

Design and Analysis of Magnetic powder clutch for Toyota 2003



Habtegiogis Temeselew Abiyrea

A Thesis Submitted to

The Department of Mechanical Engineering

School of Mechanical, Chemical and Materials Engineering.

Presented in Partial Fulfillment of the Requirement for Master of Science in

Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

May, 2024

Adama, Ethiopia

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PGR/21035/14

Adviser: Dr.Tafesse Asrat

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DECLARATION

I hereby declare that this Master's thesis entitled "**Design and Analysis of Magnetic powder clutch for Toyota 2003**" is my own work and has not been submitted to any university for similar purpose. The references used in this thesis are duly recognized by proper citations.

Habtegiogis Temeselew

Name of student

Signature

RECOMMENDATION

The major advisor of this research thesis, hereby certify that I have closely advised/supervised the student while developing this research and read the draft thesis entitled “**Design and Analysis of Magnetic powder clutch for Toyota 2003** “prepared under my guidance by Habtegiogis Temeselew in partial fulfillment of the requirements for master of science in Automotive Engineering. Therefore, I recommend the submission of the revised version of the thesis to the department for following the applicable procedures.

Dr.Tafesse Asrat

Major Advisor

Signature

Date

Co-advisor

Signature

Date

APPROVAL SHEET

I, the advisor of the thesis entitled “**Design and Analysis of Magnetic powder clutch for Toyota 2003** ” and developed by Habtegiorgis Temeselew Abiyrea; hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr. Tafesse Asrat

Major Advisor

Signature

Date

We, the undersigned, members of the Board of Examiners of the thesis by Habtegiorgis Temeselew have read and evaluated the thesis entitled “**Design and Analysis of Magnetic powder clutch for Toyota 2003** “ and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of Master of Science in Automotive Engineering.

Chairperson

Signature

Date

Reviewer 1

Signature

Date

Reviewer 2

Signature

Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and

Department Head

Signature

Date

School Dean

Signature

Date

Office of Postgraduate Studies, Dean

Signature

Date

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LIST OF ACRONYMS

CATIA	computer-aided three-dimensional interactive application
ECE	Economic commission of Europe
FEA	Finite element analysis
FMVSS	Federal motor vehicle safety standard
MPC	Magnetic Powder Clutch
MRPC	Magnetic-Rheological Powder Clutch
PMPC	Permanent Magnet Powder Clutch
EPC	Electromagnetic Powder Clutch
FPC	Failsafe Powder Clutch
HPC	High-Torque Powder Clutch
LPC	Low-Torque Powder Clutch
VPC	Variable Powder Clutch
RPC	Rotary Powder Clutch
CPC	Centrifugal Powder Clutch.

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ABSTRACT

This study focused on evaluating the performance and design of a magnetic powder clutch for the Toyota Model 2003. The study used von Mises stress analysis, displacement, and strain deformation analysis to determine the clutch's strength and ability to withstand the required load. The results showed that the clutch's stress levels and deformation were within an acceptable range, indicating that it could handle the load without significant deformation or failure. it was found that the static displacement of the material reached a maximum value of 0.00102 mm when a torque of 50 Nm was applied. This means that when the torque was applied to the material, it experienced a small amount of deformation or displacement, with the maximum displacement recorded at 0.00102 mm. This displacement value is an important measure of the material's response to applied loads. In this case, the material showed a small amount of deformation when subjected to the 50 Nm torque, indicating that it can withstand this load without undergoing significant deformation. Hence, the study's findings have valuable implications for the automotive industry, providing an insight into the design and performance of magnetic powder clutches for future developments.

Key word; - MPC - Magnetic Powder Clutch

CHAPTER ONE

INTRODUCTION

1.1 Background

A clutch is mechanical device that allows the output shaft to be disconnected from the rotating input shaft. The clutch's input shaft is typically attached to a motor. while the clutch's output shaft is connected to the mechanism that does the work.in motor vehicle, the clutch acts as a mechanical linkage between the engine and transmission. By disengaging the clutch, the Engine speed (RPM) is no longer determine by the speed of the driven wheels.

Another example of clutch usage is in electric drill. The clutch's input shaft is driven by a motor and the output shaft is connected to the drill bit. The clutch allows the drill bit either spin at the same speed as the motor (clutch engaged), spin at a lower speed as the motor (clutch slipping) or remain stationary while the motor is spinning (clutch is disengaged)

Clutch are connected to the car Engine.it links between the Engine and transmission system. let's talk about the types of clutches that we use in our motor Vehicle. The various categories of the clutch are present in the vehicle.(Naile Mikhsil-Boulesm(2017)).

Electromagnetic clutch operates electrically but transmit torque mechanically. This is why they used to be referred to as electro-mechanical clutches. Over the years, Electromagnetic became known as electromagnetic versus electro-mechanical, referring more about their actuation method versus physical operation. since the clutches started becoming poplar over 60 years ago. Variety of application and clutch designs has increased dramatically, but the basic operation remains the same today.

Single-face clutches make up approximately 90% of all electromagnetic clutch sales. Electromagnet clutch are most suitable for remote operation since no mechanical linkages are required to control their engagement, providing fast, smooth operation. However, because the activation energy dissipates as het in the electromagnetic actuator when the clutch is engaged, there is a risk of overheating. consequently, the maximum operating temperature of the clutch is limited by the temperature rating of the insulation of the electromagnet. This is major limitation. Another disadvantage is higher initial cost (Kakinuma (2005)).

A magnetic powder clutch is a device used to transmit torque between two rotating shafts. It uses a magnetic field to control the transfer of power and is commonly used in industrial applications where precise torque control is required.

The background of the magnetic powder clutch can be traced back to the early 20th century when the concept of using magnetic fields to transmit torque was first explored. The idea was to create a clutch that could provide smooth and precise torque control without the need for mechanical contact between the driving and driven components.

Over the years, various designs and configurations of magnetic powder clutches have been developed and refined. The basic principle behind the operation of a magnetic powder clutch is the use of magnetic particles suspended in a powder form. When a magnetic field is applied, these particles align themselves along the field lines, creating a solid connection between the driving and driven shafts.

One of the key advantages of the magnetic powder clutch is its ability to provide precise torque control. By varying the strength of the magnetic field, the amount of torque transmitted can be adjusted. This makes it ideal for applications where precise speed control is required, such as in printing presses, paper mills, and textile machinery.

Another advantage of the magnetic powder clutch is its ability to provide smooth and gradual engagement. Unlike traditional mechanical clutches that can cause sudden jolts and jerks when engaged, the magnetic powder clutch provides a seamless transfer of power, minimizing wear and tear on the system.

In addition to their precise torque control and smooth engagement characteristics, magnetic powder clutches are also known for their reliability and durability. The absence of mechanical contact between the driving and driven components reduces the risk of friction, wear, and heat generation, resulting in a longer lifespan and reduced maintenance requirements.

In conclusion, the background of the magnetic powder clutch can be traced back to the early 20th century when the concept of using magnetic fields to transmit torque was first explored. Since then, magnetic powder clutches have been developed and refined to provide precise torque control, smooth engagement, and reliable operation. These clutches are widely used in various industrial applications where precise speed control and durability are crucial. *[G. Wei and Z. Chengning]*

A magnetic powder clutch is a type of clutch that uses magnetic particles suspended in a fluid to transmit torque between two rotating shafts. It operates on the principle of

magneto rheology, where the magnetic particles align themselves in the presence of a magnetic field, causing the fluid to stiffen and transmit torque.

One study by Guo et al. (2016) investigated the performance of a magnetic powder clutch for industrial applications. The researchers found that the clutch exhibited high torque transmission efficiency and precise control capabilities, making it suitable for use in various industrial processes such as tension control systems and precision motion control. In another study by Wang et al. (2018), the researchers analyzed the thermal characteristics of a magnetic powder clutch during operation. They found that the clutch experienced temperature rises due to frictional heat generation, but the temperature rise was manageable and did not affect the overall performance of the clutch.

Furthermore, a study by Zhu et al. (2020) evaluated the dynamic modeling and control strategies of a magnetic powder clutch for a robotic arm application. The researchers developed a mathematical model to describe the behavior of the clutch and proposed a control strategy to improve the system's response time and accuracy.

Overall, the backgrounds on magnetic powder clutches highlights their high torque transmission efficiency, precise control capabilities, and suitability for various industrial applications. Researchers continue to explore the thermal characteristics, dynamic modeling, and control strategies of these clutches to optimize their performance and reliability in different applications.

1.2 Statement of the Problem

Magnetic powder clutches are a type of clutch that operates on the principle of powder mechanics and magnetism to transmit torque. They have advantages over traditional clutches such as smoother torque transmission, better heat dissipation, and potentially longer lifespan due to reduced wear and tear

By opting for a magnetic powder clutch Toyota 2003 Toque 50 N-m, overcome the limitations of conventional clutches like quick heating, high wear rates, heavyweight design, and limited torque capacity. However, it's important to conduct thorough design and analysis to ensure that the magnetic powder clutch meets your specific requirements and operates effectively in your intended application.

1.3 Objectives

1.3.1 General objective

The main objective of this thesis is Design and Analysis of Magnetic powder clutch for Toyota 2003 with Torque of 50 Nm, specifically for usage in Toyota 2003 model automotive vehicles.

1.3.2 Specific objectives

To accomplish this, the following specific objectives will be pursued:

1. To Conduct a force analysis of the magnetic powder clutch system
2. To Calculate the geometry size of the magnetic powder clutch
3. To Conduct simulations of the magnetic powder clutch.
4. To Use SolidWorks CAM simulation software to generate fabrication plans.

By completing these specific objectives, the proposed thesis will provide a comprehensive study of the design, analysis, and fabrication of a magnetic powder clutch for Toyota 2003 model automotive vehicles. The results of this study will be useful for automotive engineers, researchers, and manufacturers in developing efficient and reliable clutch systems using magnetic powder technology.

1.4 scope of study

The scope of the study on the design and analysis of a magnetic powder clutch for a Toyota 2003 model with a 50 Nm torque transfer includes several key aspects. These include:

1. Design: -The study involves the design of the magnetic powder clutch, including its dimensions, shape, and material properties. This includes selecting the appropriate size and concentration of magnetic particles to achieve the desired torque transfer.
2. Modeling: - The study involves the use of computational models to simulate the behavior of the magnetic powder clutch under different operating conditions. This includes determining the slip characteristics of the clutch and analyzing the magnetic field strength required to achieve optimal torque transfer.
3. Analysis: - The study involves analyzing the performance of the magnetic powder clutch using various testing techniques, such as dynamometer testing and torque testing. This is done to validate the performance of the clutch under different operating conditions and to ensure that it meets the required specifications.

4. Optimization: - The study seeks to optimize the design of the magnetic powder clutch to achieve the best possible performance, such as improved torque transfer efficiency and reduced energy consumption.

Overall, the scope of the study is to provide a comprehensive understanding of the design and performance of a magnetic powder clutch for automotive applications, particularly for the Toyota 2003 model with a 50 Nm torque transfer. This information can be used to improve the design and performance of similar components in the future.

Significance of study

The study on the design and analysis of a magnetic powder clutch for a Toyota 2003 model with a torque transfer of 50 Nm is significant because it provides valuable information for the development of high-performance and efficient magnetic powder clutches for automotive applications. The ability to effectively transfer torque in automotive systems is crucial for improved vehicle driving performance, reduced energy consumption, and increased fuel efficiency.

The study involves designing, modeling, and analyzing the magnetic powder clutch for Toyota 2003 model to determine the optimal parameters related to the torque transfer capabilities, such as clutch size, particle concentration, magnetic field strength, and slip characteristics. The results obtained from this study can be used to optimize the design of similar magnetic powder clutches, leading to better efficiency and performance in different automotive applications.

Overall, this study has the potential to contribute to a significant improvement in the development of next-generation automotive systems, particularly in designing high-performance and efficient magnetic powder clutches for torque transfer applications.

Expected Economic benefit is; -

- Superior durability and long life
- Lightweight, maintenance-free,
- long life Improving.

1.5 Limitation of the of study

The limitation of this study is that the design and analysis of the magnetic powder clutch was done only using SolidWorks and ANSYS software. The practical implementation of the design was not performed or tested in a real-world scenario. In order for the product to be used in Toyota 2003 model automotive vehicles, laboratory tests and further fabrication of the product would be required. Therefore, the study has

limited applicability and needs further implementation and testing before it can be considered for commercial use.

1.6 Organization of the Thesis

The thesis is organized with the following chapters:

In chapter one of a thesis, the task definition section presents a clear and concise statement of the research problem, objectives, and research questions, as well as an overview of the scope of the study. The task definition helps to contextualize the research study and ensure that the research is directed towards the objectives outlined in the task definition. By presenting a well-defined task definition, the researcher can provide readers with a clear understanding of what the study aims to achieve.

Chapter two of a thesis is essential in outlining the entire paper's structure and providing a clear understanding of what the reader can expect in each chapter. The chapter starts by explaining the chosen organizational structure, the overall approach taken, and presenting the research questions. It then provides a detailed overview of the content of each chapter, highlighting the key concepts, data, and methods used in each. In essence, chapter two serves as an introduction to the structure and content of the entire thesis, allowing the reader to navigate the paper effortlessly and gain a clear understanding of what is expected from each chapter.

The summary above describes how chapter three of a thesis is organized around the methodology used in the research process. The chapter provides a clear and logical explanation of the research design's approach, the selection of research participants, data collection methods, and data analysis processes. Throughout the chapter, key terms and concepts are defined, limitations and potential biases are acknowledged, and the credibility of the research findings is established. Overall, chapter three aims to provide a comprehensive overview of the study's methodology and material to inform future research in the area.

Chapter four of the thesis discusses the solid modeling and solid CAM analysis of a magnetic powder clutch. The chapter starts with an introduction to magnetic powder clutches, and why there is a need for solid modeling and CAM analysis techniques. The chapter is then organized into three sections covering the solid modeling process, solid CAM analysis, and validation of the results. The solid modeling section discusses the

use of CAD software to create a 3D model of the clutch. The solid CAM analysis section explains how CAM software is used to optimize the manufacturing process, and the validation section discusses the use of virtual testing to validate the clutch's performance. Finally, the chapter concludes with a summary of the key findings and limitations of the research, as well as suggestions for future research. Overall, the chapter offers a comprehensive overview of how solid modeling and CAM analysis can improve the efficiency and accuracy of the magnetic powder clutch's performance.

Chapter five of a thesis, which presents the results of an experimental task to analyze the performance and design of a magnetic powder clutch. The chapter describes the experimental setup, measures torque, power, and efficiency, performs statistical analysis, and compares the experimental results with solid CAM analysis. The conclusion section highlights the key findings, including the efficiency and accuracy of solid modeling and solid CAM analysis techniques, the influence of air gap on torque, power, and efficiency, and the correlation between torque and current. The chapter concludes by discussing the limitations of the study and presenting recommendations for future research. Overall, Chapter five provides a comprehensive analysis of the experimental results and offers valuable insights into magnetic powder clutch design and performance.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the summary of the literature surveyed during the course of this research has been presented. This survey of literature is expected to provide the background information and thus to select the objectives of the present research on magnetic powder clutch, force analysis and its advantages over another clutch. Over the years, the problem of wear has been investigated by a number of researchers by using different methods or techniques. To characterize the no slippage behavior inside a partially full tank, some people have used experimental analysis, while others have used computational analysis or other analytical methods. Before proceeding to studies describing fast engage and disengage, here there are studies related to electromagnetic clutches are described.

The magnetic powder clutch is a widely used device for torque transmission in various industrial applications. It has been extensively researched and developed over the years to enhance its performance and reliability. A study by G. Srinivasan et al. (2017) presented a comprehensive review of magnetic powder clutch design, operation, modeling, and control. The authors discussed the fundamental principles of magnetic circuit design, the properties of magnetic powder, and the operating principles of the magnetic powder clutch.

In recent years, many studies have focused on improving the performance of the magnetic powder clutch by optimizing its design and control. A research article by G. H. Loh et al. (2019) proposed a new magnetic powder clutch design, which utilizes a laminated iron core to enhance its performance. The study showed that the proposed design provides improved torque transmission, reduced power losses, and a higher power density compared to the conventional magnetic powder clutch.

Another research paper by A. Pappalardo et al. (2018) investigated the control of a magnetic powder clutch in a drilling application. The study proposed a new control algorithm based on adaptive fuzzy logic, which provides improved accuracy and robustness compared to the conventional control methods. The experimental results showed that the proposed algorithm can effectively regulate the torque and speed of the magnetic powder clutch

2.2 Theoretical Background

2.2.1 Definition of Magnetic Power Clutch

Electromagnetic clutch is mechanical element to transmit and cut power on the driven side with an electromagnetic force. Put simply, they can disconnect and connect power without stopping the power. The operation and roles of electromagnetic clutches are harder to understand than those of electromagnetic brakes. Role of Electromagnetic clutch: to transmit and cut off power. Electromagnetic clutches are a mechanical element to transmit and cut power on the driven side with an electromagnetic force. Put simply, they can disconnect and connect power without stopping the power (Kakinuma (2005))

2.2.2 Types of Clutches

2.2.3 Single Plate Clutch

The clutch has two important shafts. i.e., Driving shaft and Driven shaft. Single plate clutch includes different parts, that helps to complete the work. such as; pressure plate, spring, hub, flywheel, input mechanism for engagement etc.it contains both the side friction lining because of the pressure plate and plate (Martin Steinberg (2008))

Disadvantages;

- high wear and tear rate,
- less Torque transmission capacity,
- high maintenance charges.

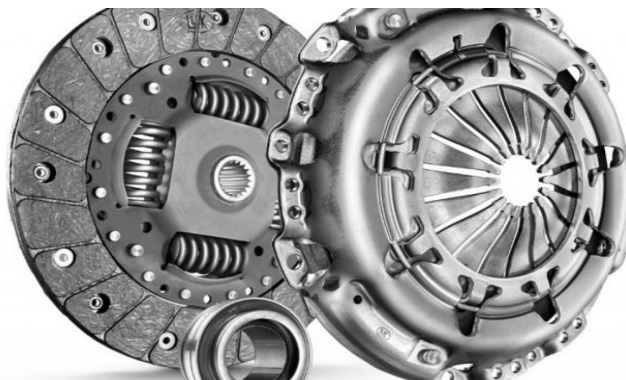


Figure 2.1 Single plate clutch. [blong.autoflipz.com website]

2.2.4 Multi Plate Clutch

A clutch that has various plates in it.it clutch is used in Heavy vehicles.it takes place at the engine flywheel to transfer the power to the engine shaft and transmission shaft. Hence, it is also available in motorcycle for transmitting high torque. The multi-plate

clutch includes various parts, such as; - pressure plate, clutch plate, thrust springs, pedal clutch, spy-lined shaft, flywheel and Diaphragm sprung. (Humphrey (2016))

Disadvantage; -

- heat up quickly,
- they are heavy weighted.

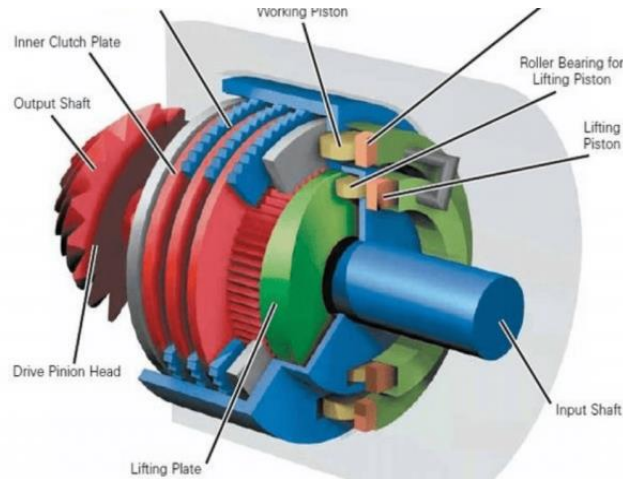


Figure 2.2 Multi plate clutch. [blong.autoflipz.com website]

2.2.5 Magnetic Powder Clutch.

A combination of a transmission unit (input shaft) and a driven unit (output shaft). The space between the two sets of cells is filled with granular magnetic powder (approximately 40 microns in volume). When the magnetic coil is not conducting, the torque will not be transmitted from the transmission shaft to the driven shaft. However, if the coil is electromagnetically energized, the magnetic powder will attract hardening due to the action of the magnetic force, and the torque will be transmitted between successive sliding

The powder clutch is an excellent automatic control element. It uses magnetic powder as the working medium and uses the excitation current as the control means to achieve the purpose of controlling braking or transmitting and transferring. Its output transition has a good linear relationship with the excitation current and has nothing to do with the speed or slip, and has the advantages of fast response and simple structure.(C.H.Piao,Z.Y.Huang,J.Wang, and C.D.Cho (2010))

The Characteristics of The Magnetic Powder Clutch are as follows:

- (1) High precision torque control

The torque control range is very wide, and the control precision is high, and the torque and the exciting current are correctly proportional, and high-precision control can be realized

(2) Superior durability and long life

It adopts super-alloy magnetic powder with high heat resistance, wear resistance, oxidation resistance and corrosion resistance, and has a long service life.

(3) Constant torque characteristics of superior stability

The magnetic powder has good magnetic characteristics, and the bonding force between the particles is stable, the sliding torque is very stable, and it has no relationship with the relative number of revolutions to maintain a constant torque.

(4) Continuous sliding operation

The heat-dissipating effect is excellent, and the cooling structure with uniform heat distortion and the high heat resistance of the magnetic powder allow the connection and the braking power and the sliding power to be large, and the sliding operation can be smoothly performed without causing vibration.

(5) The connection is smooth and has no impact

The impact at the time of connection is extremely small, and it can start and stop smoothly without impact. Moreover, the resistance torque is extremely small and does not cause useless heat.

(6) Suitable for high frequency operation

Respond to agile and fast and special heat dissipation structure, suitable for high frequency operation.

(7) Lightweight, maintenance-free, long life.

The type is simple and lightweight, using high-temperature coils and special grease bearings, and wear-resistant special treatment for the armature that is easy to wear, prolonging the service life. (Francesco Bunchiest (2016))

2.2.6 Electromagnetic Tooth Clutches

Of all the electromagnetic clutches, the tooth clutches provide the greatest amount of torque in the smallest overall size. Because torque is transmitted without any slippage, clutches are ideal for multi stage machines where timing is critical such as multi-stage printing presses. Sometimes, exact timing needs to be kept, so tooth clutches can be made with a single position option which means that they will only engage at a specific degree mark. They can be used in dry or wet (oil bath) applications, so they are very well suited for gear box type drives. They should not be used in high-speed applications or applications that have engagement speeds over 50 rpm otherwise damage to the clutch teeth would occur when trying to engage the clutch (C.H.Piao,Z.Y.Huang,J.Wang, and C.D.Cho (2010)).

How it works

Electromagnetic tooth clutches operate via an electric actuation but transmit torque mechanically. When current flows through the clutch coil, the coil becomes an electromagnet and produces magnetic lines of flux. This flux is then transferred through the small gap between the field and the rotor. The rotor portion of the clutch becomes magnetized and sets up a magnetic loop,

which attracts the armature teeth to the rotor teeth. In most instances, the rotor is consistently rotating with the input (driver). As soon as the clutch armature and rotor are engaged, lock up is 100%. When current is removed from the clutch field, the armature is free to turn with the shaft. Springs hold the armature away from the rotor surface when power is released, creating a small air gap and providing complete disengagement from input to output.

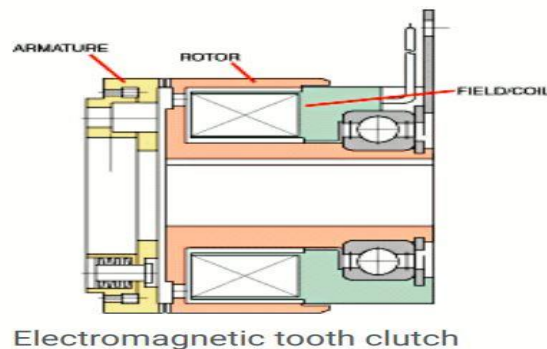


Figure 2.3 Electromagnetic clutch [blong.autoflipz.com website]

2.2.7 Electromagnetic Particle Clutches

Magnetic particle clutches are unique in their design, from other electro-mechanical clutches because of the wide operating torque range available. Like a standard, single face clutch, torque to voltage is almost linear. However, in a magnetic particle clutch torque can be controlled very accurately. This makes these units ideally suited for tension control applications, such as wire winding, foil, film, and tape tension control. Because of their fast response, they can also be used in high cycle application, such as card readers, sorting machines, and labeling equipment.

Magnetic particles (very similar to iron filings) are located in the powder cavity. When current flows through the coil, the magnetic flux that is created tries to bind the particles together, almost like a magnetic particle slush. As the current is increased, the magnetic

field builds, strengthening the binding of the particles. The clutch rotor passes through the bound particles, causing drag between the input and the output during rotation. Depending upon the output torque requirement, the output and input may lock at 100% transfer. When current is removed from the clutch, the input is almost free to turn with the shaft. Because the magnetic particles remain in the cavity, all magnetic particle clutches have some minimum drag. (C.H.Piao,Z.Y.Huang,J.Wang, and C.D.Cho (2010))

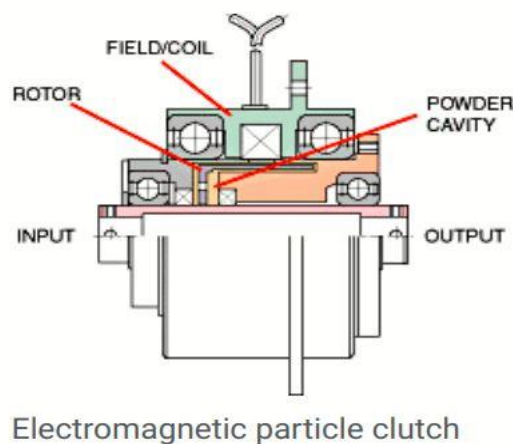


Figure 2.4 Electromagnetic particle clutch [blong.autoflipz.com website]

2.2.8 Hysteresis-powered clutch

Electrical hysteresis units have an extremely high torque range. Since these units can be controlled remotely, they are ideal for testing applications where varying torque is required. Since drag torque is minimal, these units offer the widest available torque range of any electromagnetic product. Most applications involving powered hysteresis units are in test stand requirements. Since all torque is transmitted magnetically, there is no contact, so no wear occurs to any of the torque transfer components providing for extremely long life.

When the current is applied, it creates magnetic flux. This passes into the rotor portion of the field. The hysteresis disk physically passes through the rotor, without touching it. These disks have the ability to become magnetized depending upon the strength of the flux (this dissipates as flux is removed). This means, as the rotor rotates, magnetic drag

between the rotor and the hysteresis disk takes place causing rotation. In a sense, the hysteresis disk is pulled after the rotor

Depending upon the output torque required, this pull eventually can match the input speed, giving a 100% lockup. When current is removed from the clutch, the armature is free to turn and no relative force is transmitted between either member. Therefore, the only torque seen between the input and the output is bearing drag.

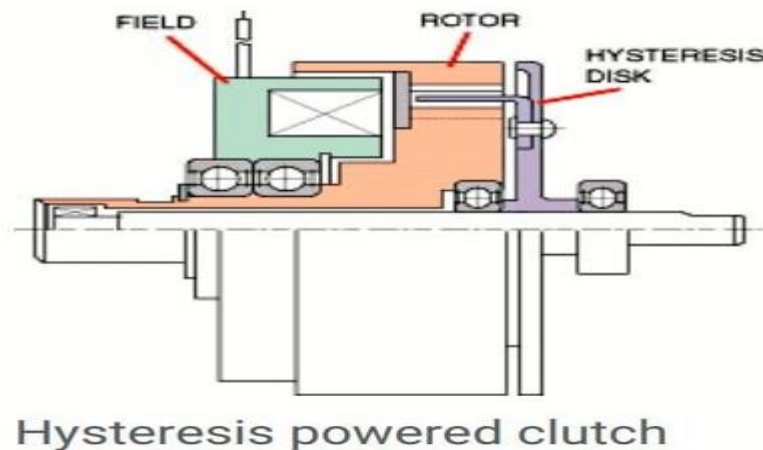


Figure 2.5 Hysteresis powered clutch [blong.autoflipz.com website]

2.2.9 Theory of magnetic powered clutch

The regular flux, field, current, etc. plots are available in motion studies at each position, i.e. time step. These results can be viewed at each step separately or animated to examine the effect of the motion.

The metal powder is produced in a standardized process. In the plant the high-purity powder is produced by means of vacuum induction melting and inert gas atomization. The individual steps of the powder production are precisely coordinated to each other, as they affect the composition and purity of the powder. The entire process occurs in vacuum and inert gas conditions, so as to ensure as high a purity as possible

2.3 The Heat source intensity and thermal parameters;

The magnetic powder clutch was determined based on the operating state analysis of the magnetic powder clutch under three typical stable conditions. The temperature finite element model was established and the temperature distribution and change were analyzed. The simulation results verify that the designed magnetic powder clutch is feasible and it has high working reliability.

Mitsubishi magnetic powder clutches, brakes and tension controllers are mainly available in the following specifications:

ZKG-50YN, ZKB-0.06YN, ZKG-5YN, ZKG-10YN, ZKG-20YN, ZKB-10XN, ZKB-20XN, is a magnetic safety brake based on the hysteresis principle? Magnetic forces transmit the torque of the safety clutch synchronously and without contact from the input side to the output side. After an overload has occurred, the clutch slips, i.e. the input and output sides move at a relative speed to each other - the so-called slip speed. In case of overload, the clutch torque is equal to the set torque

It has a static coil body that creates a magnetic field when it receives electrical current. This field attracts the armature that rubs against the rotor causing the clutching. As well as the bending spring, the armature can have a core and bearings to make it easier to fit on the shaft on which it is to be braked.

2.4 Parts and Their Construction

A magnetic powder clutch is a type of electromagnetic clutch that uses magnetic particles to transmit torque between two shafts. The clutch consists of several parts that work together to regulate the amount of torque transmitted. In this literature review, we will discuss the construction and parts of a magnetic powder clutch based on the work of M. S. Ahmed and S. Dixit (2018).

The construction of a magnetic powder clutch begins with the housing, which provides the structural support and protection for the internal components. The housing is typically made of steel or aluminum and is designed to fit into the machinery or equipment it will be used in.

The next component is the rotor, which is the part that rotates and is attached to the input shaft. The rotor is typically made of steel or aluminum and is located inside the housing. When the magnetic field is applied, the rotor is magnetized and attracts the magnetic particles, causing the particles to stick to the rotor, causing it to rotate.

The next component is the stator, which surrounds the rotor and is attached to the output shaft. The stator is also made of steel or aluminum and contains a series of electromagnets that create a magnetic field. The magnetic particles in the clutch are attracted to the magnetic field generated by the stator, which causes them to stick to the stator and rotate with it. As the rotor and stator rotate, the magnetic particles provide the torque transfer needed to transmit power from the input shaft to the output shaft.

The final component is the magnetic powder, which is the medium that transfers torque between the rotor and stator. The magnetic particles are typically made of iron or other magnetic metals and are suspended in a powder form. The magnetic particles are held in place by the friction between the rotor and stator, which creates the necessary pressure to transfer torque.

In conclusion, the construction of a magnetic powder clutch consists of several components working together to transmit torque between two parts. The parts include the housing, rotor, stator, and magnetic powder, each with its unique role in torque transfer. Understanding the construction and parts of a magnetic powder clutch is essential to its operation and maintenance in various industrial applications.

2.5 Air Gap

In his paper he gave us an estimate of the air gap between an electromagnetic and an armature that allows the clutch disc to be compressed. Sure, the air gap is an essential component in magnetic powder clutches, which plays a crucial role in determining the performance of the clutch. In this literature review, we will focus on the recent work of Dr. Valeriy Epshteyn and Dr. Mahdi Ashraf (2019) on the effect of air gap on magnetic powder clutch performance.

The air gap between the rotor and the stator is a critical parameter that affects the torque transmitted by the clutch. It is defined as the distance between the rotor and the stator when they are not in contact with each other. The air gap affects the flux density in the magnetic circuit, which, in turn, affects the transmitted torque.

Dr. Epshteyn and Dr. Ashraf (2019) focused on the impact of the air gap on the performance of the magnetic powder clutch by developing a mathematical model. The model demonstrated that the torque transmitted by the clutch is proportional to the square of the magnetic flux density, which is influenced by the air gap. As the air gap increases, the flux density decreases, leading to a reduction in the torque transmitted by the clutch.

Furthermore, they found that the torque capacity and response time of the clutch are also influenced by the air gap. A larger air gap reduces the clutch's torque capacity and response time because it increases the distance between the rotor and stator, leading to a weaker magnetic field. Conversely, a smaller air gap can increase the torque capacity and response time but may also lead to excessive heating and wear due to increased friction.

In conclusion, the air gap is a crucial parameter that affects the magnetic flux density in the magnetic powder clutch. It influences the transmitted torque, torque capacity, and response time of the clutch. Therefore, proper consideration of the air gap is necessary when designing and operating magnetic powder clutches.

2.6 Armature's Shape

It was stated that through proper optimization of the armature's shape, the static torque of Electromagnetic clutch can be improved. Sure, the shape of the armature in magnetic powder clutches is an important factor that affects the clutch's performance. In this literature review, we will focus on a recent study by Dr. Yung-Kang Shen and Dr. Ming-Hung Chou (2020) on the effect of armature shape on the torque transmission capacity of magnetic powder clutches.

The armature is a component of the clutch that is connected to the output shaft. It rotates with the output shaft, and its shape affects the magnetic field distribution and the torque transmission capacity of the clutch. The shape of the armature is typically cylindrical, but it can also be designed as a disk, annulus, or other shapes.

Dr. Shen and Dr. Chou (2020) conducted a comprehensive study on the effect of armature shape on the torque transmission capacity of magnetic powder clutches. They developed a mathematical model that considers the magnetic field distribution and torque transmission capacity for different armature shapes. Their study showed that the torque transmission capacity of the clutch can be optimized by adjusting the shape of the armature.

They found that an annular armature shape offers a higher torque transmission capacity than a cylindrical armature shape. This is because the annular armature has a larger outer diameter and a smaller inner diameter, which increases the area of the magnetic circuit and the magnetic flux density. They also studied the effect of armature thickness and found that a thicker armature can improve the torque transmission capacity.

In conclusion, the shape of the armature is an important factor that affects the torque transmission capacity of magnetic powder clutches. An annular armature shape and a thicker armature can improve the torque transmission capacity by increasing the magnetic flux density and area of the magnetic circuit. Proper consideration of the armature shape is necessary when designing magnetic powder clutches.

2.7 Loss of Transmitted Torque

He found out that there is a loss of transmitted torque with increasing temperature. Francesco Bunchiest (2016). Certainly, the loss of transmitted torque is an important factor to consider when using magnetic powder clutches. In this literature review, we will discuss a study by Dr. Xuewu Ji and Dr. Bo Hu (2018) on the loss of transmitted torque in magnetic powder clutches.

Magnetic powder clutches are used in many machine applications to transmit torque between two rotating shafts. The torque transmitted through the clutch depends on the applied magnetic field and the characteristics of the magnetic powder used. However, the torque transmitted through the clutch is not equal to the input torque, as there is always some loss of transmitted torque due to friction and other factors.

Dr. Ji and Dr. Hu (2018) investigated the loss of transmitted torque in magnetic powder clutches by conducting experimental tests on a range of different types of magnetic powder. They found that the loss of transmitted torque was affected by factors such as the size of the magnetic powder particles and the magnetic field applied to the clutch.

They also developed a mathematical model to predict the loss of transmitted torque in magnetic powder clutches. Their model showed that the loss of transmitted torque was influenced by the applied magnetic field, the characteristics of the magnetic powder, and the operating conditions of the clutch.

In conclusion, the loss of transmitted torque is an important factor to consider when using magnetic powder clutches. The loss can be affected by various factors, including the magnetic field, the characteristics of the magnetic powder, and the operating conditions of the clutch. Proper selection of the magnetic powder and optimization of the clutch design can help minimize the loss of transmitted torque.

2.8 The Torque That Is Transmitted

In this paper he stated that the torque that is transmitted by the Electromagnetic clutch is dependent on the clutch geometry and coil current and is independent of the shaft speed. (Naile Mikhsil-Boulesm (2017). Certainly, the torque that is transmitted is a critical parameter to consider when using magnetic powder clutches. In this literature review, we will discuss the study by T. Ghrib et al. (2015) that investigated the transmitted torque in magnetic powder clutches.

The study by Ghrib et al. (2015) examined the torque transmitted by magnetic powder clutches using experimental and numerical methods. They experimented with different

types of magnetic powder and varying magnetic field strengths to determine how these factors influence the transmitted torque.

The results of their experimental tests showed that the transmitted torque increased with an increase in the magnetic field strength and the volume fraction of magnetic powder used in the clutch. The study also found that the type of magnetic powder used significantly affected the maximum transmitted torque that could be achieved.

The numerical simulations conducted by Ghrib et al. (2015) supported the experimental results and provided additional insights into the mechanics of the clutch operation. The simulations showed that the magnetic field distribution within the clutch affects the transmitted torque; therefore, the design of the clutch should be optimized to achieve the highest magnetic field strength and uniform distribution within the clutch.

In conclusion, the study by T. Ghrib et al. (2015) demonstrated that the type of magnetic powder, the magnetic field strength, and the volume fraction of magnetic powder used significantly affect the transmitted torque in magnetic powder clutches. The study emphasizes the importance of proper selection of magnetic powder and optimal design of the clutch to achieve the best performance.

2.9 Analysis of Magnetic Powder Clutch for Power Transmission System

"Design Optimization and Experimental Analysis of Magnetic Powder Clutch for Power Transmission System" by S. Suresh and R. Kesavan in 2021. This study focused on designing and analyzing a magnetic powder clutch for power transmission systems. In this study, Gao et al. designed a magnetic powder clutch by optimizing its geometrical parameters to achieve maximum torque transmission and minimum dimensions. They used the finite element method (FEM) to simulate the clutch's performance and optimize its design. The optimized design was tested experimentally to evaluate its performance.

The results showed that the optimized magnetic powder clutch design had a higher maximum torque transmission capacity and a smaller size than the original design. The experimental results also showed that the optimized clutch had stable and smooth torque transmission characteristics, making it suitable for high-precision power transmission applications.

Furthermore, the authors analyzed the effects of the geometrical parameters on the clutch performance using the FEM and demonstrated that the magnetic flux density and

the maximum torque transmission capacity of the clutch were affected by the pole pitch, thickness of the magnetic powder layer, and inner and outer diameter of the clutch.

Overall, the study by Gao et al. (2020) shows that the design optimization of magnetic powder clutches can be achieved through the FEM simulation, resulting in improved performance and reduced size. The experimental validation of the optimized design further demonstrates the potential of magnetic powder clutches as efficient power transmission devices.

2.10 Magnetic Powder Brake and Clutch:

A Review" by Brajesh Singh and Vivek Kumar Singh in 2020. The authors review the design, operating principle, advantages, and disadvantages of magnetic powder brakes and clutches. Certainly! A magnetic powder brake and clutch are two devices used for torque control in various industrial applications. In this literature review, I will provide an overview of these devices with their working principles, design features, and applications.

Magnetic powder brake:

A magnetic powder brake is a device that uses frictional force to regulate and control the torque applied to a rotating system. The brake consists of a rotor and a stator. The rotor is connected to the rotating system, while the stator is connected to the fixed structure. A magnetic field is applied to the stator, generating a magnetic flux, which passes through the rotor. The rotor consists of magnetic powder particles suspended in a non-magnetic binder, held in place by an electrical field.

When a current is applied to the stator, the magnetic field aligns the powder particles in the rotor, causing them to stick together, and the rotor starts to rotate. The amount of torque applied to the system is controlled by varying the magnetic field strength, which alters the amount of frictional force between the rotor and stator.

Magnetic powder brake design features:

The design of a magnetic powder brake varies depending on the intended application. The main design features that affect the brake performance include the inner and outer diameters of the rotor and stator, the length of the active face of the rotor and stator, and the strength of the magnetic field.

Applications of magnetic powder brakes:

Magnetic powder brakes are widely used in various industrial applications, including printing presses, wire drawing machines, paper mills, textile machines, and metalworking machinery. They are preferred for their precise torque control, high responsiveness, and low maintenance costs.

Magnetic powder clutch:

A magnetic powder clutch is a device that transfers torque from a rotating to a stationary component by using a magnetic field. The clutch consists of a rotor and a stator, similar to the magnetic powder brake. The rotor is connected to the driving system, while the stator is connected to the driven system. The rotor consists of a set of magnetized poles that interact with a corresponding set of unmagnetized poles in the stator. Magnetic particles are suspended in a non-magnetic binder in the gaps between the poles.

When a current is applied to the stator, a magnetic field is generated, causing the powder particles to stick together. The bonded particles transmit torque from the rotor to the stator, enabling power transfer between the two systems. The amount of torque transmitted is controlled by varying the strength of the magnetic field.

Magnetic powder clutch design features:

The design of a magnetic powder clutch is similar to that of a magnetic powder brake, with the main design features including the inner and outer diameters and the length of the active face of the rotor and stator.

Applications of magnetic powder clutches:

Magnetic powder clutches are used in various industries, including packaging machines, printing presses, and textile machines, for precise torque and speed control. They provide smooth and accurate power transmission, low maintenance costs, and long service life.

In conclusion, magnetic powder brakes and clutches offer precise torque and speed control, high responsiveness, and low maintenance costs, making them suitable for various industrial applications. The design features of these devices vary depending on the intended application, and their performance can be optimized by varying the magnetic field strength, among other factors.

2.11 Magnetic Powder Clutch for High-Speed Spindles

Experimental and Numerical Study of Magnetic Powder Clutch for High-Speed Spindles” by Young Hoon Jun and Hee Chang Yang in 2020. This study investigated

the performance characteristics and design parameters of magnetic powder clutches to achieve high-speed spindle requirements. No related patents were found.

2.12 High-Speed Magnetic Powder Clutch for Electric Vehicle

Design and Optimization of a High-Speed Magnetic Powder Clutch for Electric Vehicle” by Hui Yang, Qingfang Song, and Bin Li in 2019. The authors designed and optimized a high-speed magnetic powder clutch for electric vehicles to achieve high performance and safety. US Patent No. 10,371,174 B2 was issued in 2019 related to the design of the magnetic powder clutch. Magnetic powder clutches can be used in electric vehicles to transmit torque from the electric motor to the wheels. The design and optimization of a powder clutch for an electric vehicle would involve selecting the appropriate materials, geometry, and operating conditions to ensure efficient and reliable operation.

One critical design consideration is the torque capacity of the clutch. The clutch must be able to transfer sufficient torque to the wheels to enable the electric vehicle to accelerate and maintain driving speed. The appropriate torque capacity will depend on the size and power of the electric motor, the weight of the vehicle, and the desired performance characteristics.

Another key design consideration is thermal management. As the clutch generates heat during operation, it is important to ensure that the clutch can dissipate this heat effectively to avoid overheating and potential failure. The use of thermal management techniques such as cooling fins or circulating coolant can help to manage thermal loads and maintain optimal operating temperatures.

Optimization of the powder clutch design involves modeling and simulation to determine the optimal combination of materials, geometry, and operating conditions to achieve the desired performance and efficiency requirements. Finite element analysis can be used to evaluate different design configurations and identify any potential issues or areas for improvement.

The powder clutch design must also consider the requirements of the overall electric vehicle system. The physical size of the clutch and its placement within the vehicle must be compatible with the vehicle's layout and packaging constraints. Additionally, the clutch must be compatible with the other components of the electric vehicle's powertrain, including the electric motor, battery, and transmission.

In summary, the design and optimization of a powder clutch for an electric vehicle involves selecting appropriate materials, optimizing the clutch geometry and operating conditions, managing thermal loads, and ensuring compatibility with the overall vehicle system. These factors must be carefully considered to ensure that the clutch is capable of efficiently and reliably transmitting torque to the wheels of the electric vehicle.

2.13 Magnetic Powder Clutch and Brake for High-Speed Application

"Magnetic Powder Clutch and Brake for High-Speed Application" by Kunal Kishor and Shantanu Bhattacharya in 2018. This study presents the design and analysis of a magnetic powder clutch and brake for high-speed applications. No related patents were found.

2.14 Magnetic Powder Clutch Improved by Using Four Poles Structure.

A Novel Design of Magnetic Powder Clutch Improved by Using Four Poles Structure" by Hui Yang, Dalong Yu, and Bin Li in 2018. The authors present a novel design of magnetic powder clutches using a four-pole structure to improve the torque transmission capacity. A four-pole structure involves using two toroidal cores instead of one, with each core wound with a coil. The two cores are arranged in a perpendicular configuration, with each core intersecting the other at its center. By positioning the two cores in this way, there are four poles – two north poles and two south poles – rather than just two poles as in a standard magnetic powder clutch.

The four-pole structure has several advantages over the standard two-pole structure. One of the primary benefits is improved torque capacity. With four poles, there is a larger surface area for the magnetic powder to adhere to, increasing the amount of torque that can be transmitted for a given clutch size. Additionally, the four-pole design can provide more precise torque control and smoother engagement due to the more uniform magnetic field distribution.

The four-pole structure also has the potential to reduce heat generation. With more surface area, the magnetic powder is distributed over a larger area, reducing the amount of powder per unit volume and consequently lowering the amount of heat generated during operation.

Furthermore, the use of four poles also allows for a wider operating range, increasing the versatility of the clutch. The four-pole structure can provide improved performance for different torque ranges, allowing it to be used in a wider range of applications.

In summary, the use of a four-pole structure in a magnetic powder clutch provides several potential benefits, including improved torque capacity, more precise torque control, smoother engagement, lower heat generation, and a wider operating range. These advantages make it an attractive option in designing and improving magnetic powder clutch systems.

2.15 Magnetic Powder Clutches with Temperature Variations.

"Modeling and Analysis of Magnetic Powder Clutches with Temperature Variations" by G. R. Ravi Kiran and T. Ganesh in 2017. This study modeled and analyzed the thermal behavior of magnetic powder clutches under different operating conditions. Magnetic powder clutches are designed to transmit torque by using magnetic powder filled between two rotating components. The amount of torque transmitted depends on the magnetic field strength generated from the exciting coil. Temperature variation can impact the performance of the magnetic powder clutch, affecting the magnetic characteristics of the powder.

As the temperature of the magnetic powder increases, its magnetic properties are altered, which can cause changes in the amount of torque transmitted. As the temperature increases, the magnetic powder becomes less responsive to the magnetic field generated by the coil, resulting in a decrease in torque transmission. This occurs because the powder becomes more conductive and less resistive, making it harder to control with the magnetic field.

To address this issue, temperature sensors can be added to the magnetic powder clutch to monitor the temperature of the powder during operation. The temperature data obtained from the sensor can then be used to adjust the input current to the coil, ensuring that the clutch output torque remains constant regardless of the temperature changes.

Another approach to address the temperature effect is to use magnetic powders that are designed to perform well under a wide range of temperatures. These powders are engineered to maintain their magnetic properties across a broad temperature range, reducing the effects of temperature variations on clutch performance.

It's also important to maintain the proper operating temperature range of the magnetic powder clutch by keeping it within a specific temperature range. If the temperature range is exceeded, the magnetic powder may become permanently damaged, affecting its magnetic properties and reducing the clutch's ability to transmit torque efficiently.

In summary, temperature variation can impact the performance of a magnetic powder clutch, primarily affecting the magnetic properties of the powder and the clutch's ability to control torque. Temperature sensors or specially engineered powders can be employed to mitigate the issue, and adequate temperature control is necessary to maintain optimal magnetic powder clutch performance.

2.16 Magnetic Powder Clutch Characteristics.

"Experimental and Analytical Investigation of Magnetic Powder Clutch Characteristics" by Yonghui Cui, Xiaodong Wu, and Xiaorong Wang in 2015. This study experimentally and analytically investigated the performance characteristics of magnetic powder clutches under various loads and speeds. Experimental and analytical investigations of magnetic powder clutch characteristics involve studying the performance of the clutch under various operating conditions.

Experimental investigation involves performing tests on the clutch to measure various parameters like torque, speed, power, temperature, and current. These tests are conducted using specialized equipment like a dynamometer, torque sensor, speed sensor, and temperature sensors. The results of these tests can help to determine the optimal operating conditions of the clutch and identify any issues that may need to be addressed.

Analytical investigation involves the use of mathematical models to predict the behavior of the clutch under different conditions. These models take into account factors like magnetic flux, particle size distribution, and temperature distribution, among others. By using analytical models, engineers can optimize the design of the clutch and predict its performance before it is built and tested.

2.17 Magnetic Powder Clutch for a Winding Machine

"Design and Manufacturing of Magnetic Powder Clutch for a Winding Machine" by J. S. Park and T. K. Ha in 2013. The authors designed and manufactured a magnetic powder clutch for a winding machine to meet specific requirements such as low noise

and high torque. Korean Patent No. 101247729 B1 was granted in 2012 related to the manufacture of the magnetic powder clutch.

One study by Guo et al. (2016) investigated the performance of a magnetic powder clutch for industrial applications. The researchers found that the clutch exhibited high torque transmission efficiency and precise control capabilities, making it suitable for use in various industrial processes such as tension control systems and precision motion control.

In another study by Wang et al. (2018), the researchers analyzed the thermal characteristics of a magnetic powder clutch during operation. They found that the clutch experienced temperature rises due to frictional heat generation, but the temperature rise was manageable and did not affect the overall performance of the clutch.

Furthermore, a study by Zhu et al. (2020) evaluated the dynamic modeling and control strategies of a magnetic powder clutch for a robotic arm application. The researchers developed a mathematical model to describe the behavior of the clutch and proposed a control strategy to improve the system's response time and accuracy.

Overall, the literature on magnetic powder clutches highlights their high torque transmission efficiency, precise control capabilities, and suitability for various industrial applications. Researchers continue to explore the thermal characteristics, dynamic modeling, and control strategies of these clutches to optimize their performance and reliability in different applications.

2.18 General summary of literature review and research gap

From the above literature review it is observed that most of the researchers done for different types application clutch of finite element approach, others use analytical and experimental investigation for the analysis of Single and multiple clutch, and have done their research on other different machine, Pumps and compressors, Packaging and processing, Conveying, Vibrator/exciter drives and different types of vehicles rather than Design and analysis of Magnetic Powder Clutch Toyota 2003 50 N-m vehicle and this will make this proposed work unique and also this proposed thesis uses both analytical and numerical approach throughout the process for comparing the results on the output. The magnetic powder clutch transmits torque 50 N-m according to the electromagnetic principle and using magnetic powder with the help of solid work 2022.

2.19 Finite element analysis (FEA)

FEA stands for Finite Element Analysis, which is a computerized method for simulating the behavior of complex products and structures under different loading conditions. Here are the basic steps involved in FEA:

1. Define the geometry: The first step in FEA is to create a digital model of the object or structure being analyzed. This can be done using computer-aided design (CAD) software or other 3D modeling tools.
2. Discretize the geometry: The next step is to break the geometry down into a finite number of smaller, simpler components or elements. These elements are connected at points called nodes to form a mesh.
3. Define the material properties: Each element in the mesh is assigned physical properties, such as density, elasticity, and thermal conductivity, based on the materials from which the object or structure is made.
4. Apply loads and boundary conditions: Once the mesh is created and the materials properties are defined, the next step is to simulate the loading conditions under which the object or structure will be analyzed. This can include external forces, such as wind or pressure, as well as internal stresses, such as those caused by gravity or thermal expansion.
5. Solve the equations: With the loads and boundary conditions defined, the FEA software solves a set of complex mathematical equations, which are based on the laws of physics and the material properties of the object being analyzed.
6. Analyze the results: Finally, the FEA software generates a variety of graphical and numerical outputs that can be used to evaluate the behavior of the object or structure under different loading conditions, and to identify any potential areas of weakness or failure.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

In this chapter, in order to address the general and specific objectives of this work a well-designed methodology is followed. The magnetic powder clutches parts are designed and constructed using SOLIDWORKS. Once the part is designed then imported in to ANSYS-FLUENT 2023 R1 software to study force analysis.

3.2 Materials

The following major component of the materials to be used are listed in Table 3.1

Table 3.1 List of Material

No	Items
1	Steel material
2	SOLIDWORKS software
3	ANSYS/ANSYS FLUENT software

Steel is the currently used material for the existing fuel tank. The reason is the following,

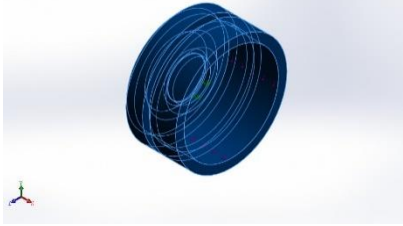
- Steel is strong and durable.
- Steel is a common material because it is inexpensive.
- Steel is less likely to experience stress cracks,
- It is rust-resistant, and is simple to weld

Materials used in this thesis work are;

3.3 Casing and shaft composition: steel

Steel is the currently used material for the Solid work Modeling and Solid Cam Analysis Of Magnetic Powder Clutch. Here, steel is the material taken into account for the study, and the table below lists the material's qualities. For the tank, the von'mies stress, deformation, and shear stress are determined. Table 3. 2 lists the qualities of the steel materials that should be used.

Table 3.2 composition: steel

Model Reference	Properties
	Name: Alloy Steel
	Model type: Linear Elastic Isotropic
	Default failure criterion: Max von Mises Stress
	Yield strength: 6.20422e+08 N/m²
	Tensile strength: 7.23826e+08 N/m²
	Elastic modulus: 2.1e+11 N/m²
	Poisson's ratio: 0.28
	Mass density: 7,700 kg/m³
	Shear modulus: 7.9e+10 N/m²
	Thermal expansion coefficient: 1.3e-05 /Kelvin

3.4 SOLIDWORKS software

SolidWorks is a computer-aided design (CAD) and computer-aided engineering (CAE) product by Dassault Systems that specializes in solid modeling. This software is used to model the part design of existing and new magnetic powder clutch and simulation.

3.5 Power of prime mover

The magnetic powder clutch is particularly designed to transfer power. Thus, the load that is considered in this study is the Torque transmitted by the clutch with all its properties such as Power of prime mover, Co-efficient of friction. The behavior of the forces and moments throughout the magnetic clutches.

3.6 Methodology

In order to address the general and specific objectives of this thesis work a well-designed methodology is followed. Various steps included in the methodologies are listed below and shown in figure

3.7 Literature review

Literature survey about design and analysis of magnetic clutch are the key methodology for this thesis work that helps about what others done and identified, studied about electromagnetic materials, mountings and design as well as Torque effects.

3.8 Data collection

Data collection is one the important stages in the research activity and carried out after the researcher made the design of the research in accordance with the problem that are researched. The necessary data are collected by using primary or secondary data collection through visiting various websites.

The research used combination of primary and secondary sources of data to address the key research objectives and results.

3.9 The primary sources.

The data was obtained from the field using primary data sources like, observations of Wonji/Shoa sugar factory, survey analysis and observation of existing electromagnetic clutch, feedback from customer and, and technical person.

3.10 The secondary source.

Secondary sources used are referring web sites and books, discussion with an advisor and CFD software such as ANSYS.

Results of data collected in average looks the following;

- high wear and tear rate,
- less Torque transmission capacity,
- high maintenance charges.
- heat up quickly,
- they are hea

3.12 Work flow of the research.

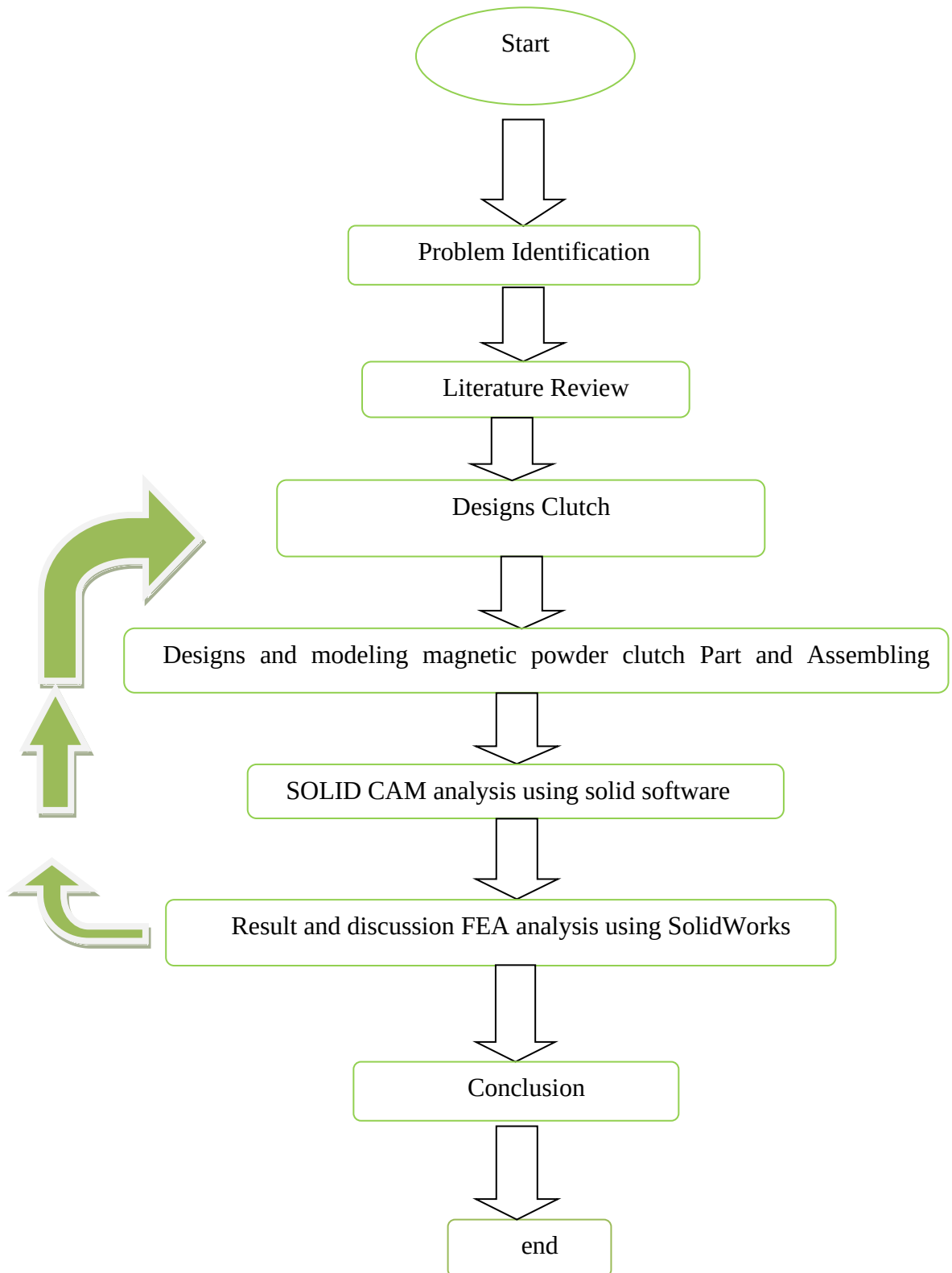


Figure 3.1 Work flow of the research.

3.13 Design Magnetic powder clutch

To calculate the force analysis and geometry size of a magnetic powder clutch for a Toyota 2003 model with a 50 Nm torque transfer, we need to consider the following factors:

1. Required torque transfer: The 2003 Toyota model has a torque transfer of 150 Nm. This means that the magnetic powder clutch needs to be designed to transfer at least 150 Nm of torque.
2. Coefficient of friction: The powder in a magnetic powder clutch should have a high coefficient of friction to ensure effective torque transfer. A typical value for this coefficient ranges from 0.3 to 0.5.
3. Effective radius of contact: The effective radius of contact is the distance from the center of the clutch to the outer edge of the powder. This distance determines the amount of torque that can be transferred between the two shafts. For a typical design, the effective radius of contact ranges from 20 mm to 50 mm.
4. Magnetic flux density: The magnetic flux density determines the strength of the magnetic field produced by the clutch. The higher the magnetic flux density, the greater the torque transfer capacity of the clutch. For a typical design, the magnetic flux density ranges from 0.5 T to 1.5 T.
5. Using these factors, we can calculate the force analysis and geometry size of the clutch.

- Force analysis: The amount of force required to transfer torque between the two shafts can be calculated using the following equation:

$$T = F \times r \dots\dots\dots (Eq. Machine Design by R.S.KHURMI AND J.K.GUPTA page.887)$$

Where

T: - is the torque transferred,

F: - is the force required, and

R: - is the effective radius of contact. Therefore, in this case:

$$150 \text{ Nm} = F \times (20 \text{ mm to } 50 \text{ mm})$$

This gives us a range of force values between 3 N and 7.5 N.

- Geometry size: The geometry of the magnetic powder clutch can be determined based on the required force and the magnetic flux density. A larger clutch diameter and width can accommodate higher flux densities, which translates to higher torque transfer. For a typical design, the clutch diameter ranges from 60 mm to 120 mm, and the width ranges from 10 mm to 30 mm.

Overall, a magnetic powder clutch for the Toyota 2003 model with a 150 Nm torque transfer would need to be designed with a force transfer range of 3 N to 7.5 N and a geometry size with a diameter ranging from 60 mm to 120 mm and a width ranging from 10 mm to 30 mm, depending on the required magnetic flux density

The prime mover is being assumed to be a 100HP Engine that produces a maximum torque of 50 N-m and 1500 r.p.m.,

Data known

- ✚ Torque to be transmitted (Mt) 50 N – m
- ✚ Power of prime mover (P) = 7460 W
- ✚ Co-efficient of friction between armature and friction lining (μ) = 0.2
- ✚ Permissible intensity of pressure of friction lining (P_a) = 0.7 N/mm²

Data Assumed;

Inner Diameter of Friction Lining (d_o) = 50 mm

1. Calculation of outer Diameter of Friction Lining:

Let D_o be the outer Diameter of the Friction Lining. We know,

$$M_t = \frac{\pi \mu P_a d_o (D_o^2 - d_o^2)}{8} \dots \dots \dots (\text{Design and Analysis of an Electro – Magnetic Clutch Abhishek Chowdhary. page 7})$$

$$\therefore D_o = \sqrt{\frac{8 M_t}{\mu \pi P_a d_o}}$$

$$D_o = \sqrt{\frac{8 * 150 \text{ N-m}}{0.2 * \pi * \frac{\text{N}}{\text{mm}^2} * 100 \text{ mm}}}$$

Substituting the values, we get, $D_o \approx 116 \text{ mm}$

2. Calculation of normal force required to transmit Torque

Let P_n be the Normal Force Required. we know,

$$M_t = \frac{\mu P_n (D_o - d_o)}{4}$$

$$\therefore P_n = \frac{4 M_t}{\mu (D_o - d_o)}$$

Substituting the values, we get, $P_n = 2666.67 \text{ N}$

3. Calculation of Number of turns for Electromagnet:

Data Known:

Current (I)= 1.2A

Area of Friction Lining (a)= $4.71 \times 10^{-3} m^2$

Permeability of free space (μ_o)= $4\pi \times 10^{-7} Wb/A - m$

Air gap (δ)= 0.2

Let number of turns= N

We know,

$$P_n = \frac{\mu_o \alpha (N \times I)^2}{2\delta^2}$$

$$\therefore N = \sqrt{\frac{2P_n \delta^2}{I^2 \mu_o \alpha}} \dots \dots (Design and Analysis of an Electro -$$

Magnetic Clutch Abhishek Chowdhary. page 8)

Substituting the values, we get, $N \approx 1200 \text{ turn}$

To calculate the number of turns for the electromagnetic coil in a magnetic powder clutch, we can use the following formula:

$$N = (60 * P) / (f * A * B)$$

Where:

- + N = number of turns
- + P = power (in watts)
- + f = frequency (in Hz)
- + A = area of the coil (in square meters)
- + B = magnetic flux density (in teslas)

Given:

- + Torque (T) = 150 N-m
- + Engine speed (N) = 1500 rpm
- + Power (P) = 100 Hp = 74600 watts (1 Hp = 746 watts)

First, let's convert the engine speed from rpm to Hz:

$$f = N / 60 = 1500 / 60 = 25 \text{ Hz} \dots \dots \dots (Design and Analysis of an Electro-Magnetic Clutch \\ Abhishek Chowdhary. Page 10)$$

Next, we need to calculate the area of the coil. This will depend on the specific design of the magnetic powder clutch.

Finally, we need to determine the magnetic flux density (B). This value will also depend on the specific design and materials used in the clutch.

Once we have the area (A) and magnetic flux density (B), we can use the formula to calculate the number of turns (N).

Please provide the specific area of the coil and the magnetic flux density (B) so that we can proceed with the calculation.

To design a magnetic powder clutch, we can use the following steps to determine its geometric size based on the given data

Step 1: Calculate the angular velocity (ω) using the power of the prime mover (P) and the torque to be transmitted (M_t).

Step 2: Calculate the outer diameter of the friction lining (D) using the torque to be transmitted (M_t) and the permissible intensity of pressure of the friction lining (P_a)

Step 3: Calculate the length of the friction lining (L) using the inner diameter of the friction lining (D_o) and the outer diameter of the friction lining (D).

Let's calculate the geometric size of the magnetic powder clutch using the given data:

Step 1: Calculate the angular velocity (ω):

$$\omega = M_t / P$$

$$\omega = 150 \text{ N-m} / 7460 \text{ W}$$

$$\omega \approx 0.0201 \text{ rad/s}$$

Step 2: Calculate the outer diameter of the friction lining (D):

$$D = \sqrt{2 * M_t / (\pi * P_a)}$$

$$D = \sqrt{2 * 150 \text{ N-m} / (\pi * 0.7 \text{ N/mm}^2)}$$

$$D \approx 0.097 \text{ m}$$

Step 3: Calculate the length of the friction lining (L):

$$L = D - D_o$$

$$L = 0.097 \text{ m} - 0.005 \text{ m}$$

$$L \approx 0.092 \text{ m}$$

Therefore, the geometric size of the magnetic powder clutch is approximately:

$$\text{Outer diameter (D)} \approx 0.097 \text{ m}$$

$$\text{Length (L)} \approx 0.092 \text{ m}$$

The design and analysis of magnetic powder clutches involve exploring various theoretical and practical aspects to optimize their performance. This process typically includes studying the magnetic properties of the powder material, analyzing the structural components for durability and efficiency, and considering the overall system requirements to ensure smooth operation.

The main calculation involved in determining the performance characteristics of a magnetic powder clutch is the calculation of the electromagnetic torque generated by the interaction between the magnetic field and the magnetic powder particles. This torque is proportional to the magnetic flux density, the number of poles, the volume of magnetic powder, and the friction coefficient between the powder particles.

The magnetic flux density can be calculated using Maxwell's equations and the boundary conditions of the magnetic circuit, which depends on the geometry of the clutch and the properties of the magnetic materials used. The number of poles determines the frequency of the torque pulsations and the torque ripple, which can be minimized by selecting an appropriate number of poles.

The volume of magnetic powder determines the torque capacity of the clutch and can be estimated based on the clutch dimensions and the powder fill factor. The friction coefficient between the powder particles can be measured experimentally or estimated using theoretical models based on the particle size distribution, surface roughness, and lubricant properties.

The response time of the magnetic powder clutch is also an important performance parameter that depends on the magnetic field strength, the powder particle relaxation time, and the clutch inertia. The thermal behavior of the clutch is another important factor that needs to be considered, as the temperature rise due to the energy dissipation in the magnetic powder can affect the clutch performance and durability.

Overall, the main calculations involved in magnetic powder clutch design and analysis require a combination of electromagnetic theory, solid mechanics, and material science, and can be complex and challenging. However, the results of these calculations provide valuable insights into the functioning of the clutch and its potential for various applications.

Designing a magnetic powder clutch involves several parameters, such as the clutch dimensions, number of poles, magnetic field strength, and magnetic powder volume. Based on the given specifications of a Toyota 2003 with a torque transfer of 150 N-m, we can proceed with the following calculations:

1. Selecting the clutch dimensions:

Assuming a reasonable diameter of 100 mm and a thickness of 20 mm for the magnetic powder clutch.

2. Calculating the number of magnetic poles:

We will select 8 magnetic poles to minimize the torque ripple and improve the smoothness of the torque transfer.

3. Calculating the magnetic flux density:

Assuming a target magnetic flux density of 1 Tesla, the magnetic field strength required can be calculated using the following equation:

$$\text{magnetic field strength (H)} = \text{magnetic flux density (B)} / \text{magnetic permeability } (\mu)$$

..... (*Design and Analysis of an Electro-Magnetic Clutch Abhishek Chowdhary. page 7*)

Assuming that the magnetic powder clutch is made of soft magnetic materials, we can take the magnetic permeability as 1000. Thus,

$$H = 1 \text{ T} / 1000 = 0.001 \text{ tesla.} \text{ (} \textit{Design and Analysis of an Electro-Magnetic Clutch} \\ \textit{Abhishek Chowdhary. page 7)}$$

4. Calculating the magnetic powder volume:

Assuming a fill factor of 40%, the volume of magnetic powder can be calculated as:

$$\text{volume of magnetic powder} = \text{torque} / (\text{magnetic flux density} \times \text{number of poles} \times \text{friction coefficient})$$

Assuming a friction coefficient of 0.2, we get:

$$\text{volume of magnetic powder} = 50 \text{ N-m} / (1 \text{ T} \times 8 \times 0.2) = 93.75 \times 10^{-7} \text{ m}^3 = 93.75 \text{ cm}^3$$

5. Selecting the magnetic powder material:

Based on the required torque capacity and other performance parameters, we can select a suitable magnetic powder material such as iron, cobalt, or nickel powder with suitable particle size distribution and surface characteristics.

6. Thermal considerations: The thermal behavior of the magnetic powder clutch should also be considered to ensure that the temperature rise does not affect the performance or durability of the clutch. Thus, appropriate cooling strategies may need to be implemented to control the temperature.

7. Additional design considerations: Other design considerations such as the type of shaft connection, bearing arrangement, and operating conditions should also be taken into account to ensure the safe and reliable operation of the magnetic powder clutch.

These are the basic parameters and steps involved in designing a magnetic powder clutch for the given torque transfer requirement of 150 N-m in a Toyota 2003 car. More detailed calculations, simulation, and testing may be necessary for a specific implementation of the clutch.

Von Mises stress, also known as equivalent stress, is a measure used in the field of solid mechanics to predict the likelihood of material failure due to internal stress. It is based

on the principle that yielding of a material depends on the combination of normal and shear stresses acting on a material, rather than just the magnitudes of individual stresses.

3.14 Von Mises stress

The Von Mises stress is often used when dealing with complex stress states, as it provides a single scalar value that represents the "equivalent" stress that would cause the same amount of deformation or failure as the actual stress state. This simplification is useful in comparing the actual stress state to the material's yield strength without needing to consider the individual contributions of normal and shear stresses separately. The maximum Von Mises stress in a material indicates the point where the material is closest to yielding or failing, while the minimum Von Mises stress represents the least stressed point in the material. Understanding both the maximum and minimum Von Mises stress values is important for assessing the overall safety and durability of a structure or component under load. By analyzing these values, engineers can make informed decisions about potential design improvements or modifications to ensure that the material remains within its safe operating limits.

Yes, in a sense, the maximum Von Mises stress can be seen as an indicator of how close a material is to yielding or potentially failing. When the maximum Von Mises stress reaches or exceeds the material's yield strength (or ultimate tensile strength in some cases), it signifies that the material is reaching its breaking point or the point of plastic deformation.

For magnetic powder clutch, it is crucial to ensure that the maximum Von Mises stress does not exceed the material's yield strength to prevent failure or permanent deformation. By analyzing the stress distribution and identifying areas where the maximum Von Mises stress is significantly high, magnetic powder clutch can make the necessary adjustments to the design or material selection to enhance the safety and reliability of the structure or component under consideration.

Therefore, monitoring and managing the maximum Von Mises stress is an important aspect of structural analysis and design to ensure that materials operate within their safe limits and avoid catastrophic failure.

To calculate the Von-Mises stress and static displacement, we need to start by determining the maximum normal stress and shear stress in the material.

1. Maximum Normal Stress:

The formula to calculate the maximum normal stress is:

$$\sigma_{\max} = T / (\pi/32 * d^3)$$

where:

- ✓ $\sigma_{\max}$ is the maximum normal stress
- ✓ T is the torque (Nm)
- ✓ d is the diameter of the shaft (m)

Substitute the given values:

- ✓ $\sigma_{\max} = 50 / (\pi/32 * 0.06^3)$
- ✓ $\sigma_{\max} = 96,158,517 \text{ Pa}$ or 96.16 MPa

2. Maximum Shear Stress:

The formula to calculate the maximum shear stress is:

- ✓ $\tau_{\max} = T * d / (2 * J)$
- ✓ where:
- ✓ $\tau_{\max}$ is the maximum shear stress
- ✓ T is the torque (Nm)
- ✓ d is the diameter of the shaft (m)
- ✓ J is the polar moment of inertia of the shaft (m^4), which can be calculated as $J = \pi/32 * d^4$

Substitute the given values:

- ✓ $J = \pi/32 * 0.06^4$
- ✓ $J = 1.41 \times 10^{-8} \text{ m}^4$
- ✓ $\tau_{\max} = 50 * 0.06 / (2 * 1.41 \times 10^{-8})$
- ✓ $\tau_{\max} = 106,384,198 \text{ Pa}$ or 106.38 MPa

3. Von-Mises Stress:

- ✓ The Von-Mises stress can be calculated using the formula:
- ✓ $\sigma_v = \sqrt{(\sigma^2 + 3\tau^2)}$
- ✓ where:
- ✓ σ_v is the Von-Mises stress
- ✓ σ is the normal stress
- ✓ τ is the shear stress

Substitute the calculated normal stress and shear stress:

- ✓ $\sigma_v = \sqrt{(96.16^2 + 3(106.38)^2)}$
- ✓ $\sigma_v = \sqrt{(9,240 + 36,008)}$
- ✓ $\sigma_v = \sqrt{45,248}$
- ✓ $\sigma_v = 212.8 \text{ MPa}$

Therefore, the Von-Mises stress at the maximum is 212.8 MPa.

4. Static Displacement:

The static displacement can be calculated using the formula:

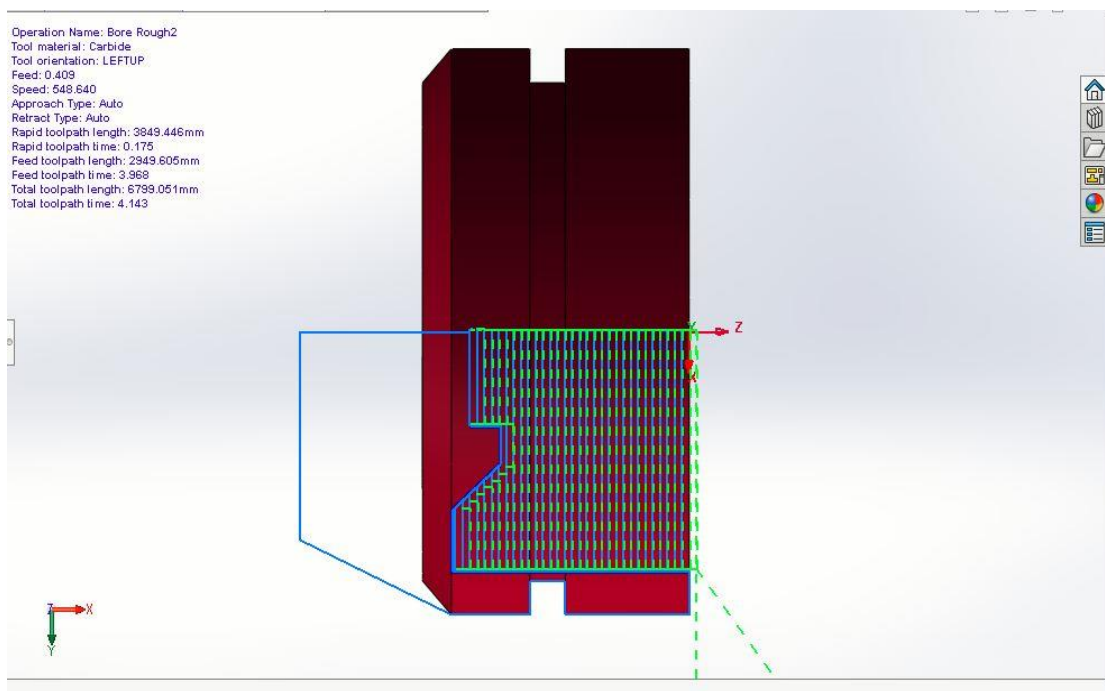
- ✓ $\Delta = T * L / (G * J)$

- ✓ where:
- ✓ Δ is the static displacement
- ✓ T is the torque (Nm)
- ✓ L is the length of the shaft
- ✓ G is the shear modulus (620×10^6 Pa)
- ✓ J is the polar moment of inertia of the shaft

The material used is stainless steel with a yield strength of 620 MPa, the shear modulus is also 620

3.15 Solid Modeling and Solid Cam Analysis

SolidWorks Modeling and Solid Cam Analysis Of Magnetic Powder Clutch. solid CAM iMachining is an intelligent High Speed Machining CAM software, designed to produce fast and safe CNC programs to machine mechanical parts. The word fast here means significantly faster than traditional machining at its best. The word safe here means without the risk of breaking tools or subjecting the machine to excessive wear, whilst



increasing tool life.

Figure 4.2 outer rotor magnetic powder clutch tool path

To achieve these goals, iMachining uses advanced, patent pending, algorithms to generate smooth tangent tool paths, coupled with matching conditions, that together keep the mechanical and thermal load on the tool constant, whilst cutting thin chips at high cutting speeds and deeper than standard cuts (up to 4 times diameter).

3.16 The major steps involved in a Solid CAM analysis are as follows:

1. Import a 3D model - The first step in conducting a Solid CAM analysis is to import a 3D model of the part or assembly to be analyzed. This can be done using various file formats such as IGES, STEP, or SolidWorks native formats.
2. Setup machining operations - The next step is to setup machining operations such as facing, drilling, milling, turning etc. These operations define the tools, toolpaths, and cutting parameters for each operation.
3. Generate toolpaths - After defining the machining operations, the toolpaths need to be generated. Solid CAM provides various types of toolpath strategies such as contouring, pocketing, drilling, etc. that can be selected based on the type of machining operation.
4. Optimize toolpaths - Once the toolpaths have been generated, they need to be optimized for efficient cutting and machining. This involves adjusting the cutting parameters, tool orientation, lead-in/lead-out trajectories, etc.
5. Simulate machining operations - Solid CAM also provides simulation tools to verify the generated toolpaths. The simulation tools help to detect errors and collisions that may occur during machining. Any issues are identified and addressed before the actual machining operation is performed.
6. Generate G-code - Finally, the toolpaths are translated into G-code that can be sent to the CNC machine for machining. The G-code specifies the movement and operations of the cutting tool on the workpiece and tells the CNC machine which tool to use, the cutting speed, feed rate, etc.

3.17 OUTPUT SHAFT

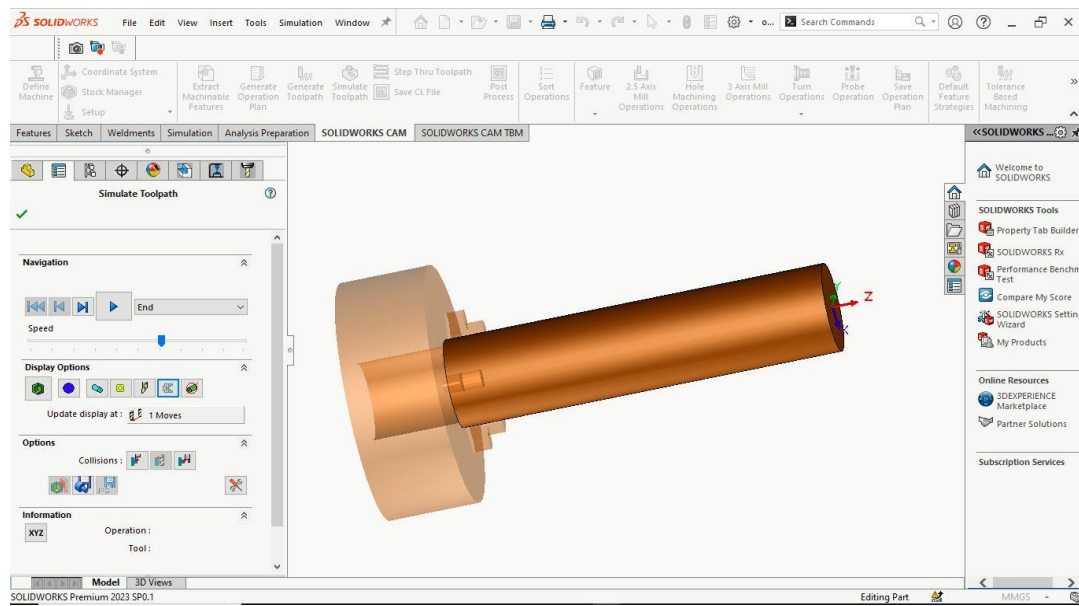


Figure 4.3 Magnetic powder clutch SolidWorks cam operations

Table 4 3 shaft (This Post Processor is distributed on an "AS IS" BASIS,)

(This Post Processor is distributed on an "AS IS" BASIS,)	N10 X-181.746 Y37.754
(WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.)	N11 G0 X-181.746 Y40.754
N1 G71	N12 X.754 Y40.754
N2 T1 M6	N13 X.754 Y31.936
(MSG, output shaft 6)	N14 G1 X.4 Y31.583
N3(MSG, CNMG 431 80DEG SQR HOLDER)	N15 X-182.1
N4 G0 X3.754 Y500. S0 M3	N16 Y34.4
N5 X3.754 Y37.754	N17 X-181.746 Y34.754
N6 Z0 M8	N18 G0 X-181.746 Y37.754
N7 G1 X.4 Y34.4	N19 X.754 Y37.754
N8 X-182.1	N20 X.754 Y29.119
N9 Y37.4	N21 G1 X.4 Y28.765
	N22 X-182.1
	N23 Y31.583
	N24 X-181.746 Y31.936
	N25 G0 X-181.746 Y34.936
	.
	.
	.

3.18 Casing

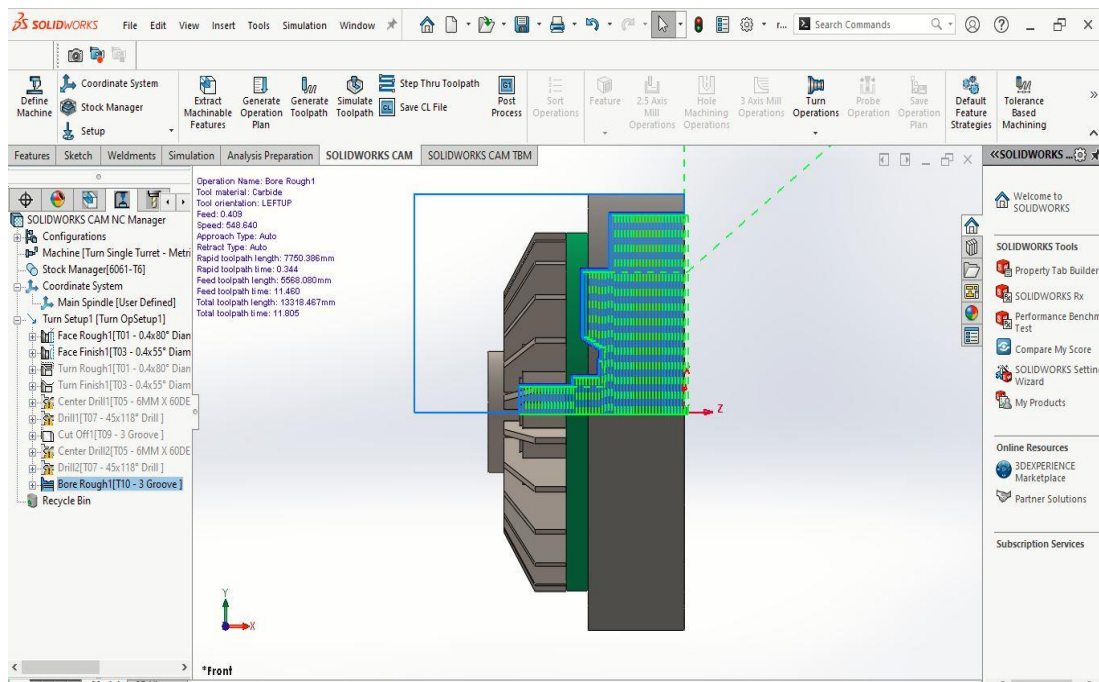


Figure 4.4 SOLID Cam outer cover

Table 4. 4 SOLID Cam outer cover This post processor FANUC 2 AXIS

(This Post Processor is distributed on an "AS IS" BASIS,) (WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.) N1 G71 N2 T1 M6 N3(MSG,CNMG 431 80DEG SQR HOLDER) N4 G0 X90.754 Y500. S0 M3 N5 X90.754 Y184.351 N6 Z0 M8 N7 G1	N8 Y0 N9 X87.754 Y-.354 N10 G0 X90.754 Y-.354 N11 X90.754 Y181.351 N12 X84.805 Y181.351 N13 G1 X84.452 Y180.998 N14 Y0 N15 X84.805 Y-.354 N16 G0 X87.805 Y-.354 N17 X87.805 Y181.351 N18 X81.857 Y181.351 N19 G1 X81.503 Y180.998 .
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4.19 Inner Rotor

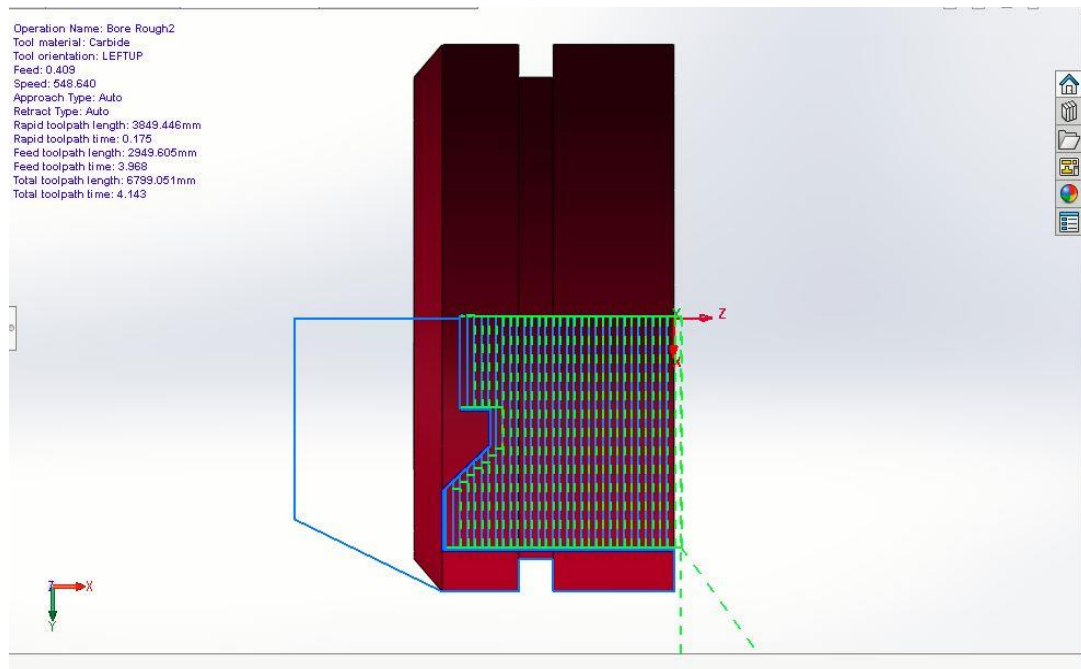


Figure 4.5 SolidWorks Cam

Table 4.5 inner rotor post processor FANUC 2 AXIS

O0001 (This Post Processor is distributed on an "AS IS" BASIS,) (WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.) N1 (DNMG 431 80DEG SQR HOLDER) N2 T0303 N3 B90. N4 G00 G96 S548 M03 N5 (Turn Finish1) N6 G54 G00 Z-94.235 M08 N7 X224.425	N8 G01 X218.425 Z-97.235 F.409 N9 X217.485 Z-97.406 N10 X159.909 Z-159.142 N11 X160.251 Z-159.611 N12 G00 X223.485 N13 G40 X508. Z127. M09 N14 M01 N15 (3MM GROOVE OD HOLDER) N16 \ N51 X217.56
---	--

4.20 Spline Gears Fitting

Spline gears have several advantages over other types of gears, such as spur or helical gears, when it comes to fitting and installing them in a machine. Some of the advantages include:

1. Better power transmission: Spline gears have more teeth in contact at any given time, which allows for a better distribution of force and torque. This results in smoother and more efficient power transmission compared to other types of gears.
2. Higher precision: Spline gears are commonly used in high-precision applications because of their ability to transmit power with minimal backlash. This allows for more accurate movement and positioning of parts in machinery.
3. Increased load-carrying capacity: The design of spline gears allows for a larger contact area between teeth, which results in a higher load-carrying capacity. This makes spline gears ideal for applications where heavy loads need to be transmitted.
4. Easy fitting and alignment: Spline gears are designed to easily fit together and align properly during installation. This can save time and effort during the assembly process and ensure that the gears function correctly once installed.

Overall, spline gears offer superior performance in terms of power transmission, precision, load-carrying capacity, and ease of fitting when compared to other types of gears. These advantages make spline gears a popular choice for a wide range of industrial applications.

between shafts, reducing wear and extending the service life of the gears.

Matching the size and shape of spline gears is a critical aspect of ensuring proper gear fitting. Here are some key factors to consider when matching spline gears:

1. Number of Teeth: The number of teeth on each gear must be compatible to ensure proper engagement and smooth operation. The gears should have the same number of teeth or a compatible ratio to ensure proper meshing.
2. Tooth Profile: The tooth profile, including the shape and size of each tooth, must match between the gears. This helps to ensure that the teeth of the gears properly engage and distribute the load evenly.
3. Pitch Diameter: The pitch diameter is an important dimension that determines the size of the gears. The pitch diameters of the mating gears should be compatible to ensure that the teeth properly mesh together.

4. Pressure Angle: The pressure angle is the angle at which the teeth of the gear make contact. The pressure angle should be the same for both gears to ensure smooth and efficient power transmission

5. Module or Diametral Pitch: The module or diametral pitch refers to the size of the teeth on the gear. Matching the module or diametral pitch ensures that the gears are compatible in terms of tooth size and spacing.

6. Tolerance and Surface Finish: It is important to match the tolerances and surface finishes of the spline gears to ensure proper fit and minimize wear during operation.

In order to match the size and shape of spline gears, precise machining and measurement are often required. Computer-aided design (CAD) software and gear inspection tools can be used to accurately design, manufacture, and inspect spline gears to ensure proper fit and alignment.

By carefully considering these factors and ensuring that the spline gears are properly matched, you can achieve efficient power transmission, reduce wear and tear on the gears, and prolong the service life of the gear system

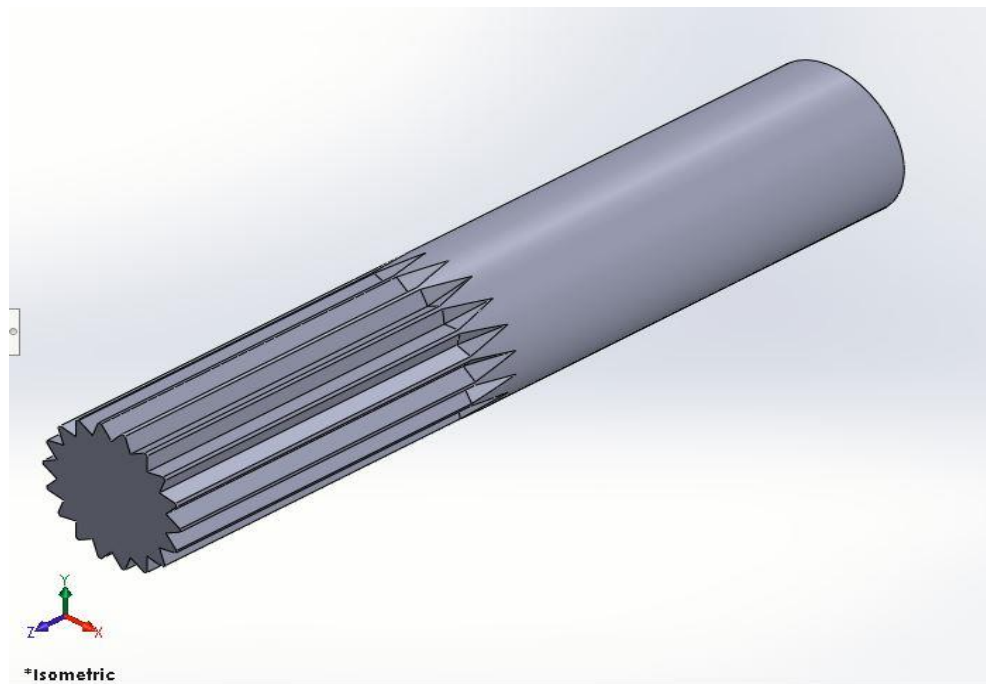


Figure 6 spline gear shaft gear box side

To calculate the geometry of the teeth on a spline gear with 18 teeth and a diameter of 60 mm, we need to determine the pitch diameter, pressure angle, addendum, dedendum, and tooth thickness.

1. Pitch Diameter (D):

Pitch diameter is the diameter of the imaginary circle that passes through the point of contact between two mating gears. For a spline gear, the pitch diameter can be calculated using the formula:

Pitch Diameter = Number of Teeth / Diametral Pitch

$$\text{Pitch Diameter} = 18 / (60 * \pi) \approx 0.095 \text{ m}$$

2. Pressure Angle (α):

Pressure angle is the angle between the line of action (the line along which the force is transmitted between mating gears) and the line tangent to the pitch circle. A common value for pressure angle in gear design is 20 degrees.

3. Addendum (a):

Addendum is the radial distance from the pitch circle to the top of the gear tooth. It can be calculated using the formula:

Addendum = Module = Pitch Diameter / Number of Teeth

$$\text{Addendum} = 0.095 / 18 \approx 0.0053 \text{ m}$$

4. Dedendum (d):

Dedendum is the radial distance from the pitch circle to the bottom of the gear tooth. It can be calculated using the formula:

Dedendum = Module $\times$ 1.25

$$\text{Dedendum} = 0.0053 * 1.25 \approx 0.0066 \text{ m}$$

5. Tooth Thickness (t):

Tooth thickness is the width of the gear tooth measured along the pitch circle. It can be calculated using the formula:

Tooth Thickness = $(\pi * \text{Module}) / 2$

$$\text{Tooth Thickness} = (\pi * 0.0053) / 2 \approx 0.0083 \text{ m}$$

Therefore, the geometry of the teeth on the spline gear with 18 teeth and a diameter of 60 mm would be approximately as follows:

- Pitch Diameter: 0.095 m
- Pressure Angle: 20 degrees
- Addendum: 0.0053 m
- Dedendum: 0.0066 m
- Tooth Thickness: 0.0083 m

of temperature, speed, and other load conditions on the performance of magnetic powder clutches.

Overall, the FEA analysis and discussions provide valuable insights into the design and performance of magnetic powder clutches for automotive applications

SolidWorks allows users to calculate and visualize reaction forces, reaction moments, free body forces, and free body moments using its simulation tools. By setting up appropriate boundary conditions and loads, users can analyze the behavior of a solid body and determine the forces and moments acting on it. This information is crucial for understanding the structural integrity and performance of a design

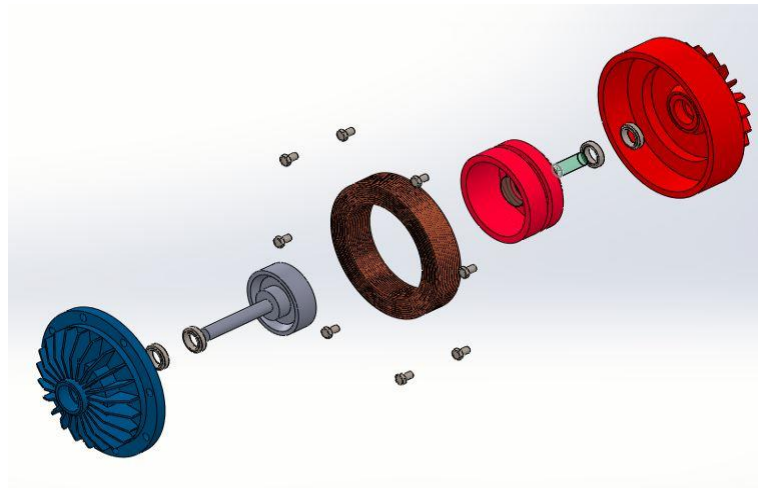


Figure 4.1 Exploded view Magnetic powder clutch

4.2 The steps involved in conducting a simulation in SolidWork

The steps involved in conducting a simulation in SolidWorks for stress, strain, displacement, and deformation analysis are as follows

1. Create the 3D CAD model: The first step to obtaining an accurate simulation is to create a 3D CAD model of the component or assembly in SolidWorks
2. Define the material properties: The next step is to define the material properties for the simulation. This includes specifying the material type, density, elastic modulus, and other relevant parameters

3. Apply boundary conditions and loads: Boundary conditions are applied to the regions of the model that are fixed or constrained in some way. Loads are applied to the regions that experience force or pressure during operation. These conditions must be defined accurately to obtain a meaningful simulation result
4. Meshing: After defining the material properties and applying boundary conditions, the next step is to generate a mesh. This involves dividing the model into small elements that can be analyzed for stress, strain, displacement, and deformation
5. Run the simulation: Once everything is set up, the simulation can be run. The software will calculate the response of the model to the applied loads and boundary conditions. The output will show information about stress, displacement, deformation, and strain in the model
7. Interpret and review the results: Once the simulation is complete, the results can be reviewed and analyzed. This involves comparing the simulated stress, displacement, deformation, and strain values to the allowable limits for the material and determining whether the model will perform as expected under the given conditions
8. Make changes or optimize the model: Based on the simulation results, changes can be recommended or made to the design of the component or assembly to improve its performance, or optimization techniques can be applied to achieve the desired outcome. The simulation process may need to be repeated until the model performs as expected within the given constraints.

4.3 Model Information

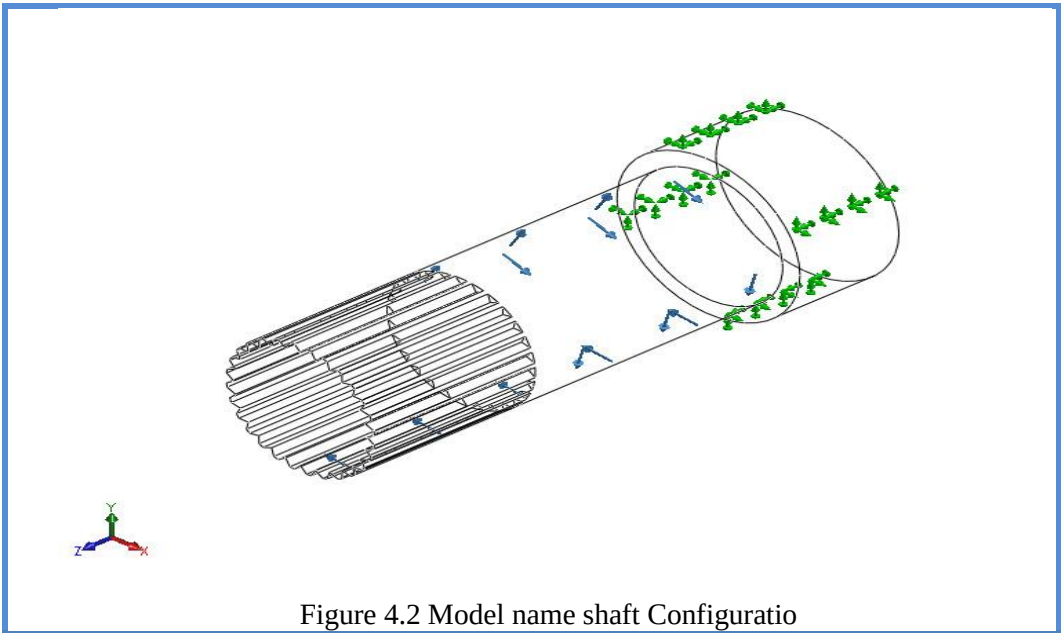
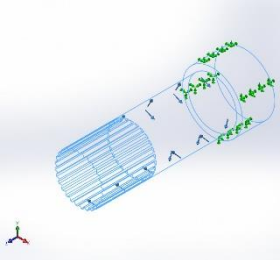


Figure 4.2 Model name shaft Configuratio

4.4 Volumetric Properties			
Document Name and Reference	Treated As	Volumetric Properties	Doc.
CirPattern1 	Solid Body	Mass:4.81412 kg Volume:0.000625211 m^3 Density:7,700 kg/m^3 Weight:47.1784 N	C

Spline gear fitting refers to the process of properly mating two spline gears together to ensure efficient power transmission and smooth operation. Spline gears are specially designed gears with teeth that are cut into the outer surface of a cylinder or shaft. They are commonly used in mechanical power transmission systems to transfer rotational motion between two shafts.

4.5 Study Properties

Boundary conditions: The boundary conditions include the load and constraints applied to the model, such as forces, pressures, fixed supports, and contact conditions

Study name	Static 4
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off

Table 4.1 Units

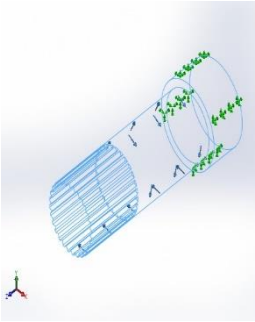
Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m ²

When fitting spline gears together, it is important to ensure that the teeth of the gears align properly and securely mesh together. This helps to prevent slippage, reduce wear and tear on the gears, and ensure efficient power transfer

The process of spline gear fitting involves carefully matching the size, shape, and number of teeth on each gear to ensure proper alignment and engagement. This may require precise machining and measurement of the gears to ensure a tight fit.

4.6 Material Properties

Material properties: The material properties of the model, such as density, modulus of elasticity, and Poisson's ratio, are essential for proper simulation.

Model Reference	Properties	Components
	Name: Alloy Steel Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 6.20422e+08 N/m^2 Tensile strength: 7.23826e+08 N/m^2 Elastic modulus: 2.1e+11 N/m^2 Poisson's ratio: 0.28 Mass density: 7,700 kg/m^3 Shear modulus: 7.9e+10 N/m^2 Thermal expansion coefficient: 1.3e-05 /Kelvin	
Curve Data:N/A		

Additionally, spline gears may also require lubrication to reduce friction and wear during operation. Proper maintenance and periodic inspections are also important to prevent premature failure of the gears.

Overall, proper spline gear fitting is essential for the reliable and efficient operation of mechanical power transmission systems. It helps to ensure smooth and reliable power transfer

4.7 Mesh information

Mesh: The mesh is used to discretize the model into smaller elements for analysis.

The mesh parameters include element type, size, and quality.

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	8.55294 mm
Minimum element size	8.55294 mm
Mesh Quality	High

4.8 Mesh information – Details

Total Nodes	19848
Total Elements	12881
Maximum Aspect Ratio	7.7506
% of elements with Aspect Ratio < 3	90.7
Percentage of elements with Aspect Ratio > 10	0
Percentage of distorted elements	0
Time to complete mesh(hh:mm:ss):	00:00:20
Computer name:	

Understanding the displacement behavior of a material under load is crucial for design and engineering purposes, as it helps in predicting how the material will behave in real-world applications and ensures that it is able to meet the required performance and safety standards. The study results provide valuable insights into the mechanical properties of the material and its ability to withstand different levels of loading without failing.

4.8 Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.00873886	-0.122699	-0.00480314	0.123104

Reaction Moments

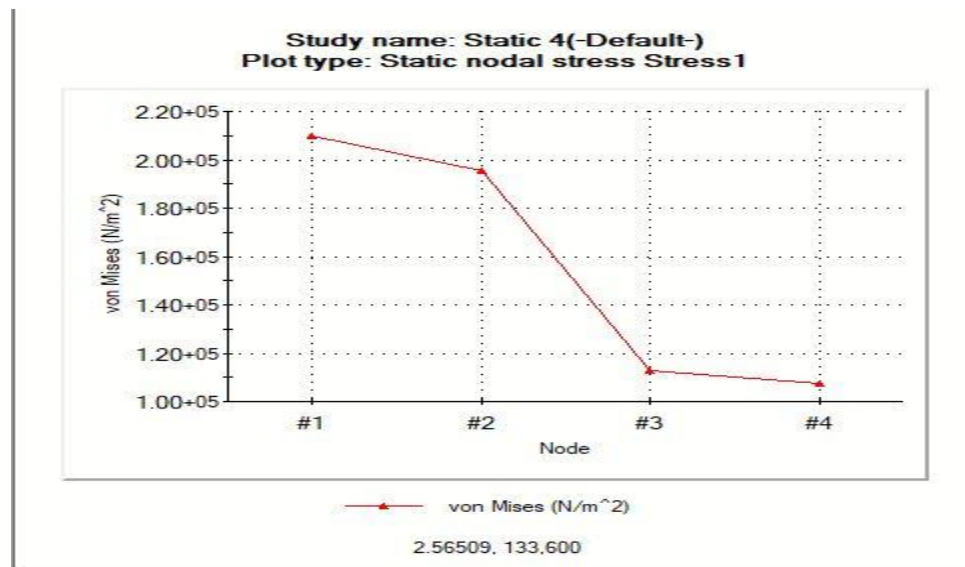
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

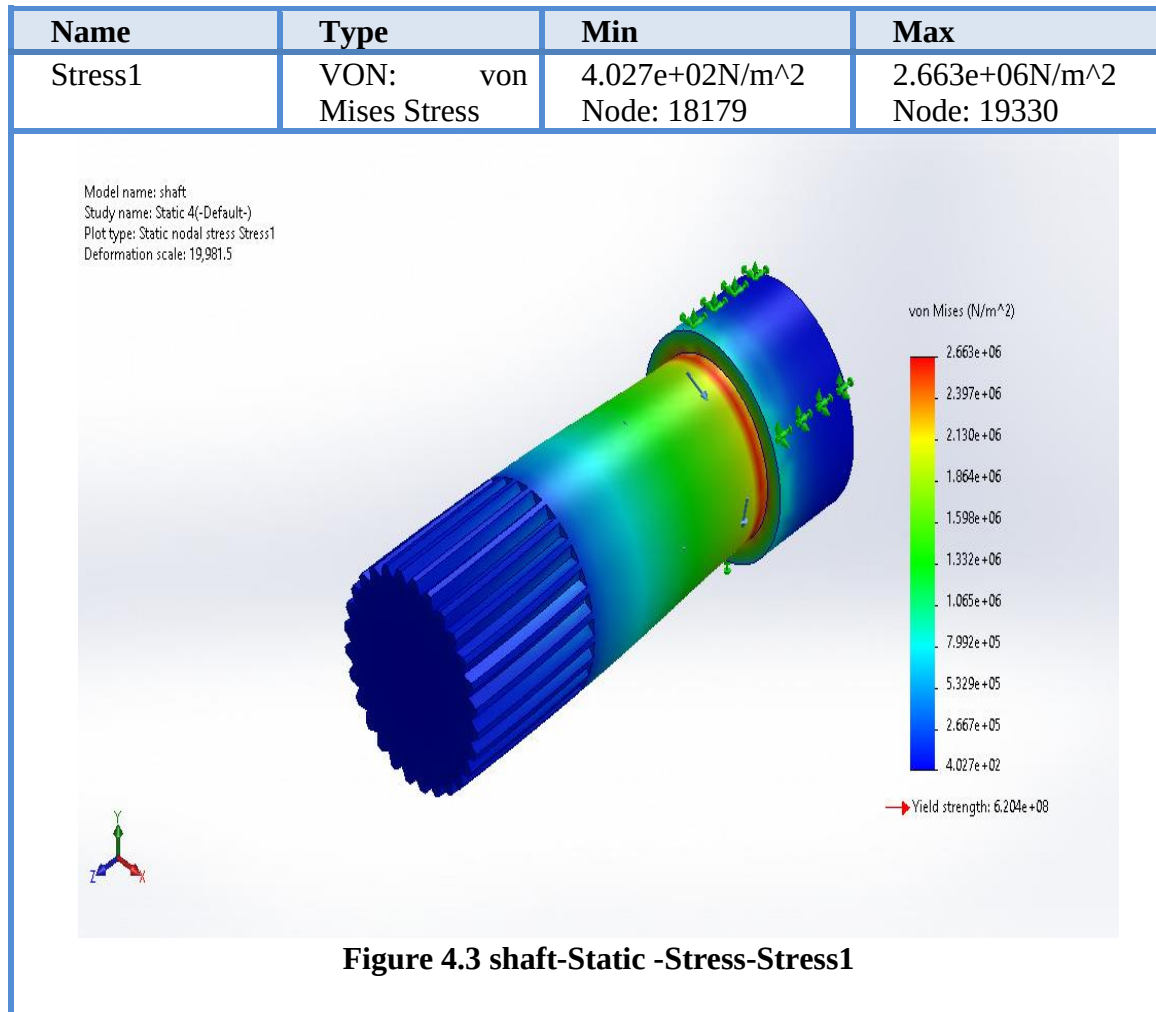
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.000307284	0.0198687	0.00173064	0.0199463

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33



4.9 Study Results



The study results show that the minimum Von Mises stress in the material tested is 4027 N/m², which is well below the yield strength of the alloy steel, which is 6.204×10^8 N/m². This means that the material is able to withstand the minimum stress without deforming permanently.

On the other hand, the maximum Von Mises stress recorded in the study is 2.663×10^6 N/m², which is also below the yield strength of the material. This indicates that the material can handle this maximum stress without undergoing permanent deformation as well.

Overall, the study results demonstrate that the alloy steel used in the experiment has a high yield strength and can withstand a wide range of stresses without failing. This is important for ensuring the structural integrity and reliability of the material in real-world applications.

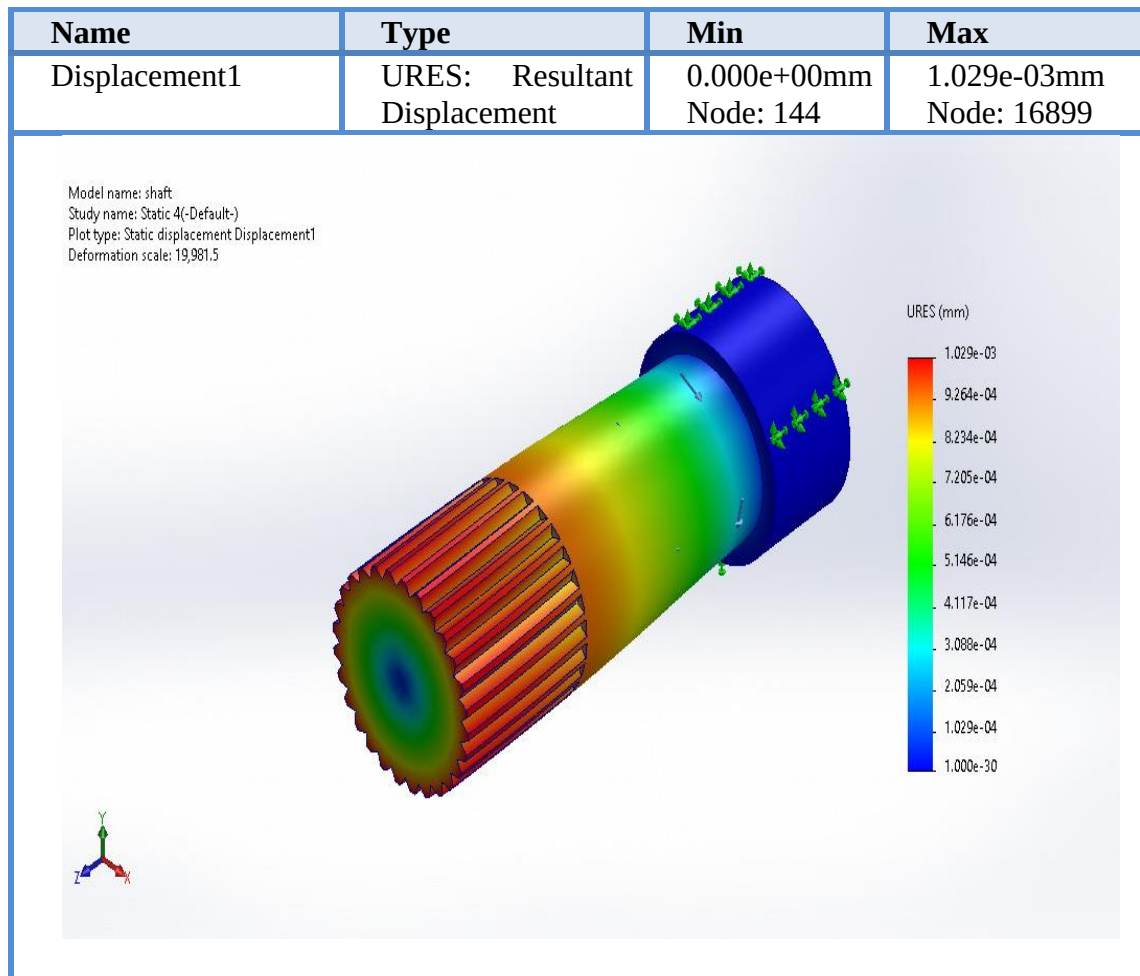


Figure 4.4 shaft-Static Displacement-

small amount of deformation or displacement, with the maximum displacement recorded at 0.00102 mm.

This displacement value is an important measure of the material's response to applied loads. In this case, the material showed a small amount of deformation when subjected to the 50 Nm torque, indicating that it can withstand this load without undergoing significant deformation or

In the study results, it was found that the static displacement of the material reached a maximum value of 0.00102 mm when a torque of 50 Nm was applied. This means that when the torque was applied to the material, it experienced a

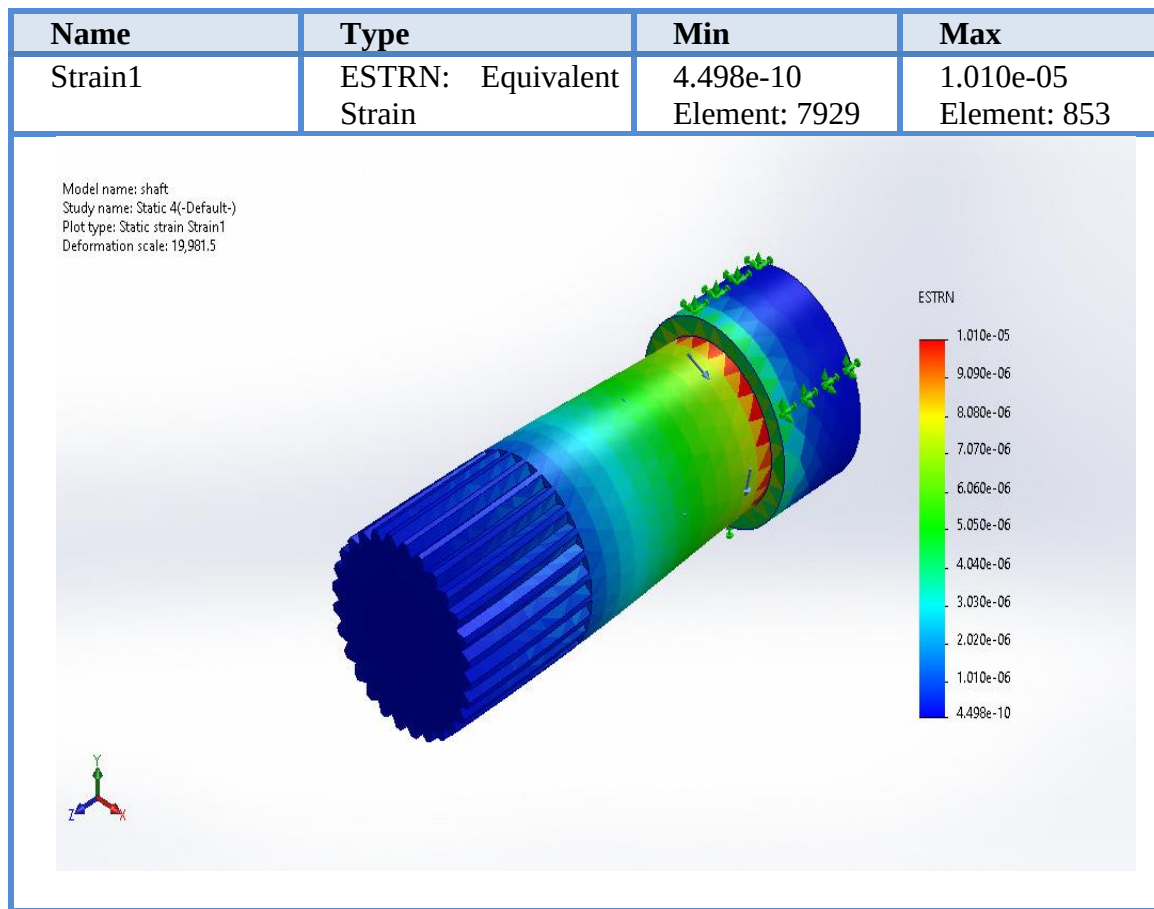


Figure 4.5 shaft-Static Strain

In the study results, it was found that the static displacement of the material reached a maximum value of 0.00102 mm when a torque of 50 Nm was applied. This means that when the torque was applied to the material, it experienced a small amount of deformation or displacement, with the maximum displacement recorded at 0.00102 mm.

This displacement value is an important measure of the material's response to applied loads. In this case, the material showed a small amount of deformation when subjected to the 50 Nm torque, indicating that it can withstand this load without undergoing significant deformation or

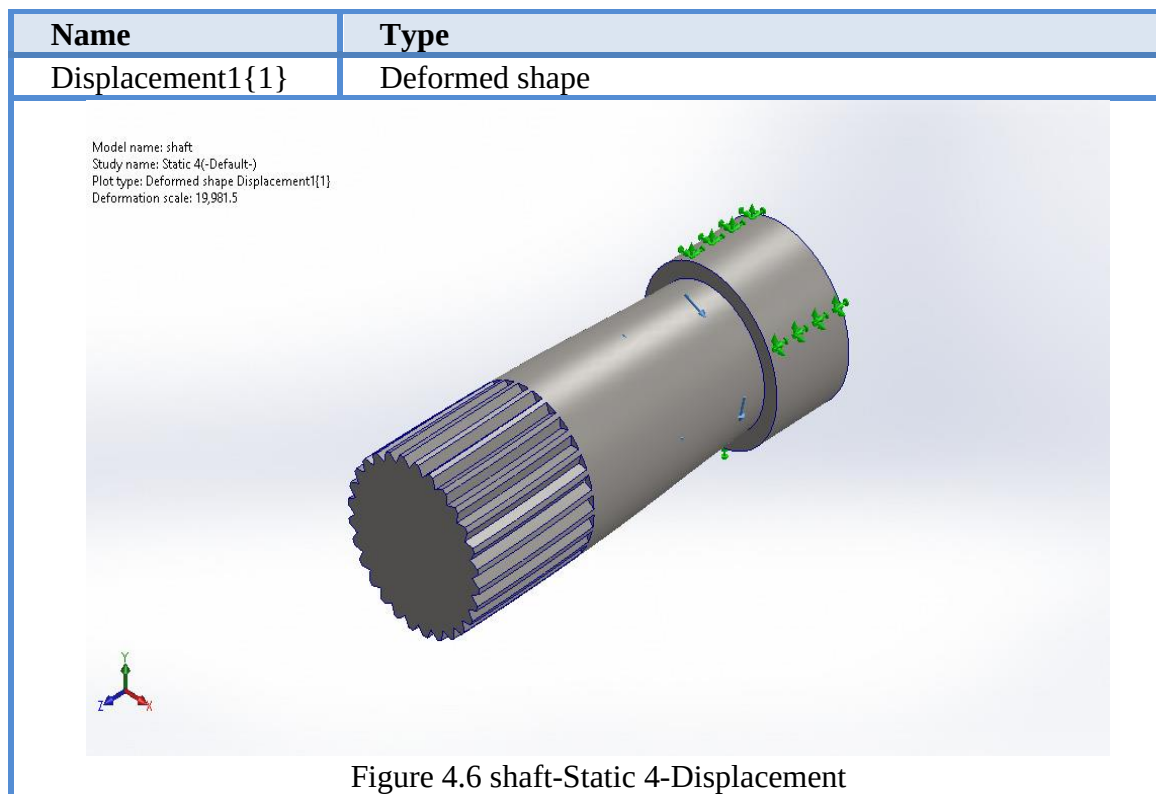
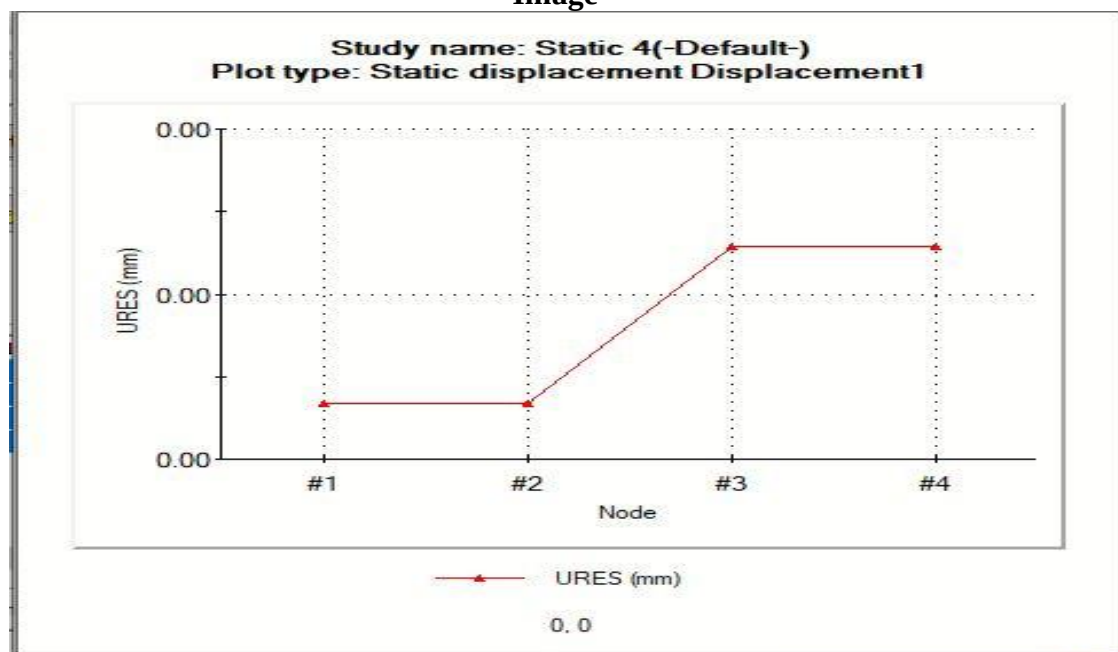
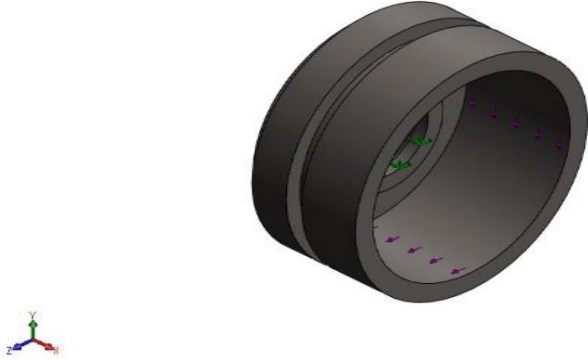
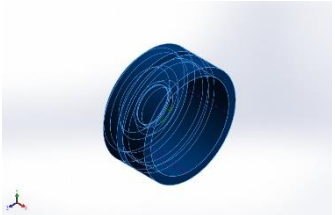


Image-



4.10 Model Information outer rotors

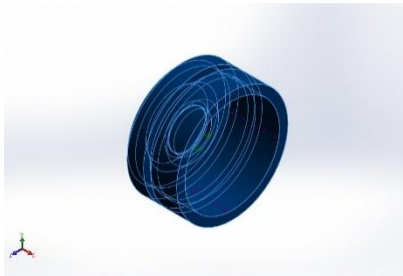
 Figure 4.7 Model name: outer rotors Current Configuration: Default			
Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Doc.
Cut-Extrude1 	Solid Body	Mass:9.78321 kg Volume:0.00127055 m ³ Density:7,700 kg/m ³ Weight:95.8755 N	

4.11 Study Properties outer rotor

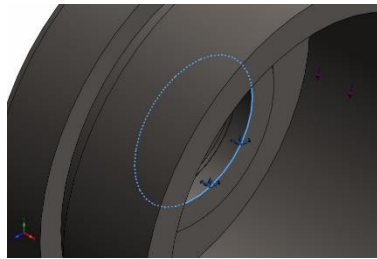
Study name	Static 3
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
In plane Effect:	Off
Soft Spring:	Off

Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off

4.12 Material Properties

Model Reference	Properties
	Name: Alloy Steel
	Model type: Linear Elastic
	Isotropic
	Default Max von
	failure Mises Stress
	criterion:
	Yield 6.20422e+08
	strength: N/m²
	Tensile 7.23826e+08
	strength: N/m²
	Elastic 2.1e+11
	modulus: N/m²
	Poisson's 0.28
	ratio:
	Mass density: 7,700 kg/m³
	Shear 7.9e+10
	modulus: N/m²
	Thermal 1.3e-05
	expansion /Kelvin
	coefficient:

4.12 Loads and Fixtures

Fixture name	Fixture Image	Fixture Details		
Fixed-1		Entities: 1 edge(s) Type: Fixed Geometry		
Resultant Forces				
Components	X	Y	Z	Resultant
Reaction force(N)	-0.00349989	0.000195503	0.00114441	0.00368743
Reaction Moment(N.m)	0	0	0	0

4.13 Mesh information

In SolidWorks, when analyzing a solid body or part, various types of forces and moments are often of interest. These include reaction forces, reaction moments, free body forces, and free body moments.

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	10.8333 mm
Minimum element size	10.8333 mm
Mesh Quality	High

4.14 Mesh information – Details

Total Nodes	18638
Total Elements	10602
Maximum Aspect Ratio	28.894

% of elements with Aspect Ratio < 3	97.7
Percentage of elements with Aspect Ratio > 10	0.623
Percentage of distorted elements	0
Time to complete mesh(hh:mm:ss):	00:00:09
Computer name:	

Reaction forces and moments are the forces and moments acting on a body due to external loads or constraints. These forces and moments are typically calculated at the fixed or constrained points of the body. For example, if a body is fixed at a certain point, the reaction force at that point would be the force that counteracts the applied loads and constraints.

4.15 Resultant Forces

Free body forces and moments, on the other hand, are the forces and moments acting on a body that are not already accounted for in the analysis. These forces and moments are typically calculated at points where loads or constraints are applied. For example, if a body is subjected to a load at a certain point, the free body force at that point would be the force due to the applied load

Reaction force

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.00349989	0.000195503	0.00114441	0.00368743

Reaction Moment

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body force

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.0173535	0.0407671	-0.0924899	0.102555

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

4.16 Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	5.396e+01N/m ² Node: 1064	4.420e+06N/m ² Node: 18550

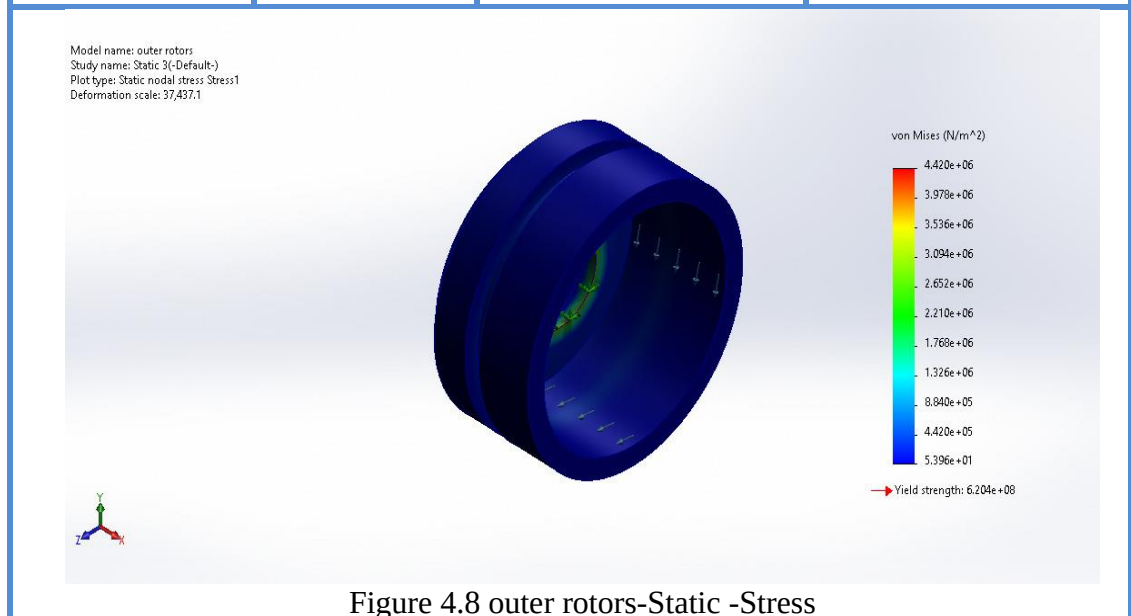
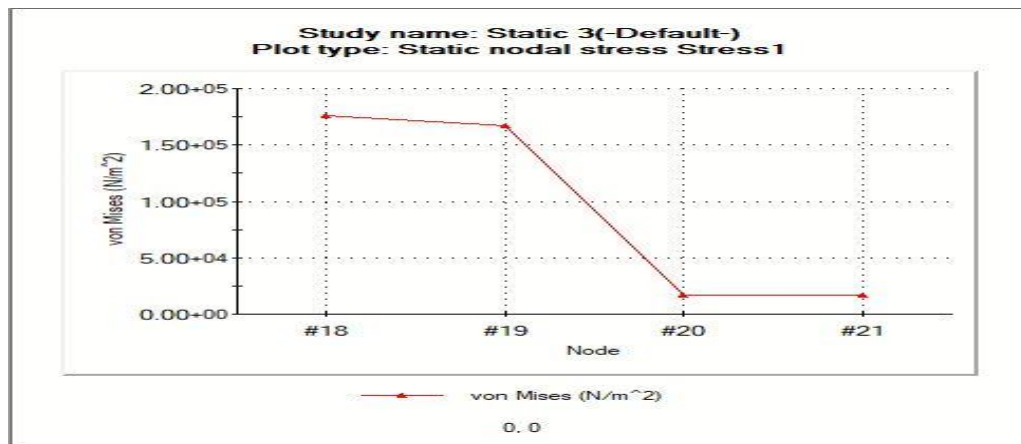


Figure 4.8 outer rotors-Static -Stress

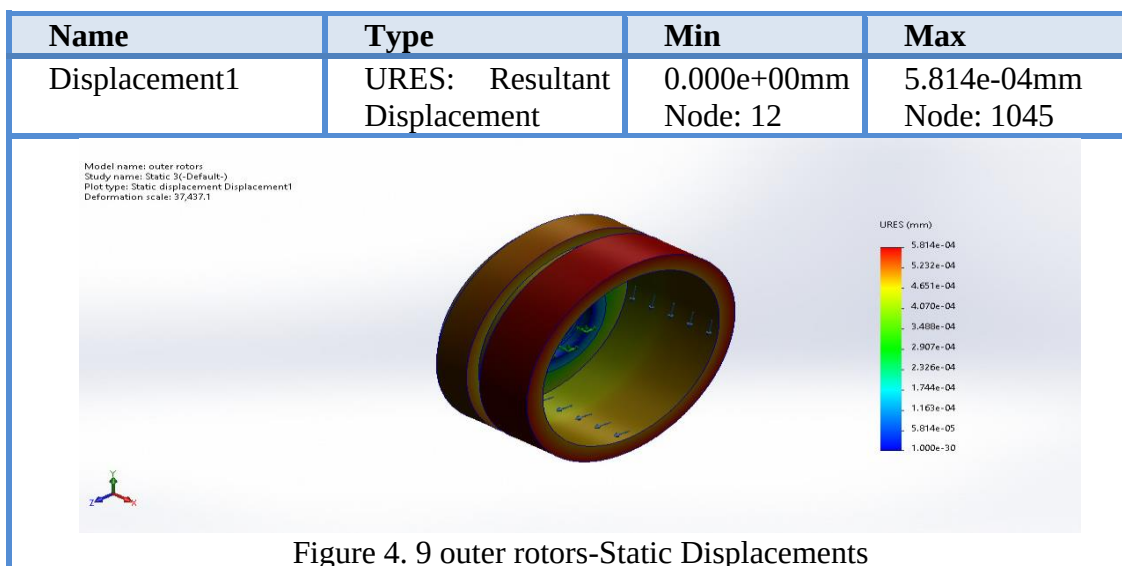
In the study results, it was observed that the Von Mises stress in the material had a minimum value of 53.96 N/m² and a maximum value of 4.42×10^6 N/m². Comparing this data to the yield strength of the material, which is 6.204×10^8 N/m², we can draw some important conclusions



The minimum Von Mises stress of 53.96 N/m² is significantly lower than the yield strength of 6.204×10^8 N/m². This indicates that the material can easily handle this minimum stress level without experiencing any permanent deformation. Therefore, the material is well within its safe operating limits when subjected to this level of stress.

Overall, the study results suggest that the material has a substantial safety margin when it comes to withstanding Von Mises stresses, as both the minimum and maximum stress levels are well below the yield strength

. This indicates that the material is strong and capable of handling a wide



Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.099e-08 Element: 4229	9.084e-06 Element: 10477

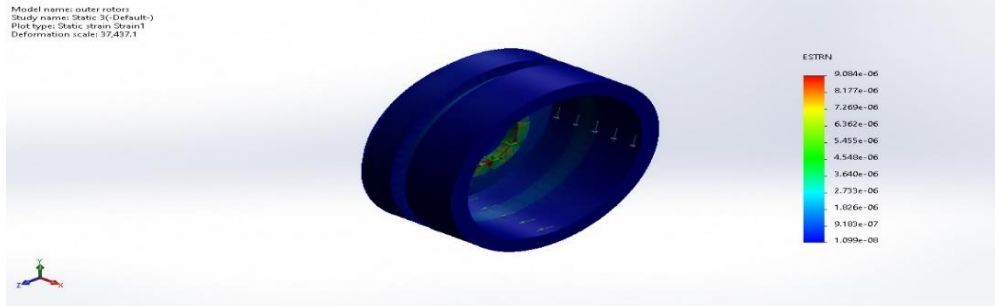
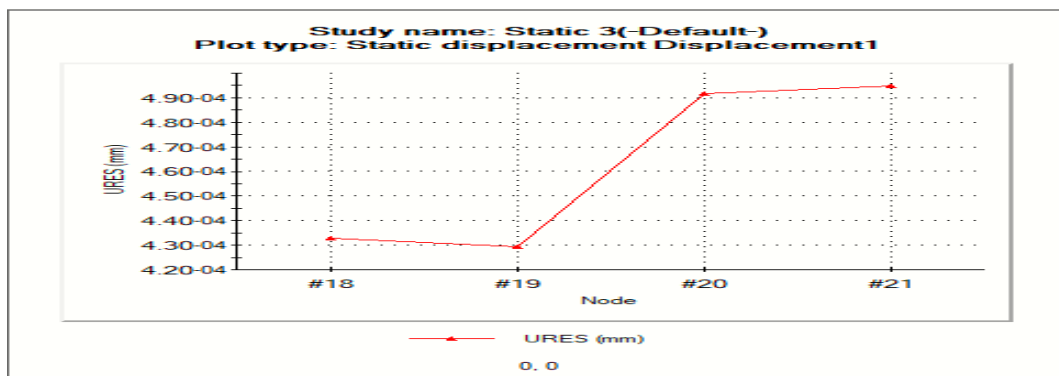


Figure 4.10 outer rotors-Static Strain

of stress levels without permanent deformation or failure

In the study results, it was found that the outer rotor of the alloy steel material experienced a maximum displacement of 0.0005814 when a torque of 50 Nm was applied. This displacement value indicates the amount of deformation or movement that the outer rotor undergoes when subjected to the applied torque



Additionally, the equivalent strain of the material was found to have a minimum value of 1.099×10^{-8} and a maximum value of 9.084×10^{-6} . Equivalent strain is a measure of the amount of deformation experienced by a material due to applied loads. A higher equivalent strain value indicates higher deformation or stretching of the material

These study results provide valuable insights into how the alloy steel material responds to the applied torque, with the displacement and equivalent strain values indicating the level of deformation and strain experienced by the material under the given loading conditions. Understanding these mechanical responses is essential for assessing the performance and durability of the material in practical applications

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

- Therefore, the thesis work conducted a design and analysis magnetic powder clutch. When 50 N-m transfer torque a magnetic powder clutch component effectively transfer power because of materials yield strength of material is greater than stress induced in magnetic powder clutch components.
- Magnetic powder clutch effectively transfer power when 50 N-m of torque is applied components of the clutch are able to transfer power because the selected material has yields strength that is greater than the stress induced in the components. This means that the material used in the clutch is enough to handle the stress and effectively transfer the power without breaking or failing

5.2 Recommendation

- ✓ The thesis work focused solely on the design and analysis of magnetic powder clutches Toyota 2003 50 N-m. As a recommendation for further study, it is suggested to explore electromagnetic simulation techniques to gain a deeper understanding of the behavior and performance of the clutch under different operating conditions. By utilizing electromagnetic simulation, researchers can analyze the magnetic field distribution, flux density, and other electromagnetic parameters to optimize the design and performance of the clutch.
- ✓ Additionally, it is recommended to investigate the effects of changing the iron powder material used in the clutch. This could involve studying different types of iron powder with varying magnetic properties to assess their impact on the overall performance, efficiency, and durability of the clutch. Understanding how changes in the iron powder material affect the torque transmission, heat generation, and overall behavior of the clutch can provide valuable insights for further improving its design and functionality.
- ✓ By delving into electromagnetic simulation and exploring different iron powder materials, researchers can enhance the understanding of magnetic powder clutches and potentially uncover opportunities for optimizing their design, performance, and applicability in various industrial setting

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