Sant Longowal Institute of Engineering & Technology Longowal, District-Sangrur, Punjab-148106
(Deemed University under MoE, Government of India)

Design and Analysis of a Gaming Platform with 4 Degrees of Freedom

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ACKNOWLEDGEMENT

We have taken sincere efforts in the project and the success of this project would have been possible with the kind of support and help of many Indians and organizations. We would like to extend our sincere thanks to all of them.

We are highly indebted to Dr Indraj Singh (Associate Professor, Dept. of Mechanical Engineering) for his guidance and supervision as well as for providing necessary information regarding the project & also for his support in completing the project.

We would like to express gratitude to our college for helping us in completing the project by allowing us to use the facility available to machine parts whenever we needed.

We would also like to thank Dr. Rajesh Kumar (HOD, ME) for his kind support. And also present our sincere gratitude to Dr. H.K Arya (Project Evaluation Coordinator, GME-17)

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ABSTRACT

Fluid power system is a very versatile system that can be used in various fields. It can be used in wide range of applications ranging from industries in which processes are automated to increase the productivity to the entertainment field in which these systems are used to create a realistic experience in the 5 D theatres and also in gaming systems to give the user a unique and realistic experience. Here, focus was given to the entertainment industry and a gaming platform with 4 degrees of freedom was developed that provides motion similar to the visuals running in the game as the user plays the game to enhance the effect and provide an immersive gaming experience. The gaming system was powered using hydraulics and a PLC with various sensors were used for control.

Figure 1: Gaming platform

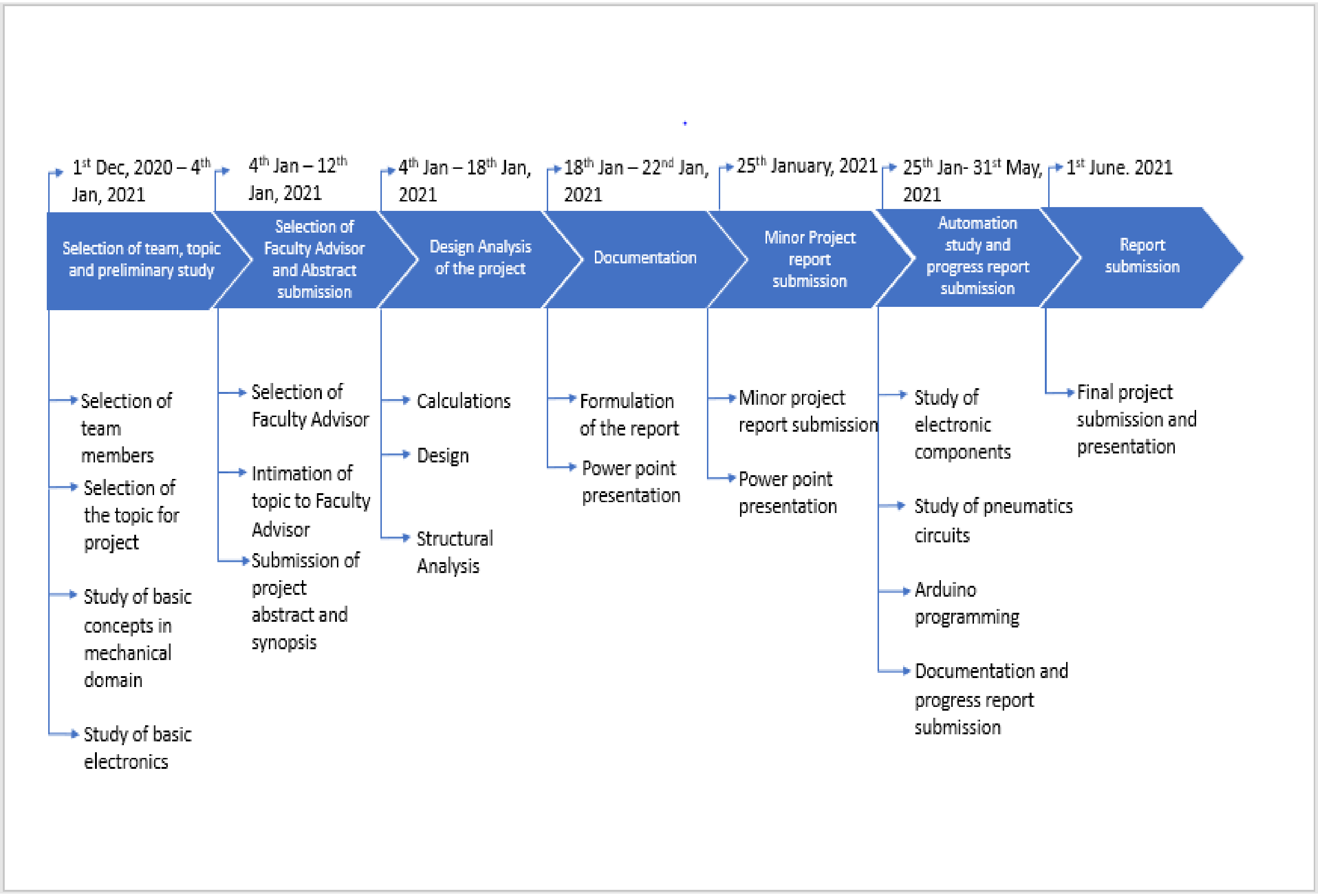
SYNOPSIS

- Assumptions and Calculations for the system.
- The gaming system will be powered using hydraulics and pneumatics.
- Designing of Prototype in CAD Software.
- Finite Element Analysis of Components and Structure for Optimum Design.
- A PLC with various sensors will be used for control.
- Selection of Controllers.
- Circuit Designing and Power Requirement Calculations.
- Embedded Programming
- Gaming Interface.

TIMELINE

The major project is annually assigned to the final year students as per the B.E. curriculum. The project aims at the design and fabrication of the 4 Degrees of freedom gaming platform with the help of fluid power. The team comprises of five members under the guidance of the faculty advisor. The strategy was to assign the various topics to the students so that the project is completed in accordance to the deadline set by the Institute administration. The team was divided into the three domains namely, mechanical design and analysis, electronics and documentation for the successful accomplishment of the project. The timeline of the project is shown below which gives an insight of the team's approach towards the project. The figure showcases the various phases in which project was divided along with their deadlines.

Figure 2: Timeline of the project



CHAPTER ONE
INTRODUCTION

Human being always strived to solve their problems from the beginning its evolution.

Nature and Science have gifted us so many things for smooth and easy-going life. One such great gift is fluid power in which pressurized fluid was used to do work. It has helped humans solve many engineering problems such carrying loads and also in performing automated cycles of operation.

1. TYPES OF FLUID POWER SYSTEMS:

Most fluid power systems use compressed air inert gases or hydraulic fluid as their operating media. Based on the media the fluid power systems are classified into 2 types

- Pneumatic systems
- Hydraulic systems

2. PNEUMATIC SYSTEMS:

Most pneumatic systems run at low pressure rating ranging from 6 to 8 bar. Two main advantages of pneumatic systems are the low initial cost and design simplicity since it is an open system i.e., Air can be obtained from and exhausted to the atmosphere. They are usually quieter in applications than the hydraulic systems. This is mainly due to the fact that the power source is installed remotely from the machine in an enclosure that reduces noise and they are cleaner when compared to hydraulic systems. Also, these systems have very high response but poor stability. These systems have some limitations such as cannot hold heavy load in a stable position as hydraulic system as air is compressible.

2.1 PARTS OF TYPIAL PNEUMATIC SYSTEMS:

- Source elements Compressor
- Filter, Regulator and Lubricator (FR) unit
- Control elements Directional control valves.
- Pressure and flow control valves
- Power circuits Actuators (linear, rotary).

2.2 APPLICATIONS:

Pneumatics are used in various fields, some of which are listed below:

- Food processing industry
- Assembly lines
- Vehicle door actuation
- Dentistry and medical applications
- Mining, etc.

3. HYDRAULIC SYSTEMS:

A hydraulic system circulates the same fud repeatedly from a fixed reservoir using positive displacement pump and a motor as prime mover. This combination of prime mover and the pump called a power pack. The fluid is an incompressible liquid. So, can be used to maintain a very accurate positions, speeds and forces

The mayor advantage of these systems is the tight force multiplication factor. They can be operated at higher pressure typically ranging tom 1500ps to 2000 1200-8000) High pressure generates larger force from smaller actuators which means that the system space reduced

The main disadvantage of hydraulic system is the high initial cost and the maintenance cost which are very high compared to pneumatics. Hydraulic systems are Usually more complex in design and it takes a skilled operator to maintain and develop the system

3.1 PARTS OF TYPIAL HYDRAULIC SYSTEMS:

- Power Pack (reservoir. pumps, motors)

- Pressure gauge Sow meter
- Direction control valves
- Pressure control valves
- Accumulators
- Actuators

3.2 APPLICATIONS:

➢ STATIONARY HYDRAULICS:
In case of stationary hydraulics, the system remains in a fixed position. Examples are listed below

- Lifting and conveying systems
- Metal forming presses
- Rolling machines
- Lifts

➢ MOBILE HYDRAULICS:
In this case the hydraulic system moves on wheels or tracks such as a tower crane or excavator truck to operate in different locations or while in motion Examples include

- Construction machinery
- Tippers, excavators and elevating platforms
- Lifting and conveying devices
- Automobiles, tractors, aeroplanes, missiles, boats

Table 1: Comparison between hydraulics and pneumatics

HYDRAULICS	PNEUMATICS
It employs pressurized liquid as fluid	It employs a compressed gas, usually air as a fluid
An oil hydraulic system operates at pressure up to 700bar.	A pneumatic system usually operates at 5 – 10bar.
Generally designed as closed system	Generally designed as open system
The system leaks down when leakage occurs	Leakage does not affect the system
Valve operation are difficult	Valve operations are easy
Heavier in weight	Light in weight
Pumps are used to provide pressurized fluid	Compressors are used to provide pressurized gas
The system in prone fire hazards	The system is free from fire hazards
Lubrication is automatically provided	Separate unit is present to provide lubrication.
Response is slower	Response is faster
Major losses are more	Major losses are negligible
System is highly stable	System stability is less
Cannot work at higher cycles per minute as inertia is high	Can work at higher cycles per minute as inertia is negligible
Compressibility is not an issue	Compressibility is an issue
Maintenance is very costly	Not much focus needs to be given for maintenance.
Clumsy system	Cleaner system

Based on the comparison between pneumatics and hydraulic systems, it is seen that hydraulic systems are in greater favor because of their greater stability and reduced space consumption. Owing to the compressibility effects of air, it is not advisable to choose pneumatic system for the application. Hence, Hydraulic system was chosen for the gaming application

CHAPTER TWO
DESIGN OF HYDRAULIC SYSTEM

- **Calculation for tilting cylinders**

Mass of person – 120 kg Mass of seat – 30 kg
Mass of supporting plate – 5 kg
Mass of ball joint – 2kg (0.5 kg each, 4no.) Total Mass – 157 kg
Total load – 157*9.81=1540.17 N Factor of Safety – 1.5
Total design load – 1540.17*1.5=2310.25 N Bore diameter of cylinder – 30 mm =0.03m Area of piston – π/4*0.03*0.03=0.000706 m^2
For worst case scenario it is considered all force is acting on one cylinder Pressure – Force/Area=3.26 MPa

- **Stroke Length Calculation**

The angle of tilt is fixed to be 20° Considering same extension of all four piston
Distance between two cylinder- 400 mm =0.4m
Stroke Length – Distance between two cylinder***θ** Where, **θ- angle** of tilt
Stroke Length – 136.80 mm

- **Pressure calculation for translating cylinders-**

Mass of person – 120 kg Mass of seat – 30 kg
Mass of supporting plate – 5 kg
Mass of ball joint – 2 kg (4 no., 0.5 kg each) Mass of cylinders – 16 kg (4 no., 4 kg each) Mass of frame – 60 kg
Total mass – 233 kg
Total load – 233*9.81=2285.73 N Fos – 1.5
Total design load – 2285.73*1.5= 3428.595 N Coefficient of friction between frame and slot – 0.65
Total friction force – coefficient of friction * normal force=2228.58 N Bore diameter of cylinder – 30 mm = 0.03m
Area of piston = 0.000706 m^2 Pressure – 3.15 MPa
Therefore, operating pressure is taken to be 3.26 MPa
Stroke Length for translation motion is taken as 120 mm which is sufficient for gaming application.

- **Flow Rate calculation-**

Stroke Length for translation motion – 120 mm Time for actuation – 1.5 sec
Velocity of piston – 0.08 m/sec
Discharge rate(Q) – Area * Velocity= $0.056*10^{-3}$ l/sec

- **Pump calculation-**

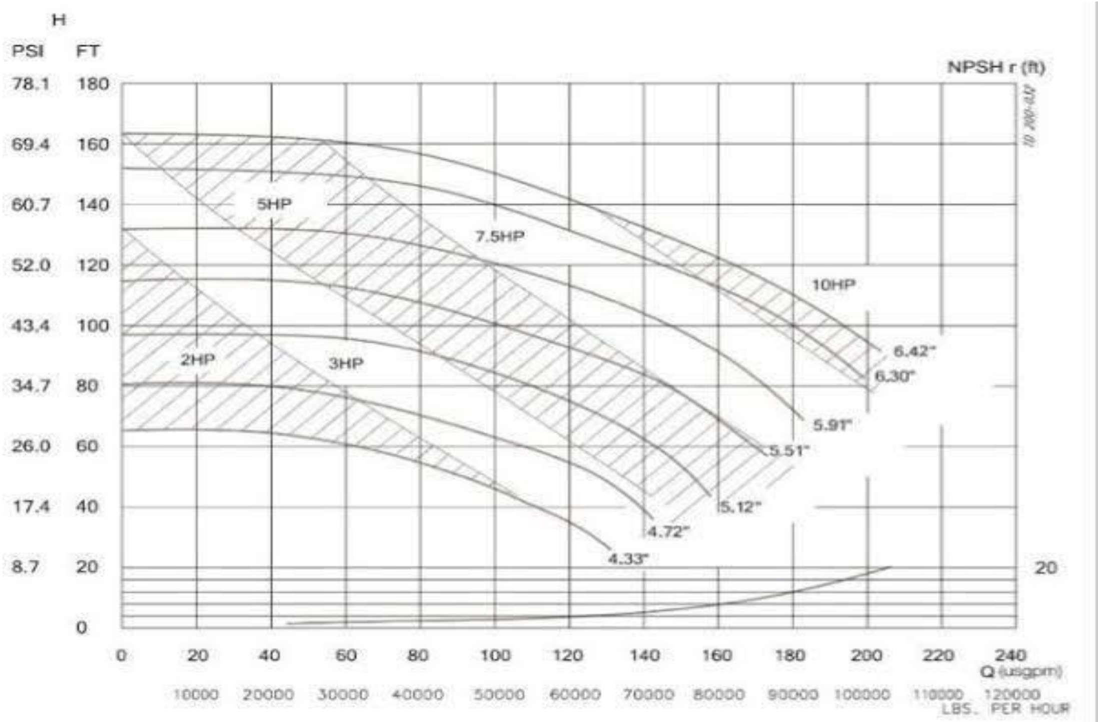
Hydraulic oil used is ISO 46 equivalent SAE grade 20 Specifications-
Density- 875 kg/m^3 Kinematic viscosity – 46.3 CST
For selecting a pump, loss in system must be taken into account to get desired output. For this we have to check flow is laminar or turbulent
Hose diameter – 12.7 mm = 0.0127 m Area of hose – $0.126*10^{-3}$ m^2
Velocity of oil in hose – Discharge/Area= 0.45 m/sec
Reynolds number (Re) **-** (ρVL)/μ=$(0.45*0.0127*10^6)/46.3$=123.43<<2000 Hence the flow is laminar
Therefore, for calculating head loss we use Darcy Weisbach Equation
Frictional head loss (hf)-($f*l*v^2$) /2gD Where,
f – Darcy friction factor L – length of hose
V – Velocity of flow D – Diameter of hose
g – acceleration due to gravity Length of hose – 9m
Velocity of oil in hose – 0.45 m/sec Diameter of hose – 0.0127 m
For laminar flow Darcy friction factor – 64/Re f – 0.5188
hf-(0.5188*9000*0.45*0.45)/(2*9.81*0.0127)=3.792 m
Applying Bernoulli's equation between reservoir and exit side of cylinder P1/ ρg + v1^2/2g + z1 + H_{pump}= P2/ ρg + v2^2/2g + z2 + hf
P1 – atmospheric pressure = 101325 pa V1= 0
Z1=0(datum)
P2 = 3.26*10^6 Pa
V2 = 0.08 m/sec Z2 = 0.45
hf= 3.792*
By solving, we get H_{pump}=365.23
Pressure at outlet = ρg(H_{pump}+hf)= 31.67 bar Pump Power = (ρQ*g*H_{pump})/ η

Where,
ρ = density of fluid Q = Discharge rate η = efficiency of pump= 0.85

Hence, Power of pump = 206.54 watt
Based on above calculation pump selected for application is direct drive Model No. 1XP050.051
Specification

Specification	**Numerical value**
Max flow	1.49 Lpm
Min. Pressure	7 Bar
Max. Pressure	69 Bar
In-let port size	3/8”
Discharge port size	¼”
RPM	1725
Material	Aluminium

Table 2: Technical Specification of electric motor



- **Calculation for Hydraulic cooler selection**

Assumptions,
Oil inlet temperature – 60° c=333.15 K Water inlet temperature- 26°c= 299.15 K Entering temperature difference (ETD)- 34 K
Discharge(Q) – $0.056*10^{-3}$ m^3/sec
Density of fluid – 875 kg/m^3
Specific heat of fluid (Cp)= 0.464 BTU/lb/F°=1942.6 J/kg K
Heat lost (Qr) =(m* cp*ΔT)/t= ρ *Q*co*ΔT= 3236.37 watt= 4.3 hp

INLET-TEMPERATURE CORRECTION FACTORS					
ETD	30	40	50	60	70
K_t	1.87	1.43	1.17	1.0	0.88

Table 3: Inlet-Temperature Correction Factors

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For ETD=34, Kt= 1.87
For Iso VG 46 Kv = 1.05
Kp = 1.3
Required cooling Qd= (Qr*Kv*Kt)/Kp
Qd = 6.49 hp . Hence, OAW 61-40 is used.

OIL-TYPE CORRECTION FACTORS		
Viscosity class	Cooling-capacity factor, K_v	Pressure-drop factor, K_p
ISO VG 22	0.95	0.9
ISO VG 32	1.0	1.0
ISO VG 46	1.05	1.3
ISO VG 68	1.2	1.7
ISO VG 100	1.35	2.2
ISO VG 150	1.6	3.0
ISO VG 220	1.9	4.3

Table 4: Oil-Type Correction Factors

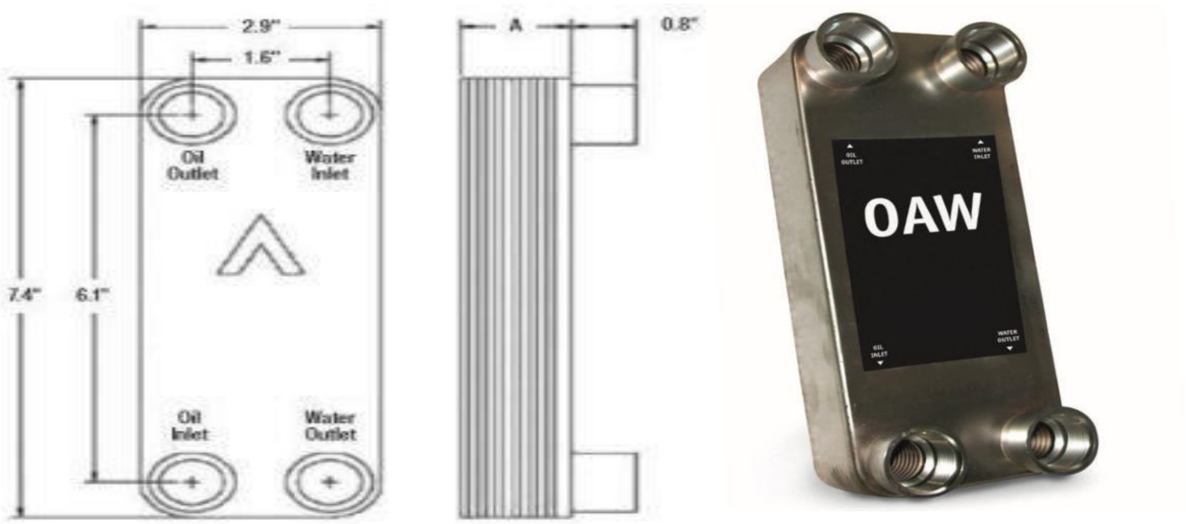
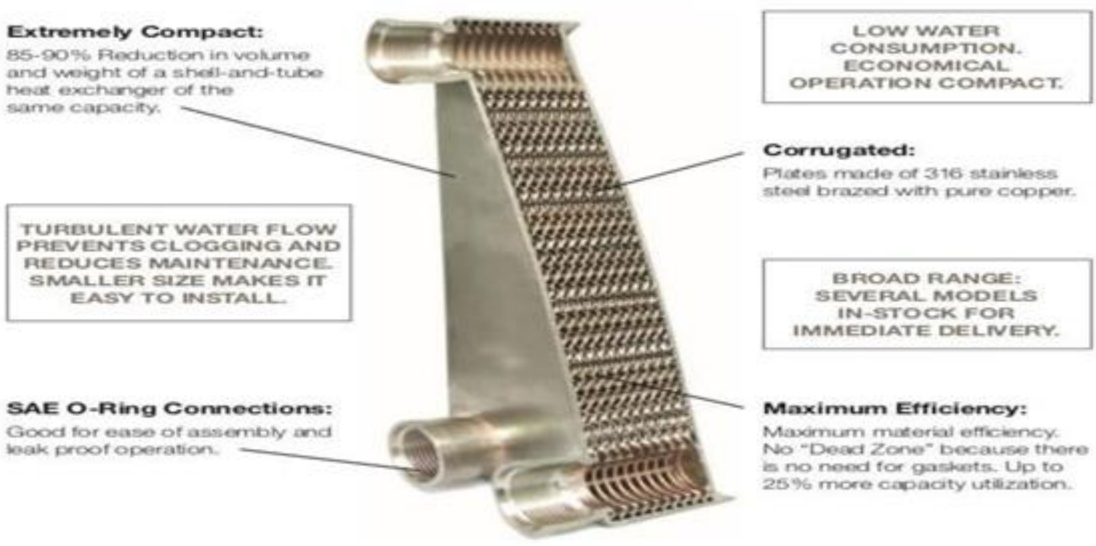
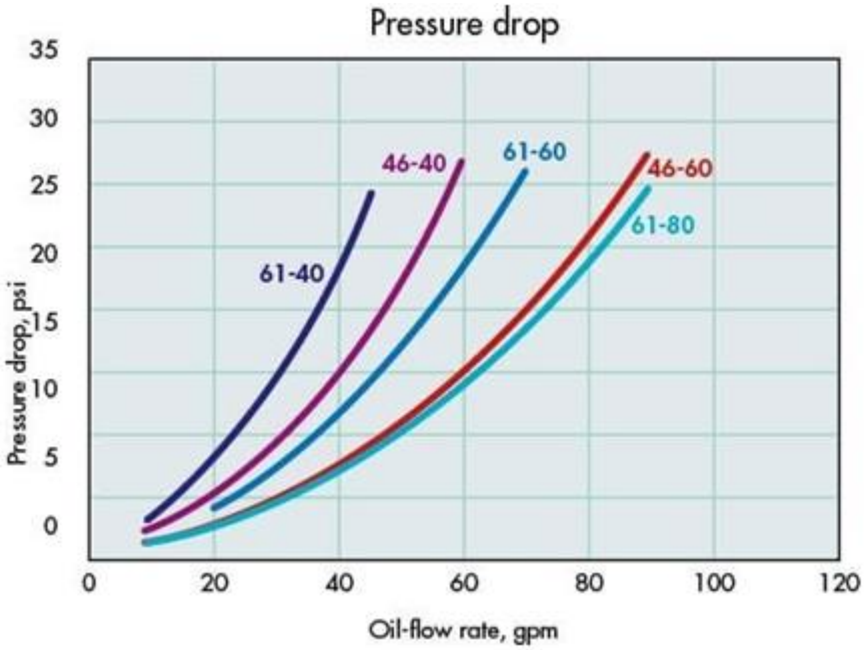
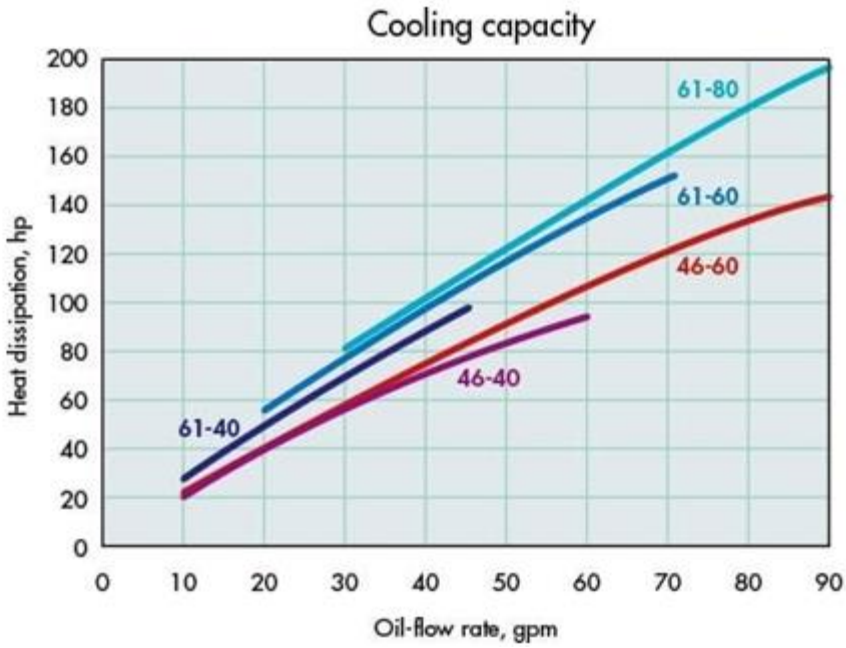


Figure 3: Hydraulic Oil Cooler





(A)



(B)

Figure 4: Hydraulic cooler **(A)** Pressure drop**; (B)** Cooling Capacity

Hence the dimension of Reservoir taken are 400 * 350* 45.

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CHAPTER THREE
HYDRAULIC CIRCUIT DESIGN

The hydraulic circuit is designed with the following emergency and fringe control modules.

- **Condition 1:**

Emergency Stop and Return to home (Manual and Automatic):

This condition is applied whenever an emergency is detected. i.e., if a person wants to come out of the theatre or gaming arena due to medical emergency, etc. the stop button can be pushed which stops and return the dynamic chair to home position immediately to help evacuate the occupants in case of emergency. This button can be provided in two or more positions for enhanced safety of the dynamic system. It is also provided with a reset switch to reset the emergency state. In addition to this there are pressure reducing valves that are used to sense pressure If the pressure in the systems drops beyond a certain value, the cylinder pistons go to home positions and rests on the frame

- **Condition 2:**

Over-Load Restriction Module:

This module helps in preventing the starting of the system if the load on the system is more than the designed load. The load sensor will actuate the relay and the relays contact is connected with the start module.

- **Force measuring sensor:**

The force sensor is used to sense the critical operating force (i.e.) to sense if the person is present on the seat or not and also sensing if the persons weight is beyond operating loads. The mass of the system along with the chair and person is limited to 200kg. hence the purpose of measuring the operating force is to break the circuit when the load is greater than the 200 kg, otherwise the cylinder rod may buckle. And also added to that there must sensing element that the person is sitting in the seat, which is also can be used to start the circuit when start push button is pressed

Here piezoelectric force measuring sensor, is used to measure the force in one direction (i.e.) z-direction (modal: 1 component force sensor 9001A).

- **Condition 3:**

Start module:

This is used to make all the actuators to be positioned at 50 % of its stroke length. This is required for safe operating of the system. While the actuators are in 50 % of its stroke length. it is safe to operate the system with various kind of movements. When the power switch is on all the cylinders will be actuated to the position 50% of its stroke length. Proximity sensors are used to sense the positions

HYDRAULIC COOLER SELECTION:

Hydraulic oil cooler is used to reduce the temperature of the working fluid to the required temperature thereby maintaining the fluid properties. For this dynamic seat movement application, the oil cooler is must as the actuations are fluctuating in a very short interval and this dynamic motion creates a huge amount of heat in the working oil. Here a water-cooled hydraulic cooler is used, as air cooled hydraulic cooler produces lot of noise. The working principle is same as radiator principle. Chilled water is flowed in one tube and the heated hydraulic oil is flowed in the tube adjacent to the water flowing tube Due to the temperature difference, in order to maintain thermal equilibrium in the system the heat from the oil is dissipated to water. Thus, the temperature of the oil is reduced for the application, the selection of cooler is based on the flow rate of the system. The hydraulic cooler can be placed either before sending the fluid to the working ports from the tank or it can be placed before the fluid enters to the tank.

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CHAPTER FOUR
STRUCTURAL DESIGN AND ANALYSIS

The structural design consists of the following elements

- Chair
- Seat plate
- Clevis joints
- Cylinders for tilting motion
- Cinders for sliding motion
- Frame

- **CHAIR:**

The structure was designed based on anthropometric data of Indian population. The height of the chair from the ground was chosen based on 95 percentile Indian male's knee to feet length. The chair seating dimensions were also obtained for a 95th percentile Indian.

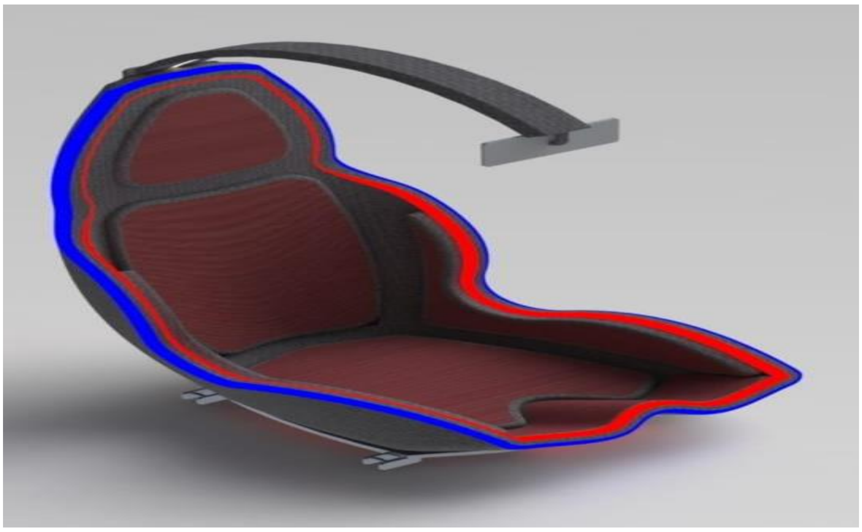

Figure 5: Ergonomically Designed chair

- **SEAT PLATE AND CLEVIS JOINTS:**

The chair so designed was coupled to the seat plate by means of M12 nuts. This seat plate acts as the interface between joints and the chair. The clevis joints selected are coupled to the cylinder's piston rod using the threads provided to provide it the desired motion.

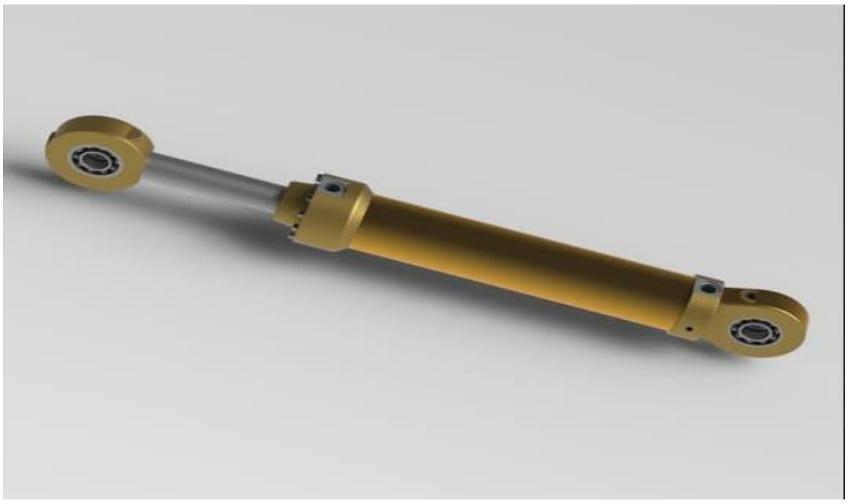

Figure 6: Hydraulic piston

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- **FRAME:**

The frame is made using several steel plates welded together. The frame is designed to carry the entire load of the chair, seat plate and the person. There are provisions made in the frame to place DCV's at the bottom and also cooling arrangements are provided for the solenoid controlled DCV by means of mounting a fan on the frame. There are bosses provided on the frame on which the cylinders can be seated and the cylinders are clamped by means of C- Clamps. The frame also has to provide translation degree of freedom for which a guideway is created at the bottom of the frame. In order to prevent the awkward visibility of the hoses, electrical cables and DCV's, a plastic acrylic cover is provided which can be screwed to the frame. This cover also provides safety to the gamer during gaming experience by concealing the electrical and hydraulic elements.

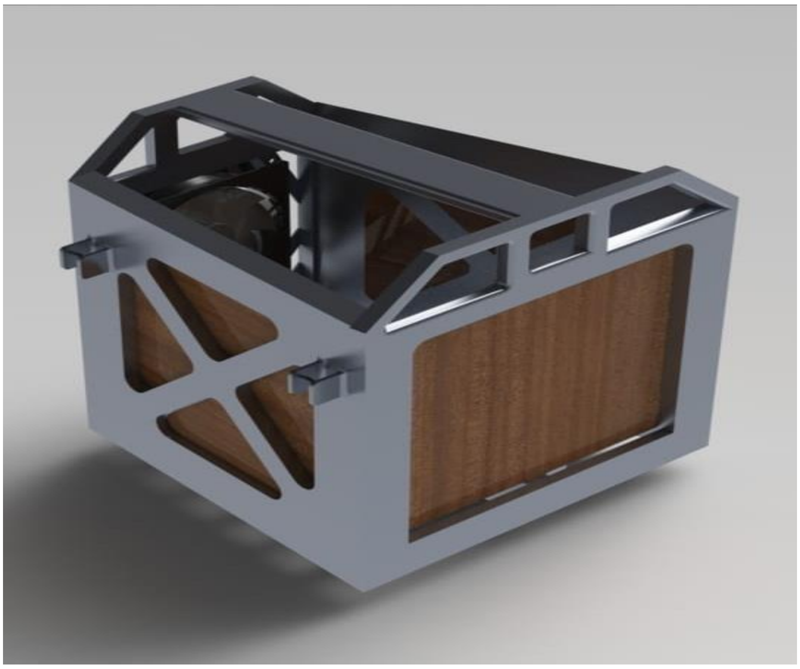
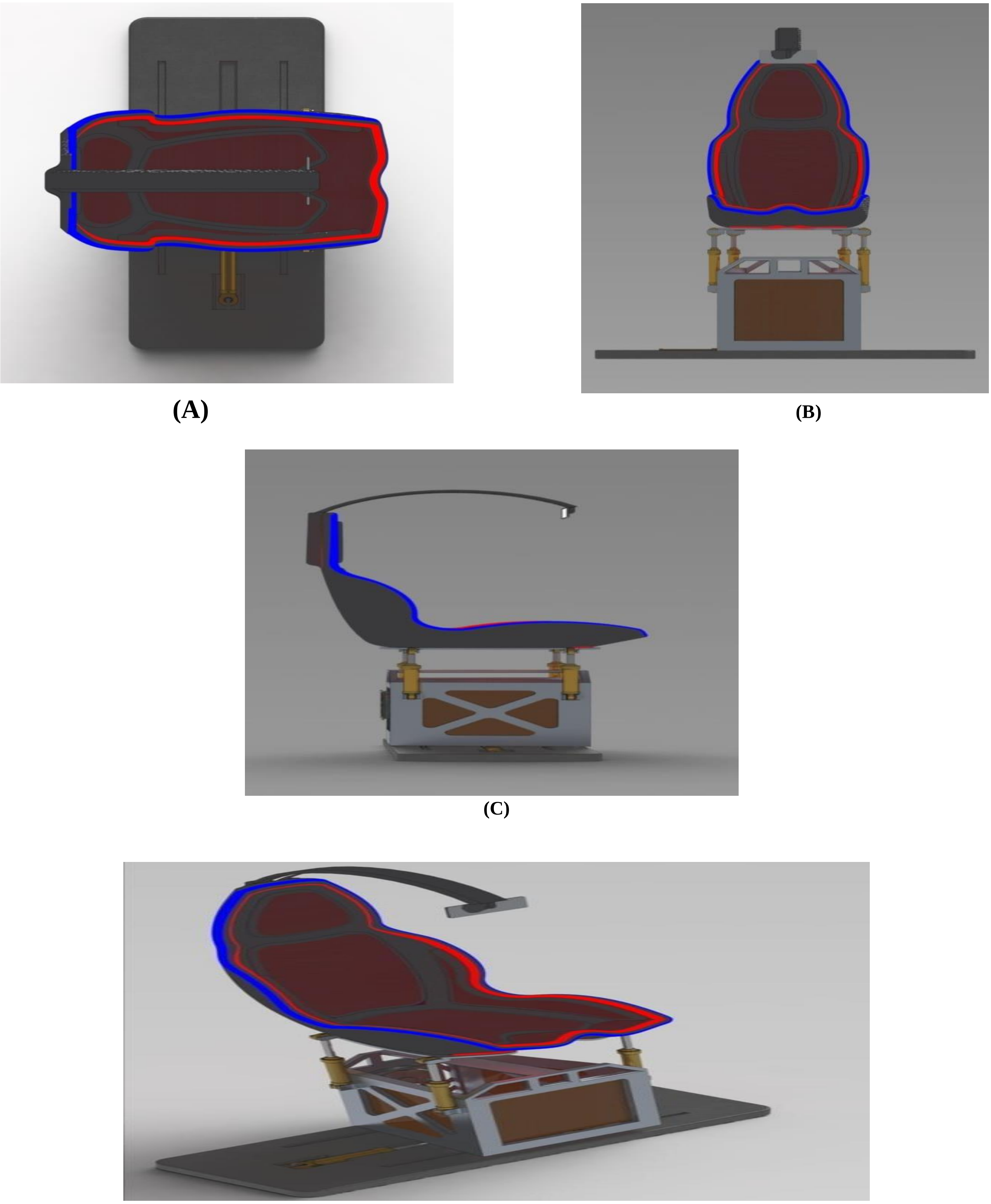


Figure 7: Design of Frame

- **BASE:**

The base is made of cast iron and is mounted firmly on the ground using concrete foundation. The base has the slot in which the guideway of the frame moves. Rollers are used to reduce friction and hence facilitate easy translation of the frame. The translation cylinder is mounted onto the base using C- clamps. The Cylinder is coupled to the frame using slots and fasteners.

Figure 8: Base of Gaming Platform



(A) **(B)**

(C)

(D)

Figure 9: Final Assembly: (A) Top View, (B) Front View, (C) Side view, (D) Isometric View

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CHAPTER FIVE
CAE ANALYSIS

Computer-aided engineering (**CAE**) is the broad usage of computer software to aid in engineering analysis tasks. It includes finite element analysis (FEA), computational fluid dynamics (CFD), multibody dynamics (MBD), durability and optimization.

Finite element method (**FEM**): It is the most widely used method for solving problems of engineering and mathematical models. Typical problem areas of interest include the traditional fields of structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The FEM is a particular numerical method for solving partial differential equations in two or three space variables (i.e., some boundary value problems). To solve a problem, the FEM subdivides a large system into smaller, simpler parts that are called **finite elements**. This is achieved by a particular space discretization in the space dimensions, which is implemented by the construction of a mesh of the object: the numerical domain for the solution, which has a finite number of points. The finite element method formulation of a boundary value problem finally results in a system of algebraic equations. The method approximates the unknown function over the domain.[1] The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. The FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

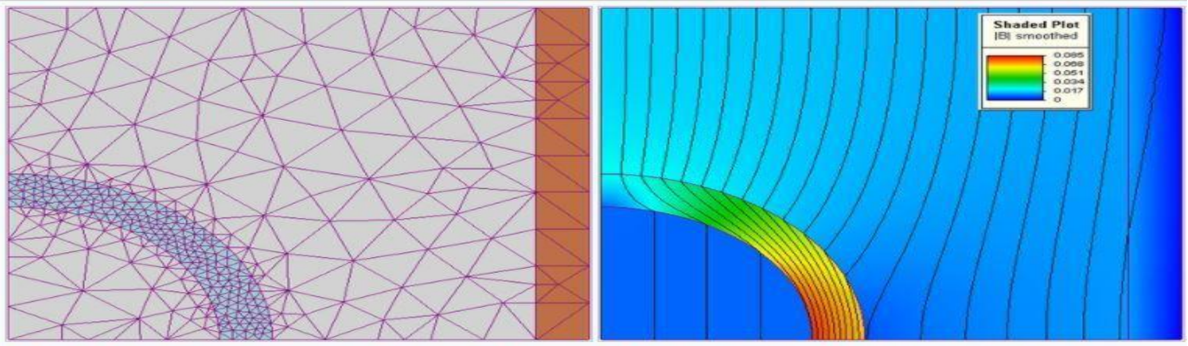
Ansys: Ansys Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analyzing strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

CHAPTER SIX
BASIC STEPS OF THE FINITE ELEMENT METHOD

As stated in the introduction, the finite element method is a numerical procedure for obtaining solutions to boundary-value problems. The principle of the method is to replace an entire continuous domain by a number of subdomains in which the unknown function is represented by simple interpolation functions with unknown coefficients. Thus, the original boundary-value problem with a finite number of degrees of freedom is converted into a problem with a finite number of degrees of freedom, or in other words, the solution of the whole system is approximated by a finite number of unknown coefficients. Therefore, a finite element analysis of a boundary-value problem should include the following basic steps:

1. Discretization or subdivision of the domain
2. Selection of the interpolation functions (to provide an approximation of the unknown solution within an element)
3. Formulation of the system of equations (also the major step in FEM. The typical Ritz variational and Galerkin methods can be used.)
4. Solution of the system of equations (Once we have solved the system of equations, we can then compute the desired parameters and display the result in form of curves, plots, or colour pictures, which are more meaningful and interpretable.)

Figure 10 to 28 contains FEM analysis of different parts of the Gaming Platform



FEM mesh created by an analyst prior to finding a solution to a magnetic problem using FEM software. Colors indicate that the analyst has set material properties for each zone, in this case, a conducting wire coil in orange; a ferromagnetic component (perhaps iron) in light blue; and air in grey. Although the geometry may seem simple, it would be very challenging to calculate the magnetic field for this setup without FEM software, using equations alone.

FEM solution to the problem at left, involving a cylindrically shaped magnetic shield. The ferromagnetic cylindrical part is shielding the area inside the cylinder by diverting the magnetic field created by the coil (rectangular area on the right). The color represents the amplitude of the magnetic flux density, as indicated by the scale in the inset legend, red being high amplitude. The area inside the cylinder is the low amplitude (dark blue, with widely spaced lines of magnetic flux), which suggests that the shield is performing as it was designed to.

Seat Plate:

ANALYSIS TYPE	Static structural
SOLVER	ANSYS mechanical APDL solver
MATERIAL	1006 Steel AISI
DENSITY	7872 kg/ cubic m
TENSILE YIELD STRENGTH	285 MPA
ULTIMATE TENSILE STRENGTH	330 MPa
YOUNGS MODULUS	205 GPa
POISSON RATIO BULK MODULUS	0.30
SHEAR MODULUS	76 GPa
BULK MODULUS	166 GPa

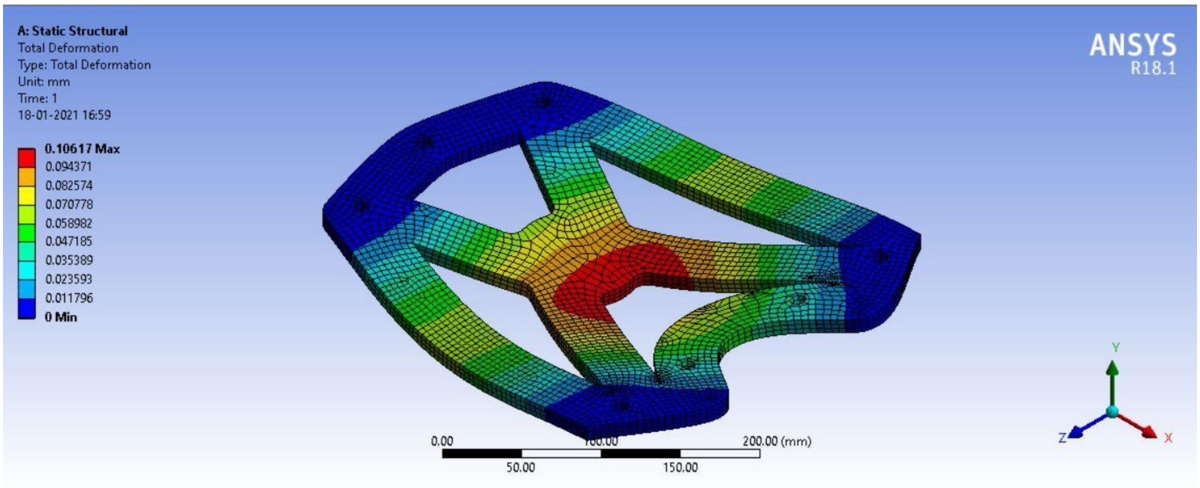


Figure 10: Total Deformation of Plate upon load

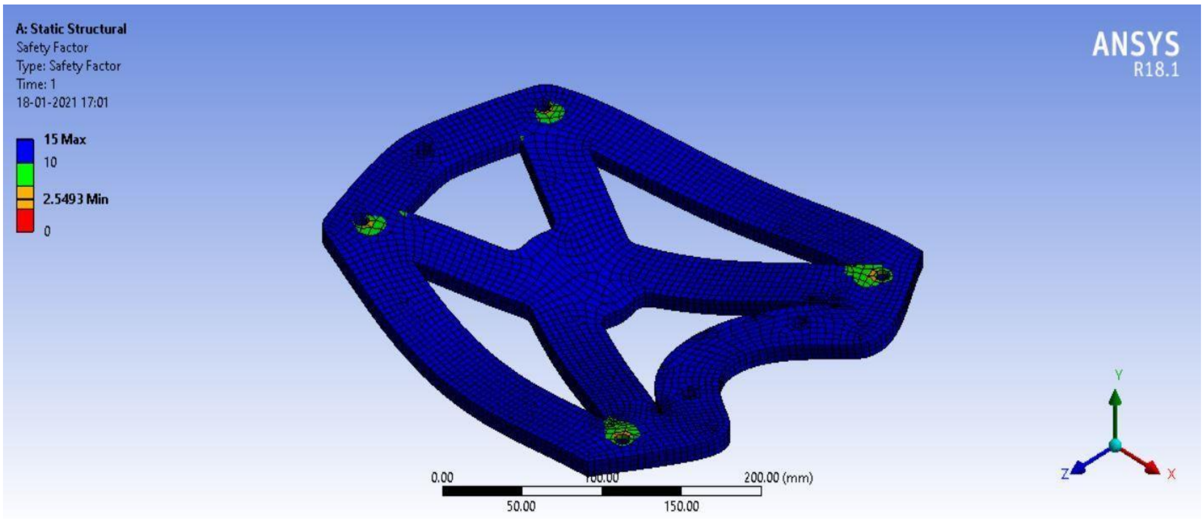


Figure 11: Safety Factor upon load

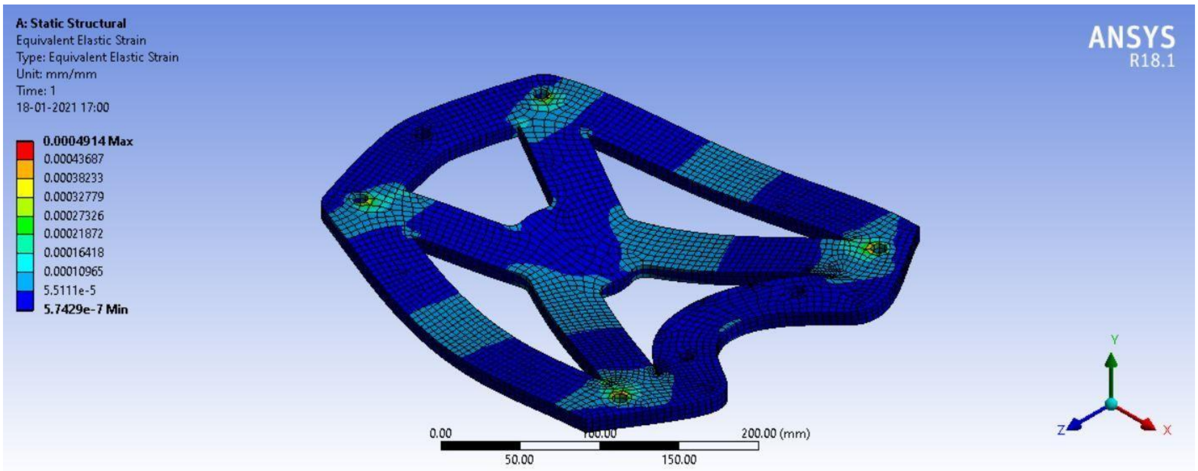


Figure 12: Equivalent Strain

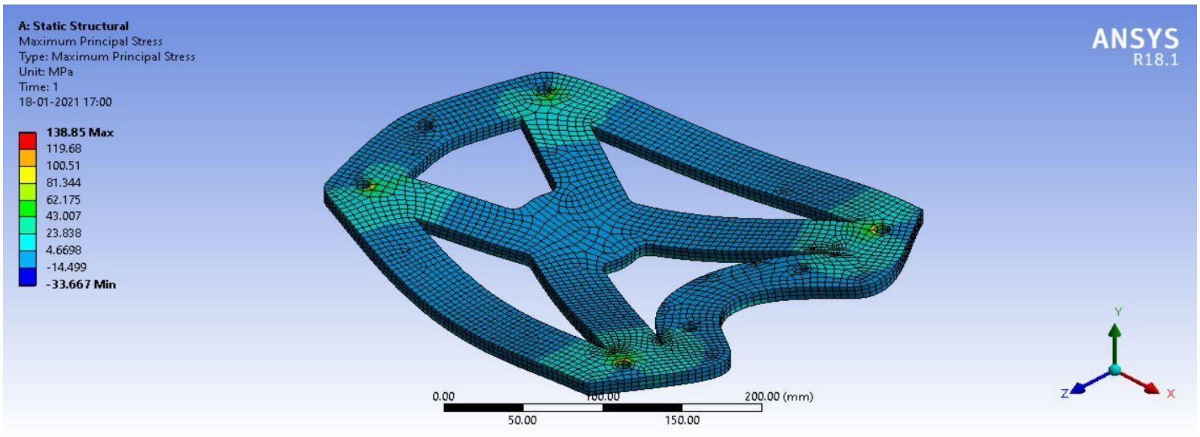


Figure 13: Maximum Principle Stress

LOAD APPLIED	2310 N
MAX STRESS	138.85 Mpa
MAX STRAIN MAX	0.0004
DEFORMATION	0.106 mm

It is seen that the deformation and stress induced is in the permissible ranges and the factor of safety is found to be

FOS= 285/138.85 = 2.05

Thus, the seat plate's material selection of AISI 1006 steel is justified.

Piston Rod:

ANALYSIS TYPE	Static structural
SOLVER	ANSYS mechanical APDL solver
MATERIAL	1006 Steel AISI
DENSITY	7872 kg/ cubic m
TENSILE YIELD STRENGTH	285 mpA
ULTIMATE TENSILE STRENGTH	330 MPa
YOUNGS MODULUS	205 GPa
POISSON RATIO BULK MODULUS	0.30
SHEAR MODULUS	76 GPa
BULK MODULUS	166 GPa

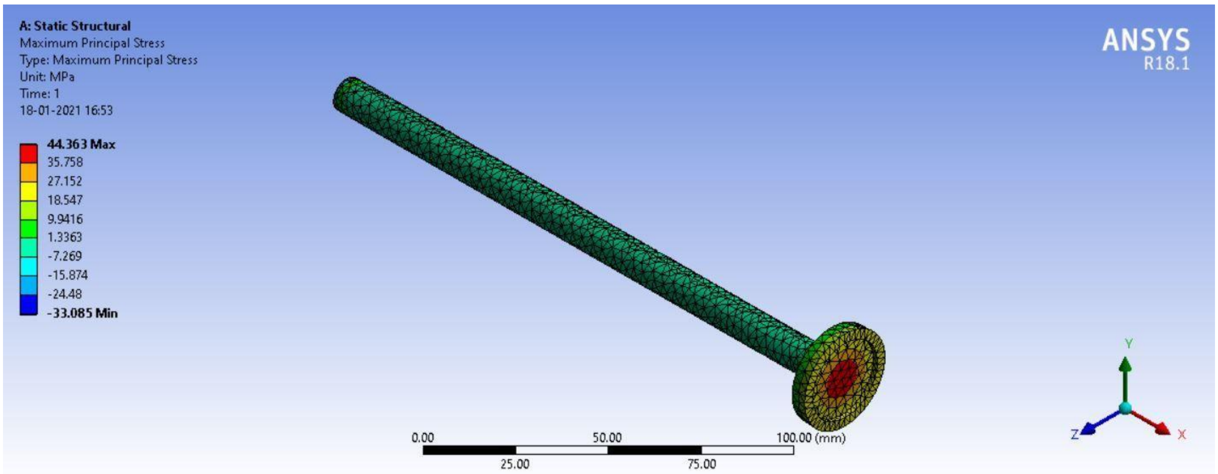


Figure 14: Maximum Principal Stress

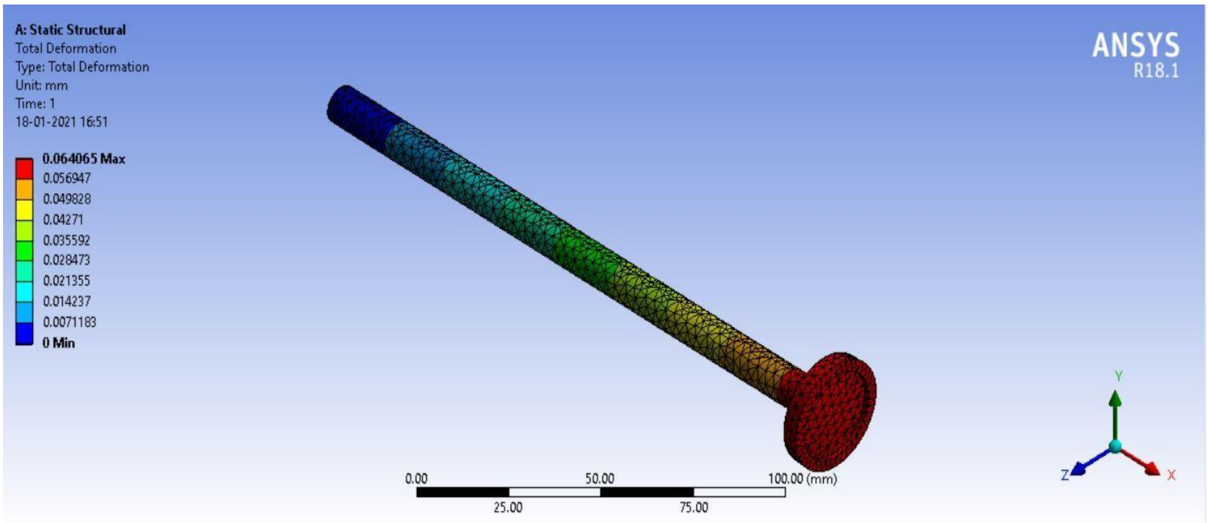


Figure 15: Total Deformation

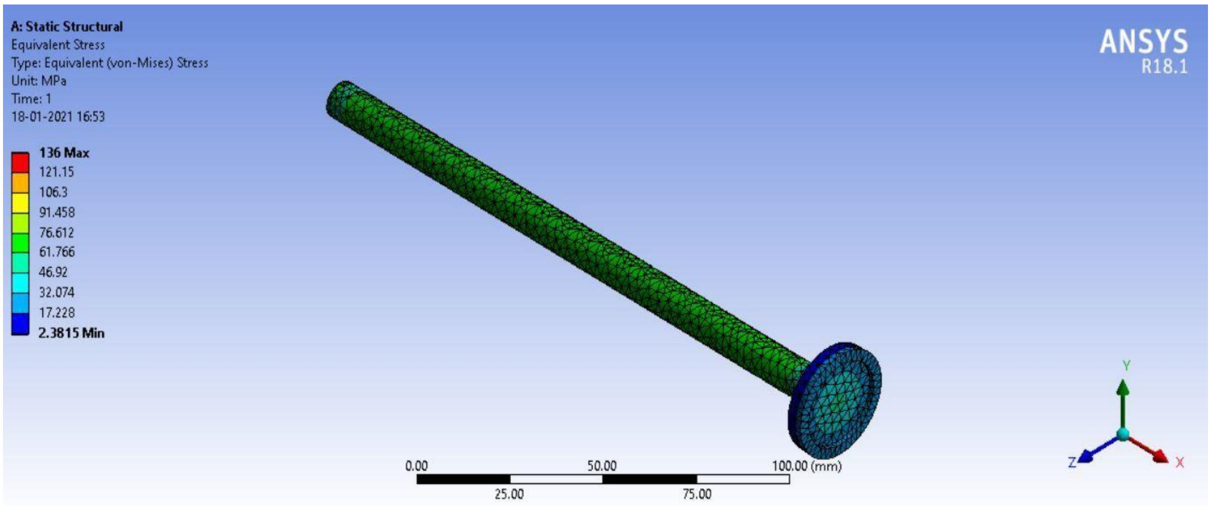


Figure 16: Equivalent (Von-Mises) Stress

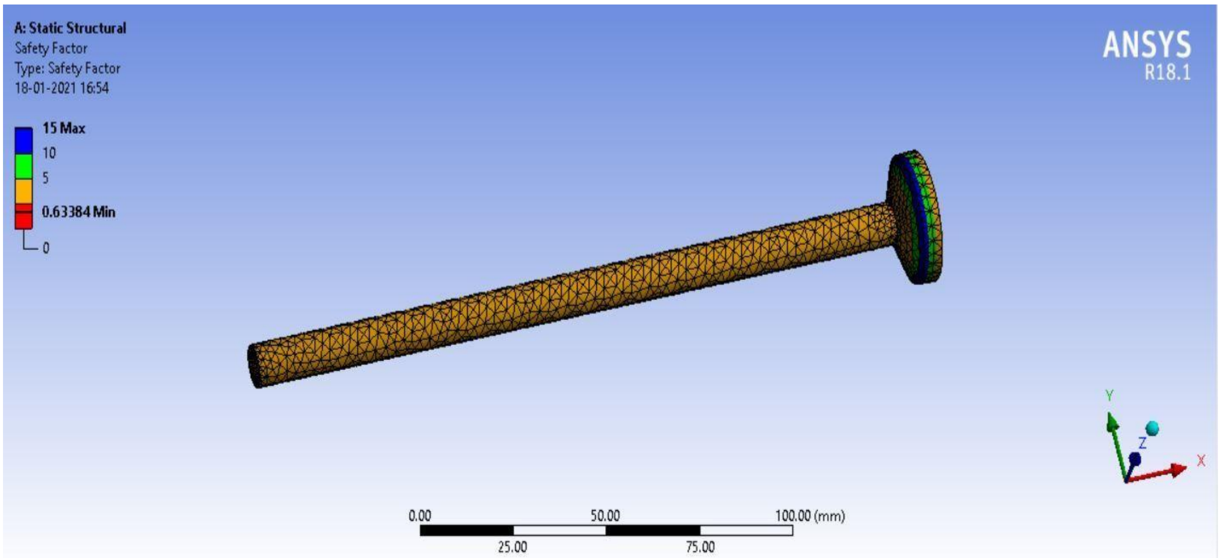


Figure 17: Safety Factor

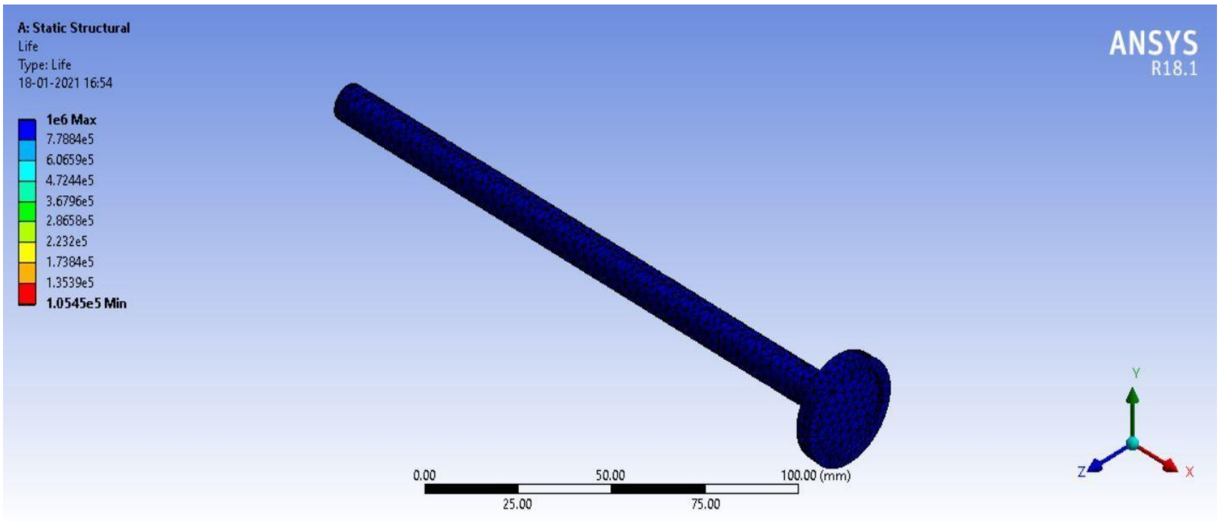


Figure 18: Life

LOAD	600 N
PRESSURE AT PISTON END	3.4 MPa
MAX STRESS	44.3 MPa
LIFE DUE TO CYCLIC LOAD MIN SAFETY FACTOR	0.63
LIFE	1e6 or infinite

It is seen that the deformation and stress induced is in the permissible ranges. For fluctuating stress cycle the life seems to be infinite since the stress induced is less than endurance strength of the maternal. Also, the buckling deformation is in the permissible limits.

Thus, the piston's material selection of AISI 1006 steel and rod diameter of 10mm is justified.

Frame:

ANALYSIS TYPE	Static structural, Modal Analysis
SOLVER	ANSYS mechanical APDL solver
MATERIAL	1006 Steel AISI
DENSITY	7872 kg/ cubic m
TENSILE YIELD STRENGTH	285 mpA
ULTIMATE TENSILE STRENGTH	330 MPa
YOUNGS MODULUS	205 GPa
POISSON RATIO BULK MODULUS	0.30
SHEAR MODULUS	76 GPa
BULK MODULUS	166 GPa

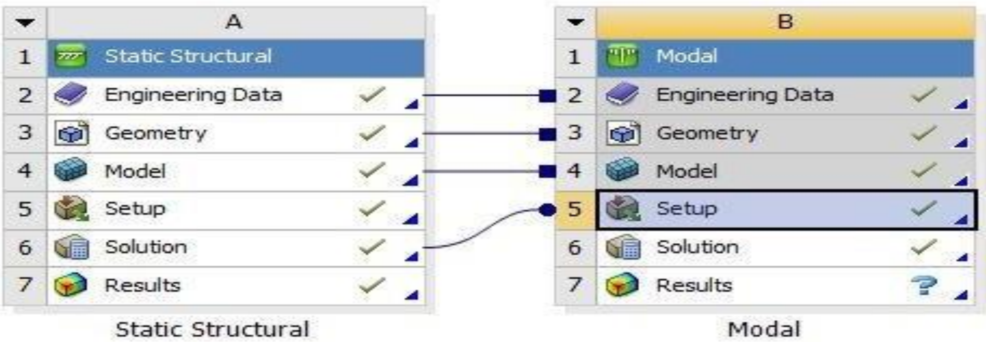


Figure 19: Project Schematics

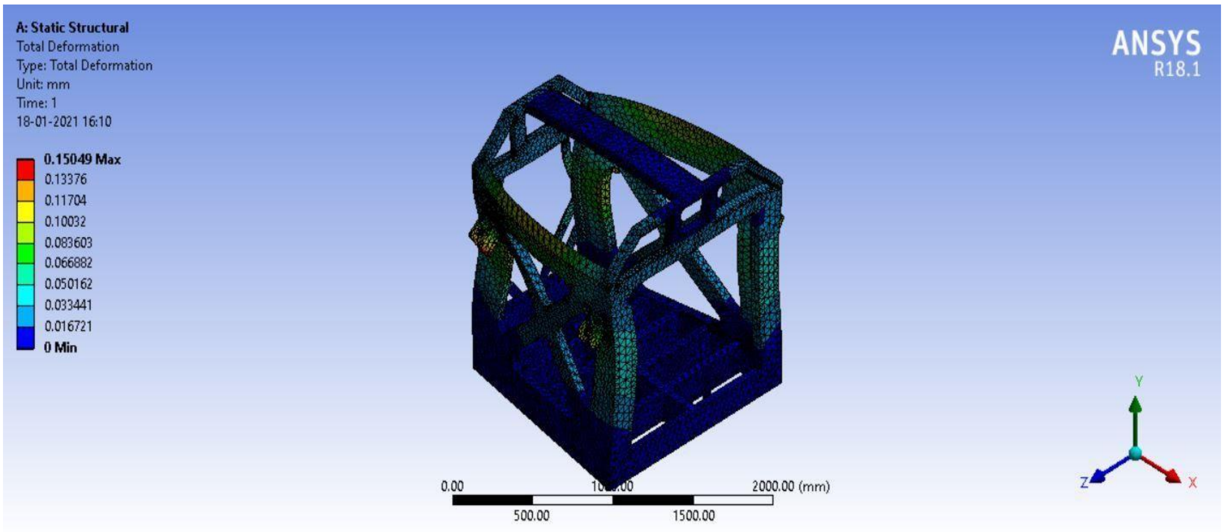


Figure 20: Total Deformation

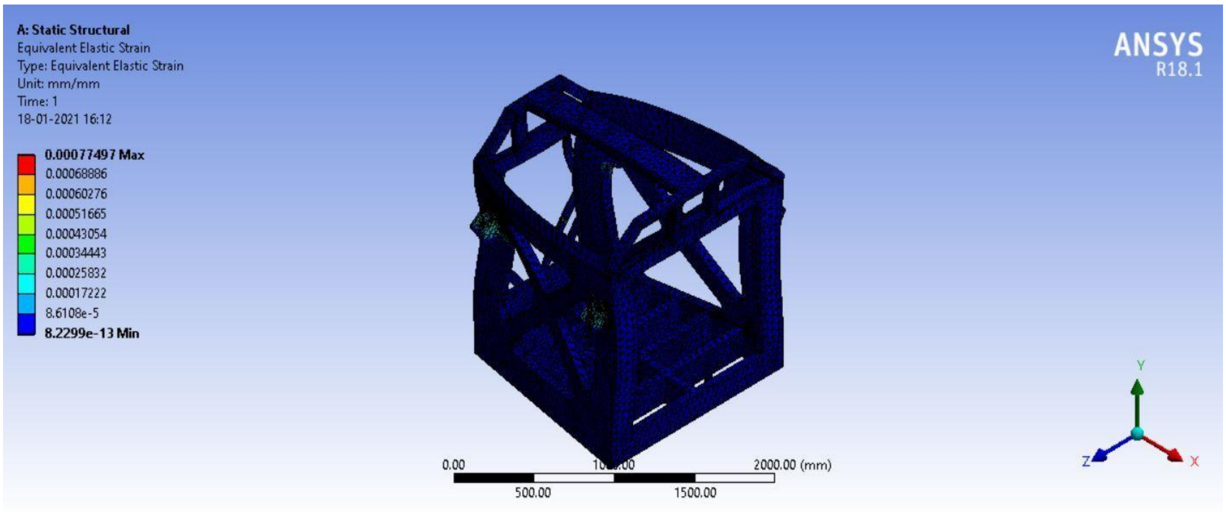


Figure 21: Equivalent Elastic Strain

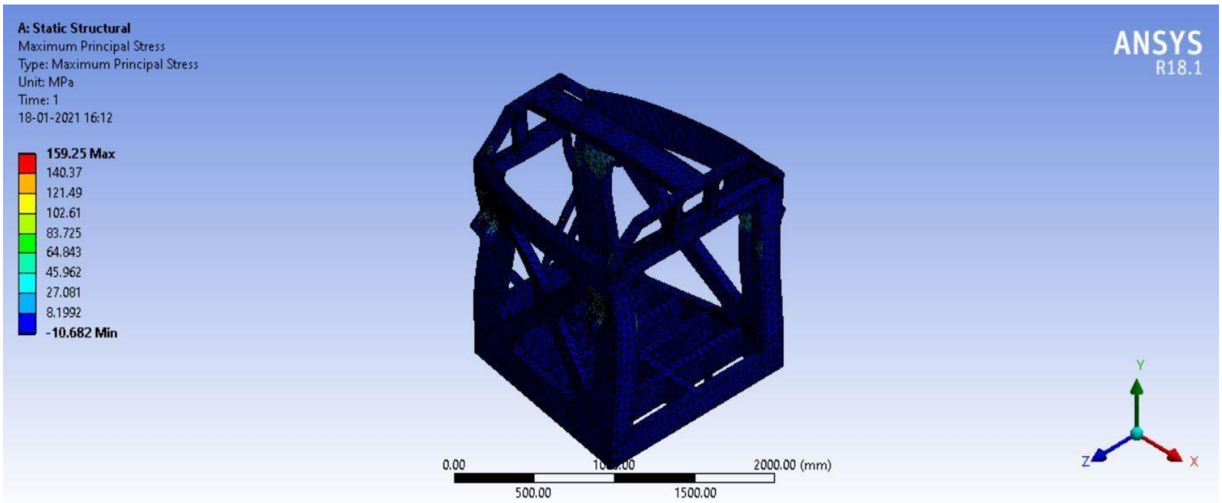


Figure 22: Maximum Principal Stress

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Modal Analysis:

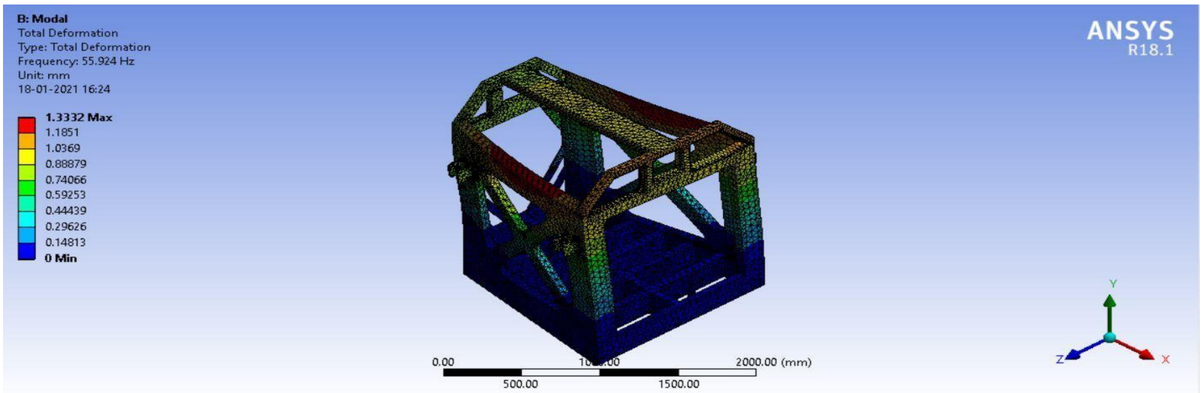

Figure 23: Total Deformation of First Mode Shape at 55.92 Hz

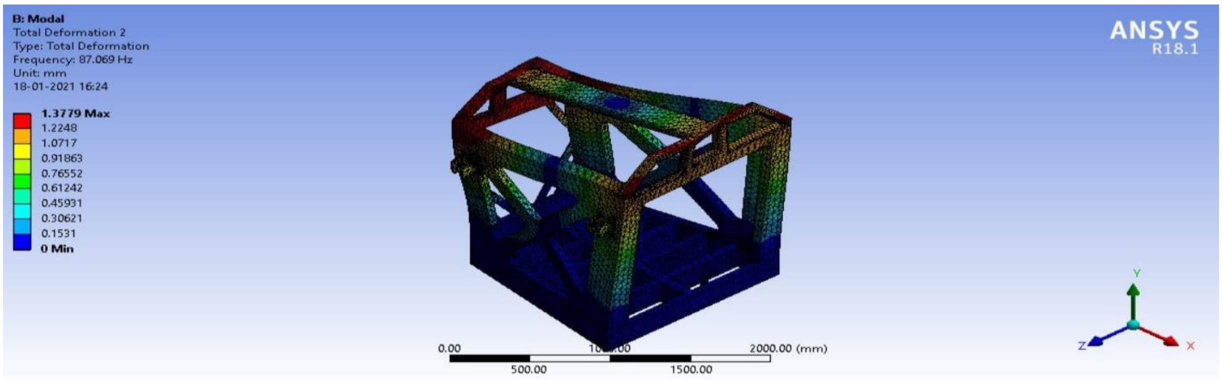

Figure 24: Total Deformation of First Mode Shape at 87.06 Hz

LOAD APPLIED	3000 N
MAX STRESS	159 MPa
MAX STRAIN	0.0007
DEFORMATION	0.15 mm

It is seen that the deformation and stress induced is in the permissible ranges and the factor of safety is found to be

FOS= 285/159 = 1.7

This is acceptable due to the fact that during motion of the chair, the person moves and center of mass shifts and this high factor of safety can account for this shift. Thus, the frame's material selection of AISI 1006 steel is justified.

Clevis Joint:

ANALYSIS TYPE	Static structural, Modal Analysis
SOLVER	ANSYS mechanical APDL solver
MATERIAL	1006 Steel AISI
DENSITY	7872 kg/ cubic m
TENSILE YIELD STRENGTH	285 mpA
ULTIMATE TENSILE STRENGTH	330 MPa
YOUNGS MODULUS	205 GPa
POISSON RATIO BULK MODULUS	0.30
SHEAR MODULUS	76 GPa
BULK MODULUS	166 GPa

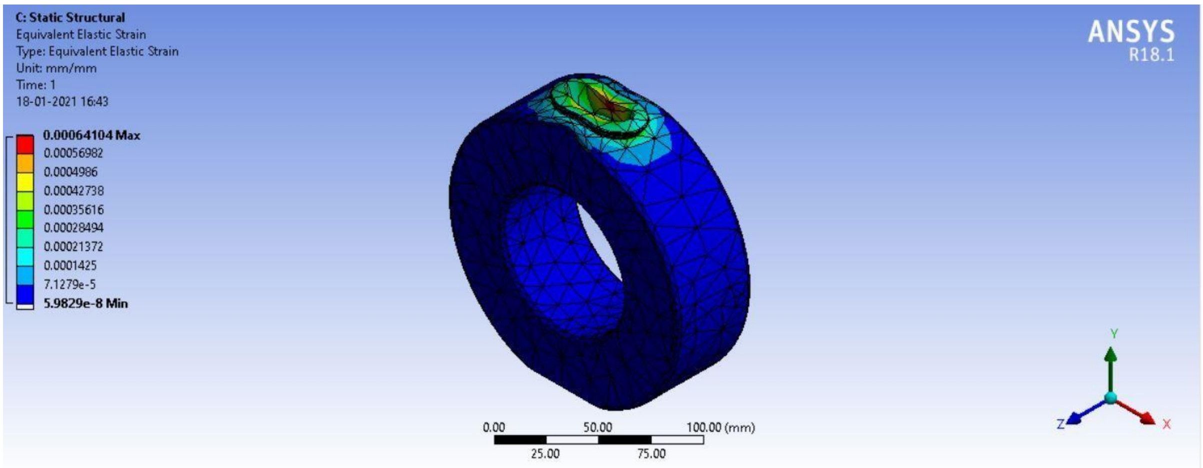

Figure 25: Equivalent Elastic Strain

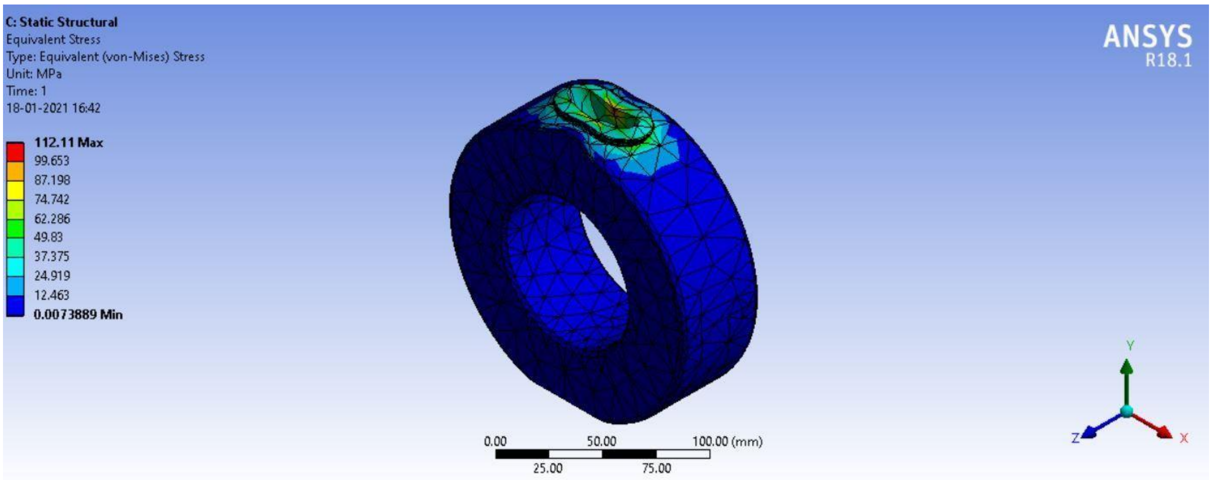

Figure 26: Von-Mises Stress

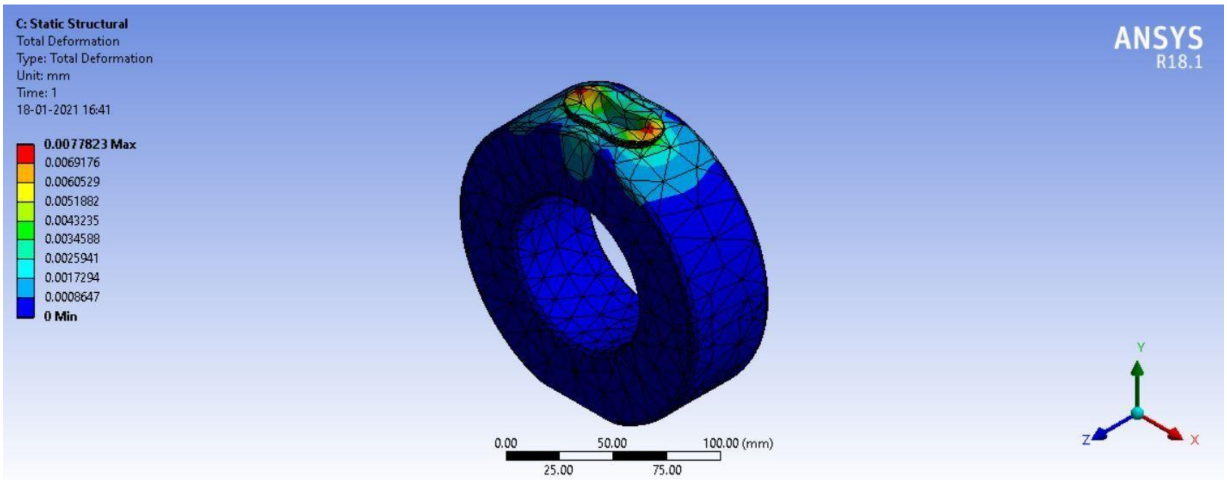

Figure 27: Total Deformation

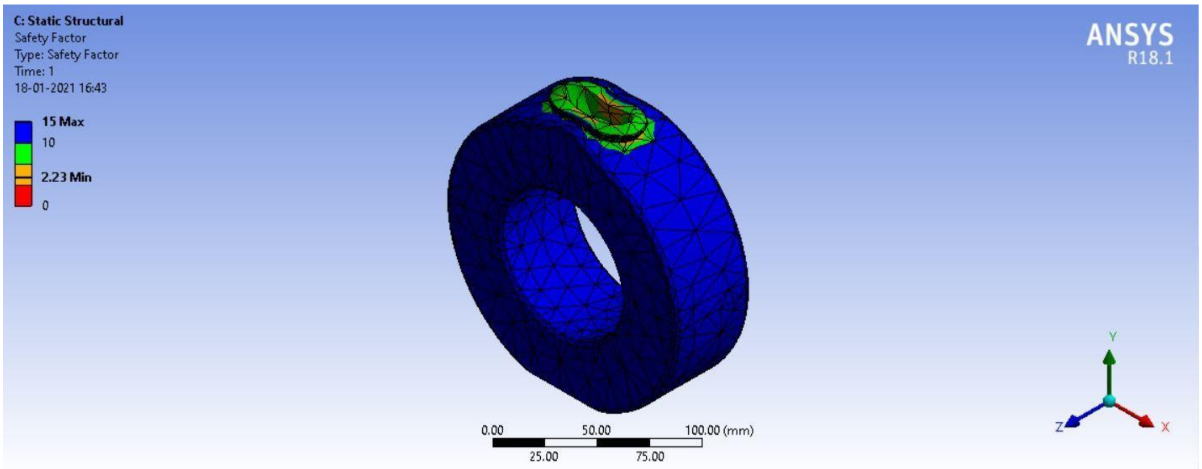

Figure 28: Safety Factor

LOAD APPLIED	1000 N
MAX STRESS	112.11 MPa
MAX STRAIN	0.0006
DEFORMATION	0.007 mm

It is seen that the deformation and stress induced is in the permissible ranges and the factor of safety is found to be

FOS= 285/112.11 = 2.54

Thus, the frame's material selection of AISI 1006 steel is justified.

CHAPTER SEVEN
OPERATIONS INVOLVED IN FABRICATION:

- Cold drawn AISI 1006 steel is to be purchased in standard sheet sizes of 15 and 20mm
- The sheets are to be cut in required sizes using power saws. Holes are to be drilled and reamed as per tolerances specified in drawing
- The assembly of sheets is to be welded using TIG welding to obtain the structure shown in drawing.
- The slideway is to be machined using end mill cutter to obtain the tolerances specified in the drawing and screwed to the frame.
- The base is to be cast, machined using end milling operation to get specified tolerances and laid on the floor using foundation bolts.
- The assembly is to be completed by using fasteners and clamps to fit the fan, cylinders, DCV's, chair, clevis joints and seat plate.

CHAPTER EIGHTH
MATERIAL SELECTION:

The properties of the materials used are:

1. **Cast Iron:** Cast iron is a group of iron-carbon alloys with a carbon content more than 2%. The alloy constituents affect its colour when fractured: white cast iron has carbide impurities which allow cracks to pass straight through, grey cast iron has graphite flakes which deflect a passing crack and initiate countless new cracks as the material breaks, and ductile cast iron has spherical graphite "nodules" which stop the crack from further progressing. Carbon (C) ranging from 1.8 to 4 wt%, and silicon (Si) 1– 3 wt%, are the main alloying elements of cast iron. Iron alloys with lower carbon content are known as steel.

Features:

a) Cast iron tends to be brittle, except for malleable cast irons.
b) It has relatively low melting point
c) Good fluidity
d) Good castability
e) Excellent machinability
f) Resistance to deformation and wear resistance.

Properties	Grey	CGI	Ductile
Tensile Strength (MPa)	**250**	**450**	**750**
Young's Modulus (GPa)	**105**	**145**	**160**
Fatigue Resistance (MPa)	**110**	**200**	**250**
Heat Conductivity (W/(mk))	**48**	**37**	**28**
Hardness (HB)	**179-202**	**217-241**	**217-255**
Relative Damping Capacity	**1.0**	**0.35**	**0.22**

Table 5: Mechanical Properties of Cast Iron

2. **AISI 1006 Steel:** Steels containing mainly carbon as the alloying element are called carbon steels. They contain about 0.4% silicon and 1.2% manganese. Chromium, nickel, aluminium, copper and molybdenum are also present in small quantities in the carbon steels. Structural steel is a category of steel used for making construction materials in a variety of shapes. Many structural steel shapes take the form of an elongated beam having a profile of a specific cross section. Structural steel shapes, sizes, chemical composition, mechanical properties such as strengths, storage practices, etc., are regulated by standards in most industrialized countries.

Features:

a) The carbon steel is soft

b) It is ductile

Properties	Metric	Imperial
Tensile strength	330 MPa	47900 psi
Yield strength (depending on temper)	285 MPa	41300 psi
Elastic modulus	190-210 GPa	27557-30458 ksi
Bulk modulus (typical for steel)	140 GPa	20300 ksi
Shear modulus (typical for steel)	80.0 GPa	11600 ksi
Poisson's ratio	0.27-0.30	0.27-0.30
Elongation at break (in 50 mm)	20%	20%
Reduction of area	45%	45%
Hardness, Brinell	95	95
Hardness, Knoop (converted from Brinell hardness)	113	113
Hardness, Rockwell B (converted from Brinell hardness)	55	55
Hardness, Vickers (converted from Brinell hardness)	98	98
Machinability (based on AISI 1212 steel as 100 machinability) The machinability of group I bar, rod, and wire products can be improved by cold drawing)	50	50

Table 6: Mechanical properties of AISI 1006 Steel

3. **Mild Steel:** Mild steel is a type of carbon steel with a low amount of carbon, also known as "low carbon steel.". The amount of carbon typically found in mild steel is 0.05% to 0.25% by weight, whereas higher carbon steels are typically described as having a carbon content from 0.30% to 2.0%. If any more carbon than that is added, the steel would be classified as cast iron. Mild steel is not an alloy steel and therefore does not contain large amounts of other elements besides iron. Since its carbon and alloying element content are relatively low, there are several properties it has that differentiate it from higher carbon and alloy steels.

Features:

a) Mild steel is typically more ductile.

b) It is machinable and weldable.

c) It is nearly impossible to harden and strengthen mild steel through heating and quenching.

Properties	Metric	Imperial
Tensile strength	440 MPa	63800 psi
Yield strength	370 MPa	53700 psi
Modulus of elasticity	205 GPa	29700 ksi
Shear modulus (typical for steel)	80 GPa	11600 ksi
Poisson's ratio	0.29	0.29
Elongation at break (in 50 mm)	15%	15%
Hardness, Brinell	126	126
Hardness, Knoop (converted from Brinell hardness)	145	145
Hardness, Rockwell B (converted from Brinell hardness)	71	71
Hardness, Vickers (converted from Brinell hardness)	131	131
Machinability (based on AISI 1212 steel. as 100 machinability)	70	70

Table 7: Mechanical Properties of Mild Steel

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CHAPTER NINE
COST ANALYSIS

S. No.	Item Name	Number of Pieces/kg	Unit Cost/per kg (or piece) in Rs.	Total Cost in Rs.
1.	Hydraulic Cylinder	5	2500	12500
2.	C-clamps	8	10	80
3.	Motor Pump	1	4300	4300
4.	L - Clamp	4	15	60
5.	Hose pipe (0.5 inch)	5 meters	175	875
6.	Material Cost	-	-	4000
7.	Air cooler	1	5500	5500
8.	Seat	1	2500	2500
9.	Pressure Control Valve	1	1500	1500
10.	Clevis joint	4	150	600
11.	Arduino Mega	1	900	900
12.	Fly sky Transmitter	1	4500	4500
13.	Relay Module	5	200	1000
14.	Miscellaneous (M12 nuts, welding cost, jumper wires etc.)	-	-	2500
			Total – Rs. 40, 815	

Table 8: Cost Report of the project

CHAPTER TEN
CONTROL SYSTEM

The development of a control algorithm and design of the control circuit, in based on the requirements specified by the problem statement. The proposed application of the 4 DoF Chair is in the Entertainment Industry, to simulate the experience of a visual stimulus. This can be further specified as simulation for either a pre- recorded or a real-time environment. The test one generally makes use of a video- based on which the response is programmed. In the second variant the response is dependent on a dynamic input and therefore, it is to be flexible to a higher degree. The mechanical design makes allowances for the response time of human perception to be factored in and thereby the dynamic input and the response will be of same order of time.

➢ DEVELOPMENT OF CONTROL CIRCUITRY FOR PROTOTYPE:

The prototype is a scaled down version of the proposal, capable of responding to a dynamic input from the user

- **<u>COMPONENTS USED</u>**

1. RC Transmitter and Receiver
2. Arduino Mega 2560
3. 8-Channel OC SV Relay Module

1. RC TRANSMITTER AND RECEIVER:

Fly Sky 24GH2 6Ch Tx & Rx is used for this purpose.

2.4 GHz system is an entry transmitter offering the reliability of 2.4GH signal technology and a receiver. The RC receiver is powered by the SV and GND ports in the Arduino Mega

Key Features:

- 6-Channel 2.4GH parameter with servo reversing.
- Easy to use control for basic models.
- Includes 6-channel receiver.
- Trainer system option.
- This system does not need a PC to program servo direction.

Figure 29: RC Transmitter and Receiver

CATEGORY	FEATURE
SKU	FS-i6
Brand	FlySky
Weight (g)	810.00
Length (mm)	240.00
Width (mm)	100.00

Table 9: Technical Specifications of RC Transmitter

2. ARDUINO MEGA 2560

The Arduino Mega is a microcontroller board It served as the heart of our operation It has 54 digital I/O pins, 16 analog pins, 4 universal asynchronous receiver transmitters, a 16 MHz crystal oscillator a USB connection a power and reset button.

Power: The Arduino Mega can be powered by USB connection or via external power supply. The board can operate on an external supply of 6 to 20V. If the supply is less than 7V, the 5V pins may supply less than 5 V and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12V.

Memory: The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library.

Input and Output: Each of the 54 digital pins can be used as I/O and they operate at 5 V. It also has 16 analog pins each of which provides 10 bits of resolution.

Programming: The Arduino Mega can be programmed using the Sketch Arduino IDE.

- **Technical Specification:**

Table 10: Technical Specifications of Arduino Mega 2560

Category	Features
Operating voltage	5V
Microcontroller	ATmega2560
Input Voltage(Range)	6 to 20 V
Current output per I/O pin	20 mA
Clock Speed	16 MHz
Digital pins	54 (15 PWM)
Analog pins	16
Flash memory	256 KB
Ram	4 KB
Length (mm)	101.52
Width (mm)	53.3
Weight (g)	37
Cost (Rs)	1000

- **Specialized Function Pins:**

Serial: Serial 0:0 (RX) and 1 (TX): Serial 1: 19 (RX) and 18 (TX); Serial 2:17 (AX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX). Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega 16U2 USB-to-TTL Serial chip.

External Interrupts: 2 (interrupt 0), 3 (Interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3). and 21 (interrupt 2). These pins can be configured to trigger an interrupt on a low level, a rising or falling edge, or a change in level

PWM: 2 to 13 and 44 to 46. Provide 8-bit PWM output with the analog Write (function SPI. 50 (MISO). 51 (MOSI), 52 (SCK). 53 (SS). These pins support SPI communication using the SP library. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Arduino / Genuino Uno and the old Duemilanove and Diecimla Arduino boards.

LED: 13 There is a bum-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, It's off.

TWI: 20 (SDA) and 21 (SCL). Support TWI communication using the Wire library Note that these pins are not in the same location as the TW pins on the old Duemilanove or Diecimila Arduino boards.

- **Physical Characteristics and Shield Capability:**

The maximum length and width of the Mega 2560 PCB are 4 and 21 inches respectively, with the USB connector and power jack extending beyond the former dimension between digital pins 7 and 8 is 0.16, not an even multiple of the 100-mil spacing of the other. Three screw holes allow the board to be attached to a surface or case. Note that the distance pins The Mega 2560 is designed to be compatible with most shields designed for the Uno and the older Diecimila or Duemilanove Arduino boards Digital pins 0 to 13 (and the adjacent AREF and GND pins analog inputs 0 0 5. the power header and ICSP header are all inequivalent locations.

- **Reason for Selecting Arduino**

It is due to its simple and accessible user experience; Arduino has been used in thousands of different projects and applications. The Arduino software is easy- to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low-cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. Makers, of course, use it to build many of the projects exhibited at the Maker Faire, for example. Arduino is a key tool to learn new things. Anyone

- children, hobbyists, artists, programmers - can start tinkering just following the step-by-step instructions of a kit, or sharing ideas online with other members of the Arduino community.

There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Netmedia's BX-24, Phidgets, MIT's Handyboard, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy- to-use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, students, and interested amateurs over other systems:

- Inexpensive - Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than $50
- Cross-platform - The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.
- Simple, clear programming environment - The Arduino Software (IDE) is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE works.
- Open source and extensible software - The Arduino software is published as open-source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to.
- Open source and extensible hardware - The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

Figure 30: Arduino Mega 2560

3. 8-CHANNEL DC 5V RELAY MODULE:

This is a LOW Level 5 V 8-channel relay interface board, and each channel needs a 15-20 mA driver current. It can be used to control various appliances and equipment with large current It is equipped with high-current relays that work under AC 250 V 10 A or DC 30 V 10 A it has a standard interface that can be controlled directly by microcontroller. This module is optically isolated from high voltage side for safety requirement and also prevent ground loop when interface to microcontroller.

- Relay Maximum output DC 30 V/ 10 A AC 250 V I 10 A.
- 8 Channel Relay Module with Optocoupler LOW Level Trigger expansion board, which is compatible with Arduino control board
- Standard interface that can be controlled directly by microcontroller (8051, AVR PIC. OSP. ARM, ARM, MSP430 TTL logic)
- Relay of high-quality low noise relays SPDT. A common terminal, a normally open, one normally closed terminal.
- Opto-Coupler isolation, for high voltage safety and prevent ground loop with microcontroller

Figure 31: Relay Module

Operating Principle:

A is an electromagnet. **B** armature, **C** spring, **D** moving contact, and **E** fixed contacts as shown in the Figure below. There are two fixed contacts, a normally closed one and a normally open one. When the coil is not energized, the normally open contact is the one that is off, while the normally closed one is the other that is on Supply voltage to the coil and some currents will pass through the coil thus generating the electromagnetic effect. So, the armature overcomes the tension of the spring and is attracted to the core, thus closing the moving contact of the armature and the normally open (NO) contact or you may say releasing the former

ISSN No:-2456-2165

and the normally closed (NC) contact. After the coil is de-energized, the electromagnetic force disappears and the armature moves back to the original position, releasing the moving contact and normally closed contact. The closing and releasing of the contacts result in switching of the power supply to the circuit.

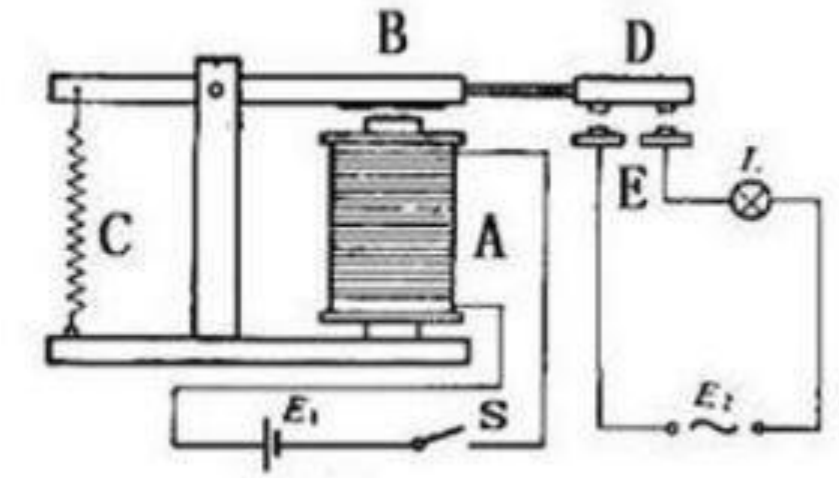

Figure 32: Operating Principle-Relay

➢ **Input:**

- **VCC:** Connected to positive supply voltage (supply power according to relay voltage)
- **GND:** Connected to supply ground
- **IN1:** Signal triggering terminal 1 of relay module
- **IN2:** Signal triggering terminal 2 of relay module
- **IN3:** Signal triggering terminal 3 of relay module
- **IN4:** Signal triggering terminal 4 of relay module • IN5: Signal triggering terminal 5 of relay module
- **IN6:** Signal triggering terminal 6 of relay module
- **IN7:** Signal triggering terminal 7 of relay module
- **INS:** Signal triggering terminal 8 of relay module

➢ **Output**

Each module of the relay has one NC (normally closed), one NO (normally open) and one COM (Common) terminal. So, there are 8 NC 8 NO and 8 COM of the channel play in total.

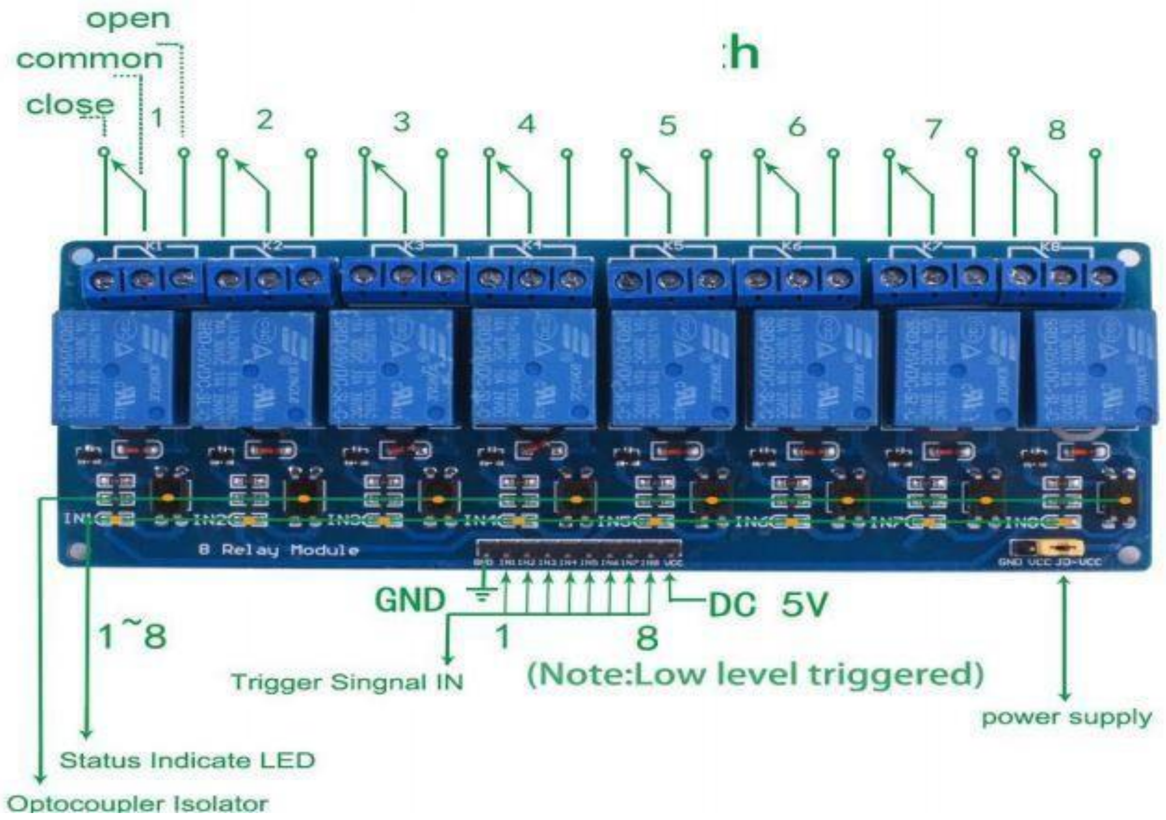

Figure 33: 8 Channel 5V DC Relay module

- **CONNECTIONS:**

RC TRANSMITTER AND RECEIVER:

- Transmitter Includes 4 channels
- Receiver includes 6 channels
- The RC receiver is powered by the 5V and GND ports in the Arduino Mega.
- Channel 1, 2, 3 and 4 of the receiver modules in connected to the pins 2 3, 4, 5 of Arduino Mega Board

ARDUINO MEGA 2560

- Pins 2.3, 4,5 gets an input from RC Receiver Pins 89, 10, 11. 12 can be used to send output signal to the Relay
- Arduino can be powered by SV power bank through the Type B USB Jack

RELAY (8 channel DC SV Relay module)

There are relays, in which we can use 5 relays where the input signal for the relay is obtained from the corresponding channels through the pins (INT, IN2. ING and INA) VCC and GND pins are connected to the 5Vpply and me ground pin of the Arduino Mega Board Each relay can be used to control a DCV

Each relay has a Common port. Normally closed, and normally open porta These ports can be Wee to give signal actuate and retract DCV.

- Normally open-toe DCV
- Normally closed-to extract DCV

Common it is given the 24 V power supply. The GROUND of al DCV's is a commonly connected to the ground of power oily.

➢ Process Flow Chart

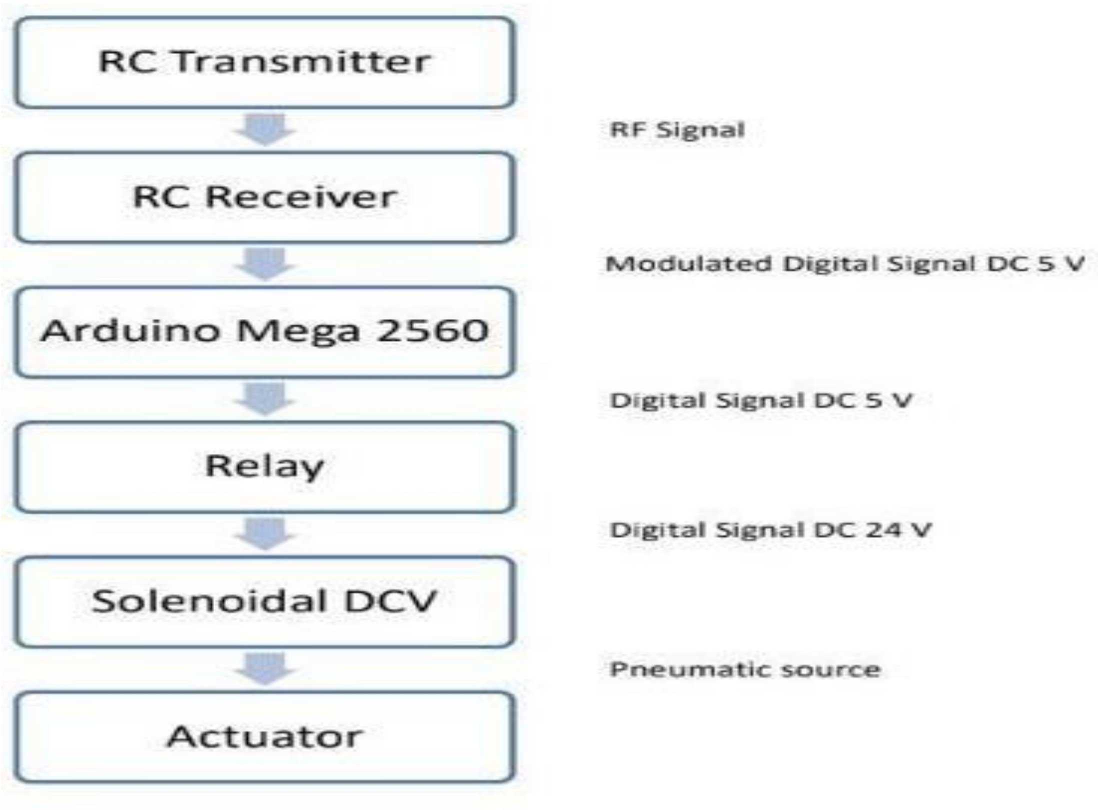

Figure 34: Process Flow chart

➢ Processes

RELAY		CYLINDER		TRANSMITTER CHANNEL AND FUNCTION		
R1	NO	A	A+	CH4: Rotation along Y axis (+ve) – Tilt Right	CH 3: Rotation along X axis (-ve) – Tilt Back	CH 2: Linear Movement along Z axis – Up and Down Movement
	NC		A-			
R2	NO	B	B+		CH 3: Rotation along X axis (+ve) – Tilt Front	
	NC		B-			
R3	NO	C	C+	CH4: Rotation along Y axis (-ve) – Tilt Left		
	NC		C-			
R4	NO	D	D+		CH 3: Rotation along X axis (-ve) – Tilt Back	
	NC		D-			
R5	NO	E	E+	CH 1: Linear Movement along X axis – Right and Left Movement		
	NC		E-			

Figure 35: Process Control Diagram

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CHAPTER ELEVEN
CONTROL CIRCUITRY FOR PROPOSED HYDRAULIC SETUP

- **SELECTION OF A CONTROLLER**:

The requirements of the problem are such that Pneumatic / Hydraulic-based control is deemed unsatisfactory. The losses faced, potential leakage, other Mechanical drawbacks, and the lag in response observed necessitate an Electrical Electronic control system. An Electro pneumatic control (similar to that exhibited in the previous section) would have its own downsides -it renders me setup bulky and requires a large number of physical components to implement the control. Thus, use of an Electronic controller is preferred.

Any Microcontroller can be programmed (and reprogrammed as needed to achieve the necessary outputs (actuations), with varying degrees of a difficulty But, it merely serves as an intermediate processing device. As with electrical controller, there is a need for physical devices (e.g., Relays, which reduces the compactness of the setup Also, control of multiple modules is Limited to the number of output pins available generally an issue with low-capacity variants), and expanding this output quantity also bring about a need for further physical field devices

Thus, the choice is made to use the Programmable Logic Controller (PLC) as a controller for the proposed setup, as it possesses in built Switching Elements, along with other microcontroller possessions like Timers, Counters and others (e.g., Boolean Algebra operando Though it is a device with capabilities far beyond the desired application. It is one that is an ideal Before the large frequency of usage, with e-programmability being relatively simpler,

Selection of the specific PLC for the application based on the following factors.

- Number of Digital Inputs/Outputs
- Memory requirement
- Scan Time
- Programming type
- Communicate type

Based on the requirements, Siemens SIMATIC S7-1200, CPU 1211CC is selected.

Rated value (DC)	24±3.6 V DC
Analog inputs	Number of analog inputs 4
Digital Inputs	8, in groups of 2
Memory Available	50 KB

Table 11: Technical Specification of PLC

- **Process Flow**

The PLC can process DC only in the range mentioned above. The input to the controller should be (as shown in the process flow chart) boosted, i.e., amplified with the Frequency Modulation retained. The Digital DC / DC booster used is the XH-M348 Converter. The signal is received from an RC Joystick, which is the same as that used for the prototype. The solenoidal equipped DCVs can be either Proportional Control Valve or Servo Valve. General solenoidal DCVs can be replaced with Proportional Control Valve. By using that valve, we could able to control both the directions and the flow rate. Servo valve can be used in addition with solenoidal DCVs. Hence both the directions and the flow rate can be controlled with the feedback system. The output from the feedback system can be given as an input to the PLC so that the positioning of the actuators can be easily done. The other differences between Proportional control valve and Servo valve are given in the below table.

S.No.	PROPORTIONAL CONTROL VALVE	SERVO VALVE
1	Output α Electronic input	Output α Electronic input
2	Position of spool and flow is controlled	Position of flow is controlled
3	Operated by solenoids	Operated by torque motors
4	Accurate	More accurate
5	Less expensive to servo valves	High cost

Table 12: Proportional control valve vs servo valve

➢ **Process Flow Chart**

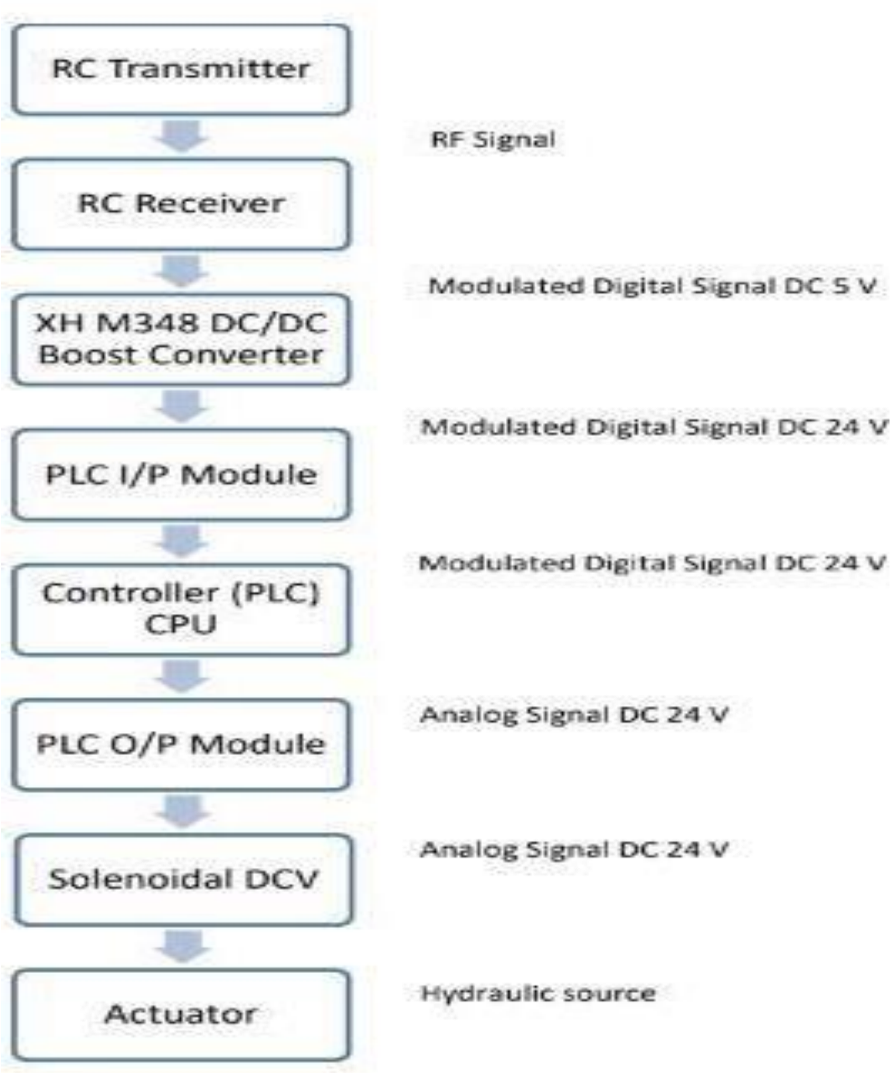

Figure 36: Process Flow Chart

➢ **Circuit Diagram for The Proposed System**

In this circuit four double acting piston cylinders are used as the mechanical actuators. These actuators are controlled by 5/3 direction control solenoid valve. The flow rate of the fluid is kept in check with the help of one directional flow controller. The fluid is supplied form an air tank. The fluid in the air tank is stored after it has been filtered and lubricated in FRL unit.

5/3 solenoid valve is used because of the 3 possible states or situations that is the motion of the piston to the either side of the cylinder and a stationary position when input is not given to that particular actuator and 5 ports for the influx, outflux and exhaust of fluid. The fluid used is drained out through the exhaust.

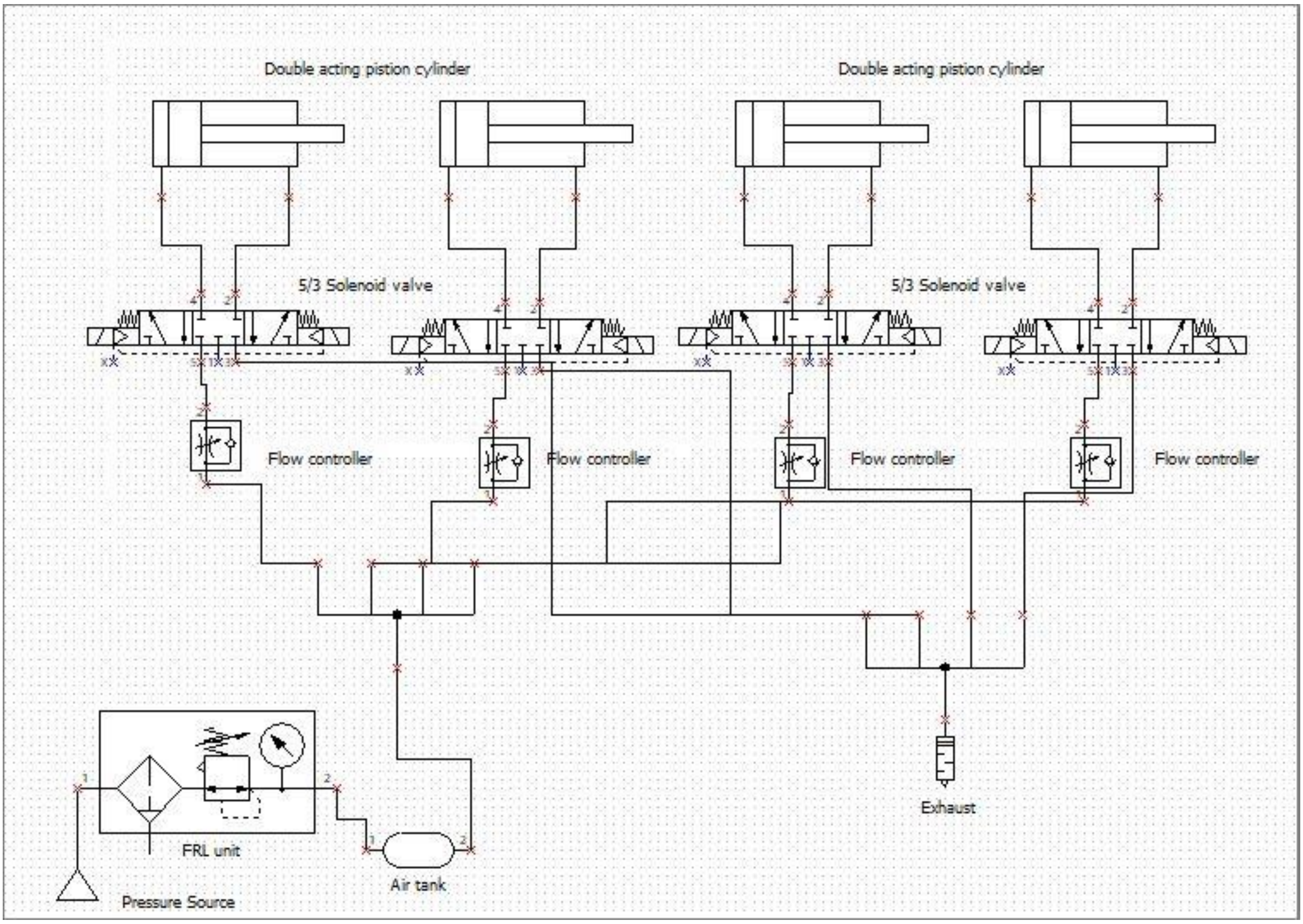

Figure 37: Circuit Diagram

➢ **Program of the Proposed System**

```
void setup ()
{
pinMode(8, INPUT);
pinMode(9, INPUT);
pinMode(10, INPUT);
pinMode(11, INPUT);
pinMode(12, INPUT);
pinMode(13, INPUT);
pinMode(2, OUTPUT);
pinMode(3, OUTPUT);
pinMode(4, OUTPUT);
pinMode(5, OUTPUT);
pinMode(6, OUTPUT);
pinMode(7, OUTPUT);
Serial.begin(9600);
```

```
}
void loop ()
{
Int a=0, b=0, c=0, d=0, e=0, f=0, g=0;
 a = digitalRead(8);
b = digitalRead(9);
c = digitalRead(10);
d = digitalRead(11);
e = digitalRead(12);
f = digitalRead(13);
if(a==0)
{
digitalWrite(2, LOW);
}
else
{
digitalWrite(2, HIGH);
}
if(b==0)
{
digitalWrite(3, LOW);
}
else
{
digitalWrite(3, HIGH);
}
if(c==0)
{
digitalWrite(4, LOW);
}
else
{
digitalWrite(4, HIGH);
}
if(d==0)
{
digitalWrite(5, LOW);
}
else
{
digitalWrite(5, HIGH);
}
if(e==0)
{
digitalWrite(6, LOW);
}
else
{
digitalWrite(6, HIGH);
}
if(f==0)
{
digitalWrite(7, LOW);
}
else
{
digitalWrite(7, HIGH);
}
}
```

CHAPTER TWELVE
GAMING INTERFACE

COMPONENTS USED

The interface is achieved by using the following components

- Gaming station
- Arduino US8 shield
- Joystick counter
- USB splitter

In Order to link the motion of the game lo a pneumatic system

- Joystick has to communicate with the system relay a game
- AT the same time joystick has to communicate with the Arduino Through USB Shield

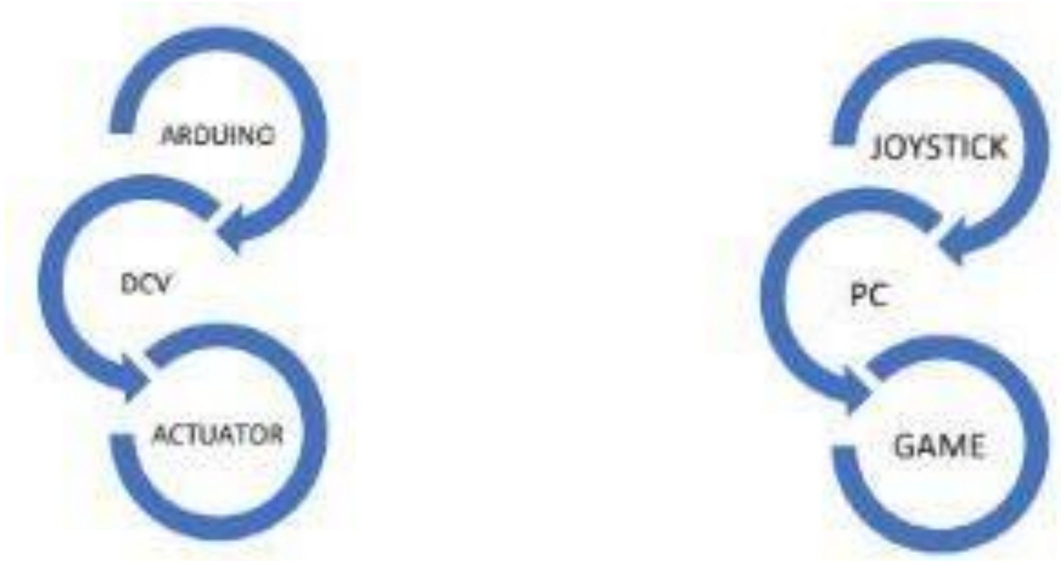

Figure 38: Signal Flow

- **USB SHIELD**:

An USB shield is a device that provides the ability to connect a USB device to an Arduino board. It is based on the MAX3421E (datasheet), which is a USB peripheral/host controller containing the digital logic and analog circuitry necessary to implement a full-speed USB peripheral or a full-/low-speed host compliant to USB specification rev 2.0 which is based on revision 2.0 of USB Host Shield and is now compatible with more Arduinos - not only UNO and Duemilanove, but also Mega and Mega 2560 work with Standard variant of the shield out of the box

Specifications

- Works with standard (dual 5/3.3V) and 3.3V-only (for example, Arduino Pro) boards.
- Operates over the extended -40°C to +85°C temperature range
- Complies with USB Specification Revision 2.0 (Full-Speed 12Mbps Peripheral, Full-/Low-Speed 12Mbps/1.5Mbps Host)

The following device classes are currently supported by the shield

- HDD devices, such as keyboards, mice, joysticks, etc.

ISSN No:-2456-2165

- Mass storage devices, such as USB sticks, memory card readers, external hard drives (FAT32 Type File System - Arduino Mega only)

Figure 39: USB Shield

CHAPTER THIRTEEN
SOFTWARES USED

Sr. No.	ACTIVITY	SOFTWARE
1.	CAD	SOLIDWORKS
2.	Static Structural Analysis	ANSYS
3.	Motion Study Analysis	ANSYS
4.	Dynamic Analysis	ANSYS
5.	Fatigue Analysis	ANSYS
6.	Renderization	SOLIDWORKS

Table 13: Software used for different purpose

CHAPTER FOURTEEN
CONCLUSION

In this project, a demonstration was made on how to build a 4- DOF (2 translational and 2 rotational) chair using fluid power systems. The angle of tilting achieved was 150. The scaled down model was fabricated using pneumatic power circuit and the scaled-up version is proposed using hydraulic system with calculations made using appropriate assumptions. The scaled-up version is not proposed using pneumatic system because pneumatic cylinders cannot be used for vertical loading conditions because they lag positional accuracy because of compressibility effects. In this present system, an Arduino was used as a controller for interfacing the joystick and the power circuit. To make the system more rugged androbust PLC's can be used along with continuous position controlling capabilities. Further enhancements can be made in future to design and control to boost the performance of the system proposed.

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ANNEXURE

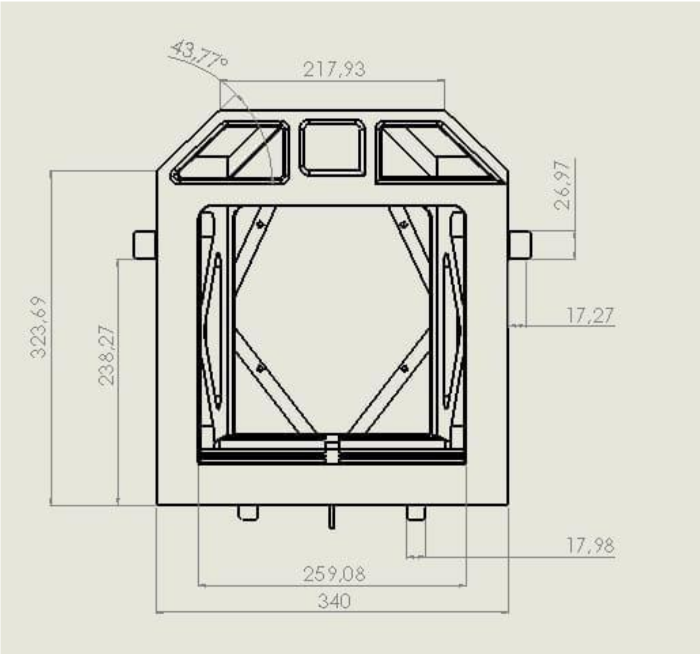

Figure 40: Design sheet of frame

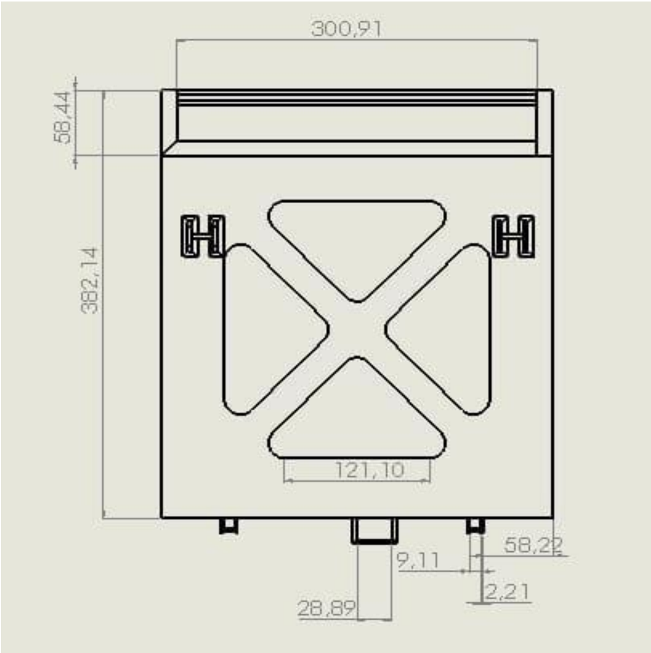

Figure 41: Design sheet of frame

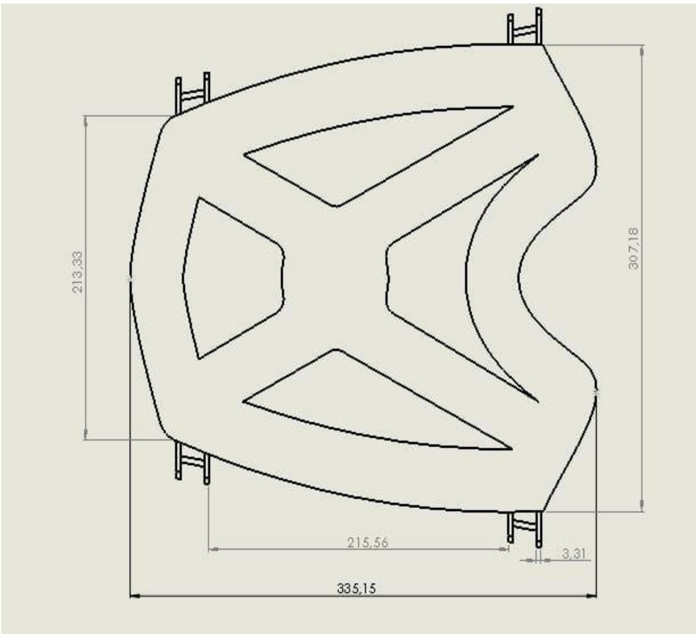

Figure 42: Design sheet of seat plate

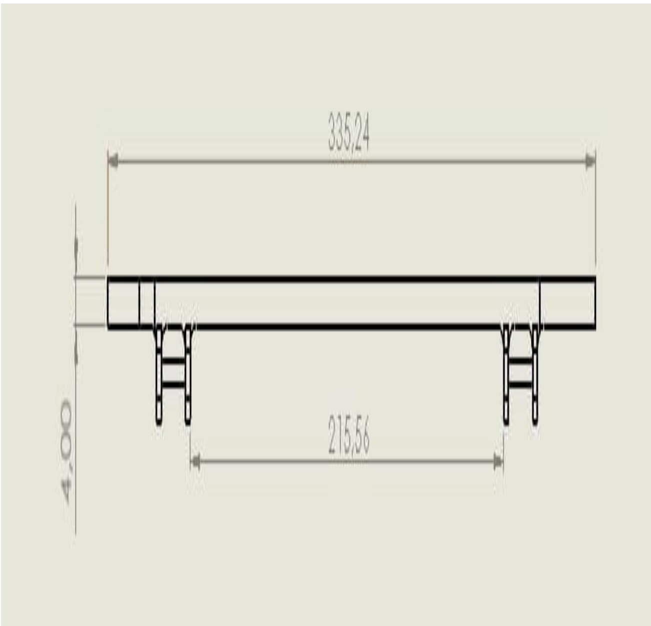

Figure 43: Design sheet of seat plate

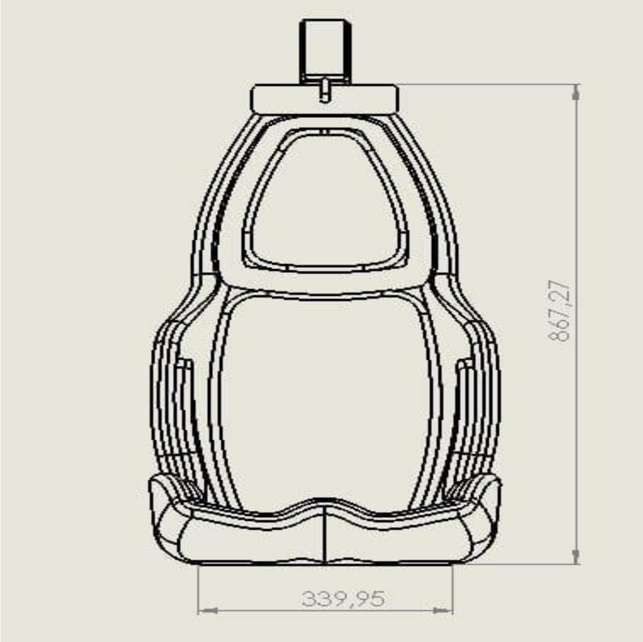

Figure 44: Design sheet of chair

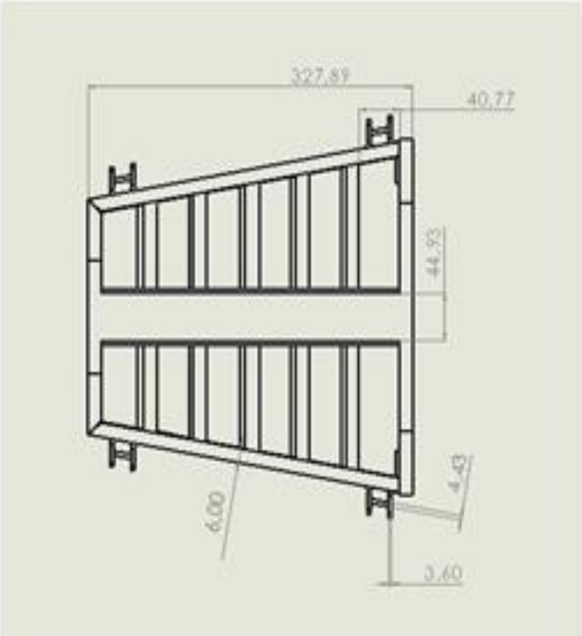

Figure 45: Design sheet of chair

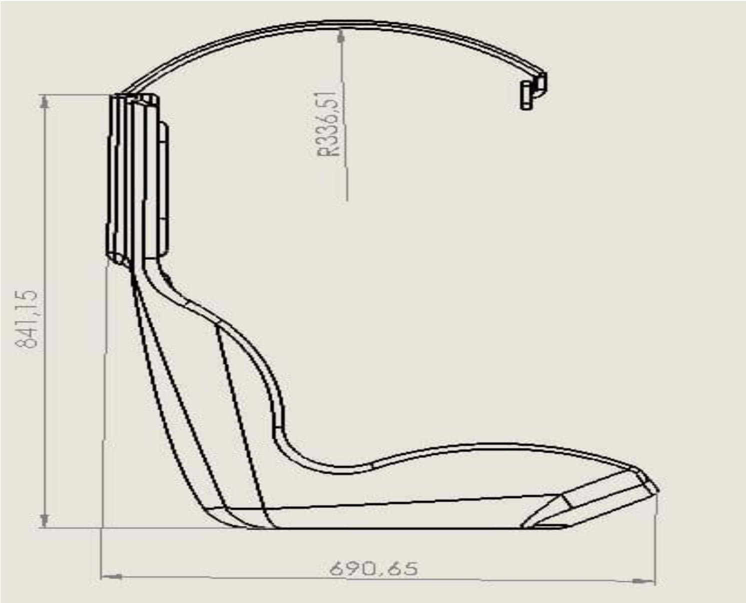

Figure 46: Design sheet of seat plate