ROTEC R2800 ENGINE MOUNT STRUCTURAL VERIFICATION

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REFERENCES

REF. 1: JAR-VLA

REF. 2: Rotec R2800 Specification sheet

1. General

The structural verification of the Rotec R2800 engine mount is hereafter presented.

The Rotec R2800 is a 110HP radial aircraft engine produced by the Australian company *Rotec Engineering Ltd*.

The reference regulation used hereafter is the JAR-VLA.

1.1. Weights and geometries

The overall weight of a complete powerplant (i.e. wet engine, accessories and installed propeller) is assumed to be (see REF. 2):

Engine dry weight	95.0 kg
Accessories (starter, alternator, carburetor,…)	7.0 kg
Wooden propeller	4.0 kg
Liquids and small ancillaries	4.0 kg
TOTAL	***110.0 kg***

The engine is longitudinally located so that the aircraft CG is close as possible to the other engine configuration offered by the aircraft manufacturer which is the 75HP Walter Mikron IIIB. On the other hand, the engine is vertically located taking into account that the thrust line should be close as possible to the aircraft CG (preferably below) and that a correct propeller ground clearance has to be respected (a 72" propeller is assumed).

The result of the powerplant's positioning is presented graphically in Figure 1-1.

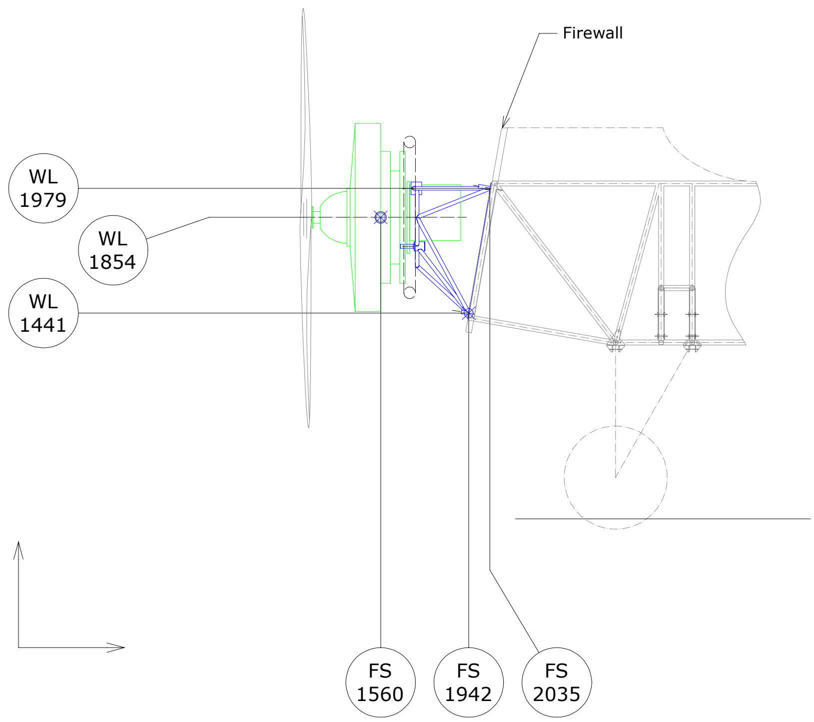

Figure 1-1: lateral view of the R2800's installation.

Initially, two engine mount configurations have been considered: #1 is the version proposed by the engine manufacturer while #2 is a traditional design, historically used for radial engines application.

Pictures of the two versions are presented in Figure 1-2. The chosen version is #2 and this report deals with its verification only.

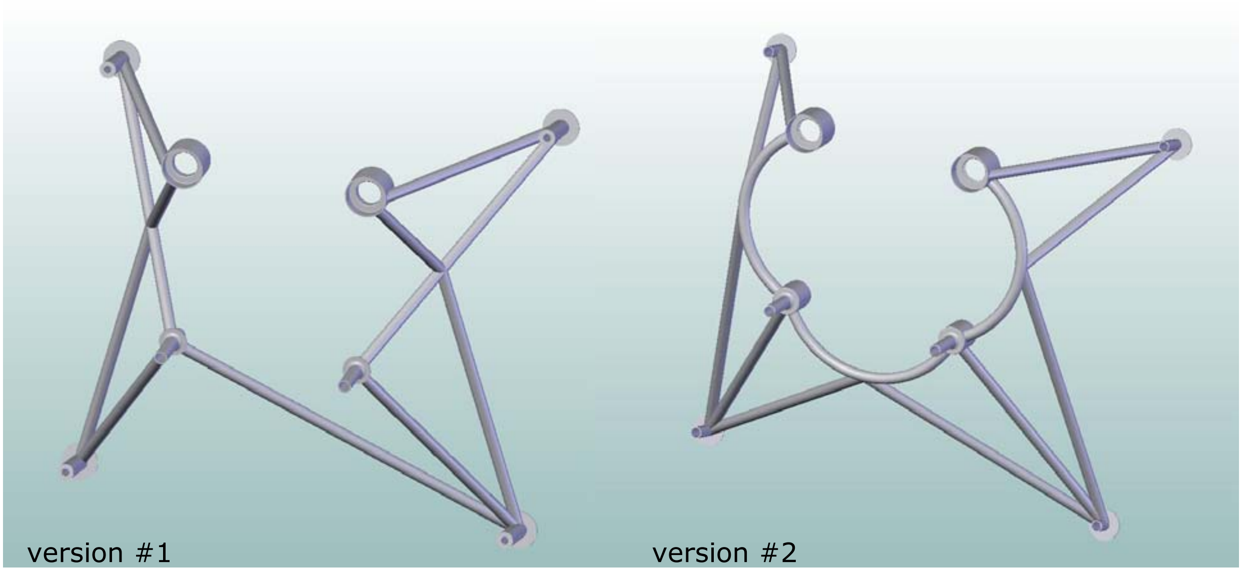

Figure 1-2: engine mount versions.

The selected version (i.e. #2) is based on a welded structure based on 25CrMo4 low alloy steel 5/8" OD x 0.035" wthk tubes (equivalent European tube dimensions are 16 mm OD x 0.9 mm wthk).

If compared to the originally proposed Rotec's engine mount which uses AISI 4130 ½" x 0.049" wthk tubes, the 5/8" x 0.035" choice has the following advantages:

1. 6.5% lower weight per ft (0.2205 lb/ft instead of 0.2360 lb/ft)
2. 58.6% higher sectional inertia (1179.1 mm^4 instead of 743.4 mm^4), thus higher instability loads,

The weight of the chosen version (i.e. #2) is about 4.9 kg (engine pin fittings included, welding material excluded).

From pure manufacturing and structural integrity considerations, version #2 is highly preferable because side beams are not intercepted by other beams and therefore are not weakened by any welding operation. Furthermore, the annular tubes are better suited for engine torque loads since they collaborate with the engine's mount plate.

1.2. Load cases

Load conditions for the engine mount are described in JAR-VLA §§ 361 and 363. Those paragraphs basically define the following load cases:

1. limit engine torque corresponding to take-off power acting simultaneously with 75% of the limit normal load factor prescribed at V_A (§ 361(a)(1)) =4 g's.

2. limit engine torque as specified under JAR-VLA §361(b)(1)(i) acting simultaneously with the limit normal load prescribed at V_A (§ 361(a)(2)).
3. lateral limit load as prescribed under JAR-VLA §§ 363(a) and (b).

As usual, the structural verification is carried out applying ultimate loads, therefore the abovementioned are to be corrected by means of the safety factor (SF=1.5).

Since no torque curves are available, engine torque is determined from engine data. The manufacturer claims to have 110HP (82'027W) at 3'700rpm (geared), thus:

$$M_T = \frac{82'027}{3'700 \cdot \frac{\pi}{30}} = 211.7Nm$$

For load case 2 the engine limit torque is obtained multiplying the maximum power torque (instead of the maximum continuous power torque) by a factor 1.33 (JAR-VLA § 361(b)(1)(i)).

Load cases are summarized in the following load matrix (ultimate load conditions shown, safety factor always included):

Loadcase ID	**$n_{Z,u}$ (N)**	**$n_{Y,u}$ (N)**	**$M_{T,u}$ [N.mm]**
1	(0.75*4)*SF=4.5 (4'854.3)	0	M_T*SF=317'550
2	4*SF=6 (6'472.4)	0	(M_T*1.33)*SF=422'341
3	0	1.33*1.5≈2 (2'158.2)	0

2. Structural verification

Structural verification has been carried out by means of a FEM analysis of both engine mount structures; the used code was ADINA v.7.3 .

The 3D wireframe model of the engine mount structure has been meshed with BEAM elements with assigned pipe sectional characteristics (diameter=15.875 mm, thickness=0.889 mm).

Assigned material characteristics were: elastic isotropic with E=200'000 N/mm^2 ν=0.3 .

The complete model has been subdivided by number of divisions (1 for each model straight line and 5 for the forward ring) and no additional end-stiffness has been assigned to the beams (i.e. pin-end terminal condition assumed), therefore leading to a more conservative analysis (in facts, welded terminals add a certain amount of stiffness to the model).

Loads (concentrated forces and moments) were applied at the engine CG (X=1'560 mm; Y=0 mm and Z=1'854 mm) and the four engine mount engine fittings were connected to the latter by means of rigid links. Since the structure is symmetric, the side force direction for load case #2 has been arbitrarily chosen to the right. Since the engine is turning clockwise (as seen from the pilot), the reaction torque on the engine mount is always directed parallel to the positive X axis vector (see figures annexed in Appendix 1).

2.1. Results and conclusions

Results are graphically shown in Appendix 1 for each considered load case condition (note that, in the FE model, the Y and Z axis are inverted).

Maximum axial loads have been found with load condition #2 (maximum normal acceleration in conjunction with maximum torque); generally speaking, the more critical elements are #34, #31 (or #10 depending on the side load direction) which are subjected to compression loads. For these elements we found (tube section is S=41.85 mm^2; J=1'179.1mm^4):

Loadcase ID	**Element ID**	**Maximum axial load [N]**	**Axial stress [MPa]**
#1	34	2'565.5	61.3
#2	34	3'420.2	81.7
#3	34	677.6	16.2
#3	31	1'005.8	24.0

Critical elements #34 and #31 have a length of L=403.4 mm and L=360.3 mm[1] and a critical instability load of (pin-end assumption as used in the FEM model, i.e. conservative assumption):

$$\begin{cases} P_{cr,\#34} = \dfrac{\pi^2 \cdot 200'000 \cdot 1'179.1}{403.4^2} = 14'302.4N \\ MS_{\#34} = \dfrac{14'302.4N}{3'420.2N} - 1 = 3.18 \\ P_{cr,\#31} = \dfrac{\pi^2 \cdot 200'000 \cdot 1'179.1}{360.3^2} = 17'928.8N \\ MS_{\#31} = \dfrac{17'928.8N}{1'005.8N} - 1 >> 1 \end{cases}$$

The verification of the other tubes is not necessary because they are submitted either to traction loads (with of course lower values) or to much lower compression loads.

As one can see, all reported values are well below both the critical instability loads and the yield limit of the considered material ($R_{P,0.2}$=440 MPa) and therefore the structure is correctly sized and safe for operation.

* * *

[1] Reported tube's lengths have been measured on the FE model: in reality, due to the presence of the engine fittings, the tubes are shorter than that. Therefore, obtained results are conservative.

3. Appendix 1

Four figures are hereafter annexed which show the meshed geometry and the results of the FEM/FEA analysis. Load cases are numbered and refer to the numbering system presented in section 1.2.

In all figures, the un-deformed mesh is superimposed to the deformed one which is magnified by a factor 100. All along the beam's mean line, the line load plot contour is shown: the line load plot contour represents graphically the entity of the local axial force (the maximum value is always reported in the legend).

Forces and moments are in N an N.mm respectively.

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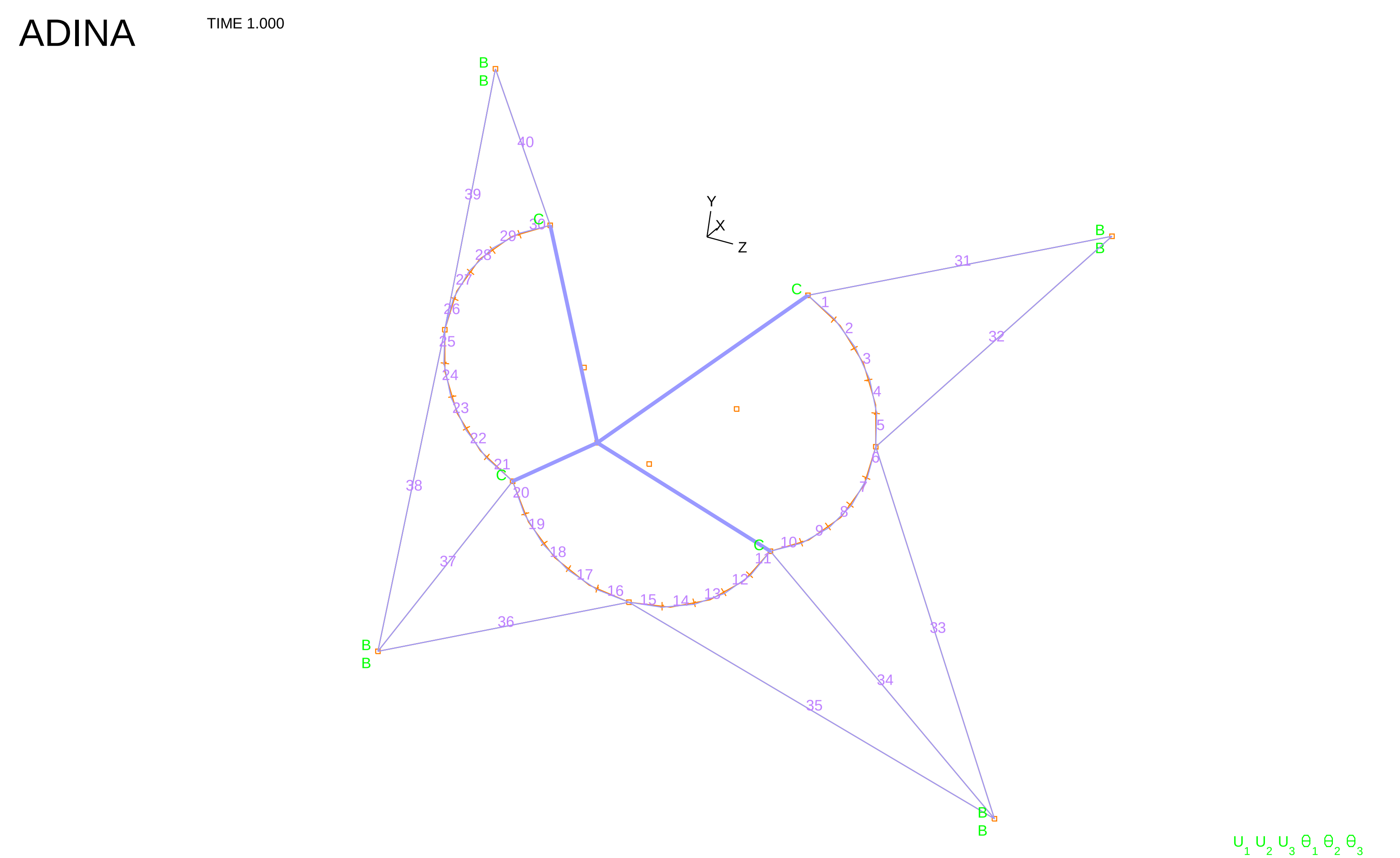

Fig. 1: structural model geometry (elements numbering).

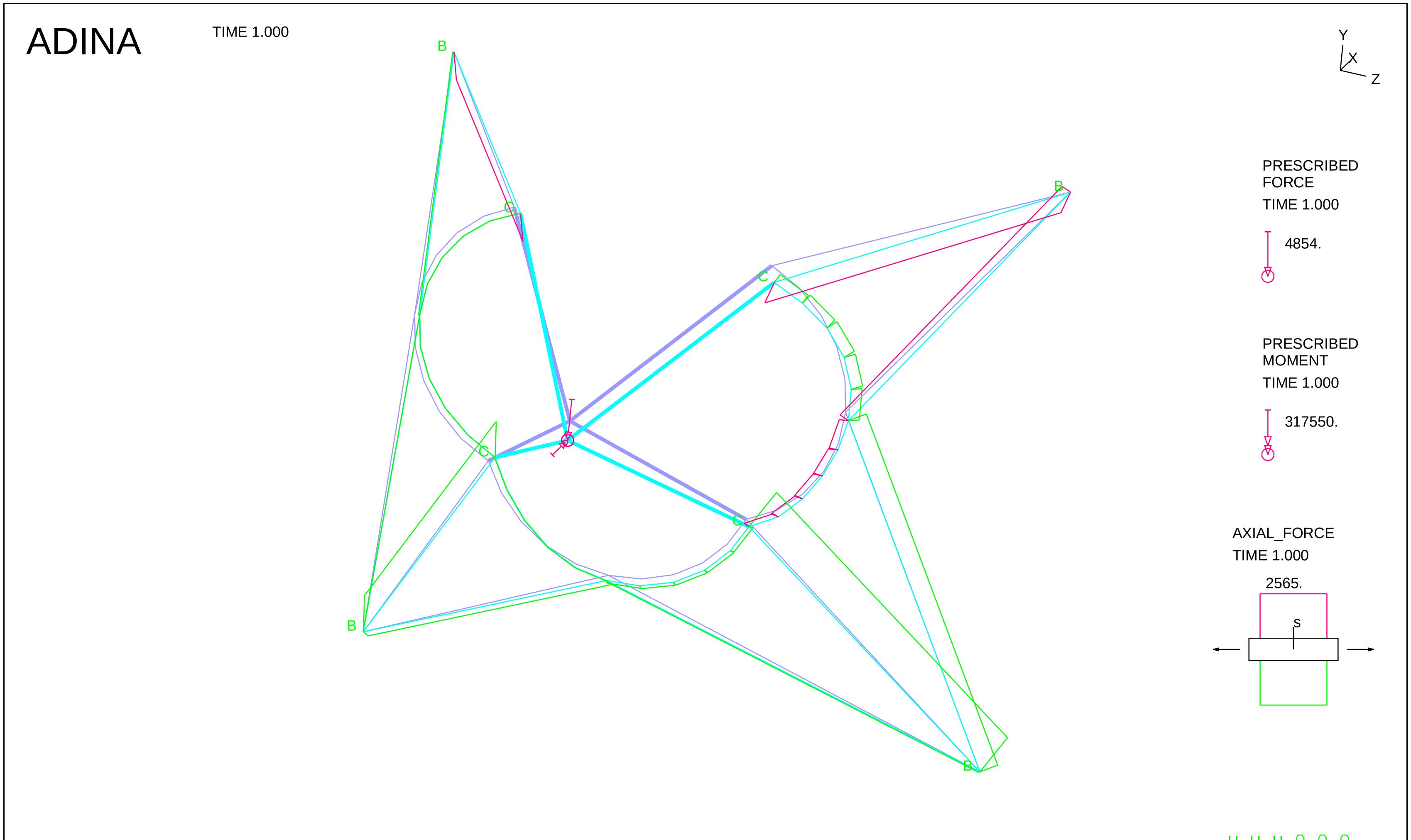

Fig. 2: loadcase #1 (F_y=4854.3N; Mt=317550Nmm).

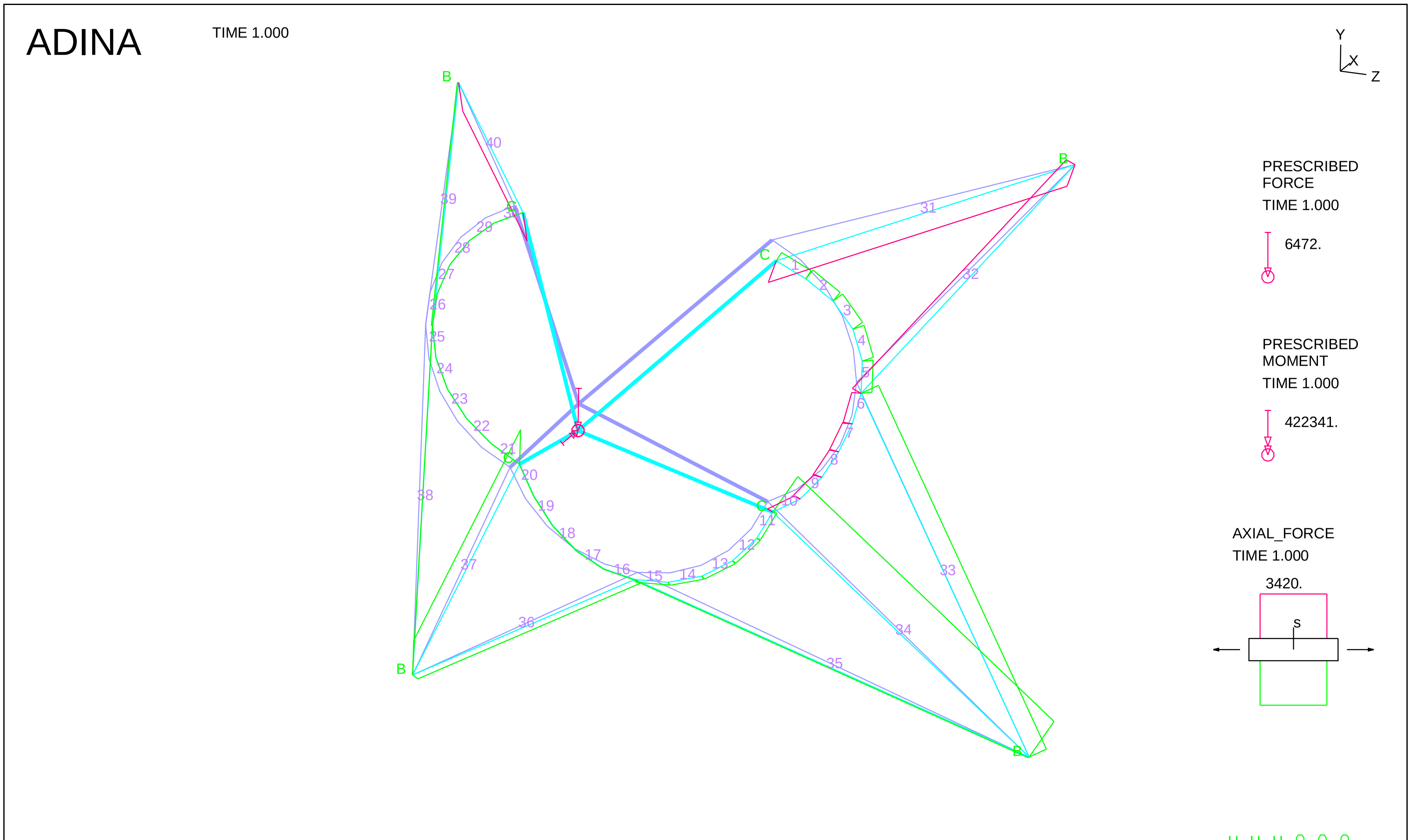

Fig. 3: loadcase #2 (F_y=-6'472.4N; Mt=422'341Nmm).

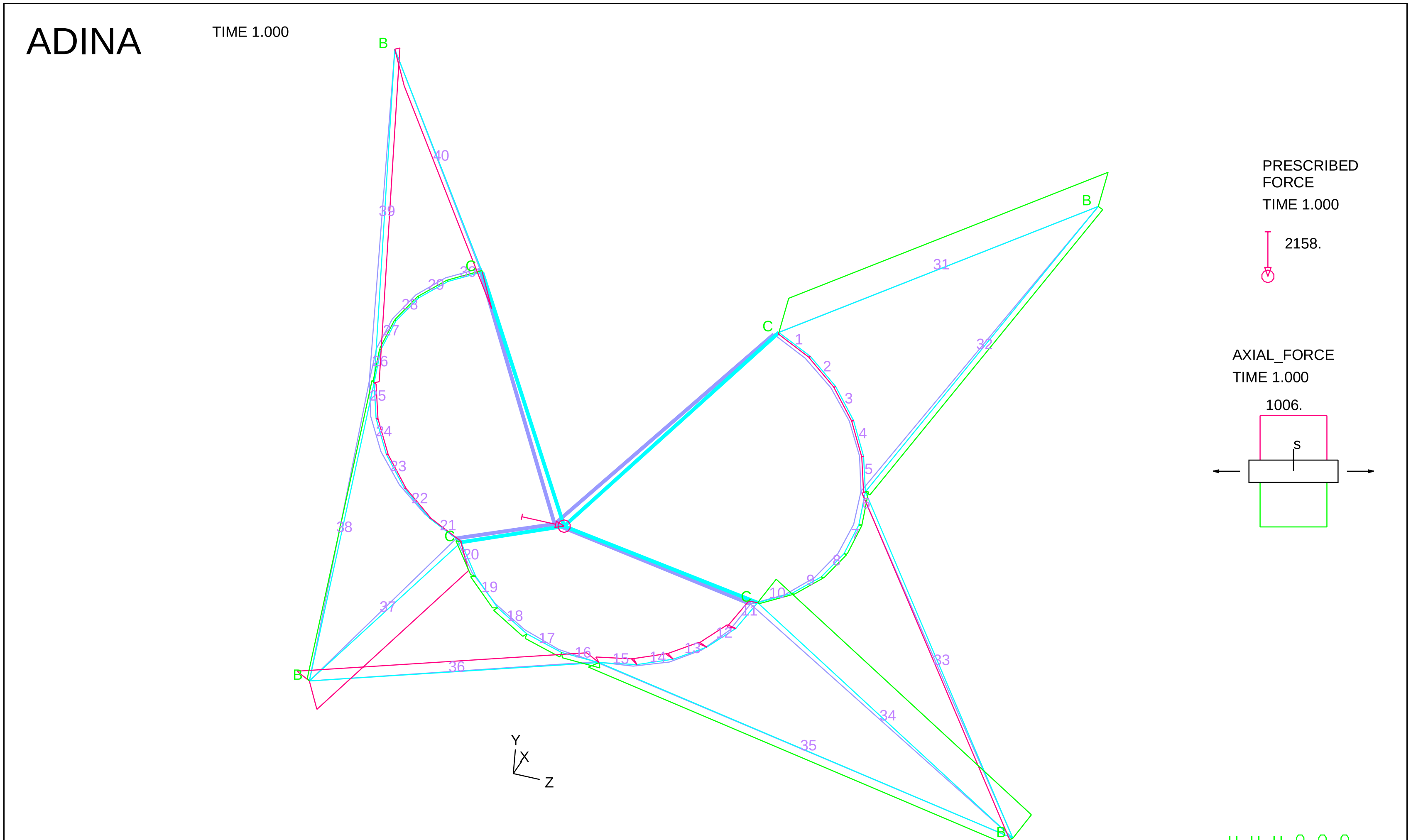

Fig. 4: loadcase #3 (F_z=2'158.5; Mt=0).