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Aerodynamic Characteristics

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Abstract

In the low-Reynolds-number range below Re = 60,000, SD7003 and Ishii airfoils are referred to as high-performance low-Reynolds-number airfoils with a comparatively high lift-to-drag ratios. Although the aerodynamic characteristics at particular Reynolds numbers are thoroughly studied, research is lacking on how Reynolds numbers affect the aerodynamic characteristics that become pronounced for general low-Reynolds-number airfoils. This study investigates the Reynolds number dependence on the aerodynamic performance of those two airfoils. The results demonstrate that the Ishii airfoil is especially less hooked in to the Reynolds number of the lift curve compared to the SD7003 airfoil. Although there's a small difference within the high angles of attack above the utmost lift coefficient, the lift slope hardly changes, even when the Reynolds number varies.

Keywords: Low-reynolds-number • Aerodynamics • Reynolds number dependence • Separation bubble • Ishii airfoil

Introduction

The aerodynamic performance of low-Reynolds number airfoils in chord Reynolds numbers (Re) but 105 is vital for various engineering applications, like micro air vehicles, unmanned air vehicles, and low-speed/high-altitude aircrafts. Recently, a replacement application for low-Reynolds-number aircraft has emerged to enable aerial exploration on Mars; this so-called Mars airplane has been considered and discussed for a several years in Japan. A Japanese research group has already developed the primary prototype for the Mars airplane with a hard and fast wing, which performed a high-altitude flight-demonstration test in 2016.

In such a low-Reynolds-number range, the formation and bursting of separation bubbles occur on the wing surface. This sort of natural phenomenon strongly depends on airfoil shape, Reynolds number, and angle of attack, and causes non-linear lift curves also as influences the Reynolds number effect on aerodynamic performance. Therefore, aerodynamic predictions supported physical properties are essential for high-performance wing design of low-Reynolds number aircrafts. The behavior of separation bubbles on representative symmetric airfoils, like NACA0012 airfoil and flat plate, has been well investigated. More practical asymmetric airfoils with aerodynamic characteristics have also been reported, including Selig-Donovan (SD) 7003 airfoil and Ishii airfoil. These two airfoils have relatively high lift-to-drag (L/D) ratios below Re = 70,000 where the low-Reynolds-number effect becomes pronounced and are referred to as high-performance airfoils at low-Reynolds numbers. Especially, Ishii airfoil is taken into account a possible main-wing airfoil candidate for the Japanese Mars airplane thanks to its high L/D round the cruising Reynolds number of 23,000. The aerodynamic characteristics of those two airfoils at Re = 23,000 via large-eddy simulations.

The results revealed that the airfoil shape of the side dominates both the formation of laminar separation bubbles and therefore the transition to turbulence round the airfoil. Moreover, the lower surface of the airfoil shape doesn't significantly affect the flow structure round the airfoil because the attached flow is usually maintained on the lower surface. Although aerodynamic characteristics and flowfields round the airfoils at the precise Reynolds numbers are studied, knowledge remains lacking about how the Reynolds number affects aerodynamic characteristics. Since low-Reynolds number aircrafts like the Mars airplane fly at various altitudes and speeds, it's necessary to reveal how changes within the Reynolds number impact aerodynamic performance, especially lift characteristics. This study investigates the Reynolds number effect on the lift and drag characteristics of Ishii and SD7003 airfoils. Within the flight sequence assumed for the Japanese Mars airplane, a Reynolds number but 23,000 may be a transitive condition. Thus, the Reynolds number was changed from 23,000 to 60,000. Additionally, the flowfield round the airfoils were visualized by employing the smoke-wire method at Re = 23,000.

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