

Impact of Variable Process Parameters of Magnetic Abrasive Finishing on Surface finish of mild Steel Using a DC current for Electromagnets

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Abstract - Fine finishing or finishing is the generally last process of the production of jobs that demand utmost quality with regard to shape, precision, and surface integrity. Fine-finishing is a process that improves the surface of the jobs, enhancing its functional and excellence aspects. The major manufacturing sectors requires accurate finishing to enhance the appearance, performance, and durability of its components. Mild steel is generally utilized in the production of various components required in automotive and other applications. Conventional finishing and fine finishing methods can be challenging to apply when manufacturing components of varied shapes and sizes. To address this, unconventional fine finishing and finishing techniques are being employed. One typical method is magnetic abrasive finishing (MAF), a finishing technique that produces components of outstanding quality. In this method a cutting tool is the flexible magnetic abrasive brush (FMAB), guided by a DC magnetic field, to achieve the preferred surface finish. Typically, the magnetic abrasives used in MAF consist of key components like DC electromagnetic field, mixture of ferromagnetic powder and abrasives powder. In this study, mild steel bars undergo fine polishing using a MAF technique, with varying process parameters being examined. Aluminum oxide (Al_2O_3) serves as the abrasive, while a hemisphere pole shaped DC electromagnet is employed for the fine-finishing process. The process key variables, including magnetic flux density, workpiece rotational speed, and the percentage of abrasives with ferrous powder in the mixer, can be adjusted to achieve best surface finishes. The efficiency of the process is influenced by factors such as the abrasive particles content in the mixing ratio, the speed of the workpiece, and the input DC voltage that regulates the magnetic flux density. The results indicate that increasing the rotation speed and DC voltage enhances the surface finish of the mild steel rods. Specifically, experiments reveal that improvements in rotation speed and DC voltage can lead to a 47% increase in the maximum enrichment of surface roughness.

Key Words: Magnetic abrasives finishing, Hemisphere electromagnet, Flexible magnetic abrasives-brush, Magnetic abrasives particles

1. INTRODUCTION

Advanced methodologies in fine and micro finishing encompass a variety of processes, including honing, polishing, lapping, buffing, super finishing, abrasives flow machining (AbFM), elastic emission machining (EEM), and magnetic abrasives finishing (MAF), among others. Figure 1 illustrates the MAF process employing hemisphere DC electromagnets. The MAF technique is predicated on the principle of coordinated motion between the workpiece and a blend of abrasive particles and ferrous, which are subjected to a DC electromagnetic field that induces a processing effect on the workpiece. The direct current (DC) electromagnetic field affects both the surface of the test piece and the abrasive particles, with this interaction being a defining characteristic of the process. The efficacy of the material removal process is intricately linked to the motion and pressure applied by the electromagnetic field on the Al_2O_3 particles. As the rotational speed of the workpiece increases, the rate of material removal correspondingly rises, influenced by the interactions among the abrasive particles and the workpiece. Furthermore, when Al_2O_3 particles impact the workpiece, they perform cutting or polishing actions that facilitate surface smoothing.

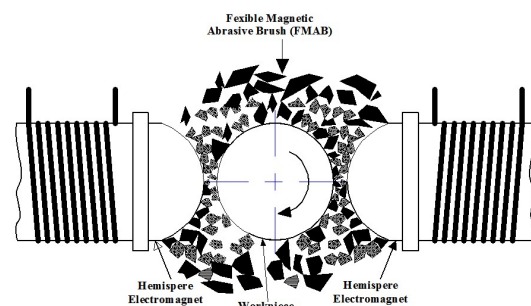


Fig -1: Schematic of the MAF

In a recent investigation conducted by Rajendra E. Kalhapure and associates, a total of 52,100 steel bars were subjected to fine finishing utilizing a magnetic abrasive finishing (MAF) apparatus that integrated various process parameters through the application of two flat pole-shaped electromagnets. Aluminum oxide (Al_2O_3) was designated as the abrasive medium for this micro-finishing methodology. Critical variables, including magnetic density, workpiece rotational velocity, and abrasive composition, can be manipulated to attain enhanced surface finishes. The efficacy of the MAF process is contingent upon factors such as the mixing ratio of abrasive particles, the rotational speed of the workpiece, and the input direct current (DC) power source employed to generate magnetic flux density. The findings reveal that the surface roughness of mild steel rods exhibited significant improvement at a voltage of 36V and a rotational speed of 1026 rpm. The experimental results further indicate that an increase in both voltage and rotational speed correlates with a marked enhancement in surface roughness. Advanced methodologies in fine and micro-finishing encompass a diverse array of processes, including polishing, buffing, lapping, super finishing, honing, elastic emission machining (EEM), abrasive flow machining (AbFM), and magnetic abrasive finishing (MAF), among others. Figure 1 delineates the MAF process utilizing hemisphere electromagnets. The MAF technique is founded on the principle of coordinated motion between the workpiece and a mixture of ferrous and abrasive particles, which are subjected to an electromagnetic field that induces a processing effect on the workpiece. Within the MAF framework, the electromagnetic field plays a pivotal role in defining the interaction between the workpiece and the abrasive particles. The direct current (DC) electromagnetic field influences both the surface of the test specimen and the abrasive particles, with this interaction being a fundamental characteristic of the process. The efficiency of the material removal process is intricately associated with the motion and force exerted by the electromagnetic field on the Al_2O_3 particles. As the rotational velocity of the workpiece escalates, the rate of material removal correspondingly increases, driven by the interactions among the abrasive particles and the test specimen. Moreover, when Al_2O_3 particles make contact with the workpiece, they execute cutting or polishing actions that facilitate surface refinement.[1] In a prior investigation conducted by Ik-Tae Im and associates, a cylindrical workpiece composed of STS 304 was subjected to processing via the MAF technique at significantly elevated speeds. The study aimed to assess the roundness, surface roughness, and variations in fine diameter of the workpiece. The findings

indicated that the micro diameter and mass of the cylindrical workpiece could be effectively regulated through a nearly linear methodology. Furthermore, the incorporation of vibrational motion applied to the workpiece facilitated enhancements in surface quality. This improvement was ascribed to the capacity of vibrational motion to proficiently mitigate irregularities in both the rotational axis and the perpendicular orientation [2]. The research conducted by Baron et al. has empirically investigated the efficacy of Magnetic Abrasive Finishing (MAF) in the removal of unwanted particles from apertures on flat surfaces. The principal elements of this methodology encompass a magnetized inductor, a powder possessing both abrasive and magnetic characteristics that functions as a cutting tool, a vibrating table, and a face electromagnetic inductor specifically designed for the finishing and deburring of flat surfaces. Furthermore, the study evaluates the effectiveness of commercially available MAb powders. A novel comparative approach has been developed to assess the effectiveness of these MAb powders and to identify the most suitable option for polishing and deburring holes drilled into flat steel surfaces. The efficacy of the deburring process for each MAb can be evaluated based on the results of the MAb experiments. Among the powders tested, Fe-TiC MAb, characterized by granule sizes ranging from 500 to 400 μm and abrasive sizes from 40 to 28 μm , which are positioned on the surface of the composite granules, demonstrated the highest effectiveness in removing burrs from steel components. MAb deburring presents the potential to improve the efficiency of deburring various precision components, including microelectronic parts, as its cutting power can be modulated through current regulation [3]. Kanish T.C. et al. investigate the influence of process parameters on the enhancement of material removal (MR) and the percentage change in surface roughness ($\%\Delta\text{Ra}$). A thorough scientific study was conducted on the specified work material employing the L27 Taguchi experimental design. This paper provides an analysis utilizing the signal-to-noise (S/N) ratio and analysis of variance (ANOVA), revealing that elevated input voltage, a reduced machining gap, an increased mesh size, a diminished feed rate, and a heightened rotational speed significantly affect MR and $\%\Delta\text{Ra}$. Their experimental findings indicate that an increase in voltage, rotational speed, and abrasive size positively correlates with MR and $\%\Delta\text{Ra}$. In contrast, an increase in gap and feed rate adversely affects $\%\Delta\text{Ra}$ and MR. [4]. In the research conducted by authors Pandey and Mulik, Magnetically Assisted Fine Finishing (MAF) is characterized as a surface refinement technique that entails the removal of material in the form of fine chips through the interaction of magnetic and abrasive particles within an electromagnetic



field. This fine-finishing methodology is influenced significantly by the finishing forces, which in turn affect the quality of the resultant testing surface and the precision of the workpiece. Given its implications for surface integrity, the parameters of torque and force magnitude are of critical importance. In this investigation, a newly engineered electromagnet was employed for Magnetically Assisted Finishing (MAF), resulting in reduced torque and force when juxtaposed with a conventional electromagnet. Measurements of finishing torque and normal force were recorded under a variety of processing conditions utilizing a Kistler dynamometer, yielding approximate values of 24 N for force and 8 Nm for torque. The experimental framework was designed employing Taguchi's L16 orthogonal array (OA), which considered four process parameters: finishing gap, supply voltage to the electromagnet, percentage of abrasive weight, and electromagnet rotational speed (rpm). The findings indicated that both finishing gap and supply voltage are significant factors influencing torque and finishing force. Furthermore, analysis through scanning electron microscopy (SEM) of the fine-finished components revealed either subsurface damage or an absence of surface defects, attributed to the notably low torque and fine finishing force applied [5]. In a comprehensive review conducted by Sinha, A., Singh, S., and Singh, L., a detailed examination of abrasive particles and their processing for the magnetic abrasive flow (MAF) process is presented. This study elucidates several methodologies for the production of magnetic abrasives, encompassing coated, unbonded (UMA), bonded (BMA), gel-type, and plasma spray techniques. Notably, a significant 74% of the research literature indicates a preference for unbonded or simply mixed types of magnetic abrasives. While coated magnetic abrasives are recognized for their superior finishing characteristics, it has been observed that the coating degrades due to the interaction with magnetic particles during processing, adversely affecting finishing performance. Furthermore, the literature delineates various categories of abrasives, including silicon carbide, aluminum oxide, boron nitride, diamond, and chromium oxide. Among these, aluminum oxide is favored by 45% of researchers, establishing it as the most prevalent abrasive material [6]. Yüewu Gao and collaborators have conducted an investigation into the modeling of material removal in the abrasive finishing process by analyzing a range of process parameters. Their findings indicate that material removal is enhanced when the feed rate, working gap of the job, and size of the material abrasive particles (MAPs) are minimized. Furthermore, the substantial cutting force exerted by diamond particles is demonstrated to effectively remove a considerable volume of material from the surface. This study highlights the potential for significant improvements in surface finish

through the application of a low working gap, reduced feed rate, fine MAPs, and elevated rotational speeds [7]. Lida Heng et al. conducted experiments utilizing various configurations of magnetic poles. The results indicated that the Magnetic Abrasive Finishing (MAF) process effectively enhanced the internal surface quality of oval-shaped tubes. This methodology employed a dynamically adjustable magnetic pole arrangement in conjunction with iron-based composite abrasives and Al_2O_3 , optimized under ideal conditions. Notably, a reduction in surface roughness of up to 79% was observed under specific parameters: increased rotational speed, D-shaped magnetic poles, reduced abrasive grain size, a wet processing technique, and extended finishing duration. Furthermore, atomic force microscopy (AFM) analysis confirmed that the iron-based composite abrasives and Al_2O_3 were proficient in removing prominent peaks and grooves from the original inner surface of the oval-shaped tubes. The artificial neural network (ANN) model exhibited significant potential as a robust instrument for evaluating and forecasting the outcomes of the inner MAF process [8]. An additional experimental investigation conducted by Singh, P., and Singh, L. employed SiC-based glued magnetic abrasives (MAB) for the internal surface finishing of cylindrical aluminum pipes. These magnetic abrasives were synthesized through the amalgamation of silicon carbide (SiC, 400 mesh) and ferromagnetic iron powder (300 mesh). In the experimental setup, the gap between the electromagnet and the workpiece was consistently maintained at 1 mm. The magnetic field strength (MFS) during the experiments was modulated using a variable direct current (DC) power supply. Scanning electron microscopy (SEM) images were captured post-experimentation to facilitate a comparative analysis between the unfinished and finished workpieces. The authors identified that the interplay between magnetic field strength (MFS) and rotational speed had a significant impact on both the material removal rate (MRR) and the percentage improvement in surface finish (PISF). As a result, surface irregularities were effectively minimized, with PISF enhancements observed in the range of approximately 27.6% to 81.5%. The optimal process parameters for attaining the maximum PISF of 81.5% included elevated magnetic field strength, increased circumferential speed, a finer abrasive mesh size, and a reduced proportion of MAB within the mixture [9]. In the paper of Abdalha, M and et al. have studied and introduces innovative pole (shape) geometry to evaluate its effect during the MAF process of the given alloy. Four process variables with three levels were taken, including pyramid-shaped pole (shape) geometry: input current, finishing time and rotational speed. The design of experiments was employed using an L9 orthogonal (Taguchi) array for analyzing the impact of all variables on results



output i.e. response, which is given by surface roughness (ΔRa). An ANOVA, analysis of variance was conducted to determine significance of these variables. To forecast the results i.e. output response, a regression model was also developed. The investigational findings indicated that rotational speed is the most influential factor, followed by input current, fine-finishing period, and the angle of the pole pyramid. The higher surface roughness achieved at higher rotational rpm, a medium working clearance, a specific fine-finishing period, and a lower pole angle. It is noticeable that as the rotational rpm speed increases, the enhancement in surface roughness becomes more pronounced. This suggests that higher rotational speeds help to minimize waviness and irregularities in the surface texture. Material removal occurs through chip formation, which is a result of the correlative motion between the work-piece surface and the flexible magnetic abrasives brush. As a result, advancement in surface roughness grows with higher rotational speeds. Furthermore, increased rotational speeds facilitate greater material removal and contribute to a smoother surface improvement due to elevated temperatures with a decrease in the coefficient of friction. In contrast, lower rotational speeds produce less centrifugal force, leading to the accumulation of MABP at the center of the work-piece. As the rotational rpm-speed rises, centrifugal force rises as well, promoting a more effective distribution of abrasive particles that can efficiently eliminate surface peaks [10]. In the scholarly article titled 'Evaluation of Parameters Affecting Magnetic Abrasive Finishing on Concave Freeform Surface of Al Alloy via RSM Method,' authored by M. Vahdati and Seyed Alireza R., the influence of magnetic abrasive (MAB) process parameters on the freeform surfaces of aluminum components is systematically examined. This methodology is characterized by the integration of computer numerical control (CNC) technology with a magnetic abrasive finishing process. In this investigation, alongside the simulation and empirical assessment of the magnetic flux density associated with an iron hemisphere and a hemispherical magnet, a suitable tool was fabricated for the MAF procedure. This tool is employed due to its enhanced distribution and accessibility of magnetic flux density across the surface of the hemispherical magnet. Simulation analyses indicate that optimal values can augment surface roughness by as much as 75%. For experimental validation, a basic hemisphere is utilized for installation on the flat regions of the magnets, with the magnets exhibiting a curvature in their spark formation. The impact of magnetic field intensity is evaluated using Maxwell's finite element software. The findings reveal that surface roughness typically decreases from an initial measurement of $1.3 \mu\text{m}$ to $0.2 \mu\text{m}$ in the concave regions of the surface. However, the minimum recorded surface roughness was $0.08 \mu\text{m}$ in select areas [11].

In their research paper, Chaowen Dong and colleagues introduce a novel plane magnetic abrasive finishing method that utilizes an alternating magnetic field. This approach addresses issues such as the susceptibility to deformation and inadequate restoration of the magnetic brush commonly seen in traditional magnetic abrasive finishing techniques. Unlike the magnetic brush used in conventional methods, the magnetic brush in this new technique maintains a relatively stable shape while finishing the workpiece under the influence of the alternating magnetic field. The paper includes a theoretical analysis of the variations in finishing force within the alternating magnetic field. Furthermore, the study examines how factors such as the size of the magnetic particles, the size of the GC particles, and the frequency of the AC power affect the finishing characteristics in order to achieve an ultra-precision plane surface [12]. In their research paper, Liaoyuan Wang and colleagues discuss the growing demand for metal additive manufactured components with complex internal cavities, driven by the rapid advancement of high-end manufacturing sectors such as aerospace and national defense. However, finishing these intricate internal surfaces, particularly for irregularly shaped parts, poses a significant challenge due to their complex geometries. The authors conduct a comparative analysis of various finishing methods, emphasizing the unique features and suitability of magnetic abrasive finishing (MAF). To address the finishing requirements of complex metal additive manufactured parts, this paper reviews the current state of research on MAF devices, processing mechanisms, the evolution of magnetic abrasives, and MAF techniques for intricate internal cavities. Additionally, the paper explores future trends in MAF for these complex internal structures, which include: (1) the development of multi-technology composite magnetic abrasive finishing equipment tailored for complex internal surfaces; (2) investigations into the dynamic behavior of multiple magnetic abrasive particles within complex cavities and their material removal mechanisms; (3) the creation of high-performance magnetic abrasives designed for challenging conditions; and (4) the exploration of MAF processes for detailed internal surfaces [13]. In their research paper, Jiang Guo and colleagues introduce a novel method called vibration-assisted magnetic abrasive polishing (VAMAP) aimed at refining microstructured surfaces without compromising their profiles. This technique utilizes magnetic force to ensure that magnetic abrasives effectively contact the microstructured surface and reach the intricate corners of the microstructures. Simultaneously, the application of vibration creates relative movement between the microstructures and the abrasives. Since the vibration direction aligns with the microstructures, the integrity of their profiles is preserved. The researchers analyzed the

relationship between vibration and magnetic force, and conducted experiments to validate the method's feasibility. The findings indicate that, following the polishing process, the surface finish around the microstructures was significantly enhanced while their profiles remained intact [14]. In their research paper, A. Y. Jiao and colleagues present a study aimed at enhancing surface integrity and homogeneity through various trajectories using a newly designed experimental device. The experiments investigated three types of polishing trajectories that incorporated rotational motion of a magnetic abrasive brush (MAB), building on the conventional magnetic abrasive finishing (MAF) process. The researchers selected surface roughness, cross-sectional shape, and 3D micro-morphology as response variables to assess the effectiveness and advantages of the proposed polishing method. The findings indicate that the improvements in polishing trajectory led to varying degrees of enhanced surface quality and plane homogeneity. Furthermore, by applying MAF theory to analyze the underlying factors, the trajectory behavior of magnetic abrasive particles (MAPs) was modeled and simulated using Graph software. The theoretical analysis aligned with the experimental results, suggesting that the examination of polishing trajectories can effectively predict polishing outcomes. Consequently, it is feasible to strategically plan polishing trajectories based on the workpiece profile and surface quality requirements [15].

This study investigates the percentage enhancement in surface roughness during the Magnetic Abrasive Finishing (MAF) process, with particular emphasis on the input direct current (DC) voltage applied to hemisphere-shaped electromagnets, the rotational speed of the workpiece, and the proportion of Al_2O_3 abrasive within the mixing ratio as critical variables. Statistical analysis of the experimental data indicates that the input DC voltage and the rotational speed of the workpiece are the primary parameters that significantly influence the improvement of surface roughness. Furthermore, this research delves into the effects of these various process variables, employing the analytical data to evaluate the characteristics inherent to the Magnetic Abrasive Finishing process.

This study examines the percentage enhancement in surface roughness during the Magnetic Abrasive Finishing (MAF) process, employing a hemisphere geometry electromagnet. The variables under consideration include input direct current (DC) voltage, workpiece rotational speed, and the percentage of Al_2O_3 abrasive within the mixing ratio. The investigation focused on the influence of these process variables on the MAF outcomes. Analytical data were employed to assess the characteristics inherent to the MAF process.

2. Experimental Methodology

2.1 Experimental Configuration

For the purposes of this experimental study, the MAF set-up is developed on Centre lathe machine using DC power supply to electromagnets seen in Figure 2. The cutting tools, mentioned as FMAB, are composed of a combination of abrasive particles, specifically aluminum oxide (Al_2O_3), and ferromagnetic material, namely iron powder. The workpiece, characterized by dimensions of $\varnothing 25$ mm in diameter and a length of 25 mm, is secured within a three-jaw chuck and positioned between electromagnetic poles. Two hemispherical electromagnets, constructed from copper wire coils as illustrated in Figure 2, are designed to be mutually opposing. A direct current (DC) power source, with specifications ranging from 0 to 36V, is working from an alternating current (AC) to DC converter to supply power to the both electromagnets, which is integrated with a lathe slide. To mitigate magnetic flux leakage onto the lathe slide, hardwood brackets, along with aluminum nuts and bolts, are utilized to secure the electromagnet in place.

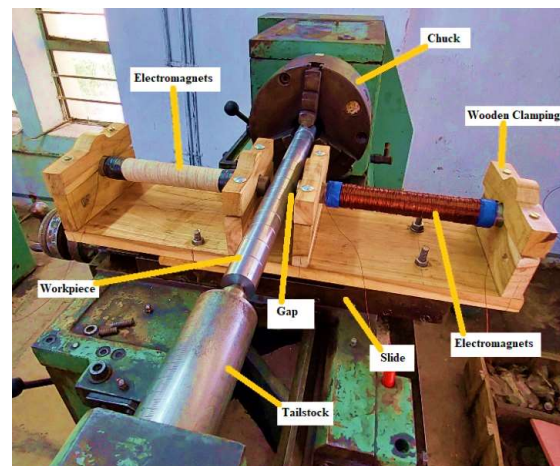


Fig -2: Photograph of actual MAF Set up



Fig -3: Hemisphere Electromagnets

A composite of iron and Al_2O_3 particles is formulated to create a flexible abrasive brush, which is cohesively maintained by

the electromagnetic field generated by the DC electromagnets, thereby providing the necessary finishing force. The resultant surface finish achieved is characterized by a mirror-like quality, as this methodology is consistently executed with exceptionally delicate forces. Figure 4 states a photographic illustration that reveals the formation of a flexible magnetic abrasive brush (FMAB) through the alignment of particles along magnetic field lines. This brush exerts finishing force on the surface of the workpiece, thereby generating finishing pressure that results in micro indentations. The tangential force produced by the FMAB constitutes the primary cutting power, facilitating fine chipping. In this abrasive finishing technique, the workpiece is strategically positioned between two electromagnets, necessitating the precise adjustment of the distance between the workpiece surface and the electromagnets through the use of appropriately sized slip gauges. Al₂O₃ abrasive particles can be employed in several configurations: unbonded, lightly bonded, or fully bonded. A composite of Al₂O₃ abrasives and iron particles has been utilized on mild steel bars within the finishing sector, where an electromagnetic field exerts the final force on the surface of the steel bars. During the process, the amalgamation of iron and abrasive particles situated on the workpiece's surface is attracted to the electromagnetic field, which exerts pressure against its outer surface. As the workpiece undergoes rotation and a direct current voltage is applied to the electromagnet, a magnetized field is established at the poles of the electromagnet.

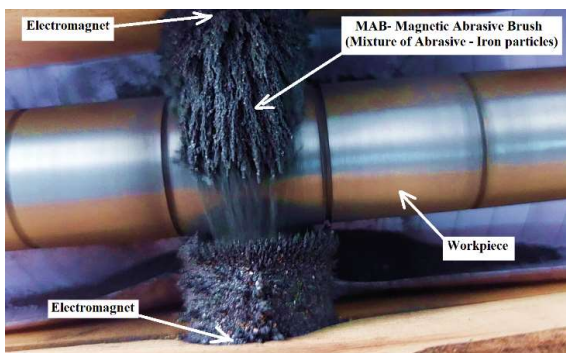


Fig -4: Actual photograph of FMAB

This magnetized field facilitates the attraction of the powder mixture applied to the workpiece. The same mixture is strategically positioned within the gap of the workpiece, where electromagnets are utilized to achieve a meticulous polishing of the surfaces. Al₂O₃ abrasive particles can be employed in several configurations: unbonded, lightly bonded, or fully bonded. A composite of Al₂O₃ abrasives and iron particles has been utilized on mild steel bars within the finishing sector, where an electromagnetic field exerts the

final force on the surface of the steel bars. During the process, the amalgamation of iron and abrasive particles situated on the workpiece's surface is attracted to the electromagnetic field, which exerts pressure against the outer surface. As the workpiece undergoes rotation and a direct current voltage is applied to the electromagnet, a magnetized field is established at the poles of the electromagnet. This magnetized field attracts the mixture of powders that has been deposited on the workpiece. The same mixture is strategically positioned within the gap of the workpiece, where electromagnets are utilized to achieve a meticulous polishing of the surfaces.

2.2 Work Material

In this research, Al₂O₃ -based magnetic abrasives were utilized to polish cylindrical mild steel rods, each with a diameter of 25 mm and a length of 25 mm, in order to achieve a superior finish. Before the final finishing process of the Magnetic Abrasive Finishing (MAF) setup, the workpieces were initially ground, followed by an assessment of their surface roughness.

2.3 Mixture of Abrasives and Iron Particles

A consistent mixture of magnetic abrasives was created by combining Al₂O₃ and iron powders in various proportions, as detailed in Table 1.

2.4 Selection of Process Parameters and Experimental Design

Actual experimentation was conducted utilizing the design of experiments methodology, specifically employing Taguchi's orthogonal array L₉ (3³), which encompasses three levels across three factors.

Table 1: Experimental Conditions Low medium High

Process Parameters	Levels		
	Low	Medium	High
Rotational speed of workpiece	226	649	1026
Input voltage	12	24	36
Abrasive content in Mixing Ratio (Abrasive: Fe)	1:2 (1)	1:1 (2)	2:1 (3)

This approach aims to estimate the effects of various process variables on performance, particularly in relation to surface finishing. The constant distance between the electromagnet and the workpiece is maintained at 1.5 mm using slip gauges, and an even finishing time of 40 minutes is applied throughout all experiments. In this study, the three factors analysed include Speed in rpm, Input DC voltage, and Mixing

Ratios, with each factor assessed at three levels: low, medium, and high.

2.5 Measurement of % Improvement in surface roughness

Experimentation is carried out for surface roughness improvement. The initial surface roughness of nine different surfaces was recorded where actual run was conducted.

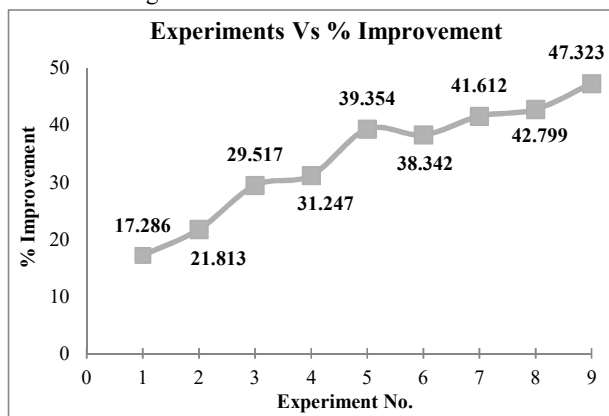
Table 2: Experimental input data and output

Expt. No.	Workpiece Rotational Speed	Input DC Voltage	Mixing Ratio	% Improvement
1	226	12	1	17.286
2	226	24	2	21.813
3	226	36	3	29.517
4	649	12	2	31.247
5	649	24	3	39.354
6	649	36	1	38.342
7	1026	12	3	41.612
8	1026	24	1	42.799
9	1026	36	2	47.323

For the 9 experiment run, Workpiece Rotational Speed, Input DC Voltage and total quantity of Al₂O₃ abrasive with fe powder in the mixture were used as process variables. Following table no. 2 shows respective input data and output measured data of percentage improvement in surface roughness.

Following are the graphs of respective input data for the nine experiments and output measured data as percentage improvement in surface roughness.

Chart 1: Graph of Experiments and percentage Improvement in surface roughness



3. RESULTS AND ANALYSIS

This section outlines the analysis of output comparing with input process parameters at three constant workpiece rotational speed

3.1: At constant workpiece rotational speed- 226 rpm

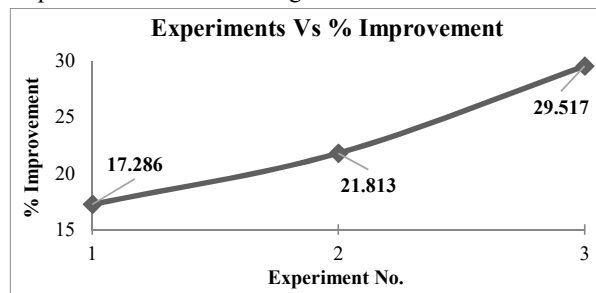
In the table 2 the first three experimentation conducted at constant workpiece rotational speed of 226 rpm with variation in input DC voltage to electromagnets and mixing ratio of abrasives and fe powders.

Table 3: Experimental input data and output

Expt. No.	Workpiece Rotational Speed	Input DC Voltage	Mixing Ratio	% Improvement
1	226	12	1	17.286
2	226	24	2	21.813
3	226	36	3	29.517

From the above table it is observed that the maximum % Improvement in surface finish is 29.517% at the input conditions, DC voltage to electromagnets and abrasive content in mixing ratio, both were at higher level. Higher level DC voltage helps in maximum magnetic density at the gap of 1.5 mm so more abrasive mixture was in contact with workpiece surface that applied maximum finishing force on it.

Chart 2: Graph of Experiments (1 to 3) and percentage Improvement in surface roughness



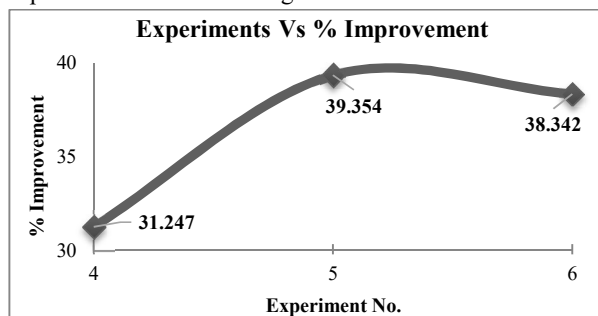
3.1: At constant workpiece rotational speed- 649 rpm

In the table 2 the experimentation run no. 4 to 6 were conducted at constant workpiece rotational speed of 649 rpm with variation in input DC voltage to electromagnets and mixing ratio of abrasives and fe powders.

Table 4: Experimental input data and output

Expt. No.	Workpiece Rotational Speed	Input DC Voltage	Mixing Ratio	% Improvement
4	649	12	2	31.247
5	649	24	3	39.354
6	649	36	1	38.342

Chart 3: Graph of Experiments (4 to 6) and percentage Improvement in surface roughness



From the above table it is observed that the maximum % Improvement in surface finish is 39.354% at the input conditions, DC voltage to electromagnets at medium level and abrasive content in mixing ratio was at higher level. It helps in sufficient magnetic density at the gap of 1.5 mm so more abrasive mixture was in contact with workpiece surface that applied maximum finishing force on it. Also it is observed that the more % Improvement in surface finish is 38.342% at the input conditions, DC voltage to electromagnets at higher level so that helps in creating maximum magnetic density at the gap of 1.5 mm so more finishing force applied on it.

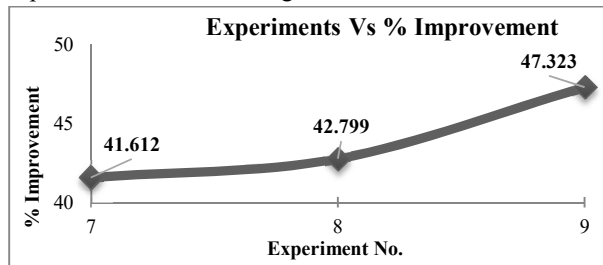
3.1: At constant workpiece rotational speed-1026 rpm

In the table 2 the experimentation run no. 7 to 9 were conducted at constant workpiece rotational speed of 1026 rpm with variation in input DC voltage to electromagnets and mixing ratio of abrasives and fe powders.

Table 5: Experimental input data and output

Expt. No.	Workpiece Rotational Speed	Input DC Voltage	Mixing Ratio	% Improvement
7	1026	12	3	41.612
8	1026	24	1	42.799
9	1026	36	2	47.323

Chart 4: Graph of Experiments (7 to 9) and percentage Improvement in surface roughness



From the above table it is observed that the maximum % improvement in surface finish is 47.323 % at the input conditions, DC voltage to electromagnets at higher level and abrasive content in mixing ratio was at medium level. It helps in greater magnetic density at the gap of 1.5 mm so more abrasive mixture was in contact with workpiece surface that applied maximum finishing force on it.

4. CONCLUSIONS

The process parameters in MAF play a vital role in increasing quality of the surface (%ΔRa). This research aims to develop a MAF process specifically for finishing mild steel and to determine the positive effective conditions that will increase surface finish. Through experimental examinations into the MAF process, this current study has led to the following conclusions:

It is clear that as the rotational speed rises, there is a corresponding enrichment in surface roughness. The surface texture's waviness and deficiencies are reduced with higher rotating speeds. This improvement occurs because material removal is achieved through chip formation resulting from relative movement of the FMAbB and the workpiece surface.

The most influential input parameters are as follows: for Speed (Level 3), a value of 1026 has a significant effect; for Input DC Voltage (Level 3), a value of 36 is crucial; and for Mixing Ratio (Level 2), a ratio of 1:1 is necessary to achieve the desired output.

The study indicates that a high level voltage of 36V and superior workpiece rotation speed of 1026 rpm have a significant impact on percentage improvement in surface roughness (%ΔRa).

Experiments show that increasing rotating speed and DC voltage leads to higher magnetic field having a positive influence on %ΔRa.

The abrasive content in mixing ratio has been shown to be affecting least.

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BIOGRAPHIES (Optional not mandatory)



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