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The study aimed to analyse the outcomes and potential applications of Magnetic Abrasive Finishing.

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Abstract*- In today's manufacturing landscape, many products are created based on the principle of interchangeability, which is made possible through large-scale production. Achieving precise dimensional accuracy is crucial for the successful assembly of various components, necessitating the manufacturing of parts to very close tolerances. Traditional finishing processes can often be inadequate when dealing with components of diverse shapes and sizes, highlighting the need for advanced micro-machining and finishing techniques. One such technique is Magnetic Abrasive Finishing (MAF), a fine finishing process that allows for superior surface quality. This process utilizes a tool known as a Flexible Magnetic Abrasive Brush, which operates under the influence of a magnetic field. Magnetic abrasives used in MAF typically consist of two primary components: ferromagnetic materials and abrasives, which must be properly bonded together. In this study, mild steel bars were subjected to finishing using an MAF setup with varying process parameters, including working gap, magnetic flux density, and rotational speed of the workpiece, to evaluate their effects on surface finish quality. MAF is particularly effective for finishing internal surfaces and can be applied to brittle materials at the nanometer scale. Suitable abrasive materials for MAF include boron carbide (B4C) and silicon carbide (SiC). The success of the MAF process is influenced by several factors, including abrasive particle size and type, mixing ratio, working gap between the magnetic surface and the workpiece, workpiece speed, properties of the work material, and the input AC or DC power supply that generates the magnetic flux density.

1. INTRODUCTION

1.1 Advanced Fine Finishing Processes

Advanced fine and micro-finishing processes include lapping, honing, superfinishing, buffing and polishing, abrasive flow machining (AFM), elastic emission machining (EEM), and magnetic abrasive finishing (MAF), among others.

1.2 Magnetic Abrasive Finishing (MAF)

The MAF process operates on the principle of correlated motion between the workpiece and abrasive particles, which are blended together in the presence of an electromagnetic field. This interaction generates a processing effect on the workpiece. The cutting tools used in MAF consist of a mixture of magnetic abrasive particles (such as SiC, Al2O3, or diamond) and ferromagnetic materials (like iron powder). The magnetic blending of iron and abrasive particles forms a tool known as the Flexible Magnetic Abrasive Brush. Due to the low forces involved in the process, the surface finish achieved is often mirror-like.

1.2.1 Working Principle

Figure 1.1 illustrates the MAF process. The magnetic abrasive particles, composed of ferromagnetic material (iron particles) and abrasive particles (such as SiC, Al2O3, or diamond), serve as cutting tools, while the necessary finishing force is provided by electromagnets.

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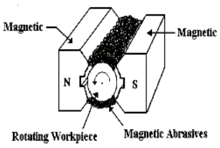

Fig. 1.1 Schematic of the MAF

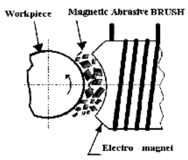

Fig. 1.2 Magnetic Abrasive Brush

Figure 1.2 illustrates the Flexible Magnetic Abrasive Brush (FMAB), which is structured along the lines of magnetic flux and exerts a finishing force against the surface of the workpiece. This finishing pressure creates micro-indentations on the workpiece surface. The tangential force generated by the FMAB serves as the primary cutting force, facilitating the micro-chipping process. During the MAF operation, the workpiece is positioned between two magnets, with the appropriate gap between the workpiece surface and the magnets established using slip gauges of the correct size. Abrasive particles can be categorized as unbonded, loosely bonded, or bonded. The bonded magnetic abrasive particles are produced by sintering a mixture of ferromagnetic powder (such as iron) and abrasive powder (like aluminum oxide) at specified temperatures and for designated periods. The effectiveness of the MAF process is influenced by various factors, including the type, size, and mixing ratio of the magnetic abrasive particles (MAPs), the working clearance between the workpiece and the magnetic pole, the rotational speed of the workpiece or pole, the vibration parameters (frequency and amplitude), the characteristics of the work material, and the magnetic flux density.

Figure 3.1 illustrates the magnetic abrasive finishing process utilizing DC electromagnets. In this method, a mixture of magnetic abrasives and iron particles is introduced onto mild steel bars within the finishing zone by means of a magnetic field, which generates a finishing force against the surface of the bar. As the magnetic abrasive particles are attracted to the workpiece by the magnetic field, they exert pressure on its outer surface.

Figure 3.2 depicts how these particles align along the magnetic field lines, forming a Flexible Magnetic Abrasive Brush (FMAB) that applies pressure to the workpiece surface, resulting in micro-indentations. The tangential force generated by the FMAB is the primary cutting force that facilitates micro-chipping during the finishing process. In a typical MAF setup, the workpiece is positioned between two magnets, and the necessary gap between the workpiece surface and the magnets is adjusted using appropriately sized slip gauges.

Abrasive particles can be categorized as unbonded, loosely bonded, or bonded. The bonded magnetic abrasive particles are created by heating a mixture of ferromagnetic powder (such as iron) and abrasive powder (like aluminum oxide) at specific temperatures and for designated durations.

1.3 PURPOSE OF STUDY

The objective of this study is to carry out fine/micro finishing processes on a magnetic abrasive finishing setup integrated into a conventional lathe machine. This will focus on the external finishing of mild steel rods using artificial abrasives (Al2O3) by applying the principles of magnetic abrasive finishing.

III. EXPERIMENTAL SETUP

The experimental setup includes an electromagnet comprised of two coils of copper wire, as shown in Figure 3.1. These coils are positioned opposite each other to create the necessary magnetic field for the finishing process.

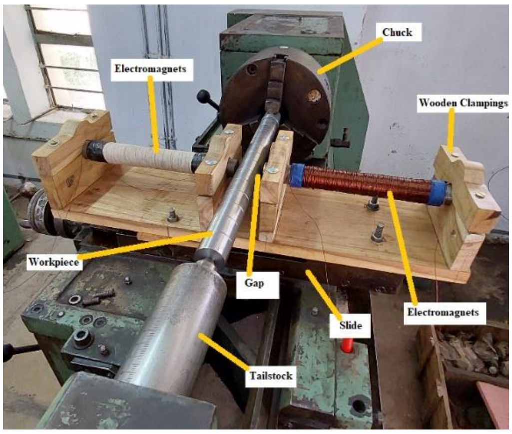

Fig 3.1: Photograph of actual MAF Set up

The workpiece is securely clamped in a three-jaw chuck and positioned between the electromagnetic poles. A DC current is supplied to the electromagnet, which is mounted on a slide, using an AC to DC converter. To minimize magnetic flux leakage to the lathe slide, wooden brackets and aluminum nuts and bolts are employed for clamping the electromagnet onto the slide.

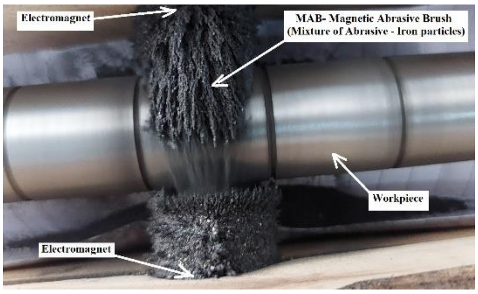

Fig. 3.2: Actual photograph of MAB - Magnetic Abrasive Brush

As a result of this correlative motion, a Flexible Magnetic Abrasive Brush is created, which processes the surfaces of mild steel bars. This brush functions as a cutting tool for micro and fine machining of the workpiece. Figure 3.2 displays an actual photograph of the flexible blended abrasive brush formed by the effects of the electromagnets. The blended abrasive particles are suspended in the gap between the workpiece and the electromagnets, facilitating the fine finishing of the workpiece surfaces.

I. EXPERIMENTAL CONDITIONS

In this study, Al2O3-based sintered magnetic abrasives were employed for finishing cylindrical mild steel rods, each measuring 25 mm in diameter and 25 mm in length. Initial grinding operations were conducted on these rods, followed by surface roughness testing.

Next, a mixture of magnetic abrasives was prepared by blending Al2O3 with iron powders in various mixing ratios, as shown in Figures 4.1 and 4.2. The mixture was subjected to a heating process at 1200°C. After a cooling period of 12 hours, the compacts were crushed into smaller particles and subsequently sieved to obtain different size ranges.

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Al_2O_3 = 50 gms

Fe = 50 gms

Fig. 4.1: Weighing of powders for mixtures

Fig. 4.2: Mixing ratios of powders for sintering mixture

The experimental conditions are summarized in Table 1. Cylindrical mild steel rods (Ø25 x 25 mm) were utilized as workpieces for this study. The experimental variables considered include input DC voltage, rotational speed, and the gap between the workpiece and the electromagnet. To evaluate the finishing characteristics of the magnetic abrasives, surface roughness measurements were taken at four points on each workpiece both before and after the finishing process, using a surface roughness tester.

Table 4.1: Experimental Conditions

Work Piece	:	Mild Steel bars of 25 mm dia. X 25mm length
Abrasive	:	Aluminium Oxide Al_2O_3
Gap between work piece and pole	:	2.25, 2.50, 2.75 mm
Input voltage	:	24, 30, 36
Rotational speed of workpiece	:	350, 490, 780

I. RESULTS & DISCUSSION

To evaluate the effectiveness of Magnetic Abrasive Finishing (MAF), experiments were conducted by varying certain process parameters while keeping others constant. The effects of these variations are discussed below.

5.1 Surface Roughness Improvement at Constant Workpiece Speed (350 rpm)

At a constant workpiece speed of 350 rpm, various measurements of surface roughness improvement (Ra) were taken while adjusting input voltage, machining time, and mixing ratios of the abrasive materials. The results indicate that changes in these parameters significantly influence the surface finish of the workpieces. The analysis of surface roughness values provides insights into the optimal conditions for achieving the desired finish quality.

The findings suggest that increasing the input voltage enhances the magnetic field strength, which in turn improves the effectiveness of the abrasive particles. Similarly, adjustments in machining time and the mixing ratio of abrasives play crucial roles in achieving superior surface roughness outcomes. Detailed results and comparisons are presented in subsequent sections to highlight these trends.

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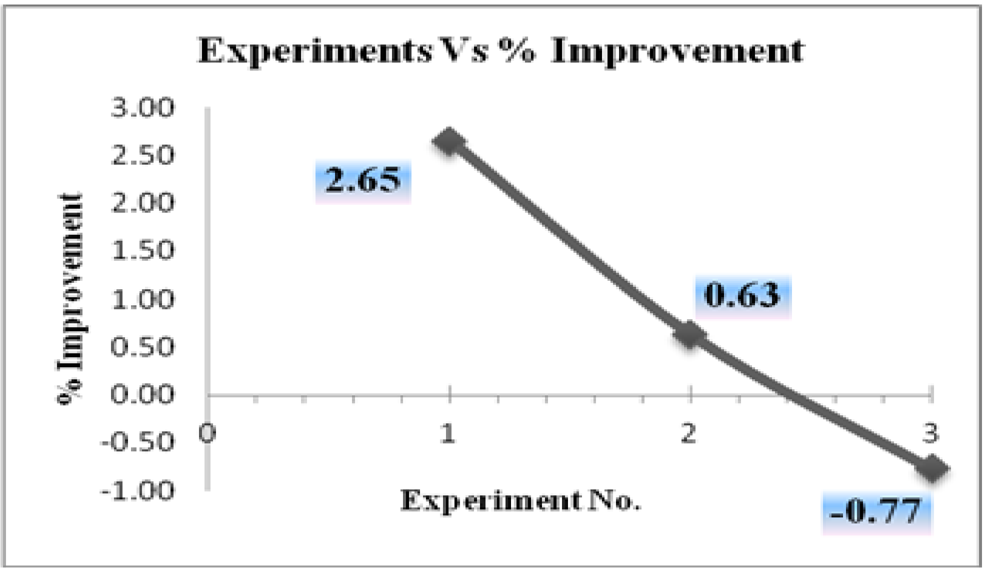
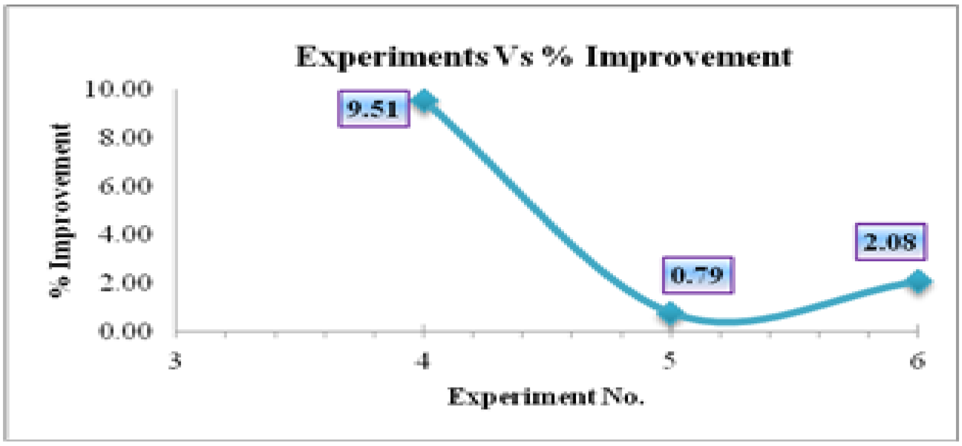


Graph 5.1: Experiments Vs % Improvement

The graph above illustrates the impact of various input voltages, machining times, and mixing ratios on surface finish. At a constant workpiece speed of 350 rpm, the optimal finishing was observed at an input voltage of 24V and a machining time of 3 minutes. This combination yielded the best surface roughness results compared to other experimental conditions. Conversely, when the input voltage was increased to 30V with a machining time of 5 minutes, or 36V with a machining time of 7 minutes, the surface finish deteriorated. This decline in quality may be attributed to excessive voltage and prolonged machining time, which can lead to overprocessing and negatively impact the finishing results.

5.2 Surface Roughness Improvement at Constant Workpiece Speed (490 rpm)

At a constant workpiece speed of 490 rpm, various measurements of surface roughness improvement (Ra) were taken while adjusting input voltage, machining time, and mixing ratios of the abrasives. The results will reveal how these factors influence surface finish at this higher rotational speed. A comparative analysis of the surface roughness values obtained at this speed will provide valuable insights into the optimal processing conditions for achieving enhanced finishing quality

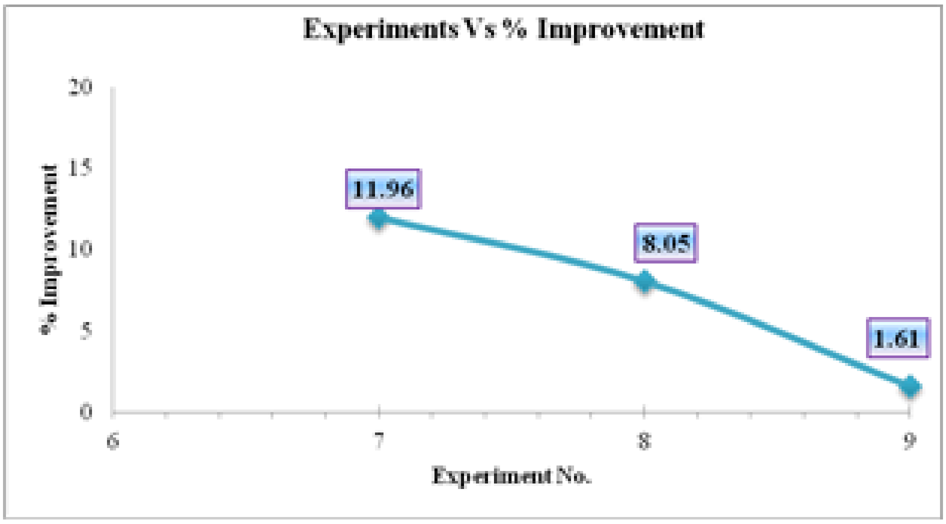


Graph 5.2: Experiments Vs % Improvement

Above graph shows the effect of various input voltage, machining time and mixing ratios on surface finish. At constant 490 rpm, input voltage is 24v and time 5 min the finishing is super. As compared to other experiments, when input voltage is 36v and time 3 min the finishing is medium and input voltage is 30v and time 7 min the finishing not proper due to higher time.

5.3 At constant workpiece Speed i.e. 780 rpm

Measured various values of surface roughness improvement (Ra) at constant workpiece speed i.e. 780 rpm and at various input voltage, machining time and mixing ratios,



Graph 5.3: Experiments Vs % Improvement

The graph above illustrates the effects of various input voltages, machining times, and mixing ratios on surface finish. At a constant workpiece speed of 780 rpm, the highest finishing quality was observed with an input voltage of 24V and a machining time of 7 minutes. In contrast, when the input voltage was increased to 30V with a machining time of 3 minutes, the finishing quality was medium. At 36V and 5 minutes, the finishing quality was poor, likely due to the excessive voltage.

CONCLUSIONS

1. The performance of the Magnetic Abrasive Finishing (MAF) process is influenced by several factors, including input voltage for magnetic flux density, abrasive mixing ratios with ferrous powder, finishing time, and workpiece rotational speed.
2. Higher rotational speeds lead to improved surface finishes, as more abrasive particles come into contact with the workpiece during the finishing process.
3. Surface finish quality is adversely affected by low workpiece speeds combined with extended finishing times.
4. The MAF process can effectively finish a wide range of materials, demonstrating its versatility in manufacturing applications.
5. The maximum percentage improvement in surface roughness (Ra) achieved was 11.96%, as shown in Graph 5.3, at a workpiece speed of 780 rpm.

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