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DESIGN AND ANALYSIS OF HYDRAULIC CAR LIFTING MACHINE USING CAE TOOLS

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Abstract: *A hydraulic lift is a mechanical device used for various applications for lifting of the loads to a height or level. A lift table is defined as a lift used to stack, raise or lower, convey and/or transfer material between two or more elevations. Conventionally a lift or jack is used for lifting a vehicle to change a tire, to gain access to go to the underside of the vehicle, to lift the body to appreciable height, and many other applications also such lifts can be used for various purposes like maintenance and many material handling operations. The main objective of the devices used for lifting purposes is to make the table adjustable to a desired height. A lift provides most economic dependable & versatile methods of lifting loads; it has few moving parts which may only require lubrication. This lift table raises load smoothly to any desired height. Lift tables may incorporate rotating platforms (manual or powered); tilt platforms, etc, as a part of the design. Lift design is used because of its ergonomics as compared to other heavy lifting devices available in the market. The frame is very sturdy & strong enough with increase in structural integrity. A multiple height lift is made up of two or more leg sets. For this research project, there are two basic requirements. The first requirement is to design and another is analysis of a model of a hydraulic lift which is to control the motion of the constructed hydraulic lift, such as following a track, which consists of straight lines and curves. These systems are done by modeling software's like CatiaV5, and analysis is done by Ansys software. It is found that they are facing some problems regarding hydraulic lift like job to be lifted are heavier which causes more deformations in hydraulic lift frame checking deformations & stresses induced in it is a major objective of this project.*

INTRODUCTION

The principles that provide the basis of fluid power were being developed as early as the 1600's (Daines, 2009). However, the hydraulic portion of the fluid power industry, as we know it today, has mainly been developed within the last century, particularly sincea hydraulic system utilizing oil instead of water was used to control guns on the USS Virginia in 1906 (Esposito, 2003). The economic impact of the fluid power industry still remains strong today; based on 2013 U.S. Census Bureau data, sales within the fluid

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power industry surpassed $22 billion and provided jobs for 71,000 people. After taking a broader view of the industry and including ten key industries that utilize fluid power components, the employment numbers increase to over 874,000 people with payroll figures exceeding $54.4 billion (Stelson, 2015).

Fig: Multiple sectors of industry incorporate fluid power components

Recent developments in the fluid power industry have focused on the incorporation of sensing and control technology to develop systems that have the potential to increase machine productivity and efficiency. For instance, automating certain machinery such as an agricultural sprayer can allow for more efficient application of agricultural chemicals and a reduced environmental impact. Achieving improvements in the efficiency and productivity of equipment like the sprayer requires improved motion control of the mechanical systems involved in the machine's operation.

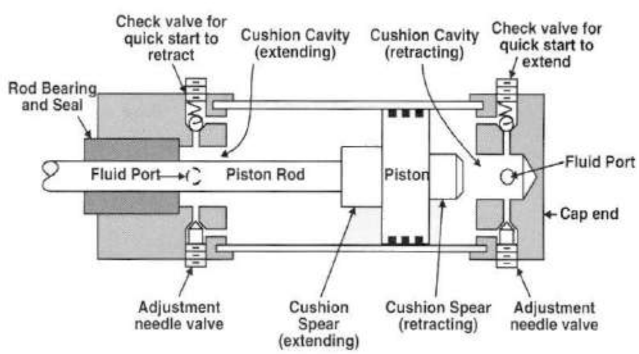

Fig: Hydraulic cylinder with cushioning spears to meter flow out of fluid port.

Objective of Research

The objectives of this research are to:

1. Design and develop a dynamic model that can predict the velocity and pressure performance of a hydraulic cylinder cushion.
2. Support the developed dynamic model through Static Structural analysis.

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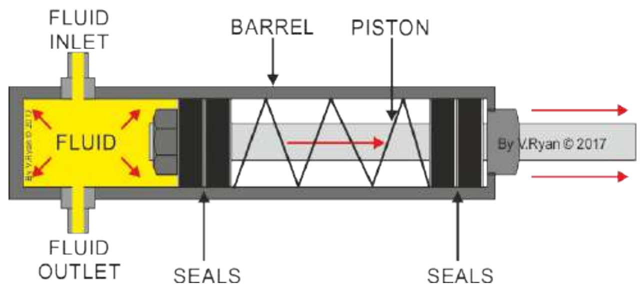

Fig: Example of a Hydraulic System

3. Utilize the dynamic model to analyse the performance of cushioning spear types commonly found in industry and compare those spears to the analytically developed spear type using Structural Analysis

LITERATURE REVIEW

Hydraulic cylinders are used extensively in industry to provide linear motion control. These cylinders are composed of cylindrically shaped metal case with a piston rod assembly (A and B respectively in Figure 2.1) that moves back and forth within the case. The piston and rod assembly separates two different volumes inside the cylinder case. For a single rod cylinder, these two volumes are called: the rod end volume, where the rod end is the end of the cylinder from which the rod protrudes, and the cap end volume, where the cap end does not have a rod (Figure 2.1 c and d respectively). As these volumes are pressurized, hydrostatic forces due to the pressurized fluid act on the surfaces of the vessel containing the fluid. Thus, the forces acting on the piston-rod assembly cause it to move, extending the rod out of the cylinder case or retracting the rod into the cylinder case (Figure 4 shows a cylinder in retraction). An external load can be attached to cylinder rod, and as the piston-rod assembly moves, a force is exerted on the load causing the load to move along a linear path. For a cylinder in retraction, the flow leaving the cap end exits through the cushioning cavity E before returning to the rest of the hydraulic circuit through the cylinder port I. The cylinder stops when the piston reaches the end of its stroke, or when the piston makes contact with the end cap. The components labelled F and G are the cylinder cushion spear and collar that decelerate the piston before it contacts the end cap in either retraction or extension, respectively.

Hydraulic cylinders provide high power density for moving heavy loads, but if the cylinders are allowed to reach end of stroke at full speed, sudden deceleration can cause excessive impact (Esposito, 2003).

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Therefore, a cushioning mechanism was designed to decelerate the cylinder piston and reduce the speed at which impact occurs.

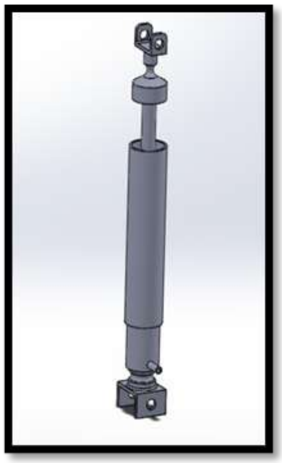
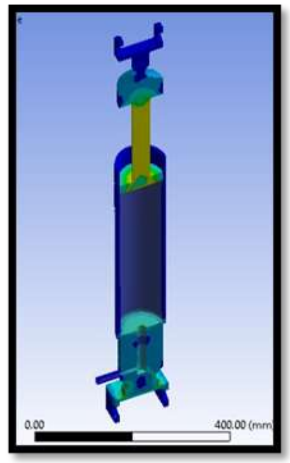

***Fig: 3D model of a Hydraulic Actuator in Hydraulic System**

***Fig: Cross-Sectional View of the Hydraulic Actuator in a Hydraulic System**

Cylinder cushions meter the flow leaving the cylinder case causing pressure to increase. When the area of the piston is exposed to this accumulating pressure, a forced envelops that opposes the motion of the piston-rod assembly causing deceleration (Norvelle, 1995). With the importance of accurately metering the fluid leaving the cylinder to create a resisting force, there is value in predicting the pressure response, i.e. the cushion pressure as a function of time, generated when the fluid is metered by the cushioning mechanism orifice.

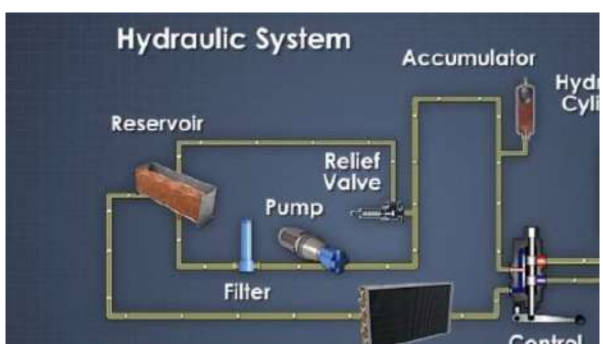

Fig: Hydraulic system components

DESCRIPTION OF THE PROJECT

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In this chapter, we will be able to:

- Understand the design model
- Identify all parts of the hydraulic system
- Design the hydraulic system and its parts
- Draw sketches based on Design of the Model

Hydraulic Cylinder:

A Hydraulic cylinder (also called a linear hydraulic motor) is a mechanical actuator that is used to give a unidirectional force through a unidirectional stroke.

Hydraulic cylinders get their power from pressurized hydraulic fluid, which is typically oil. The hydraulic cylinder consists of a cylinder barrel, in which a piston connected to a piston rod moves back and forth. The barrel is closed on each end by the cylinder bottom (also called the cap end) and by the cylinder head where the piston rod comes out of the cylinder. The piston has sliding rings and seals. The piston divides the inside of the cylinder in two chambers, the bottom chamber (cap end) and the piston rod side chamber (rodend). The hydraulic pressure acts on the piston to do linear work and motion.

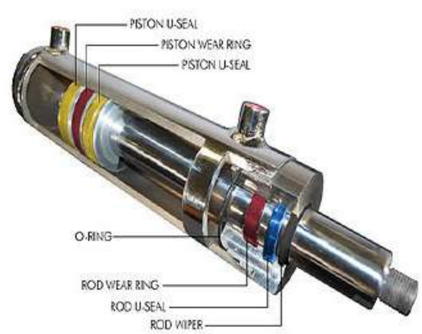

Fig: Schematic View of a Hydraulic Cylinder

Cylinder base or cap:

In most hydraulic cylinders, the barrel and the bottom portion are welded together. This can damage the inside of the barrel if done poorly. Therefore, some cylinder designs have a screwed or flanged connection from the cylinder end cap to the barrel. (See "Tie rod cylinder", below) In this type the barrel can be disassembled and repaired.

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Cylinder head:

The cylinder head is sometimes connected to the barrel with a sort of a simple lock (for simple cylinders). In general, however, the connection is screwed or flanged. Flange connections are the best, but also the most expensive. A flange has to be welded to the pipe before machining. The advantage is that the connection is bolted and always simple to remove. For larger cylinder sizes, the disconnection of a screw with a diameter of 300 to 600 mm is a huge problem as well as the alignment during mounting.

Piston:

The piston is a short, cylindrical metal component that separates the two parts of the cylinder barrel internally. The piston is usually machined with grooves to fit elastomeric or metal seals. These seals are often O-ring, U-cups or cast-iron rings. They prevent the pressurized hydraulic oil from passing by the piston to the chamber on the opposite side. This difference in pressure between the two sides of the piston causes the cylinder to extend and retract. Piston seals vary in design and material according to the pressure and temperature requirements that the cylinder will see in service. Generally speaking, elastomeric seals made from nitrile rubber or other materials are best in lower temperature environments, while seals made of Viton are better for higher temperatures. The best seals for high temperature are cast iron piston rings.

Piston rod:

The piston rod is typically a hard chrome-plated piece of cold-rolled steel which attaches to the piston and extends from the cylinder through the rod-end head. In double rod-end cylinders, the actuator has a rod extending from both sides of the piston and out both ends of the barrel. The piston rod connects the hydraulic actuator to the machine component doing the work. This connection can be in the form of a machine thread or a mounting attachment, such as a rod-clevis or rod-eye. These mounting attachments can be threaded or welded to the piston rod or, in some cases; they are a machined part of the rod-end.

Coatings:

Wear and corrosion resistant surface are desirable on the outer diameter of the piston rod. The surfaces are often applied using coating techniques such as Chrome Plating, Laser Cladding, PTA welding and Thermal Spraying. These coatings can be finished to the desirable surface roughness (Ra, Rz) where the seals show optimum performance. All these coating methods have

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their specific advantages and disadvantages. It is for this reason that coating experts play a crucial role in selecting the optimum surface treatment procedure for protecting Hydraulic Cylinders.

Cylinders are used in different operational conditions and that makes it a challenge finding the right coating solution. In dredging there might be impact from stones or other parts, in salt water environment there is extreme corrosion attack, in off-shore cylinders facing bending and impact in combination with salt water, steel industry there are high temperatures involved, etc... It is important to understand that currently there is no single coating solution which successfully combats all the specific operational wear conditions. Every single technique has its own benefits and disadvantages.

Bill of Material

Component	Material	Mass (Kgs)	Density (kg/m3)
Hydraulic Cylinder	Steel	16.276	7860
Hydraulic Piston	Steel	8.251	7860
Hydraulic Cylinder	Iron	16.297	7870
Hydraulic Piston	Iron	8.261	7870
Hydraulic Cylinder	Aluminum	5.612	2710
Hydraulic Piston	Aluminum	2.845	2710

Table: Mechanical Properties, Chemical Composition and Dimensional Tolerances of a Cylinder Barrel

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Table: Material Mechanical Properties:

Mechanical Properties	Units	AL 4340 Steel	Al 6061 T6	Grey Cast Iron
Young's Modules (λ)	MPa	190	69	180
Fatigue Strength	MPa	540	96	100
Poisson's Ratio (ν)	-	0.29	0.33	0.29
Shear Modulus(μ)	MPa	$73x10^3$	26	$69x10^3$
Shear Strength (τ)	MPa	770	210	200
Ultimate Tensile Strength (σ)	MPa	1280	310	180
Yield tensile Strength	MPa	860	270	120

DESIGN METHODLOGY OF HYDRAULIC SYSTEM

Introduction to CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).

Modeling of Hydraulic System in CATIA V5

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This Hydraulic System is designed using CATIA V5 software.

This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design.

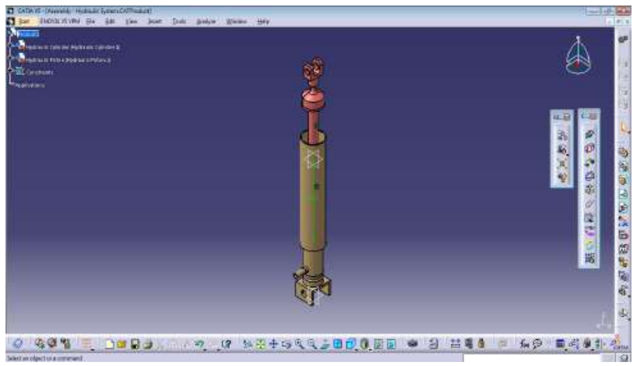

Fig: Model design in CATIA-V5

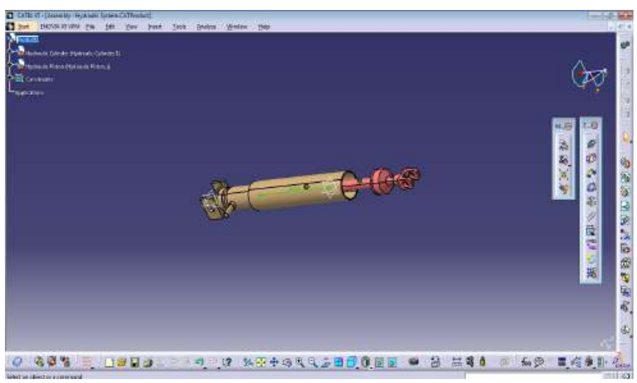

Fig: Model arrangement in CATIA-V5

ANALYSIS OF HYDRAULIC SYSTEM

STRUCTURAL ANALYSIS

Import the CAD. igs assembly model using below method.

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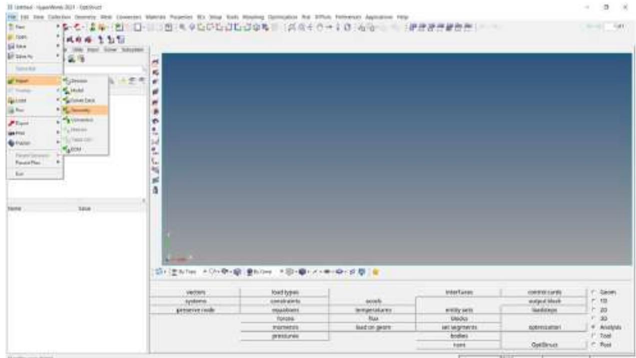
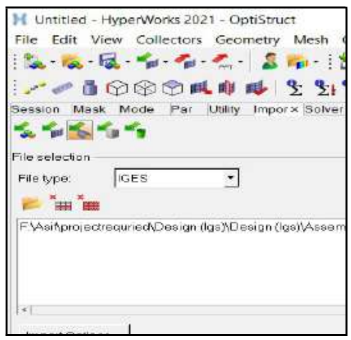
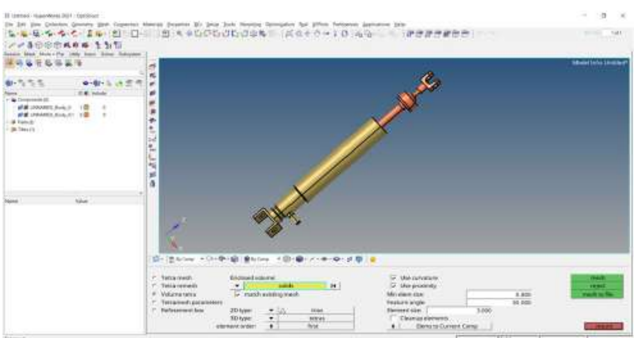


File pull down menu- import-geometry option



Once the model is imported, we have to use 3D Page-Tetra mesh-Volume tetra for doing 3D Mesh.



Using element size of 3mm the mesh using Tetra mesh panel has been meshed

ANALYSIS RESULTS

Al-4043 Material Static Results

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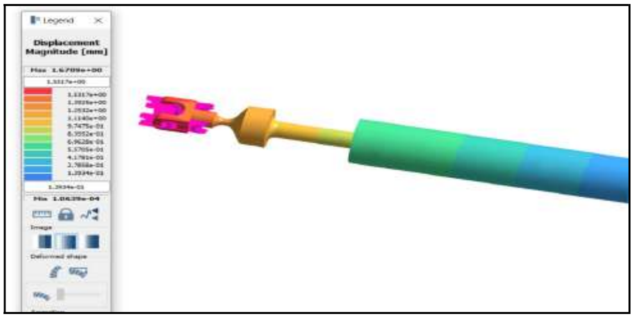
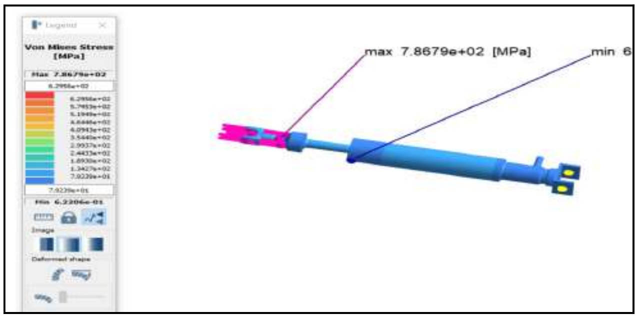
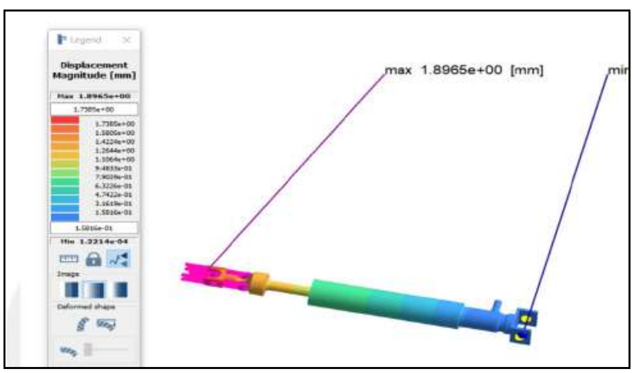


Displacement 1.67mm

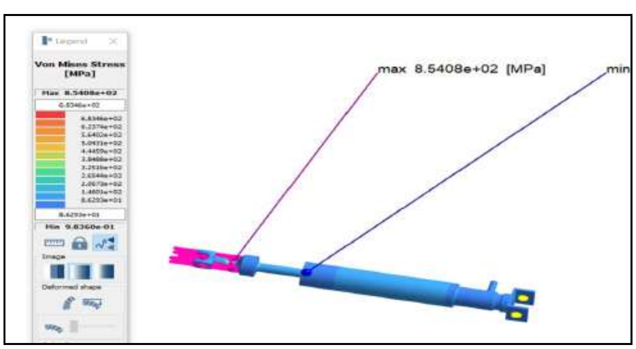


Stress: 786Mpa

Al-6061 Material Static Results

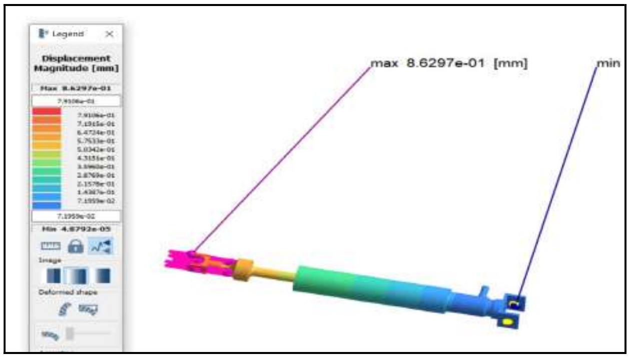


Displacement 1.89mm

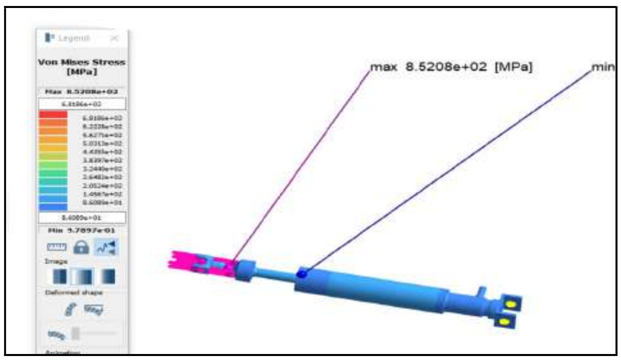


Max stress is 683Mpa

Gray Cast Iron Static Analysis Results

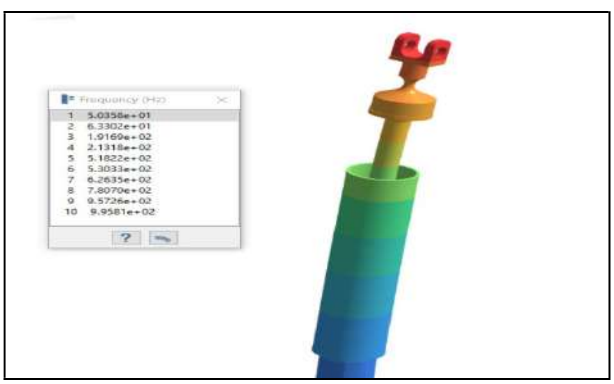


Displacement is 8.62mm



Stress is 852MPa

Transient Mode Analysis Results for Al 4043



Freq is 50Hz and displacement is 1mm

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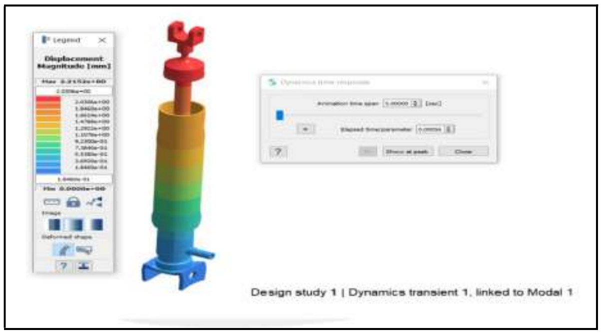
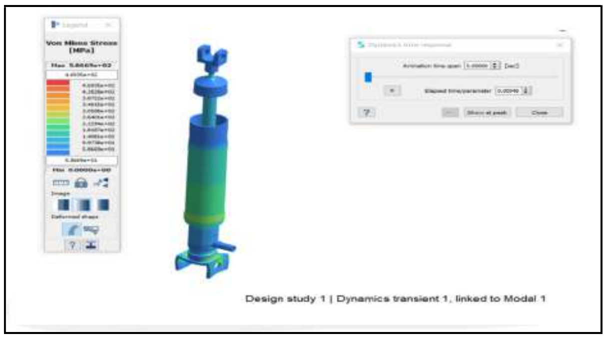
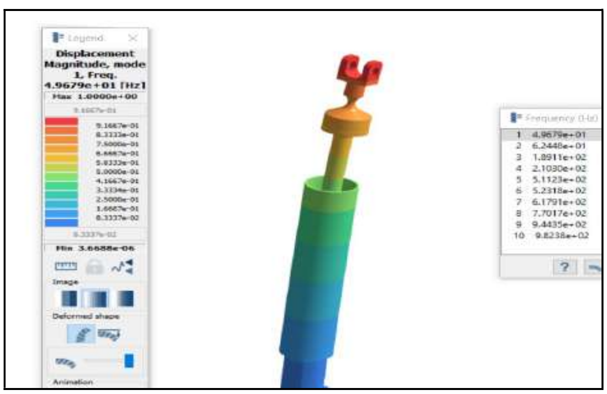


Transient Displacement is 2.215mm



Stress for Transient is 469Mpa

Transient Mode Analysis Results for Al 6061



Displacement is 1mm at 49Hz

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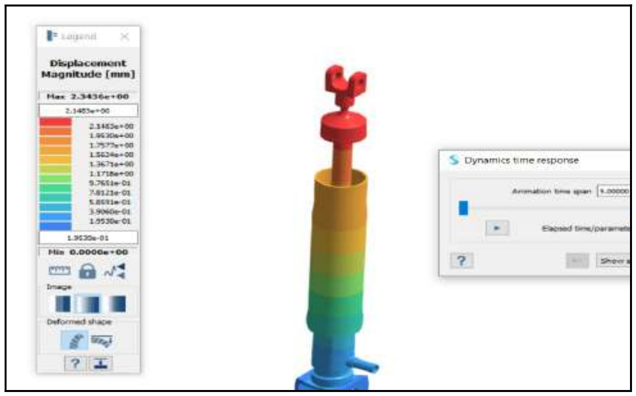
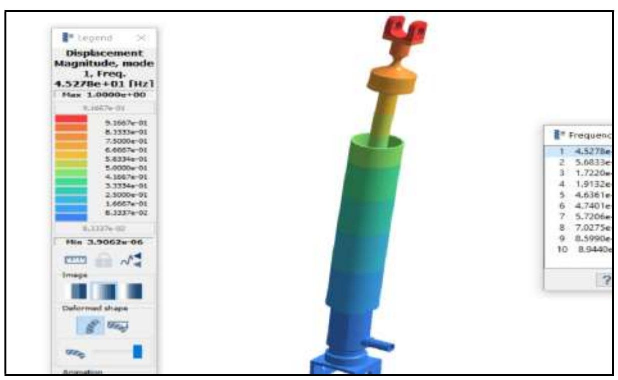


Transient Displacement is 2.14mm

Transient Analysis Stress is 469Mpa

Transient Mode Analysis Results for Gray Cast Iron



Displacement is 1m at 45Hz

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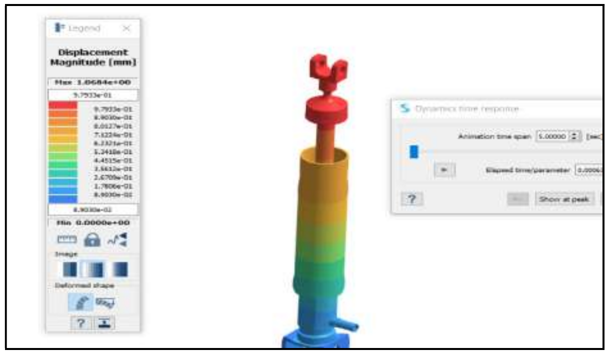

Transient Displacement is 1mm

Transient Stress is 485Mpa

CONCLUSIONS

- Static Analysis is considered worst load case scenario and the assembly is able to sustain the load. This is observed that under static condition assembly is safer and by mean that it can lift the load up to 143000 Newton.

S.No.	Type of Analysis	Material	Displacement	Stress
1	Static	Al 4043	1.670 mm	786 MPa
2	Static	AL6061	1.89 mm	854MPa
3	Static	Gray Cast Iron	0.86mm	852 MPa
S.No.	**Type of Analysis**	**Material**	**Displacement**	**Freq(Hz)**
1	Modal	Al 4043	1 mm	50

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2	Modal	AL6061	1 mm	49
3	Modal	Gray Cast Iron	1 mm	45
S.No.	**Type of Analysis**	**Material**	**Displacement**	**Stress**
1	Transient	Al 4043	2.215mm	586 MPa
2	Transient	AL6061	2.34mm	586 MPa
3	Transient	Gray Cast Iron	1 mm	606MPa

- Under transient analysis the same load is used as an excitation load the deformation is coming in to constant shape after 4 minutes. Here the dynamic loads are observed the component is safer.

- Finally, by observing the three load cases the Hydraulic component can sustain all the static loads by which we can conclude that we can go for the production of the assembly with all safety measurements. By observing above results the three materials which we used for research work the sustainable material will be Al 4043 Material. The results of static and transient results the displacement and stress are under the limit.

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