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Application of Magnetorheological Fluid in Machining Process

Ganapathy Srinivasan R.[1], **Shanmugan S.**[2] **and Palani S.**[3]

ABSTRACT

Surface fining is most important properties in Machining process. Due to bad surface fining process we have Low quality product. The quality is most important precision devices. In traditional machining process cannot get cost effective finishing and also not in flexible. For that we developed the machining process to improve surface finishing during operation. Magnetorheological fluid sponsored such kind of high quality surface finish machining process. Hence this research review details of Magnetorheological Fluid in Finishing Process (Magnetorheological abrasive flow finishing, Magnetorheological finishing, Magnetorheological honing, Ball end Magnetorheological finishing, Magnetorheological jet finishing). This paper be responsible for complete details of application of Magnetorheological fluid in Machining process and also conversed various progresses in Magnetorheological Fluid Process.

Keyword: Surface Roughness; Nano Finishing; Magnetorheological Fluid; Precision, Quality:

1. INTRODUCTION

Fine machining in multifaceted geometries as well as quality product be constantly with respect to distress worker concentrated along with challenging in the direction of manage. Abrasives with little various cutting edges be usually employed for get favorite surface finish characteristics and geometrical accuracy by removing unnecessary material from the work piece. In Traditional we had some of finishing processes such as Grinding, Lapping and Honing works. For that reason of progress the novel materials which are problematic for machine as well as multifaceted manufacturing components required shape, that conventional Machining processes be unaccompanied not accomplished of manufacturing essential required finishing along with additional characteristics of the product and also processing of these essential wide ranging equipment's usage and effective labour

Modern advance finishing process in machining Process also having qualified reduction of tool resistance condition limitations i.e. in EDM, ECM, USM, AJM etc. cutting edge relative motion with Pre distinct motion and respect to the work piece surface be the foremost restraint during machining multifaceted shapes. For that avoid the restriction little various cutting edges in a few insecurely bonded from be heading for multifaceted Shapes to be machine. But due to the lack of control over the finishing forces, these possess the limitation for finishing complex geometry and moreover sometimes these processes communicate surface and subsurface damages. Many advanced finishing processes have been established to challenge these issues. Magnetorheological fluid aided finishing processes are one such kind of finishing processes, which has greater flexibility towards process control and one can finish by required tolerances among without destructive surface profile. Many newly developed Magnetorheological fluid assisted finishing processes make use of Magnetorheological fluid (MR fluid) to superficially manage the machining. Optics manufacturing center in Rochester, N.Y. done the process of machining for lens by using MRF (Kordonski and Golini 1999).Since then, more number of polishing techniques are evolved using Magnetorheological

[1] Department of Mechanical Engineering, Vel Tech Multitech, *Emails: ganapathysrinivasan@veltechmultitech.org, spalani@veltechmultitech.org*

[2] Assistant Professor, Department of Physics, Vel Tech Multitech, *Emails: s.shanmugam1982@gmail.com*

fluid. Few of them are Magnetorheological abrasive flow finishing, Magnetorheological finishing, Magnetorheological honing, Ball end Magnetorheological finishing,

This paper delivers complete details of application, machining and process of MR fluid as well as discuss with experimental analysis. The progresses of Magnetorheological finishing and its associated processes have been discussed.

2. MAGNETORHEOLOGICAL FLUID (MRF)

The MR fluid is a one of oil having capable of changing character by applying magnetic or electrical power. By that changing character means here change the apparent viscosity (amount of shear stress with respect to shear rate). In that condition we can manage the magnetic field till to fluid yield stress is active state. The result of that the fluid can be control force by the applying electromagnet.

Magnetorheological fluid is different compare to Ferro fluid It have minor particles. That is mostly on the micrometer size as well as thick for Brownian motion towards stay hovering. Ferro fluid particles be mainly nanoparticles that are hovering by Brownian motion also commonly is not resolve below normal situation. In that point clearly we get that two fluids keep various application. The behavioural structure of abrasive particles in magnetic field with Magnetorheological Fluid is shown in Figure 1.

The abrasive is having minor size with the various shapes be hovering contained be oil are dispersed arbitrarily as well as postponement with normal conditions. Figure 2 shows the iron particles presents in carrier oil.

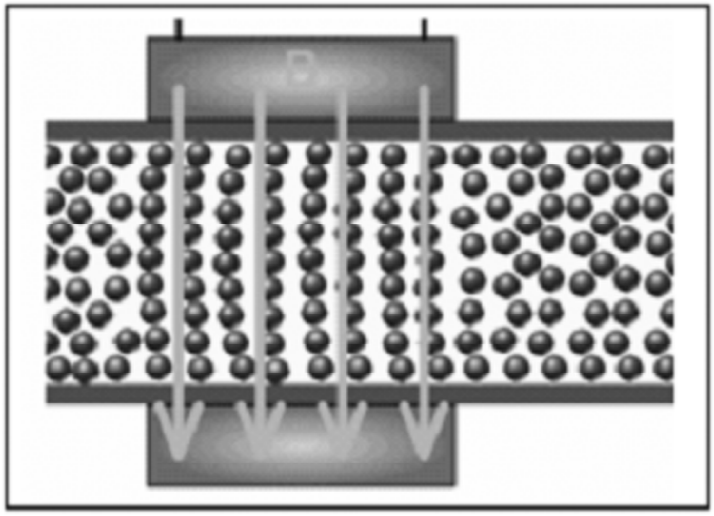

Figure 1: Abrasive particle in magnetic field with Magnetorheological Fluid

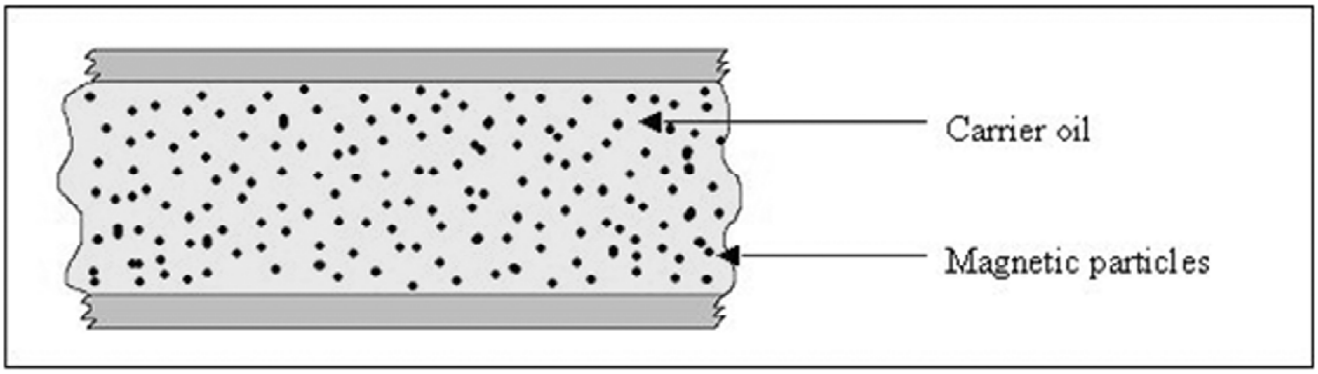

Figure 2: Iron particles presents in carrier oil (MRA Fluid)

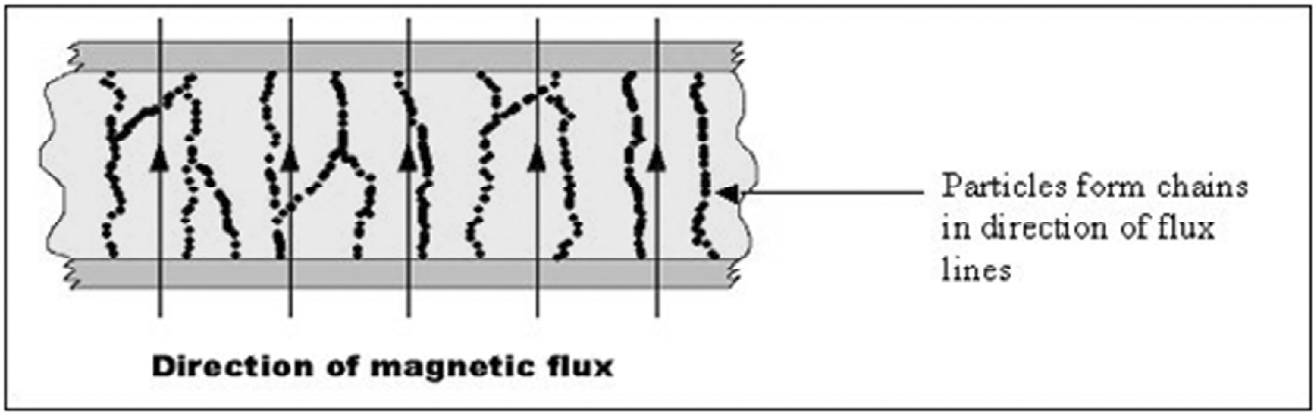

Figure 3: Behaviour of iron particles in Magnetic field

If we give the magnetic power to fluid the abrasive (0.1-10 μm) arrange a line themselves that is show in figure 3.

3. MAGNETORHEOLOGICAL FLUID MATERIAL BEHAVIOR

For that recognize of MRF performance is mainly important to make and control the process during the machining. From that points we discuss the fluid had stumpy viscosity is a deficiency be the functional magnetic field. The medium is stimulating until the yield properties similar to a solid. That stages the fluid shear stress more than the shearing.

Generally stated that apparent yield stress is reliant on the medium apply by means of magnetic power, That effect will be consider as the fluid reach maximum state of magnetic flux density after that point no one effect happen. The performance of the Magnetorheological fluid is to be considered like to a Bingham plastic a material model which has been well-investigated.

But, a Magnetorheological fluid characteristic is considered as approximately characteristics of a Bingham plastic. For example, The Bingham plastic yield stress performs as aviscoelastic material, with a multifaceted modulus. That is dependent on magnetic field intensity. We know that the Magnetorheological fluid substance to shear thinning. In that the viscosity will be increase shear rate due to decrease yield. Also, the performance of Magnetorheological fluid give as "off" stage as well as temperature and non-Newtonian dependent, still the simple analysis departs minute sufficient for fluid will be eventually considered as a Bingham plastic.

Hence our Magnetorheological fluid model behavior in the shear mode be develops:

$$\mathcal{T} = \mathcal{T}_y(H) + \eta \frac{dv}{dz},\ \mathcal{T} > \mathcal{T}_y$$

Where H = Magnetic field intensity, η = Newtonian viscosity; $\mathcal{T}_y$ = yield stress; $\mathcal{T}$ = shear stress; $\frac{dv}{dz}$ is the velocity gradient in the z-direction.

4. MAGNETORHEOLOGICAL FINISHING(MRF)

MRF is an external field sponsored accuracy machining process established and profitable by QED Technologies Inc. (Kordonski and Jacobs 1996; Jacobs, Kordonski et al. 2000). MRF is a precision processes that will produce surface precision on respective apparent micro-roughness less than 10Å rms and 30nm peak to valley (Kordonski and Jacobs 1996). MRF can be used for diversity raging. Magnetorheological Fluid was initiated in Belarus, Minsk by Prokhorov, Kordonski, coworkers and Gorodkin, in 1988. Formerly

Magnetorheological Fluid procedure basics were transported to the Centre for Optics Manufacturing (COM) in 1994. In 1996, MRF which was shown in fig. 1 & 2 was invented and commercialized at COM in 1996(Jacobs and Arrasmith 1999). In 1999, MRF was fully commercialized by QED Technologies. Magneto rheological Fluid and MR polishing fluid will be depositing on rotating wheel rim by a nozzle, whereas transported the medium to the surface of work piece. By magnetic field converging gap exposed to a form wheel rim & surface can be machined. The rim surface moving wall makes a flow attractively stiffened Magnetorheological polishing fluid through converging gap. The magnetically stiffened MR fluid produces a sole pressure delivery on space that is accompanying with an unsheared fluid, that is form of the affecting wall. Quasi–solid affecting margin to be efficiently shaped nearly close 169 | International Conference on Advances in Mechanical Sciences 2014. The QED Technologies Inc. (Kordonski and Jacobs 1996; Jacobs, Kordonski et al. 2000) Procedure commercialized and established. MRF is precision machinery that will present surface precision with the respective 30nm crest to root and machined effect not more than 10Å rms (Kordonski and Jacobs 1996). MRF can be used for materials variability raging to hard crystals from optical glasses.

Magnetorheological Fluid was initiated in Belarus, Minsk by Prokhorov, Kordonski, coworkers, and Gorodkin in 1988. Then Magnetorheological Fluid procedure basics were transported to the Centre for Optics Manufacturing (COM) in 1994. In 1996, MRF which was shown in fig. 1&2 was invented and commercialized at COM in 1996(Jacobs and Arrasmith 1999). In 1999, MRF was fully commercialized by QED Technologies. In MRF, MRPF supplied to the rotating wheel rim by means of nozzle. For that move the medium to be machine area. By form converging space the wheel rim & surface will be machined.

The magnetically stiffened MR fluid makes an exclusive pressure delivery in the space will be relate to an unsheared medium. That will efficiently shape extremely nearest the machined surface. That region is noted of machining area. Nonmagnetic abrasive particles material elimination will improve. When the MR fluid mixed with abrasives flows over specimen surface, the shear stress of the fluid generates a drag force to move the abrasives, which results in material removal (Kordonski and Golini 1999; Kordonski and Golini 1999; Shorey, Jacobs et al. 2001). The process of material removing by Magnetorheological fluid is shown in Figure 4.

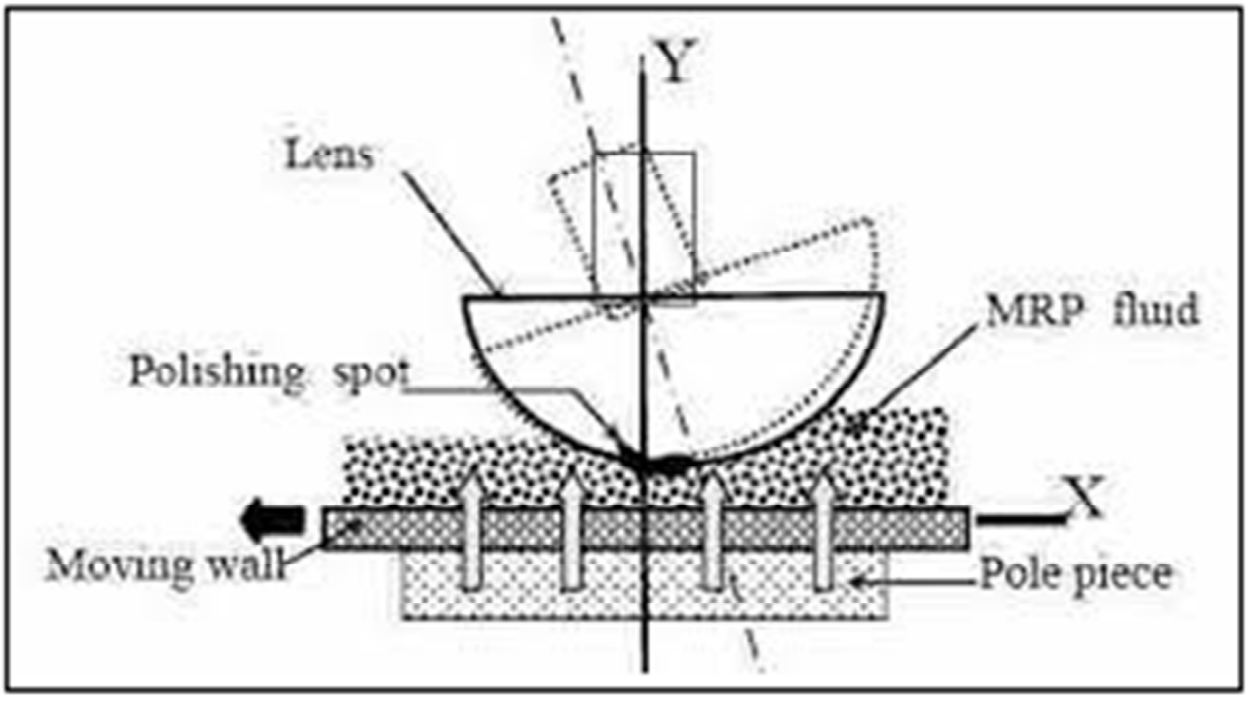

Figure 4: The process of material removing by Magnetorheological Finishing

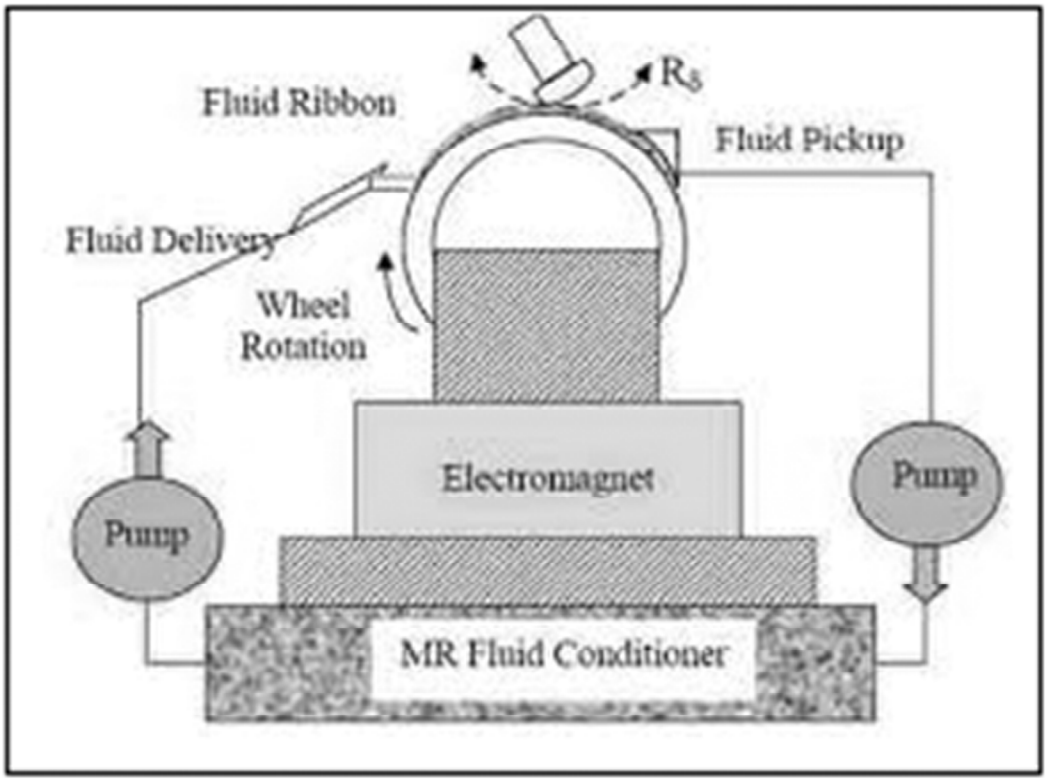

Figure 5: Magnetorheological Finishing machine

The complete set up for Magnetorheological Machine is shown in Figure 5. In MRF, the yield stress and Viscosity affected MRPF yield stress to be control that means of manage magnetizing in process region. Magneto rheological polishing medium includes be CIPs & required abrasives distributed on the carrier fluid, which exhibitions sole flexible modify the Magnetorheological characterizes for the function & elimination the exterior area. The Magnetorheological physiognomies & closeness strong point grown. Magnetorhelogical machining tool has been developed by means of QED technologies. In this Magnetorheological machining medium circulated unceasingly through the Magnetorheological fluid process. Due to the fluid adheres the periphery, the magnetic field of the wheel and the shape of the fluid be fined by the magnetic field strength, space involving workpice, wheel speed and wheel, & FFR (Schinhaerl, Smith et al. 2008). Researchers have tried different variants in wheel type MRF both include using permanent magnets and electromagnets. Due to the lack of the space, only few of them are discussed in this paper.

Cheng et al. (Cheng, Yam et al. 2009) were presented an innovative polishing tool design as shown in Fig 2. And also they presented an investigational study be fined. They observed that the viscosity will be increase with the driving voltage. They also conducted experimental study using this wheel to polish K9 mirror and MR fluid composition taken as 33.84% CI particle, 57.34% silicone oil, 2.82% stabilizing agent, and 6% CeO2. Surface precision be developed over three periods with abrasives in the fluid compared to the without abrasives.

5. MAGNETORHEOLOGICAL FLUID ABRASIVE FLOW FINISHING PROCESS (MRAFF)

This process to be an innovative accuracy machining process established at I.I.T. Kanpur in place of nanomachining of multifaceted internal shapes by means of smart MR polishing fluid. This process delivers improved in-process regulator above abrasive magnetorheological possessions loaded machining intermediate. MRPF includes of CIPs and silicon carbide discrete that viscoelastic form on mineral oil & grease, exhibitions change on rheological behavior in attendance of exterior magnetic field. That MR-Polishing Fluid behavior is applied to exactly regulate the machining forces, hereafter final surface finish.

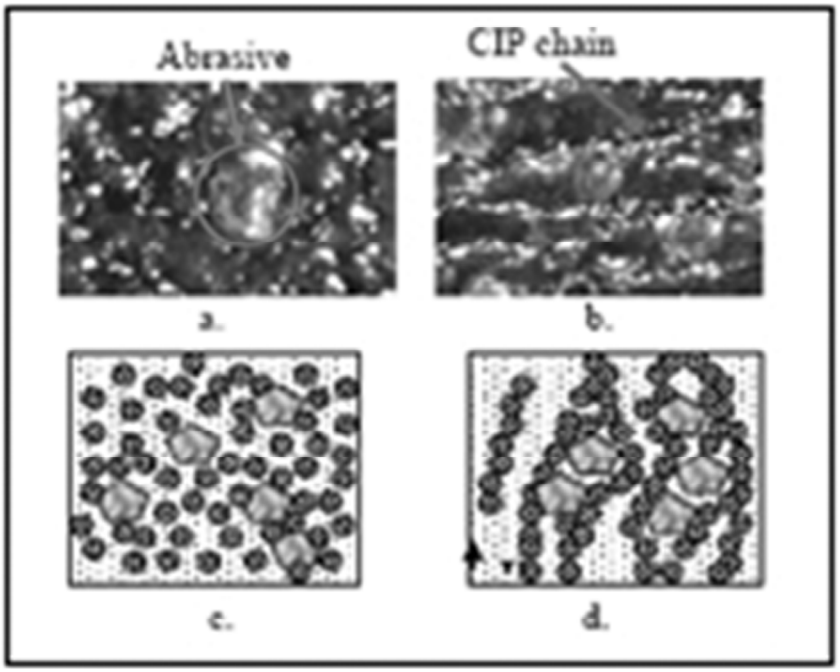

Figure 6: Structure of MRPF

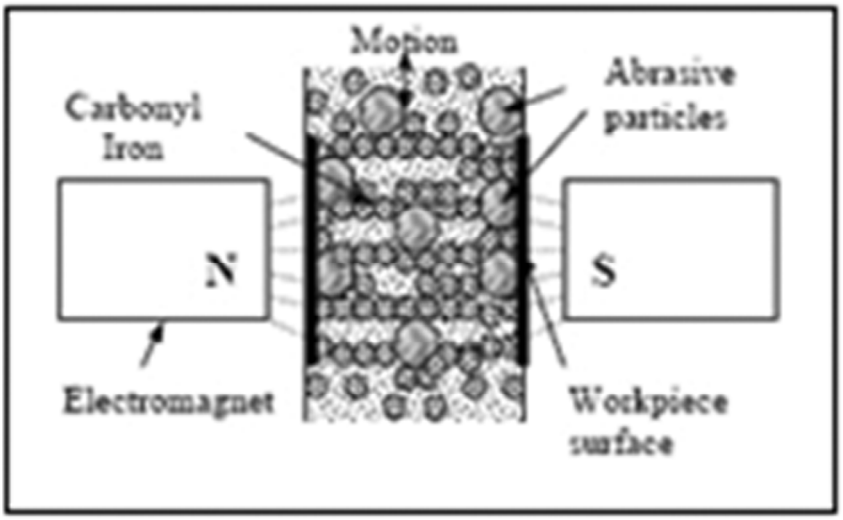

Figure 7: Mechanism of MRAFF

Figure 6a & Fig 6b demonstrations real pictures available by optical microscope of CIPs consistent chain structure. Fig 6c demonstrates the structure formed when no magnetic field is applied whereas Figure 6d demonstrations the structure formed with abrasives trapped and embedded between iron chains, in attendance of finite observe area.

The MRAFF mechanism function is shown in Figure 7. The abrasive particles under the function of exactly organized standard magnetic force due to CIP chains and tangential hydraulic extrusion force eliminate indiscretions on the work piece surface to machine them in nanometer range. A hydraulically device investigational setup is presented in Figure. 6 is intended be observe the procedure performance and characteristics.

Experimentation is conducted on required work piece at various environmental powers for that detect that's consequence ultimate machining. The MRAFF experimental setup is shown in Figure 8. Not at all assessable modification on machining roughness is denoted following machining negligible magnetic fields.

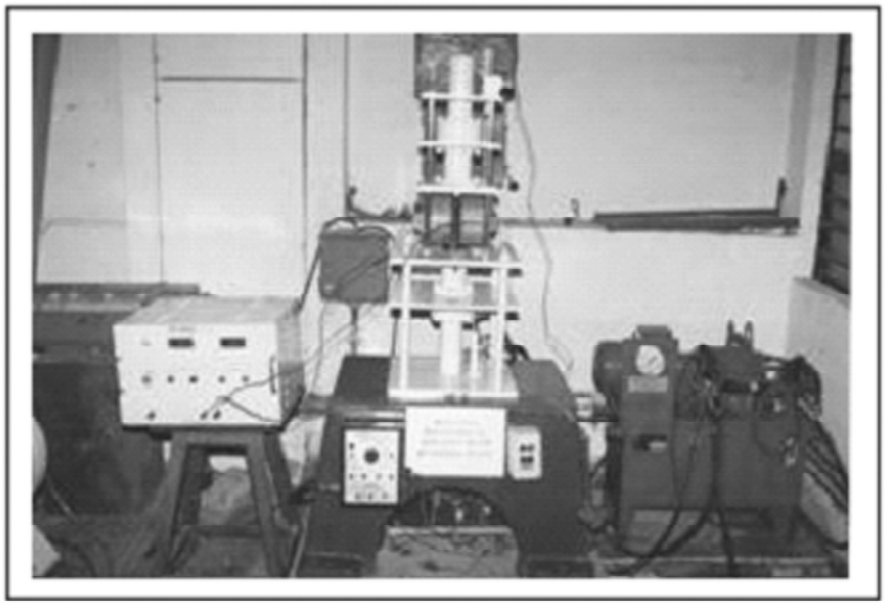

Figure 8: MRAFF Experimental setup

Whenever, as similar series amount the machines decreases progressively by growth of magnetic area. The consequences on silicon nitride and stainless steel work pieces are fairly inspiring and Ra up to 30 nm. It is also observe by this process. (Professor V. K. Jain & Professor P. S. Ghoshdastidar)

6. MAGNETORHEOLOGICAL ABRASIVE HONING (MRAH)

In the present work, a combination of reciprocation and rotation is used and hence authors refer to it by means of MRAH. Magnetorheological fluid consists of a carrier medium like castor oil loaded with carbonyl iron particles (CIP) of appropriate size and concentration. Particles of abrasives such as silicon carbide are also mixed with the MR fluid. A surfactant is added be avoid the settling of the particles in the carrier medium & stirred thoroughly be achieve uniform mixing. The container filled with abrasive MR fluid is kept between the poles of a direct current electromagnet. The magnetic arena be varied by changing power fed electromagnet coil. The abrasive included Magnetorheological fluid be moved up and down inside the container using a crank-driven piston at the bottom and a spring-loaded sliding disc at the upper position. A holder carrying the specimens is rotated within the abrasive MR fluid using a direct current motor. More details can be found in the paper published by Sadiq and Shunmugam (2009a). Magnetic medium absence, machine particles be free to shift in the Magnetorheological fluid. At what time magnetic power be applied, the CIP align along be field direction and the abrasive be locked between the carbonyl iron particles. This phenomenon prevents the free movement of abrasive particles and causes the abrasive mixed MR fluid to stiffen to different degree, depending on the magnetic field strength. The stiffened medium when rubs against the surface, material is removed in micron level and the surface finish is improved. With certain degree of flexibility in the MR fluid medium, the process has a potential to finish complex surfaces.

7. BALL END MAGNETORHEOLOGICAL FINISHING (BEMRF)

The application of MRF and MR jet machining processes are to be restricted to particular shapes like convex, aspherical, concave and flat due to limitation of relative effort of machining and work piece. In 3D complicated shaped surface will be inexpert of machining. For that avoid that drawback A Kumar etc al. developed a novel precision machining for nano finishing of 3 Dimensional surface machining (Kumar Singh, Jha et al. 2011). When there were no magnetic fields the forced Magnetorheological fluid pass in the central rotating core top end. It will reach quickly the tool tip surface magnetic flux density was provided.

Tool of ball end milling was rotated and reciprocating motion (longitudinal feed and cross feed) was provided to the work piece. The researchers (Kumar Singh, Jha et al. 2012) were conducted experiments about study of surface roughness in final condition in the result of amount of machining. They achieved finish is very stumpy as 16.6nm, 30.4nm, 71nm then 123nm on flat, 30, 45 as well as 3 dimensional work piece. And also they found the ground surface presentation of the machining be improved compare with crushed surface. The researchers (Singh, Jha et al. 2012) were also conducted experiments, he studied the result of machining time on concluding surface roughness in that conditions of cerium oxide abrasive bonded with silica glass that observe roughness value after 90 minutes. Here surface roughness became very low from 0.74nm to 0.146nm.

8. CONCLUSIONS

This paper is obtainable overview detail of MRF, MRAFF, MRAH, and Ball end MRF. From that following Conclusion can be drawn. The Magnetorheological Fluid can be applied in effective finishing process such as optical material in complicated shapes. R-MRAFF and MRAFF procedure has been recognized as a novel deterministic machining process. This process similarly keeps the capability to valued roundness cylindrical stainless tubes error hard. The capability of novel established ball end finishing tool be decrease finishing appearances & progress that finishing roughness on the work piece be verified & that authorizes advanced technique of machining procedure be capacity of performance nanomachining achievement. Magnetic flux density in Difference Magneto static imitation of machining area designates clear shape of ball end machining surface.

REFERENCES

[1] Jha A. K. S., Pandey P. M., "Mechanism of material removal in ball end magnetorheological finishing process" Wear Vol. 302, pp. 1180–1191, 2013.

[2] Singh, A.K., Jha, S. and Pandey, P.M., "Nano finishing of a typical 3D ferromagnetic workpiece using ball end magnetorheological finishing process, International Journal of Machine Tools & Manufacture, Vol. 63, pp. 21–31, 2012.

[3] Singh, A.K., Jha, S. and Pandey, P.M. "Design and development of nanofinishing process for 3D surfaces using ball end MR finishing tool, International Journal of Machine Tools & Manufacture, Vol. 51, pp. 142–151, 2011.

[4] López-López, M., J. de Vicente, "Stability of magnetizable colloidal suspensions by addition of oleic acid and silica nanoparticles", Colloids and Surfaces A: Physicochemical and Engineering Aspects, Vol. 264, 1–3, pp. 75–81, 2005.

[5] Lee, S.N., S.J. Park, "Application of MRF scheme for low-loss transmission lines on CMOS-grade silicon" IEEE Explore, Proceedings Electronic Components and Technology, ECTC '05, Vol. 2, pp. 514–1518, 2005.

[6] Miao, C., S. N. Shafrir, "Shear stress in magnetorheological finishing for glasses" Applied Optics, Vol. 48, (13) pp. 2585-2594, 2009.

[7] Park, J. H., B. D. Chin, "Rheological properties and stabilization of magnetorheological fluids in a water-in-oil emulsion" J Colloid Interface Sci., Vol. 240(1), pp. 349-354, 2001.

[8] Seok T, J., Lee S. O., "Tribological properties of a magnetorheological (MR) fluid in a finishing process" Tribology Transactions, Tribology Transactions Vol. 52(4), 2009.

[9] Smith M G, "Mathematical modelling of influence functions in computer-controlled polishing: Part I", Applied Mathematical Modelling, Vol. 32 (12) pp. 2888–2906, 2008.

[10] Jacobs A B S D, "Experiments and observations regarding the mechanisms of glass removal in magnetorheological finishing" Appl Opt. Vol. 1; 40(1): pp. 20-33. 2001.

[11] Jha A K S, "Nanofinishing of Fused Silica Glass Using Ball-End Magnetorheological Finishing Tool", Materials and Manufacturing Processes, Vol. 27(10), 2012.

[12] Sidpara, A., M. Das, "Rheological Characterization of Magnetorheological Finishing Fluid" The International Journal of Advanced Manufacturing Technology, Vol. 42(7), pp. 656-668, 2009.

[13] Saraswathamma K., "Magnetorheological Finishing: A Review", International Journal of Current Engineering and Technology, Special Issue-2, February 2014, Available at http://inpressco.com/category/ijcet.