Design of Rotorcraft MAV for Operation in Mars Atmosphere

Ajo Joseph Anto[1], Vellingiri Ramanujam R[2], Shamrao[3*], Ranjith M[4]

[1] MS Student, Department of Aerospace Engineering, IIT Madras (antoajo@gmail.com))

[2] PhD Student, Department of Aerospace Engineering, IIT Madras (ramanujam3458@gmail.com)

[3] Scientist/Engineer-'SF', Spacecraft Mechanisms Group, URSC Bengaluru (shamrao@ursc.gov.in).

[4] Assistant Professor, Department of Aerospace Engineering, IIT Madras(ranjith.m@iitm.ac.in)

*Corresponding Author E-mail: (shamrao@ursc.gov.in)

Abstract:

The research focusses on establishing the feasibility of a Rotorcraft MAV for operation in Martian atmosphere. An aerial vehicle can obtain terrain information and perform other atmospheric measurements on Mars while being able to cover a larger distance in a shorter time as compared to a ground vehicle, it can act as scout vehicle for Rovers as well [1]. This can be of valuable aid in optimizing the path planned by ground vehicles.

Mars atmosphere is approximately 100 times less dense compared to Earth atmosphere. Also it is composed mainly of CO_2 and has an average surface temperature of 210K[2]. These conditions require a Rotorcraft to be designed to operate at low density, which translates to low Reynolds number flows. However, to generate the necessary thrust at low density, a higher rotating speed of the rotor is employed, which could mean high Mach number flow. So, the vehicle has to operate in an unusual aerodynamic regime of low Reynolds number and high Mach number, which is not well studied, and lacks aerodynamic data in literature.

The aerodynamic coefficients were estimated using XFOIL which has been found to agree reasonably well with CFD simulations performed in a separate study. Further, estimation of aerodynamic performance is carried out using Blade Element Momentum Theory (BEMT). An experimental setup is fabricated to study the aerodynamics of the rotor system to be used in the Rotorcraft. A steel chamber is built to simulate low density using a vacuum pump and a 1m diameter test rotor powered by an electric motor is setup inside the chamber, the thrust and power values are measured using a loadcell. The results are verified with analytical (BEMT) and CFD computations. The initial studies confirm the feasibility of designing a rotor system that can operate in the Martian atmosphere.

Keywords: Rotorcraft, MAV, Martian, Rover, Reynolds number, Mach number, XFOIL, CFD, BEMT, Airfoil, Rotor, Chamber.

Figure 1: Experimental setup inside low density chamber

References:

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