AE462

Lab Exercise 5

Aircraft Wing Analysis

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Exercise 4:

Content

Procedure Flowchart:

1. Pre-processing Part
- Modelling
- Part defining(material used)
- Assembly
- Application of Loads & Boundary Conditions
- See Results Obtained

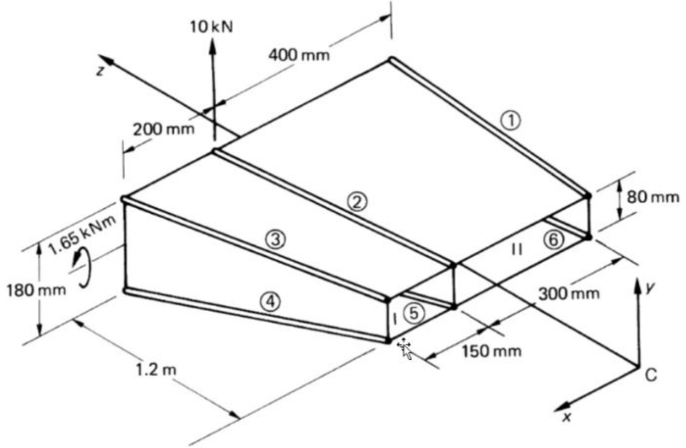
2. Post-processing Part
- Multiple Files will get generated
- Use .odp file to see the Results

Problem Statement

Example 23.4

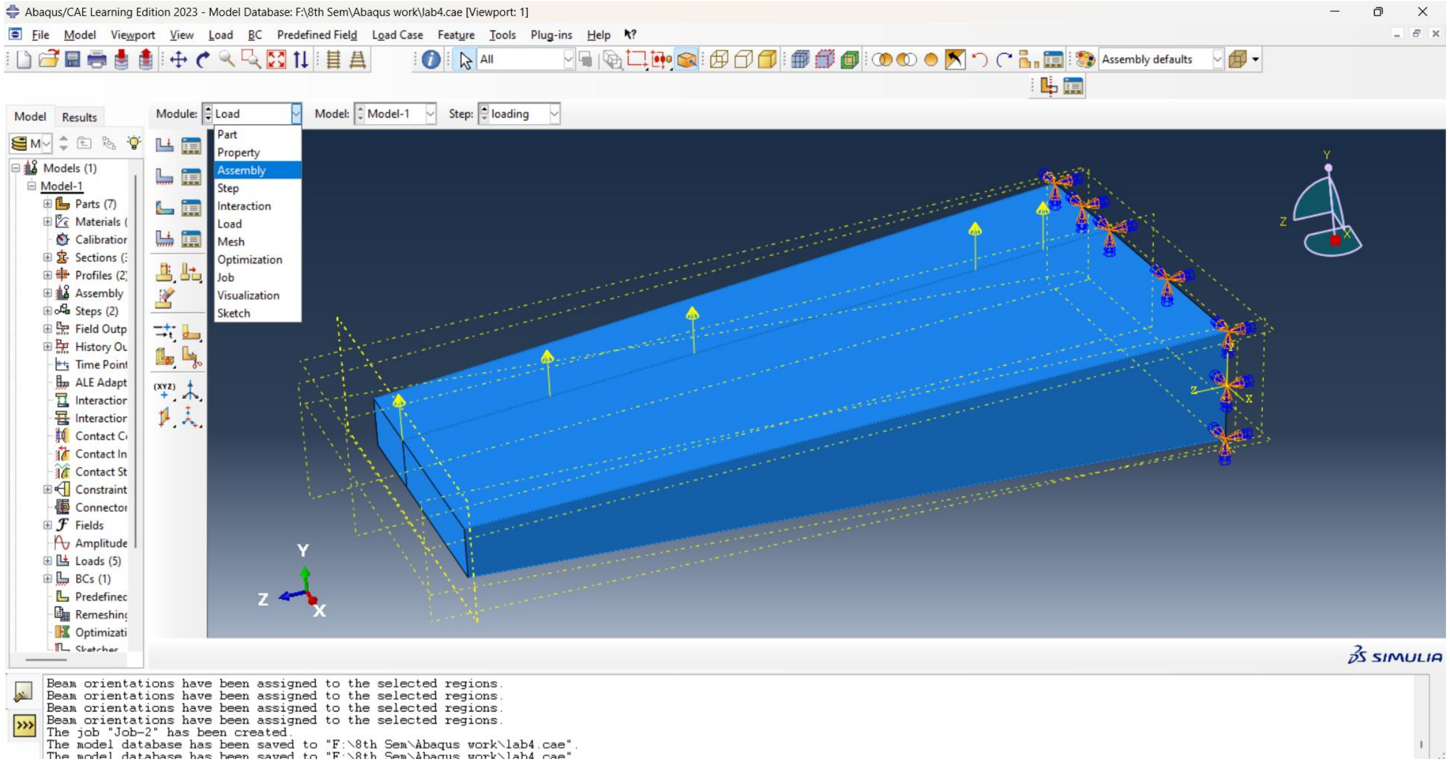
A two-cell beam has singly symmetrical cross-sections 1.2 m apart and tapers symmetrically in the y direction about a longitudinal axis (Fig. 23.12). The beam supports loads which produce a shear force $S_y = 10$ kN and a bending moment $M_x = 1.65$ kN m at the larger cross-section; the shear load is applied in the plane of the internal spar web. If booms 1 and 6 lie on a plane which is parallel to the yz plane, calculate the forces in the booms and the shear flow distribution in the walls at the larger cross-section. The booms are assumed to resist all the direct stresses while the walls are effective only in shear. The shear modulus is constant throughout, the vertical webs are all 1.0 mm thick, while the remaining walls are all 0.8 mm thick:

$$\text{Boom areas: } B_1 = B_3 = B_4 = B_6 = 600 \text{ mm}^2, \; B_2 = B_5 = 900 \text{ mm}^2$$

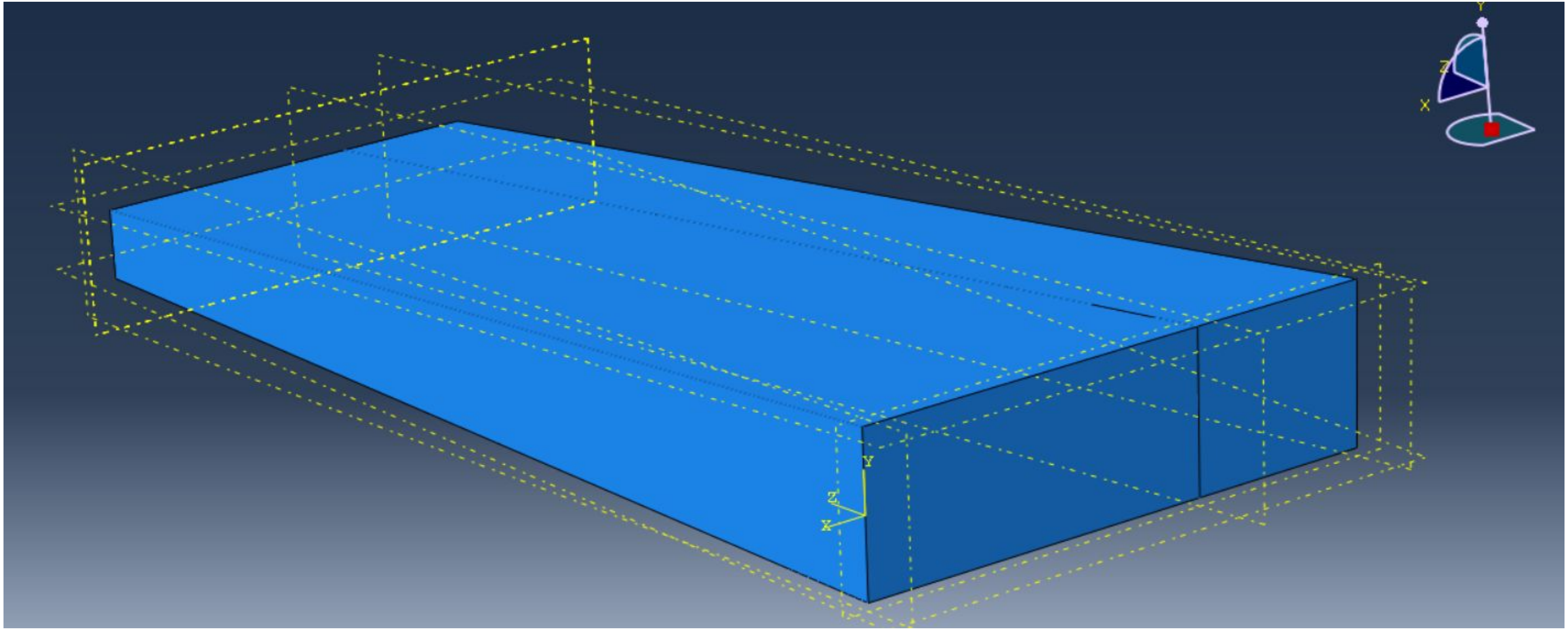


Link for CAE file- [Lab4_Group11]

Abaqus Workspace

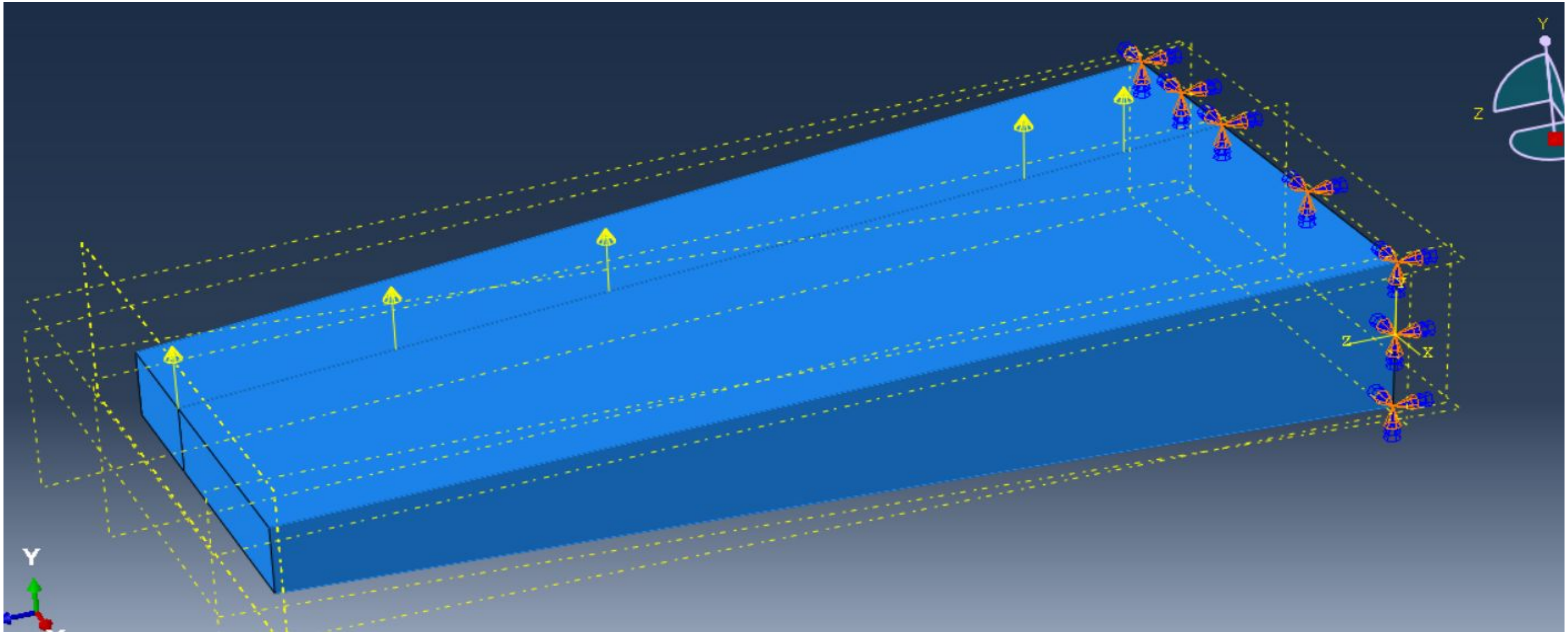


Model of a Two-Cell Beam

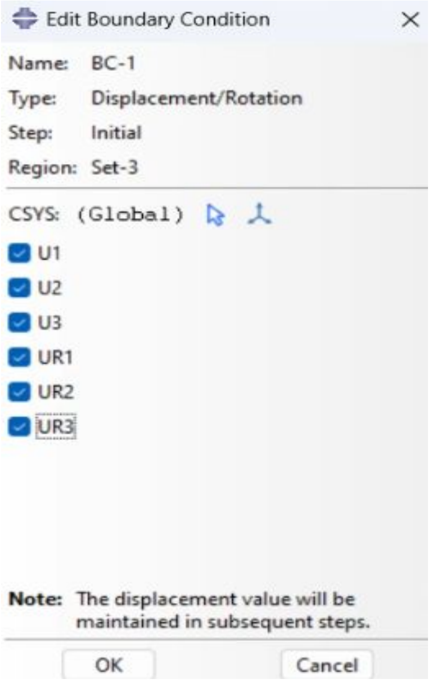


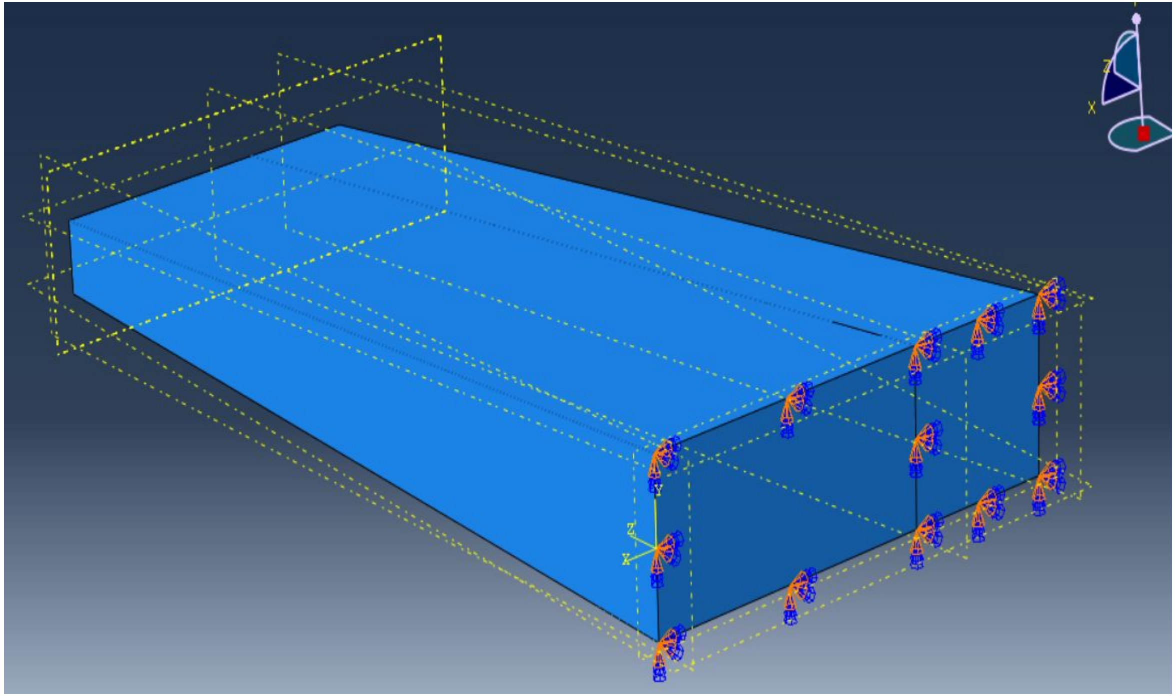
Loads Applied along with Boundary Conditions

Distance from root	Force(KN)
0.1	6
0.2	3.5
0.6	0.3
0.8	0.15
1	0.05

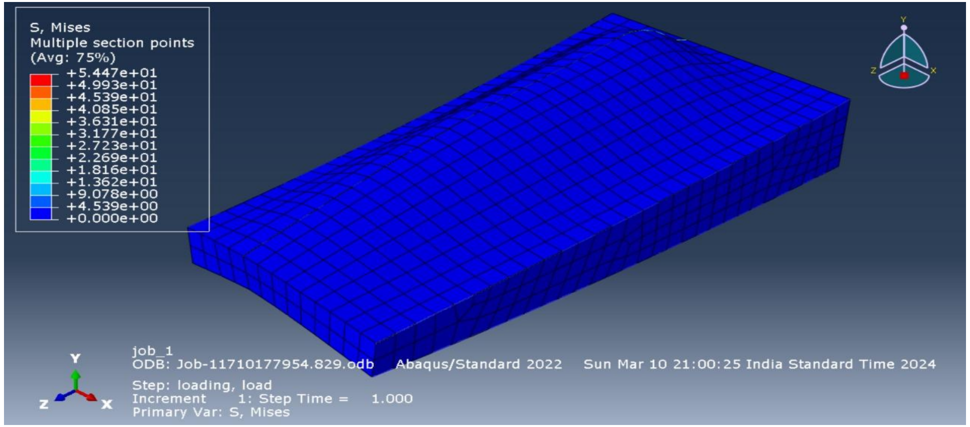


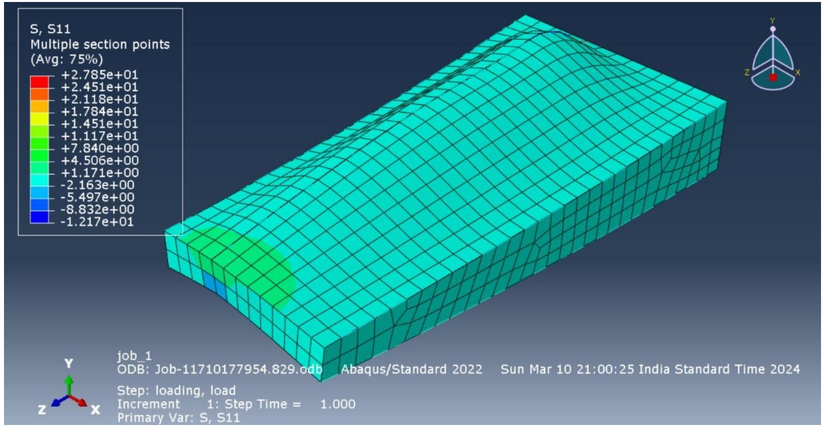
Boundary Conditions:

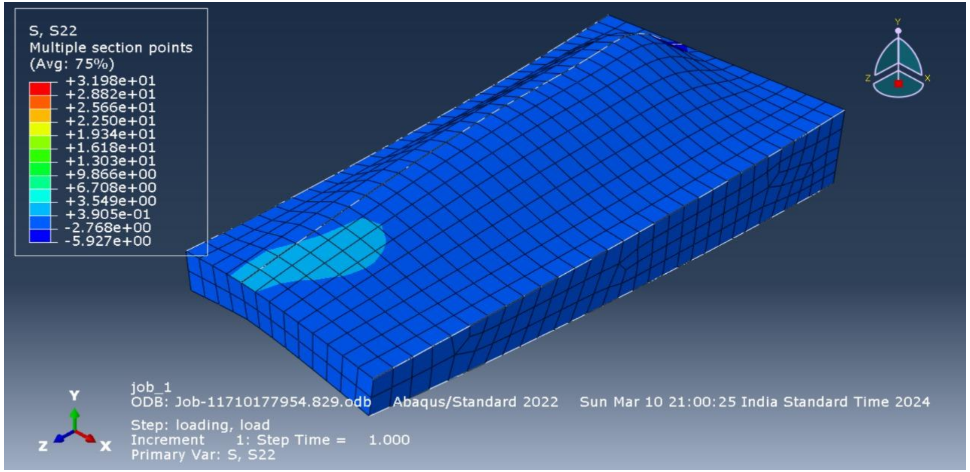


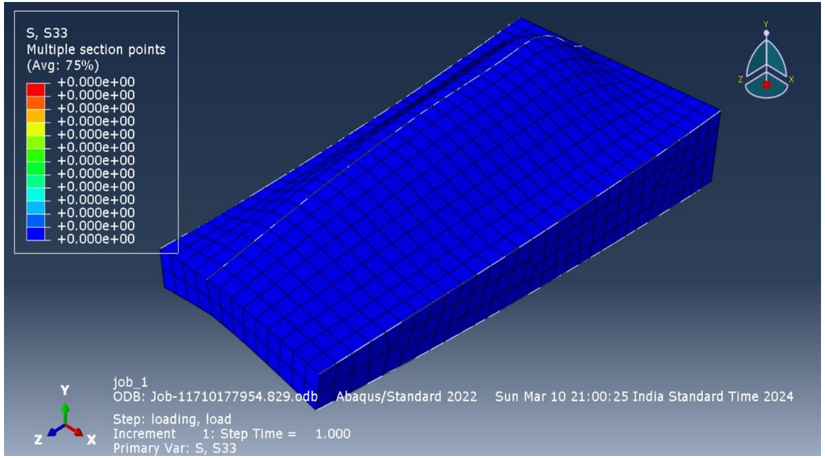


Stress Analysis:

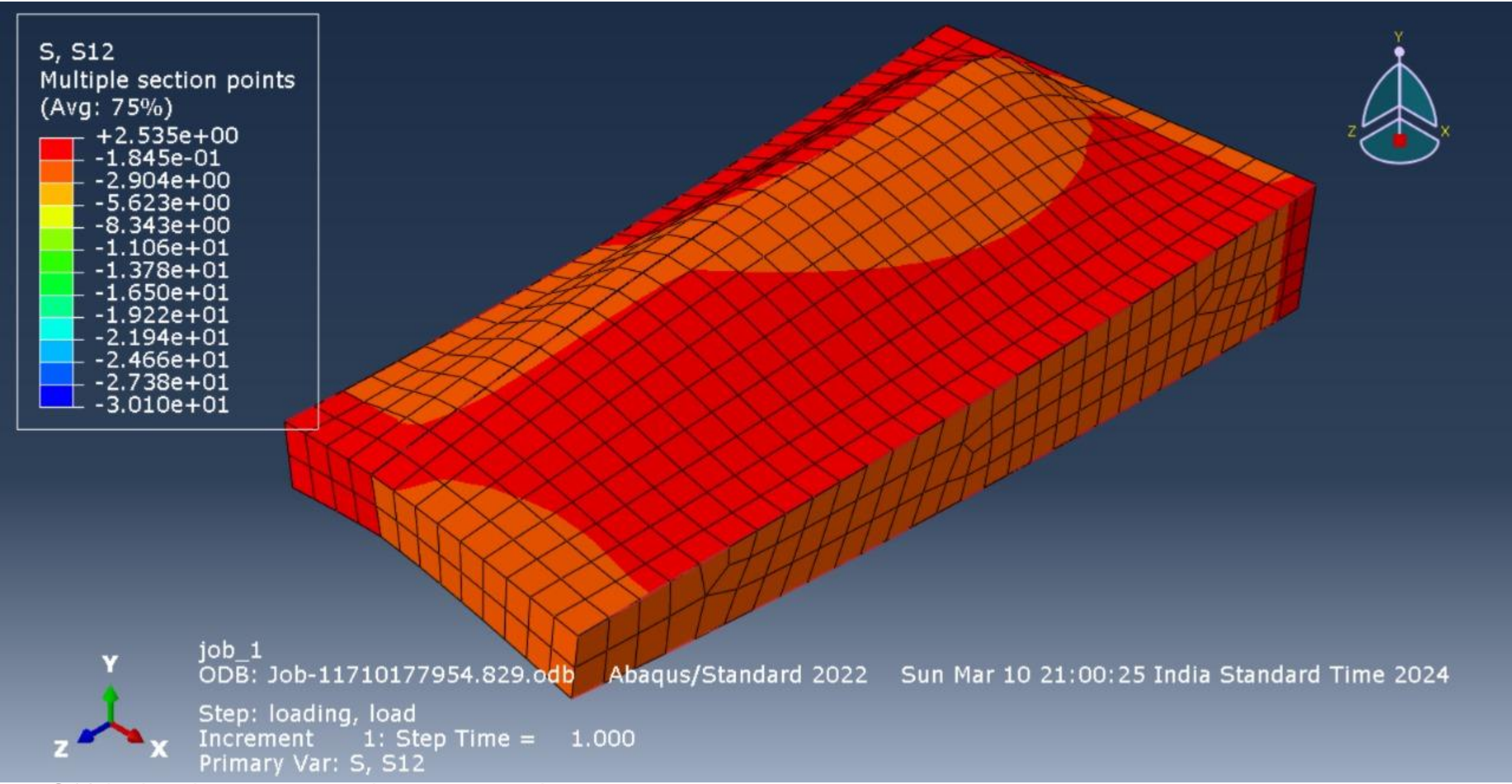






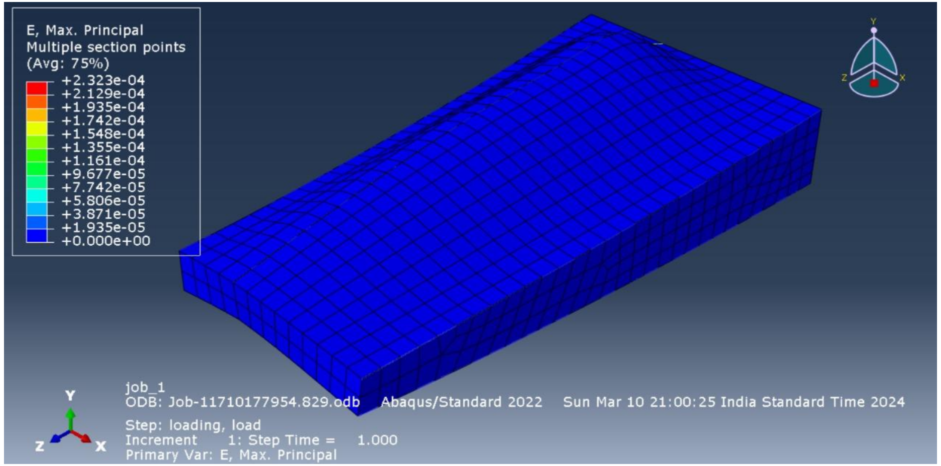


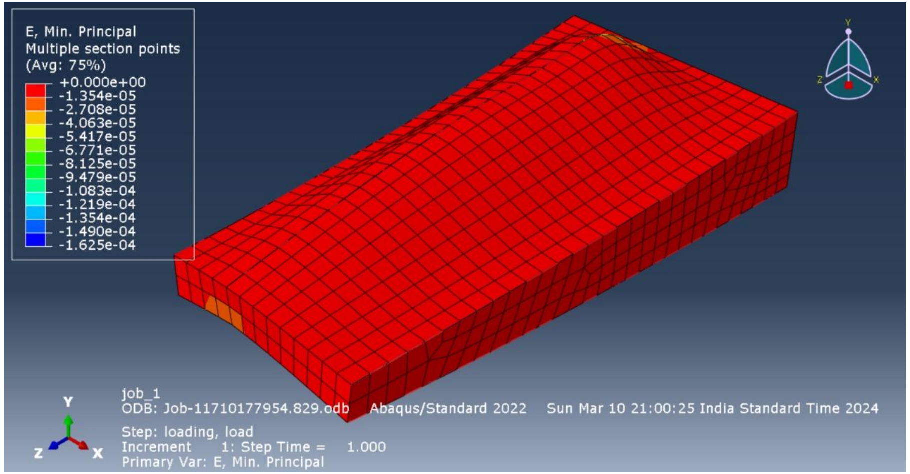
S11, S22 and S33 are principal stresses in three directions.

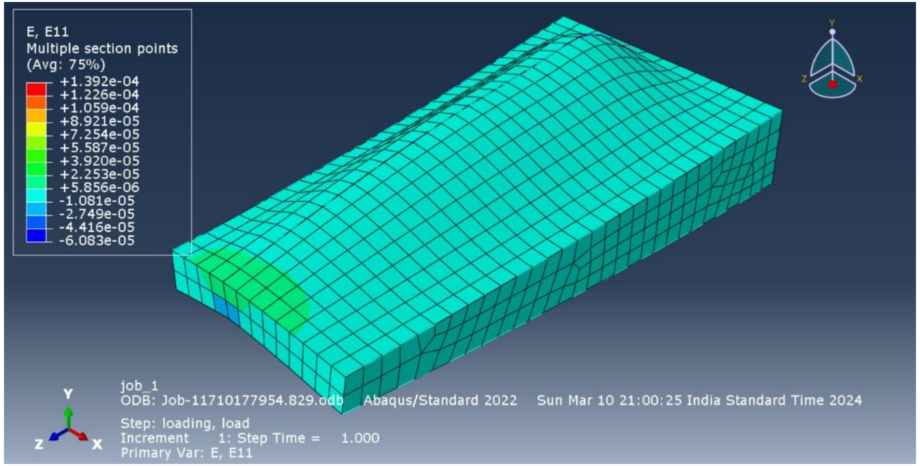


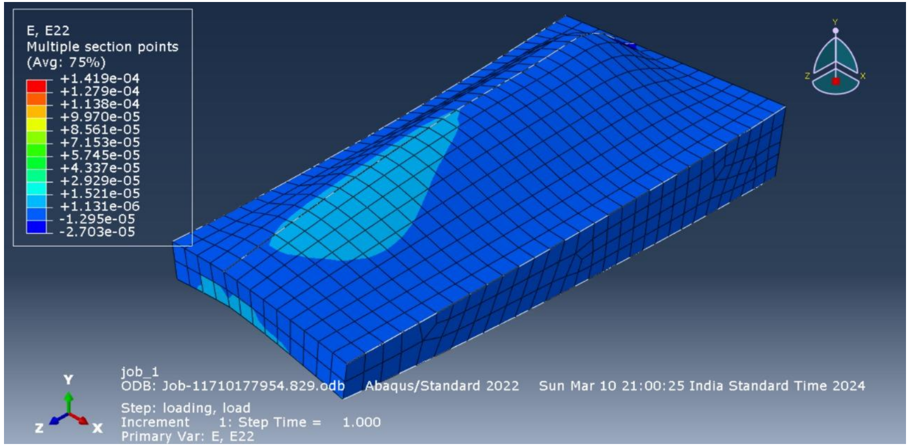
S12 is the shear stress acting along y axis

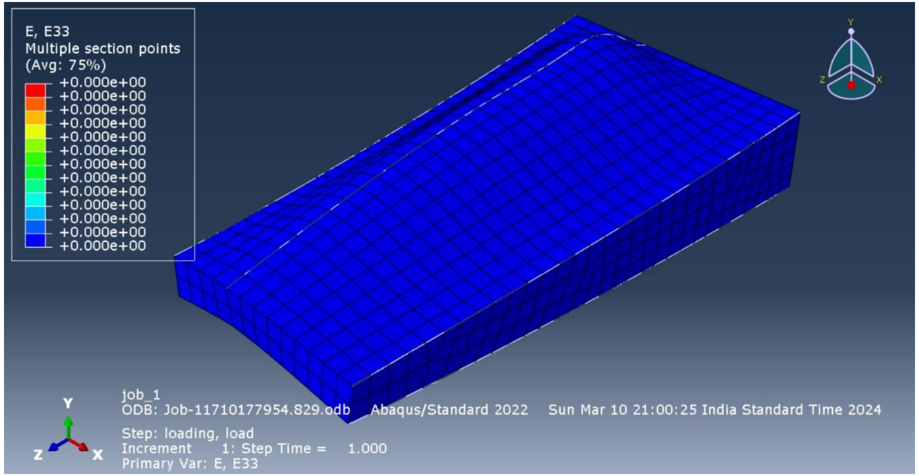
Strain Analysis:

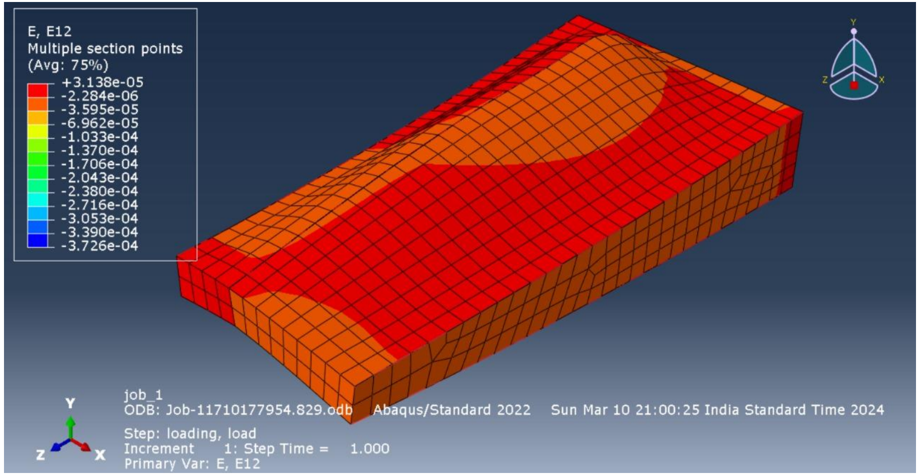








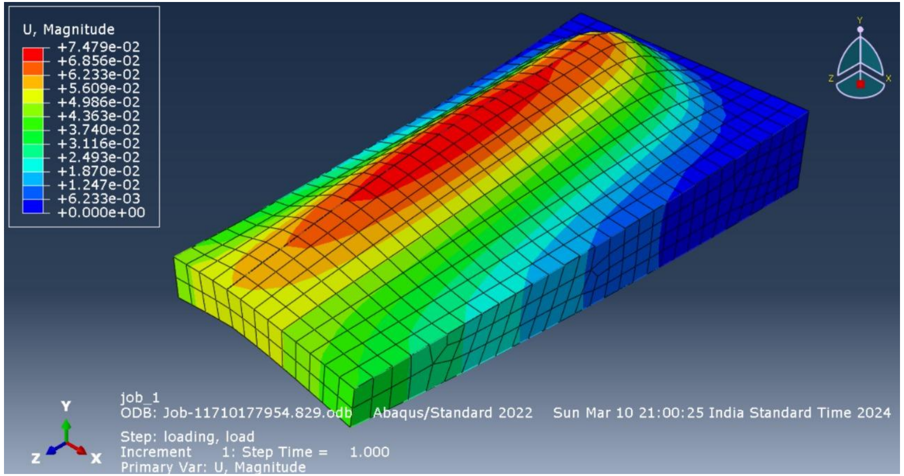


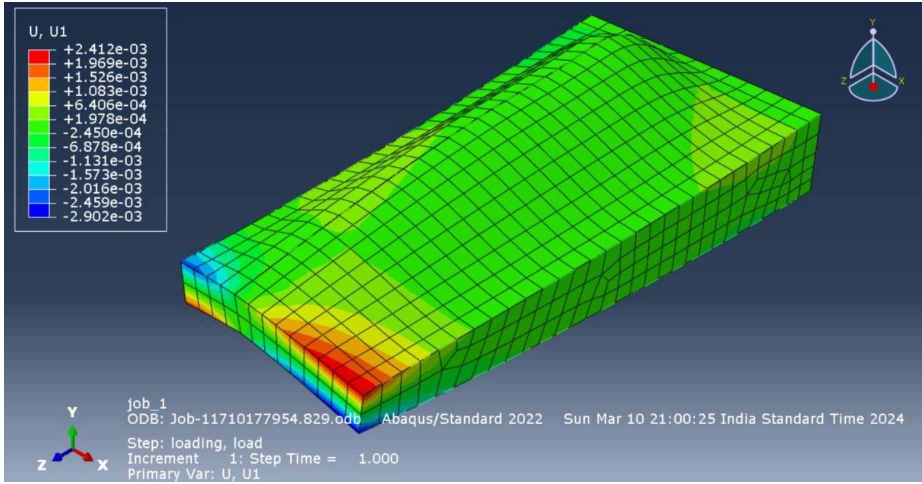


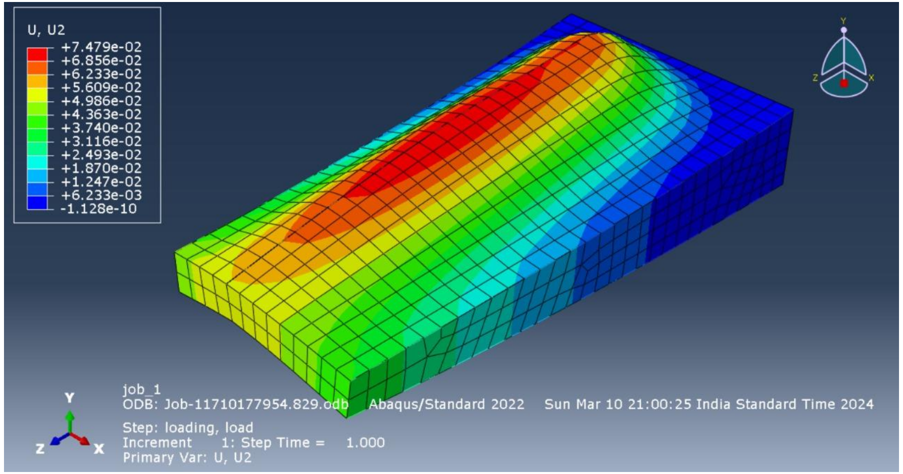
E11, E22, and E33 refer to the three principal components of strain in a three-dimensional stress state.

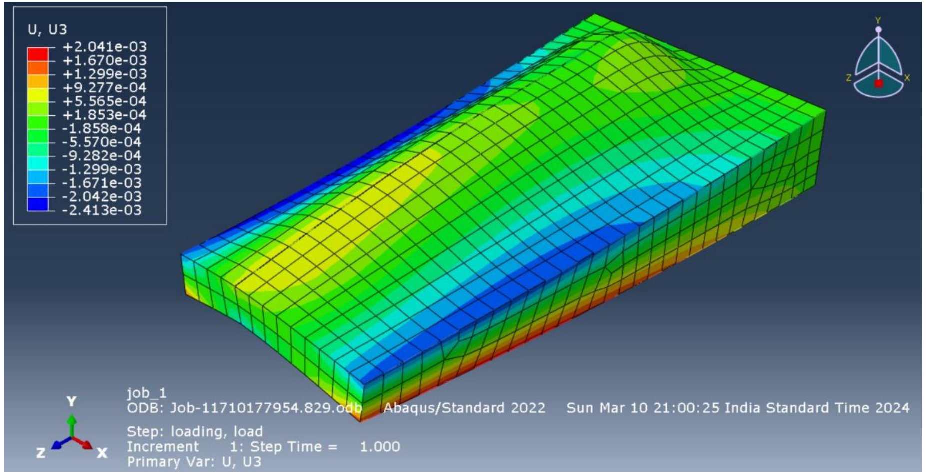
E12 represents the strain in the direction parallel to the axis 2 due to loading in the direction of axis 1.

Deflection Analysis:









Insights:

1. **Material Behavior:**
   Material properties such as modulus of elasticity, yield strength, and Poisson's ratio significantly influence stress and strain distributions.
   Higher modulus of elasticity leads to stiffer behavior and lower deflections under load.
   Variations in material properties, such as defects or imperfections, can cause localized stress concentrations.
   Understanding material behavior allows for optimization of material selection to improve overall structural performance.
2. **Structural Integrity:**
   Critical points of stress concentrations often occur at areas subjected to high loads.
   Stress concentrations can lead to material failure or fatigue over time, impacting structural integrity.
   Simulation results provide insights into potential failure modes such as yielding, buckling, or fracture, aligning with theoretical expectations.
3. **Performance Enhancement:**
   Design modifications such as adding ribs or reinforcements can enhance structural performance by distributing loads more effectively.
   Enhancing geometric features to promote uniform stress distribution can improve overall structural integrity and longevity.
   Performance enhancements based on FEA insights lead to more resilient and reliable structures in service.

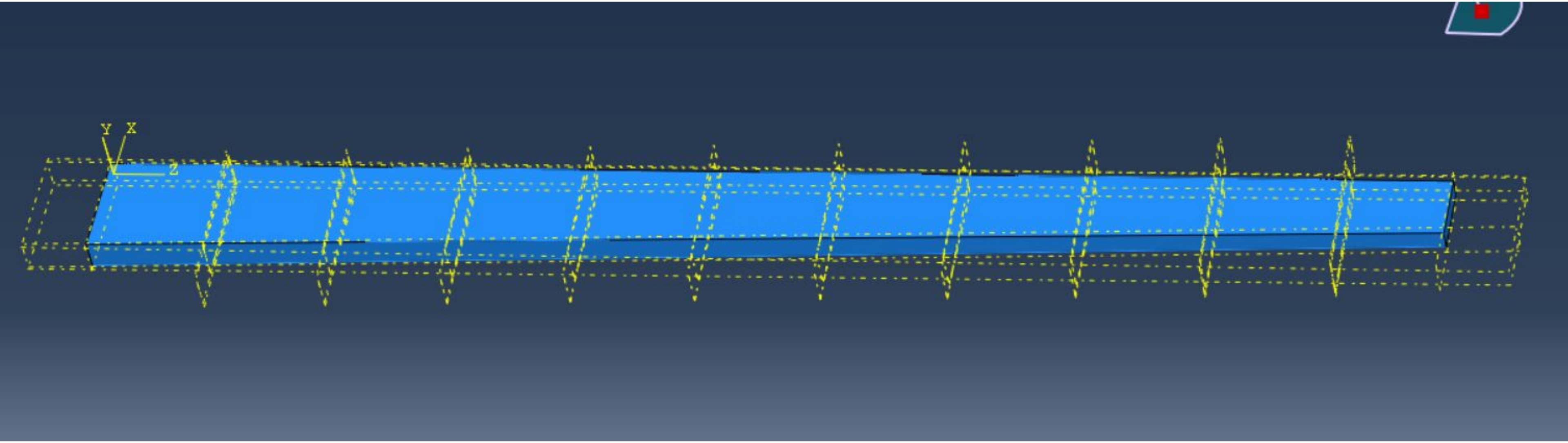
Exercise 5
Aircraft Wing Analysis

Problem Statement

Prepare the finite element model in Abaqus of your aircraft wing and carry out the analysis with the loads determined in an earlier exercise.

Prepare a report in the form of a powerpoint presentation and include all details of the model and results. This includes finite elements used for various parts, boundary conditions, loads applied, and the results obtained (deflections, stresses and strains). Most importantly, some kind of insights and validation of the results should be also be included.

Wing Model



A Tapered wing with 4 booms

Max web skin thickness and max spar web thickness has been used for shell skin for entire wing(ignoring the variation of these thickness along wingspan)

Loads on wing

We have used total 11 ribs in this wing, which divides the wing in 11 sections.
We've calculated Load(Q) generated for each section ($Lift_{section}$-$Weight_{section}$)
And torsion(T) in each rib about its CG.
Now since we are idealizing the wing cross section with inter spar box. We need to modify the loads accordingly.
We are applying loads on front and rear spars(say La(front spar) Lb(rear spar))
The summation of these loads(La+Lb) in for a section should equal to $Q_{section}$
And the torsion due to these two loads about the CG of wing box should equal to torsion(T) that we calculated earlier.
Since we have idealized the wing cross section with inter spar box(by equating cross sectional areas to calculate height of box) the wing box itself represents the entire wing and hence the CG should lie at the center of wing box

Hence for each section we get,
La+Lb=Q
(La-Lb)(interspar length/2)=T

Where
Q=Lift-Weight
T(about wing CG)=L(chord/4)

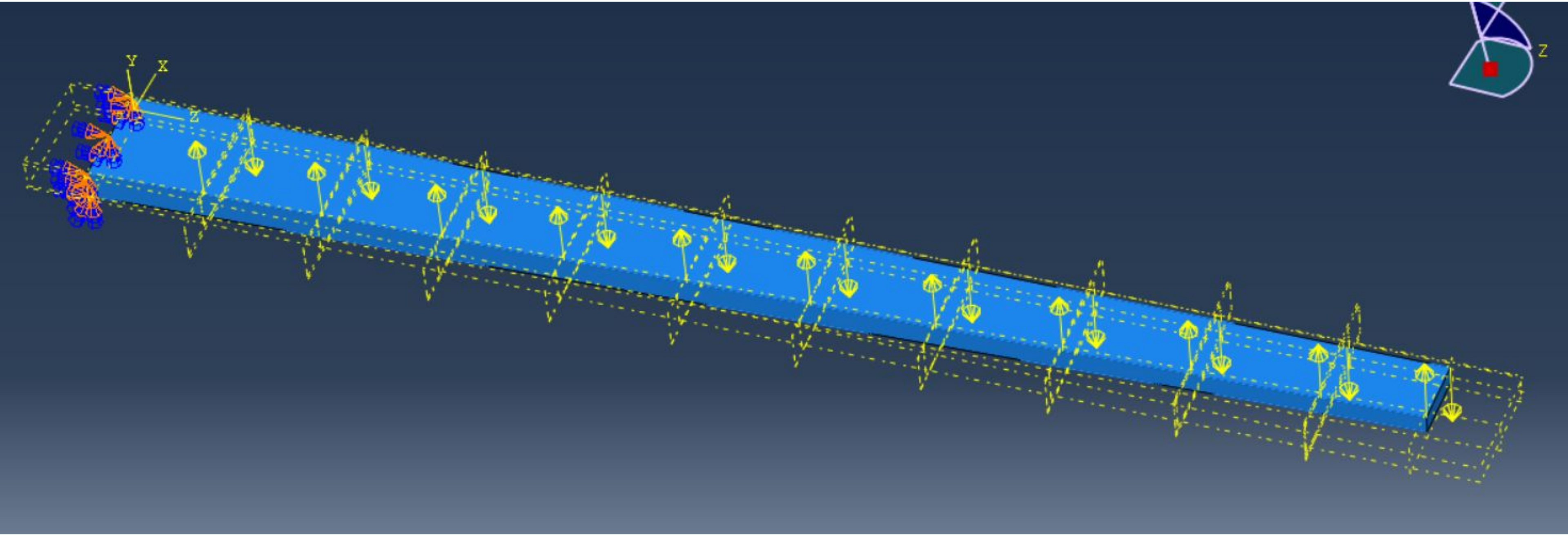
Loads on wing

Link- [Excel for Loads on wing box]

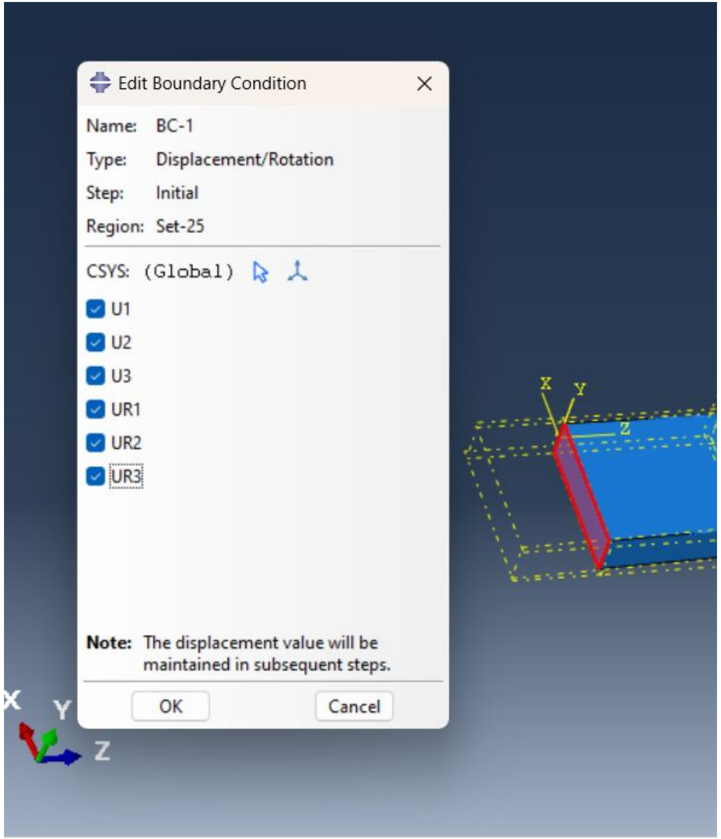
Using two eqn we can find La(force on front spar) and Lb(force on rear spar) for each section(these loads would be applied at ribs)

Rib(location)in m	La(in N)	Lb(in N)
0.5	361.7305691	-69.69480384
1	569.6130056	-283.4324993
1.5	770.8658731	-492.0756911
2	964.4351128	-694.6544475
2.5	1149.149368	-890.1390665
3	1323.655777	-1077.400982
3.5	1486.312187	-1255.154875
4	1634.982595	-1421.862314
4.5	1766.5754	-1575.546705
5	1875.636132	-1713.349466
5.4	1936.413019	-1808.640468

Loads Applied along with Boundary Conditions

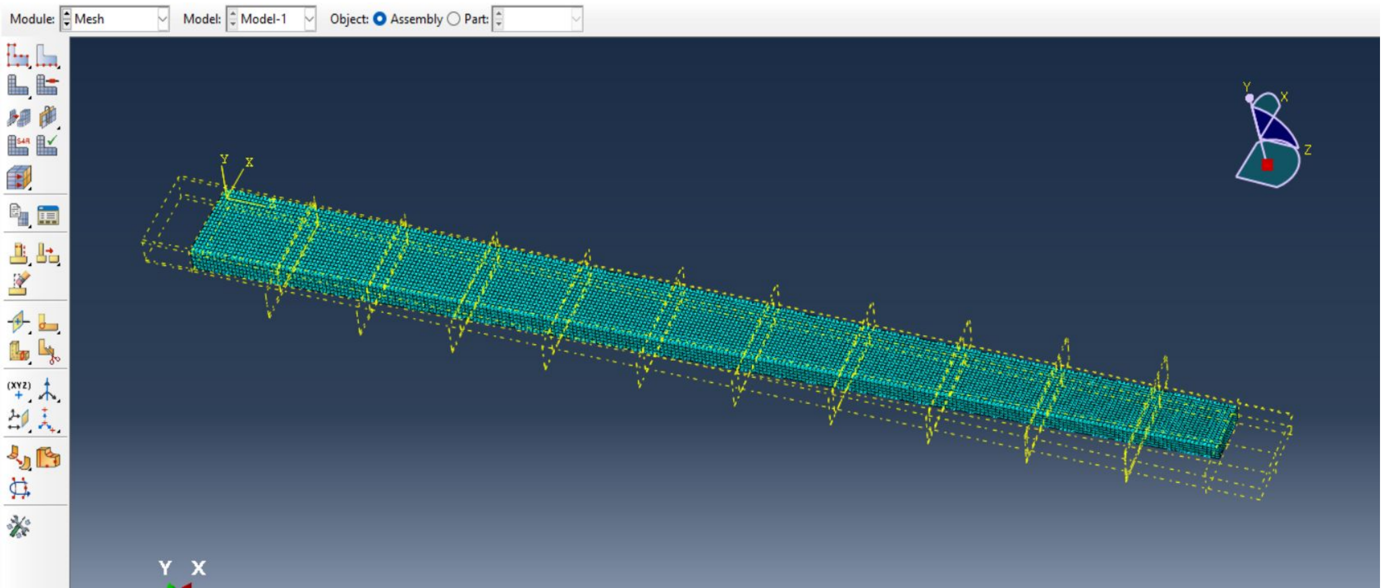


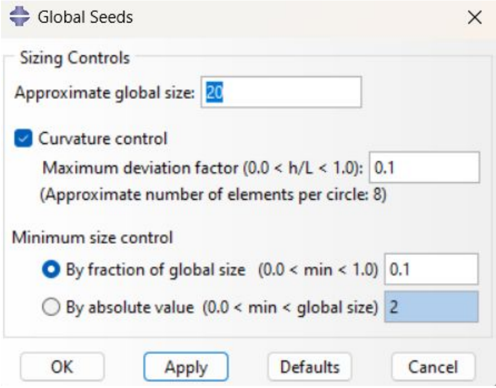
Boundary Conditions:



Meshing

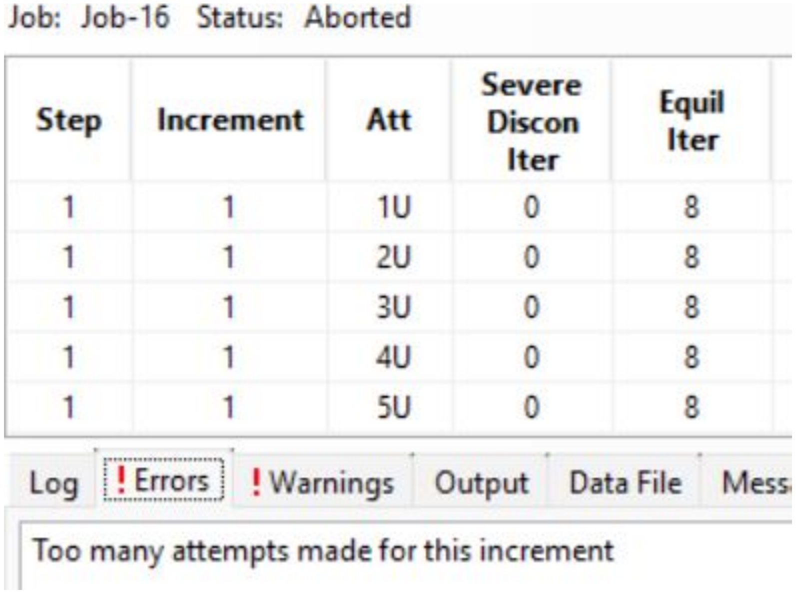
For our earlier model, we were facing meshing error(some elements were of unusable quality)
We recreated the model using similar approach and seed size 20(mm)





Visualization(errors)

We were facing ‘too many attempts for one increment’ error hence we tried changing(increasing) the time increment value

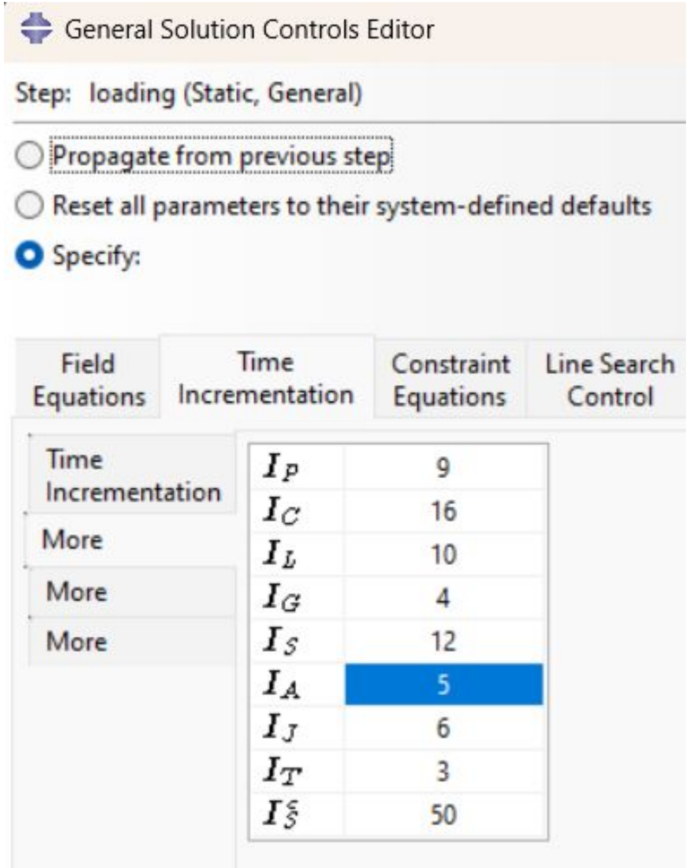


Job: Job-16 Status: Aborted

Step	Increment	Att	Severe Discon Iter	Equil Iter
1	1	1U	0	8
1	1	2U	0	8
1	1	3U	0	8
1	1	4U	0	8
1	1	5U	0	8

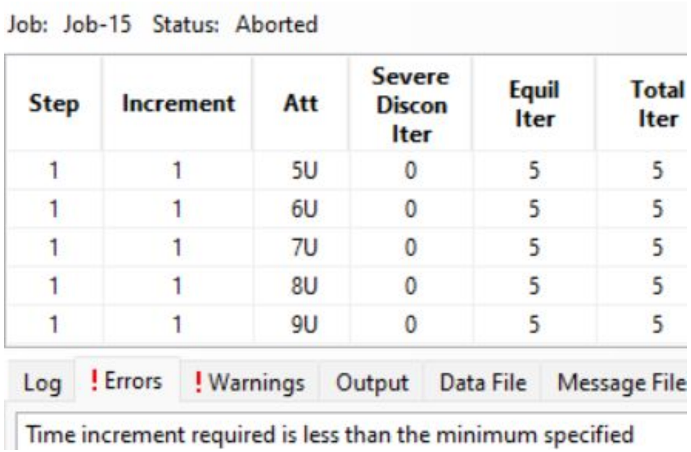
Log | ! Errors | ! Warnings | Output | Data File | Mess

Too many attempts made for this increment



Visualization(errors)

but then faced error ‘time increment required is less than the minimum specified’
We tried reducing the min increment size and initial increment size and increasing the max no of increments

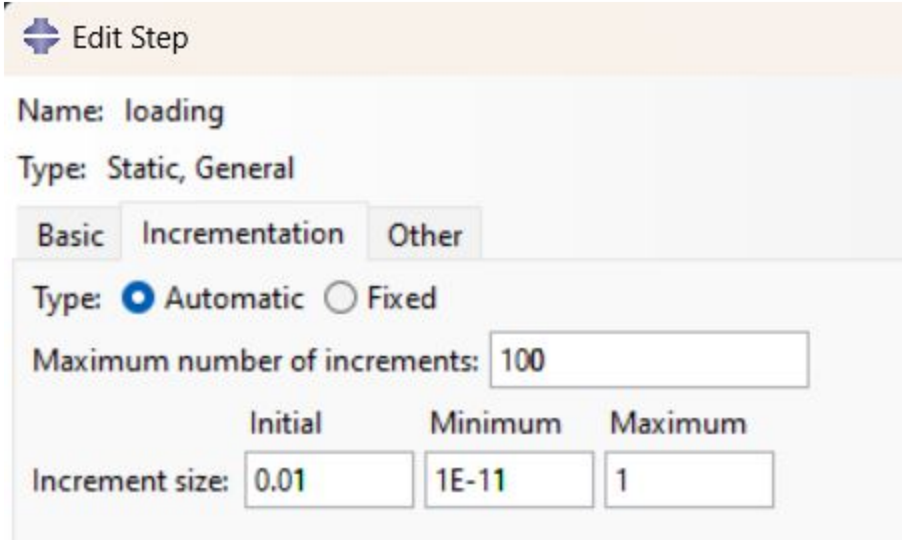


Job: Job-15 Status: Aborted

Step	Increment	Att	Severe Discon Iter	Equil Iter	Total Iter
1	1	5U	0	5	5
1	1	6U	0	5	5
1	1	7U	0	5	5
1	1	8U	0	5	5
1	1	9U	0	5	5

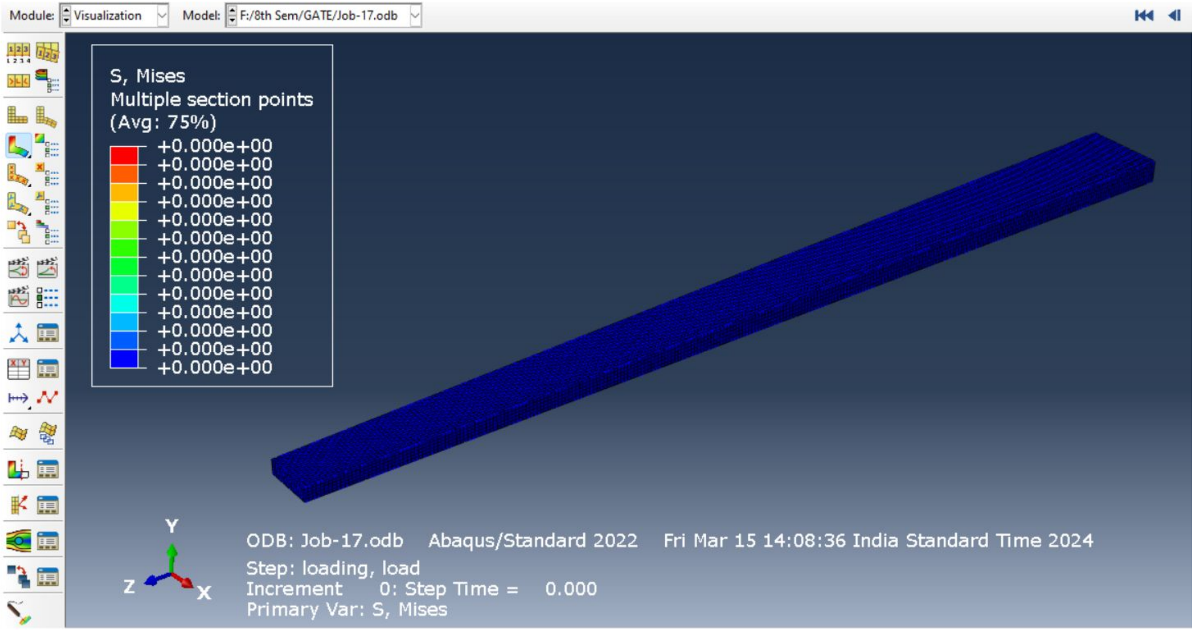
Log ! Errors ! Warnings Output Data File Message File

Time increment required is less than the minimum specified



Visualization(errors)

Another reason could have been meshing, hence we made finer meshing for all corners but still same error occurred.



We have tried all the solutions available on internet for potential reasons for such error but unable to solve this issue
Link for cae file of this model Lab 5 Group 11

We solved the meshing error(due to which we couldn't submit on Thu) by making new model but, since we could successfully mesh the model, there are hardly any problems with model(and hence I didn't modeled again from scratch)

Thank You