Design of a Magneto-Rheological based Shock Absorber for an Aircraft Landing Gear

A Project Report Submitted to
Visvesvaraya Technological University, Belagavi

In partial fulfilment of requirements of V semester Project work – 20AE5DCMP1:

BACHELOR OF ENGINEERING in AEROSPACE ENGINEERING

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March - 2023

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Certificate

This is to certify that the project entitled '**Design of a Magneto-Rheological based Shock Absorber for an Aircraft Landing Gear'** is a bonafide work carried out by

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in partial fulfilment for the award of **Bachelor of Engineering in Aerospace Engineering** of the Visvesvaraya Technological University, Belgaum, during the year **2022 – 23**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of **Mini Project – I (20AE5DCMP1)** prescribed for the said degree.

Signature of Guide **Signature of HOD**

Signature of Principal

Name of the Examiners **Signature with Date**

1.

2.

Declaration

We hereby declare that the project work entitled '**Design of a Magneto-Rheological based Shock Absorber for an Aircraft Landing Gear'** has been independently carried out by us at Department of Aerospace Engineering, under the guidance of Prof. Kamesh J V, Department of Aerospace Engineering, B. M. S. College of Engineering, Bengaluru, in partial fulfilment of the requirements of the degree of Bachelor of Engineering in Aerospace Engineering of Visvesvaraya Technological University, Belagavi. We further declare that we have not submitted this report either in part or in full to any other university for the award of any degree.

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Place: BENGALURU

Date: 13/03/2023

Acknowledgment

We are extremely privileged to have got the support and motivation for the completion of this mini-project work.

We take this opportunity to thank our institution, B.M.S. College of Engineering for giving us the platform to do this project and a positive atmosphere for learning. We would also like to express our gratitude to Dr. S. Muralidhara, Principal, B. M. S. College of Engineering, Bengaluru for his cordial support of our endeavours.

We express our sincere gratitude to our HOD (Head of Department), Dr. Y. S. Rammohan, Department of Aerospace Engineering, B.M.S. College of Engineering, Bengaluru for his invaluable guidance and support throughout the project.

Our sincere gratitude to our guide PROF. KAMESH J.V, Associate Professor, Department of Aerospace Engineering, B.M.S. College of Engineering, Bengaluru for his patient guidance, encouragement, valuable inputs, and kind supervision at every stage of the project for its successful completion.

We thank all teaching and non – teaching faculties of our department for their constant support. We are thankful to our beloved Parents, who have motivated, installed confidence in us, and have constantly supported our endeavours.

Also, we thank all those who have helped us directly or indirectly during this project work. Finally, we are obliged to all the team members for their efforts, cooperation, and valuable inputs provided.

Abstract

This report aims at gaining an insight into the development and analysis of an MR shock absorber and how the damping relates to ride comfort and structural integrity.

MR fluid shock absorbers are advanced devices that use a special fluid whose viscosity can be changed by an applied magnetic field, providing a highly controllable and adaptable damping response. Hence, they could be a better option compared to conventional hydraulic dampers as their viscosity can be controlled and changed to suit our situational requirements

Contents

CHAPTER 1

INTRODUCTION

Aircraft landing gear is one of the most important aircraft components.
It ensures safe and efficient operation of aircraft.

Primary function of the landing gear is to absorb the landing force and prevent the fuselage from hitting the ground.

Landing gear consists of structural members, hydraulics, energy absorption components, brakes, wheels, tyres additional components include steering devices and retracting mechanisms.

During take-off and landing the landing gear systems are subjected to a significant amount of stress and shock which can cause damage to the aircraft and compromise the safety of passengers and crew.

Energy absorption components are key to reduce the impact of landing
There are several types of energy absorption devices used in the aircraft landing gear including hydraulic, pneumatic and electromechanical systems.

These use damping mechanisms like shock absorbers to convert the kinetic energy of the aircraft into heat or other forms that can be dissipated safely.

CHAPTER 2

CONCEPT OF VIBRATION

Vibration refers to the back-and-forth motion of an object or medium around a fixed position or equilibrium point. This motion can occur in different forms, such as mechanical, electromagnetic, or acoustic vibrations, and can be caused by various factors, such as an external force, an electrical current, or a sound wave.

2.1 BASIC THEORY OF VIBRATION:

- The frequency of a vibration refers to the number of cycles per second, usually measured in Hertz (Hz).

- Time period, also known as the period, is the time required for a vibrating system to complete one cycle of oscillation or vibration, measure in seconds.

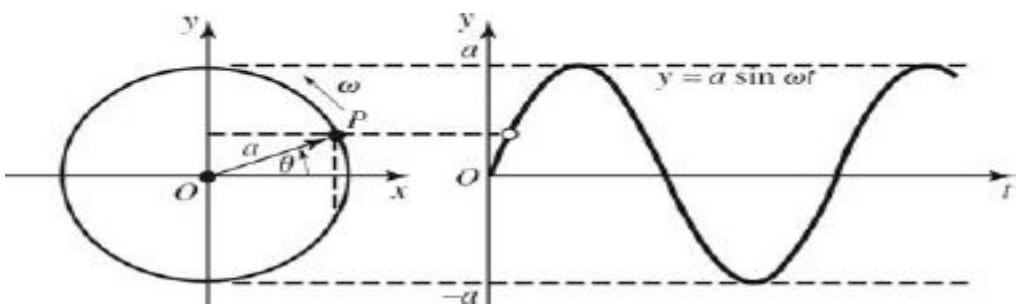
- The amplitude refers to the magnitude or intensity of the vibration, often measured in units such as meters, volts, or decibels.

- The wavelength is the distance between two consecutive peaks or troughs of a wave, measure in metres .

- Vibrating system: A system that experiences periodic motion or oscillation.

- Natural frequency: The frequency at which a vibrating system oscillates when disturbed from its equilibrium position.

- Resonance: The condition in which a vibrating system oscillates at its natural frequency, resulting in large amplitude vibrations.



2.2 DIFFERENT TYPES OF VIBRATIONS:

There are various types which can be classified based on their nature, frequency and source:

- **Free vibrations**: These vibrations occur when a system is set into motion and left to vibrate on its own, without any external force acting on it.
- **Damped vibrations**: are a type of vibration that decreases in amplitude over time due to the dissipation of energy from the vibrating system to the surrounding environment. This dissipation of energy can be due to various factors, such as friction, air resistance, or viscosity. There are three major types of damping :

   I. Over-damped system: A system that is highly damped and takes a long time to return to its equilibrium position after being displaced, without oscillating around its equilibrium position.
   II. Under-damped system: A system that is poorly damped and oscillates around its equilibrium position several times before returning to it, resulting in a slower return to the equilibrium position.
   III. Critically-damped system: A system that is optimally damped, and returns to its equilibrium position in the shortest possible time without oscillating around it.

- **Forced vibrations:** These vibrations occur when a system is subjected to an external force or excitation, such as a sound wave or a mechanical force.
- **Resonant vibrations**: These vibrations occur when a system vibrates at its natural frequency, which can amplify the vibration and potentially cause damage.
- **Transverse vibrations:** These vibrations occur when a wave moves perpendicular to the direction of the vibration, such as the vibration of a guitar string.
- **Longitudinal vibrations:** These vibrations occur when a wave moves parallel to the direction of the vibration, such as the vibration of air molecules in a sound wave.
- **Torsional vibrations:** These vibrations occur when a shaft or other cylindrical object is twisted around its axis, such as the vibration of a helicopter rotor.

- **Random vibrations:** These vibrations occur when there is no specific pattern or frequency to the vibration, such as the vibration of a car on a bumpy road.
- **Harmonic vibrations:** These vibrations occur when the frequency of the vibration is a multiple of the fundamental frequency, creating a harmonic pattern, such as the vibration of a guitar string at a particular fret

CHAPTER 3

SHOCK ABSORBER

They are the mechanical devices that are designed to absorb and dampen the impact of forces generated during landing and to dampen any vibrations or oscillations that may occur during normal operations. The basic principle is that a piston in the shock absorber moves inside a cylinder filled with fluid.

In aircraft landing gear, a shock absorber is a device that helps to cushion the impact and dissipate the energy of the aircraft during landing. The landing gear shock absorber consists of a piston and cylinder assembly filled with hydraulic fluid or gas, such as nitrogen. When the aircraft lands, the shock absorber compresses, allowing the piston to move inside the cylinder, and the hydraulic fluid or gas is forced through small ports or orifices in the piston or cylinder, which dissipates the energy and slows down the compression. This helps to prevent the landing gear from bottoming out or bouncing and provides a smoother landing for the passengers and crew. Shock absorbers used in landing gear are designed to withstand high loads and are often subjected to rigorous testing and certification standards to ensure their reliability and safety.

3.1 3D MODELLING OF SHOCK ABSORBER:

The basic methodology of creating the model using AUTOCAD Software :

- Created a new layer for the damper components by selecting the respective views and setting the appropriate properties such as color and line type by predetermining the drawing units to the appropriate units based on respective requirements.
- Began by creating the basic shape of each damper components such as the cylinder , piston , spring etc using the appropriate drawing tools, such as the LINE, ARC, BOX commands.
- Using the EXTRUDE command to create a 3D model of the damper from the 2D drawing. Specified the height and direction of the extrusion to create the desired shape and thickness of the damper.
- Applying materials and textures to the damper components to enhance the appearance of the model. This was done using the MATERIALS or RENDER commands in AutoCAD.

- The dimensions were taken according to the table 1.1.

The 3D model was created and is viewed in all the respective views . This is depicted in the fig.1.2.

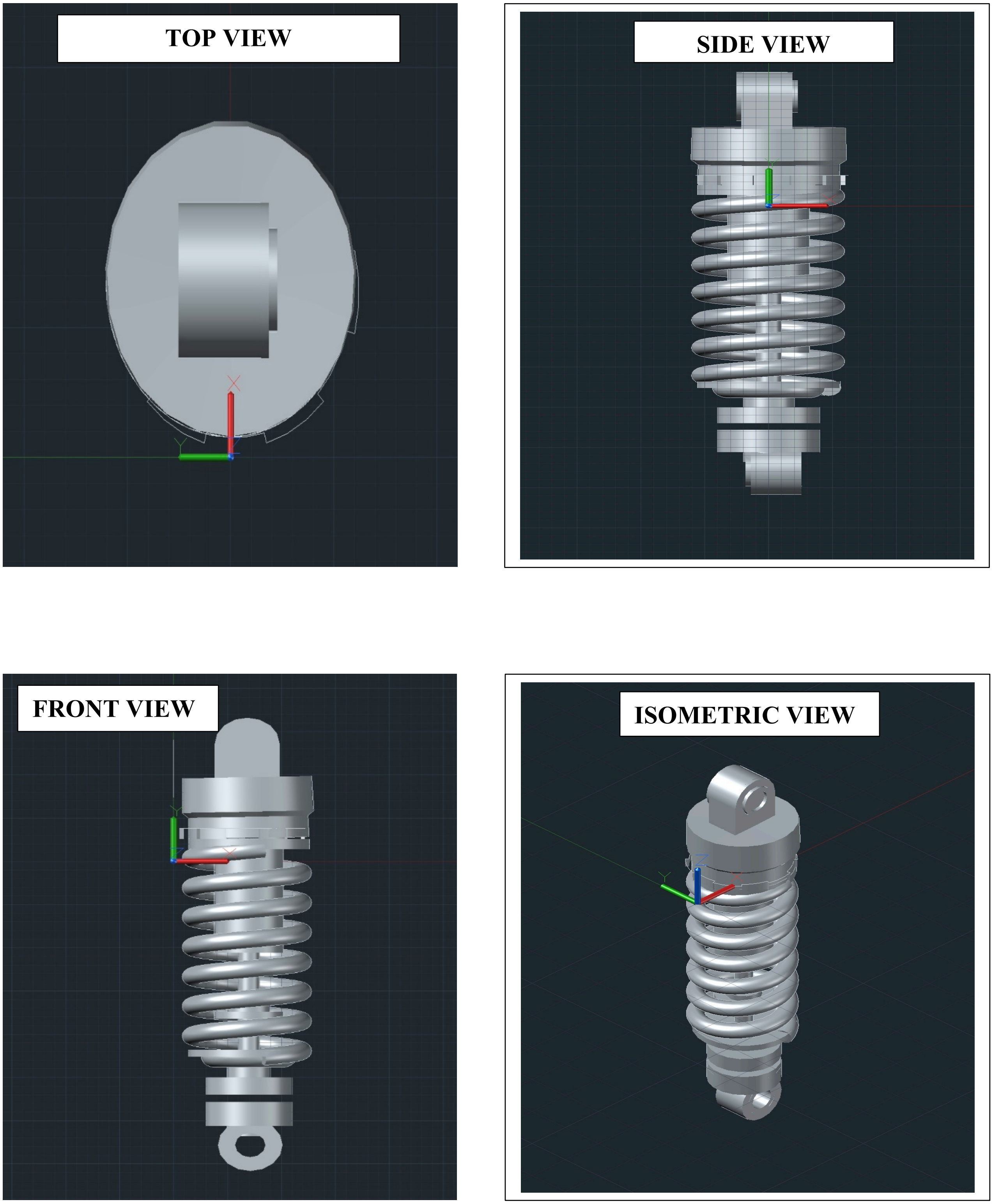


Fig 1.2

Piston head	55 mm
Length of piston head	30 mm
Length of piston rod	150 mm
Height of the cylinder	132 mm
Outer diameter of the cylinder	57 mm
Thickness of the cylinder	1 mm
Diameter of spring	

Table 1.1: Geometric dimensions of the CAD model

3.2 PARTS OF SHOCK ABSORBER:

The main parts of shock absorber include:

- **Pistons:** In shock absorbers can come in different shapes, such as flat or cup-shaped, and can have various features such as grooves, ridges, or holes to control fluid flow. Some pistons are designed to have a self-centering feature, which helps to keep the piston centered within the cylinder and minimize side loading on the seals. Others may have rebound or compression damping features, which provide different levels of resistance to fluid flow depending on the direction of piston movement. The design of the piston can greatly affect the damping characteristics and performance of the shock absorber.(depicted in fig 1.3a)
- **Piston rod**: The piston rod is typically made of high-strength steel, and may be chrome-plated or coated with other materials to resist corrosion and wear. Some piston rods may have a threaded end, which allows for easy installation of mounting hardware or other components. Others may be fitted with bearings or bushings to minimize friction and wear inside the shock absorber. The surface finish of the piston rod is also important, as a smooth finish can help to reduce friction and improve seal life. Some piston rods may also be equipped with a gas-charged bladder or accumulator, which can provide additional damping force and improve ride comfort. Overall, the design and construction of the piston rod is critical to the overall durability and performance of the shock absorber.(depicted in fig 1.3b)
- **Cylinder:** Tube shaped component which includes the piston and fluid. It is also made up of metal or composite material which is designed to be strong and durable. (depicted in fig 1.4)

- **Fluid**: specialized oil or other liquid that is used to dampen the movement of the piston inside the cylinder.
- **Valving system:** series of small ports and passages that are designed to control the flow of fluid inside the shock absorber.
- **Mounting**: part of the shock absorber that is connected to the aircraft. It consists of a series of brackets, bolts and other hardware that is designed to securely attach the shock absorber to the other components. (depicted in fig 1.5)
- **Spring:** used to provide additional support and cushioning during operations. Helps to improve overall performance and reduce wear and tear on other components of the system. (depicted in fig 1.6)

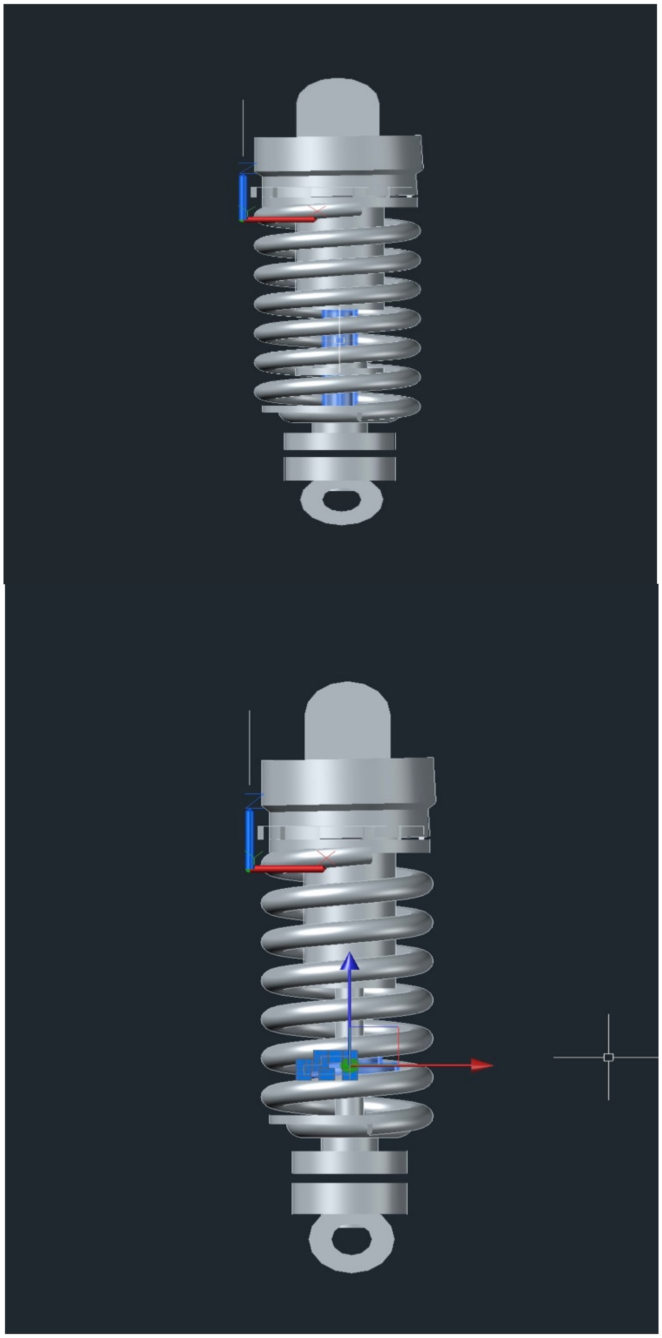


Fig 1.3a – piston rod
Fig 1.3b - piston

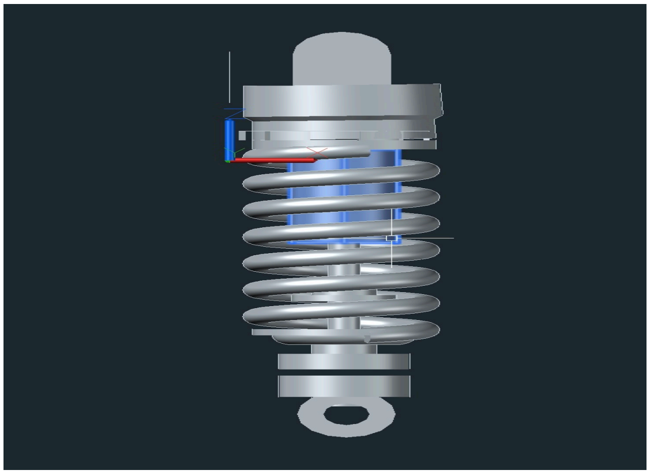


Fig 1.4

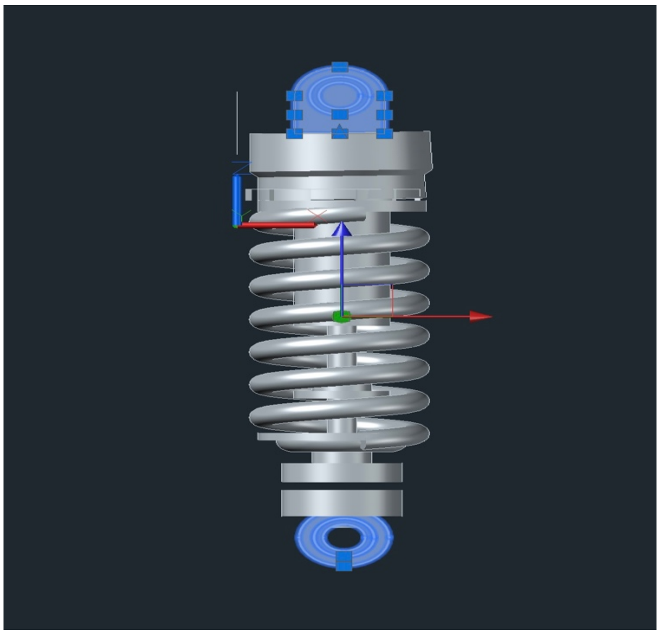


Fig 1.5

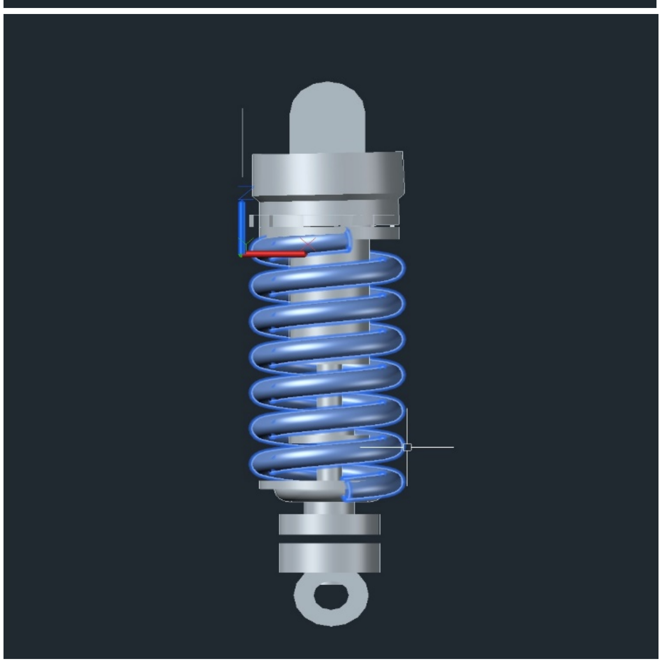


Fig 1.6

3.3 TYPES OF SHOCK ABSORBERS

1) **Hydraulic shock absorbers**: use a fluid-filled cylinder and piston to absorb the energy of the landing gear during compression. The fluid is typically oil or a synthetic hydraulic fluid, and the damping characteristics of the shock absorber can be adjusted by changing the fluid viscosity or the orifice size in the piston. Hydraulic shock absorbers are widely used in landing gear systems due to their ability to provide good damping characteristics and their compact and lightweight design. They are also relatively easy to control and adjust, and have low maintenance requirements. However, hydraulic shock absorbers can be susceptible to fluid leakage and wear over time, and may require frequent maintenance.

2) **Pneumatic shock absorbers:** use compressed air to absorb the energy of the landing gear during compression. The air is typically stored in a separate chamber or bladder, and the damping characteristics of the shock absorber can be adjusted by changing the pressure in the air chamber. Pneumatic shock absorbers are lightweight and have a compact design, and are good at absorbing high shock loads. They also have low maintenance requirements, and can be adjusted to different pressure levels for varying load conditions. However, pneumatic shock absorbers can be more complex to control and adjust than hydraulic shock absorbers, and may be affected by temperature and altitude changes.

3) **Mechanical shock absorbers:** use a spring and damper system to absorb the energy of the landing gear during compression. The spring stores energy during compression, and the damper dissipates the energy as heat. The damping characteristics of the shock absorber can be adjusted by changing the viscosity of the damper fluid or by changing the spring rate. Mechanical shock absorbers are simple and reliable, and can handle high shock loads. They also have low maintenance requirements and are cost-effective compared to other types of shock absorbers. However, they have limited damping characteristics compared to hydraulic or MR dampers, and can be noisy or generate vibrations during operation.

5) **Magnetorheological (MR) shock absorber**: MR dampers use a fluid with magnetic particles suspended in it, which can be controlled by an electromagnetic field to adjust the damping characteristics of the shock absorber in real-time. The damping force can be adjusted almost instantaneously to varying load conditions, making them highly controllable and adjustable. MR dampers are lightweight and compact, and are good at absorbing vibrations and shock loads. They also have low maintenance requirements, and can be integrated with advanced control systems for improved performance. However, MR dampers are more expensive than hydraulic or pneumatic shock absorbers, and may require complex control systems for optimal performance. They may also be sensitive to temperature and pressure changes, and may not be suitable for extreme or high-load conditions.

3.4 WORKING OF MAGNETO-RHEOLOGICAL DAMPER

An MR (Magneto-rheological) damper is a type of semi-active damper that uses magnetorheological fluid to provide variable damping force. It works on the principle of changing the viscosity of the fluid through the application of a magnetic field.

In the context of aircraft landing gear, the MR damper is typically installed in the shock strut assembly, which is the part of the landing gear that compresses upon landing and absorbs the energy of the impact.

When the aircraft lands, the shock strut assembly compresses and the MR damper is activated. When current flows through the coil ,the magnetic field is applied to the magnetorheological fluid which causes the viscosity of the fluid to change almost instantaneously, resulting in a change in damping force. The amount of damping force provided by the MR damper can be precisely controlled by varying the strength of the magnetic field which is varying the amount of current flowing through the coil which is typically controlled by an electronic controller that receives input from sensors that measure various landing conditions, such as aircraft weight, landing speed, and runway conditions.

The electronic controller can adjust the current flowing through the coil almost instantaneously to provide precise control over the damping force and adapt to changing landing conditions, ensuring optimal landing performance and safety.

When the aircraft lands, the shock absorber compresses as the weight of the aircraft is transferred to the landing gear. As the shock absorber compresses, the damping mechanism is activated, providing resistance to the motion of the landing gear. The damping mechanism is typically a hydraulic system that uses fluid to dissipate the energy of the landing

3.5 CONCEPT OF VIBRATIONS WITH RESPECT TO MR-DAMPER

In a landing gear system, the shock absorber is a critical component that is designed to absorb the energy of the aircraft's impact with the runway and dissipate it in the form of heat. This is accomplished through the use of a damping mechanism that is integrated into the shock absorber.

The amount of damping force provided by the shock absorber is a critical factor in determining its effectiveness in reducing vibration. The damping force is a function of the velocity of the landing gear and the viscosity of the fluid in the hydraulic system. The damping force must be carefully balanced to provide enough resistance to vibration while still allowing the landing gear to compress enough to absorb the energy of the impact. The design of the shock absorber must also take into account the frequency of the vibrations that it is intended to dampen. The natural frequency of the shock absorber must be carefully matched to the frequency of the vibrations in the landing gear system. If the natural frequency of the shock absorber is too high or too low, it will not be effective in reducing vibration.

3.6 CONCEPT OF MAGNETIZATION WITH RESPECT TO MR-DAMPER

Magnetization plays an important role in the operation of magnetorheological (MR) shock absorbers used in aircraft landing gear. In an MR shock absorber, a magnetorheological fluid is used as the damping medium instead of a conventional fluid.

When a magnetic field is applied to the MR fluid, the magnetic particles in the fluid become magnetized and align with the direction of the magnetic field. This results in an increase in the viscosity of the fluid and hence an increase in the damping force of the shock absorber.

The strength of the magnetic field applied to the MR fluid can be varied using an electromagnetic coil, and this allows for precise control of the damping force. By adjusting the strength of the magnetic field in real-time based on the changing landing conditions, an MR shock absorber can provide optimal damping and control during landings.

CHAPTER 4

STATIC STRUCTURAL ANALYSIS

Static structural analysis is a method used in engineering to determine the stress and deformation of a structure under a given set of external loads. It involves calculating the internal forces and deformations within the structure in response to the external loads applied. This type of analysis is typically used to determine if a structure is strong enough to support the loads it will be subjected to during operation, and if any modifications or reinforcements are needed to ensure the safety and reliability of the structure.

In a static structural analysis, the structure is assumed to be in static equilibrium, which means that the forces acting on the structure are balanced and do not change with time. The analysis is based on the laws of mechanics, such as Newton's laws of motion and Hooke's law, which describe the behavior of materials under loading.

The analysis process involves several steps, including defining the geometry of the structure, applying boundary conditions, assigning material properties, and specifying the external loads. The finite element method (FEM) is commonly used to solve the equations that govern the behavior of the structure under the applied loads.

The output of a static structural analysis includes the stresses, strains, and deformations of the structure under the given loads. These results can be used to evaluate the safety and performance of the structure, and to make design modifications as necessary.

Overall, static structural analysis is an essential tool for engineers to ensure the safety and reliability of structures in a wide range of applications, from aerospace and automotive engineering to civil and mechanical engineering.

4.1 METHODOLOGY USED IN ANSYS WORKBENCH:

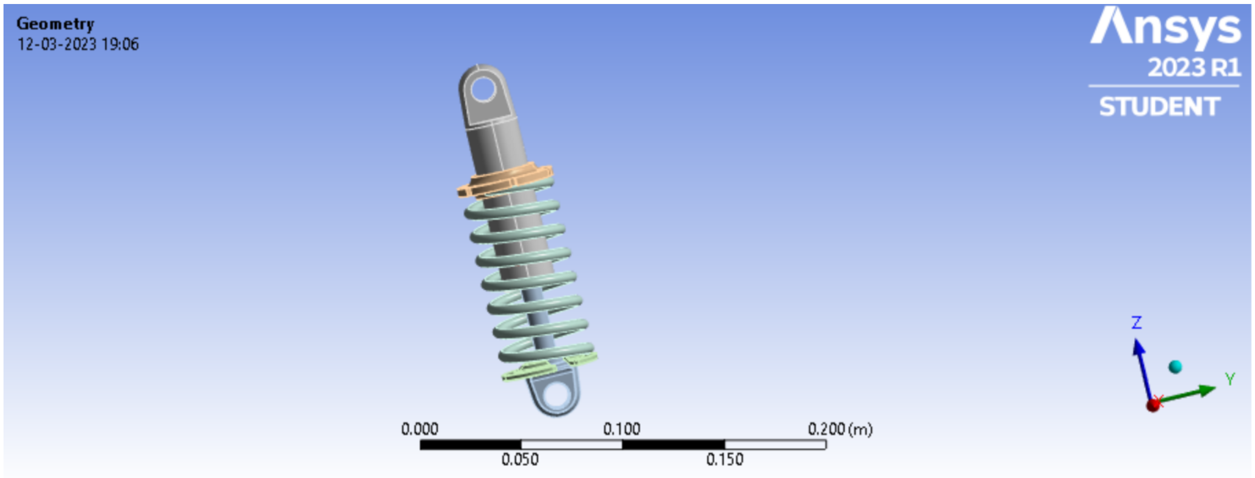
The first step is to create the geometry of the shock absorber in ANSYS Design Modeler. This is done by using the sketching tools to create the required shapes.

Once the geometry is created, it is imported into ANSYS Mechanical by utilising the Model option .
The next step is to set up the material properties of the shock absorber which includes defining the material type, Young's modulus, Poisson's ratio, and density of the material as mentioned in fig 1.7 (pre-determined values) by using structural steel as the material .
Once the material properties are set up , boundary conditions are applied. This includes fixing the points that are not supposed to move in this case the top portion of the piston-head assembly is fixed and applying the loads on the opposite end to the points where the external forces are acting .
The next step is to mesh the model. This is done by dividing the geometry into small elements that can be analyzed by the software. A good quality mesh is important to obtain accurate result.
After meshing the model the analysis type is defined. For a static structural analysis, the analysis type is set to "Static Structural".
Suitable load force of 5437 kN is applied to the model.
We solve the analysis to determine total deformation, equivalent strain and equivalent stress .

Properties of Outline Row 3: Structural Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7850	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
5	Coefficient of Thermal Expansion	1.2E-05	C^-1		
6	Isotropic Elasticity				
7	Derive from	Young's Modulus and Poisson...			
8	Young's Modulus	2E+11	Pa		
9	Poisson's Ratio	0.3			
10	Bulk Modulus	1.6667E+11	Pa		
11	Shear Modulus	7.6923E+10	Pa		
12	Strain-Life Parameters				
13	Display Curve Type	Strain-Life			
14	Strength Coefficient	9.2E+08	Pa		
15	Strength Exponent	-0.106			
16	Ductility Coefficient	0.213			
17	Ductility Exponent	-0.47			
18	Cyclic Strength Coefficient	1E+09	Pa		
19	Cyclic Strain Hardening Exponent	0.2			
20	S-N Curve	Tabular			

Fig 1.7


Geometry
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Ansys
2023 R1
STUDENT
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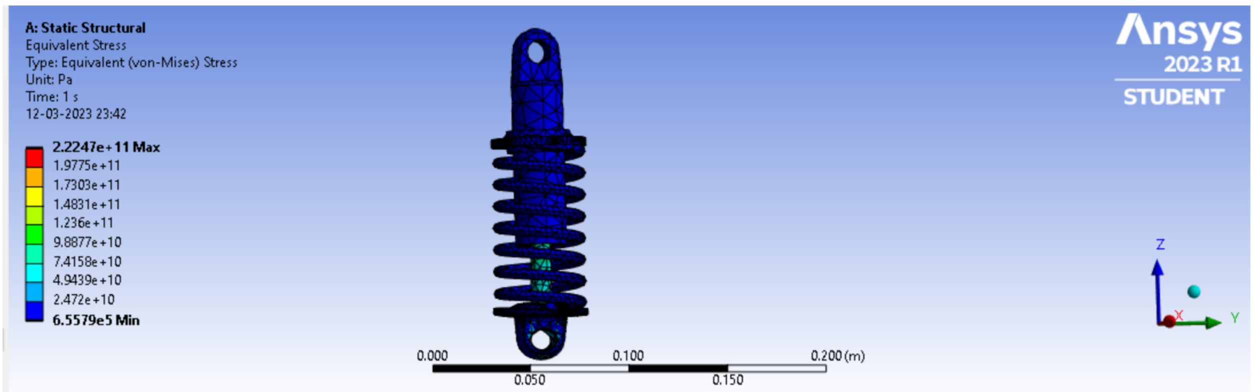
0.050
0.100
0.150
0.200 (m)
Z
Y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Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: Pa
Time: 1 s
12-03-2023 23:42
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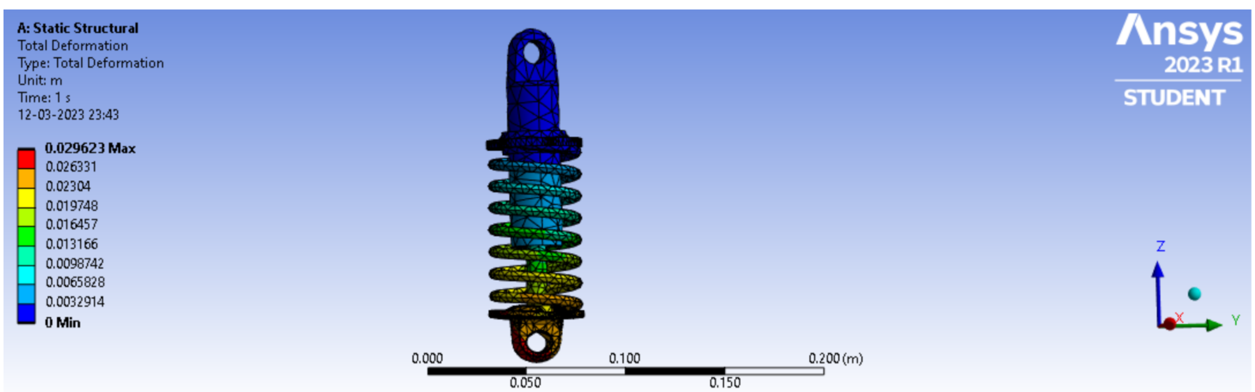
1.9775e+11
1.7303e+11
1.4831e+11
1.236e+11
9.8877e+10
7.4158e+10
4.9439e+10
2.472e+10
6.5579e5 Min
Ansys
2023 R1
STUDENT
0.000
0.050
0.100
0.150
0.200 (m)
Z
X
Y


A: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 1 s
12-03-2023 23:43
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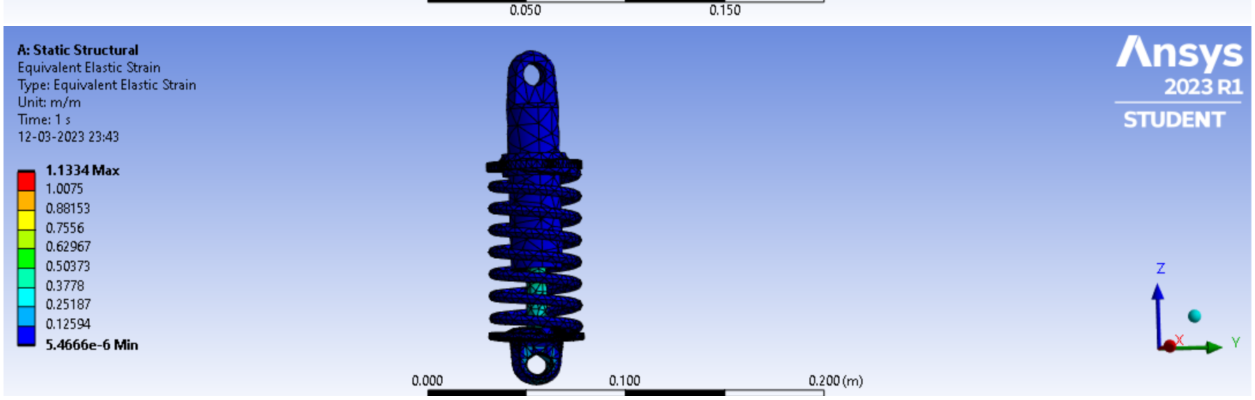
0.02304
0.019748
0.016457
0.013166
0.0098742
0.0065828
0.0032914
0 Min
Ansys
2023 R1
STUDENT
0.000
0.050
0.100
0.150
0.200 (m)
Z
X
Y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Equivalent Elastic Strain
Type: Equivalent Elastic Strain
Unit: m/m
Time: 1 s
12-03-2023 23:43
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0.7556
0.62967
0.50373
0.3778
0.25187
0.12594
5.4666e-6 Min
Ansys
2023 R1
STUDENT
0.000
0.100
0.200 (m)
Z
X
Y

4.2 PURPOSE OF STATIC STRUCTURAL ANALYSIS

The purpose of static structural analysis is to determine how a structure or mechanical component behaves under different loading conditions, such as tension, compression, bending, or twisting. By analyzing, the stresses and strains that occur in the structure or component, engineers can evaluate its safety, durability, and performance. This information is critical for designing and optimizing structures to withstand the loads they will experience in real-world applications. Static structural analysis is widely used in industries such as aerospace, automotive, civil engineering, and manufacturing to ensure the safety and reliability of products.

CHAPTER 5

MR FLUID ANALYSIS

5.1 MAGNETO-RHEOLOGICAL FLUID

Magneto-rheological fluid, also known as MR fluid, is a type of smart fluid that can change its viscosity or stiffness in response to an external magnetic field. The fluid is typically made up of micron-sized magnetic particles, such as iron or steel, suspended in a carrier fluid, such as oil or water.

When a magnetic field is applied to the MR fluid, the magnetic particles align themselves along the direction of the magnetic field, creating chains or structures that increase the stiffness and viscosity of the fluid. This effect can be controlled by adjusting the strength and direction of the magnetic field, allowing for precise control of the fluid's properties.

MR fluid has a wide range of potential applications, including in the automotive industry for shock absorbers, brakes, and clutches, as well as in robotics, civil engineering, and medical devices. The ability to quickly and precisely adjust the stiffness of the fluid in response to changing conditions makes it a highly versatile and useful material for a variety of applications.

5.2 PROPERTIES OF MAGNETO-RHEOLOGICAL FLUID

5.21 PROPERTIES IN THE “OFF” STATE:

The density of MR fluids in the off state is primarily determined by the density of the carrier fluid. For example, the density of an MR fluid composed of silicone oil and iron particles with a volume fraction of 10% is approximately 1,170 kg/m^3.

• The viscosity of MR fluids in the off state is primarily determined by the viscosity of the carrier fluid. For example, the viscosity of an MR fluid composed of hydraulic oil and iron particles with a volume fraction of 10% is 80 Pa s. In ambient conditions, for example an ambient temperature of 25 °C, off state viscosity is found to range from 0.1 to 1 Pa s.

• The shear modulus of MR fluids in the off state is primarily determined by the particle concentration and the size of the particles. For example, the shear modulus

of an MR fluid composed of silicone oil and iron particles with a volume fraction of 5% and an average particle size of 9 µm is 67 kPa.
• The thermal conductivity of MR fluids in the off state is primarily determined by the thermal conductivity of the carrier fluid. For example, the thermal conductivity of an MR fluid composed of hydraulic oil and iron particles with a volume fraction of 10% is 0.13 W/m·K.

5.22 PROPERTIES IN THE "ON" STATE:

• Dynamic yield strength values are in excess of 50MPa for magnetic strength of 0.15 to 0.25 T, and when saturated, can exhibit values of over 100MPa. Typical values for the dynamic yield stress of MR fluids used in aircraft dampers range from 20 to 1000 kPa.
• The viscosity of MR fluids can increase by several orders of magnitude in response to the application of a magnetic field. Viscosity values for MR fluids used in aircraft dampers range from 100 to 10000 Pa·s.
• The shear modulus of MR fluids can increase by several orders of magnitude in response to the application of a magnetic field. Typical values for the shear modulus of MR fluids used in aircraft dampers in the on state range from 500 to 5000 kPa.
• The thermal conductivity of MR fluids can increase slightly in response to the application of a magnetic field due to the alignment of the particles in the fluid. Typical values for the thermal conductivity of MR fluids used in aircraft dampers in the on state range from 0.1 to 0.4 W/m·K.

5.3 CODE FOR USER-DEFINED-FUNCTION OF MR FLUID MATERIAL

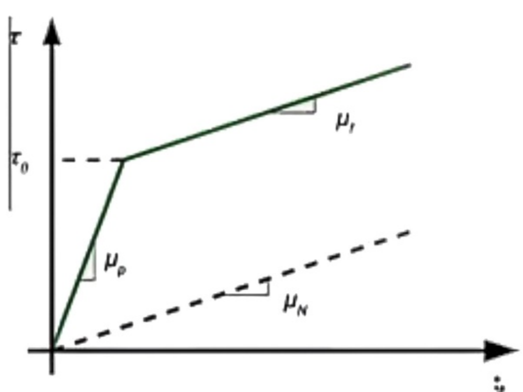
```
#include "udf.h"

DEFINE_PROPERTY(Bingham_viscosity, c, t)
{
real vis;

real ys;
real yielstr=0;
real muf;
//real strain;
muf = 0.092
```

```
#if !RP_HOST
//strain = C_STRAIN_RATE_MAG(c,t);
yieldstr=(372.655*pow(C_UDMI(c,t,2),3)-
6869*pow(C_UDMI(c,t,2),2)+3.37e4*(C_UDMI(c,t,2))-2403.717)/40;
//printf("yirld %f \n",yieldstr);
//C_UDMI(c,t,43)=yielstr;
if((yieldstr/9.2>C_STRAIN_RATE_MAG(c,t)) && C_UDMI(c,t,2)!=0)
{
vis=9.2;
//printf("Strain %f \n",C_STRAIN_RATE_MAG(c,t));
}
else if((yieldstr/9.2<C_STRAIN_RATE_MAG(c,t)) && C_STRAIN_RATE_MAG(c,t,2)!=0)
{
vis= muf + yieldstr/C_STRAIN_RATE_MAG(c,t);
//printf("Viscosity %f \n",vis);
}
else
{
vis=0.092;
}
return vis;
#endif
}
```

5.4 SHEAR STRESS VS SHEAR STRAIN RATE



Graph : 1.1

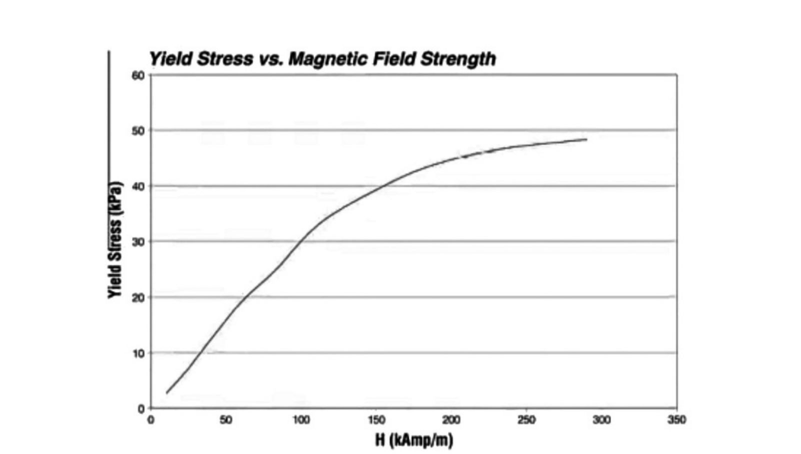
- From the above graph 1.1, until the point of yield stress, the viscosity is given by µp.
- Once the limit has crossed point of yield stress, the failure viscosity is given by µf.

- The relation is given as μp = 100 μf, where our value of μf = 0.092 Pas.

Therefore, in the UDF,

```
if((yieldstr/9.2<C_STRAIN_RATE_MAG(c,t)) && C_STRAIN_RATE_MAG(c,t,2)!=0)
{
vis= muf + yieldstr/C_STRAIN_RATE_MAG(c,t);
```

5.5 YIELD STRESS VS MAGNETIC FIELD



Graph 1.2

From the graph1.2 , we have derived the formula of yield stress, and written into the code as:

- yieldstr=(372.655*pow(C_UDMI(c,t,2),3)-6869*pow(C_UDMI(c,t,2),2)+3.37e4*(C_UDMI(c,t,2))-2403.717)/40;

- The relation between yield stress and magnetic field is given by the function “C_UDMI(c,t,2).

5.6 SIMULATION OF FLUID FLOW CHARACTERISTICS ON A 2D MESH

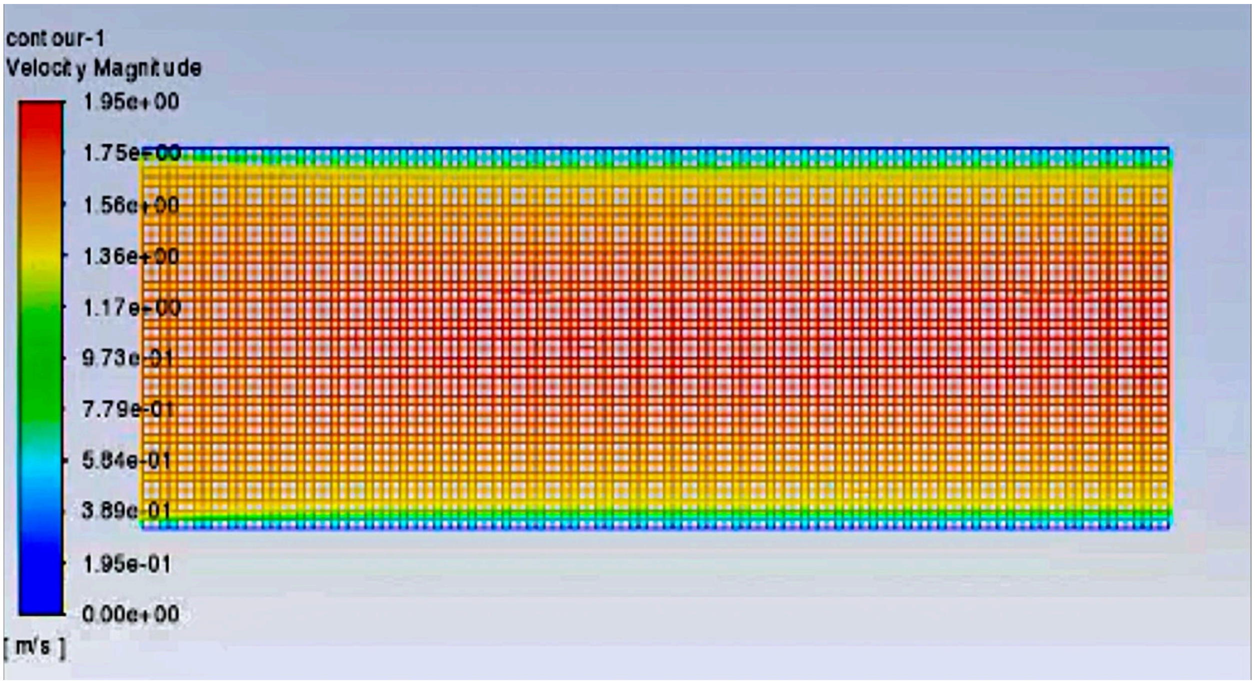
In the ANSYS software, the mesh is created with dimensions of:

- L = 132mm
- W = 56mm
- The inlet pressure applied on the left hand side is 10000 Pa.

- The applied magnetic field has a value of 0.2 Tesla.

It can be viewed in the simulation data, that at the boundaries, the velocity has a value of 1.56 m/s, which is a significant value to dampen shocks that occur on the runway.

Hence, further simulation with the use of 3D mesh and piston, can provide data on landing impact damping characteristics.



CHAPTER 6

FUTURE WORK

6.1 RAM AIR TURBINE:

A RAT can be used to generate an EMF by capturing free stream air and using it to drive a small turbine that powers a generator. This electrical energy can be used to generate a magnetic field that changes the viscosity of the MR fluid to suit our requirements.

This would help us avoid using permanent magnets to generate a magnetic field to change viscosity.

The RAT must be placed within the front landing gear so that it can capture the air.

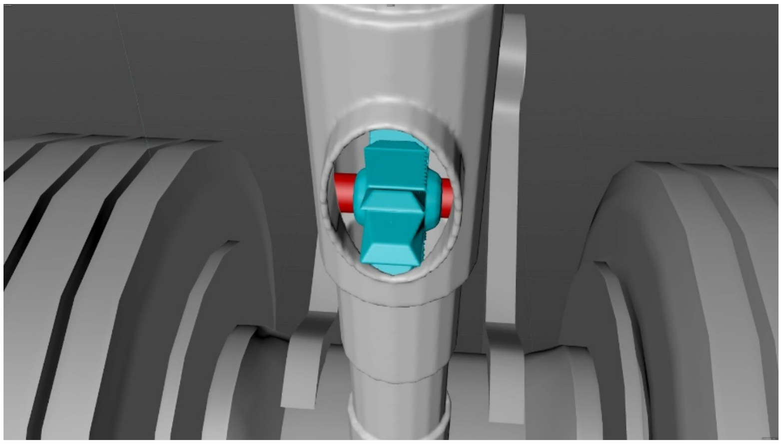
STAGES OF A RAM AIR TURBINE:

1. Air intake: As the aircraft moves forward, the RAT uses a small intake to capture air and direct it into the turbine. The air flows through the turbine, causing it to rotate.

2. Generator: The rotating turbine is connected to a generator that converts the mechanical energy from the turbine into electrical energy.

3. Output: The electrical energy generated by the RAT is used to power critical systems in the aircraft, such as the communication and navigation systems, or to recharge the aircraft's batteries, or in this case to induce an EMF.

RAT IMPLEMENTED IN LANDING GEAR CONCEPTUAL DESIGN:



When the aircraft is in approach phase, air enters the intake at free stream, and rotates the RAT which is mounted on a shaft. The mechanical rotation of this shaft would further be converted to electrical energy and provide current to induce EMF.

6.2 DYNAMO SYSTEM

A dynamo is installed in the aircraft's landing gear system. This dynamo is connected to a rotating shaft that is driven by the aircraft's wheels during landing and takeoff.

Mechanical energy: As the wheels turn, the rotating shaft drives the dynamo, which converts the mechanical energy into electrical energy.

Voltage regulator: The electrical energy generated by the dynamo is then regulated by a voltage regulator, in order to ensure that the voltage remains constant, even as the speed of the rotating shaft changes. The regulator can be modified in such a way that, as speed of the aircraft reduces, the wheel speed reduces, hence the induced EMF would reduce, thereby reducing damping effects.

This design can allow for ride comfort as well as improved efficiency of MR fluid even in taxi condition.

The regulated electrical energy is then supplied to the MR dampers in the landing gear system. The MR dampers use this electrical energy to control the magnetic field that controls the viscosity of the MR fluid, thereby adjusting the damping force.

The entire system is controlled by a computer that monitors the aircraft's speed and altitude. The computer uses this information to adjust the damping force in real-time, ensuring a smooth ride during landing and takeoff.

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