Rocket Airbrake

Analyzation and optimization

Graduate

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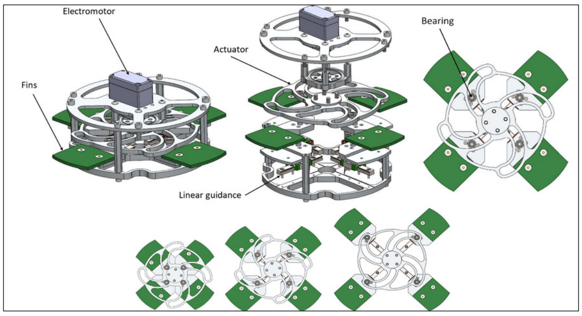
Introduction: Projeto Jupiter is a student initiative at the University of São Paulo founded in 2015. Students develop their own rocket with which they compete in national and international competitions. To achieve maximum points in competitions, the rocket must reach a precise apogee altitude. This is intended to be accomplished through the implementation of an airbrake, which slows down the rocket ecactly the right amount to reach the desired apogee. Since this technology has not been used by the team before, there is no prior experience or existing models. However, a prototype has already been developed. This work aims to analyze and optimize the mechanical part of the prototype of the airbrake system.

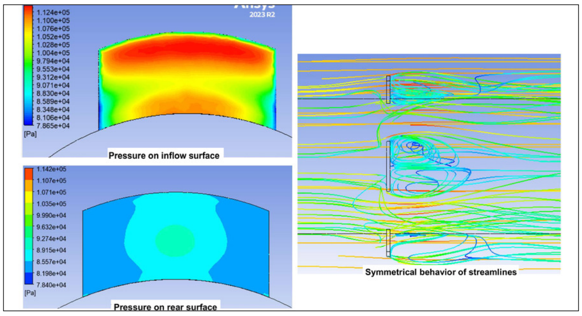
Approach: In order to simulate the forces acting on the airbrakes, a fluid simulation was conducted as a first step. The boundary conditions were chosen to simulate the maximum force on the fins and verify their ability to withstand it. The following ambient conditions were assumed: Ambient pressure = 101325 Pa, Mach number M=0.7 and fully extended fins. The determined pressure (Inflow surface: 136077 Pa ; rear surface: 78400.6 Pa) was then transferred to a structural analysis in order to determine the load-bearing capacity of the aluminium fins. A peak stress of 147.52 MPa on the edge where the screw head presses on the fin and a max. deformation of 0.093969 mm were identified. Those values were used to make optimization proposals. To select a suitable motor, a formula was elaborated to calculate the required torque of 0.2 Nm. Finally, optimization options were identified by using a morphological box and market research.

Conclusion: The fins can withstand the applied forces with a safety factor of 1.9. EN AW 6061-T6 is recommended as the fin material due to its high strength and
availability. To reduce weight, it is advised to 3D-print the actuator plate (SLA/PLA) and look for topology optimization opportunities in the design. A servo motor with a torque of 0.2 Nm is recommended to ensure smooth deployment of the fins during flight. Possible motors include the KST X08N or the Dynamixel XL-320. To reduce stress peaks, a plate should be installed beneath the screw heads to distribute the load over a larger area. A minimum distance of 0.1 mm between the rear fin surface and the rocket's slit edge is advised to prevent interference.
For future analyses and optimizations, the k-ω SST model with compressibility effects should be used for higher Mach numbers or a more detailed turbulence analysis of the rocket body. If the airbrakes are reused, a transient analysis is recommended to evaluate their lifespan. Expanding the morphological box within the team can generate additional concepts, and the best concept should be selected using a Decision Matrix Analysis, followed by calculations and simulations to ensure technical feasibility.

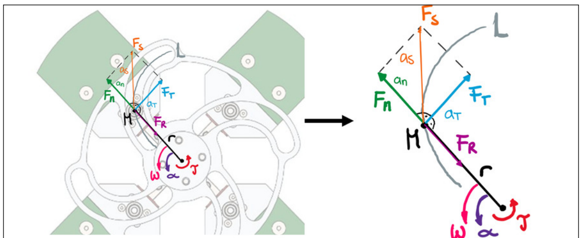
Airbrake model and deployment mechanism
Team 151 Technical Report 2024 Spaceport America Cup



Result of fluidsimulation (pressure on inflow and rear surface and generated streamlines)
Own presentment



Force model with derived torque formula
Own presentment



$$\underbrace{\left(M_a \cdot \frac{2\,L_p}{t^2}\right)^2}_{F_S} = \underbrace{\left(\frac{\mathcal{T}}{I}\, r\, M_a\right)^2}_{F_T} + \underbrace{\left[\left(\frac{\mathcal{T}}{I}\, t\right)^2 r\, M_a - \mu_f \left(\frac{1}{2}\,\rho\, C_d\, V^2 A + m\, g\right)\right]^2}_{F_R}$$

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Subject Area
Simulation Technology, Product Development