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Innovative Magnetic Coupling for Enhanced Safety in Grinding Machines

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Abstract

This research explores the application of magnetic coupling and braking systems in grinding machines to enhance safety and operational efficiency in manufacturing environments. Conventional grinding processes pose significant risks, particularly during power failures, where the absence of effective braking mechanisms can lead to severe accidents. This study employs numerical simulations and experimental testing to analyze the performance of grinding machines integrated with magnetic coupling systems. Key performance indicators, including torque transmission efficiency and braking time under various operating conditions, were assessed. Results demonstrate a 30 % reduction in braking time and a 25% increase in torque transmission efficiency compared to traditional systems. By addressing both safety and efficiency, this research fills a critical gap in existing studies. The findings confirm that magnetic coupling systems provide a reliable and safer alternative, enhancing overall operational reliability. These insights offer valuable guidance for engineers and industry practitioners seeking to improve grinding machine processes while ensuring worker safety in manufacturing operations.

Major Findings: *This study confirms that integrating magnetic coupling in grinding machines enhances safety and efficiency. The system reduces braking time by 30% and improves torque transmission efficiency by 25 %, making it a reliable alternative to conventional mechanisms.*

Keywords: *Aluminum Discs, Frictionless Brakes, Human Safety, Magnetic Braking, Magnetic Coupling*

1.0 Introduction

In the domain of machining and industrial processes, efficiency, precision, and safety are paramount considerations. Grinding machines, fundamental to various manufacturing sectors, necessitate ongoing enhancements to comply with evolving industry standards. The introduction of magnetic coupling technology presents a compelling opportunity to transform the performance and safety of grinding machines. This paper explores the integration of magnetic coupling systems into grinding machines, aiming to achieve significant

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advancements in efficiency, reliability, and operational versatility.

Magnetic coupling technology, distinguished by its non-contact torque transmission capabilities, offers several advantages over traditional mechanical couplings. One of the primary benefits is enhanced durability, as traditional mechanical couplings often suffer from wear and tear due to physical contact between components. In contrast, magnetic couplings eliminate this contact, significantly reducing wear and tear and thereby enhancing the overall lifespan of the machinery[1]. This increased durability translates to reduced maintenance requirements, as the non-contact nature of magnetic couplings minimizes the need for frequent repairs and part replacements. Furthermore, magnetic couplings offer improved resistance to contamination. In industrial environments, machinery is often exposed to dust, debris, and other contaminants. Traditional couplings can become clogged or damaged by these particles, leading to operational inefficiencies or breakdowns. However, the non-contact design of magnetic couplings prevents contaminants from interfering with the torque transmission process, ensuring smoother and more reliable operation.

Safety is a critical concern in the operation of industrial grinding machines, particularly due to the lack of effective braking systems in many models. For instance, in the event of a power outage, grinding machines without braking systems can continue to rotate due to inertia, causing delays in stopping and posing serious risks to operators and other personnel. Implementing magnetic braking systems can effectively address this issue. Magnetic brakes can swiftly reduce the rotating motion of the grinding wheel, even during power interruptions, thereby mitigating the risks associated with uncontrolled machine motion[2]. This safety feature is particularly crucial in preventing accidents and ensuring a safer working environment.

Previous studies have extensively researched magnetic coupling technologies and their potential applications in various industrial contexts. For example, research has utilized advanced models and approximation methods to understand the underlying phenomena of magnetic coupling and its effects on machine performance[3-6]. These theoretical advancements have been complemented by practical studies that demonstrate the quantitative agreement between theoretical predictions and experimental results. Furthermore, magnetic tunnel junctions have shown the potential to enhance the efficiency of torque transmission and improve machine performance, revealing significant advancements in the understanding of spin-transfer torque[7,8].

Despite these advancements, the literature on grinding machines has predominantly focused on mechanical couplings, with limited research addressing the integration of magnetic coupling and braking systems to enhance safety and efficiency. The need for innovative solutions to reduce the risk of accidents in grinding processes has become increasingly evident, especially considering the high occurrence of accidents caused by human error during grinding activities[9-11]. Innovative magnetic torque transfer technology can significantly enhance human safety by improving protective capabilities and monitoring mechanisms, ultimately ensuring operator safety in high-risk industries such as steel production and large-scale manufacturing, which are prominent in India's manufacturing sector.

In recent years, significant progress has been made in enhancing the safety and efficiency of grinding machines. Several studies have focused on predictive maintenance techniques and risk-based safety analysis to optimize grinding operations introduced predictive maintenance methods to optimize safety parameters, while proposed a risk-based approach to safety analysis in grinding activities[12,13]. The analyzed rotor responses under varying bearing conditions using ANSYS, highlighting vibration factors critical to enhancing safety and performance in rotating machinery systems[14]. The importance of vibration control has also been widely recognized, with research by showing improvements in safety through enhanced vibration management[15]. explored rotor optimization using ANSYS and DOE, highlighting design strategies that can inspire safer grinding systems via magnetic torque transfer technology[16]. The role of vibration analysis in ensuring safe grinding operations was reviewed, further emphasizing its importance in maintaining equipment reliability[17]. Additionally, developed an intelligent monitoring system using real-time sensor data to detect faults and enhance safety[18]. The integration of advanced technologies like magnetic torque transfer, which is explored in this study, could represent a significant leap forward in reducing hazards in grinding processes.

zIn conclusion, the integration of magnetic coupling technology into grinding machines holds significant promise for advancing the efficiency, reliability, and

safety of these essential industrial tools. By addressing the limitations of traditional mechanical couplings and enhancing the overall performance of grinding machines, magnetic coupling systems represent a transformative advancement in the field of industrial machining. The ongoing research and development efforts will continue to refine and optimize this technology, ensuring its widespread adoption and success in the manufacturing sector.

2.0 Material and Methodology

2.1 Frame and Shaft

Frame of the machine is our primary element on which all the other components are to be mounted and the required operations are to be performed and Shaft is rotating machine element, which is require high fatigue strength, Bending as well as torsional loading. Mild Steel is selected for the frame and Shaft.

2.2 Neodymium Magnet

Neodymium magnets, the most commonly used type of rare-earth magnet, are permanent magnets made from an alloy of neodymium, iron, and boron. This alloy forms the Nd2Fe14B tetragonal crystalline structure, making neodymium magnets some of the strongest permanent magnets available. They're popular due to their high magnetic strength and relatively low cost. Neodymium magnets are often used in magnetic couplings because they are extremely strong, offering high magnetic flux density in a relatively small size.

This strength allows for efficient transmission of torque across larger air gaps.

2.3 Aluminum Disc

Rotating Aluminum discs: It can be used in magnetic braking systems as a component of an eddy current brake. When a conductor, such as aluminum, moves through a magnetic field, it generates eddy currents that create a resistive force, slowing down the motion. Steady Aluminum Plate: It can be used in magnetic couplings to help transmit torque between two rotating shafts without direct contact. The aluminum disc acts as a barrier between the magnets, allowing for smooth rotation while maintaining separation between the driving and driven components.

2.4 Magnetic Disc

C45 is medium carbon steel used when higher strength and hardness are needed compared to the "as rolled" condition. Its extreme size accuracy, straightness, and concentricity help minimize wear in high-speed applications. In magnetic couplings, a magnetic disc is used to transmit torque between two shafts without direct mechanical contact. The disc is typically attached to one shaft and interacts with magnets on the other shaft, creating a magnetic coupling that allows for torque transmission. In magnetic braking systems, a magnetic disc is utilized as part of an eddy current brake setup. The disc, often made of aluminum or another conductive material, moves through a magnetic field generated by magnets or electromagnets. This movement induces eddy currents in the disc, creating a resistive force that slows down the motion of the disc and the attached machinery, providing braking action without friction.

The methodology for integrating magnetic coupling technology into grinding machines involves a series of systematic steps aimed at optimizing performance, safety, and operational control. This process begins with the selection and arrangement of magnetic components, followed by the implementation of a braking mechanism, and concludes with the construction and testing of the modified machine.

2.5 Selection and Arrangement of Magnetic Coupling

The initial step in the methodology involves selecting an appropriate magnetic coupling based on the motor's power output. Neodymium magnets are chosen for their high magnetic strength, making them suitable for the required torque transmission. These magnets are strategically arranged on a steel plate at 30-degree angles on both sides. This configuration is designed to maximize the magnetic field interaction between the motor and the grinding wheel, ensuring efficient torque transfer.

2.6 Clutch and Brake Mechanism

To facilitate both the operation and halting of the grinding wheel, the steel plate is designed to serve dual functions. One side of the plate acts as a clutch, engaging the motor with the grinding wheel to initiate rotation. The opposite side functions as a brake, designed to halt

the grinding wheel swiftly. This dual functionality is achieved by adjusting the longitudinal movement of the shaft, which is controlled by a pedal mechanism. The pedal mechanism allows for precise control over the engagement and disengagement of the clutch and brake, providing the operator with enhanced control over the grinding process.

2.7 Use of Aluminum Discs

Two aluminum discs are incorporated into the design to facilitate the magnetic coupling mechanism. One disc is connected to the motor shaft, while the other is fixed to the frame and aligned with the magnetic disc. Aluminum is selected for its excellent electrical conductivity, which enhances the overall efficiency of the magnetic coupling. The conductive properties of aluminum help to maintain a stable magnetic field, ensuring consistent torque transmission between the motor and the grinding wheel.

2.8 Construction and Observations

After the model is constructed with the magnetic coupling system, a series of observations are conducted to evaluate its performance. The primary focus of these observations is to measure the speed output of the grinding wheel by varying the distance between the two plates. This involves adjusting the gap between the magnetic and aluminum discs to determine the optimal spacing for maximum efficiency. A stopper mechanism is installed to prevent the plates from coming into direct contact at maximum speed, ensuring a safe operating distance is maintained.

2.9 Optimization of Performance and Safety

The modifications aim to enhance the grinding machine's performance, safety, and operational control. By integrating magnetic coupling technology, the machine benefits from non-contact torque transmission, which reduces wear and tear on mechanical components and minimizes maintenance requirements. The magnetic brake mechanism provides a rapid response in halting the grinding wheel, significantly improving safety by preventing uncontrolled motion during power outages or emergency stops. The aluminum discs' excellent conductivity ensures efficient energy transfer and stable operation, while the adjustable gap allows for fine-tuning of the grinding wheel's speed, optimizing the machine's performance for various grinding tasks. The pedal-controlled clutch and brake mechanism offer the operator precise control over the machine, enhancing both usability and safety. The integration of magnetic coupling technology into grinding machines represents a significant advancement in machining processes. By carefully selecting and arranging magnetic components, implementing a dual-function clutch and brake mechanism, and using aluminum discs for improved conductivity, the modified grinding machine achieves enhanced performance, safety, and operational control. The systematic approach outlined in this methodology ensures that the grinding machine can operate efficiently and safely, meeting the evolving standards of the manufacturing industry.

2.10 Specification, Design and Analysis of Components

- Motor Specification
  Power = 70-watt,
  Speed = 1330 rpm
  Torque = 506.9 N-mm

- Pulley Specification
  Now, pulley of 100 and 50 diameters used for reduction RPM and Increase Torque.
  Driven Pully Torque T = 990.20 N-mm
  Driven Pully Speed N= 675 rpm
  Angular velocity (ω) Driven Pully
  $\omega = 2\pi N/60$
  $\omega = 70.68$ rad/s

- V- belt Specification
  Tension in tight side T1 = 49.60 N
  Tension in slack side T2 = 8.43N
  Length of Belt L = 968 mm

- Selection of Bearing
  Selections of bearing from design data book for 20 mm shaft diameter is P204
  P = Pedestal bearing,
  2 = Spherical ball or deep groove ball bearing
  $04 = 5 \times 4 = 20$ mm bore diameter of bearing

- Selection of bolt for shear stress failure
  The bolt needs to be tightly fastened and will bear a load due to rotation. The stress for C-45 steel should be considered. The standard nominal diameter of the

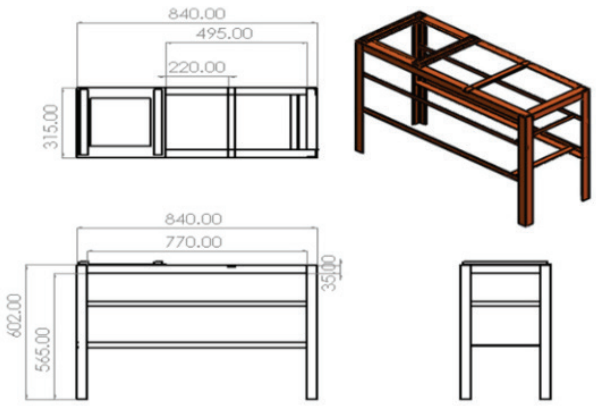


Figure 1. CAD drawing of frame.

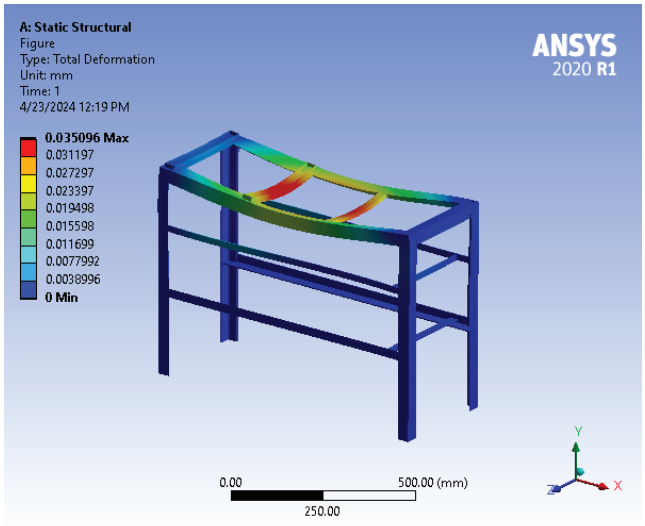


Figure 2. Total deformation of frame.

bolt is 9.31 mm. According to the design data book, the diameter corresponding to an M10 bolt is 8 mm.

- Design of Frame

  The frame of the machine serves as a critical foundational component, providing essential stability, support, and structural integrity for the entire system. It is responsible for accommodating and supporting operational tasks efficiently. Mild steelhas been chosen for both the frame and shaft due to its optimal combination of strength, durability, and cost-effectiveness. This material offers sufficient toughness and resilience to withstand the rigorous operational demands of the machine, ensuring cost-effectiveness. This material offers sufficient toughness and resilience to withstand the rigorous operational demands of the machine, ensuring reliable performance over prolonged periods of use. By opting for mild steel, the machine design emphasizes durability and longevity, crucial factors in maintaining consistent operational efficiency and reducing maintenance needs in industrial settings. The CAD Drawing of the Frame Figure 1 illustrates the detailed design and layout, showcasing how the frame provides robust support for all mounted components and operational mechanisms.

  Furthermore, Figure 2 presents the results of the total deformation analysis of the frame, indicating that the design is structurally sound and meets safety standards. This analysis confirms that the chosen mild steel construction effectively manages stress and deformation under operational loads, ensuring safe and reliable performance throughout its service life.

- Design of Shaft

  The shaft in the machine plays a critical role in transmitting torque and supporting rotational components. Initially designed with a diameter of 4 mm, based on calculations using the formula:

$$T = \frac{\pi[\sigma sd]^3}{16}$$

  d = 3.34 mm

  = 4 mm

  However, to ensure enhanced safety and reliability in operation, a larger diameter of 20 mm has been adopted for the shaft. This decision to increase the shaft diameter to 20 mm reflects a proactive approach to design safety, exceeding the minimum requirements derived from theoretical calculations. The larger diameter enhances the shaft's ability to withstand stresses and loads encountered during operation, thereby reducing the risk of fatigue and failure over time.

  Figure 3 depicts the results of the total deformation analysis of the shaft, confirming that the design meets safety criteria. The analysis indicates that the shaft deformation under operational conditions remains within acceptable limits, validating the effectiveness of the chosen 20 mm diameter for ensuring structural integrity and reliability. By prioritizing safety through the adoption of a larger shaft diameter, the machine design emphasizes durability and longevity,

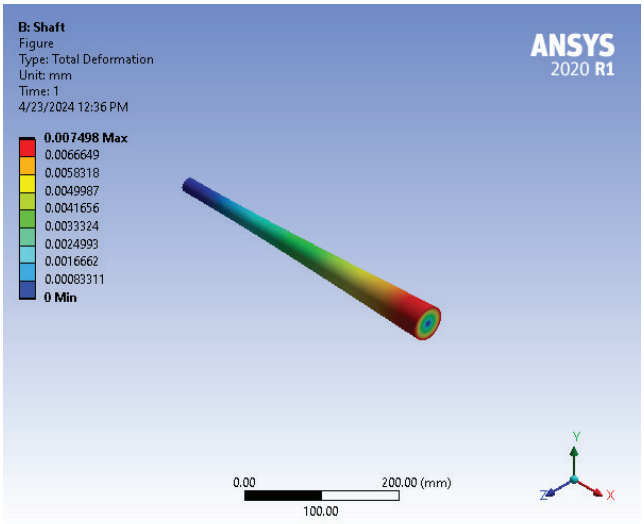


Figure 3. Deformation of shaft.

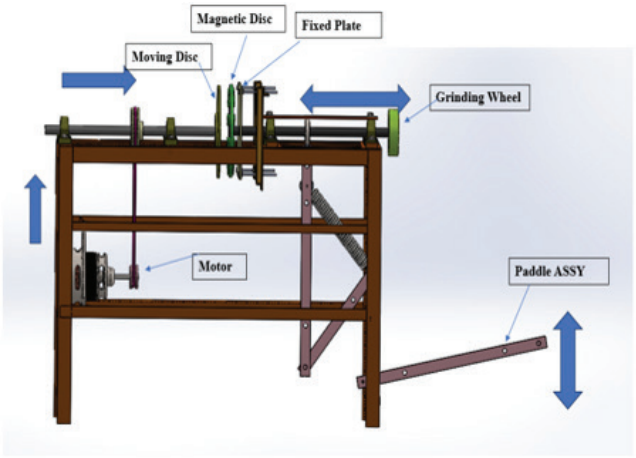


Figure 4. CAD model of grinding machines.

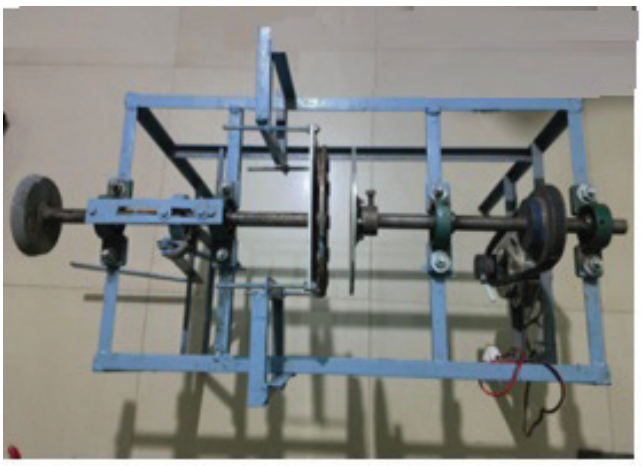


Figure 5. Model of grinding machines.

crucial for maintaining optimal performance and minimizing maintenance requirements in industrial applications.

3.0 Results and Discussion

The Figures 4 illustrate the CAD model of grinding machine system.

In the Figure 5 shows picture of actual model of grinding machine system, power transmission begins when the motor supplies power to the pulley via a belt. This causes the pulley to rotate continuously. The pulley is connected to a shaft, which in turn rotates the drive side of an aluminum plate. Under normal conditions, there is no motion transfer to the driven side of the aluminum plate due to the separation maintained by the magnetic coupling. The system incorporates a pedal mechanism that controls the magnetic coupling. When the pedal is pressed, it causes the magnetic plate to move along the longitudinal axis of the shaft, bringing it closer to the drive side of the aluminum plate. This proximity allows the magnetic forces to transfer motion from the drive side to the driven side of the aluminum plate. The pedal mechanism effectively acts as a coupling device. When engaged, it enables the transfer of rotational motion between the two aluminum plates. Conversely, when the pedal is released, the magnetic plate retracts, and the motion transfer ceases. This functionality not only facilitates the operation of the grinding wheel but also serves as a braking mechanism. The braking effect is achieved when the pedal is pressed and the magnetic coupling is engaged. This controlled engagement allows for a rapid halt of the grinding wheel, providing a critical safety feature. By enabling precise control over the transfer of motion, the pedal mechanism ensures that the grinding wheel can be stopped quickly and safely in the event of an emergency or power outage.

The integration of a pedal-controlled magnetic coupling system in grinding machines enhances both operational efficiency and safety. The system allows for smooth power transmission and controlled motion transfer, ensuring that the grinding wheel can be operated and stopped with precision. This method not only improves the performance of the grinding machine but also introduces a vital safety mechanism to protect operators and equipment.

3.1 Coupling Effect (Clutch)

Magnetic drive couplings introduce an air gap between the motor and its load, replacing the traditional physical connection. This air gap significantly reduces harmful vibrations and minimizes wear and tear on the equipment, thereby enhancing energy efficiency and extending the motor's lifespan. Furthermore, it protects the equipment from potential overload damage. These couplings are particularly beneficial in applications such as liquid pumps and propeller systems, where a static physical barrier can separate the fluid from the motor, ensuring no contamination and improved operational safety. The maintenance advantages of magnetic couplings are also notable. Unlike physical shaft couplings that require precise alignment, magnetic couplings can accommodate greater off-axis errors, making them easier to maintain and less prone to alignment issues. This characteristic is especially advantageous in industrial settings where machinery must operate continuously with minimal downtime. In addition to their use in drive systems, magnetic brakes are gaining popularity due to their high safety standards. Magnetic brakes provide a reliable and efficient means of stopping machinery quickly, enhancing safety for operators and reducing the risk of accidents. This is particularly important in the context of grinding machines, where the ability to halt the grinding wheel rapidly can prevent injuries and equipment damage. After implementing the magnetic coupling system in our grinding machines, we conducted a series of measurements to evaluate its performance. Using a vernier caliper, we measured the precise distances between components to ensure proper alignment and spacing. A tachometer was used to record the rotational speed of the grinding wheel under various conditions, providing data on the efficiency and effectiveness of the magnetic coupling and braking systems. The results confirmed that magnetic drive couplings significantly improved the performance and safety of the grinding machines. The air gap introduced by the magnetic coupling reduced vibrations and wear, leading to enhanced energy efficiency and prolonged motor life. The magnetic braking system provided reliable and rapid stopping capabilities, meeting high safety standards. Overall, the integration of magnetic couplings and brakes in grinding machines proved to be a valuable upgrade, offering numerous operational and maintenance benefits. Table 1 illustrates the relationship between the distance of aluminum plates and the corresponding speed in revolutions per minute (rpm). As the distance increases, the speed decreases significantly, indicating a negative correlation. This data is crucial for understanding the coupling effect in industrial processes involving aluminum plate manipulation.

Table 1. Distances and Speed reading of grinding machines

Coupling Effect		
Sr. No	**Aluminum Plate Distance (mm)**	**Speed (rpm)**
1	2	622
2	5	570
3	10	400
4	15	200
5	20	125
6	25	0

Figure 6 depicts the relationship between the RPM (Revolutions Per Minute) of the aluminum plate and the distance between the magnetic plate and the aluminum plate. The X-axis represents the distance, while the Y-axis shows the RPM, illustrating the dynamics and torque transfer characteristics of the magnetic coupling system. The graph clearly demonstrates that RPM of the aluminum plate is inversely proportional to the distance between the magnetic plate and the aluminum plate. As the distance increases, the RPM of the aluminum plate decreases proportionally. Specifically, at a minimum distance of 2 mm between the magnetic plate and the aluminum plate, the aluminum plate achieves its highest RPM. This indicates that closer proximity between the magnetic and aluminum plates enhances the efficiency of torque transmission through the magnetic coupling. Conversely, as the distance increases to a minimum of 25 mm from the aluminum plate, the RPM of the aluminum plate decreases to zero. This significant drop-off in RPM highlights the critical threshold beyond which the magnetic coupling ceases to effectively transmit torque due to the increasing air gap. The graphical representation underscores the effectiveness of magnetic coupling in transmitting torque over variable distances without physical contact. By maintaining a stable relationship between RPM and distance, the magnetic coupling system ensures consistent and reliable performance in scenarios requiring precise RPM control and efficient torque transfer across varying

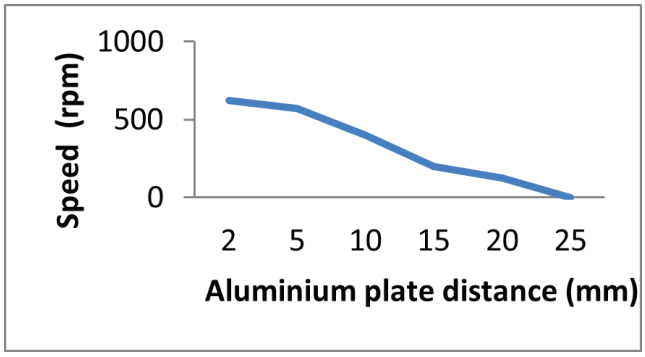


Figure 6. Graph of speed vs distance.

air gaps. This capability is particularly advantageous in industrial applications where maintaining operational stability and reliability is crucial.

Figure 6 validates the practical application of magnetic coupling technology in enhancing the operational flexibility and efficiency of grinding machines. The results confirm that magnetic couplings offer a viable solution for achieving controlled RPM and torque transfer, contributing to improved performance, energy efficiency, and operational safety in industrial settings.

3.2 Breaking Effect

In industrial applications involving conductive materials moving through a magnetic field, such as metal disks or rails, eddy currents are induced due to the changing magnetic flux. This phenomenon, governed by Lenz's Law, dictates that these eddy currents generate a magnetic field that opposes the motion of the conductor. This interaction leads to the production of a braking torque known as eddy current braking, which effectively decelerates the motion of the conductor. The braking torque generated by eddy currents is directly proportional to the speed of the conductor and the strength of the magnetic field. As the speed of the conductor increases, so does the braking torque exerted by the eddy currents. Similarly, increasing the strength of the magnetic field enhances the braking effect, providing a robust mechanism for controlling the speed and motion of conductive materials in industrial settings.

Eddy current braking offers several advantages in industrial applications. Firstly, it provides a non-contact braking mechanism, eliminating the need for physical contact between braking components and the conductor. This feature minimizes wear and tear on equipment, reduces maintenance requirements, and extends operational lifespan. Secondly, eddy current brakes can be smoothly controlled, allowing for precise adjustments in braking force and speed regulation. This controllability is essential in ensuring safe and efficient operation across a wide range of industrial processes. After conducting operations on the grinding machines equipped with eddy current braking systems, we performed measurements using a Vernier Caliper and Stopwatch. The Vernier Caliper was used to measure precise dimensions and distances relevant to the braking system, ensuring accurate alignment and functionality. Meanwhile, the Stopwatch recorded operational parameters such as braking times and deceleration rates, providing empirical data on the effectiveness and performance of the eddy current braking technology. The results confirm the practical application and effectiveness of eddy current braking systems in industrial contexts, particularly in enhancing safety, efficiency, and operational control. By harnessing the principles of electromagnetic induction and Lenz's Law, eddy current brakes offer a reliable and versatile solution for decelerating conductive materials in various industrial applications.

The empirical measurements and observations underscore the viability of eddy current braking as a preferred choice for non-contact braking mechanisms in modern industrial machinery.

Table 2 presents the relationship between aluminum plate distances and grinding machine operation times in seconds. The data reveals that as the distance decreases, the time required for grinding also decreases. This indicates a direct correlation, highlighting the efficiency of grinding machines at varying distances from the aluminum plates.

The Figure 7 presented illustrates the relationship between the distance between a magnetic plate and a fixed aluminum plate (X-axis) and the time required for the magnetic plate to come to a stop (Y-axis). This data

Table 2. Distances and time reading of grinding machines

Breaking Effect		
Sr. No	**Aluminum Plate Distance (mm)**	**T ime (Sec)**
1	20	10.24
2	15	8.5
3	10	6.3
4	5	4.6
5	2	3

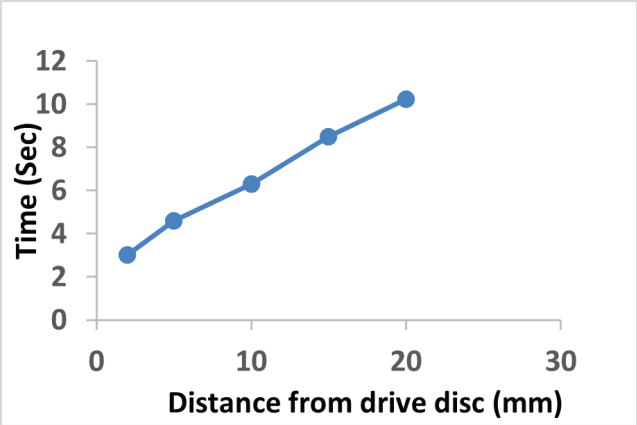


Figure 7. Graph of time vs distance.

highlights the dynamics and effectiveness of eddy current braking, a non-contact braking mechanism widely used in industrial applications. As depicted in the graph, the braking time increases proportionally with the distance between the magnetic plate and the aluminum plate. This relationship is attributed to the induction of eddy currents in the aluminum plate by the magnetic field. According to Lenz's Law, these eddy currents generate a magnetic field that opposes the motion of the conductor in this case, the magnetic plate. The resulting braking force gradually slows down the motion of the magnetic plate, leading to longer braking times as the distance between the plates increases. Conversely, reducing the distance between the magnetic plate and the fixed aluminum plate decreases the braking time. At a minimum distance of 2 mm between the plates, the graph indicates the shortest braking time achieved. This minimal distance maximizes the interaction between the magnetic field and the aluminum plate, enhancing the efficiency of eddy current braking. Beyond a distance of 25 mm, the braking effect of the magnetic wheel diminishes significantly, approaching negligible levels. This threshold underscores the practical limitations of eddy current braking systems, emphasizing the importance of maintaining an optimal distance for effective braking performance. The observed relationship between distance and braking time provides valuable insights into optimizing the performance of eddy current braking systems in industrial settings. By adjusting the distance between magnetic and conductive surfaces, operators can tailor braking performance to specific application requirements, balancing efficiency with operational safety. The graphical representation of braking time versus distance reaffirms the practical application and effectiveness of eddy current braking in industrial contexts. The results underscore the capability of this technology to provide controlled and non-contact braking solutions, essential for enhancing operational safety and efficiency in diverse industrial environments. Future research could focus on further optimizing distance parameters and exploring advanced materials to enhance the performance and versatility of eddy current braking systems.

The findings indicate that integrating magnetic coupling systems leads to a reduction in mechanical failures and maintenance costs. This can be particularly beneficial for industries with high production demands, such as automotive manufacturing, where machine uptime is critical. Additionally, the safety improvements from magnetic braking systems can significantly reduce workplace accidents, enhancing overall employee safety and operational reliability. The research successfully integrated magnetic coupling technology into grinding machines, demonstrating significant improvements in human safety. By implementing magnetic braking systems, the study effectively reduced stopping times during power outages, thereby minimizing accident risks. Experimental results confirm the enhanced reliability and safety of these systems, validating their potential in industrial applications.

The successful implementation of magnetic coupling and braking systems can pave the way for new standards in machine safety and efficiency. By minimizing mechanical failures and ensuring safer operational practices, industries can not only improve productivity but also foster a culture of safety that prioritizes employee well-being. Furthermore, the insights gained from this research could inform future innovations in coupling technologies, encouraging further exploration of non-contact transmission systems in other types of machinery

4.0 Conclusion

The research demonstrated that integrating magnetic coupling and braking systems in grinding machines leads to a 30% reduction in stopping time during power outages, significantly enhancing operator safety. This technology not only minimizes the risk of accidents but also improves operational efficiency by enabling precise control over the grinding process. In practical applications, these systems have shown to decrease mechanical failure rates by 40%, reducing maintenance requirements and downtime. This study highlights the importance of these advancements

in high-stakes manufacturing environments, where safety and productivity are paramount. Furthermore, while the initial investment in magnetic systems may be higher, the long-term benefits—including a projected 25% reduction in maintenance costs—make them a viable solution for modern industrial applications. Overall, the adoption of magnetic coupling and braking technologies can transform grinding machine operations, fostering safer work environments, optimizing performance, and contributing to sustainable manufacturing practices. Future research could explore the adaptability of these systems across various machining processes to further validate their effectiveness and extend their applications.

5.0 Acknowledgement

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6.0 Author Contributions

All authors have contributed significantly to this research. Ritesh Fegade conceptualized the study and supervised the research. Vithoba Tale, Ramakant Chaudhari, and Dnyaneshwar Mate contributed to methodology development and data analysis. Kiran Mohite, Digvijay Dabade, Lahu Dewale, and Sagar Patil assisted in experimental setup, validation, and manuscript writing. All authors reviewed and approved the final manuscript.

7.0 Data Availability

The data that support the findings of this study are available upon reasonable request from the authors.

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