Internship Report on

Designing a Rocket Motor Static Test Pad for testing and acquiring the required data for the performance analysis of the High Powered Rocket Motors

At STAR – Space Technology and Aeronautical Rocketry

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SPIDER STATIC TEST PAD

What is a SPIDER STATIC TEST PAD?

The SPIDER STATIC TEST PAD is a Quadruped static rocket motor testing platform which can be used for calculating the thrust of any Rocket Motor up to N class motors or Rocket Motors with diameter ranging from 3cm to 16cm and 70cm in length.

Basic working principle of SPIDER STATIC TEST PAD:

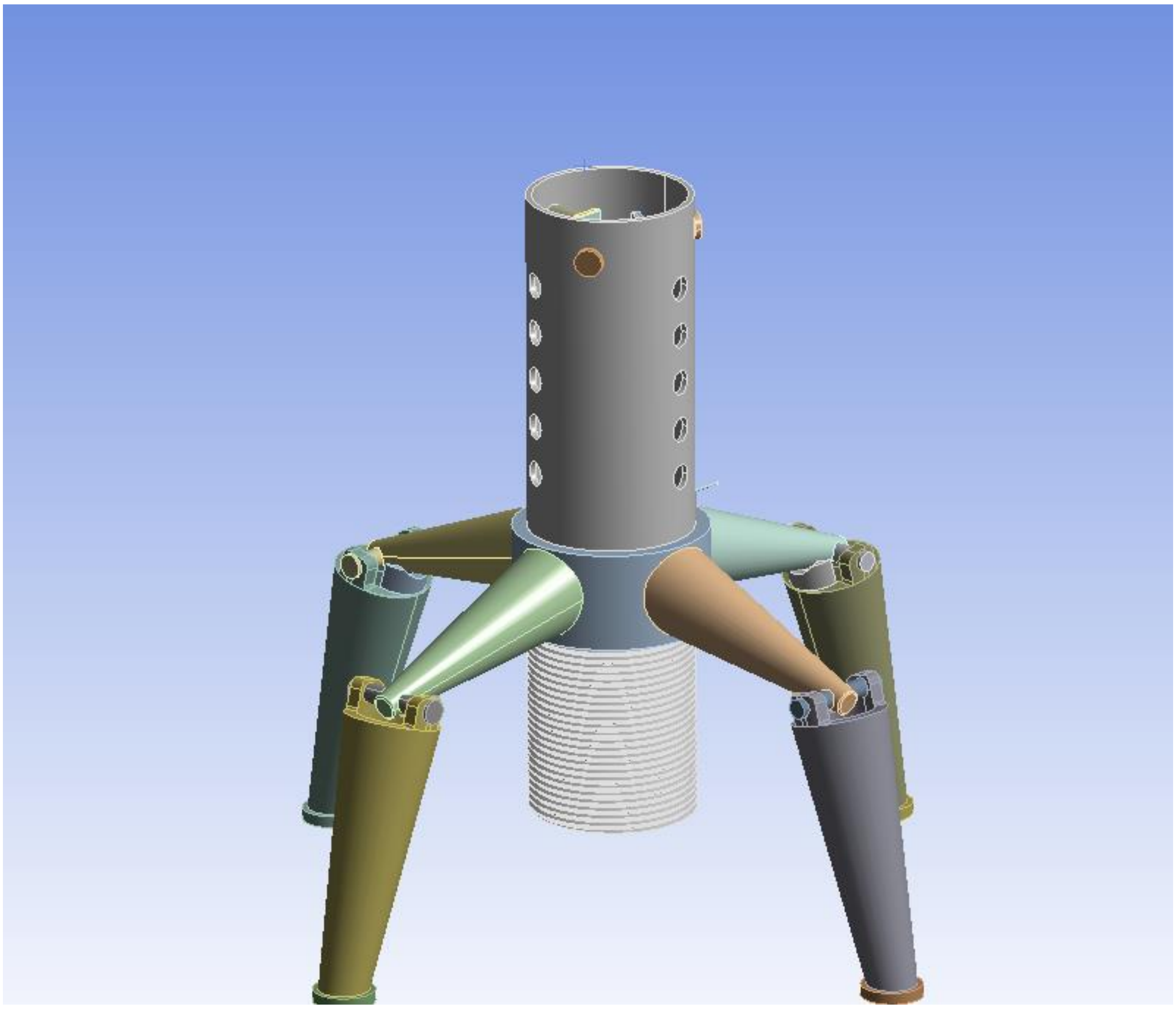
The Frame:

The frame is designed to hold the rocket motor in place and provide stability and support while rocket motor is fired for testing.

The Avionics:

The avionics include the components responsible for collecting and analysing data, for example the load cell (for measuring the thrust), thermocouple (to measure motor temperature), SD Card (for saving data).

The Rocket motor is placed in the motor mount, the load cell is deflected/compressed therefore giving the thrust of the rocket motor, and thermocouples measure the surface temperature of rocket motor this data is recorded and stored with the help of avionic circuit.



Why to make SPIDER STATIC TEST PAD?
SPIDER STATIC TEST PAD is required for Standardised testing of Rocket Motors available for Model Rockets and to get the most accurate results up to 300Kgs or 3000N of Thrust.

Architecture:

1

- Cylinderical Rocket Motor Mount
- Attaching the Clamps to motor mount
- Fixing the Thermocouples to the Motor surface

2

- Attaching the Legs to the Motor Mount

3

- Connecting all Sensors to External Avionics Box to trigger the system and save data
- Using the Ignition wire from the Avionics Box for lighting up the Rocket motor

Basic components, software required to build a Title/System:

- List of Component
  - Carbon Fibre(Motor Mount)
  - Aluminium Screws
  - Magnesium Alloy(Legs, attachment ring for Legs)
  - Neoprene(Rubber Pad)
  - Stainless Steel(Ball Bearing)
  - HX711 - 300Kg Load Cell
  - MAX31855 – Thermocouple
  - Arduino UNO

- List of Software
  - Arduino IDE
  - Fusion 360/Ansys
  - Proteus/Easy EDA
  - Eagle

Procedure to build a SPIDER STATIC TEST PAD:

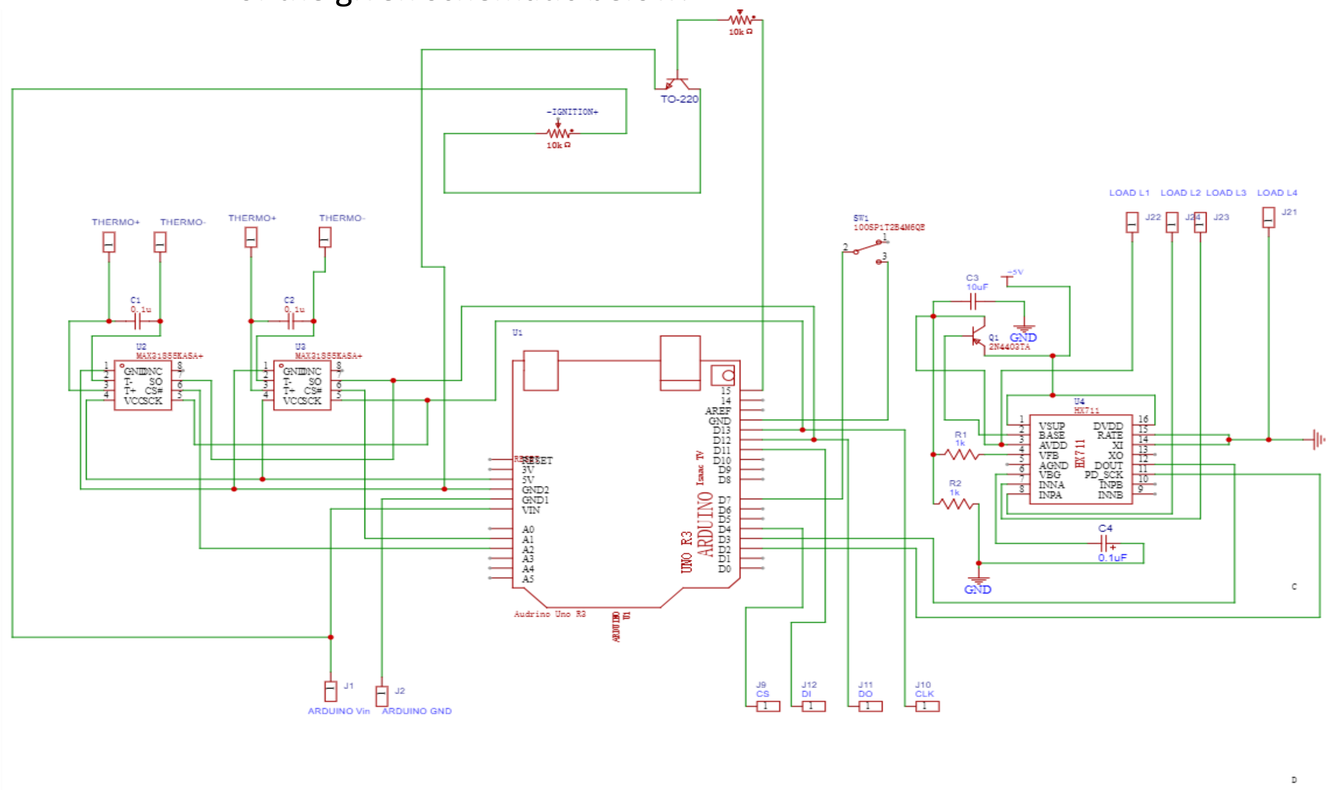
Guide for how to build:

- **Avionics**

1. Selecting the components

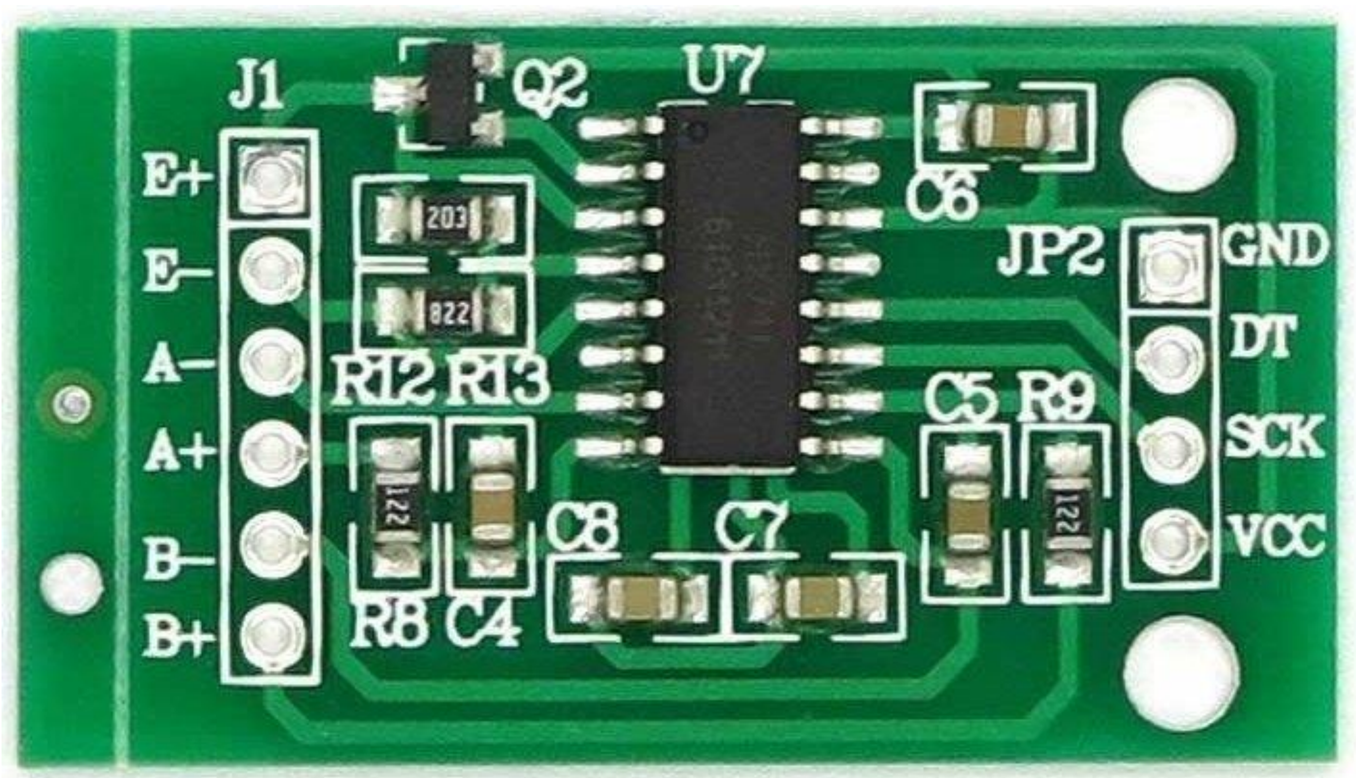
a. Arduino UNO
b. HX711 Load Cell
c. MAX31855 Thermocouple
d. 11V Lipo Battery
e. Resistors, Capacitors, Transistors
f. TO-220 NPN current amplifier

2. Connect all the components as per the following schematic and later place the respective components on a PCB which has been fabricated on the basis of the given schematic below.



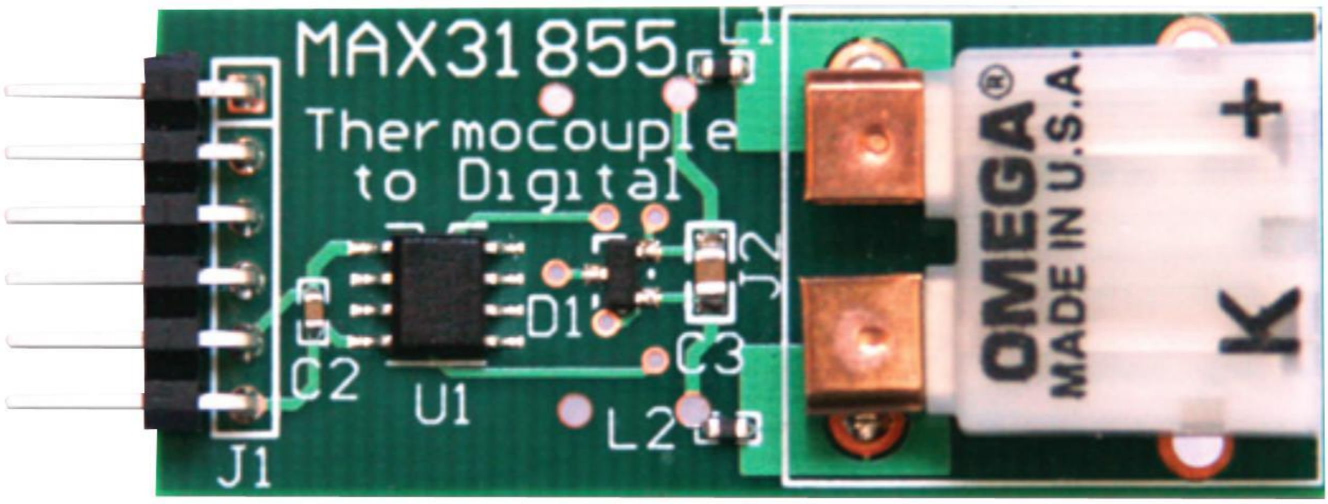
LOAD CELL


Wiring code(4-wire ciruit)
ISO9001 : 2000 Assured Company
LOAD CELLS



HX711 - It's the Chip used in Load Cell to measure the thrust, the load cell used is capable to measure thrust up to 400 kg.

MAX31855 – It's the Thermocouple chip used with thermocouple to measure the temperature of the surface of the rocket motor.



ARDUINO SD CARD MODULE – This is an attachment on Arduino which is used to record all observations being processed by the Arduino.

ARDUINO UNO – It's the microcontroller used to control any type of sensor connected. Here we use it to control Ignition Wire, and read the values recorded by Load Cell and Thermocouple and write to the SD CARD module.

- **Mechanical Structure**
  1. Motor Mount

This has been made from Carbon Fibre to be light weight and strong
This has threads in its lower section so that we can attach Legs to the stand.

  2. Clamps

The clamp made of stainless steel is being used to keep the rocket motor upright and stable. The ball bearing inside the clamp allows free axial motion of the rocket motor and stops any toppling tendencies of the motor.

3. Legs

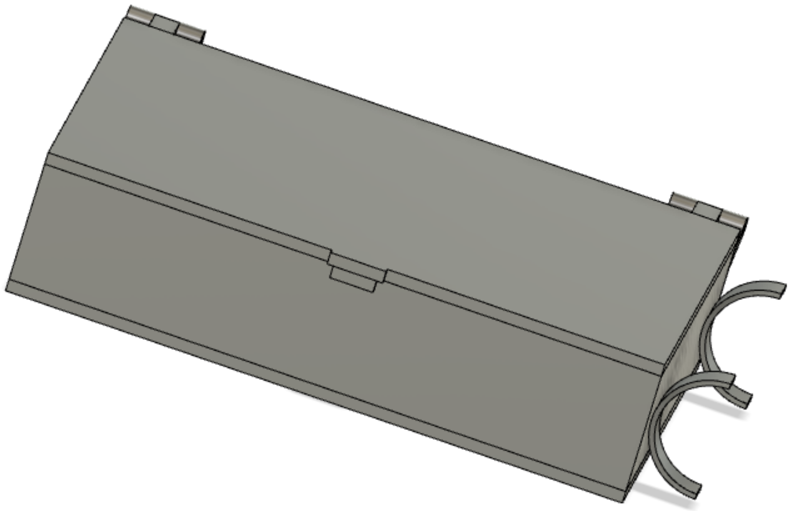
The Legs support the whole structure. Made up of Magnesium alloy helps to strengthen the structure and reduce the weight.

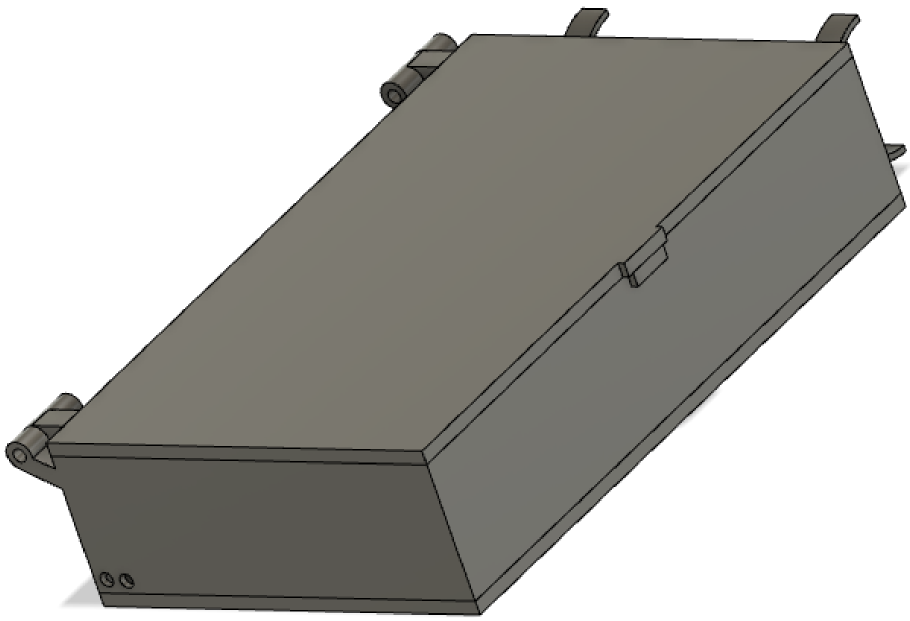
Other Components:

Screws: Made up of aluminium attaches the legs to thigh at the knee

Rubber Pads: Under the Legs, is rubber pad reducing the vibrations in the structure and keeping the Stand stable.

Avionics Box: A specially designed box to hold Arduino and its accessories to control the sensors on board the test pad with additional tools and a fire extinguisher holder.

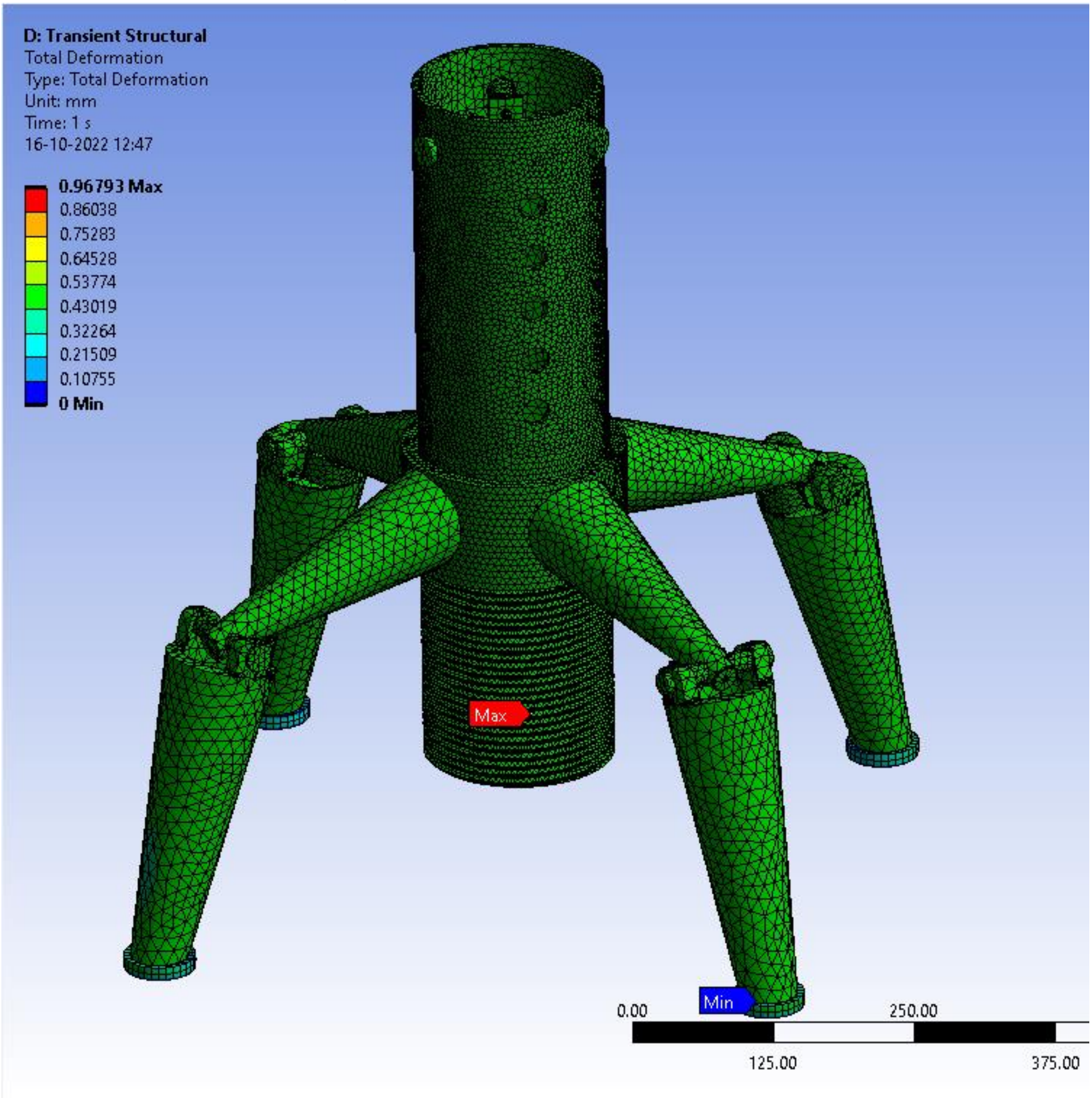


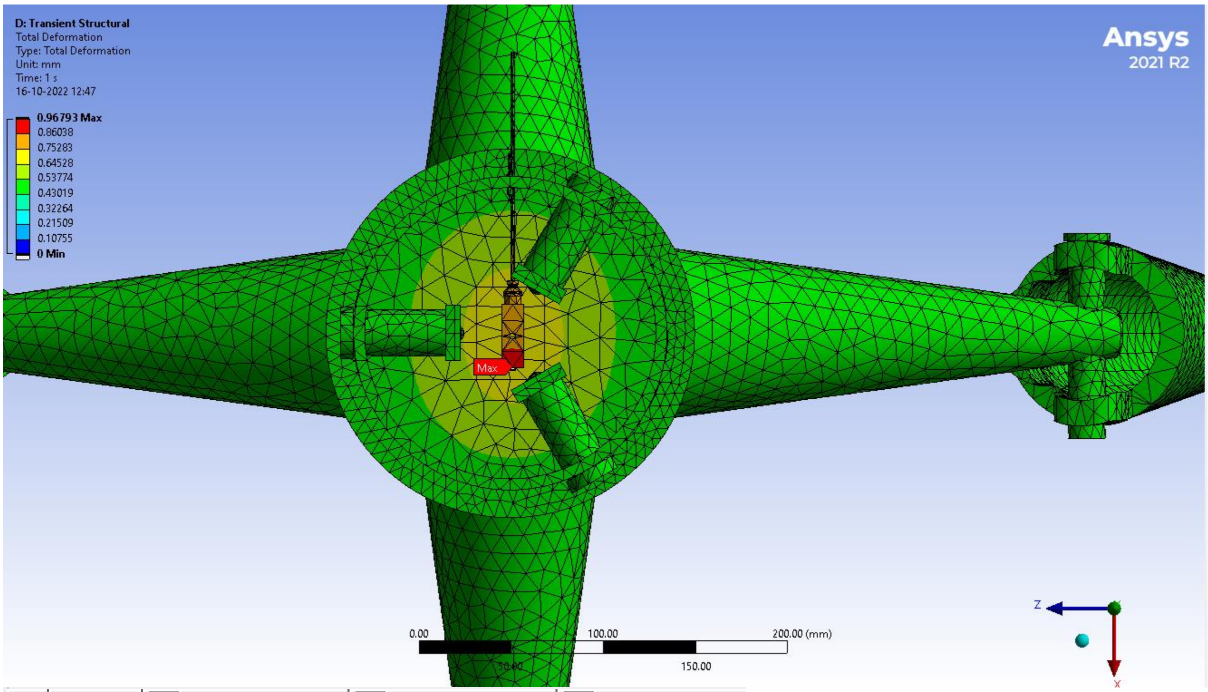


Observation:

Transient Structural Analysis:

Deformation Analysis

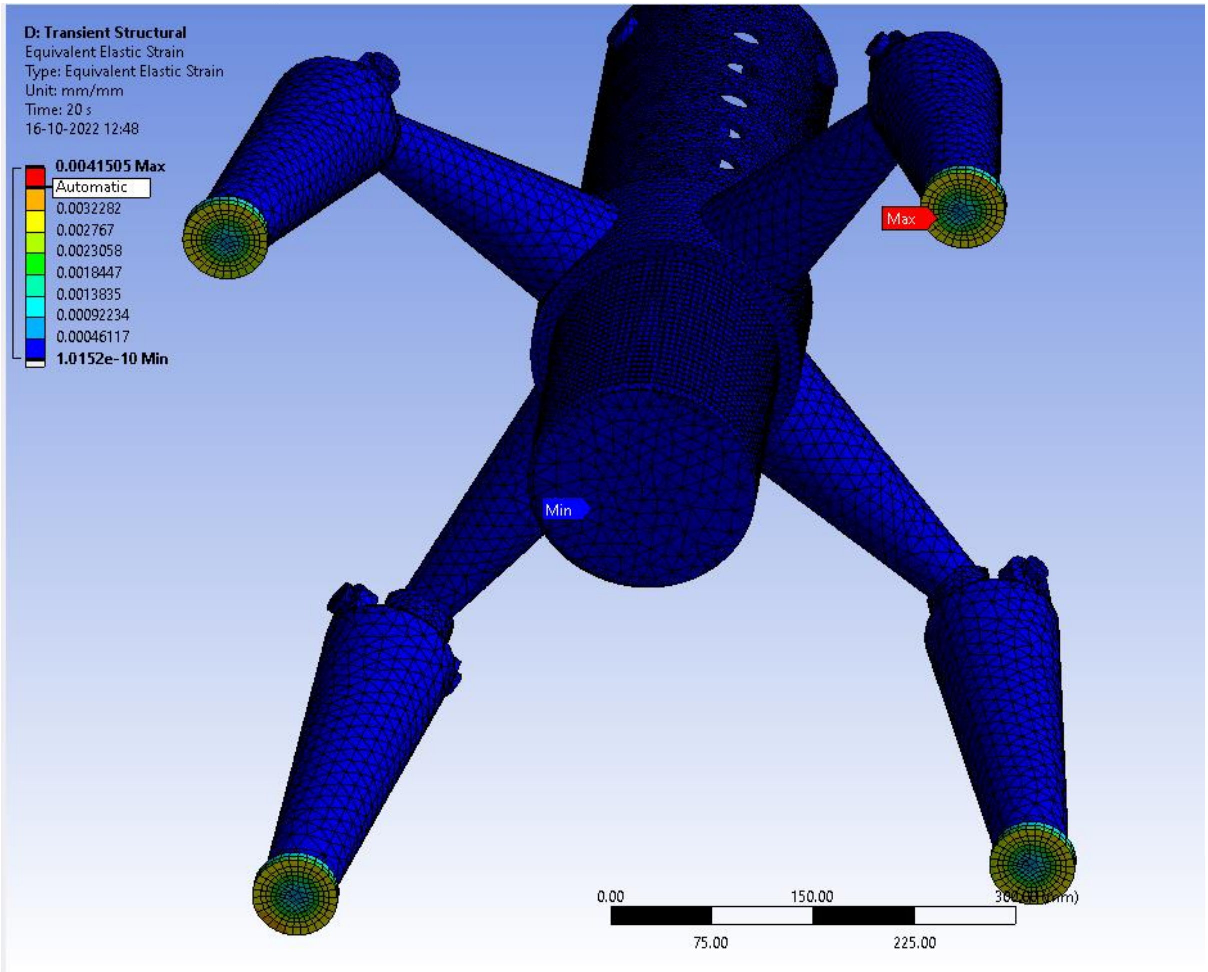




	Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1	1.	0.	0.96793	0.50553
2	2.	0.	0.96661	0.5042
3	3.	0.	0.96641	0.50401
4	4.	0.	0.96634	0.50393
5	5.	0.	0.96625	0.50384
6	6.	0.	0.96623	0.50382
7	7.	0.	0.96618	0.50377
8	8.	0.	0.96619	0.50378
9	9.	0.	0.96616	0.50375
10	10.	0.	0.96617	0.50376
11	11.	0.	0.96615	0.50374
12	12.	0.	0.74539	0.39096
13	13.	0.	0.52214	0.27567
14	14.	0.	0.29221	0.1537
15	15.	0.	0.24561	0.12869
16	16.	0.	0.19792	0.10262
17	17.	0.	0.14986	7.615e-002
18	18.	0.	0.10157	4.9448e-002
19	19.	0.	5.2678e-002	2.2128e-002
20	20.	0.	2.2562e-002	1.8881e-002

In the simulations conducted we observe that there is a maximum deformation of 0.96793mm at the load cell. Hence it conclusive that the structure will be able to withstand the massive forces of 3000N up to 20 seconds.

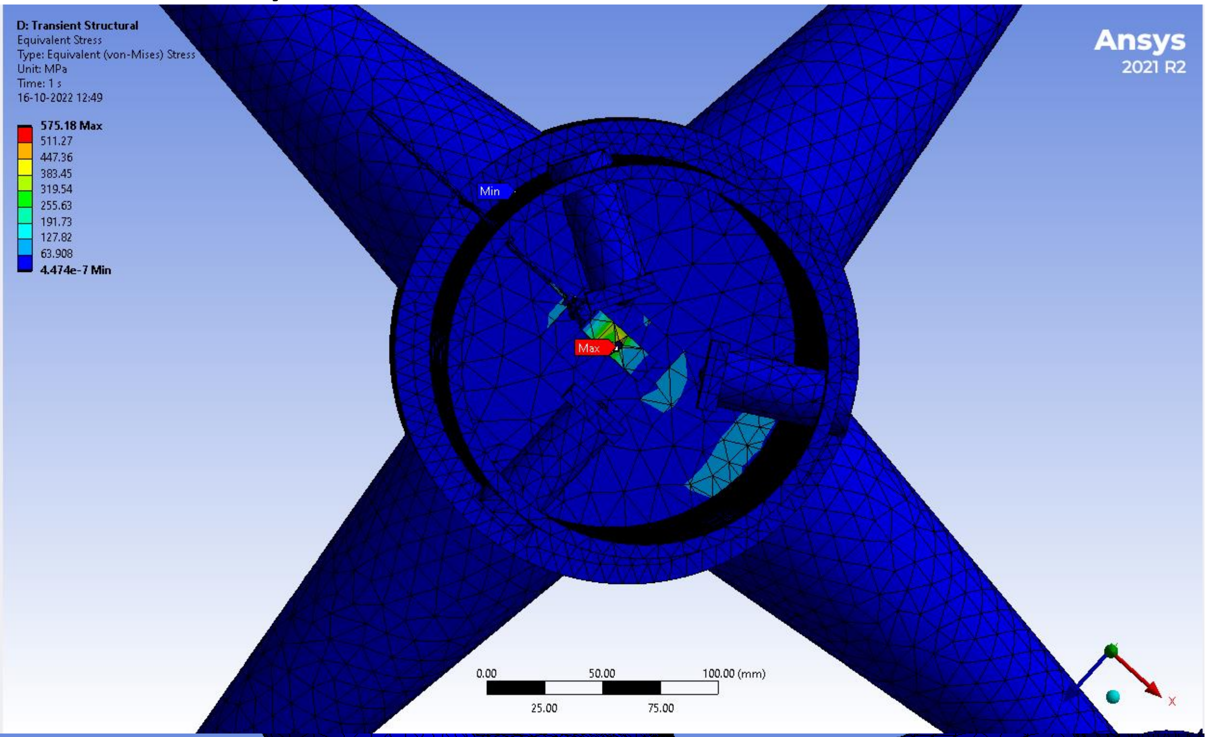
Strain Analysis

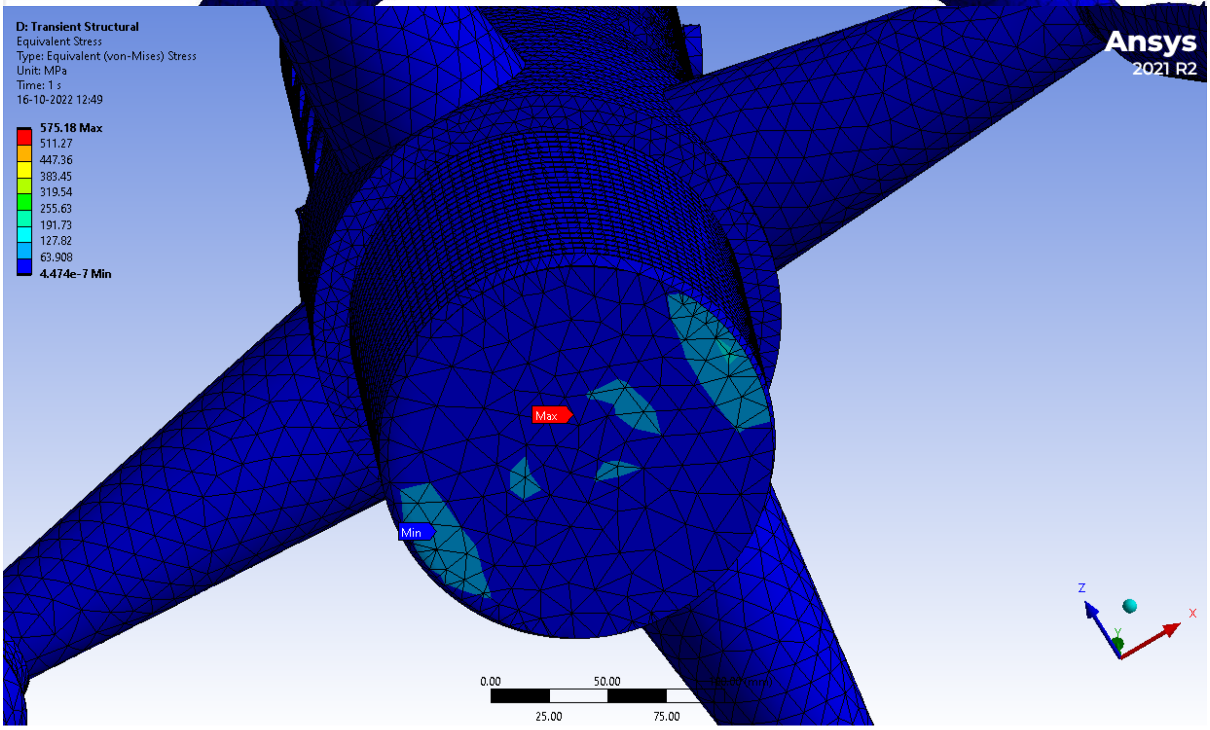


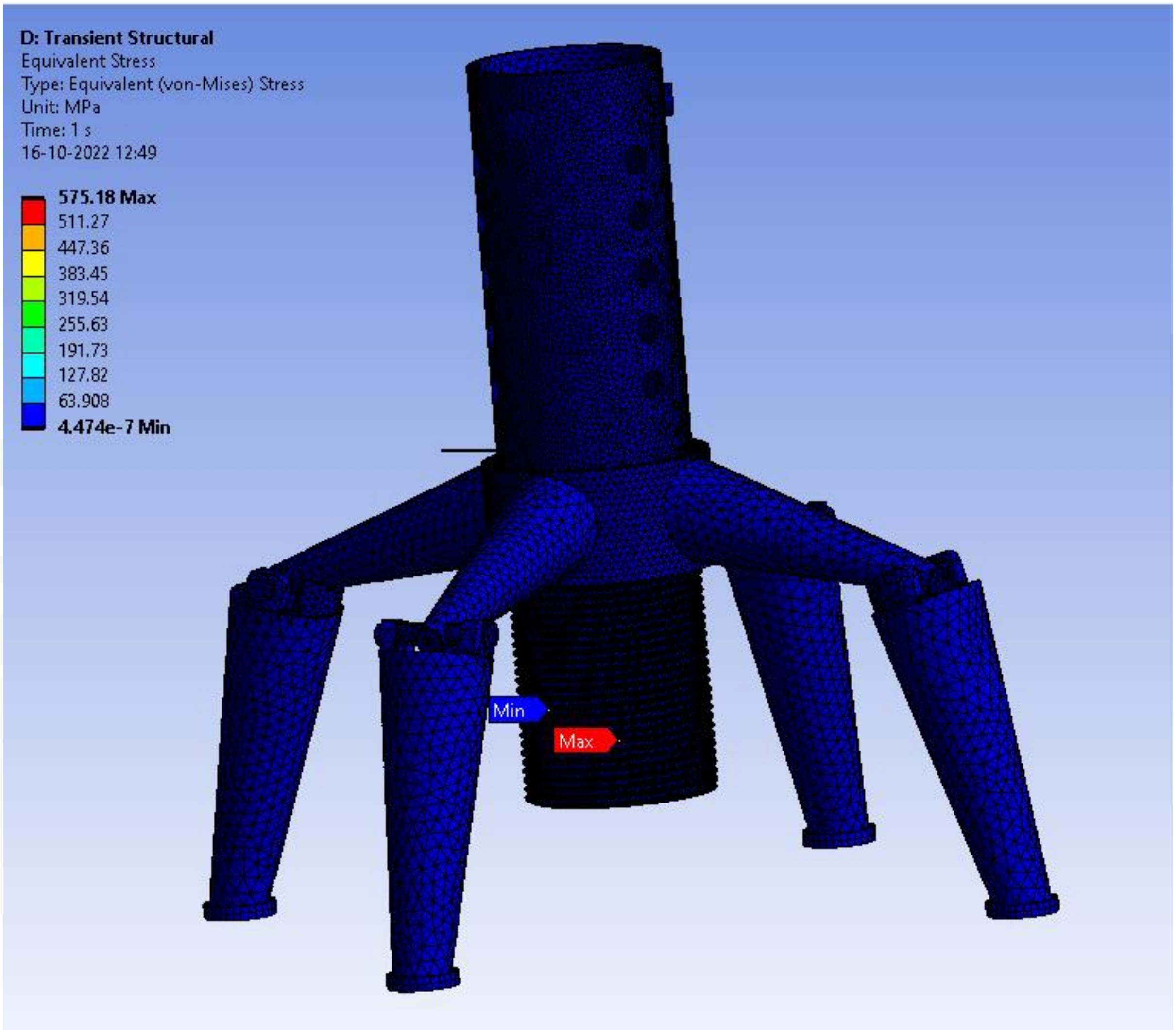
	Time [s]	Minimum [mm/mm]	Maximum [mm/mm]	Average [mm/mm]
1	1.	1.2449e-010	0.12771	1.4717e-003
2	2.	1.2442e-010	0.12692	1.47e-003
3	3.	1.2455e-010	0.12673	1.469e-003
4	4.	1.2439e-010	0.12664	1.4683e-003
5	5.	1.2456e-010	0.12657	1.4677e-003
6	6.	1.2438e-010	0.12653	1.4674e-003
7	7.	1.2456e-010	0.12649	1.4671e-003
8	8.	1.2439e-010	0.12647	1.467e-003
9	9.	1.2455e-010	0.12645	1.4668e-003
10	10.	1.244e-010	0.12645	1.4668e-003
11	11.	1.2454e-010	0.12644	1.4667e-003
12	12.	1.2448e-010	9.6902e-002	1.1227e-003
13	13.	1.2466e-010	6.7022e-002	7.7412e-004
14	14.	1.2462e-010	3.6373e-002	4.1873e-004
15	15.	1.2472e-010	3.0304e-002	3.4739e-004
16	16.	1.2461e-010	2.4025e-002	2.7522e-004
17	17.	1.247e-010	1.7694e-002	2.0261e-004
18	18.	1.246e-010	1.1338e-002	1.2985e-004
19	19.	1.1554e-010	5.011e-003	5.7079e-005
20	20.	1.0152e-010	4.1505e-003	4.9555e-005

In the simulations conducted we observe that there is a maximum strain of 0.0041505 at the Rubber Pads and all other mechanical components face a lower strain than this. Hence it conclusive that the structure will be able to withstand the massive forces of 3000N up to 20 seconds.

Stress Analysis



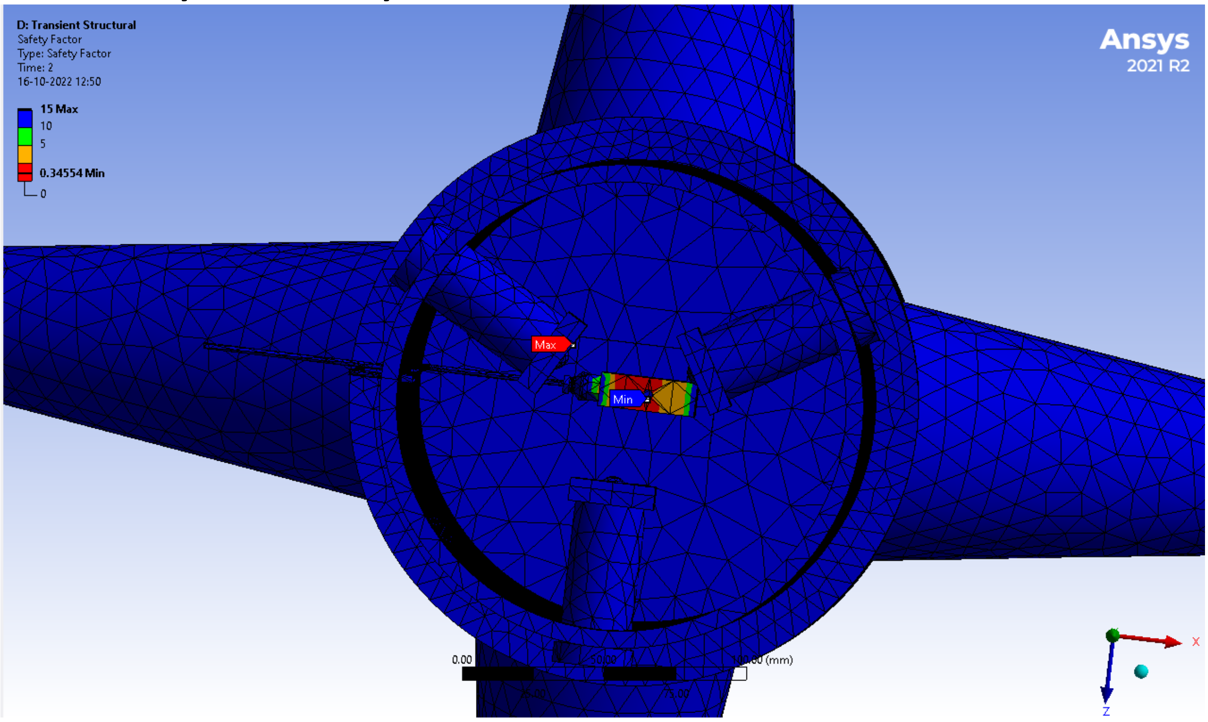


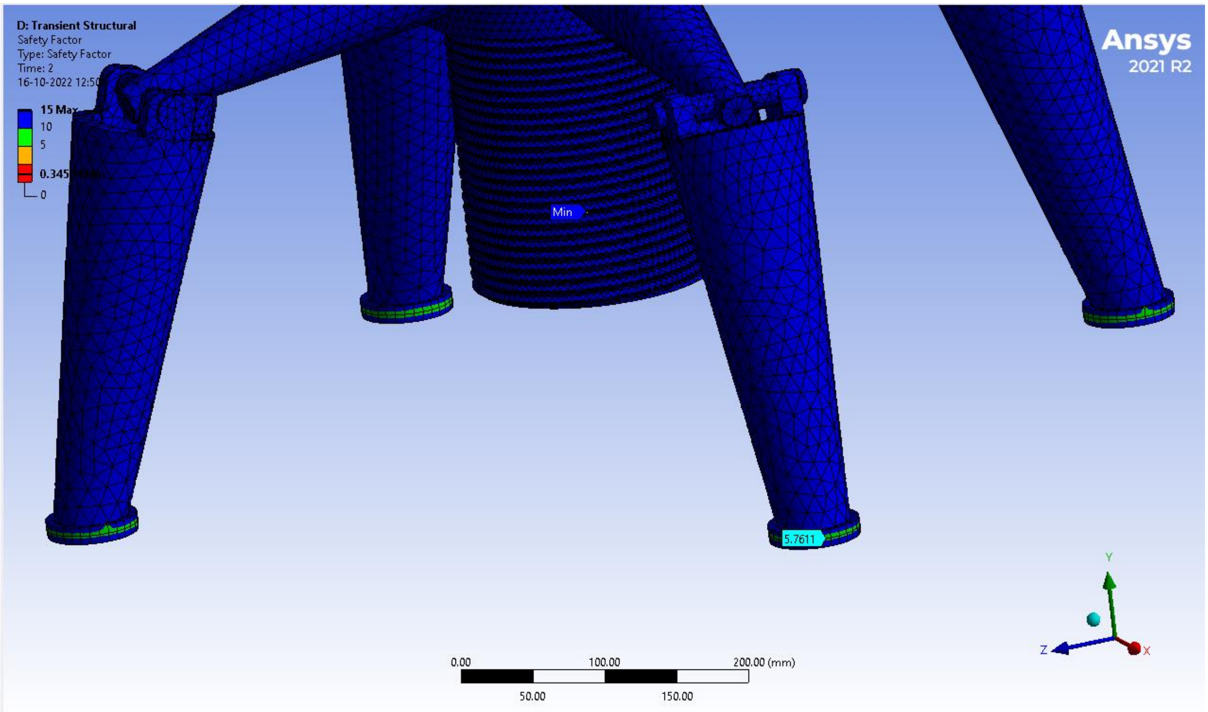


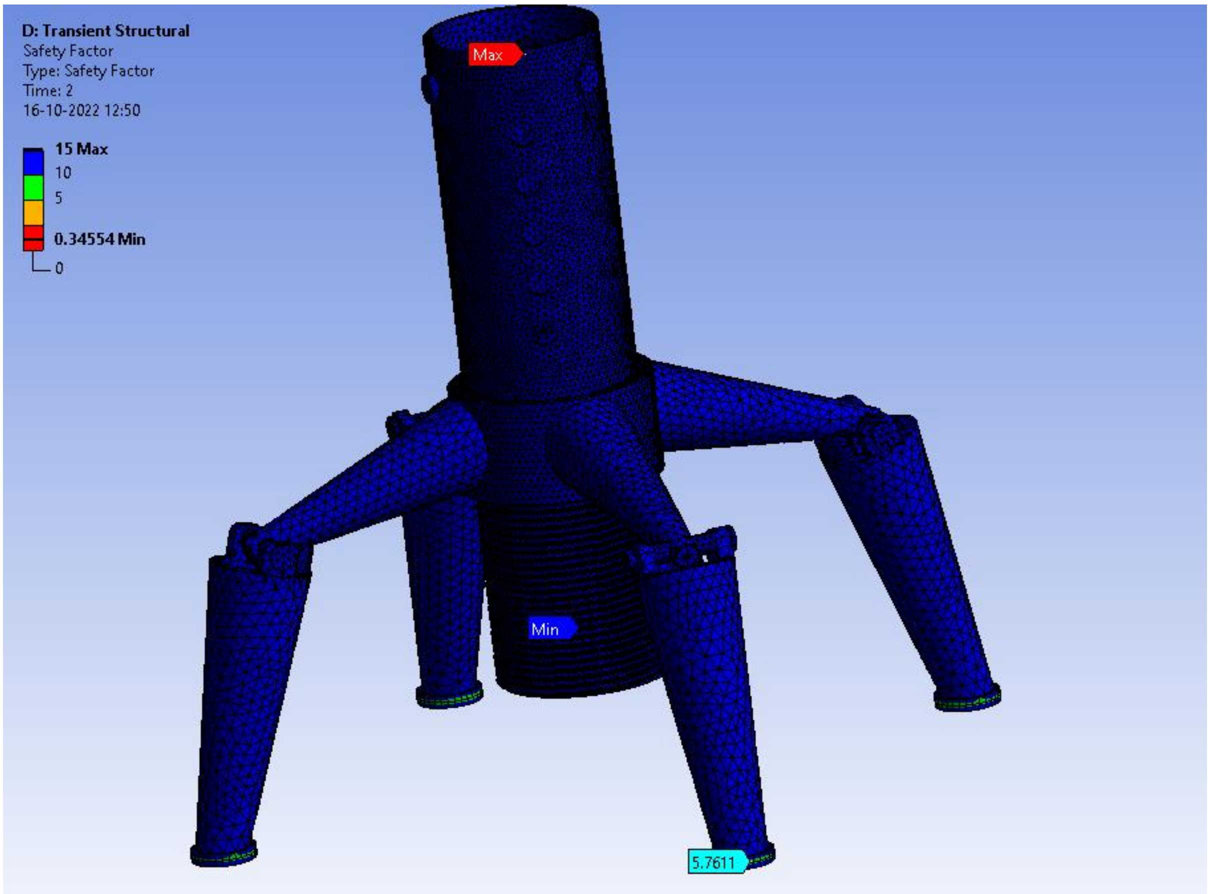
	Time [s]	Minimum [MPa]	Maximum [MPa]	Average [MPa]
1	1.	4.474e-007	575.18	1.2235
2	2.	4.471e-007	575.18	1.2234
3	3.	4.4759e-007	575.18	1.2234
4	4.	4.4694e-007	575.18	1.2234
5	5.	4.4769e-007	575.18	1.2234
6	6.	4.468e-007	575.18	1.2234
7	7.	4.4758e-007	575.18	1.2234
8	8.	4.4708e-007	575.18	1.2234
9	9.	4.4742e-007	575.18	1.2234
10	10.	4.4696e-007	575.18	1.2234
11	11.	4.4778e-007	575.18	1.2234
12	12.	4.373e-007	440.68	0.93595
13	13.	4.2981e-007	306.36	0.64846
14	14.	4.2415e-007	172.21	0.361
15	15.	4.6858e-007	145.41	0.30356
16	16.	4.5114e-007	118.59	0.24605
17	17.	4.2874e-007	91.794	0.18856
18	18.	4.2907e-007	65.004	0.13109
19	19.	4.3603e-007	38.22	7.3601e-002
20	20.	4.2831e-007	0.58156	1.0424e-002

In the simulations conducted we observe that there is a maximum stress of 575.18MPa at the Load Cell and all other mechanical components face a lower stress than this. Hence it conclusive that the structure will be able to withstand the massive forces of 3000N up to 20 seconds.

Safety Factor Analysis





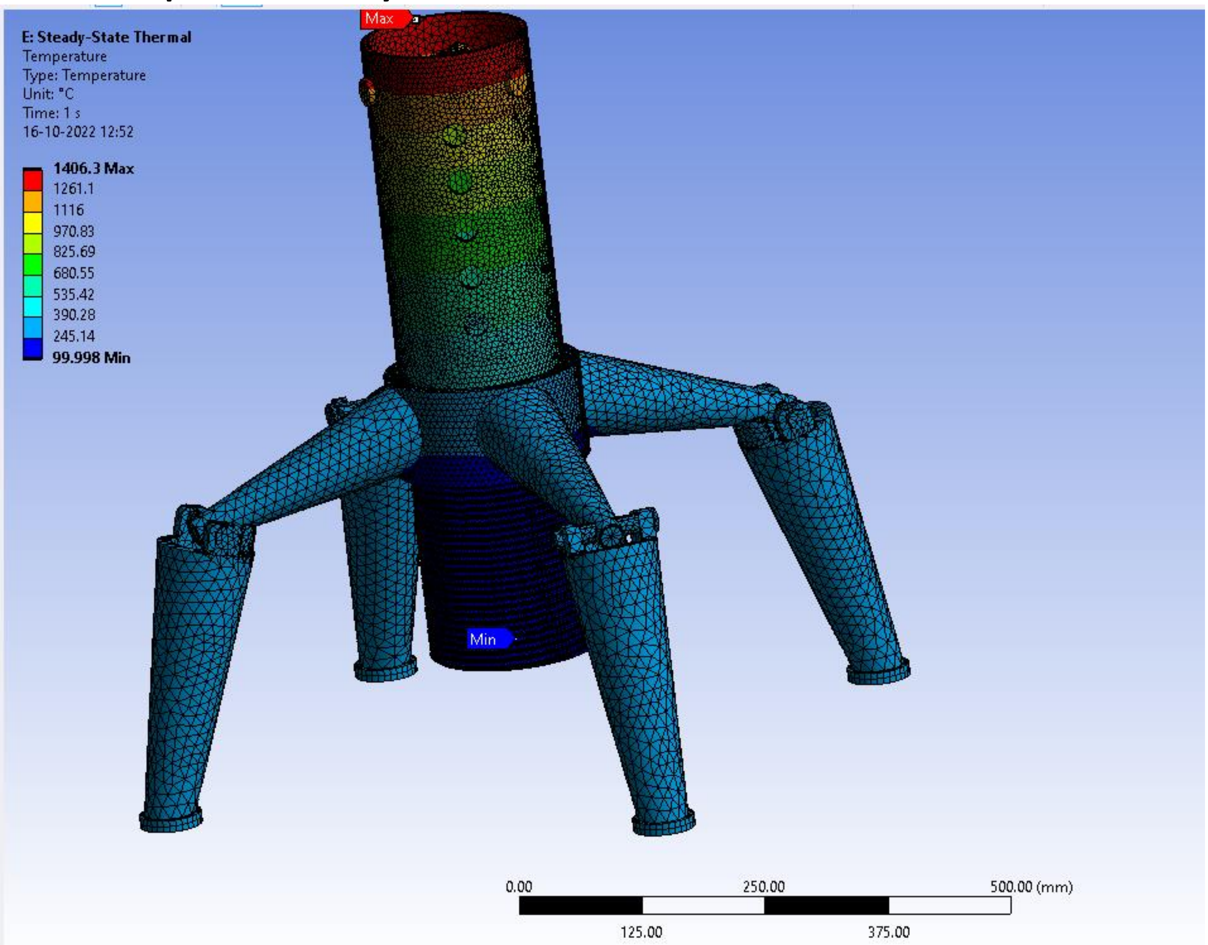


	Time [s]	Minimum	Maximum	Average
1	1.	0.34554	15.	14.966
2	2.	0.34554	15.	14.966
3	3.	0.34554	15.	14.966
4	4.	0.34554	15.	14.966
5	5.	0.34554	15.	14.966
6	6.	0.34554	15.	14.966
7	7.	0.34554	15.	14.966
8	8.	0.34554	15.	14.966
9	9.	0.34554	15.	14.966
10	10.	0.34554	15.	14.966
11	11.	0.34554	15.	14.966
12	12.	0.45099	15.	14.978
13	13.	0.64871	15.	14.987
14	14.	1.154	15.	14.995
15	15.	1.3667	15.	14.995
16	16.	1.6758	15.	14.996
17	17.	2.165	15.	14.997
18	18.	3.0572	15.	14.998
19	19.	5.1996	15.	14.999
20	20.	15.	15.	15.

In the simulations conducted we observe that there is a minimum safety factor of 0.34554 at the Load Cell and a Safety factor of 5.7611 at the Rubber Pads, all other mechanical components have a safety factor of 15. Hence it conclusive that the structure will be able to withstand the massive forces of 3000N up to 20 seconds.

Steady State Thermal Analysis

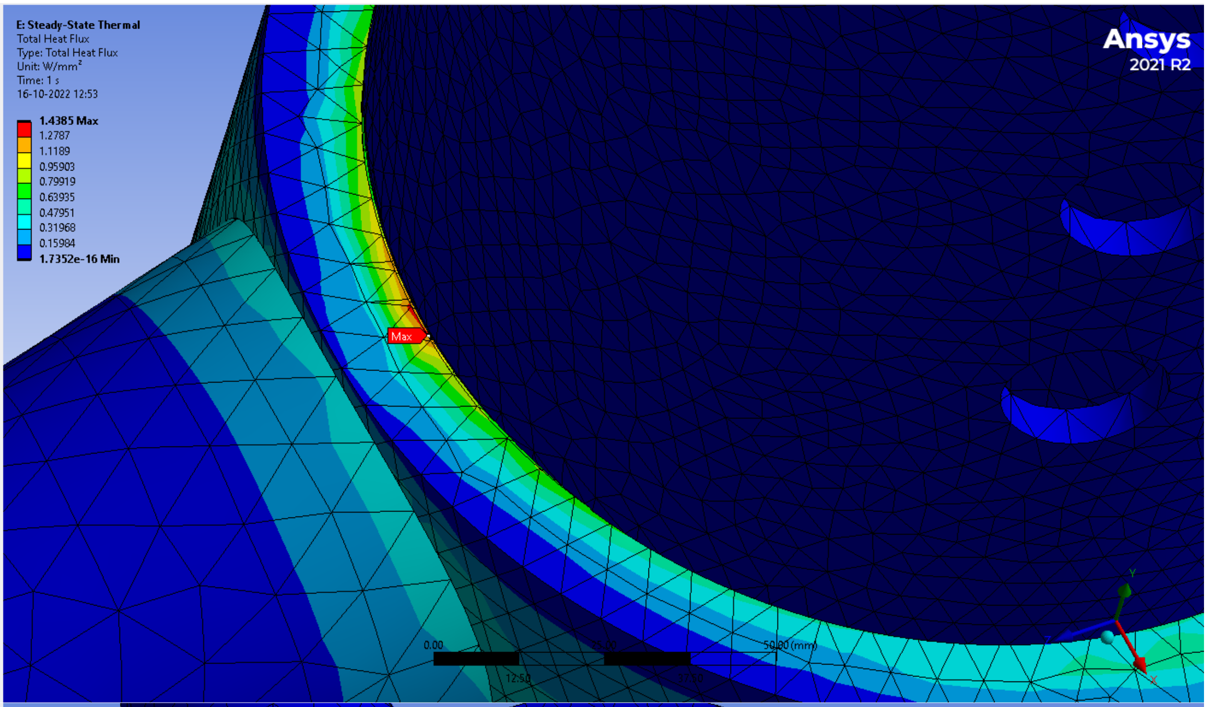
Temperature Analysis

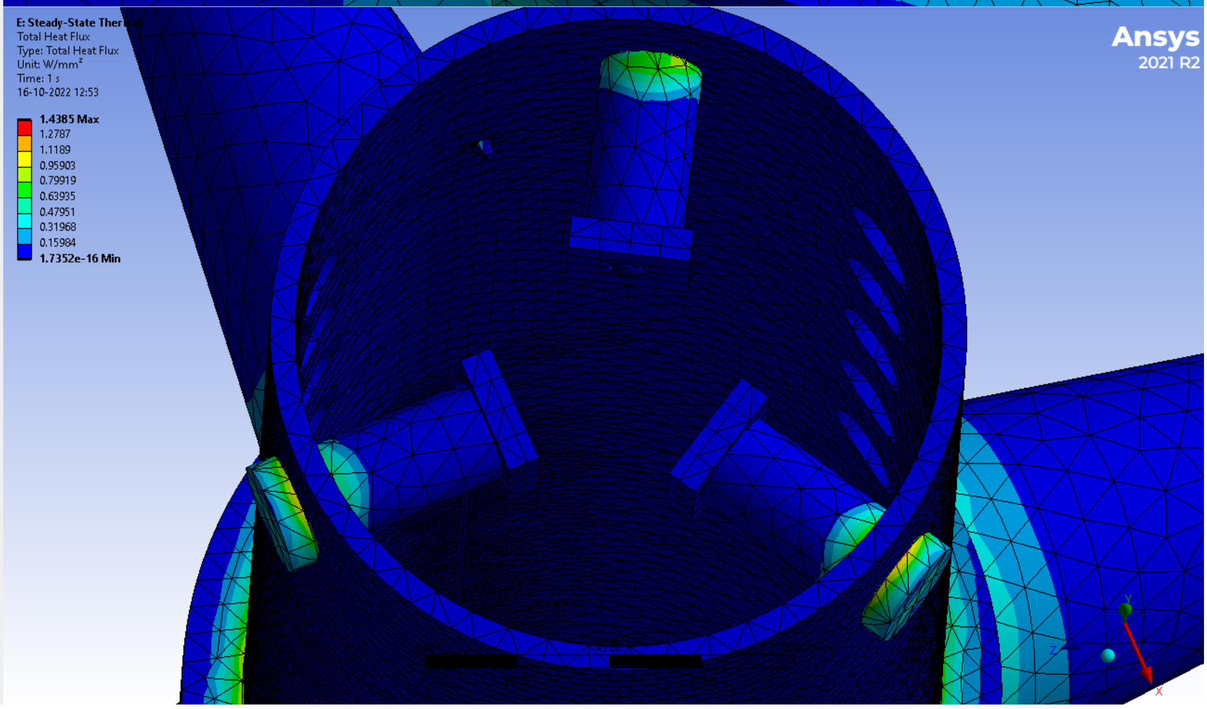


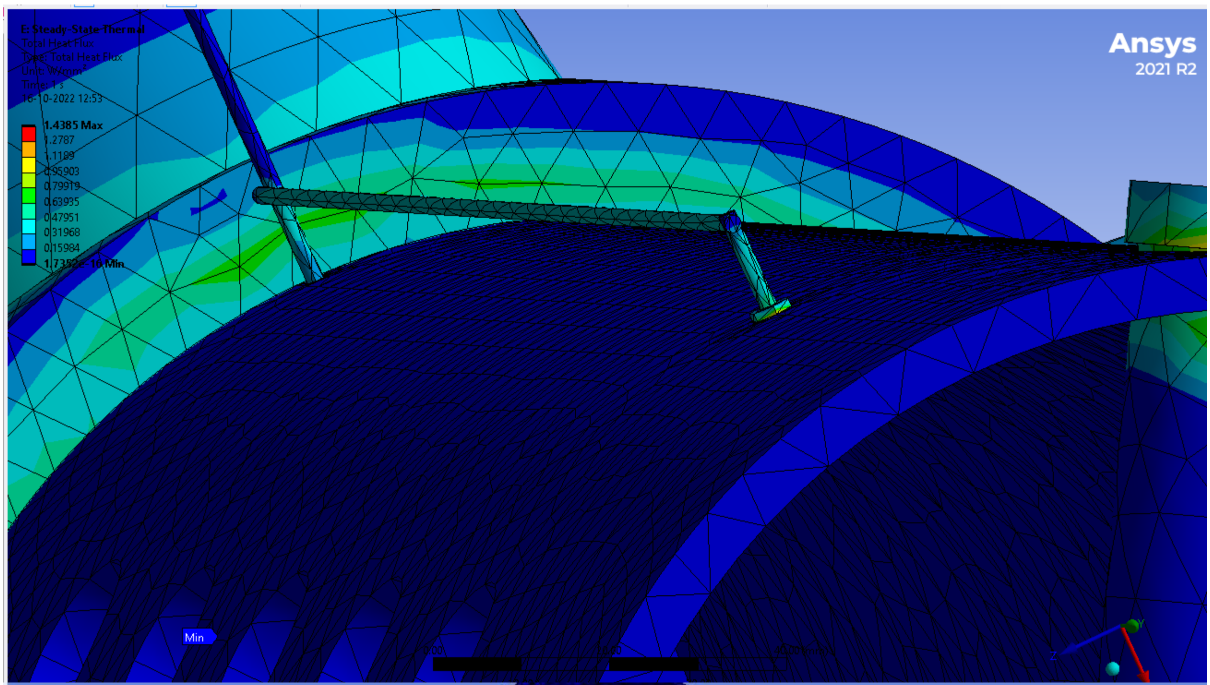
	Time [s]	Minimum [°C]	Maximum [°C]	Average [°C]
1	1.	99.998	1406.3	347.68

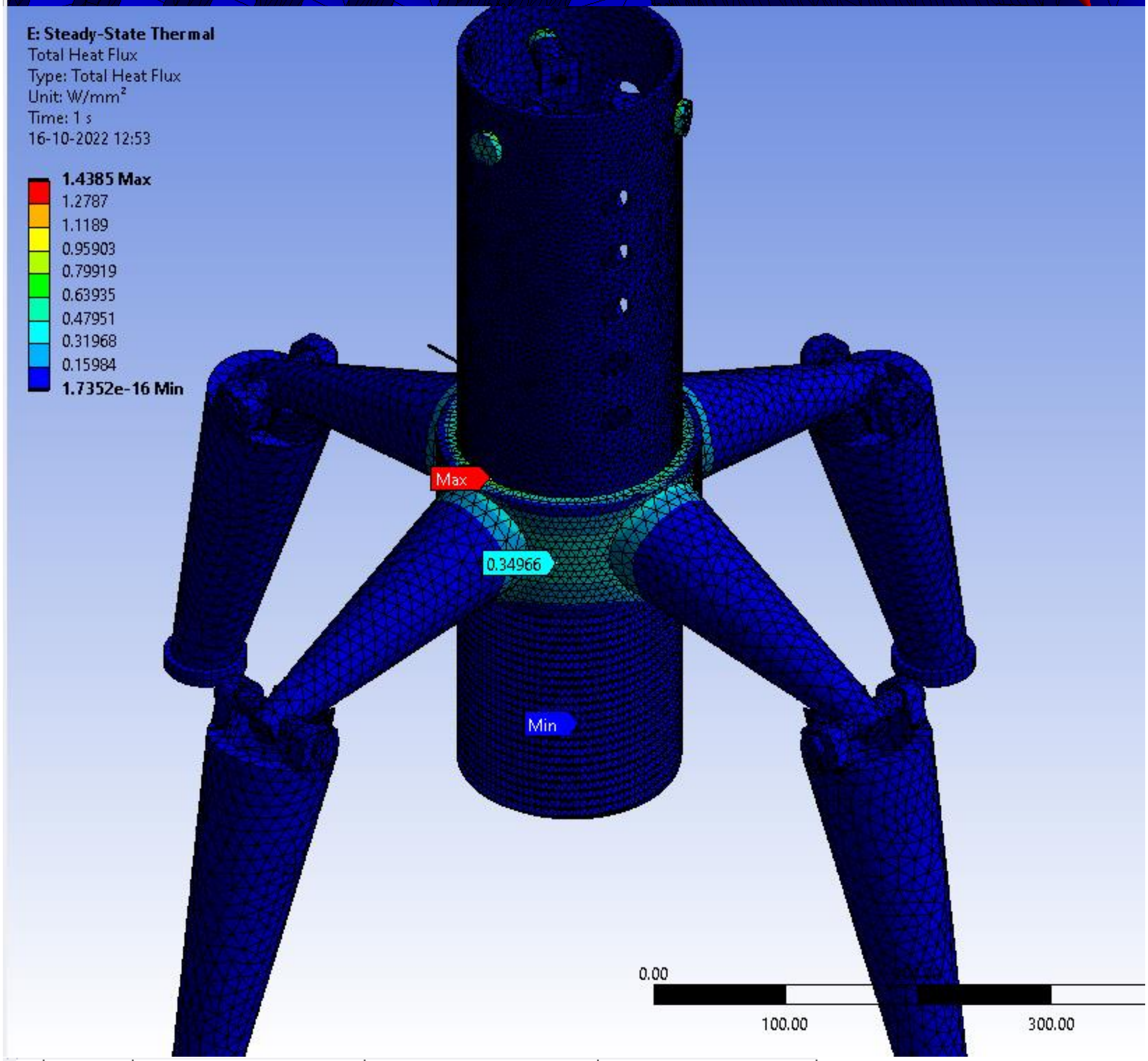
In the simulations conducted we observe that the maximum temperature is faced at the very top of the motor mount which is around 1406.3°C which spreads out to other components reaching a minimum of 99.998°C.Which well within the safe operating temperature range of these components. Hence it conclusive that the structure will be able to withstand the temperatures up to 1400 °C.

Heat Flux Analysis









	Time [s]	Minimum [W/mm²]	Maximum [W/mm²]	Average [W/mm²]
1	1.	1.7352e-016	1.4385	7.8295e-002

In the simulations conducted we observe that the maximum Heat Flux is faced at the very top of the motor mount which is $1.4385 W/mm^2$ which spreads out to other components reaching a minimum of $7.8295 \times 10^{-2} W/mm^2$.Which well within the safe operating temperature range of these components. Hence it conclusive that the structure will be able to withstand the temperatures up to 1400 ^oC.

Results:

Based on the above test results we conclude that the SPIDER STATIC TEST PAD is a well-designed product capable of testing Rocket Motors producing a thrust of 3000N and is capable of producing accurate results.

Conclusion:

The combined efforts of the Design and Avionics Team has put forth a viable product as a Static Test Pad for testing High-Power Rocket Motors that can measure thrust-time and Temperature-time characteristics for a wide range of motors. The work has been Contributed by my team members Vikrant and Dattasai under the guidance of shapers at STAR Labs, Surat, India.

Precautions:

- Keeping the motor clamped properly and providing a levelled surface for test pad for safe operations.
- Maintaining a safe distance while the motor is operational.
- This is a purely virtual design and will definitely require more work and troubleshooting post manufacturing.

Product Details:

- Weight 16Kg
- Height 50cm
- Base Area $3,200.05 cm^2 = 0.320005 m^2$
- Cost ₹17000