

Design and Analysis of Hydraulic Actuator for Regenerative Circuit

Neha Deshpande¹, Furqan Gadwal², Prajwal Dhore³, Vaishnavi Dudhade⁴, Shubham Deshtwad⁵

¹⁻⁵Undergraduate Student, Department of Mechanical Engineering, VIT, Pune, Maharashtra, India

Abstract - The design and analysis of a hydraulic circuit plays a major role nowadays because many industries are using hydraulic systems due to their cheap and efficient operation. Hydraulic Linear Actuator is mostly used due to their simple construction and smooth working. In this paper we tried to focus on regenerative circuit. A regeneration circuit can double the extension speed of a single-rod cylinder without using a larger pump. This means that regeneration circuits save money because a smaller pump, motor, and tank can produce the desired cycle time. It also means that the circuit costs less to operate over the life of the machine. We designed a hydraulic actuator in solid works, analysed it in Ansys and finally we developed the circuit in the software DSH Plus. This paper will help to develop interest in students and researchers to explore in Hydraulic Circuits.

Key Words: Actuator, Hydraulic, Regenerative, Analysis

1.INTRODUCTION

A regeneration circuit can also replace a double rod-end cylinder in some circuits. With equal rod diameters, a double-rod cylinder's area is the same on both ends. Equal areas mean identical force and speed both ways at a given pressure and flow. Reciprocating tables often use double rod-end cylinders for this reason. Regenerative circuits are used when it is desirable to rapidly advance an actuator into position to reduce cycle time. When configured as a regenerative system, the operation is more rapid than in normal operation with the pump flow rate alone.

To achieve the process of regeneration, the fluid leaving the rod end of the cylinder is routed back to the cap side of the cylinder to combine with the pump flow rate from the pump. A Regenerative Circuit is used to speed up the extension stroke of a double-acting single rod cylinder. Allowing fluid to flow into both the ports of a single rod cylinder to make it expand or at least try to expand as areas of contradictory sides of the piston are inadequate, the piston end of the cylinder has more force than the rod side. Regenerative circuit requires smaller pump and can also double the extension speed of a single-rod cylinder. This means that regeneration circuits save money because a smaller pump, motor, and tank can produce the desired cycle time. It also

means that the circuit costs less to operate over the life of the machine.

2.OBJECTIVES

1. To get familiar with the concept of Regenerative Circuit
2. To design the Hydraulic Circuits
3. Understand the cylinder forces equilibrium.
4. Understand the relation between the cylinder velocity and the flow-rate supplied by the pump.
5. To analyze the circuit and find out the results

3.HYDRAULIC COMPONENTS USED

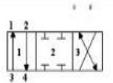
Uni-directional PDP	
Pressure Relief Valve	
4/3 DCV	
Double Acting Cylinder	

Fig.1 Components used in Regenerative Circuit

4. WORKING OF REGENERATIVE CIRCUIT

The regenerative circuit is used to speed up the extending speed of double acting hydraulic cylinder. The pipeline to both end of the hydraulic cylinder is connected in parallel and that one of port of the four-way valve is blocked. The operation of the cylinder

during the retraction stroke is the same as that of regular double acting cylinder. Fluid flow through the Direction Control Valve via the right envelope during retraction. In this mode, fluid from the pump bypass the DCV and enters the rod end of the cylinder. Fluid in the blank end returns back to the tank through the DCV as the retraction takes place.

When the DCV is shifted into the left direction, envelope the cylinder extends. The speed of extension is greater than that for regular double acting cylinder because the flow from the rod end regenerates with the pump flow to provide the total flow rate, which is greater than pump flow rate to the blank end of the cylinder. A conventional cylinder can exert a larger force extending than retracting because of the area difference between full bore and annulus sides of the piston.

A cylinder which is having its bore twice its annulus is known as a differential cylinder. When the cylinder extends, the pressure line is acted to the rod end side of the piston and hence the force is acted upon it. But in the cap end side the pressure remains same but the area will reduce to half. So, the net force in the cap end side will increase.

4.1. REGENERATIVE CIRCUIT (DURING EXTENSION)

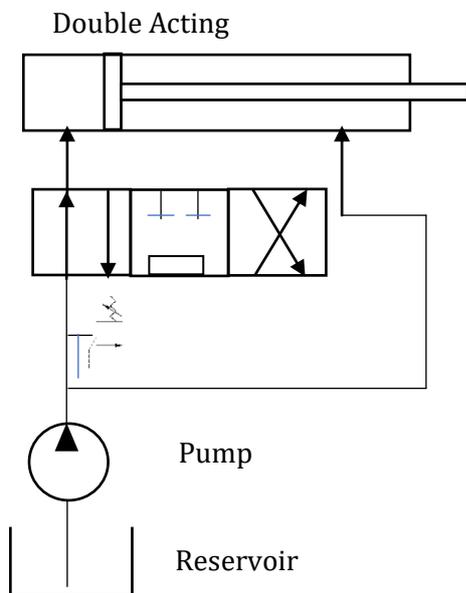


Fig.2 Regenerative Circuit- During Extension

4.2. REGENERATIVE CIRCUIT (DURING RETRACTION)

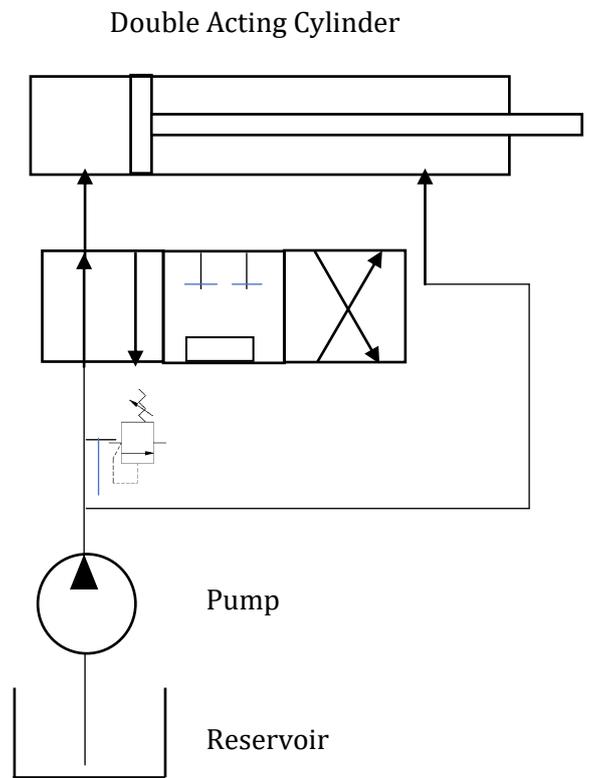


Fig.2 Regenerative Circuit- During Retraction

5. CALCULATIONS

Normal working pressure:

Application	Range	Average
Machine Tool	20-70	33
Industrial Robot	5-140	64

HYDRAULIC ACTUATOR CALCULATIONS:

$P = 50 \text{ kg/cm}^2$ Force Req. = 4000kg

$P = F/A$ $A = F/P = 4000/50$
 $= 80 \text{ cm}^2$

So, $A = (\pi/4) (D)^2$

Therefore, $80 = (\pi/4) (D)^2$

$D = 100 \text{ mm.}$

Standard bore diameters sizes in mm:

32	40	50	63	80	100	125	140
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To calculate the flow (Q):

$$Q = A \times V$$

Motor Power:

$$= P \times Q / 612 \times \text{eff.}$$

Heat Generated:

$$H = L \times (100 - \text{eff.}) \times 860 / 100.$$

Calculations for drilling machine:

Cylinder Specifications

$$\text{Clamping} = \Phi 12.5 \times \Phi 5.0 \times 20 \text{stroke}$$

$$\text{Drilling} = \Phi 6.3 \times \Phi 3.5 \times 100 \text{ stroke}$$

Load or Force Acting on the Cylinder:

$$\text{Clamping} = 400 \text{ Kg.}$$

$$\text{Drilling} = 250 \text{Kgf}$$

Speed of Actuators:

$$\text{Clamping} = 1.5 \text{ M/min}$$

$$\text{Drilling} = 0.1 \text{ M/min}$$

Pressure Required for Clamping:

$$P1 = F/A = 400/122.7$$

$$= 3.3 \text{ Kg/ (cm)}^3 \text{ [Area} = \pi/4 \times D^2 = 122.7 \text{cm}^2]$$

Pressure Required for Drilling:

$$P2 = F/A \text{ [Area} = \pi/4 \times D^2 = 31.3 \text{ cm}^2]$$

$$P2 = 250 / 31.2$$

$$P2 = 8 \text{ Kg/cm}^2$$

Flow rate:

1. For Clamping

$$Q1 = A \times V$$

$$= 122.7 \times 1.5 \times 100$$

$$= 18405 \text{ cm}^3/\text{min}$$

$$Q1 = 18.405 \text{ LPM}$$

2. For Drilling

$$Q2 = A \times V$$

$$= 31.2 \times 0.1 \times 100$$

$$= 312 \text{ cm}^3/\text{min} = 0.312 \text{ LPM}$$

Electric Motor Power:

$$\text{Motor Power} = (P \times Q) / 612 \times \text{efficiency.}$$

[Efficiency = 0.85]

$$= 8 \times 18.4 / 612 \times 0.85$$

$$= 0.28 \text{ KW.}$$

Design & Analysis of Hydraulic Actuator (Linear):

Main specifications for hydraulic actuator:

Bore diameter: 100.08 mm

Rod diameter: 49.96 mm

Bolt: M30X2 mm

6.MATERIAL SELECTION

1. Piston rod:

Stainless steel is selected for piston rod as its piston has to work in outside environment & the operation of the piston rod needs to be smooth. So, in order to ensure smooth operation & avoid corrosion of the piston rod from foreign elements, this material is selected.

2. Piston:

The piston has to operate at very high operating loads and pressures due to which the strength of the piston is of utmost important. And hence, in order to ensure higher strength of the piston alloy steel having high tensile strength is selected. The grade for material is EN 19.

3. Cylinder Barrel:

The barrel is the stationary part of the hydraulic actuator due to which very high impact loads from the piston as well as hydraulic fluid is experienced on the barrel. Hence, mild steel is considered for this part as it has high impact strength.

4. Backing seal:

The backing seal is situated in the cylinder barrel itself. Due to continuous operation of the hydraulic actuator, there is generation of heat in the cylinder so the copper material is selected which has very good thermal conductivity.

5. Piston seal:

The clearance between piston and cylinder needs to be properly adjusted for which rubber material is best.

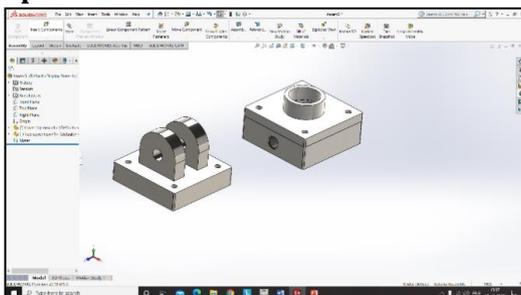
The components of the actuator are as follows:

1. Lower cap
2. Top cover
3. Cylinder barrel
4. Backing seal
5. Piston
6. Piston rod
7. Rod nut
8. Piston seal
9. Rod guide
10. Rod guide seal
11. Rod guide nut
12. Fork
13. Nuts & bolts.

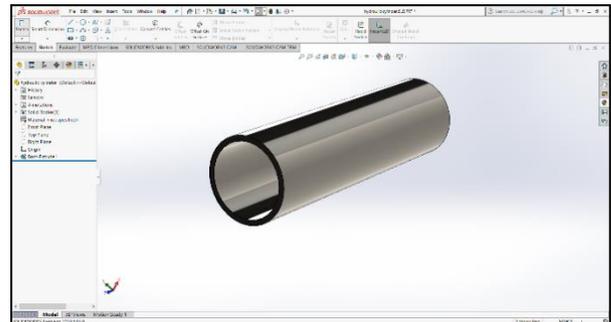
All the above individual components were designed in part design workbench of Solid works 2019.

7.CAD MODELS OF INDIVIDUAL COMPONENTS

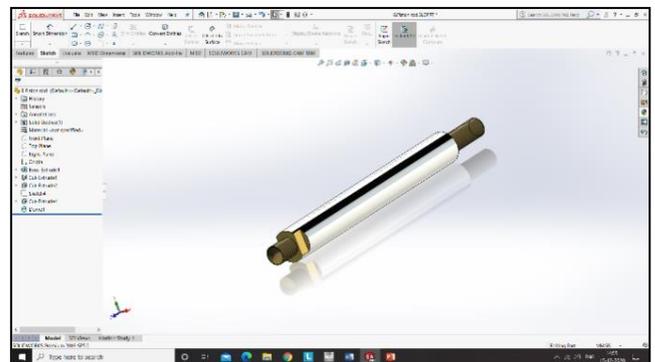
1. Top & Bottom cover



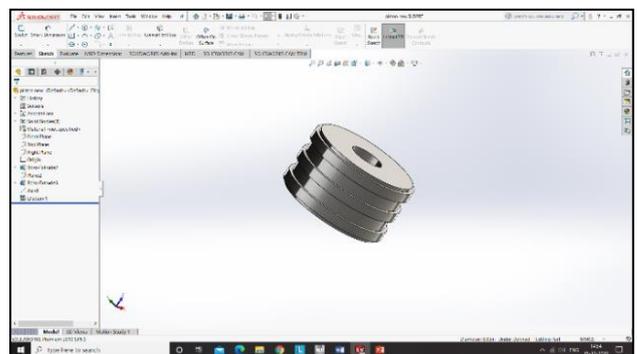
2. Cylinder Barrel



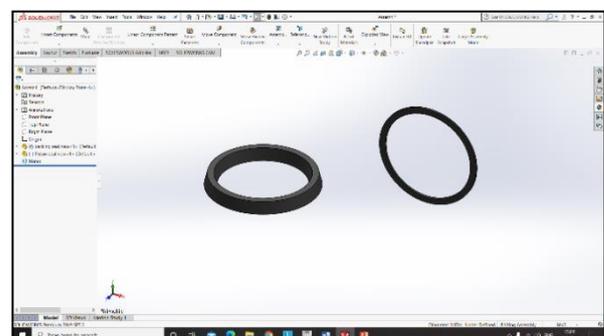
3. Piston Rod



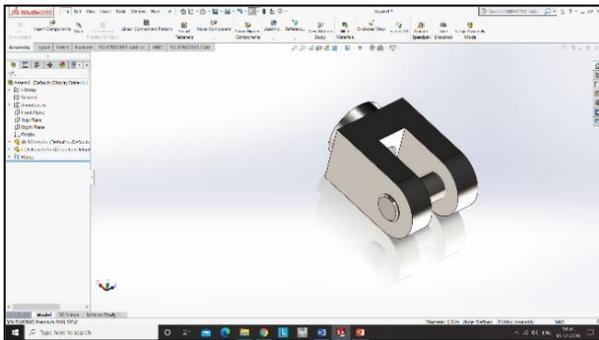
4. Piston



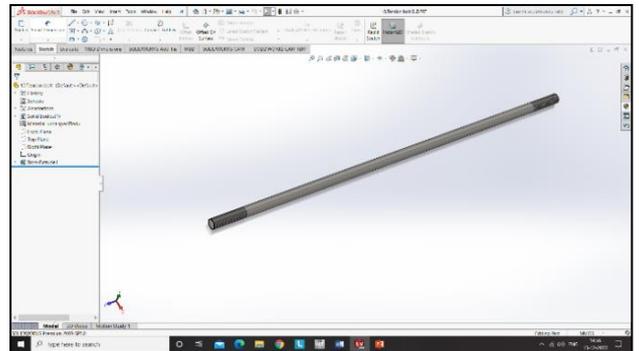
5. Piston & Backing seal



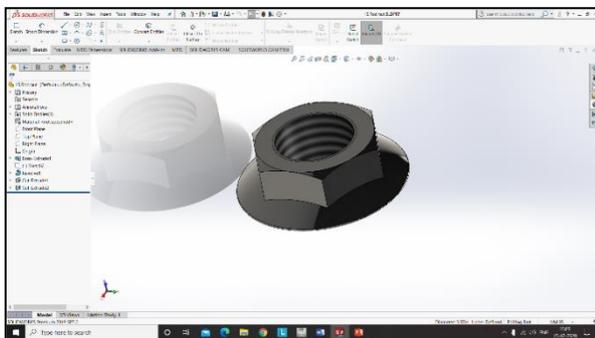
6. Coupling fork



10. Tension bolt



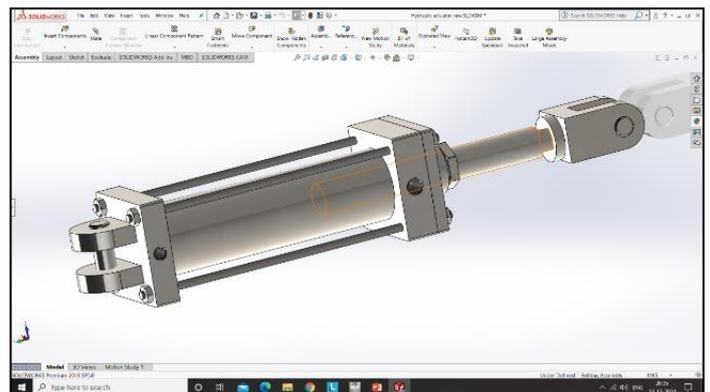
7. Piston Rod Nut



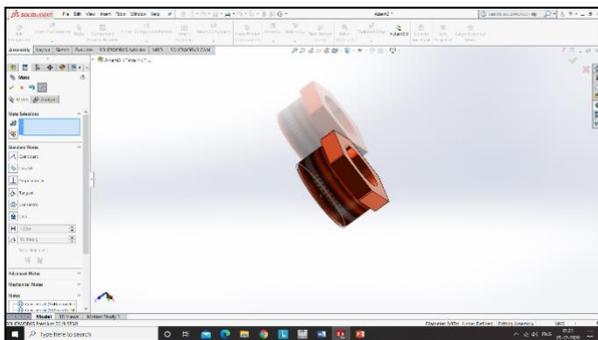
Assembly of hydraulic actuator:

The assembly of all the individual components was done in assembly workbench of solid works 2019.

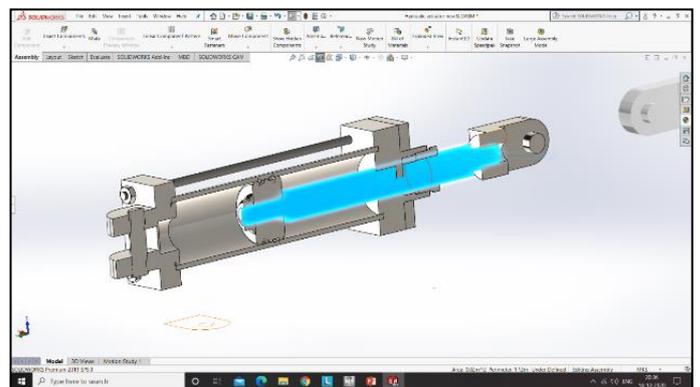
1. Assembly of hydraulic actuator



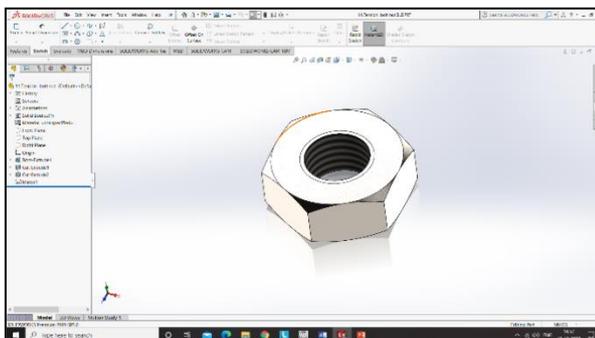
8. Rod, guide, nut and seal



2. Sectional view



9. Nut



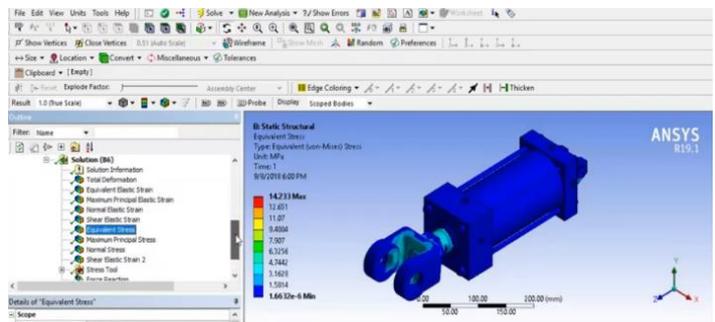
8.ANALYSIS OF CAD MODEL IN ANSYS

Finite element model details. ANSYS 19.0 version was used for finite element analysis.

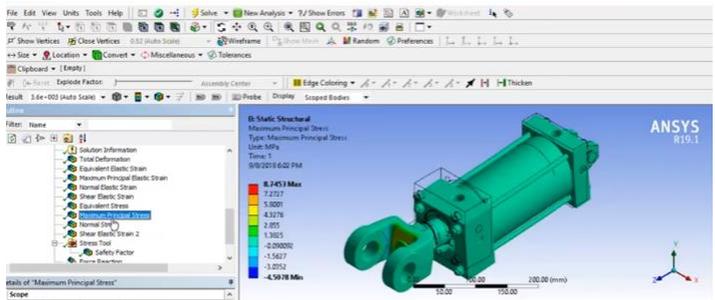
1. Meshing type is Tetrahedral type
2. Tension force at fork end - 400 N
3. Bolt pretension -300 N
4. Standard earth gravity -9.8
4. Support at end

Ansys model of hydraulic actuator

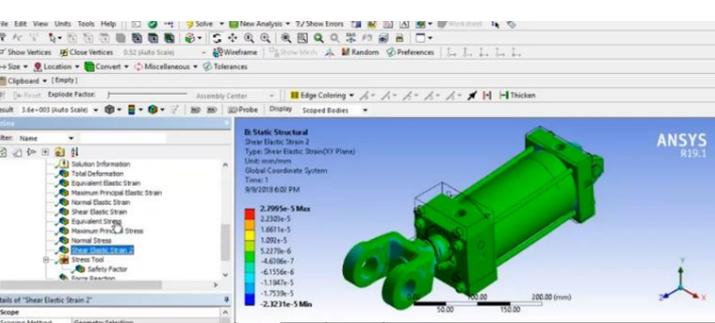
Equivalent Stress



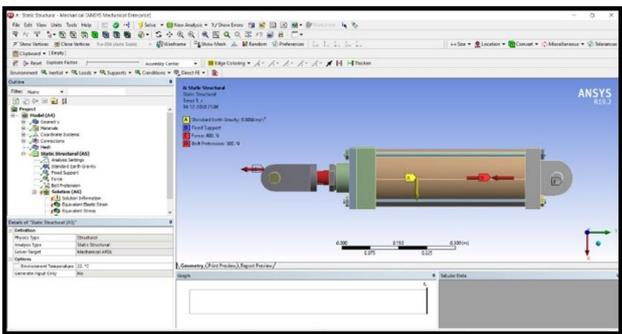
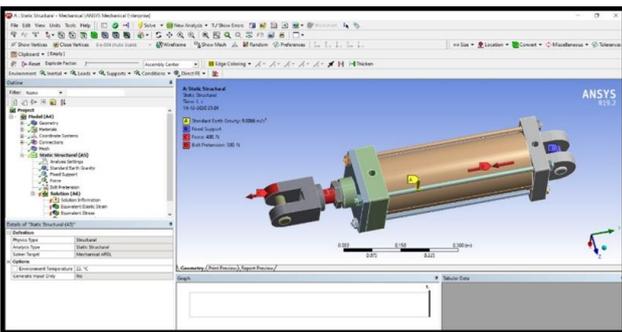
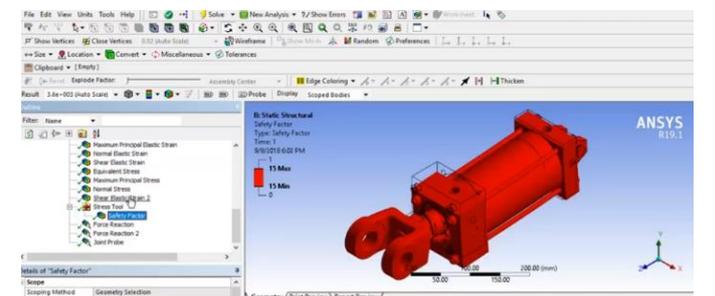
Maximum Principal Stress



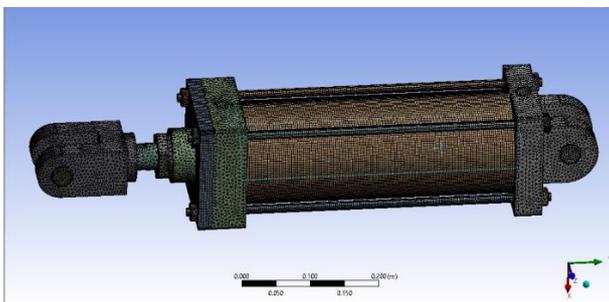
Shear Elastic Strain



Factor of Safety

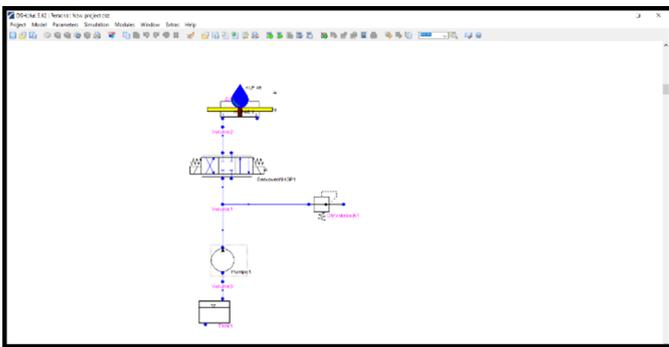


Meshing of Actuator



9. ACTUAL HYDRAULIC CIRCUIT IN DSH PLUS

The detailed analysis of the hydraulic actuator was done in the ANSYS software. The next step is to model the hydraulic circuit in appropriate software. In this project we used DSH Plus Fluidon software. We specified the values which were done in the calculation part. The Fluid used is HLC 48. The direction control valve, pressure relief valve, tank, actuator was specified according to the calculations and hence the circuit is designed.



10. CONCLUSION

The term regeneration can be applied to any system that diverts all or part of its output and adds it to its input to enhance some aspect of its performance in hydraulic cylinder. By doing this project we come to know how to design the hydraulic circuit. We changed the parameters and modified our design according to it. And analyzed in Ansys. Also, we designed the actual hydraulic circuit in the software DSH Plus which is used especially for Hydraulics.

11. REFERENCES

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