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AERODYNAMIC DESIGN AND SIMULATION OF MARS ROTORCRAFT

Abstract

The greatest obstacle for Mars exploration rotorcraft design and application is Martian extremely thin atmosphere. The density of Martian atmosphere on surface is only 1/80 of it on Earth. That means much less lift will be generated on Mars than on Earth for the same rotorcraft at the same altitude. Although the gravity on Mars is lower than the gravity on Earth, the lift may be insufficient to keep existing rotorcrafts in air on Mars. For aerodynamic design of Mars rotorcraft, low density and speed will lead to low Reynolds flow. The air flow will easily separate from rotor surface which resulting in lower aerodynamic efficiency and more operation complexity. Besides atmosphere density, the lower speed of sound and temperature, compositions of atmosphere (96% carbon dioxide) on Mars increase the difficulty of propulsion system design. The tip speed of rotor is always constrained below drag divergence Mach number for the considering of aerodynamic efficiency. Lower speed of sound means lower tip speed of rotor and less lift for the same rotor on Mars than on Earth. This paper analyzed existing conventional helicopters, quad-rotor in the view of hover power, forward flight velocity and rotor tip velocity to exam if they can fly on Mars. Scaling analysis method was used in the analysis and power ratio criterion of Mars rotorcraft was given. It is an important guideline for our design. In this paper, we proposed a electric propulsion autonomous coaxial helicopter project with mass of about 10kg and endurance of about 20minute. This Mars helicopter can be deployed on a rover, which can be seen as a moving site. After mission completed, the helicopter will return with samples or data and recharge for next mission. This paper emphasized on aerodynamic design and analysis of Mars helicopter in the thin Martian atmosphere. In the low Reynolds situation, there exists complex flow field around the helicopter especially around the rotor. To simulate the flow field accurately, computational fluid dynamics (CFD) method is used. The code solves 3-dimensional Navier-Stokes equations on structural grid. We used overset grid method to simulate the unsteady flow around the rotor. Finally the simulation result was compared with the flow field on Earth and the capability of Mars helicopter was analyzed based on the simulations.