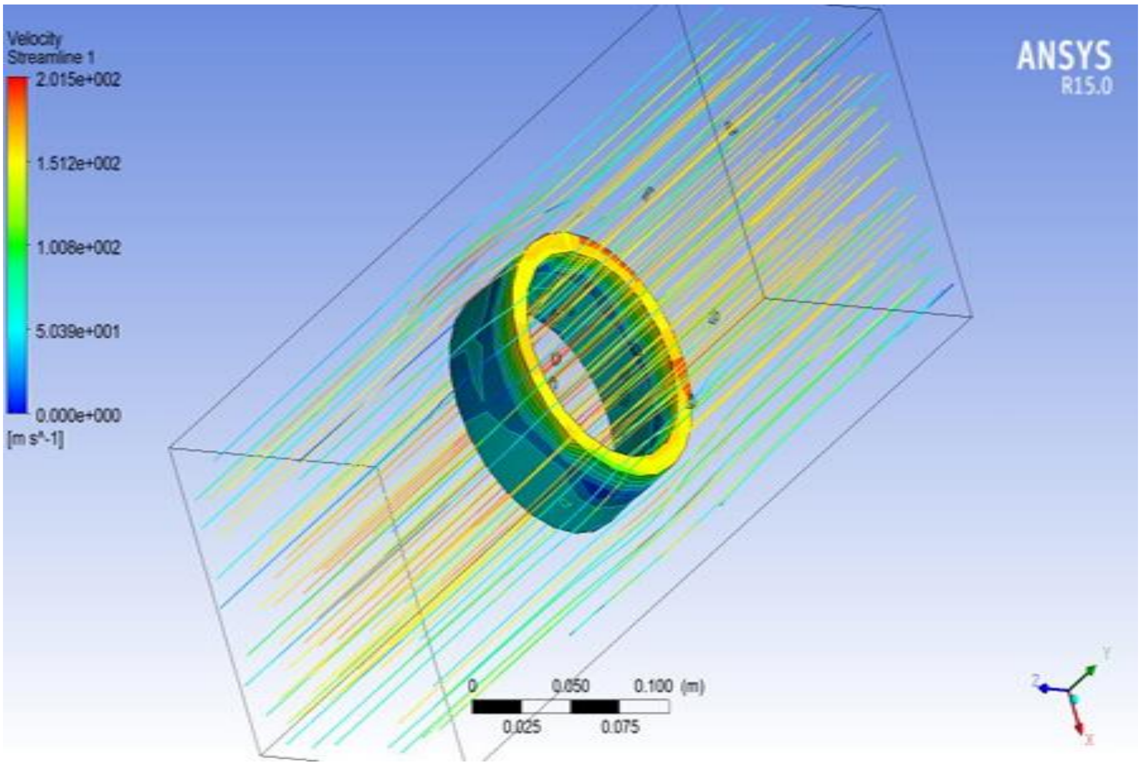

Figure 7 Streamline of Media on Workpiece

IV. CONCLUSION

It is evident from the discussion that abrasive flow machining has a broad scope and find its application in the prominent areas of the finishing and machining application. It is clear from the literature review that abrasive flow machining is touching a broad domain in manufacturing, but like all other finishing processes, it does possess some drawbacks. The major drawback of the AFM process is its Low MR which, although the rapid hybridisation process, has been rectified. Also, the method establishes its roots in finishing 3D printed products and being rapidly used in the finishing of MMC. The article's main focus was to highlight the capability of AFM and its applicability in the area of machining. To prove its accuracy, simulations were performed to bring the requisite changes into considerations.

1. Abrasive flow machining is an efficient finishing process that can achieve finishing up to the Nano level.
2. The finishing of the Conventional abrasive finishing process may be increased with the help of the hybridisation process.
3. The abrasive finishing process finds its application in machining nanotubes and thermal recast layers in EDM applications.
4. Abrasive flow machining is an emerging process finding its application in the machining of metal matrix composites
5. The maximum and minimum pressure value obtained is suitable for the given pressure range between 40 MPa and 20 MPa.
6. There would be effective machining inside the hollow workpiece due to the bell effect phenomenon.

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