SUMMARY:

This design report will document the progression of propulsion integration for the MANTA aircraft. Specifically, the design decisions made and implemented to develop a final version of the hinge mechanism that will be implemented as part of integrating the propulsion unit with the rest of the aircraft will be discussed. Finite element analysis (FEA) was performed on the hinge mechanism and the results are presented. A brief discussion is provided for the work done last semester along with several other hinge designs that were under consideration.

Revision History

Version	Date	Description
A	07/04/2025	Initial version-peer review
B	08/04/2025	Final Version

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1.0 Scope

MANTA is a blending wing bodied aircraft designed primarily designed to haul cargo with VTOL capabilities. This report presents the design progression of a hinge mechanism for the Manta aircraft to satisfy one of its design requirements, having VTOL [1] capability by making all of the propulsion units have a range of motion from 0 to 90 degrees, in particular, a hinge mechanism for the actuation system to allow the riblets to have a range of motion from 0 to 90 degrees for achieving VTOL [1] capabilities. The purpose of designing this kind of mechanism is to give the motor assembly space when it actuates, and both the motor assembly and the riblets are meant to be actuating simultaneously.

The baseline for building a hinge for the riblets was a version of the wing design which was designed by the person in charge of the main wing [7].

The current design of the mechanism uses precision needle bearings to uphold the dynamic forces expected on the hinge. One of the design constrains was the C-shaped cross-section of the spars. Modifications done to the aft spar was minimal which was one of the design constraints in making this.

In performing FEA, the boundary conditions were set based on numbers provided by the main wing structures team member.

This report will provide a detailed insight on the rationale behind many of the design decisions, assumptions and results provided, along with a step-by-step progression from one design to another and why the other designs were discarded.

2.0 Airworthiness Standards

According to the Airworthiness Manual Chapter 523 for Normal Category airplanes -Canadian Aviation Regulations (CARs), Subchapter C- structures, an aircraft must have the follow the following,

2.1 523.2210 Structural Design Loads.

“Determination of the applicable structural design loads resulting from likely externally or internally applied pressures, forces, or moments that may occur in flight, ground and water operations, ground and water handling, and while the aeroplane is parked or moored [2].”

2.2 523.2215 Flight Load Conditions

“The applicant must determine the structural design loads resulting from the following flight conditions:

- (a) Atmospheric gusts where the magnitude and gradient of these gusts are based on measured gust statistics [2].
- (b) Symmetric and asymmetric manoeuvres [2].
- (c) Asymmetric thrust resulting from the failure of a powerplant unit [2]."

2.3 523.2225 Component Loading conditions

- "(a) Each engine mount and its supporting structure such that both are designed to withstand loads resulting from:
  - (1) Powerplant operation combined with flight gust and manoeuvre loads [2]; and
  - (2) For non-reciprocating powerplants, sudden powerplant stoppage [2]."

In terms of why mentioned the Airworthiness standards apply to the current design, it can be stated that in terms of "Structural Design Loads", it is crucial to know the path taken by the loads. In this case, the primary loads that are present in this situation, are the thrust produces by the motors and the weight of the motors, the moments resulting from the thrust and weight application. These are considered to be the primary loads and to make sense of the design, the load propagation must be known and accounted for. Similarly, in terms of "Flight Load Conditions", due to the change in orientation of the motor assembly, there are changes in the dynamics and load conditions during cruise. In terms of the "Component Loading Conditions", the engine mount is taken into consideration which was the focus of design in Fall 2024[]. As the motor mount structure is the primary connection between the propulsion unit and the attachment lug which then transmit the load to the aft rib section.

3.0 Project Management

Weekly updates on the progress were reported every Monday on the scheduled meeting time for the BEFAV team. Constructive feedback was given on these weekly updates by the project managers and the feedback was used to improve for future presentations and project work. Aside from this scheduled project meeting, weekly discussions were held every Monday evening with the lead engineer for the structures team and technical aspects for each component were elaborated on. Difficulties or setbacks faced during the development process of everyone's part were also cleared in the Monday meeting. In terms of individual time, 15 to 20 hours per week were dedicated to the work on the hinge design and related components.

Lastly, depending on everyone's work, meetings were scheduled personally with specific members from team A and C to discuss certain aspects of our design due to the interconnective nature of this project where the Controls and Aerodynamics team needs to share information.

Initial plans for the hinge mechanism were laid out at the end of the previous term. Weekly updates were given via presentation slides to the entire team which included Gantt charts showing the timeline of development. An updated Gantt chart and work breakdown structure was attached in the appendix section, Figure 23 and 22.

Out of the 4 primary tasks highlighted in the WBS, most of the objectives were achieved as the winter WBS primarily focused on hinge mechanism as seen in figure 22. Similarly, in the Gantt chart, the timeline set to achieve a completed hinge mechanism was also achieved as seen in figure 23

4.0 Design

In this section, the design of different iteration of the hinge design will be shown along with a brief discussion on why they were ultimately discarded. The current design will be explored at the end of this section.

4.1 Previous Term Work

Before the start of the winter 2025 semester, a complete design was formulated for the motor mount and four different configurations were tested in ANSYS. The four configurations of the design was the traditional truss structure with spar attachment and rib attachment, and a topology optimized design with spar and rib attachments.

When comparing the stress and deformation values for all four configurations, it was found out that the topology optimized structure with the spar attachment had the best performance in terms of minimizing stress compared to predecessor's design. Primary takeaways from analyzing these four configurations were that all designs experience axial bending and twisting of the semi-circular brackets to hold the motor in place, the lugs experienced stress concentrations at different areas, and the detailed results can be seen in the fall report [6]

4.2 General overview of the hinge mechanism and design criteria

The topic of discussion in this report is a hinge mechanism which will be able to achieve a range of motion from 0 to 90 degrees. Behind each decision taken to achieve this, the path of the load propagation was the primary catalyst. A flowchart explaining the load path is illustrated in figure [] in the appendix.

The loads considered in this case are the thrust and weight which are propagated along all of the components illustrated above.

To make sure that the load propagation is occurring properly, special considerations were taken when designing and fixing on the current hinge design relating to the spar. This was done as the spar, which is the primary beam component of the wing, is meant to handle all the major loads which are experienced by the wing like lift, drag, torsional loads and wind gust loads. Making any sort of major modifications like cutting the spar will disrupt the load distribution capabilities of the wing, as opposed to making cuts/modifications on the rib, which primarily serves to maintain the airfoil shape. The final design discussed in this report avoids making any major modifications to the spar by fixing the shaft with supports which are bolted onto the Aft flat surface of the C-shaped spar.

4.3 Slotted Design Concept

This mechanism achieves the desired range of motion by having the thickness of the riblets being increased by 3 mm on both sides so that a slot can be used to overlap the mid-rib section.
Initially, this design was entertained as the intend was to achieve a structurally sound mechanism where there are minimal modifications to the mid-section of the rib. But adding thickness to the aft rib section will result in more added mass.
Precision needle roller bearings of diameter 40 mm with a shaft diameter of 25 mm are used in each riblet, and a singular shaft is used to drive all of the ribs which is meant to be press-fitted into the bearing shafts. One of the advantages of this configuration is the low placement of the drive shaft, which is at the bottom tip of the riblet, allowing more space for other components like a rotary actuator which is supposed to be placed between the spaces in each rib section as seen in Figure 1.
The drawback of this design is evident by the fact that a small section of the spar had to be cut to accommodate the full rotation of the riblet which as discussed previously, is not possible as it will disrupt the spars capability of handling applied loads on the wing.

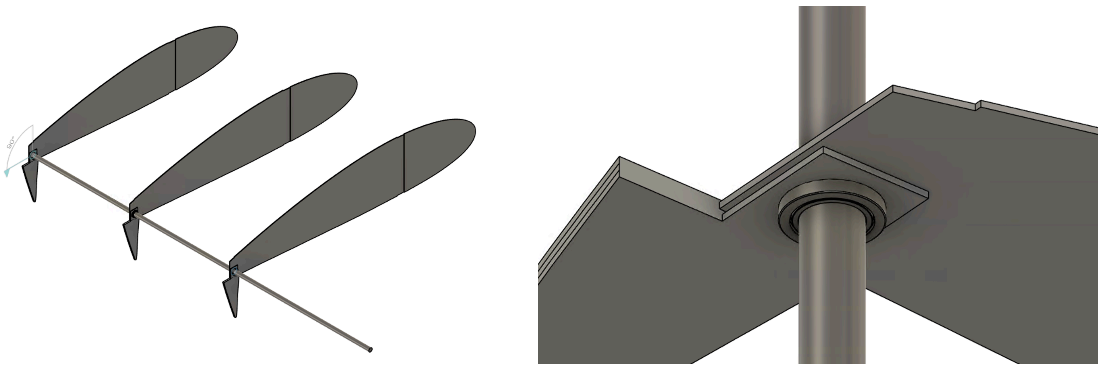

Figure 1: Slotted mechanism for aft rib section hinge

4.4 Protruding Bearing Housing Concept

This configuration was pursued to minimize cutting into the spar, but this was not fully developed as a decision was made to not cut into the spars at all.

A bearing housing was made by making a 20 mm wide cut at the bottom edge of the spar as seen in Figure 2. Precision needle roller bearings with a shaft diameter of 15 mm were used for the hinge mechanism and a linear servo actuator was planned to be fitted in order to drive the riblets.

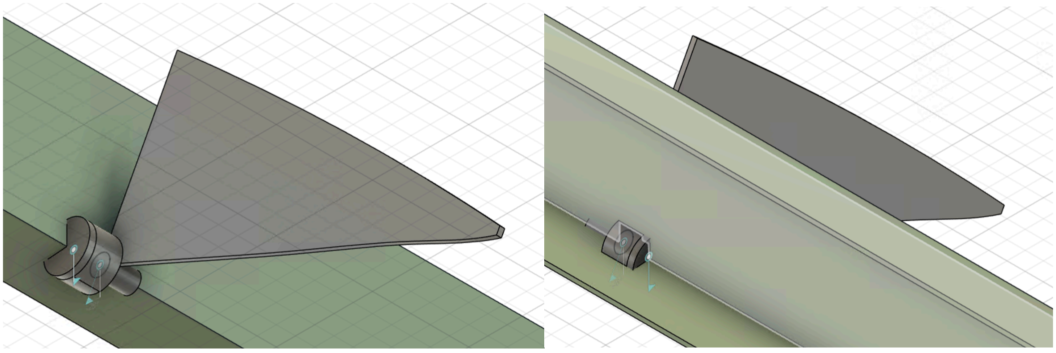

Figure 2: Bearing cut-out design of aft rib section for hinge

4.5 Protruding Hinge Concept

Before coming to a conclusion on the current design, the protruding hinge design was entertained, and this design gave a few benefits over the other ones in the sense that no modifications were done to the spars at all.

In terms of drawback of this design, as seen in Figure 3, a semi-circular extension was created to bypass the spars altogether, and this component will tend to protrude from the skin and a separate housing for this part would have to be designed which will be added weight including the weight of the shaft and the motors.

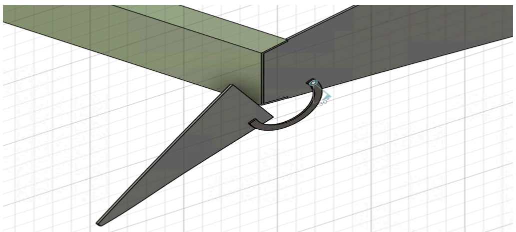

Figure 3: Protruding hinge design of aft rib

4.6 Current design

Before choosing the current design, a weighted criteria study was done and each criterion was scored out of a 100 points with 3 major criteria contributing in the decision behind choosing one design over the other. As seen in Table 1, the highest importance was given to the ability have uniform load propagation and as seen by the final score of 69/100, the current design was chosen as this was the one which satisfied all three of the criterions.

Table 1: Weighted design criteria table

		Assigned Score			
Criteria	Weight	Protruding Hinge Concept	Protruding Bearing Housing Concept	Slotted Design Concept	Current design
Uniform load propagation	60%	70	30	20	80
Added weight	30%	20	40	20	50
Aerodynamic efficiency	10%	30	20	50	60
Weighted scores	100%	51	32	23	69

After experimenting with different configurations of the hinge mechanism, the current design solves the problem of making cuts into the spars by moving the pivot further away from the spar and then using a singular shaft to drive the entire set of riblets at the same time.

As shown in the Figure 4 two circular shaft mounts were designed which holds the drive shaft on both ends of the spar and they are intended to be bolted together with the spar.

Both ends of the spar are held together by precision needle roller bearings and the driving mechanism is intended to be placed in between a riblet and a mount that is in the vicinity of the fuselage as this arrangement allows all heavy components to be near the centre of gravity of the airframe. The bearing selection was not finalized at this stage

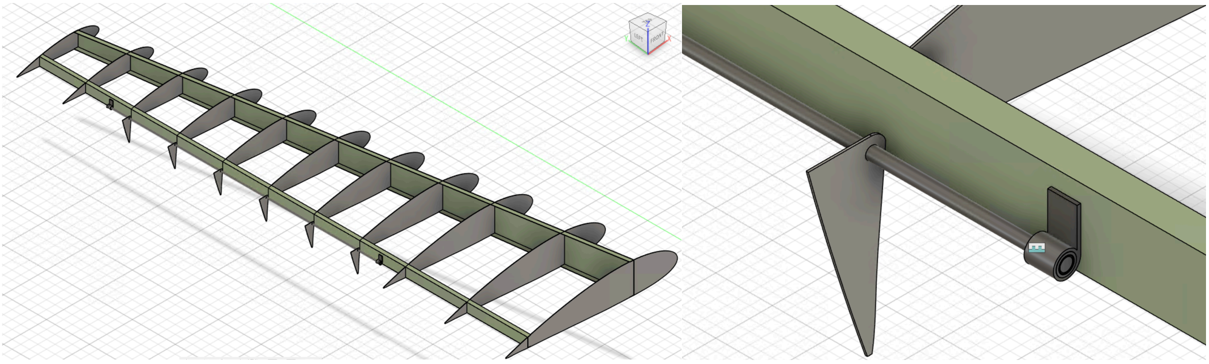

Figure 4: Current design

4.6.1 Newest Iteration of Current design

After changes were made to the entire wing structure, specifically topology optimization was performed by the wing design team and the shape of the aft spar section was changed to include a C cross section as seen in Figure 5. Moreover, 5 mounting holes were created as seen in figure 5 for the new attachment lugs and the pivot holes were modified to accommodate a keyed shaft.

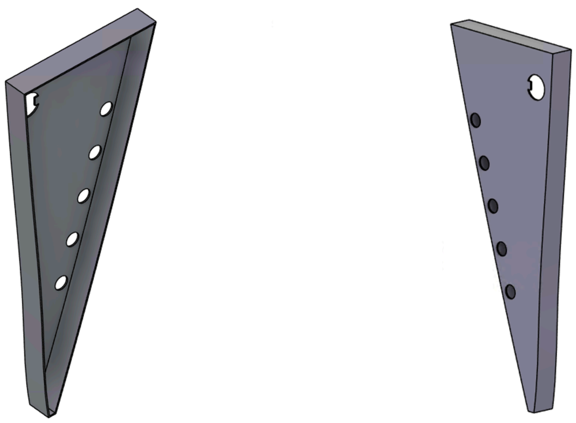

Figure 5: Modified Aft rib section of newest iteration

Before going in depth about the new iteration of the hinge design, the areas where the design was improved are tabulated as shown in Table 2,

Table 2: Differences between early and new iteration

Criterion	Early iteration	New iteration
Number of drive shafts	One drive shaft 6 to 8 rib section	One drive shaft for four rib sections
Number of shafts supports	Two shaft supports in each wing	Eight shaft supports per shaft
Distance of aft rib section from spar	Aft rib flush with the spar	Shaft was shifted 8 mm backwards
Number of bearings	Two bearings per shaft	Eight bearings per shaft

The decision to increase the number of shafts and bearings was done to distribute the load carried by each.

Figure 6 will depict the newest iteration of the current design showing a shaft which carries the load transmitting from 4 propulsion units. And Figure 8 will also show clearly the changes made, like the new design having 8 shaft supports and 8 bearings.

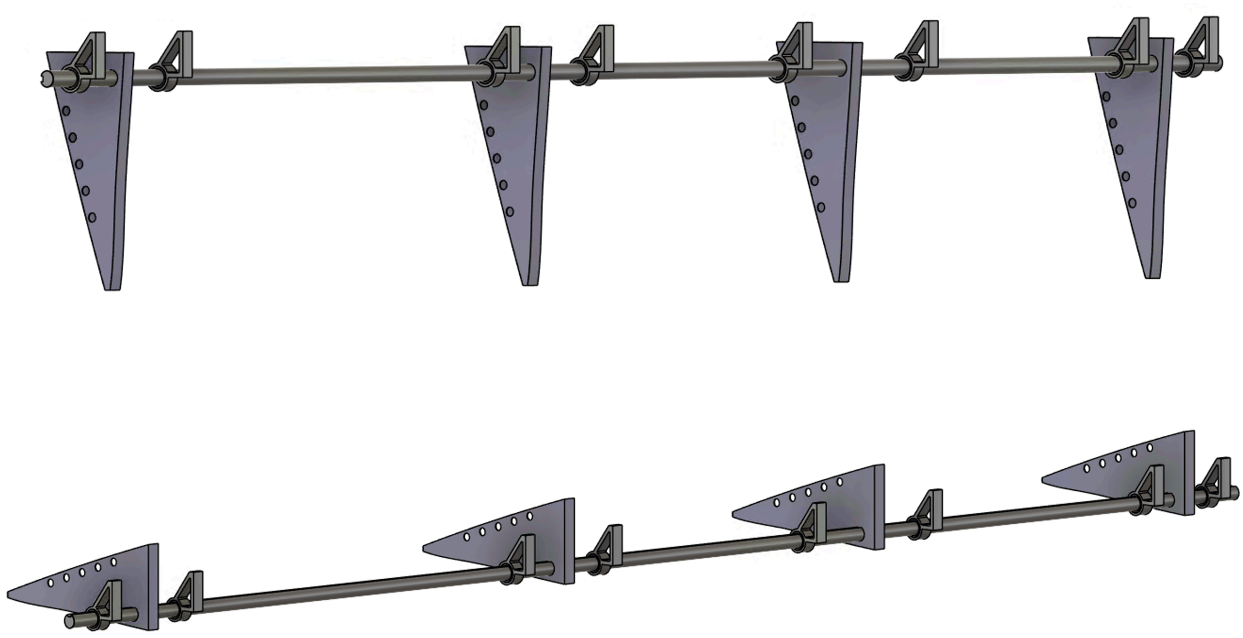

Figure 6: New iteration of hinge design

For simplifying the analysis, some assumptions/design decisions were taken as bearings were replaced by dummy bearings which were used in the model instead of the actual bearings, but the dimensions of the dummy bearings were kept the same as this bearing model.

Additionally, shaft supports were designed to adjust the position of the shaft in order to give the Aft rib section clearance to rotate in order to avoid contacting the spar and the redesigned shaft support was able to push the shaft by 8 mm. The shaft support is depicted in Figure 7,

Figure 7: Shaft support

4.6.2 New attachment lug design

As changes to the aft rib section were made, a new attachment lug was designed so that it can perfectly contour around the flanges, the design is based on the aft rib section and follows its general profile. As depicted in figure 8,

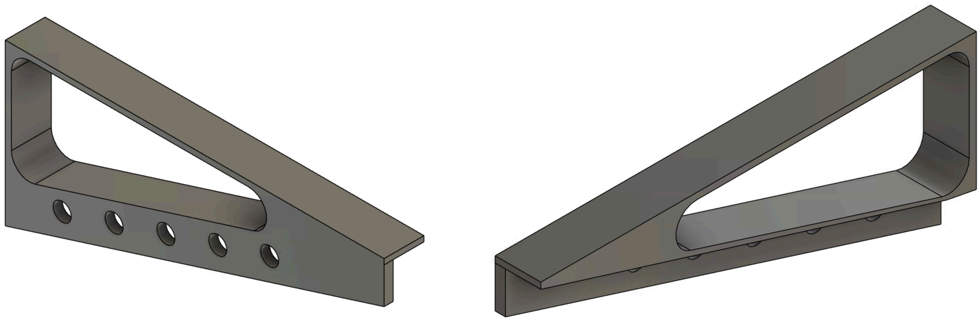

Figure 8: Attachment lug design

4.6.3 Complete assembly

The complete assembly consists of the motor mount from Fall 2024[6], attachment lung, and the aft rib section, as seen in Figure 9, a single propulsion unit is shown and in Figure 10, the full assembly on a single shaft is shown and two of these assemblies will be on each of the main wing.

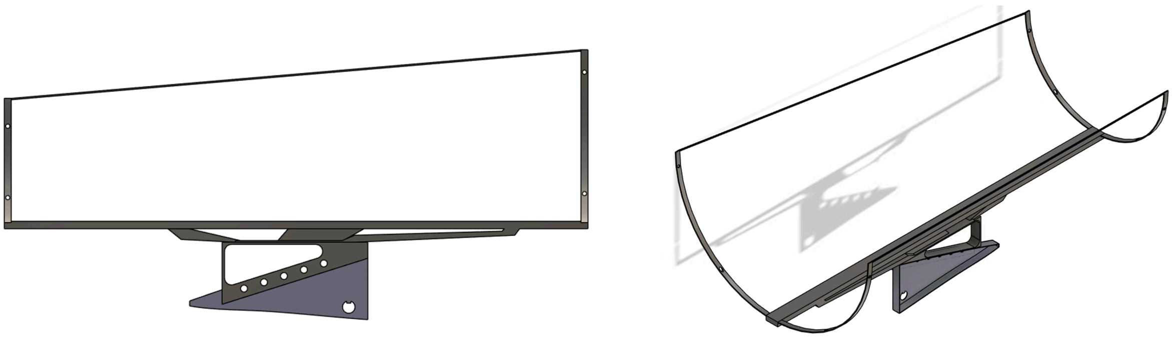

Figure 9: Singular propulsion unit

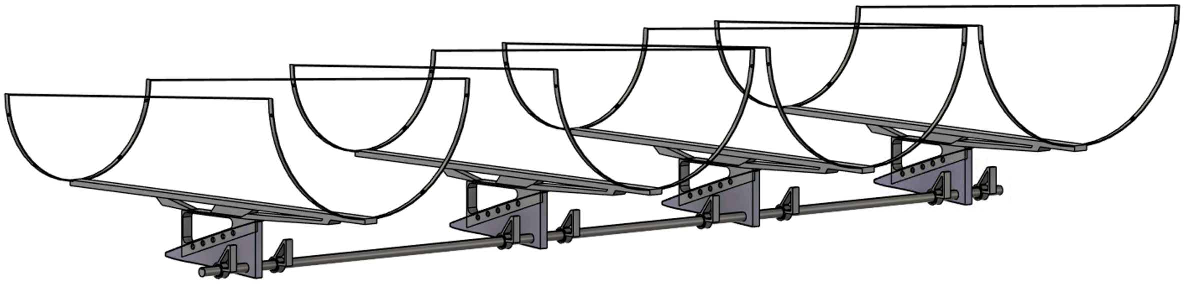

Figure 10: Complete assembly with 4 propulsion units

5.0 Finite Element Analysis of hinge designs

This section will document the Finite Element Analysis of the new iteration of the current design. Two configurations of the riblets were chosen to do a finite element analysis, In the first configuration, all the riblets are actuated fully to 90 degrees, and the second one is when they are at 0 degrees, resting position. The rib sections were set to 2D elements and shaft, shaft support, bearings were set to 2D elements.
More information about meshing will be found in section 5.4

5.1 Boundary conditions

In terms of loading conditions for VTOL configuration, the force figures were taken from the wing design team, which were 5248.4 N of force, representing the weight of all the motors combined on one main wing was applied in each of the mounting holes. The 5248.4 N figure was divided by 2 for 2 shafts in each main wing, getting force value of 2624.2 N, and this value was divided by 4, to get the individual forces acting on each rib section by each motor, 656.05 N. This force value will act in the -z direction in each rib section and the point of application are the 5 mounting holes. Additionally, a force of 1524 N which is the trust, obtained from the ducted fan engineer was applied in the +z direction at the same location, which gives a resultant force of 867.95 N acting in the +z direction, as seen in Figure 11.
Additionally, moment caused by the thrust acting in the +z direction was calculated and applied at the same location as the force as well, which are at the 5 mounting points in each rib. The moment calculation is given below,
Assumption is made about the line of action of the force, it is assumed that the thrust and weight is acting through the midpoint of the center of the inlet.
The distance is assumed to be 0.246 m [6], and the direction is set to -x, so distance,

$$d = -0.246\hat{\imath}$$

Force, $F = 867.95\,\hat{k}$, so, Moment, $M = -0.246\hat{\imath} * 867.95\hat{k}$

$$= 213.5177\hat{\jmath}$$

The moment is acting in the +y direction as seen in Figure 11.

Fixed supports were applied at the back flat surface of each of the 8 shaft mounts, as they are supposed to be bolted onto the spar.

For Cruise condition. The thrust 1524 N was applied at each of the rib sections acting through the mounting holes of each rib and the weight of the motors, 656.05 N was applied perpendicular to the thrust at the same location. Moments were also applied in the same direction, and it was calculated by, distance

$$d = 0.246\hat{k}$$

Force=thrust,$F = -1524\hat{\imath}$, Therefore, Moment, $M = 0.246\hat{k} * -1524\hat{\imath}$

= -379.332j

The moment is acting in the -y direction as seen in Figure 12. Fixed supports were set at the same position, at the back flat surface of the shaft support.

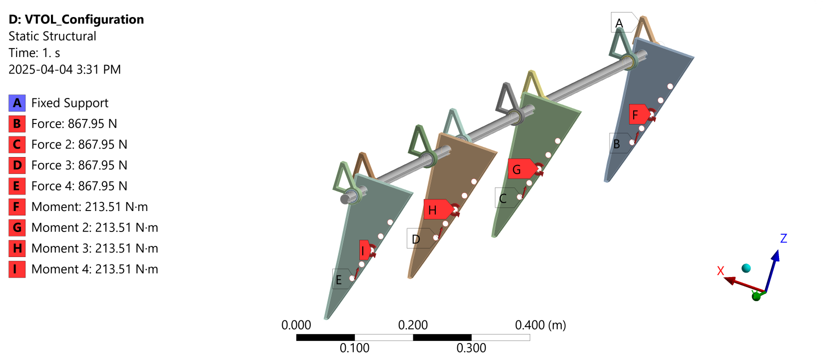

Figure 11: Boundary and loading Conditions at Cruise for aft rib section

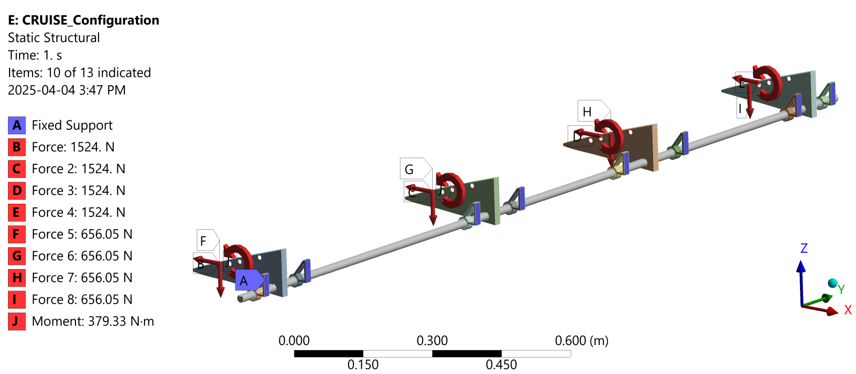

Figure 12: Boundary and loading Conditions at Cruise for aft rib section

All of the force and moments were set to be simulated through the 5 mounting holes in each rib section as this is where the entire propulsion unit meets the hinge mechanism.

5.2 Total deformation

Total deformation in both cruise and VTOL were detected at the tip of the aft rib section. In cruise, the deformation was recorded as 1.3 cm and during VTOL, the deformation was recorded as 7.2 mm. The reason behind high deformation in cruise can be attributed to less supporting structures at the aft rib section and as result, in both cases, the deformation is consistent with the behaviour of a cantilever beam as in one end is fixed and forces and moments are acting on one surface through the mounting holes. As a result, the free end of all of the ribs is experiencing deformation due to lack of a supporting structure as seen in Figure 13,14 and 15.
This can be mitigated by reinforcing the free end with either a shaft-like structure or a miniature spar/beam.

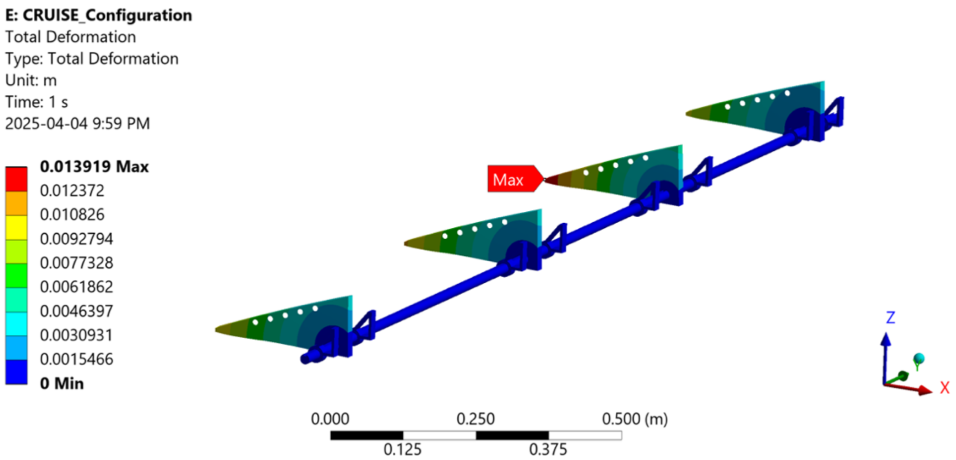

Figure 13: Total deformation during cruise condition of the Aft rib section

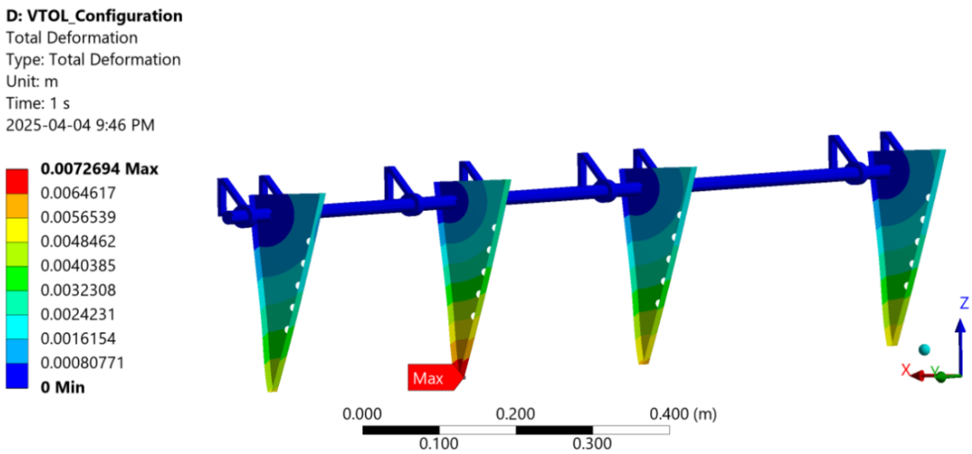

Figure 14: Total deformation during VTOL condition of the Aft rib section

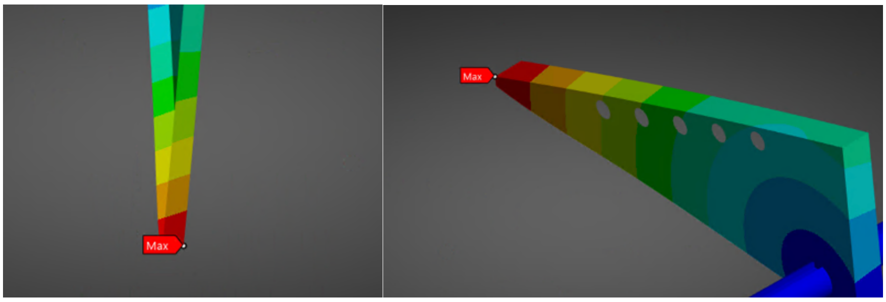

Figure 15: Total deformation during VTOL [left] and cruise[right] condition[Zoomed] of the Aft rib section

5.3 Stress

Maximum stress in both the cases are observed at the junction between the pivot/keyed shaft hole and the shaft. The thickness being just 1 mm at the rib sections is unable to contain the twisting caused by the thrust and weight acting through the rib section.

To mitigate this issue, specific parts of the rib section, namely the shaft/rib junction needs to be reinforced with more material. This can be done in the form in increasing the rib thickness in specific areas, like at the junction. The recorded stresses were 1.89 Gpa as seen in Figure 16 for cruise condition and 0.952 Gpa as seen in figure 17 for the VTOL condition.

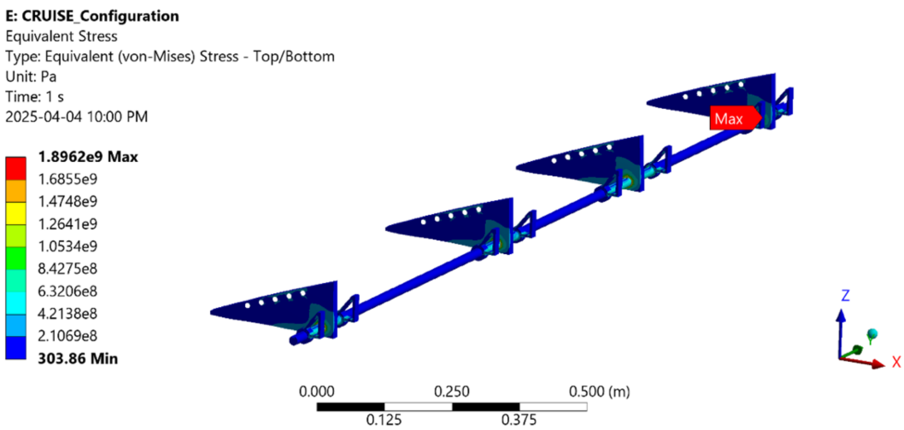

Figure 16: Equivalent stress during cruise condition of the Aft rib section

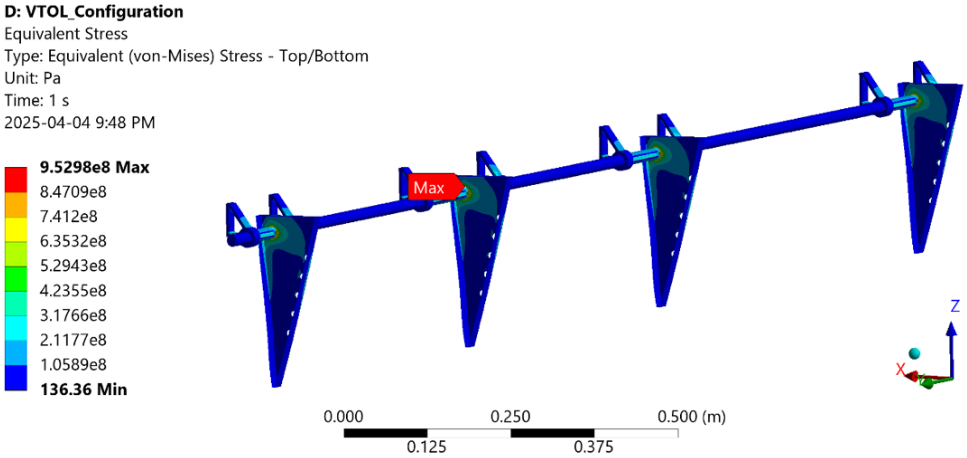

Figure 17: Equivalent stress during VTOL condition of the Aft rib section

Figure 18 shows a zoomed in view of the stresses at the junction location.

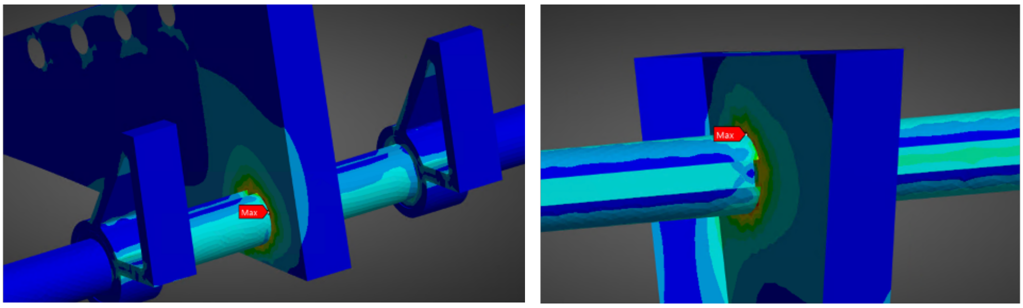

Figure 18: Equivalent stress during cruise [left] and VTOL [right] condition [Zoomed] of the Aft rib section

5.4 Summary of Mesh characteristics

The aft rib section was done as a 2D mesh for more accuracy as the minimum thickness is 1mm. 2D elements were achieved by mid-surfacing selected parts like the rib sections. All of the other components like the shaft supports, shafts, bearings were done using 3D elements.

In terms of mesh quality, all mesh metrics except for aspect ratio are close to the acceptable range as the aspect ratio is 52.9, this is because the element size is bigger than the smallest thickness present in the model. This resulted in bad elements. This is also due to the geometry at the junction region between the rib section and the shaft.

Table 3: Mesh details

	Cruise	VTOL
Element size	4.171e-3	4.171e-3
Nodes	155462	155243

Elements	87333	87281

Table 4: Mesh metric [VTOL]

Mesh metric	Ideal Value [5]	Minimum	Average	Maximum
Element quality	1	5.4886e-2	0.82629	1
Aspect ratio	1	1.0001	2.0727	52.9
Jacobian Ratio (Corner nodes)	1	2.537e-2	0.92117	1
Skewness	0	1.7446e-5	0.25854	0.99953

The mesh metrics for Cruise condition are very similar so they are not shown in this section, but all of the mesh metric graphs were attached in the appendix in Figure 24,25,26,27

5.5 Conclusion regarding FEA

The reasons for high deformation and high stress can be attributed to the reasons talked about in section 5.2 and 5.3. The bad mesh quality can be resolved by fixing some parts of the geometry like the junction points, by making them reinforced.

6.0 Bioinspiration

6.1 Bird bone inspired T joints

This concept was first introduced for the motor mount structure to reduce stress concentrations in parts with irregular geometry, but this concept can also be relevant in structures related to the hinge mechanism as parts can be machined with this concept in mind.

Traditional T joints or L joints are prone to high stress concentration at the bends which can cause delamination failure [4]. Taking inspiration from bird bones, a new method for implementing T, L or any type of joints with a bend are being tested and implemented which show significant improvement over traditional joints. The governing principle behind this idea can be found by looking at the intricate structure of bones from the wings of different birds. It can be observed that a bird bone has a thick exterior but a hollow, chambered interior. This results in a greater radius for the bend to propagate stress to and the hollow interior acts as a damper, and this also provides space for the structural component to expand into [4].

Following this basic structure, the traditional T joint can be improved by eliminating the sharp angle between the flange and the web, making a chamfered edge and inserting a damping material like foam inside a cavity which lies inside the junction between the web and the flange.

This design principle can be implemented in the Manta's motor mount, as well as in certain components of the riblet to eliminate the stress concentration developed in 90-degree bends, like in certain portion of the riblet, where cuts are made to avoid overlap.

If we look at the work on the motor mount designs done in last semester, a clear analogy between the proposed change to the Manta's motor mount can be visualized by looking at Figure 19 and comparing it to the specific location of high stress mentioned in the motor mount design illustrated in Figure 20.

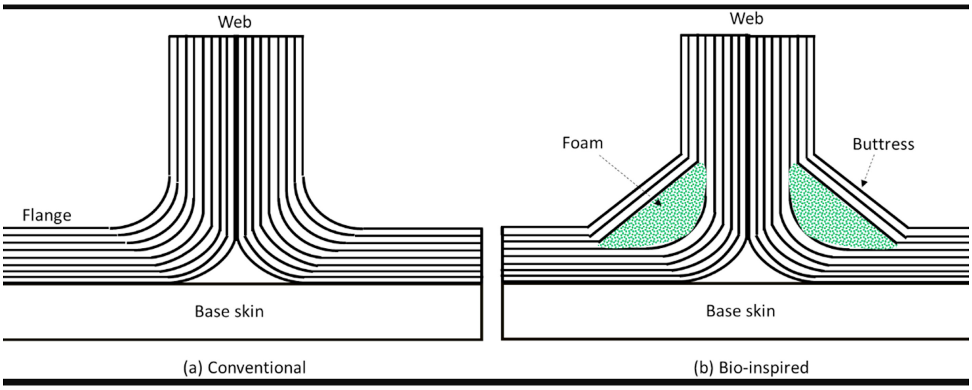

Figure 19: Bird bone inspired T joint [4]

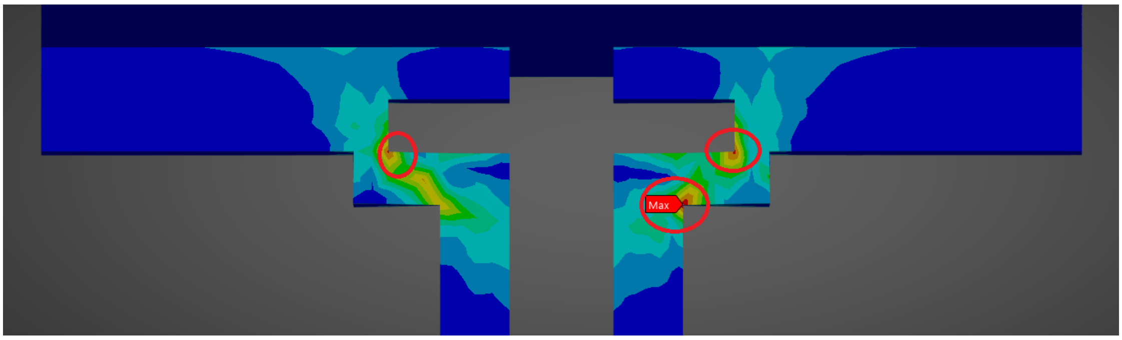

Figure 20: Stress concentration points in the motor mount [6]

The areas in marked in red can be improved by implementing this design philosophy. The results from a tensile-load test are tabulated below in Table 5 to show in improvements from the novel design [4].

Table 5: Tensile test comparison

T- Joint	Peak load (kN)	Displacement at damage initiation (mm)	Elastic stiffness (N/mm)	Source
Bird bone Inspired	7.20	1.38	4081	[4]
Conventional	5	0.83	2425	[4]
% improvement	44	66	68	[4]

According to the data, significant improvements can be seen across the board and implementing this in MANTA would also allow the use of more complex geometry across small junctions like between the riblet and the spar.

7.0 Environmental Impact of Designs

One of the main aspects of the BEFAV team is to make a product which will be environmentally friendly by incorporating bioinspired elements into the design language. Taking inspiration from the natural world helps in keeping the design environmentally friendly. This aspect becomes more relevant for the structures team as all the designs mentioned were formulated with efficiency in mind. Some of the accepts which needs to be discussed are weight of the aircraft and the bioinspired component of the design. Weight saving is important for a project like this as more weight will mean more energy and as a result, more emissions. By utilizing methods like topology optimization, significant weight savings were done by cutting off material where it is not needed. Secondly, in terms of the bioinspired aspect, the bioinspired lubricants and bird bone inspired T-joints show increased efficiency in loading conditions and other aspects which will allow the design to be more efficient. Moreover, the electric propulsion system of the MANTA has a very low carbon footprint.

8.0 Conclusion

The improvements made to the current design after the midterm report attributed to the design being more refined. The addition of more bearings, shafts and shaft supports helped in decreasing the overall stress and deformation as the load was divided into two shafts per main wing as compared to one shaft for the entire wing.

The current issues with design can be fixed with improvements to the junction region of the aft rib section and the shaft, including adding reinforcements to the aft rib section.

Moreover, implementing the bird bone inspired T joints in the shaft supports and some parts of the motor mount will also result in a better design.

After looking at the current design for the hinge mechanism, this can be considered to be a start in the right direction as the primary constraint for designing this mechanism, which was to make a hinge mechanism that actuates the desired range by also maintaining structural integrity of the spar was met.

9.0 Recommendations and future work

If the current design iteration of the aft rib hinge mechanism is continued to be developed, then the recommendation mentioned in section 5.2 and section 5.3 about reinforcements by adding thickness and fixing the ribs with a beam will fix majority of the design challenges.
Refinement of the mesh can be done as well by changing and trying out different mesh parameters. Additionally, next steps should be to work with the controls team, team c in implementing a suitable actuator which can allow the motion to happen for both the motor mount and the aft rib sections.

General recommendation is to not make any major modifications to the spars and to increase the thickness of certain parts of the aft rib sections. If an extra spar or beam is decided to be fixed at the aft ribs, then it will have to determined if the motion range is still possible, with 0 degrees at cruise and 90 degrees at VTOL configuration

10.0 References

[1] Microsoft teams, MAAE 4907O- BEFAV Design Project- 2024-2025, "Design Requirements-Summary.pdf"

[2] Government of Canada, "Airworthiness Manual Chapter 523, subchapter C-structures -Normal Category Aeroplanes-Canadian Aviation Regulations (CARs)," 2024.[Online].URL: https://tc.canada.ca/en/corporate-services/acts-regulations/list-regulations/canadian-aviation-regulations-sor-96-433/standards/airworthiness-manual-chapter-523-normal-category-aeroplanes/airworthiness-manual-chapter-523-subchapter-c-structures-canadian-aviation-regulations#523-2200

[4] ScienceDirect, Roya Akrami, Sakineh Fotouhi, Mohamad Fotouhi, Mahdi Bodaghi, Joseph Clamp, Amir Bolouri, High-performance bio-inspired composite T-joints,Composites Science and Technology,Volume 184,2019,URL: https://www.sciencedirect.com/science/article/pii/S0266353819324170

[5] MECHEAD, URL https://www.mechead.com/mesh-quality-checking-ansys-workbench/

[6] Shadman Sakib Rashid, fall design report, Microsoft teams general folder, 2024-25, deliverables, fall 2024, shadman sakib rashid.

[7] Half_wing_topology_optimization_interation2.iges, Author: Laura Morris

Appendix A

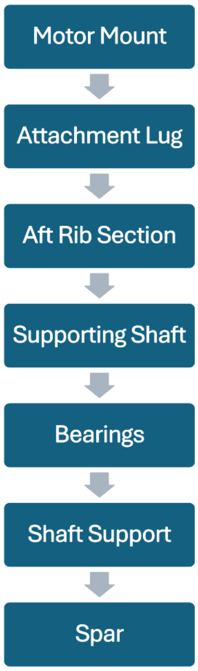

Figure 21: flowchart describing load path

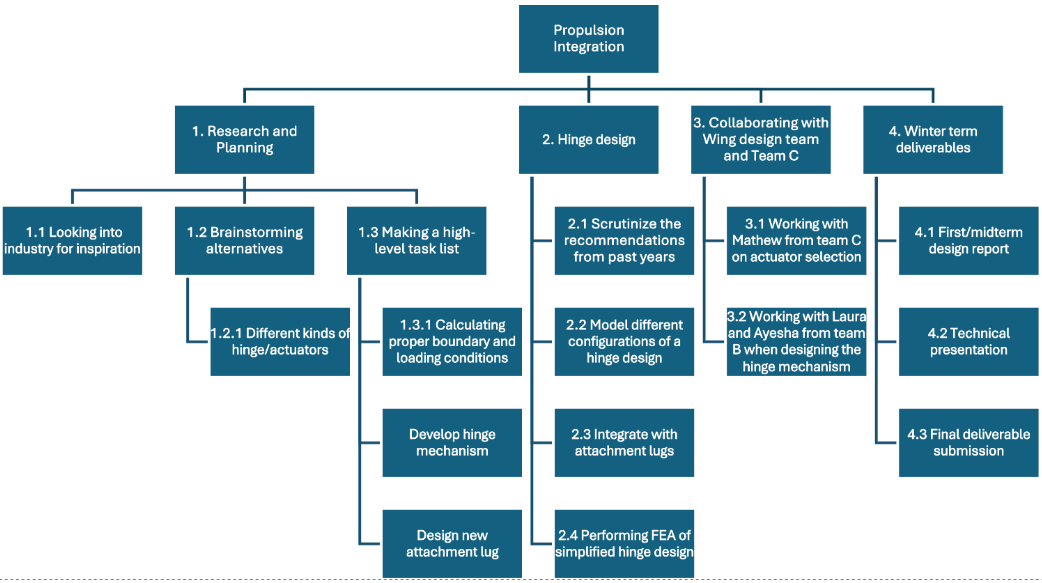

Figure 22: Work breakdown structure

[BEFAV]

TASK NAME	START DATE	END DATE	DURATION (days)
Research on Actuators	2025-01-01	2025-04-01	91
Testing out different models/ Calculating	2025-02-01	2025-03-30	58
Research on hinge designs	2025-01-15	2025-04-01	77
Hinge ieration 1	2025-01-20	2025-01-30	11
Hinge iteration 2	2025-02-05	2025-02-20	16
Hinge iteration 3	2025-02-25	2025-03-03	7
Current hinge design	2025-03-01	2025-04-05	36
Research on locking mecha	2025-02-15	2025-04-15	60
Selecting actuator for riblet	2025-02-09	2025-04-08	59
Calculating forces required	2025-03-08	2025-03-30	23
Running FEA on hinge design	2025-01-15	2025-04-05	81
Iterating all the FEA for mid-s	2025-02-27	2025-03-25	27
Making new Lug	2025-03-10	2025-04-01	23
Modifying aft rib section	2025-03-15	2025-04-03	20
Modifying motor mount from	2025-03-10	2025-04-01	23
Work on midterm report	2025-02-28	2025-03-10	11
Work on final report	2025-03-10	2025-04-15	37
Work on final design present	2025-03-20	2025-04-10	22
Evaluating out full assembly	2025-03-10	2025-04-03	25
Work Technical presentatior	2025-03-10	2025-03-24	15

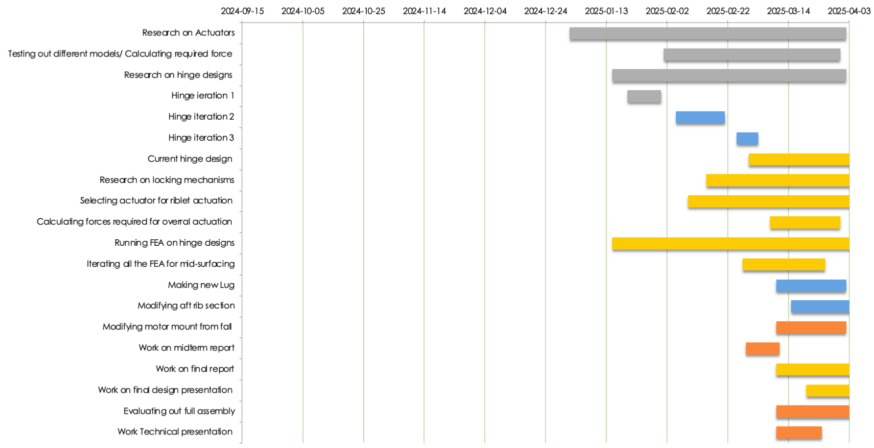

Figure 23: Gantt chart

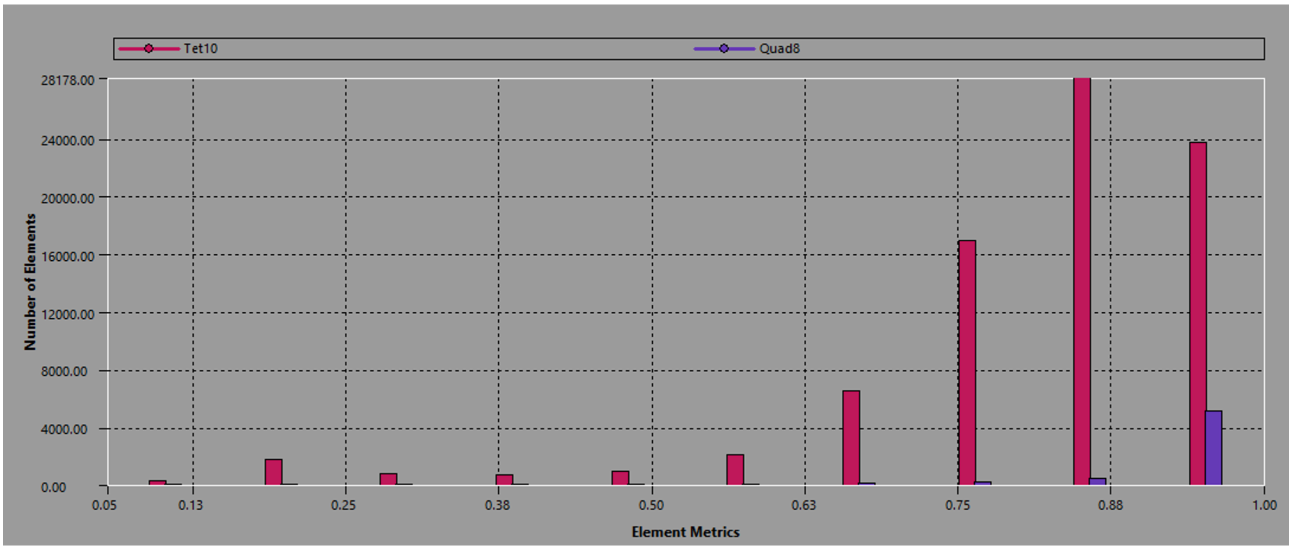

Figure 24: Element quality

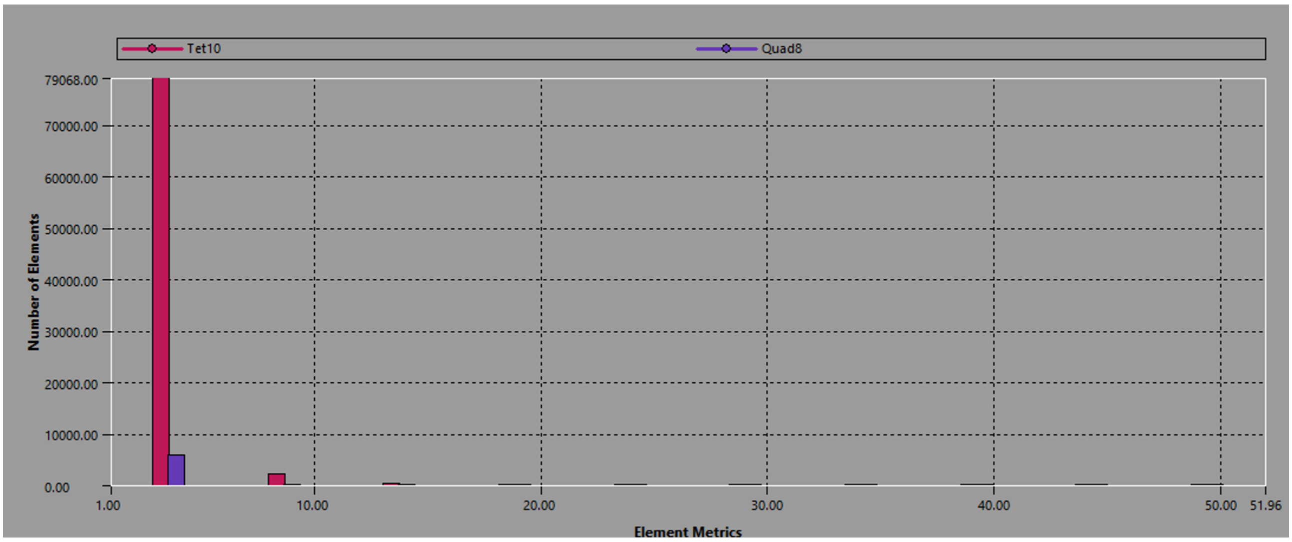

Figure 25: Aspect ratio

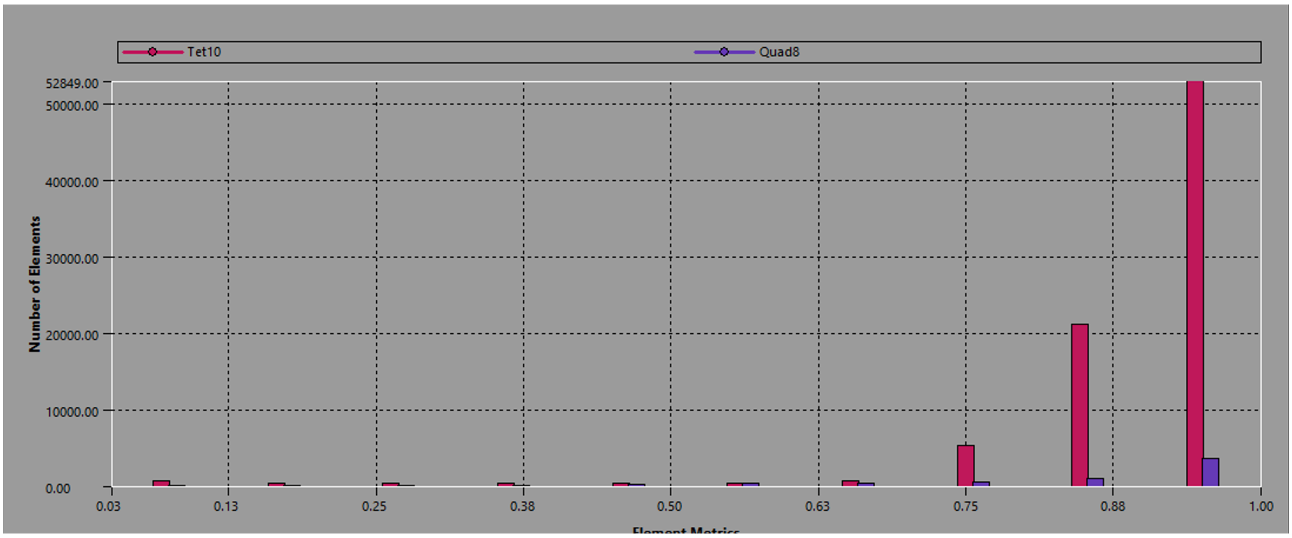

Figure 26 : Jacobian ratio

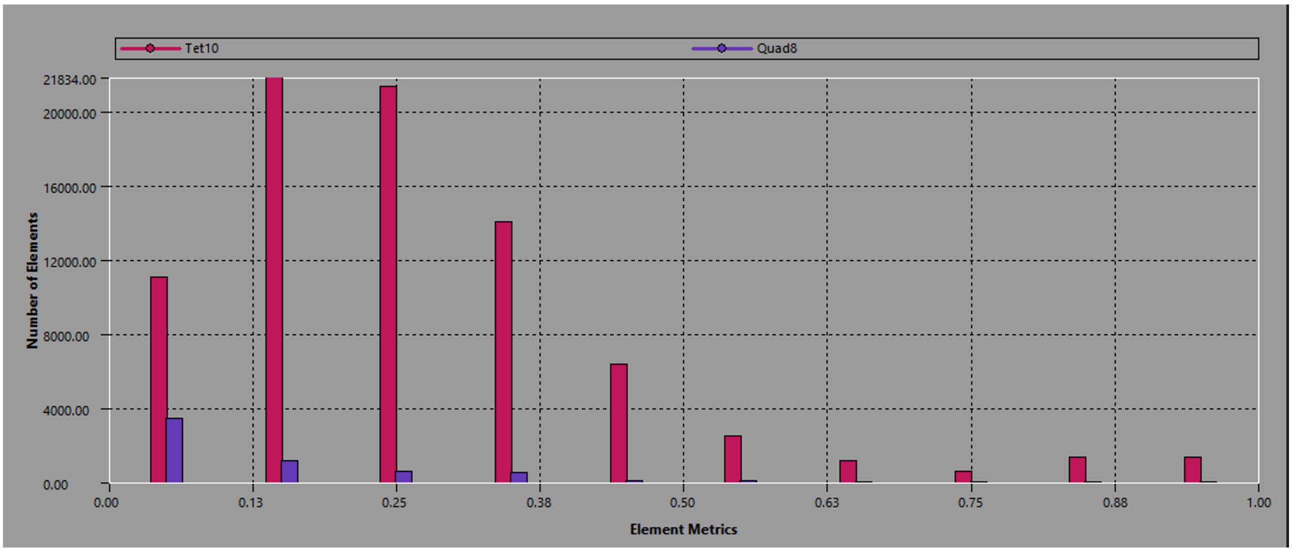

Figure 27: Skewness