DEVELOPMENT AND PERFORMANCE EVALUATION OF MAGNETIC ABRASIVE SETUP FOR THICK CYLINDERS

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By

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled **"Development and performance evaluation of magnetic abrasive setup for thick cylinders"** in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of (Mr. Gursharan Singh Gandhi, Assistant Professor) Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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"There is no substitute to hard work."

-Thomas A. Edison

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(Vaibhav R. Nanavare)

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LIST OF ABBREVIATIONS

MAF	Magnetic abrasive finishing
MAP	Magnetic abrasive particles
MAFB	Magnetic abrasive flexible brush
RSM	Response Surface Methodology
PISF	Percentage improvement of surface finish
CCD	Central composite design
ANOVA	analysis of variance method
MRM	Material removal mechanisms
MAB	Magnetic Abrasive Brush
UAMAF	Ultrasonic-assisted magnetic abrasive finishing
MRR	Material removal rate
DDMAF	Double Disk Magnetic Abrasive Finishing process
PAM	Plasma Arc Machining
EDM	Electro Discharge Machining
ECM	Electro Chemical Machining
AJM	Abrasive Jet Machining
USM	Ultrasonic Machining
IBM	Ion Beam Machining
LBM	Laser Beam Machining
EBM	Electron Beam Machining

ABSTRACT

Magnetic Abrasive Finishing (MAF) is a non-conventional finishing method, that can improve the surface quality. The finishing of the surface in MAF is achieved by removal of micro-chips by the magnetic abrasives particles (MAP) under an induced magnetic field. This paper deals with the detailed parametric study of finishing of leaded tin bronze thick tube internally by MAF. The main objective is to design and fabricate a MAF setup to achieve Nano-finishing of the finished surface. Statistically designed experiments based on Taguchi methods shows that all input parameters have significant effect on the surface roughness obtained. The study emphases on achieving excellent surface finish with low material removal for application of various industrial uses.

CHAPTER 1
INTRODUCTION

1.1 Conventional and Non-Conventional Machining Processes

With the developments in field of robotics, medical research, CNC machines etc. there is desperate necessity of machining methods which are capable of giving handy surface complete finished alongside tight tolerances. Furthermore this, new materials are constantly produced to acknowledge those necessity of present industry. The properties of few materials are such that they face quite a lot of difficulty to be machined by conventional methods of machining. A family of new machining systems called non-conventional machining processes is being established. These recently developed methods are serving the industry to accomplish the essential degree of accuracy and surface finish. In contrast to these measures the regular machining forms have constrained execution and productivity. Hard to machine materials and complex shapes can also be machined using these non-conventional processes. Mentioned are some of the non-conventional processes are broadly being used now-a-days are:

i Plasma Arc Machining (PAM).

ii Electro Discharge Machining (EDM).

iii Electro Chemical Machining (ECM).

iv Abrasive Jet Machining (AJM).

v Ultrasonic Machining (USM).

vi Ion Beam Machining (IBM).

vii Laser Beam Machining (LBM).

viii Electron Beam Machining (EBM).

These machining methods have their own working domain. They are not here to substitute the conventional machining processes. The determination of a machining process relies upon the following features:

- Physical parameters.
- Material properties of workpiece
- Workpiece shape.
- Process capability.
- Financial considerations.

1.2 Magnetic Abrasive Finishing Process

Conventional fine finishing operations, for example, grinding, lapping, or honing utilize a rigid or unbending tool that subjects to the work piece to significant normal stresses which may cause micro cracks bringing about decrease in quality and strength of the machined part. A relatively innovative fine finishing method, called magnetic abrasive finishing (MAF) is a propelled finishing process in which the cutting force is primarily controlled by magnetic field. It limits the likelihood of micro cracks on the work piece, especially in hard brittle material, because of control low forces acting on abrasive particles. This process can produce surface roughness of nanometer variety on the level surfaces and in addition external and internal cylindrical surfaces. It can likewise be utilized for internal finishing of non-rotatable work like engine cylinder blocks, bent tubes and elbows. The MAF procedure offers many advantages, for example, self-adaptability, controllability, self-sharpening, and the finishing tools require neither dressing nor compensation. In Magnetic Abrasive Finishing, the work piece is to be kept between the two magnetic poles. The working gap between the magnet and the work piece is loaded with magnetic abrasive particles (MAPs), made from ferromagnetic particles and abrasive powder. MAPs can be either used as bonded or unbonded. Bonded MAPs are set up by sintering of ferromagnetic particles and abrasive powder while unbonded MAPs are a mechanical blend of ferromagnetic particles and abrasive powder. Small amount of lubricant is also added with unbounded MAPs. The reason of lubricant is to offer some holding strength amid the constituents of MAPs. The magnetic abrasive particles on setting up the magnetic field join each other along the lines of magnetic force between the work piece and the magnetic pole.

This joining of abrasives is known as magnetic abrasive flexible brush (MAFB). For the finishing operation MAFB acts similar to a multi-point cutting tool. At the point when the magnetic N-post is pivoting, the MAFB likewise turns like an adaptable grinding wheel and according to the forces which are acting on the abrasive particles finishing quality of the surface is achieved. It is normally expected that there is no slip between the N-post and MAFB. In the MAF procedure, a cutting tool that comprises of ferrous particles and non-ferrous abrasives under oil has flexibility. The tool can expel a little measure of material from a work piece and afterward a superior surface can be delivered subsequent to cleaning the work piece without damage at first glance because of this flexibility. By and by, it is exceptionally hard to polish non-ferrous materials utilizing the MAF process since this process is on a very basic level through the assistance of magnetic forces.

A magnetic abrasive finishing method is characterized as a method by which material is evacuated, such that the surface finishing and deburring is performed with the existence of an induced magnetic field in the machining region. The strategy was initially presented in the Soviet Union, with assist key research in different nations including Japan. These days, the investigation of the magnetic field helped completing procedures is being led at modern levels far and wide.

Majority of the past research work has been centred around the finishing qualities and component from a plainly visible perspective utilizing the surface roughness profiles as the measure. Nonetheless, those methodologies don't sufficiently portray the behaviour of abrasive cutting edges acting in contradiction of the surface amid the expulsion procedure.

1.3 Processing Principle of MAF

The poles placed alongside the Leaded Tin Bronze bushing, produce the magnetic field desired for attracting the magnetic abrasive for the finishing by magnetic force. The electromagnet setup is installed on the vertical drill machine. The workpiece to be finished is installed on the spindle of the machine. The spindle is rotated at various rotational speed as per the parameters set. The space amid the workpiece and electromagnet is kept constant. The abrasive particles are introduced in the tube. The electromagnets generate the required magnetic field to form the magnetic abrasive finishing brush (MAFB). The MAFB should be flexible enough. This depends on the magnetic field strength. The magnetic field should be that strong to produce the MAFB but shouldn’t be that strong that it would affect the surface finish negatively. The Magnetic abrasive particles through magnetic pressure would finish the work piece. Aluminium oxide based sintered abrasives are utilized as magnetic abrasives in this study.

1.4 Factors Affecting MAF

1. **Magnetic flux density:** The force acting on the abrasive particles is determined by the variation in the magnetic flux density in the machining gap, which during MAM generates finishing pressure on the work piece surface. In most of studies it is observed that the range of magnetic flux density is 0.4T to 1.2T.
2. **Working gap:** Increasing the machining gap will decompress the magnetic brush and lowers down the magnetic flux density, and therefore the strength of the brush becomes low. This will result in weaker magnetic force acting as well as decreased material removal. The working gap in most of the cases is varied from 1 to 3mm.
3. **Abrasive grit size:** To acquire the smoothness of the surface with as less as material expulsion, the surface must be cut steadily from the pinnacles of the uneven surface. The higher number of abrasive grains, the smaller is the force that follows up on every abrasive squeezed against the surface. This outcomes in the smaller profundity of cut by smaller finishing force of the abrasive, which in the long run delivers smoother finished surface. From 70 micrometres and 600 micrometres the abrasive grit size is varied.
4. **Lubricant:** Lubricant must maintain the condition for smooth relative movement of the abrasive against the work piece. Increment of lubricant improves the material expulsion, producing smooth finished surface in a much shorter finishing time. The level of lubricant is differed from 5 to 25 % of the volume of abrasives.
5. **Machining time:** Material removal rate be contingent upon machining time. In utmost of the experiments the machining time is varied in the range of 10 to 60 minutes.
6. **Rotational speed:** Material removal is directly proportional with work piece rotational speed and after some value of surface finish is adversely affected due to the speed jumbling of abrasive starts. Usually it is kept between 300-1200 rpm in various experiments.
7. **Material and size of work piece:** Stainless steel, Brass, Ceramic, Aluminium etc. are the materials on which most of the work is being done. Surface finish and material removal produce diverse results depending on the selection of the work piece material.

8. **Vibration frequency:** In utmost of the situation the freq. is altered between the range of 0-5 Hz, but then in some of the extremely odd cases frequency is considered almost up to 20 Hz.
9. **Vibration amplitude:** Amplitude in most of the experimentation is varied from the range of 1mm to 2 mm.
10. **Percentage of iron in magnetic abrasive:** Iron percentage of the abrasive volume is usually varied from 60 to 90 %.

1.5 Merits of Magnetic Abrasive Machining

- Self-adaptability, controllability, self-sharpening and also the finishing tool require neither dressing nor compensation.
- Abrasive grains are spread homogeneously over the treated surface, this allows precise finishing of complex-shaped components.
- Instantaneous temperature spikes can be readily avoided.
- On ferromagnetic materials selective polishing is possible.
- Instantaneous temperature spikes can be easily avoided.
- Won't cause pollutant problems.
- As cutting forces are small, minor stresses are induced in machined component.
- Material surface is free from burns and thermal defects.
- Low energy consumption.
- Non- ferrous materials can also be finished with ease.
- Simple in implementation.
- From economical point of view its more efficient.

1.6 Limitation of Magnetic Abrasive Machining

Magnetic abrasives are uncommon and are a bit expensive due to exceptional production process.

1.7 Magnetic Abrasives

An abrasive is a material, regularly a mineral that is utilized to finish a work piece through rubbing which prompts some portion of the piece being worn away. Abrasives are to a great degree ordinary and are utilized broadly in a wide assortment of domestic, technological, and industrial applications. This offers ascend to a substantial variety in the chemical and physical structure of abrasives and additionally the shape of the abrasive. Basic uses for abrasives incorporate polishing, honing, sharpening, buffing, cutting, drilling, grinding, and abrasive machining.

Abrasive particles are divided into two broad categories, that are, natural and artificial.

1.7.1 Natural abrasives:

These are produced by uncontrolled forces of nature. These are:

- **Solid quartz:** It is the most profuse mineral in the earth's mainland crust. It comprises of a lattice of silica tetrahedral. It is utilized as abrasive or as Piezo electric crystal.
- **Brown super emery:** Emery is hard rock type which is used to make abrasive powder. It comprises of 30-40 % Iron and 50-60 % crystalline Al_2O_3 and also some other impurities. It is one of the inexpensive abrasives.
- **Corundum:** It is a crystalline type of aluminum oxide and one of the stone framing minerals. It is normally evident, yet can have diverse colours when debasements are available. Its arrangement is 75-90 % crystalline Al_2O_3 and Iron. Because of Corundum's hardness, it can scratch practically every other mineral, deserting a dash of white on the other mineral. It is usually utilized as a abrasive, on everything from sandpaper to vast machines utilized as a part of machining wood, plastics and metals.
- **Diamonds:** Diamonds are particularly prestigious as a material with superlative physical qualities; they make amazing abrasives since they can be scratched just by different jewels which additionally mean they hold a polish greatly well and hold a gloss.

- **Garnet:** Garnet is a gathering of minerals that have been utilized since the Bronze Age as gemstones and abrasives. Garnets are frequently found in red, yet are accessible in a wide assortment of hues spreading over the whole range. Garnet sand is a decent abrasive and a typical swap for silica sand. Blended with high pressure water, garnet is utilized to cut steel and different materials in water jets. Garnet sand is likewise utilized for water filtration media.

1.7.2 Artificial abrasives:

- **Aluminium Oxide:** Aluminium oxide is referred to as alumina in the ceramic, mining and material science communities. It is delivered by the Bayer procedure from Bauxite. Its most critical utilize is in the generation of Aluminium metal, in spite of the fact that it is additionally utilized as a abrasive because of its hardness and as a stubborn material because of its high melting point.
- **Silicon Carbide:** Because of the uncommonness of natural silicon carbide, it is normally man-made. Regularly it is utilized as an abrasive. The least complex assembling process is to join silica sand and carbon in an Acheson graphite furnace at a high temperature, in the vicinity of 1600 and 2500º C. Unadulterated SiC is vapid. The brown to black colour of modern items comes about because of iron impurities.
- **Boron Carbide:** Boron Carbide is a to a great degree hard ceramic material utilized as a part of tank reinforcement, bullet proof vests, and various mechanical applications. It is the fifth hardest material known behind boron nitride, diamond, ultra-hard fullerite, and diamond nano bars. A considerable lot of its application rotate around its wear protection including, for example, utilizes as abrasives and as nozzle material.
- **Boron Nitride:** Boron Nitride is a double substance compound, comprising of equivalent quantities of boron and nitrogen molecules. Boron nitride is isoelectronic with carbon, and like carbon, boron nitrides exists as different polymorphic structures, one of which is comparable to diamond and on practically equivalent to graphite. Cubic boron nitride is created by treating hexagonal boron nitride at high temperature and pressure, much as manufactured diamond is delivered from graphite.

In the current work aluminium oxide combined with iron (sintered) are selected as magnetic abrasive. Both Aluminium oxide and Iron particles are selected of 300 mesh size. Aluminium oxide and Iron particles are mixed in the ratio of 80% and 20% by weight respectively.

1.8 Applications of Magnetic Abrasive Finishing Process

Following are some of the applications of Magnetic Abrasive Finishing:

- MAF can be utilized for inner surface finishing of long and wide size elbows, slim tubes and so on.
- MAF is relevant for delivering exceedingly finished inner surfaces of workpieces utilized as a part of basic applications, for example, semiconductors.
- MAF can likewise be utilized to finish hard to machine materials. As per an examination it is conceivable to finish SI3N4 bar utilizing diamond coated magnetic abrasives.
- MAF can likewise be utilized for edge finishing.
- MAF is additionally material for inner finishing of thin austenitic steel tubes, which passes on fluid solutions in pharmaceutical industrial facilities.
- MAF does not require use of dangerous arrangements of acids and soluble bases this innovation is more best both from natural and financial perspectives.
- MAF can be utilized to finish the parts in which high precision and high accuracy is most needed like wave-guides, vacuum tubes, medical instruments, etc.

CHAPTER 2
SCOPE OF THE STUDY

- Mechanically mixed abrasives can be utilized for economic purpose.
- The percentage composition of aluminium oxide and ferrous can be varied.
- Diamond paste and Fe can be used for preparation of magnetic powder for varying results.
- The study can also be done on numerous materials like aluminium, copper, ceramics and also various non-magnetic materials.
- The effects of the MAF process can also be studied by using permanent magnets.
- The whole study can also be performed by inducing vibrations.

CHAPTER 3
OBJECTIVES OF THE STUDY

Considering the literature obtained on Magnetic Abrasive Finishing, the current research work is being considered with the subsequent objectives:

- To develop an innovative Magnetic abrasive finishing setup for inner surface finishing of tubes
- To investigate finishing performance of Magnetic abrasive finishing setup for finishing Leaded Tin Bronze (SAE 660) bushing internally.
- To achieve Nano-finished surface by the MAF apparatus developed.
- To examine the effects of input parameters on the performance features like PISF by the use of response surface methodology.

CHAPTER 4
LITERATURE REVIEW

Magnetic abrasive finishing is one of the non-conventional machining methods. A great deal of work has been done in most recent two decades or somewhere in the vicinity. This part gives the understanding into the sort of work has been done till date here. The literature review has been displayed in sequential order.

Sasan Khasalaj Amnieh et al., (2017) proposed an apparatus for carrying out magnetic abrasive finishing of spiral groves, which was done using Al 7075 cylindrical tube specimen. Experimentation for the same were carried out by installing the MAF setup on a CNC machine. By setting up a magnetic field with the help of Nd-Fe-B magnets and varying parameters like rotational speed, finishing time and abrasive mesh number they studied the effect of these parameters on the surface finishing of the work piece. The experimentation results showed that both the rotational speed as well as the finishing time showed a direct proportionality relation with the surface roughness improvement. In contrast to these two parameters, the rotational speed and the finishing time, the abrasive mesh number didn’t show a consistent relation with the change in surface roughness. The parameters also had direct influence on the material removal rate. The author concluded that on increasing the rotational speed and the finishing time, the amount of material removed kept on increasing, while the amount of material removal decreased on increasing the mesh number of the abrasive particles used in the finishing process. Setting the optimal values for the given parameters resulted into improvement of surface roughness as well as reduction the amount of material removed verifies the capability of the process for surface finishing of internal spiral grooves.

Sumit et al., (2017) experimented magnetic abrasive finishing (MAF) on Stainless Steel-409 workpiece. The objective of the study was to achieve Nano-finish on the workpiece surface. Parameters such as abrasives mesh size, percentage of Iron powder and current was evaluated to achieve the results. In this study a set of experiments was conducted by applying Response Surface Methodology (RSM). The effects of the above-mentioned parameters were examined on the percentage improvement of surface finish (PISF) and material removal. It was observed that with increase in the value of current and also percentage of iron powder, the material removal also increased. The same thing was observed with PISF also. Percentage of Fe powder, current as well as mesh size of abrasives were directly proportional to material removal. In this experimentation Nano-finishing of the workpiece was achieved.

M. R. Muhamad et al., (2016) studied and experimented the effect of combination of electrolysis process and MAF process on finishing characteristics of the inner surface of an A6063 aluminium pipe. The authors stated that the electrolysis produced aluminium oxide film on the inner surface which indeed helped in the acceleration of removal of surface initial hairline morphology. This film was later on removed with the help of MAF process which gave enhanced improvement in surface roughness. The experimentation of MAF was carried out by varying working gap, ECM for current values and iron powder and abrasive combination. Their results indicated that smaller iron particle size contributed sufficient machining force and caused fewer scratches on the work piece. The experiments carried out for the combination of the two-process revealed positive results. The whole study was done to reduce the time taken for the finishing process and electrolysis process actively assisted MAF process by initially promoting surface planarization and reducing a huge amount of finishing work. By doing so the initial time-consuming process by only following MAF was tremendously cutting it down too few minutes. Thus, proving the excellence of the Electrolysis Magnetic Abrasive Finishing (EMAF) process.

NhatTan Nguyen et al., (2016) proposed a theory for solving the problem for finishing of multi-curved surface with the help of MAF. They experimented SUS202 work piece on a vertical milling machine process with the help of MAF. Designing and manufacturing of the electromagnets in the form of upward working gap was required. The setup was designed in such a way that combination of N-S poles formed a ring magnetic field that makes MAPs parcelled well on the work piece's surface. After validating the calculated values by experimentation mirror like images of surface finishing were obtained by the authors giving an excellent result to the proposed theory. The setup arrangement effectively worked on finishing simultaneously convex and concave surface, thus proving that it can be widely used in application of industrial finishing of multi-curved surface.

Vijay Kumar Jain et al., (2016) studied the effect of different parameters such as applied magnetic field, rotational speed, and the concentration of abrasive particles and iron particles in FMAB on the finishing forces that are generated on the work piece. Normal and tangential forces play quite a vital role in the finishing of the surface. Optimizing these values can lead to quality surface finishing. For experimentation purpose the designed setup was mounted on a vertical milling machine. The results state that normal and tangential force are mostly influenced by current supplied to the electromagnets and the working gap. Suppling more current and setting less working gap, increased both the forces magnitude. The same output was obtained on increasing the rotational speed. Abrasive particle mesh number had negligible effect on normal, while tangential force kept on decreasing as the mesh number of the abrasive particles was increased. Percentage composition of oil also affects the tangential force as it influences the shearing effect work piece and abrasive particles, but this parameter won’t affect the intensity of normal force.

Girish Chandra Verma et al., (2016) introduced a novel tool based on magnetic abrasive finishing principle for polishing holes, blind holes, grooves, and vertical surfaces. The tool designed consists of two permanent magnets of identical poles facing each other, this helps in creating a high density magnetic flux around the circumferential area between the magnets. The setup was installed on a vertical milling machine and experimentations were carried out. To evaluate the performance of the tool, the authors have performed the experiments based on central composite design (CCD) technique on stainless steel pipes. The obtained results are then examined by analysis of variance method (ANOVA). The outcomes prove that magnetic flux density is an important parameter in the given range of variables.

Harinder Singh Grewal et al., (2015) investigated different parameters of MAF process individually on the basis of percentage improvement of surface finishing (PISF). Parameters like rotational speed, lubricant type, quantity of magnetic abrasive and machining time were examined. The setup was mounted on a lathe machine. Electromagnets were used, and the magnetic field was set accordingly by increasing or decreasing the A.C. supply. Taguchi method for design of experiments was used. The optimal surface roughness was achieved by with 550 rpm using toothpaste as a lubricant. Also, the PISF increased with increase of speed up to 550 rpm and later started decreasing with any increase in speed. PISF went down with the increase of quantity of abrasives because at the high level of quantity of abrasives the Flexible Magnetic Abrasive Brush (FMAB) was not generated. Improvement in surface finish with all the lubricants kept on reducing with increase in machining duration.

Y. Choopani et al., (2015) investigated the effect of parameters like working gap, work piece rotational speed, and material removal mechanism of the MAF process on the external surfaces of the AISI 440C stainless steel cylindrical parts. For controlling the distance between the work piece and magnetic poles the setup had adjustable magnets. Lathe machine provided the rotational movement of the work piece. The setup had a suction pump by means of which abrasive slurry was injected to improve the finishing surface quality. It was observed that by reducing the working gap, the surface roughness had increased. Also, improvement in surface roughness was observed on increasing the work piece rotational speed up to 355 rpm. The authors study also states that using the diamond paste as the abrasive tool as compared with Al2O3 or SiC abrasive slurry injection, uniform surface can be achieved and in shorter time an appropriate smooth surface was possible.

Farzad Pashmforoush and Abdolreza Rahimi, (2015) studied the material removal mechanisms (MRM) of MAF process. They simulated the MAF process as an indentation and sliding method of a piercing abrasive and the main MRM were attained by MAF of BK7 optical glass. The setup for the experimental work consisted of magnetic abrasive particles, work piece, and Nd-Fe-B permanent magnets. The magnets were fixed on a holder and were mounted on the vertical milling machine's spindle. The authors have done few pre-experimentation and later with the results have decided to use sintered abrasive particles to get better finishing results. They deduced that the parameter MAP size and abrasive size were dominant among the rest. The increase in the size of the MAPs and abrasives directly lead to increase in the value of normal force which in turn if exceeding the optimal limiting started causing micro-fractures on the work piece. While for smaller sizes of MAPs and abrasives, the governing mechanism was micro-cutting but with the increase in size it shifts to micro-fracture.

Jinzhong Wu et al., (2015) studied the effect of low frequency alternating magnetic field on the MAF process. To polish the SUS 304 stainless steel plate by using low frequency magnetic field they designed and fabricated their MAF setup. Parameters like rotational speed, cutting fluid and current frequency to study the change in surface finishing and material removal. On experimentation they plotted their results and found out that both the material removal and finishing force were directly proportional to the magnetic pole's rotational speed. They found out that angle of variation of magnetic particles also played an important role in the finishing characteristic of the material. The upsurge of angle variation did endorse the roll of abrasive particles and also enhanced the operation rate of the abrasive. The results showed that angle of variation was inversely proportional to the finishing force. Neat cutting oil proved to be a better option than water soluble cutting fluid and silicon fluid when used it was used in MAF process. It was observed that neat cutting oil combined well with magnetic particles and abrasives adequately. It also helped the magnetic cluster to yield achievable fluctuating magnetic force.

A. Y. Jiao et al., (2015) worked on a theory that would improve the surface homogeneity and surface integrity with numerous trajectories by afresh self-designed experiment device. They experimented three varieties of polishing trajectories with involved revolution motion to magnetic abrasive brush based on MAF process. The setup was designed in such a way that both rotational and revolutionary motion were performed on the work piece plate with the help of motor drivers. The movement of surface was restricted by vacuum absorption method. The results concluded that it not only enhances the surface consistency and surface excellence but also can significantly increase the effective finishing region by refining the trajectory of Magnetic Abrasive Brush (MAB). Attaching changed revolution radius to MAB decreases the maximum height variance in polishing region. Also, trajectories of magnetic abrasive particles mostly go through the side and middle polishing regions; it was constant with the features which polishing region and side regions.

H. Yun et al., (2015) modified and developed a new technique as of MAF for alumina ceramic tubes to improve the efficiency and irregular texture of inner surface. They accomplished this by presenting a new technology of ultrasonic-assisted magnetic abrasive finishing (UAMAF). Parameters like work piece speed and frequency were set to check for surface roughness and material removal rate (MRR). For the experimentation inside the ceramic tube a V-shaped magnet along with MAPs is placed. The V-shaped magnet enhanced the magnetic force following up on MAPs. Additionally, the V-shaped magnet is induced to ultrasonic vibration with some amplitude and frequency. On comparison of results of UAMAF with the MAF process proved that the MRR and also the surface roughness is significantly improved with the assistance of the induced vibrations. Also on increasing the frequency, the surface quality improved and material removal was also increased. The work piece speed also played a substantial role in the removal of material, but it had slight influence on the surface roughness.

Hamzeh Shahrajabian et al., (2015) examined the effects of gap between poles and tube, rotational speed, finishing time and abrasive ratio on surface roughness. The mechanical mixture Fe and Aluminium oxide was taken into consideration as abrasives. The fixture consisting of four magnets placed at an angle of 90° degrees to each other were mounted on a lathe machine. The results showed that on increasing the working gap, the surface roughness also increased. On increasing the abrasive ratio from 25% to 50%, the surface roughness was not attained as expected. But on further increasing the ratio surface roughness kept on increasing. Increasing the work piece rotational speed almost up to 750 rpm, the surface roughness was improved. Ahead of this speed an appropriate finishing is not achieved. Finishing time also influenced the surface roughness. Decreasing the finishing time from 20 to 5 minutes, the surface roughness increased.

Lida Heng et al., (2015) introduced an innovative un-bounded magnetic abrasive by preparing diamond and CNT particles abrasive particles mixed with Fe particles for finishing the surface Mg alloy, and later the surface and dimensional accuracy were investigated. Their MAF setup consisted of a high-speed spindle controller, programmable controller, slider power, motion controller, air spindle, air cylinder, work piece, electric slider and magnet. On finished with CNT particles, the finest value of Ra, i.e., 0.02 μm, was attained at an rpm of 25000 due to extreme minute grain size along with high thermal conductivity of CNT and high strength abrasives particles. When the bar was finished by CNT particles blended with diamond abrasive (1 μm) in various rotational speeds, it was observed that at 25000 rpm proved to be the most optimum speed for improving finish of Mg alloy bar.

Baljinder Singh and Charanjit Singh Kalra, (2015) prepared Aluminium oxide based sintered magnetic abrasives. It consisted of iron powder (300 mesh size) and the aluminium oxide (300 mesh size). The experiments performed on Brass tubes examine the effects of different parameters rotational speed of work piece, quantity of abrasives, abrasive mesh size, working gap and machine time. The permanents magnets induced magnetic field and inside the brass tube magnetic abrasives were placed. The working-gap in between the magnets and work piece could be altered based on the OD of the work piece. The results conclude that surface roughness designates that machining time and amount of magnetic abrasives are important parameters influencing surface roughness. The optimal processes parameters were 220 mesh size of abrasive particles, 15 grams of magnetic abrasive, 4 mm working gap, 80 minutes of machining time, and 600 rpm rotational speed.

Prateek Kalaa and Pulak M. Pandey, (2014) investigated the torque and finishing force in Double Disk Magnetic Abrasive Finishing process (DDMAF). The parameters investigated were upper and lower working gap, rotational speed and abrasive wt. %. The setup comprised of lower and upper disks of Al with blind holes (4 in number) in each disk. Ten tiny magnetic disks were placed inside each of those blind holes. Each set of magnetic disks were placed in such a way that they formed a magnetic tool by means of four alternate poles. They also designed a fixture to install the dynamometer. Their results outcome showed that all four parameters inversely influenced normal force. The maximum influence was observed on varying lower working gap. Increase in upper and lower working gap or abrasive wt. percentage gave rise to in decline in finishing torque. Though, the results showed that any increment in rotational speed produced an increment in finishing torque. The finishing torque was mostly influenced by lower working gap.

Yi-Hsun Lee et al., (2014) developed a surface polishing method by the combinayion of planetary motion with 2-D vibration-assisted magnetic abrasive finishing also coined as PM-2DVMAF. Planetary motion involved both rotation as well as revolution, consequently creating radial acc., which strengthened the normal force applied on the work piece surface. Their setup of PM-2DVMAF control system comprised of the PLC, servomotors and motor drivers. Motor drivers are used to receive the digital signals that are sent by the PLC which in turn drive the servomotors for diverse alterations and handles so as to confirm that machining is directed under the identical conditions. PM-2DVAMAF caused abrasives to revolve and rotate along the polishing paths, therefore contributing to improved finished surface. 3-D profiles of finished surface mark the effective exclusion of scratches under the PM-2DVAMAF and additional improvement in surface quality. Experimental results showed that PM-2DVAMAF is far superior to conventional MAF and also 2DVAMAF. Authors concluded it can enhance surface quality, but also shorten machining time and reduced the quantity of abrasives required.

Mithlesh Sharma and Devinder Pal Singh, (2013) made a study on maximising the effectiveness in relations of material removal rate (MRR). The setup comprised of components like control unit, electromagnet, variable D.C. supply and D.C. motor. They modified the lathe machine to put up an electromagnetic setup on carriage instead of tool post. Abrasives were initially packed inside the pipe in addition over one of the end, cap is fixed to keep the abrasive in the pipe. The results showed surface finish is improvised on increasing the rotational speed. Increment in flux density had negative effect on the surface finish quality. Also, it was observed that the working gap of 5 mm with Aluminium oxide abrasive contributed to an enhancement in surface finish. Alike tendency was noticed with Silicon Carbide abrasives also.

Junmo Kang and Hitomi Yamaguchi, (2012) experimented to describe the finishing features and mechanism that control the multiple pole-tip system and enhance the finishing. Also, achieving homogeneously finished surface is a major objective of this study. The setup was composed by including a couple of pole tips to a solitary pole-tip system and burdened together to create magnetic fields. The finishing area in this case is doubled due to introduction of magnetic abrasive into two sections of the tube. Authors experimentation gave us multiple results like the multiple-pole tip method required the utilization of a tool through alternating non-magnetic and magnetic sections. A short magnetic area on the tool with ends conforming to the pole-tip ends quintessence the magnetic flux, which duplicates the quantity of borders of the magnetic sections to entice the magnetic abrasive. This method served to attract the magnetic abrasive even more sturdily to the tool by the magnetic force. The addition of magnetic tool by means of magnetic abrasive enables the exclusion of material as of the peaks of the surface asperities. This accomplishes a efficiently finished surface with a lesser amount of material removal than the utilization of magnetic abrasive individually.

Ching-Lien Hung et al., (2010) have developed a finishing method for stainless steel. Also, this study pursues to improve surface finish of portions to achieve customer's necessities. The setup involved MAF apparatus by means of permanent magnets, work piece, a work piece holder, and magnetic abrasives. The magnetic flux density was calibrated to about 1.2 Tesla when a working gap of 1.0 mm was set. The South pole of the permanent magnet was set with a shaft fitted in the spindle of a CNC machine. The North pole of the same magnet was intended to attract the magnetic abrasives. The magnetic pole selected consisted of OD of 20 mm and 40 mm in length. The current research utilized 81 experimental statistics and established the fuzzy-nets estimated model and experimental test of 10 sets of data were showed; the accuracy achieved by the system was almost 97 %. Hence, the projected statistical aided fuzzy-nets surface finish prediction, also coined as S-FNIPSFP, structure could be useful to the succeeding steps of adaptive control structure development of MAF methods.

4.1 Gaps in Existing Research:

After studying the literature review, it has been observed that earlier established Magnetic Abrasive Finishing setups for internal finishing were mostly on thin tubes only. Quite few research has been achieved on thick cylinders. Also, research on Leaded Tin Bronze (SAE 660) is not been observed much.

CHAPTER 5

EQUIPMENT, MATERIALS, AND EXPERIMENTAL SETUP

5.1 Components of Magnetic Abrasive Finishing:

1. **Electromagnet:** The FMAB in MAF process is formed due to the magnetic field generated by the electromagnet. The force due to the magnet acting on the Fe particles is proportional to the volume and the magnetic susceptibility of the Fe particles. The magnetic field intensity shouldn't be kept extremely high as it could result into quite high magnetic force which would led to rigid brush. This magnetic field intensity is varied by the supply of current to the electromagnetic setup. Thus, the supply of current also plays a vital role in surface finishing. On keeping low magnetic field intensity, the formation of FMAB is not possible and even if it is formed it won't have the capacity to finish properly. Thus, magnetic field intensity is a vital issue to be considered. The magnetic lines of forces pattern might also influence the process quality this is because the ferromagnetic particles with abrasive particles procedure a chain structure along the magnetic lines of forces.

2. **Radial drill machine:** It's a bulky geared head drill press. In this machine the head can be enthused along an arm that exudes from the machine's column. By means of the machine is conceivable to swing the arm in respect to the machine's base, a radial arm drill press can work over an extensive zone without repositioning the work piece. Thus, impressive time is saved since it is substantially speedier to reposition the bore head than it is to unclamp, move, and after that re-clip the work piece to the machine's table.

5.2 Selection of Workpiece Material:

Leaded Tin Bronze: SAE 660 (C93200) Bearing Bronze is viewed as the standard bearing material for light obligation applications. Even though it is effectively machined, the alloy is enough hard, strong and impervious to wear. It likewise adjusts well to journal abnormalities and is less reliant on lubrication than different alloy. It has sensible corrosion resistance from seawater and saline solution.

Chemical Composition (in percentage) are mentioned below:

Copper	081.00-085.00
Tin	006.30-007.50
Lead	006.00-008.00
Zinc	002.00-004.00
Iron	002.00
Nickel	001.00
Antimony	000.35
Phosphorous	001.50
Sulphur	000.08
Aluminium	000.005
Silicon	000.005

Table 5.1 Chemical Composition (in percentage)

SAE 660 is used in various applications. Some of them are mentioned below:

Fasteners	Washers
Automotive industries	Automotive fittings
Other industrial applications	Pump Fixtures, Fuel Pump Bushings, Hydraulic Press Stuffing Box, Pump Impellers, etc.

Table 5.2 SAE 660 in various applications

5.3 Experimental Setup:

The experimental setup comprises of radial drilling machine of changeable rpm, work piece, stationary electromagnets, and working table. The workpiece is fixed on the spindle and can be rotated at various speed, while the electromagnets are fixed (kept stationary) on the working table. The sintered aluminium oxide magnetic abrasives are introduced in the work piece. Due to magnetic pull the abrasives are attracted such that MAFB is formed. This MAFB induces a normal force on the workpiece and the rotation of workpiece causes the finishing process. The rotation of the workpiece is accomplished by the radial drilling machine.

CHAPTER 6
RESEARCH METHODOLOGY

The experimentation would start with initially calibrating the workpiece surface finish. The values of each of the sample are noted down so that proper comparison could be made after the surface finishing is done by MAF. The next task would be preparation of abrasive particles for the MAF process. The magnetic abrasives comprise of aluminium oxide and Fe particles which are sintered. The sintering process consists of five major sub-categories. They are as follows:

- Ball milling process of aluminium oxide and Fe mixture.
- Compacting of abrasive powder.
- Annealing of the compact material.
- Breaking of annealed material.
- Abrasive powder formation as per required mesh size.

Ball milling process is used for alloying of the aluminium oxide and iron particles. In this process crushing of the mixture continuously takes place. The ball milling process takes almost 6 to 7 hours to prepare a sample of abrasive powder. After the alloying process is done compacting of the powder is done on hydraulic press machine. In this process due to application of high pressure the solidification of the abrasive particle takes place. This solidified abrasive sample is then subjected to annealing heat treatment in inert conditions. This process is done to strengthen the abrasive particles. The later to process are done to finally attain the abrasive particles as required for the MAF setup.

After the preparation of magnetic abrasive particles is done, the setup would be installed on the radial drilling machine. The workpiece would be set on the radial drill machine's spindle. The designed and fabricated electromagnetic setup would be fixed on the table. Working gap, lubrication adding, and various parameters would be set before the process begins. The number of trial runs is decided by the design of experiments to get precise results.

CHAPTER 7

PROPOSED WORK PLAN WITH TIMELINES

Week/Month	**September**	**October**	**November**
Week 1	N/A	Literature review	Abrasive preparation: Ball milling process
Week 2	Topic discussion with mentor	Literature review	Workpiece material finalization with mentor
Week 3	MAF related research discussion with mentor	Finalized the procedure for MAF setup and abrasives preparation	Abrasive preparation: Ball milling process
Week 4	Literature review	Abrasive preparation: Ball milling process	Dissertation-2 report work

Table 7.1 Work Plan

CHAPTER 8
EXPECTED OUTCOMES

Magnetic abrasive finishing is a non-conventional process which is being developed for better surface finishing of material surface. The study is conducted for improving the surface finish of leaded tin bronze bushing. Surface roughness plays a vital role in the life of the bushing, hence the experimentation with aluminium oxide abrasives is conducted. The surface quality should be improvised to quite a great extent by this process. The process is also being selected from economic point of view making is useful for industrial purposes. The experimentation would be conducted on the thick cylinder selected with multiple parameters. By doing so an optimal solution to achieve quality surface finish could be achieved. We are expecting to achieve Nano-finished surface. Conventional methods usually cause micro-cracks and other surface defects due to the tool being in contact with the surface. MAF is a process in which abrasives are replaced by tools, this technique helps us avoid the surface defects as well as micro-cracks. Another aim of this experimentation is to study the influence of input parameters on the output parameters, such as % improvement in surface finish (PISF) and material removal rate (MRR).

CHAPTER 9
CONCLUSION

As compared to the traditional methods of finishing surfaces, MAF proves much better. Glass like surface finished can be easily achieved by MAF. Tool life is of no concern in MAF finished surface. Also, the problems like micro-cracks or other surface defects are excluded by the use of MAF. The designed and fabricated setup of electromagnet provides the required amount of magnetic field. Each and every input parameter plays a vital role in the quality of surface finish and material removal. The PISF and MRR results from review of literature are positive enough. Scanning electron microscope and X-ray diffraction are planned to be conducted on the finished sample to study its surface tropology.

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