SCEPTOR

X-57 Maxwell

SCEPTOR Structural Loads Requirements for Cruise Motor

REQ-CEPT-010

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Revision Sheet

REVISION	DATE	LIST OF CHANGES
-	11/2/2016	(1) Baseline
A	8/1/2017	(1) Typo on Max Thrust & Regen Loads. Changed to 2446.5N from 2246.5N.

Cruise Motor Structure Loads Requirements

- Cruise motor structure shall be designed and tested for the following loads requirements. Structural fatigue shall be addressed as well.
  - Inertial loads
  - Max thrust loads & Regen
  - Max torque loads
  - P-factor loads
  - Gyroscopic loads
  - Propeller imbalance loads
  - Ground handling / Abuse loads
  - Thermal loads
- All structure shall have positive Margin(s) of Safety. Beyond showing a non-negative margin on ultimate load, it should be shown that structural yielding will not occur within the design limit load.
- Margin of safety is defined as: MS = (allowable load / ultimate load) - 1
- Ultimate load is defined as: ultimate load = factor of safety x design limit load.

Factor of Safety (FS)

- Unless otherwise stated, the appropriate ultimate factor of safety prescribed below shall be used for any new or modified structures.
- The ultimate factor of safety for
  - Metallic structure shall be of 2.25.
  - Composite structure shall be of 3.0 when using well established composite processes and materials.
  - Thermal loads shall be of 1.2.
- The factor of safety prescribed above must be multiplied by the highest pertinent special factors of safety prescribed in FAR 23.619.

Sign Conventions

- Nx: Longitudinal, Aftward (+)
- Ny: Lateral, Right (+)
- Nz: Vertical, Up (+)

Inertial Loads (Limit Loads)

- The structure shall be designed for the following limit load factors.
- Flight loads (maneuver and gust)
  - Upward, 3.4g
  - Downward, -2.0g
  - Sideward, +/- 1.33g
- Ground loads (taxi, and landing)
  - Downward, -2.0g
  - Sideward, +/- 1.33g
  - Forward, -3.0g

Max Thrust & Regen Loads (Limit Loads)

- The structure shall be designed for the max thrust and regen load
  - Max thrust is estimated to be +/-2446.5 N (+/-550 lbs)

Engine Torque Loads (Limit Loads)

- The structure shall be designed for the new motor max torque load of 470 Nm (4160 in-lbs).
- This load acts simultaneously with the 100% of the inertial limit load on the engine mount.

P-factor Loads (Limit Loads)

- P-factor shall be taken into account for the propeller loads at various extremes flight condition (angle of attack α from -15 to +15 degrees and angle of sideslip β from 0 to 15 degrees)
- The structure shall be designed for
  - Fx = +/-2837.05 N (P-factor)
  - Fy = +/-332.86 N (P-factor)
  - Fz = +/- 397.96 N (P-factor)
  - Mx = +/-470 Nm (Max torque)
  - My = +/- 297.64 Nm (P-factor)
  - Mz = +/-364.90 Nm (P-factor)
- This load acts simultaneously with the other load conditions.

Note: The cruise propeller loads listed below were analyzed for the Rev3 Mod3 cruise propeller geometry for SCEPTOR using OVERFLOW solver. All the loads are scaled using a 2446/945.81 factor except torque (Mx). The scale factor is computed based on the max thrust (2446 N) and the Fx (945.81 N) of level flight condition.

Table 1: Propeller Forces and Moments at Sea Level Standard Conditions, 85 knots Freestream Velocity, 2250 RPM.

α, deg	β, deg	F_x, N	F_y, N	F_z, N	M_x, N-m	M_y, N-m	M_z, N-m	P, kW
15	0	-1020.43	39.05	113.82	227.50	39.07	94.59	53.6
10	0	-978.48	27.57	77.66	221.06	25.66	65.37	52.1
0	0	-945.81	2.06	1.97	218.73	1.83	2.66	51.5
15	15	-1097.02	-91.72	153.88	237.23	-77.85	141.10	55.9

α, deg	β, deg	F_x, N	F_y, N	F_z, N	M_x, N-m	M_y, N-m	M_z, N-m
15	0	-2638.98	100.99	294.35	470	101.04	244.62
10	0	-2530.49	71.30	200.84	470	66.36	169.06
0	0	-2446.00	5.33	5.09	470	4.73	6.88
15	15	**-2837.05**	-237.20	**397.96**	470	-201.33	**364.90**
0	15	-2644.07	**-332.86**	108.70	470	**-297.64**	127.16

Gyroscopic Loads (Limit Loads)

- The structures shall be designed for the maximum gyroscopic loads per FAR 23.371 (a). This load acts simultaneously with the inertial limit load conditions. A minimum normal load factor of 2.5 is required.
  - Gyroscopic couple (Yaw) = 392 Nm
  - Gyroscopic couple (Pitch) = 157 Nm

Note: These loads are based on MTV-7-A/152-64 (59.8") propeller and the Moment of Inertia value of 0.37kg*m^2.

Propeller Imbalance Loads (Limit Loads)

- In fact, as soon as the aircraft starts operation, the propeller will be out of balance. Propeller imbalance loads shall be considered. Dynamic loads and vibration due to the imbalance shall be analyzed using dynamic analysis.
- Imbalance loads (Radial), Fc = 667 N (150 lbs).

- Assumptions:
  - MTV-7-A/152-64 propeller (34 lbs)
  - Maximum imbalance displacement from the shaft centerline is 0.02 inches
  - At 2500 rpm

Ground Handling / Abuse Loads (Limit Loads)

- The structures shall be designed for the following ground handling loads
  - Fx = +/- 667 N (150 lbs)
  - Fy = +/- 667 N
  - Fz = +/- 667 N

Thermal Loads

- Thermal Loads shall be considered in assemblies where component of disparate coefficients of thermal expansion are joined together, and are exposed to sufficient temperature variation to cause significant thermal stress generation.
- Thermal stress in design shall be considered
  - 0°F to max operational temperature or not lower than +165°F.

Fatigue Criteria

- Vibration caused by the motor unbalanced disturbances can lead to structural fatigue failure over time.
- A scatter factor of 4 times the planned number flight cycles or flight hours shall be used for fatigue analysis.

Summary of Limit Load Cases

Case	Condition	Design Limit Load Factor			Thermal Stress	Thrust, Torque & P-factor Loads	Gyroscopic Loads	Propeller Imbalance Loads	Ground Handling /Abuse Loads
		Nx	Ny	Nz					
1	Flight	0	+/-1.33	3.4	x	x	x	x	
2	Flight	0	+/-1.33	-2.0	x	x	x	x	
3	Flight	0	+/-1.33	3.4	x	x		x	
4	Flight	0	+/-1.33	-2.0	x	x		x	
5	Ground	-3.0	+/-1.33	-2.0	x				
6	Ground				x				x

Note: x means these loads should be included.

Worst-case loads for each component should be identified and analyzed.

Loads	F_x, N	F_y, N	F_z, N	M_x, N-m	M_y, N-m	M_z, N-m
Max Thrust & Regen & P-factor	+/-2837.05	+/-332.86	+/-397.96		+/-297.64	+/-364.90
Max Torque				+/- 470.0		
Gyroscopic					+/-157.0	+/-392.0
Ground handling / Abuse	+/-667	+/-667	+/-667			
Propeller Imbalance Loads	Radial load of 667 N					

Sign Conventions:

- Nx: Longitudinal, Aftward (+)
- Ny: Lateral, Right (+)
- Nz: Vertical, Up (+)

Margin of safety is defined as: MS = (allowable load / ultimate load) - 1

Ultimate load is defined as: ultimate load = design limit load x factor of safety.

Reference Materials

- NASA AFRC G7123.1-001
- Federal Aviation Regulations, FAR Part 23.
- TECNAM Flight Loads, Report No. 2006/011, Jan 27th 2009
- TECNAM Ground Loads Rev 2, Report No. 2006/016, 19th May 2009.