The Effect of Process Parameters on the microsurface finish of Magnetorheological Fluid Technology: A Review

Ankur
Department of Production and Industrial Engineering, Punjab Engineering College (Deemed to be University), Chandigarh- 160012 Chandigarh India.
Email- ankur3611421@gmail.com

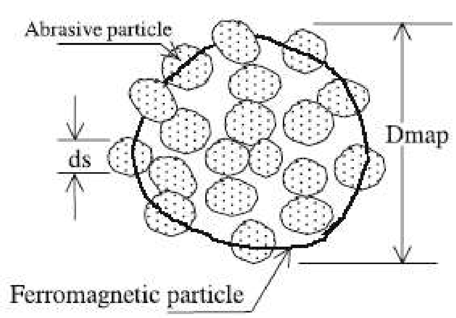
Rahul Vaishya
Department of Production and Industrial Engineering, Punjab Engineering College (Deemed to be University), Chandigarh- 160012 Chandigarh India.
Email- rahul_mv@yahoo.com

Abstract- MR Fluid is a carrier fluid which when subjected to a controlled level of magnetic field application viscosity of the fluid increases that gives rise to visco-elastic solid in an applied magnetic field. The fluid developed can transmit the kinematic forces and motion in a controlled manner to enhance the performance characteristics. Magnetic field intensity along with the tool developed imparts high tool flexibility and better control over the finishing force. In this Analysis, the examination of the aspects of various influential process parameters such as the working gap, rotational speed (in rpm) and grain size (in mesh), ball milling time, etc. in the different experiment to examine their effectiveness in the process of surface finish of materials used in the various experiments. The basic material used the preparation of Magnetorheological, is carried out by using the ball milling of ferromagnetic material i.e Iron and Silicon carbide as an abrasive followed by the addition of binder PVA. XRD and SEM are carrying out for the developed fluid. The prime objective of process is to study the approaches that are going to be followed is examined, to enhance the life of the finishing tool MRF, based upon the experiments.

Keywords – PVA XRD SEM MRF PolyVinyl-Alcohol X-Ray Diffraction Scanning Electron Microscope MagnetoRheological Fluid.

I. Introduction

Conventional metal finishing processes utilize the hard tools to remove the material thereby produces normal stresses and sometimes, they may lead to the generation of microcracks. These normal stresses and micro-cracks affect the strength, durability, and reliability of the component subjected to machining[1]. Due to these reasons, the conventional metal finishing processes find difficulty in generating the required surface finish and it stimulated the developments of advanced machining processes (AMPs) like magnetorheological abrasive flow finishing (MRAFF) process which has the advantage of both magneto rheological (MR) finishing and abrasive flow machining [2].



[Figure 1 Figure shows the magnetic abrasive particle in bonded form ;
Dmap: magnetic abrasive particle Diameter; ds: abrasive particle diameter [1-4]

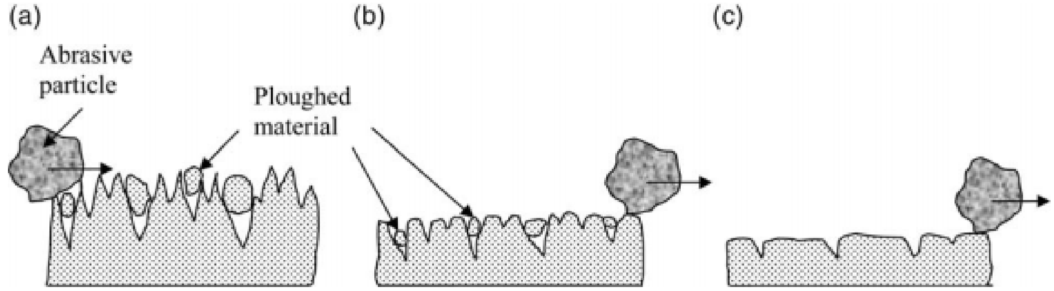


Fig. 2 .a) ploughed materials left after grinding in Abrasive grain approaching peaks; b) At the mild magnetic field, remove ploughed material and the peaks of abrasive particles shear; c), exposing small valleys on surface (low Ra) magnetic field higher abrasive particle sheared and remove material completely.[5]

This particular technique utilizes the magnetic force to control the metal removal process effectively employing ferrous and abrasive particles. Modeling and simulation of the MRAFF process were carried out where the effect of particle sizes in the MR fluid on the final SR was evaluated[6]. The MR fluid flow during the MRAFF process was analyzed through a finite difference method and dealt with the normal force acting on the abrasive particles[7]. The effect of swirling of inlet flow on the final SR obtained by the MRAFF process was elaborated[8]. A rotational MRAFF process on stainless steel tubes to obtain nano-finishing was studied by using response surface regression analysis[9].

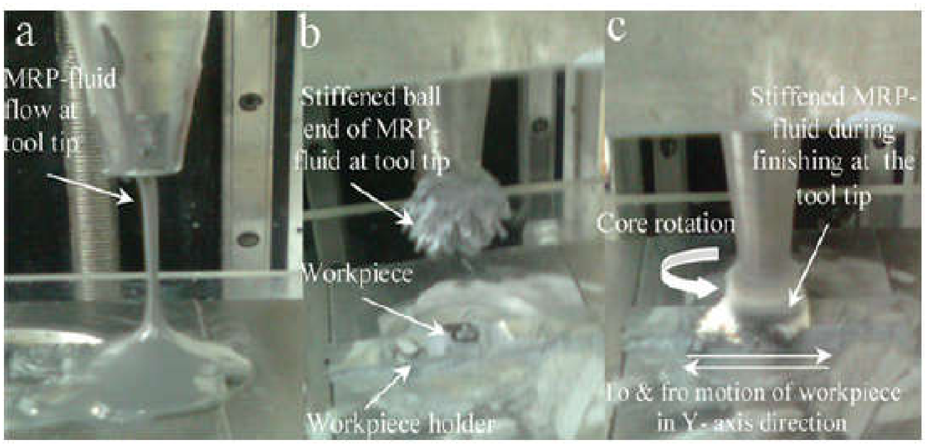


Fig: 3 MR polishing fluid at the tip of the MR finishing tool (a) when the magnet is OFF; (b) stiffened ball end shape when the magnet is ON and (c) during finishing operation [10-11].

A ball end MR finishing process on ferromagnetic materials was analyzed toward the effect of volume % of the abrasive constituent of the MR polishing fluid on final surface roughness (SR)[10]. In the same kind of ball end MR finishing process, the performance of a bidisperse ferrous constituent was studied[12]. The effect of the addition of Fe_3O_4 nanoparticles in MR fluids on the surface finishing process was experimentally analyzed[13].

To enhance the performance of MR fluids, surfactant compounding was proposed and analyzed[14]. Many researchers have focused to predict the performance of the magnetic field-assisted abrasive finishing process employing linear models[15], neural networks to produce ultrafine finished surfaces[17]. SR was investigated[18] as a quadratic model in the abrasive water jet machining process and turning process of metal matrix nano-composites[19].

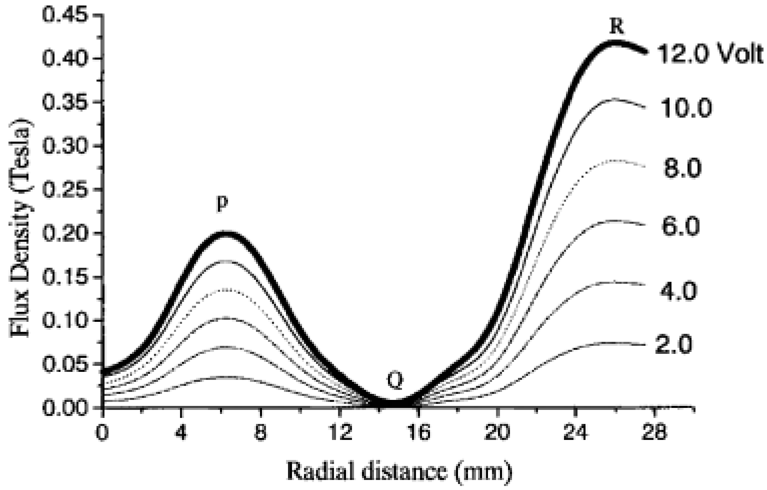


Fig.4. 1.5 mm is the Working gap and different voltages lead to Change in flux density from the outer pole towards the center at different radial points. [15-16]

Using the above literature survey, it is understood that very few parametric studies have been conducted especially for the MRAFF process[20]. Determination of ideal input parameters is a standout amongst all the machining processes including both conventional and AMPs. Hence, the objective of this analysis is to find out the optimal input parameters within the selected range that will fetch the minimum SR and maximum material removal rate (MRR)[21].

In the present work, response surface methodology (RSM) was followed to build the MRAFF model using the actuation pressure of hydraulic cylinders, electromagnetic voltage, and several finishing cycles as the input process parameters[22] and optimized toward the minimum SR and maximum MRR. For constrained optimization, a nontraditional evolutionary optimizer called the firefly algorithm (FFA) was used by taking the regression equations of RSM as input.[23]

[40]To control the non-linear terms caused by inertia forces and magnetic body force, the mathematics is our major emphasis and also the tool on which we dependent[41]. To perform the nonlinear energy stability analysis a suitable generalized energy functional is introduced. [42] The Prime objective of the widespread-phase alloys is to provide strength to the alloy matrix by the restrictions to the motion of dislocations[43].The matrix residue to be the higher load-bearing component and will be used to provide strength fractionally to the productiveness of the dispersion as a restriction to the movement of dislocations.[44]

II. LITERATURE REVIEW:

Zhao Z et. al. [24] Used ferrosilicon particles in the powder form in ferromagnetic form. Due to increased temperature Binders act in the inorganic form of adhesives. To characterize the elemental composition, as well as the morphology, (EDS) energy dispersive spectrometer and (SEM) scanning electron microscope, were used respectively. Durability and the performance of magnetic abrasives carried out by the experiment and analysis show that the result of the experiment that the good ability and long time shows abrasives characteristics .12 µm is the surface roughness of grinding sample and 25 minute is usage time.

Ahmad S et. al. [25] describe the improvement in manufacturing engineering further shows the behavior of part machined and enhance the surface finish characteristics with good accuracy. This shows the application of a magnetic abrasive finishing process during the magnetic abrasive finishing process. Magnetic abrasive used as a finishing tool. some special technique is used for the fabrication of magnetic abrasive and sintering method the adhesive method and plasma method at Sector the examination shows the magnetic abrasive finishing characterized by the sintering method. Due to centering an enhancement like the magnetic abrasive is obtained because these abrasive particles stick to the base Matrix. Iron is used as a magnetic particle and Aluminum as an abrasive particle. stainless steel 202 is used for experimenting to check the effect abrasive particle size machining gap rotating speed electromagnetic voltage so the surface roughness inspection of the surface roughness is carried out that tells that the average particle size influence on the machine surface for surface finish.

Singh RK et. al. [26] show the response and process parameter on the surface finish during the experiment, machining gap, and magnetic flux density and is highly dependent on the surface finish as well as the material removal rate in the study. Various techniques are used like the simulation of magnetic force, finite element analysis for modeling and mathematical Modeling and have the ability of magnetic abrasive finishing process by the application of magnetic abrasive finishing process composite super alloy and ceramics can be easily finished and also magnetic abrasive finishing is an advanced process for machining for material removal and produces high-quality workpiece surface magnetic abrasive finishing has been classified according to the nature of surface like cylindrical surface plane surface for circular surface, etc.

Li X et al. [27] set up for the Rotary inner and outer surface finishing is being developed in the semi-solid state with an improved magnetic surface finishing medium was prepared and presented Ansys Maxwell 14.0 was used for the simulation and to check the accurate angle between north and South Pole .due to the functioning of magnetic pressure and velocity based on Archard square model and mathematical modeling to improve the material removal rate and simulation shows that the material removal rate of the metal depends upon the entire of abrasive ferromagnetic particles and the magnetic field density rotational speed of poles (magnetic) mass ratio rotational speed of arm. the coefficient of the material removal rate was determined by the predicted simulations. the error percentage between the standard or theoretical and experimental value was 4.51 % material removal rate and the surface roughness of the magnetic finishing experiment was examined the amount of increase in material removal rate percentage change in surface roughness value and in surface roughness with the increase in the number of mesh size and rotational speed of the abrasive article based polymer mass ratio abrasive phase and ferromagnetic phase maximum material removal rate is 1.916 and enhancement in the Ra value is 96.67%.

Yang W et. al. [28] To overcome the randomness of free abrasive polishing (CMP), abrasive waste, and the resulting hydration layer, this paper presents a fixed abrasive polishing technique in the anhydrous environment. We have achieved a stable polishing wheel sintering process. The pellet we made has applied to fused silica polishing. It is found that the surface profile accuracy and roughness convergence speed are significantly improved comparing with the free abrasive polishing, and the pellet did not break and wears evenly. The influences of changing parameters including pressure, rotation speed on the material removal rate, and surface roughness are examined. Removal rate does not increase with applied pressure and rotation speed, which is inconsistent with Preston's formula. The heat generated in the machining process is paramount parameters determining removal efficiency. To get the most suitable processing temperature, We employed an in-situ infrared camera and finite element analysis to test the temperature, which clarifies the material removal does not increase with applied pressure and rotation speed in dry fixed abrasive polishing. Further, for testing the properties and stability of the pellet, the chips and polishing wheel were chemical analyzed using EDS and XRD; the results show a probable mechanism.

Zakeri M et. al. [29] ball milling of silicon molybdenum Titanium and graphite element powder with different ball to powder ratio of composite powder was successfully prepared mosi2 -Tic. X-ray diffraction method was used to study the formation of the composite that is prepared and transmission electron microscope and scanning electron microscope is used for the microstructure analysis and the morphological analysis of the milling powder respectively. time fall for ball milling is 30 hour and ball to powder ratio is 5: 1 for incomplete formation but with 20: 1 and 15: 1 ball to powder ratio composite formation takes place after 10 hours. partial transformation of Beta to mosi2 we use relatively high Ball to Powder Ratio BPR with a high melting time. Nanomaterial powder with the average grain size relatively less than 25 nm is prepared in almost all the ball to powder ratio for the ball to powder ratio 10: 1 and 15: 1, an agglomerated form of fine Submicro powder was prepared.

Chen HL et. al. [30] the obtained experimental results show that the abrasive formed by the hot pressing sintering process, long service life, adaptability, and goods finishing performance and can efficiently and enhance surface quality. magnetic abrasive finishing has a diverse application, high efficiency, good effort low cost as a kind of precise surface finishing Technology. the efficiency of magnetic abrasive finishing is the only main factor that affects finishing.

Chen HL et. al. [31] study shows that the bonded magnetic abrasive grains are one of the greatest factors affecting magnetic abrasive finishing. various performance indexes show that there is the relation between the magnetic abrasive grains which are shown by the examination of the process parameters that influence its properties like grains shaped, permeability, grain size, ingredients ratio, economy, and service life. further temperature is another important index for the bondage of magnetic abrasive grains and some innovative ideas and thoughts are available for the enhancement of magnetic abrasive grains. chemical composition and thermal stability are preferred through examinations and on the bonded magnetic abrasive grains.

Polanski M et. al. [32] shows that the ball milling as well as in mechanical alloying the ball to powder ratio is a processing parameter which is usually examined during experiment .now ball to powder ratio shows a dominant milling parameter and in comparison can neglect other parameters like quality of ball milling, the number of balls in milling, the diameter of balls, volume of the container and the mass of the Powder now as a constant BPR. , Different samples of the magnesium Hydroxide milled build using varying powder mass and ball size .investigation of the Powder is carried out by the X-ray diffraction method, phase analysis, and differential scanning calorimeter. by using the constant ball to powder ratio is scanning rate of 5°C / minute shows an allowable difference in desorption, the highest temperature among the samples used during the million.

Niranjan MS et. al. [33] show the calculation of the percentage of reduction in the surface roughness value was noted and compared with the surface roughness obtained with the unbounded magnetic abrasive based Magnetorheological finishing by finishing the work surface and found superior result and almost same composition. The design of the experiment was selected for 5 levels and 3 level factors, after comparison 55% of the volume of base fluid is mixed with the 45% volume of the magnetic abrasive sintered. scanning electron microscope and vibration sample magnetometer are used for particle characterization to magnetic abrasive 20% carbonyl iron powder and 25% of volume silicon carbide abrasive was uniformly mixed for the development of sintered magnetic abrasive and then followed by the centering in the tabular furnace at 12000° C in Argon atmosphere to finish the surface of the mild steel in nanometer level and the tool is presented in the form of ball end magnetorheological finish.

Shukla VC et. al. [34] The importance of magnetic abrasive powder (MAP) in finishing the surface of work materials as a flexible cutting tool in the presence of a magnetic field during the ultrasonic-assisted magnetic abrasive finishing (UAMAF) process is quite evident. A sufficiently intense magnetic field provides the desired magnetic force to the iron particles. This holds nonmagnetic abrasive particles firmly and thus makes flexible chains. However, at higher rotational speeds of the magnet due to the requirement of high centripetal force, the chains start flying away from the finishing zone. In the present work, to overcome this deficiency, bonded MAPs were developed using the sintering technique. The effect of various process parameters on the magnetic property (magnetization) of sintered MAPs was investigated. The design of experiments (DoE) was planned as per the L8 orthogonal array of the Taguchi method, and magnetizations along with M-H curves for all eight different MAPs were measured. It was observed that sintering temperature affects magnetization the most. Scanned microscopy (SEM) and X-ray diffraction (XRD) analysis were also carried out to investigate bonding strength in sintered MAP.

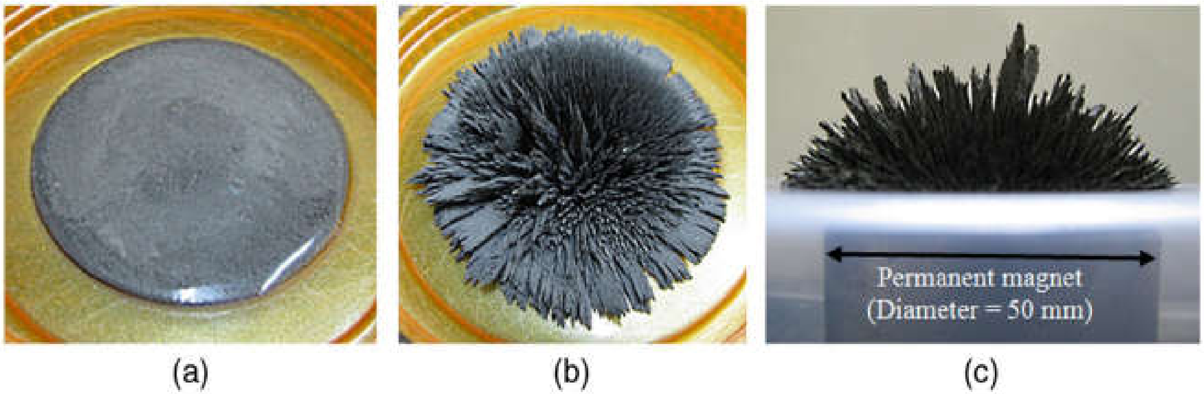


Fig.5 .(a)MR fluid Condition without application of magnetic field (b) with the application of magnetic field (c) side view[35-36]

Comparison Table : Different Process Parameters and Techniques

S.N.	Author & Year	Magnetorheological Tool material	Workpiece Material	Input Parameters	Response Parameters	DOE	Conclusion / Findings/ Contributions
1. [1]	Jayswal S. et.al. 2005	Ferromagnetic Particles with abrasives		Magnetic Force, Contact Time of tool	surface roughness	Mathematical modeling and Finite Element Analysis	The magnitude of the normal magnetic force is relatively Higher near the edge of the magnetic pole due to the edge effect.
2. [17]	Teimouri R. et. al.	Magnetic Abrasive Brush	AISI 52100 steel	Voltage Mesh number Poles Rotational Speed (rpm) Percent weight of abrasives	Surface roughness	Simulated Annealing and Particle Swan Optimization.	Firstly optimization was implemented by SA and then the optimal solutions were verified by PSO.
3. [37]	Bedi T. et. al.	MR polishing fluid (usually a mixture of 20% CIPs, 20% SiC abrasive particles with 60% viscoplastic base medium	stainless steel workpiece	magnetic flux density surface working gap	Surface roughness profile	Finite Element Analysis	Ball end type MR finishing method is found to be the best a suitable method for the finishing of 3D surfaces

4. [13]	**Liu X. et. al.**	**Soft magnetic carbonyl iron particles nanometer Fe3O4 particles Dimethyl silicone oil**	**Magneto-Rheological fluid**	**nanometer Fe3O4 particles size electric current Time of sedimentation**	**shear yield stress**	**visual examination method and SNB-1 rotation viscometer**	**a certain Amount of nanometer Fe3O4 particles (4 and 6 wt%), excellent performance MRFs that have nice sedimentation stability, low zero-field viscosity, and high shear yield stress could be obtained.**
5. [38]	**Choi H. et. al.**	**Magnetic nano-sized carbonyl iron (CI) particle as an additive for micron-sized CI based magnetorheological (MR) fluid, pentacarbonyl iron (Fe(CO)5).**		**Applied Magnetic Field, shear strain**	**shear stress**	**vibration sample magnetometer (VSM), morphology was observed via TEM**	**micron-sized CI and magnetic CI nanoparticle were being oriented in magnetic field direction under applied magnetic field and with strengthened structure.**
6. [39]	**Jain V. et. al.**			**Alumina abrasive Amplitude of vibration Applied voltage Ferromagnetic particles size Finishing time Frequency of vibration Input current**	**m (material removed), Ra and percent improvement in surface finish**		**working gap and the circumferential speed of workpiece are the parameters which significantly influence the material removal, change in surface roughness, percent improvement in surface finish.**

IV.CONCLUSION

The mechanical energy in the fluid is stored due to the lines of the magnetic field in the Magnetorheological finishing application. The magnetic field density of the permanent magnet shows the application of polishing pressure applied to the Magnetorheological fluid that is intermediate between the tool and the work surface. The properties of MR fluid are dependent on the nature of base metal used, abrasive size i.e. mesh number of the composition and rotational speed as well as the nature of the material used for finishing.

- MRF finishing is an important process for the recent development in the magnetorheological fluid the micro finishing techniques can be utilized for the finishing of the external surface finish for the internal surface of any object.
- To avoid heating problem electromagnets are replaced by the permanent magnet nowadays to finish any ferrous material in comparatively less time.
- MRF finishing shows a greater control on the application of force whether it is high or lows it controls the application of the forces so precisely so that we can get a better surface finish

- overall it is a better technique for the finishing of ferrous material and for an optimum material removal rate and energy efficient.

REFERENCES

[1] Jayswal SC, Jain VK, Dixit P. "Modeling and simulation of the magnetic abrasive finishing process", The International Journal of Advanced Manufacturing Technology, 26(5-6):pp.477-490, 2005.

[2] Chang GW, Yan BH, Hsu RT. "Study on cylindrical magnetic abrasive finishing using unbonded magnetic abrasives", International Journal of Machine Tools and ManufactureApr,42(5):pp.575-583. 2002

[3] Shinmura T, Takazawa K, Hatano E. "Study on magnetic-abrasive finishing. Effects of machining fluid on finishing characteristics", Bulletin of the Japan Society of Precision Engineering.;20(1):pp.52-54. 1986

[4] Shinmura T, Takazawa K, Hatano E, Matsunaga M, Matsuo T. "Study on magnetic abrasive finishing", CIRP annals 1;39(1): pp.325-328,1990.

[5] Jha S, Jain VK. "Design and development of the magnetorheological abrasive flow finishing (MRAFF) process", International Journal of Machine Tools and Manufacture1;44(10): pp.1019-1029, 2004.

[6] Jha S, Jain V. "Modeling and simulation of surface roughness in magnetorheological abrasive flow finishing (MRAFF) process", Wear. ;261(7-8): pp.856-866, Oct 2006.

[7] Das M, Jain VK, Ghoshdastidar PS. "Fluid flow analysis of magnetorheological abrasive flow finishing (MRAFF) process", International Journal of Machine Tools and Manufacture. 1;48(3-4): pp.415-426. 2008.

[8] Kheradmand S, Esmailian M, Fatahy A. "A novel approach of magnetorheological abrasive fluid finishing with swirling-assisted inlet flow", Results in physics;6:pp.568-580, 2016.

[9] Das M, Jain VK, Ghoshdastidar PS. "Nano-finishing of stainless-steel tubes using rotational magnetorheological abrasive flow finishing process", Machining Science and Technology. 1;14(3): pp.365-389, 2010

[10] Singh AK, Jha S, Pandey PM. "Performance analysis of ball end magnetorheological finishing process with MR polishing fluid", Materials and Manufacturing Processes; 30(12): pp.1482-1489. 2015

[11] Singh AK, Jha S, Pandey PM. "Design and development of nano finishing process for 3D surfaces using ball end MR finishing tool", International Journal of Machine Tools and Manufacture.;51(2): pp.142-151, 2011.

[12] Niranjan M, Jha S, Kotnala RK. "Ball end magnetorheological finishing using bidisperse magnetorheological polishing fluid", Materials and Manufacturing Processes.;29(4): pp.487-492,2014

[13] Liu X, Wang L, Lu H, Wang D, Chen Q, Wang Z. "A study of the effect of nanometer Fe3O4 addition on the properties of silicone oil-based magnetorheological fluids", Materials and Manufacturing Processes. Feb 1;30(2): pp.204-209,2015

[14] Fei C, Zuzhi T, Xiangfan W "Novel process to prepare high-performance magnetorheological fluid based on surfactants compounding", Materials and Manufacturing Processes.;30(2): pp.210-215,2015

[15] Singh DK, Jain VK, Raghuram V. "Parametric study of magnetic abrasive finishing process", Journal of materials processing technology.;149(1-3): pp.22-29, 2004.

[16] Griffiths DJ. "Introduction to electrodynamics",pp.574-574,2005.

[17] Teimouri R, Baseri H. "Artificial evolutionary approaches to produce smoother surface in magnetic abrasive finishing of hardened AISI 52100 steel", Journal of Mechanical Science and Technology;27(2): pp533-539, 2013.

[18] Naresh Babu M, Muthukrishnan N. "Investigation on surface roughness in abrasive water-jet machining by the response surface method", Materials and Manufacturing Processes;29(11-12): pp1422-1428, 2014.

[19] Priyadarshi D, Sharma RK "Optimization for turning of Al-6061-SiC-Gr hybrid nanocomposites using response surface methodologies", Materials and Manufacturing Processes;31(10): pp1342-1350,2016.

[20] Yusup N, Zain AM, Hashim SZ. "Evolutionary techniques in optimizing machining parameters: Review and recent applications (2007–2011)". Expert Systems with Applications.;39(10): pp9909-9927,2012.

[21] Yusup N, Sarkheyli A, Zain AM, Hashim SZ, Ithnin N. "Estimation of optimal machining control parameters using artificial bee colony", Journal of Intelligent Manufacturing.;25(6): pp1463-1472. 2014.

[22] Zain AM, Haron H, Sharif S. "Application of GA to optimize cutting conditions for minimizing surface roughness in end milling machining process.", Expert Systems with Applications.;37(6): pp4650-4659, 2010.

[23] Kathiresan S, Mohan B. "Experimental analysis of magnetorheological abrasive flow finishing process on AISI stainless steel 316L", Materials and Manufacturing Processes;33(4): pp422-432,2018.

[24] Zhao ZD, Huang YH, Zhao YG. "Preparation of Magnetic Abrasive by Sintering Method. advanced Materials Research 2010 (Vol. 135, pp. 382-387)", Trans Tech Publications Ltd.

[25] Ahmad S, Gangwar S, Yadav PC, Singh DK. "Optimization of process parameters affecting surface roughness in the magnetic abrasive finishing process", Materials and Manufacturing Processes;32(15): pp1723-1729, 2017.

[26] Singh RK, Singh DK, Gangwar S. "Advances in Magnetic Abrasive Finishing for Futuristic Requirements-A Review". Materials today: proceedings.;5(9): pp20455-20463,2018.

[27] Li W, Li X, Yang S, Li W. "A newly developed media for magnetic abrasive finishing process: Material removal behavior and finishing performance", Journal of Materials Processing Technology.;260: pp20-29, 2018.

[28] Tang H, Yang W, Liu W, Ma J, Luo X. "Characteristics of fixed abrasive polishing for fused silica in the anhydrous environment", Optik.;202:163623, 2020.

[29] Zakeri M, Ramezani M, Nazari A. "Effect of the ball to powder weight ratio on the mechanochemical synthesis of MoSi2-TiC nanocomposite powder", Materials Research.;15(6): pp891-897, 2012.

[30] Chen HL, Li WH, Yang SQ, Yang SC. "Research of magnetic abrasive prepared by the hot pressing sintering process". In2010 5th IEEE Conference on Industrial Electronics and Applications (pp. 776-778). IEEE. 2010.

[31] Chen HL, Li WH, Yang SC. "Study on the performance and evaluating indexes of magnetic abrasive grains", In2009 4th IEEE Conference on Industrial Electronics and Applications (pp. 1673-1675). IEEE, 2009.

[32] Kuziora P, Wyszyńska M, Polanski M, Bystrzycki J. "Why the ball to powder ratio (BPR) is insufficient for describing the mechanical ball milling process", International journal of hydrogen energy.;39(18): pp 9883-9887, 2014.

[33] Niranjan MS, Jha S. "Experimental investigation into tool aging effect in ball end magnetorheological finishing", The International Journal of Advanced Manufacturing Technology.;80(9-12): pp 1895-1902, 2015.

[34] Shukla VC, Pandey PM. "Experimental investigations into the sintering of magnetic abrasive powder for the ultrasonic-assisted magnetic abrasive finishing process", Materials and Manufacturing Processes.;32(1): pp 108-114, 2017.

[35] Kala P, Pandey PM. "Experimental study on finishing forces in double-disk magnetic abrasive finishing process while finishing paramagnetic workpiece". Procedia Materials Science;5:pp1677-1684, 2014.

[36] Kumari C, Chak SK. "A review of magnetically assisted abrasive finishing and their critical process parameters", Manufacturing Review; 5:13, 2018.

[37] Bedi TS, Singh AK. "Magnetorheological methods for nano finishing–a review". Particulate Science and Technology.;34(4):pp412-422, 2016.

[38] Park BJ, Song KH, Choi HJ. "Magnetic carbonyl iron nanoparticle-based magnetorheological suspension and its characteristics", Materials Letters;63(15):pp1350-1352, 2009.

[39] Jain VK, Kumar P, Behera PK, Jayswal SC. "Effect of the working gap and circumferential speed on the performance of the magnetic abrasive finishing process", Wear; 250(1-12) pp:384-390, 2001.

[40] Singh J, Vaishya R, Kumar M (2019) "Fabrication of micro features on quartz glass using developed WECDM setup". ARPN J Eng Appl Sci 14:725-731

[41] Kumar M, Vaishya RO, Oza AD, Suri NM (2019) "Experimental Investigation of Wire-Electrochemical Discharge Machining (WECDM) Performance Characteristics for Quartz Material". Silicon 12:2211-2220. https://doi.org/10.1007/s12633-019-00309-z

[42] Kumar M, Vaishya RO, Suri NM (2020) "Machinability Study of Zirconia Material by Micro-ECDM". In: Sharma V, Dixit U, Sørby K, Bhardwaj A, Trehan R (eds) Manufacturing Engineering. Lecture Notes on Multidisciplinary Industrial Engineering. Springer, Singapore, pp 195-209. https://doi.org/10.1007/978-981-15-4619-8_15

[43] Dhiman P, Vaishya R, Kumar M (2019) " A review on machining by electrochemical discharge phenomena." Int J Tech Innov Mod Eng Sci 5:71-74.

[44] Kumar, M., R. Vaishya, and P. Parag. 2018. "Real-Time Monitoring System to Lean Manufacturing." Procedia Manufacturing 20: 135–140. doi:10.1016/j.promfg.2018.02.019.