Imperial Journal of Interdisciplinary Research (IJIR)
Vol-3, Issue-9, 2017
ISSN: 2454-1362, http://www.onlinejournal.in

Study of Magnetic Abrasive Finishing Using Diamond Abrasive

Simpy Atray[1] & Dhananjay Singh[2]
Department of Mechanical Engineering SITE, Meerut, UP, India

***Abstract**: In this paper, we study the internal finishing of stainless steel using diamond based loosely bonded magnetic abrasives and the effect of input process parameters on the performance characteristics like Percentage Improvement in Surface Finish (PISF) and Material Removal Rate (MRR). The stainless steel 304 grade tubes of 38 mm diameter and 1 mm thickness were used as work pieces. The preliminary experiments were conducted by using diamond based loosely bonded magnetic abrasives of different mesh sizes. The experiments were designed using Response Surface Methodology. It has been found that the diamond based unbonded magnetic abrasives have fine finishing capability and from AFM, SEM micrographs it has been concluded that tool marks and scratches are removed by MAF and there is no effect of MAF on surface of finished work piece. The maximum percentage improvement in surface finish over the initial surface finish was around 85% (At 300 mesh size, 60 min. machining time, 800 rpm rotational speed, quantity 40 gm and percentage of abrasives 40%). The finishing of stainless steel 304 grade tube proves the applicability of diamond based magnetic abrasives in industry as 304 grades is widely used in industry.*

***Keywords**: Magnetic Abrasive Finishing, Non-Conventional machining Process, Percentage Improvement in Surface Finish.*

INTRODUCTION

Some of the materials used in modern industries and industrial applications are difficult to finish with high accuracy and minimal surface defects using conventional machining and polishing techniques. Use of traditional machining techniques for finishing of these materials may lead to various defects like micro cracks, errors in work piece geometry and work piece surface distortions. Due to the these limitations of the traditional machining processes, there was need of new family of machining and finishing methods known as non-traditional or modern machining methods has been developed. In MAF, to form the magnetic abrasive brush, magnetic strength and magnetic abrasives are the primary requirements. These can be classified into two groups depending on the method of application of abrasive grains on the work piece. The first one is known as bonded abrasive process and the other one is known as loose abrasive process. In case of bonded abrasive processes, the geometry of the finished work piece depends on shape of abrasive tool formed by clasping together the abrasive grains within a matrix. Generally bonded process includes: Diamond wire cutting, Honing, Abrasive belt machining, Buffing etc. The abrasive grains are not connected to each other in loose abrasive process. They may be used without lubricant in the form of dry powder, or with lubricant in the form of abrasive slurry. In this process the independently moving grains are forced into the work piece with the help of some other object like polishing cloth. Processes employing loose abrasives include: Polishing, Lapping, Abrasive Flow Machining (AFM), Water-jet cutting, Magnetic Abrasive Machining etc. The Advanced Abrasive Finishing Processes can be divided into two groups to understand their working principles. First one includes Abrasive Flow machining (AFM), Elastic Emission Machining (EEM) and Chemo-Mechanical Polishing (CMP) where forces on the work piece acting during the finishing process are not possible to control externally. The second one includes Magnetic Abrasive Finishing (MAF), Magneto Rheological Finishing (MRF), Magneto Rheological Abrasive Flow Finishing (MRAFF), and Magnetic Float Polishing (MFP). In these processes, it is possible to externally control the forces acting on the work piece by varying electric current flowing in the magnetic coil or by changing the working gap while using a permanent magnet.

A change in the electric current, changes magnetic flux density in the working zone due to which, the normal force exerted by an abrasive particle on the work piece changes. This change in normal force changes finishing rate and critical surface finish that can be achieved by the process under the given finishing conditions. The experiments were designed using Response Surface Methodology. The response parameters were measured with help of high precision instruments (electronic balance, Surf test SJ-301, SPM and SEM) using standard measuring practices. It has been found that the diamond based unboned magnetic abrasives have fine finishing capability and from AFM, SEM micrographs it has been concluded that tool marks and scratches are removed by MAF and there is no effect of MAF on surface of finished work piece. The maximum percentage improvement in surface finish over the initial surface finish was around 85% (At 300 mesh size, 60 min. machining time, 800 rpm rotational speed, quantity 40 gm and percentage of abrasives 40%). The finishing of stainless steel 304 grade tube proves the applicability of diamond based magnetic abrasives in industry as 304 grades is widely used in industry.

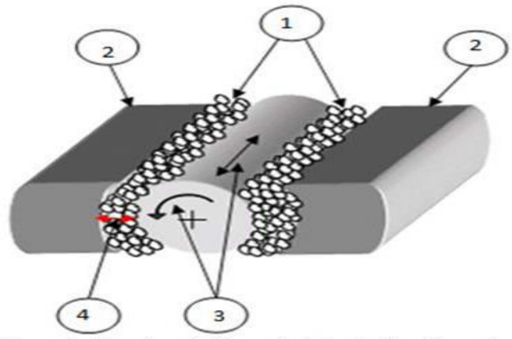
PRINCIPLE OF MAF

Magnetic Abrasive Finishing (MAF) is the process which is capable of precision finishing of different type of work pieces. In this process, usually ferromagnetic particles are sintered with fine abrasive particles (Al_2O_3, SiC, CBN, or diamond), and such particles are called ferromagnetic abrasive particles (or magnetic abrasive particles-MAP). In MAF process in which finishing action is controlled by the application of magnetic field across the machining gap between the work pieces and magnetic coil pole. The magnetic field acts as a binder and retains ferromagnetic abrasive particles in the machining gap.). In case of un bonded (un sintered) magnetic and abrasive particles (homogeneously mixed powder), the abrasive particles get entangled in between the chains and within the chains formed by ferromagnetic particles. MAF uses this FMAB for surface and edge finishing.

The FMAB has multiple cutting edges and it behaves like a multi-point cutting tool to remove material from the work piece in the form of tiny chips. Since the magnitude of machining force caused by the magnetic field is very low but controllable, a mirror like surface finish (Ra value in the range of nanometre) is obtained. MAF can also be used to perform operations such as polishing and removal of thin oxide film from high-speed rotating shafts. The principle of plane finishing in which work piece is given vibrations in vertical and horizontal direction and magnetic abrasive brush held by magnet is given rotational motion. When this brush of magnetic abrasives rotates with respect to work piece, the finishing will take place. The magnetic field needed for machining region is applied via yoke from a separately installed magnetic coil. The polishing pressure in conventional magnetic abrasive finishing process is affected by magnetic flux density as given by following equation **[5]**.

Polishing pressure, $P = B^2/2\mu_o (1-1/\mu_1)$

Here μ_1 is the relative magnetic permeability of magnetic brush, consisting of ferromagnetic material (pure iron), abrasive particles (alumina) and air.

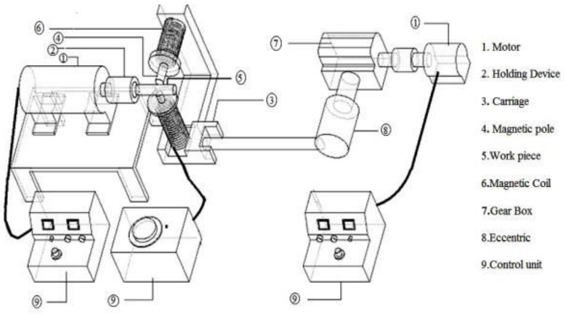


1.Magnetic Abrasives 2.Magnetic Poles 3. Rotation and Vibration of workpiece 4. Working Clearance

Working Principle of MAF

EXPERIMENTAL SET UP

The fabricated setup has major components like motor, holding device, carriage, magnetic pole, work piece, magnetic coil, gearbox, eccentric and control unit. The magnetic coil is installed on the frame to ensure that manual feed may be given to the magnetic coil along desired length of work piece. The magnetic coil consists of enamelled copper wire wound over magnetic core. Due care has been taken while installing the magnetic coil on to the carriage so that there is no direct contact between magnetic coil and the carriage in order to prevent leakage of magnetic flux. Non-magnetic brass bolts are used for screwing the frame to prevent leakage of current. The experimental setup comprising of a magnetic coil was further connected to a source where the magnetic coil becomes energized. This energized magnetic coil creates a magnetic field which confined to the small gap between the magnetic poles. The work piece tends to rotate in between the magnetic poles. Magnetic field is generated on each side of the work piece. Magnetic field strength can vary for experimentation with the help of variable dc supply. The magnetic field strength depends upon weight percentage of the magnetic particles, present in the magnetic abrasive powder. An autotransformer is connected to the motor of the experimental set up to control its speed. It works on the principle of reducing the speed of the motor by varying the supply voltage. Magnetic coil is connected to another control unit, the magnetic density of which is proportional to the magnitude of current flowing in magnetic coil.

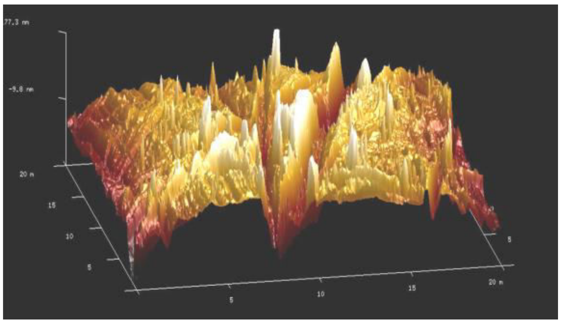


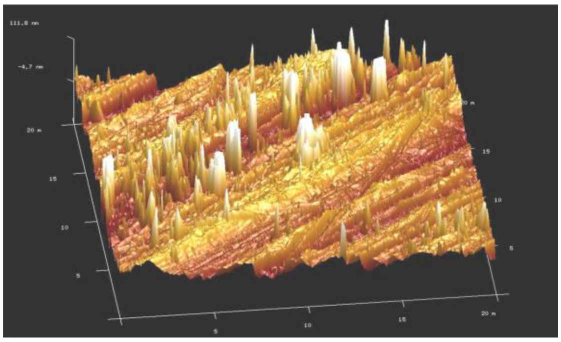
Schematic view of set up

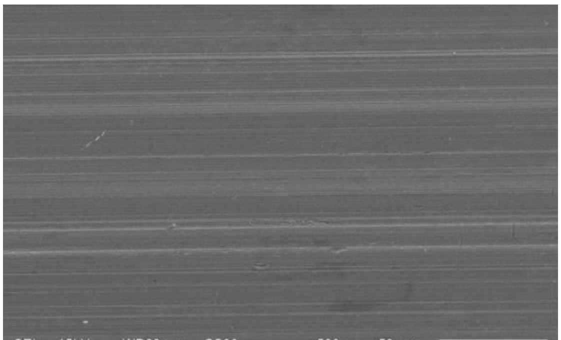
EXPERIMENTAL CONDITIONS

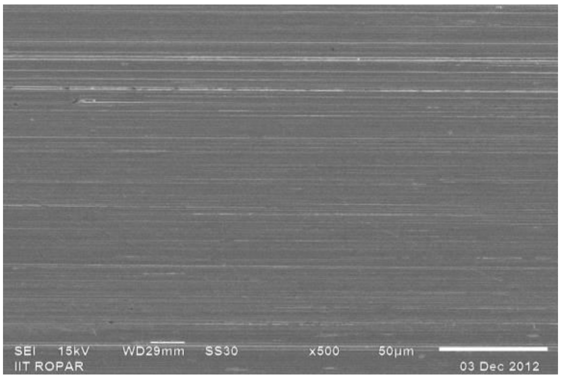
The experiment was performed keeping some parameters constant and varying other parameters like current, quantity of magnetic abrasives, and rotational speed of work piece and percentage of abrasives in magnetic abrasives. Before starting each experiment, the surface finish and weight of the bored work piece, was measured. The work piece was held in the holding device mounted on the motor, for providing rotational motion. The working gap between the work piece and the poles was kept constant during experimentation. The magnetic abrasive powder was prepared just before each test by adding the lubricant and fed to the work piece. To hold together the mixture of magnetic and abrasive particles for a longer time period, lubricating oil (5% by wt. of MA) was added to the mixture of ferromagnetic and abrasive particles. After addition of oil, mixture forms conglomerate. The conglomerate helps the MAPs in staying in weak bonded condition in the working gap in the initial stage. This conglomeration increases effective working time of MAPs before replacement. During the test, magnet was made active by switching on the electric supply power. The finishing operation was continued for 60 minutes. The MAPs were attracted to each other magnetically between magnetic pole and work piece along the lines of magnetic force. Ferromagnetic and abrasive particles were held together by the magnetic field, in the form of flexible magnetic abrasive brush. The abrasive particle of the flexible magnetic abrasive brush removes the peaks of the irregularities on the surface of the work piece being finished. Only those abrasive particles which are in direct contact with the rotating work piece surface, remove material by shearing in the same way as done in AFM. It was envisaged that some abrasive particles get blunt and if these abrasive particles (entrapped between the ferromagnetic particles) continue to rub (without cutting) against the work piece surface, improvement in the surface finish becomes slow and the force required for cutting increases. It was also envisaged that due to heat (heat generated due to friction between the abrasive particles and work piece and due to machining/finishing of work piece), the lubricating oil (weak bonding material) evaporate and it further weakens the bonding between the abrasive and ferromagnetic particles. Such weakly bonded (or unbonded) abrasive particles reach towards the bottom of the work piece and do not contribute towards cutting action. The work piece was taken out from the holding device, once the finishing operation was completed. After cleaning the work piece with acetone, its surface finish and weight were measured.

RESULTS









From AFM (Abrasive Force Microscopy) images it is concluded that at higher speeds the surface finish is poor. The heights of the peaks are non-uniform because of magnetic strength as well as abrasive particles protrusion heights are non-uniform. Smaller peaks indicate the area where abrasive particles are held more strongly than other areas and hence could reduce the peak heights more compared to other areas. AFM micrographs show that valley to peak height is reduced considerable by MAF and there is no bad effect of MAF on surface of finished work-piece.

The scanning electron microscope (SEM) is a type of electron microscope that images the sample surface by scanning it with a high energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition and other properties such as electrical conductivity.

The surface generated by boring consists of deep scratches produced by the interaction of abrasive cutting points with the work piece surface. The initial surface profile has periodic peaks and valleys generated by boring. However marks due to boring, pits and digs disappear after MAF but fine scratching marks produced by MAF appear on the surface. Most of the peaks have been sheared off to much smaller height by MAF resulting in improved surface finish. It shows that some deep scratches appear when finishing operation was performed at higher rotational speeds. It also shows that some deep scratches are left even after MAF, when finishing was performed using low quantity of magnetic abrasives and at low percentage of abrasives in mixture.

CONCLUSIONS

After carrying out the finishing on non-magnetic steel (304 Stainless steel) sheets with MAF process by using diamond based sintered abrasive, it is found that rotational speed, feed of work piece and machining time are the significant parameters that affect the percentage improvement in the surface finish.

At all levels of rotational speed, with increase in current, MRR decreases first and increases rapidly when current increases MRR increases at a higher rate with increase in rotational speed for low levels of current. For high levels of current it increases at a lesser rate for rotational speed when quantity of abrasives and percentage of abrasives are constant. Relatively higher values of the current and percentage of diamond abrasives may be selected for obtaining a better material removal rate. It is concluded that at higher rotational speeds the surface finish is poor. SEM micrographs show that valley to peak height is reduced considerably by MAF. Most of the peaks have been sheared off to much smaller height by MAF resulting in improved surface finish.

REFRENCES

[1] S.C. Jayswal, V.K. Jain and P.M. Dixit (2005), *"Modeling and Simulation of Magnetic Abrasive Finishing Process",* International Journal of Advance Manufacturing Technology, 26, pp.477–490.

[2] Hitomi Yamaguchi and Kotaro Hanada (2008), *"Development of Spherical Magnetic Abrasive Made By Plasma Spray*", Journal of Manufacturing Science and Engineering, Vol. 130, pp.71–79.

[3] V.K. Jain, Prashant Kumar, P.K. Behera and S.C. Jayswal (2001), *"Effect of Working Gap and Circumferential Speed on The Performance of Magnetic Abrasive Finishing Process", "*Wear*"*, 25, pp.384–390.

[4] Shaohui Yin and Takeo Shinmura (2004), *"Vertical Vibration-Assisted Magnetic Abrasive Finishing and Deburring for Magnesium Alloy*", International Journal of Machine Tools and Manufacture, 44, pp.1297–1303.

[5] V.K. Jain (2009), *"Magnetic Field Assisted Abrasive Based Micro-/Nano-Finishing",* Journal of Materials Processing Technology, 209, pp.6022–6038.

[6] Shaohui Yin and Takeo Shinmura, (1998) "*Study of Magnetic Abrasive Finishing Process Using Pulsed Finishing Pressure and Its Processing Characteristics",* International Conference at Graduate School of Engineering, Utsunomiya University, Japan, pp.237-244.

[7] Hitomi Yamaguchi and Takeo Shinmura (2000), *"Study of an Internal Magnetic Abrasive Finishing Using a Pole Rotation System Discussion of the Characteristic Abrasive Behavior",* Journal of The International Societies for Precision Engineering and Nanotechnology 24, pp.237–244.

[8] V.K. Jain (2000) "Advanced Fine Finishing Processes", *International Journal of Manufacturing Sciences and Production*, Vol. 2, No.1, pp. 55-68.

[9] Ahmed B. Khairy (2001), *"Aspects of Surface and Edge Finish by Magneto abrasive Particles,"* Journal of Materials Processing Technology, 116, pp.77-83.

[10] Sehijpal Singh and H.S. Shan (2002), *"Development of Magneto Abrasive Flow*

Machining Process", International Journal of Machine Tools and Manufacture, 42, pp.953–959.
[11] Hitomi Yamaguchi, Takeo Shinmura and Maki Takenaga (2003), *"Development of A New Precision Internal Machining Process Using An Alternating Magnetic Field*", Precision Engineering, 27, pp.51–58.
[12] T. Mori*, K. Hirota and Y. Kawashima (2003), *"Clarification of Magnetic Abrasive Finishing Mechanism",* Journal of Materials Processing Technology, 143-144, pp.682-686.
[13] Shaohui Yin and Takeo Shinmura (2004), "*A Comparative Study: Polishing Characteristics and Its Mechanisms of Three Vibration Modes in Vibration-Assisted Magnetic Abrasive Polishing*", International Journal of Machine Tools and Manufacture, 44, pp.383–390.
[14] Dhirendra K. Singh, V.K. Jain and V. Raghuram (2005), *"Super finishing of Alloy Steels Using Magnetic Abrasive Finishing Process"* International Journal of Advance Manufacturing Technology, 30, pp.671–675.
[15] Hitomi Yamaguchi, Takeo Shinmura Megumi Sekine (2005), *"Uniform Internal Finishing of SUS304 Stainless Steel Bent Tube Using A Magnetic Abrasive Finishing Process*", Journal of Manufacturing Science and Engineering, August, Vol. 127, pp.605-611.
[16] Y. M. Baron, S.L. Ko and J. I. Park (2005), *"Characterization of The Magnetic Abrasive Finishing Method and Its Application to Deburring*", Key Engineering Materials, Vol. 2, pp.291-296.