Modelling Of Viscoelastic Fluid In Finishing Processes

Krovvidi Srinivas, Q. Murtaza, A.K Agarwal

Abstract: The Traditional Finishing process mostly lapping, honing, buffing, superfinishing etc contains various disadvantages like labour intensive work, high Production cost and time. Moreover, the quality of surface finish achieved is not up to the mark but in present era there is requirement of better quality of products with desired surface finish, in order to overcome this finishing issue Abrasive Magnetic Finishing and Abrasive Flow Machining process comes into the consideration. Both the Process uses a Viscoelastic media which contains an adequate amount of Polymer, gel, Oil and abrasives. Magnetic Abrasive Finishing includes polymer media with carbonyl particle which align along the magnetic field and results in effective machining. This paper includes solid modelling of the process and simulation on Ansys Fluent module and analyse the Flow parameters of the viscoelastic polymer media and its effect on material removal.

Index Terms: viscoelastic Magnetic Abrasive Finishing (VMAF), Magnetic Abrasive Finishing (MAF), Material Removal (MR), Surface Finish, Ansys Maxwell, Polymer Media, Abrasive Flow Finishing (AFF).

1 INTRODUCTION

Magnetic abrasive finishing is an effective machining process in which magnetic field is used to machine the target surfaces of the workpiece by influencing the carbonyl particles and directing them towards the wall of the workpiece for machining. In conventional abrasive machining process both the workpiece and the target surface are polarised and due to the interplay of magnetic field, a Brush of abrasive is formed which results in the effective machining of the workpiece. This effective concept of machining got the eyeball of many scholar and initiated a large number of researches in this field like Kang and Yamaguchi [1] developed a multipole dip- system for the machining of internal surface of the capillary tube. The researchers highlighted the difficulties faced in machining of the capillary tube mainly in controlling the magnetics abrasive in MAF process, the researchers suggested that the multipole system with alternate magnetics and nonmagnetic region simultaneously applied on the workpiece which results in the effective machining of the long capillary tube. This process has allowed the application of MAF on long Capillary tube as well which was earlier confined to the short length tube only. The final conclusion of the researcher was that the double pole system finishes the workpiece in half a time as compare to the single pole system. V.K Jain [2] explained various non-traditional machining process which are used in modern times which involves the use of abrasive and the media to support it. The various process which he discussed in its paper was Abrasive Flow Finishing (AFF), Magnetic Abrasive Finishing (MAF), Magnetorheological Finishing, Magnetorheological Abrasive Flow Finishing, Elastic Emission Machining (EEM) and Magnetic Float Polishing. he laid attention on the magnetic abrasive finishing process and gave some important conclusion like involvement of slot in the magnet over non machining zone and the use of pulse Dc supply rather than smooth DC supply in the system. Wani et al. [4] gave stress on Magnetic Abrasive flow finishing which is a process made by combining the advantage of both abrasive flow machining and the magnetic abrasive finishing process, and used finite element method to find distribution of magnetic potential in the magnetic brush. Through this distribution the researcher evaluated machining pressure, surface finishing and material removal. After the successful evaluation of the results the researcher claims that these results are similar to those present in the literature. Kala et al. [4] developed a setup which aims to catch the force signature for double disc magnetic abrasive finishing process and the conventional abrasive magnetic abrasive finishing process and by these properties the researchers aims to understand the working of the flexible magnetic abrasive brush. Thus, to do this the researchers performed the magnetic abrasive finishing operation in single as well as double disc and finally understood the property of flexible magnetic abrasive brush behaviour from it. Wu et al [5] developed a model of magnetic abrasive finishing process and analyzed its properties based on the rotational speed, cutting fluid and the magnetic pole and current frequency and its effect on change in material removal and surface finish are invested. The researchers finally claimed that the neat cutting oil is required for processing which results in higher material removal and finer finish. They also concluded that finishing is better with the increasing in rotational speed and as the current frequency increases the angle variation of the particle increases and if frequency is low the surface requirement is up to few nanometers. Rathod et al. [6] correlated the difference shape factor with wide range of particle size. The researcher made use of slurry abrasion tester with silica sand slurry and commented on the effect of sliding distance slurry abrasion volume, where they argued that volume loss is proportional to the sliding distance. They also studied the effect of micro ploughing and cutting. Srivastav et al. [7] simulated a model of electrochemical magnetic abrasive finishing process in which the researchers used stainless steel workpiece whose radius was ten mm and thickness was 2.5 mm. the researchers used chromium oxide as the abrasive particle whose average diameter was 387 micrometers, the intensity of magnetic field was around 1 tesla and the rotational speed of tool was taken as 5835 rpm and its diameter was 6 mm. the electrolyte used for the experiment was brine solution with twenty percent concentration. The researchers study the thermal model in both steady and transient model. Srivastav and Amit [8] did the thermal analysis of work-brush interface and along the workpiece depth in magnetic abrasive finishing process with the help of ANSYs R15 software in both steady and thermal state. The value of magnetic field intensity given to 6 mm diameter tool was 1 tesla. The researcher used chromium oxide abrasives of about 387 micrometer Diameter. The workpiece has a radius of 10 mm and 2.5 mm thickness and the material of the workpiece was silicon nitride. Singh et al. [9] used Taguachi L orthogonal array to design an experiment which could measure surface temperature of the finishing surface of mild steel using MAF process. The researchers used current, working gap, Rotational speed and abrasive weight as its important process parameters. After the Taguachi optimization the Fuzzy logic is used by researcher through which prediction of surface temperature is and also it is validated. Jaiswal et al. [10] made FEM model of MAF and investigated the distribution of magnetic force on the workpiece. The researcher also made a theoretical model for computing the material removal and surface roughness. For this the workpiece was considered of uniform surface without statically distribution. Numerical experiments were also computed which were validated later on through literature. Yan et all [11] performed the experiment on MA genetic abrasive finishing based on a simulated model which is based on FEM model of electromagnetic inductor. He then compared the simulated model with the actual electromagnetic inductor and predicted a marginal error of only 7 percent. Li et all [12] developed a finishing setup having new media for finishing the rotatory surface ANSYS Maxwell was used to determine the optimum angle between the poles and the mathematical model was made to compute the MRR in which pressure and velocity was computed based on arced wear model. The MRR computation model was made which predicted MRR as a function of pole rotational speed, Magnetic flux density, cam rotational speed and the ferromagnetic and abrasive particles' diameter. Li et all [13] proposed a new viscoelastic magnetic Abrasive based on analysis of field characteristic and existing finishing process. They also discussed the motion locus of the abrasives. The present scenario, abrasive flowing finishing, grinding, abrasive brush deburring, magnetorheological finishing, manual deburring etc. are broad name in term of finishing but still they possess some limitations in finishing quality and efficiency. Shimamura et al. [14], [15] modelled and tested that magnetic abrasive particles are subjected to the pressure for machining and that pressure is a function of magnetic flux density, number of abrasive particles and the permeability of abrasive medium. Fox et al [16] observed that the magnetic force (function of the volume and magnetic susceptibility of the ferrous particles in the magnetic field, magnetic field intensity and the gradients at the finishing area). Srinivas et al. [17] studied the distribution of the magnetic field intensity along with the computation of torque and force and related flow parameters of Viscoelastic Magnetic Abrasive finishing process with magnetic field intensity. The Researchers used ANSYS Maxwell and ANSYS Fluent in order to find co relation between the flow parameters and magnetic field intensity and commented on the successful application of the proposed viscoelastic media. The researchers also plotted the graph between the magnetic field intensity and the current which is applied on the single pole electromagnet to produce the desired magnetic field for machining in the magnetic abrasive finishing process. Srinivas and Anant [18] studied the pressure variation in abrasive flow machining process with the help of a simulated model made on Ansys Fluent and commented on the effect of pressure variation in the machining operation. They used viscous media similar to that used in viscoelastic magnetic abrasive finishing with the difference that in later process there is an addition of carbonyl particles which gets activated by magnetic field. The researcher computed pressure difference between 40 MPa and 20 MPa and the value of pressure so obtained was validated with the help of literature review. Ali et al. [19] reviewed various researches on AFM which uses a viscoelastic media and semisolid media which can support various abrasive based finishing process including both magnetic and non-magnetic based finishing process. Bhardwaj et al [20] compiled the researches which contained the use of viscoelastic media in various hybrids of abrasive flow machining process, the researchers also commented on the tooling and fixturing in various hybrids of AFM and the compatibility of the viscoelastic media with the hybrid process. So it can be seen that Viscoelastic Magnetic Abrasive Finishing has a vital role in Finishing department and must be consider for effective machining operation.

2 SIMULATION AND MODELING

A simulation model was proposed to overcome the research gap in the process of magnetic abrasive finishing process. For this purpose, ANSYS Fluent was used so a basic geometry was made in CREO 3.0 software and was then transferred to ANSYS fluent as an IGES File. The basic model contains a brass workpiece with alumina abrasive mixed in the viscous fluid whose property are listed in the tables. When a geometry is port into the ANSYS fluent software, it undergoes 5 steps. The first step (Figure 1) is the geometry where we do name selection and perform the Boolean operations if required. So, we did name selection in which the selections were Inlet, Outlet, workpiece and fluid Domain, next was the Boolean operation where we created path for the fluid flow within the internal surface of the workpiece. Then the file was transferred into the meshing section in which the mesh was created which is depicted by figure 2 and 3. The total elements in mesh was about 3X 10^3 and the shape of the element was majorly tetragonal. After successful meshing the next step was to load the fluent setup for which is shown in figure 4. This is the major step in which we select the type of simulation, energy equation, material assignment, boundary condition and select the number of iterations for the process of simulation. For the process the laminar simulation with the boundary condition on was chosen and the adequate material is assigned to the parts. The boundary condition used for the simulation was Pressure inlet of 40 MPa and the outlet at 20 MPa, the workpiece and walls were stationary. The detail of boundary condition is given in table 2. Initially the fluid is not given any velocity but its movement would be there through the pressure difference which would do machining. The effective machining may be done when we will be placed magnet inside the system which cannot be done on ANSYS fluent, although for that ANSYS Maxwell must be taken into consideration. After all this assignment the simulation is allowed to run for iteration and the plot of energy along with the X, Y and Z velocity was plotted against the number of iterations, which is shown in figure 6.

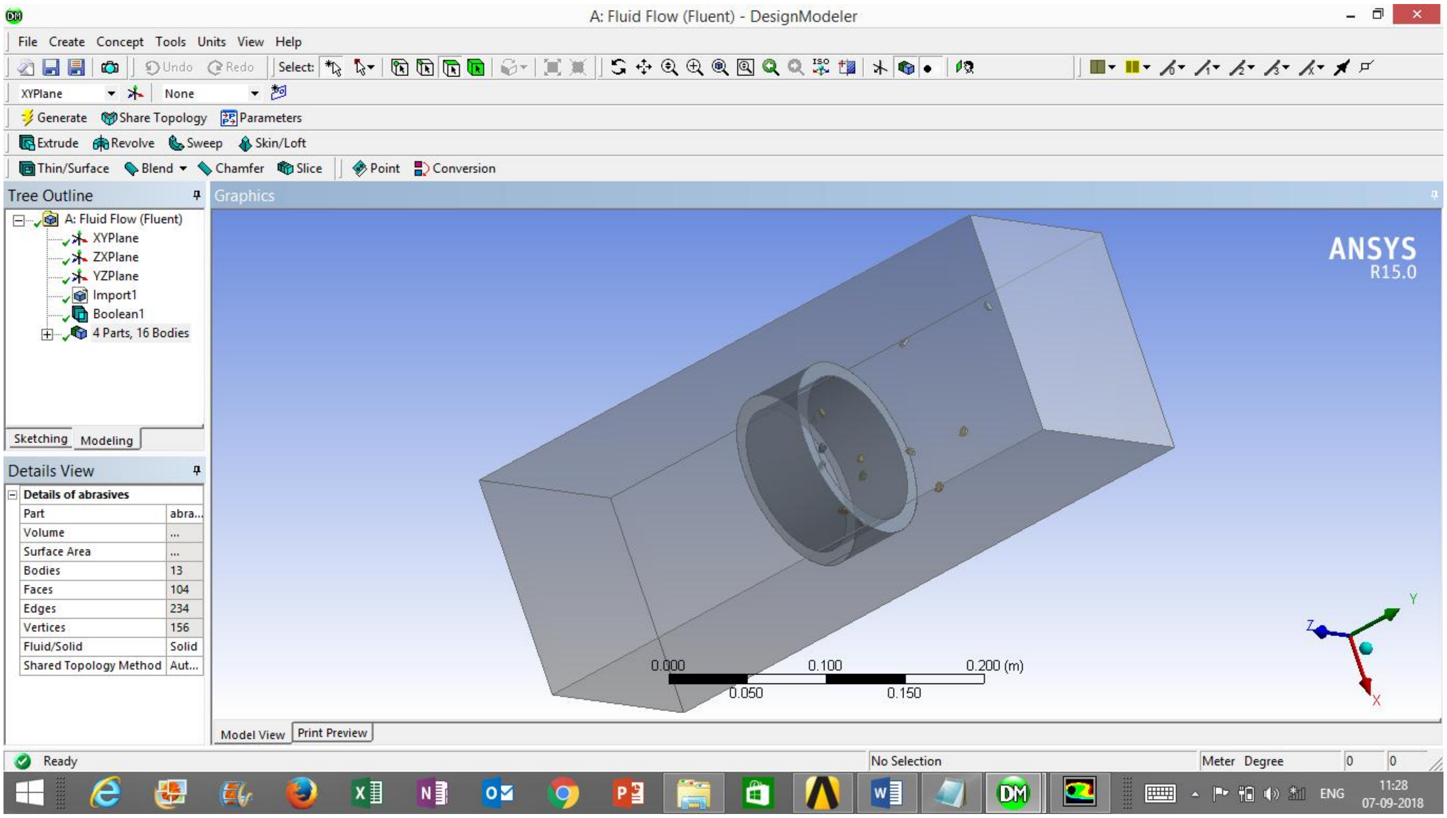

Fig.1. *Initial geometry in ANSYS fluent*

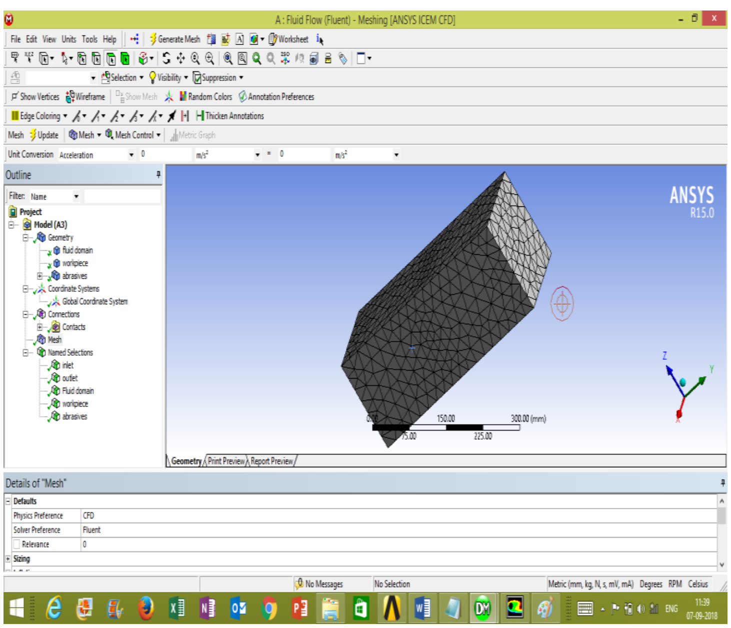

Fig. 2. *Meshing of Fluid Domain*

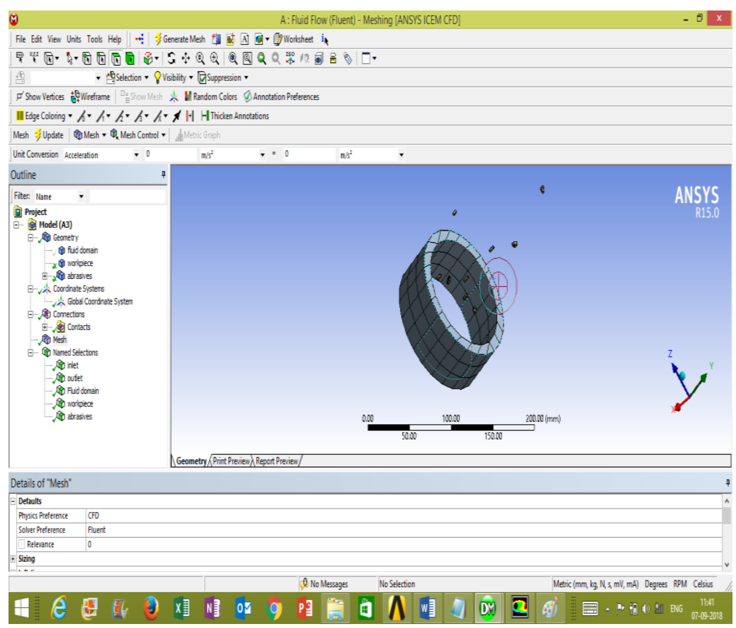

Fig. 3. *Meshing of work piece*

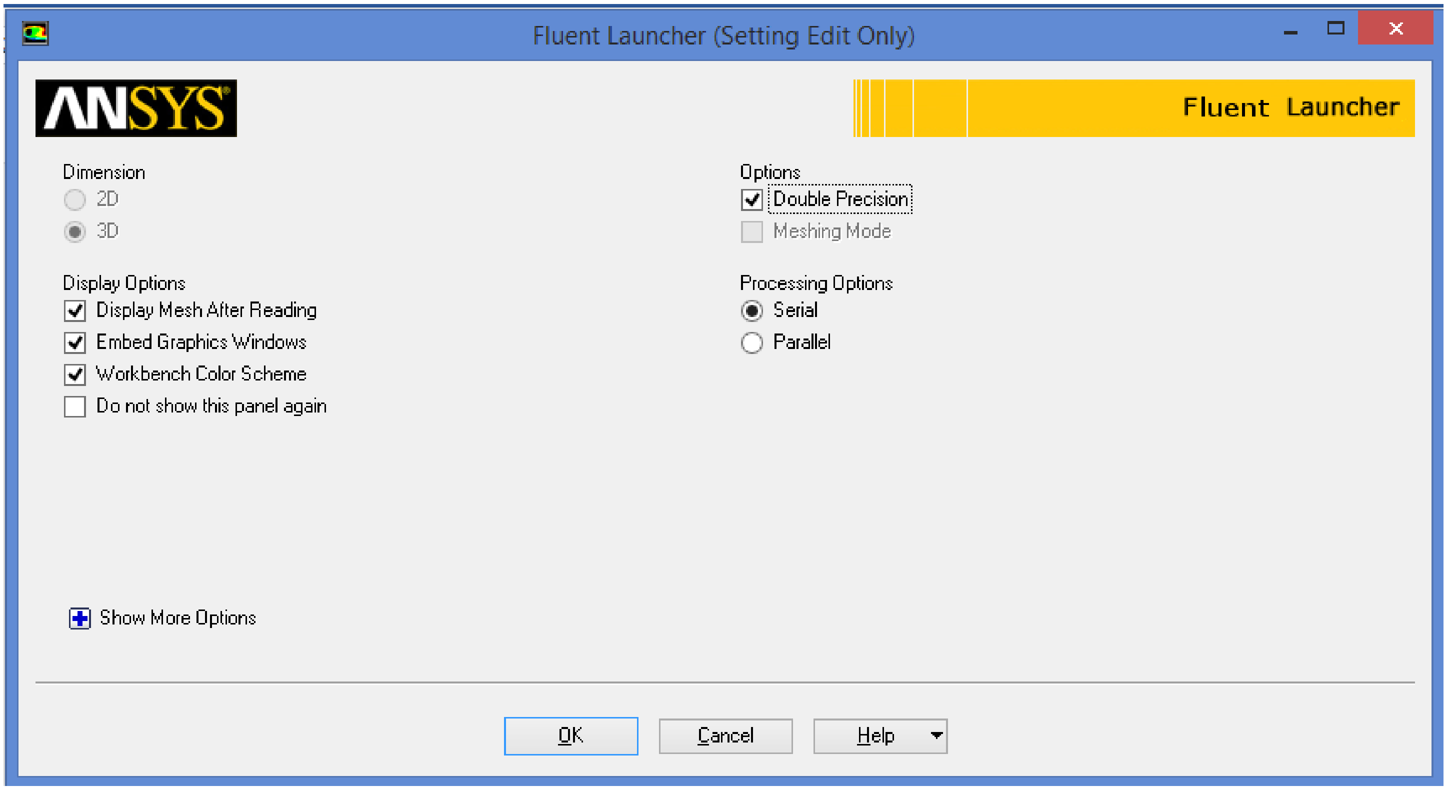

Fig.4. *Initial setup*

TABLES

Table 1 *Showing the Domain Nodes and Elements of Simulations*

MATERIAL	TYPE	DENSITY (Kg/m^3)	VISCOSITY (Kg/ m-s)	THERMAL CONDUCTIVITY (W/ m-K)	SPECIFIC HEAT (J/Kg-K)
Viscous Fluid	Fluid	1219	0.789	0.22	20.25
Brass	solid	8300		109	401
Alumina abrasives	solid	3950		12	451

Table 2 *showing The Boundary condition of simulations*

Sr no.	Name Selection	Boundary condition
1	Inlet	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	Outlet Pressure 20 MPa

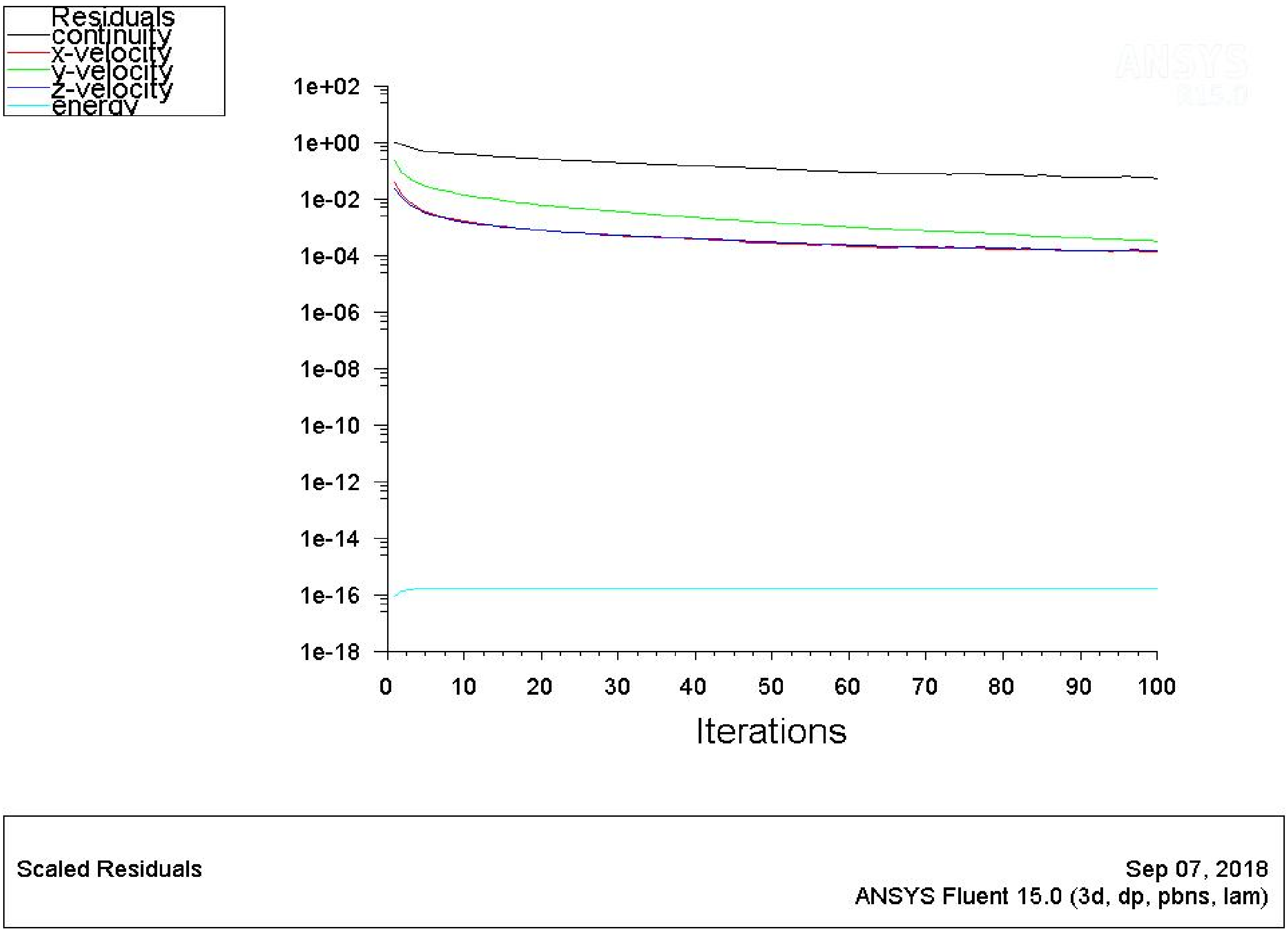

***Fig**. 5. Energy Vs Iteration curve*

3 Results and Discussions

As The results show the maximum pressure is 26.2455 MPa and the minimum Pressure obtained after the analysis is 10.4519 MPa which is an optimum value for machining the brass workpiece at the pressure range of 40 MPa to 20 MPa (Figure 7). The pressure drops in the reason of the workpiece due to the bell effect, When the surface area decreases at the neck region the velocity of the media decreases resulting in the increase in the pressure value at the neck region which is at the starting of workpiece in the direction of the flow, But the value of the pressure decreases throughout the flow of the polymer media which can be seen through the subsequent figure in which the pressure variation along the plane is given, in which the drop in the pressure is shown. Figure 8 shows the streamline variation of the Polymer media. As observed from the figure the stream lines are uniform and smooth and representing the flow due to the pressure difference only. The effective machining may also be achieved by putting a magnet around the workpiece which will attract the carbonyl particle present in the media which would further hit the magnetic particles. The figure 9 shows the force applied by the polymer media on the workpiece, though the force applied would be uniform as the abrasive would be uniformly mixed with the polymer media which results in the application of force on the workpiece. Though the maximum value of the force is 5440 N. The force would be maximum at the point where the abrasives strikes the surface of the workpiece. The figure 10 shows the distribution of velocity of the polymer media on the workpiece, the polymer media is specially made by combining various polymer, gel, oil and abrasives blended together to form a semisolid putty which is extruded up and down with the pressure difference to achieve the effective machining of the process. As Described by the process the maximum velocity is 183.2 m/s and the minimum velocity is 6.94 m/s, again this point must be taken care of that the figure is showing the velocity distribution at the region of the workpiece and not along the flow. The distribution of velocity along the flow would be different. The figure 11 shows the pressure variation along the entire length of the cylinder in the abrasive flow machine rather than the workpiece regions. It shows the pressure at the upper side is 29 MPa and at the lower side is 10.45 MPa the region for the pressure drop and is already discussed. Hence simulation was successful in showing machining characteristic of Viscoelastic media

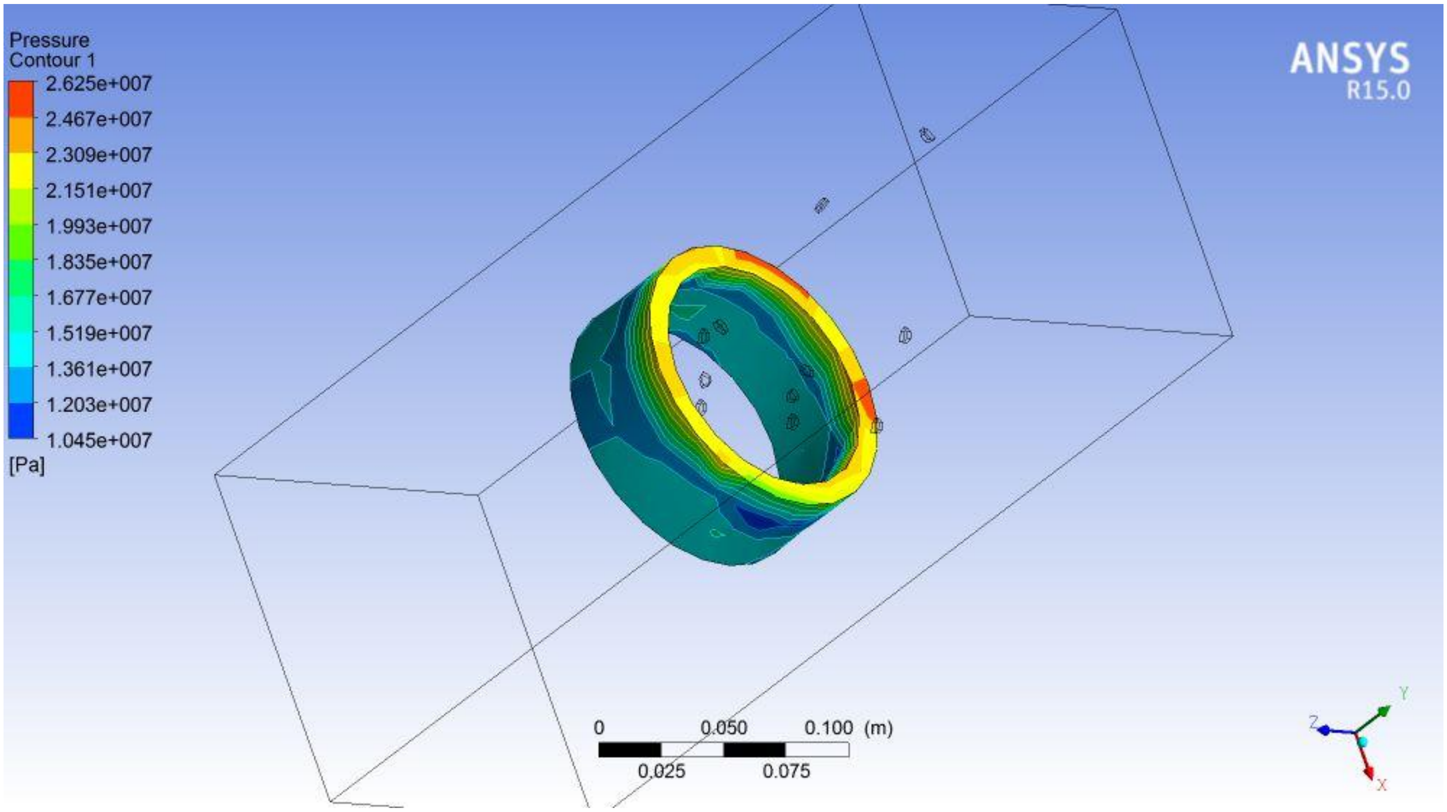

FIG.6 *EFFECT OF PRESSURE VARIATION ON WORKPIECE*

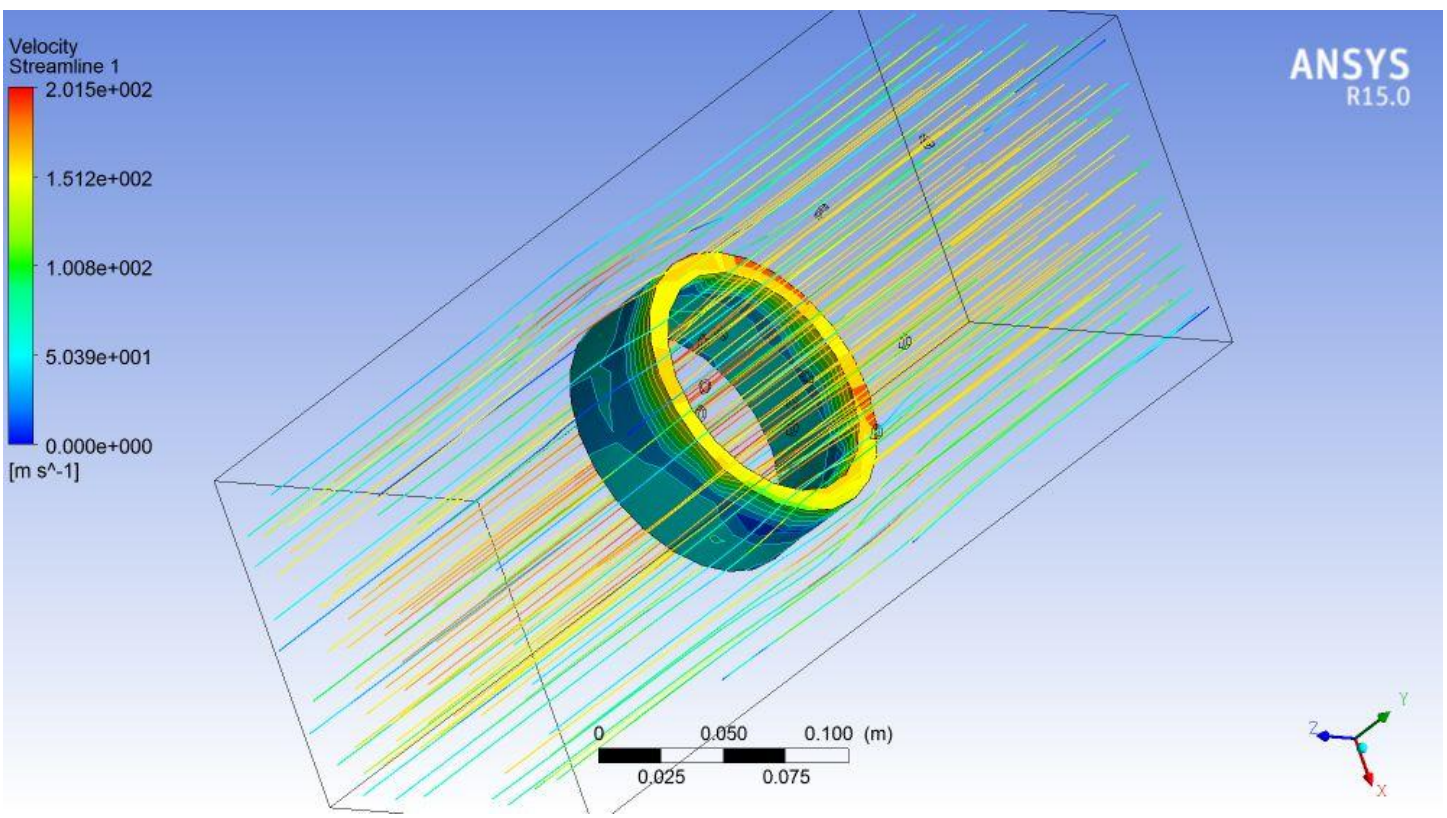

FIG.7 *STREAMLINE VARIATION OF POLYMER MEDIA*

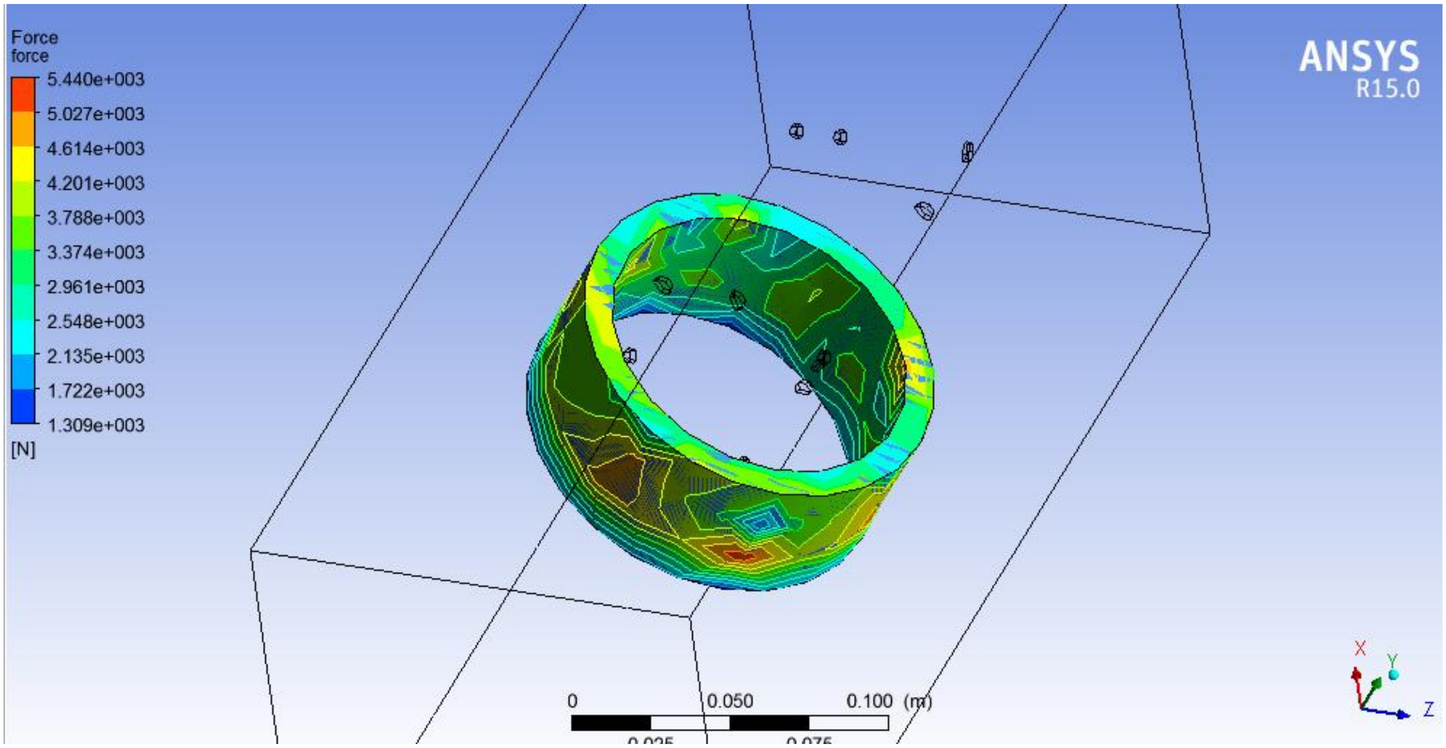

FIG.8 *FORCE APPLIED ON POLYMER MEDIA ON WORKPIECE*

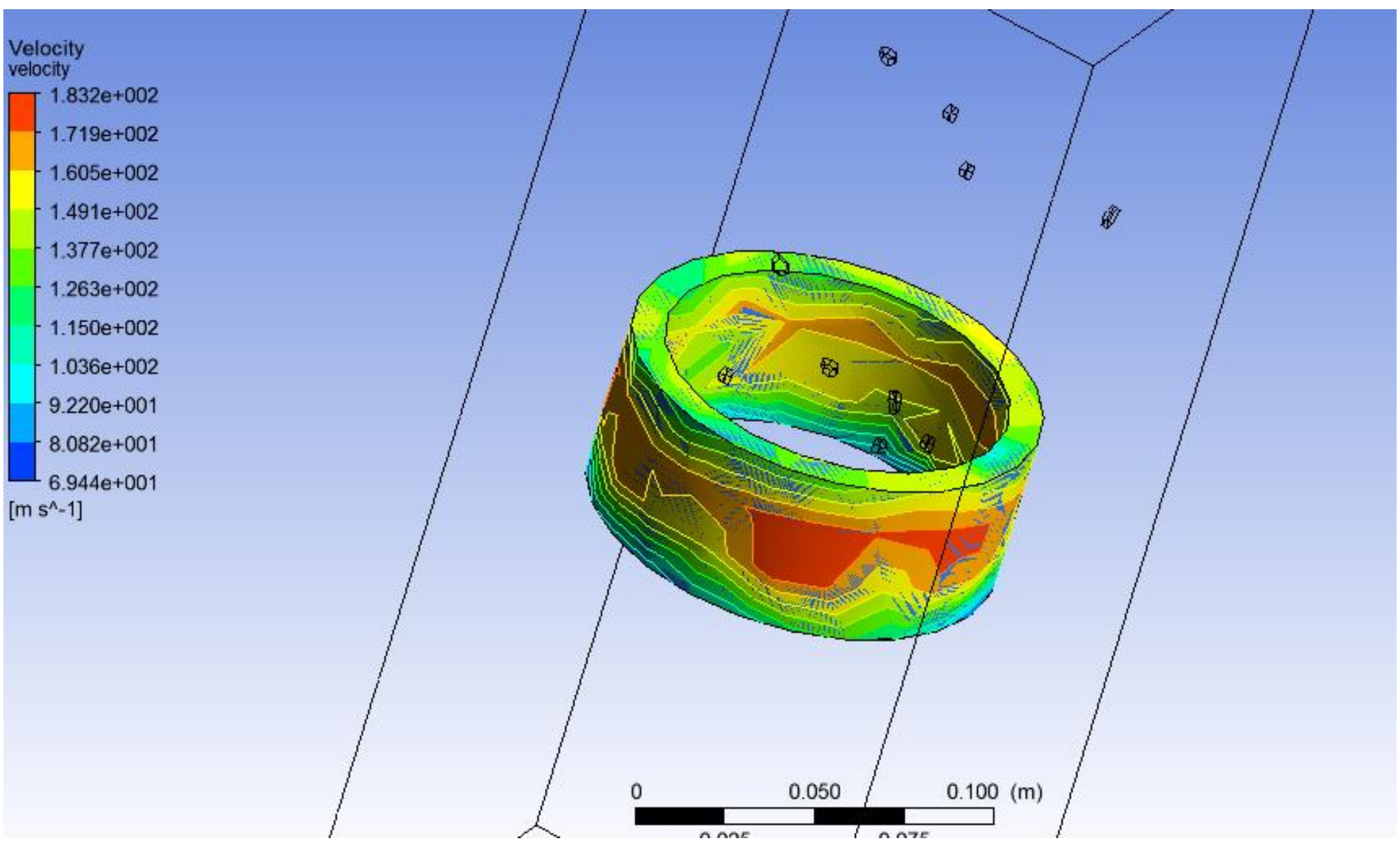

Fig 9 *VELOCITY OF POLYMER MEDIA*

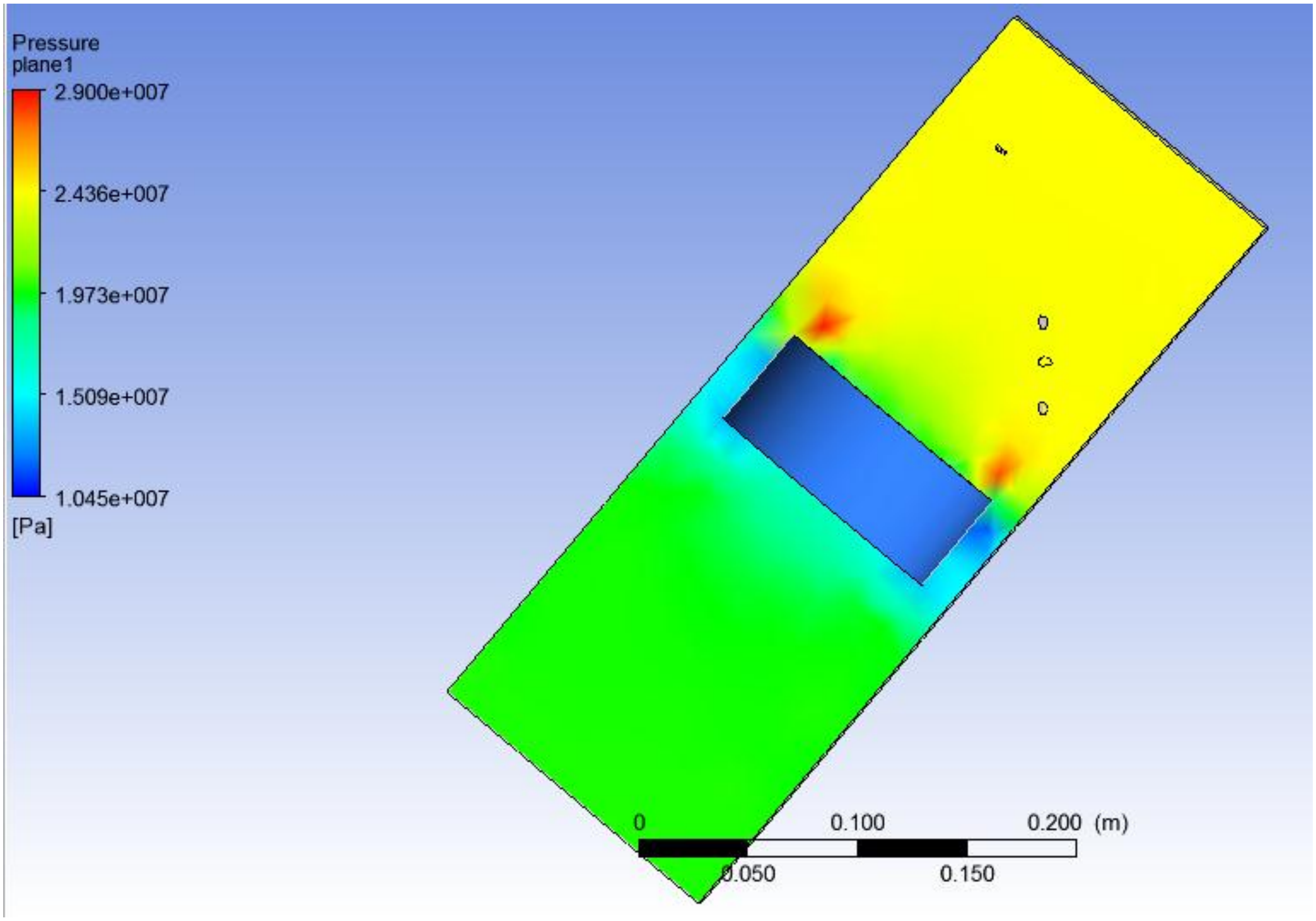

Fig 10 *PRESSURE VARIATION ALONG POLYMER MEDIA*

REFERENCES

[1] Kang, Junmo., Yamaguchi, Hitomi: Internal finishing of capillary tubes by magnetic abrasive finishing using a multiple pole-tip system, Precision Engineering 36 (2012) 510– 516, 2012.

[2] Jain, V. K: Magnetic field assisted abrasive based micro-/nano- finishing, Journal of Materials Processing Technology 209 (2009) 6022–6038, 2009.

[3] Wani, Amit. M., Yadava, Vinod., Khatri, Atul: Simulation for the prediction of surface roughness in magnetic abrasive flow finishing (MAFF), Journal of Materials Processing Technology 190 (2007) 282–290.

[4] Kala, Prateek., Pandey, Pulak. M., Verma, Girish. C., Sharma, Varun: Understanding flexible abrasive brush behaviour for double disk magnetic abrasive finishing based on force signature, Journal of Manufacturing Processes 28 (2017) 442–448, 2017.

[5] Wu Jinzhong., Zou, Yanhua., Sugiyama, Hitoshi: Study on finishing characteristics of magnetic abrasive finishing process using low-frequency alternating magnetic field, Int J Adv Manufacturing Technology 85:585– 594 DOI 10.1007/s00170-015-7962-9, (2016).

[6] Rathod, Avishkar., Sapate, S. G., Khatirkar, R. K: Shape factor analysis of abrasive particles used in slurry abrasion testing, International Journal of Mechanical and Industrial Engineering (IJMIE) ISSN No. 2231 –6477, Vol-2, Iss-4, 2012.

[7] Srivastava, Ankit. Kumar., komma, V.R: Finite Element Modelling of Electrochemical Magnetic Abrasive Finishing, Imperial Journal of Interdisciplinary Research (IJIR), Vol- 2, Issue-12, 2016, ISSN: 2454-1362.

[8] Srivastava, Ankit. Kumar., Katiyar. Amit.: Modelling and Simulation of Magnetic Abrasive Finishing for Thermal Analysis, Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-12, 2016 ISSN: 2454-1362.

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[12] Singh, Rajneesh. Kumar., Singh, D.K., Gangwar. Swati.: Fuzzy logicoptimization of process parameters affecting surface temperature in MAF, IOP Conf. Series: Materials Science and Engineering 404 (2018) 012017 doi:10.1088/1757-899X/404/1/012017.

[13] Jaiswal, S.C., Jain, V. K., Dixit, P.M.: Modelling and simulation ofmagnetic abrasive finishing process, Int J Adv Manufacturing Technology (2005) 26: 477–490, DOI 10.1007/s00170-004-2180.

[14] Yan, Q. S., Qiu, T.X., Gao, W.Q.,Meng, L: Simulation and Experimental Analysis of Electromagnetic Inductor for Magnetic Abrasive Finishing, Key Engineering Materials Vols. 389-390 (2009) pp 193-198 Online: 2008-09-26 © (2009) Trans Tech Publications, Switzerland, doi: 10.4028/www.scientific.net/KEM.389- 390.193.

[15] Li, Wenhui., Li Xiuhong., Yang, Shengqiang., Li, Weidong: A newly developed media for magenetic abrasive finishing process: Material removal behaviour and finishing performance, Journal of Materials Processing Tech 260(2018) 20-29.

[16] 13.Li, Xiuhong., Li, Wenhui., Yang, Shengqiang.: Effect of coupling Agent on Interfecial Bonding Properties of Visecoelastic Magnetic Abrasive Tools and Finishing Performance, ISSN 1473-804 online, 1473-8031 print, DOI 10.5013/IJSSST.a.17.28.17.

[17] 14.Shinmura T, Takazawa K, Hatano E, Matsunaga M. (1990) Study on magnetic abrasive finishing. Ann CIRP, 39(l): 325-328.

[18] 15.Shinmura T., Takazawa K., Hatano E., Aizawa T. (1985) Study on magnetic abrasive process-process principles and finishing possibility, Bull. Japan Soc. Prec. Eng. 19(1) 54–55.

[19] 16.Kim JD., Choi MS. (1995) Simulation for the prediction of surface accuracy in magnetic abrasive machining. J Mater Process Tech 53:630–642.

[20] 17.Srinivas. K., Murtaza. Q., Aggarwal. A.K.: Variation of Flow parameters and Magnetic Flux in Viscoelastic Magnetic Abrasive Finishing process, ISSN 0973-4562 Volume 14, Number 8, pp. 1940-1946, (2019).

[21] 18.Srinivas. K., Bhardwaj, Anant.: Pressure variation in Abrasive Flow machining: Modelling and simulation, 3rd international conference on Advanced Production and Industrial Engineering (ICAPIE'18), Paper ID ICAPIE-2018-PE MT 218.

[22] Ali, Parvesh., Ranganath, M.S., Walia, R.S., Murtaza, Q.: Various developments in Abrasive flow machining process: A Review, 3rd international conference on Advanced Production and Industrial Engineering (ICAPIE'18), Paper ID ICAPIE-2018- PE MT 215.

[23] Bhardwaj, Anant., Ali, Parvesh., Walia, R. S., Murtaza, Qasim., Pandey, S. M.: Development of Hybrid Forms of Abrasive Flow Machining Process: A Review, Advances in Industrial and Production Engineering pp 41-67, Part of the Lecture Notes in Mechanical Engineering book series (LNME), conference paper (2019).