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Airfoil aerodynamic optimization for Mars exploration aircraft

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Abstract
Martian exploration has always attracted attention of space scientists owing its peculiar surface conformation, with the potential to host life due to presence of water [1, 2, 3]. Currently, researchers are particularly interested in ground surface observation through high resolution images. Apart from recently developed technologies based on Mars helicopter rotors, to date, rovers and orbiters represent a viable way to Martian surface exploration. Rovers can be used for very accurate explorations over limited areas of the planet, because of their relatively slow and rather difficult movement on Martian surface. Although rovers' observation is very accurate, they have the drawback of being locally confined, by leaving large unexplored areas. On the other hand, orbiters are capable of long-range explorations and covers larger areas, but with low image resolutions (approximately 0.3 m/pixel) if compared to 0.1 m/pixel required for in depth observation. Development of fixed-wing drones for Mars exploration has been an active area of research for several decades, to provide a way to gather scientific data about the Martian atmosphere and surface. Several literature studies at low-Reynolds-number have been conducted to design airfoil suitable to fly in Martian atmosphere. Because of the non-linearity of aerodynamic coefficients of an airfoil, created by laminar separation bubble at low-Reynolds number, researchers focused on the modification of specific geometric features which shown to improve airfoil aerodynamic performances. In this framework, the present paper deals with an optimization procedure able to design airfoil for fixed wing aircraft with enhanced aerodynamic performance despite the low Reynold flow conditions. Low-density Martian atmosphere, in fact, promotes laminar separation without reattachment, which complicates airfoil optimization due to extreme sensitivity of the aerodynamic coefficients. To provide understanding of different Low-Reynolds design two separate airfoil parameterization are developed and coupled to the potential flow solver X-foil, to feed the optimization algorithm. A genetic algorithm is adopted to generate the optimal airfoil shape, considering the maximum efficiency as objective of optimization. Finally, the validation of the optimized airfoil is addressed by performing several CFD simulations in flow similarity conditions aimed at defining the airfoil aerodynamic performance. RANS computations were carried out at low Reynolds number and Mach numbers, suitable for flight conditions of Mars exploration aircraft.

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