Assessment of the Structural Suitability of Tensegrity Aircraft Wings

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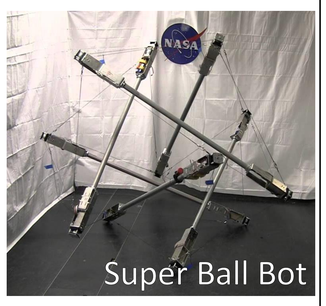
Objective: To assess the structural viability of tensegrity systems configured as aircraft wings by comparing their simulated structural performance to a baseline conventional wing structure.

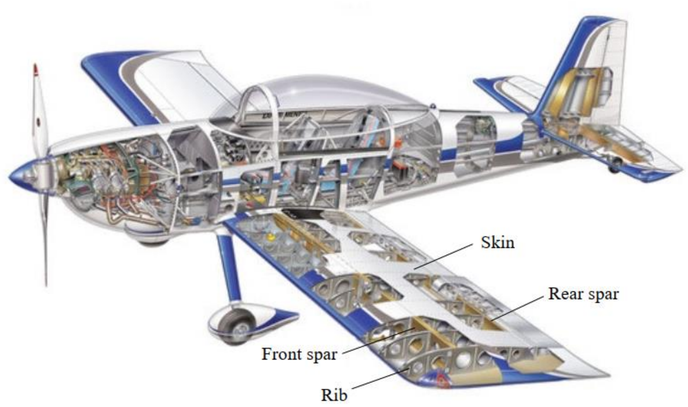
Introduction

This research examines the suitability of tensegrity aircraft wing concepts by comparing two tensegrity-based wing designs, generated through designer insights and structural topology optimization methods, to the aluminum Van's RV-4 aircraft rib/spar wing structure, chosen as the baseline performance case. The structural performance of the aircraft wings is simulated under realistic loading conditions characteristic of the baseline wing structure. Wing performance with and without skin is analyzed in consideration of the skin providing a significant contribution to stiffness. Tensegrity systems consist of a series of compressed struts connected by tensioned cables that place the system in a self-equilibrium state. Tensegrity systems offer structural efficiency while being able to alter shape by changing strut or cable lengths , both beneficial to aerospace structures.

Existing Tensegrities

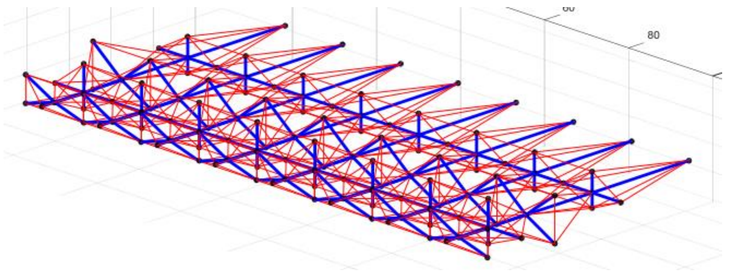


Van's RV-4 Baseline Conventional Wing



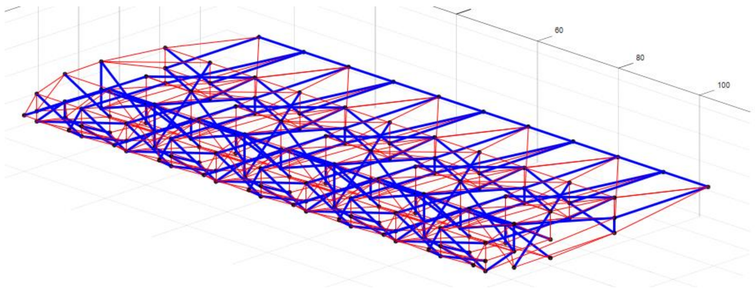
Designer Developed Tensegrity Wing

(by replicating a rectangular-cross unit cell)

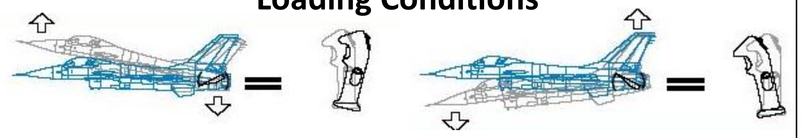


Topology Optimization Tensegrity Wing

(computational method that determines the structure with the best rigidity per unit mass)



Loading Conditions

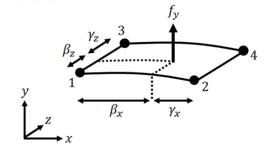


2g Pullup 1g Pushover

Analysis Methods

XFOIL Subsonic Airfoil Development System

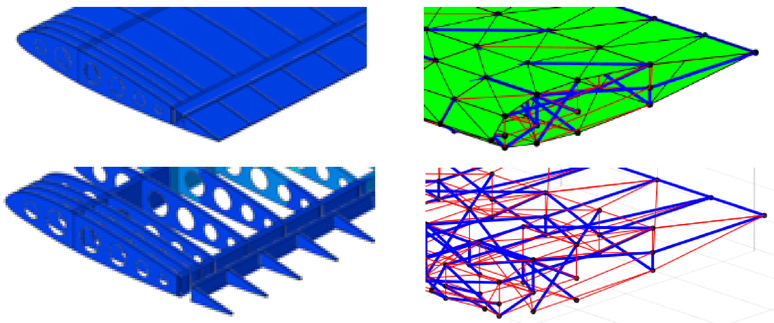
Load generation



Load interpolation to nodes

SIMULIA ABAQUS

MATLAB



Results and Conclusion

		Conventional	Tensegrity Designer-developed	Tensegrity Topology Optimization
Without skin	Mass	10.8 kg (23.9 lb)	6.4 kg (14.2 lb)	5.3 kg (11.6 lb)
	+2g max deflection	170.9 mm (6.73 in)	169.4 mm (6.67 in)	170.2 mm (6.70 in)
	+2g strain energy	149.0 N-m (1319 in-lb)	172.6 N-m (1529 in-lb)	192.3 N-m (1702 in-lb)
	-1g max deflection	-85.6 mm (-3.37 in)	-86.9 mm (-3.42 in)	-78.7 mm (-3.10 in)
	-1g strain energy (no skin)	37.3 N-m (330 in-lb)	43.3 N-m (383 in-lb)	46.8 N-m (414 in-lb)
With skin	Mass	25.7 kg (56.6 lb)	19.9 kg (43.8 lb)	36.0 kg (44.41 lb)
	+2g max deflection	18.3 mm (0.72 in)	18.3 mm (0.72 in)	16.8 mm (0.66 in)
	+2g strain energy	20.7 N-m (184 in-lb)	21.9 N-m (194.4 in-lb)	21.5 N-m (190 in-lb)
	+2g max strut stress	121 MPa (17.6 ksi)	229 MPa (33.3 ksi)	152 MPa (22.0 ksi)
	+2g max cable stress	–	478 MPa (69.4 ksi)	218 MPa (31.6 ksi)
	-1g max deflection	-9.1 mm (-0.36 in)	-9.2 mm (-0.36 in)	-8.3 mm (-0.33 in)
	-1g strain energy	5.2 N-m (46 in-lb)	5.5 N-m (48 in-lb)	5.5 N-m (48 in-lb)

The designer-developed tensegrity wing weighs 56% that of the baseline wing, and the topology-optimized wing weighs 49% of the baseline wing.