AERODYNAMIC CHARACTERISTICS OF AIRFOIL AT LOW REYNOLDS NUMBER IN MARTIAN ATMOSPHERE

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Summary: The unique atmospheric conditions of Mars require the wings and propellers of Martian aircraft to operate at low Reynolds numbers (Re=10^3~10^5) and relatively high Mach number (Ma=0.3~0.5). Therefore, the airfoil performance has some specific characteristics, such as nonlinear lift curve caused by the formation or burst of laminar separation bubbles (LSB). With the increasing interest in the design of aircraft for Mars, the precise prediction for aerodynamic performance of airfoil in Martian atmosphere and the clear understanding of the flow mechanism of LSB is required. Direct numerical simulations (DNS) of a triangular airfoil designed for Martian atmosphere are conducted to study the aerodynamic characteristics of an airfoil at low Reynolds numbers, especially the laminar-turbulent transition through LSB around the critical angle of attack (AoA).

A CFD code ASTR based on the compact sixth-order central scheme and tenth-order filter is used as the numerical solver. The O-grid was generated around the triangular airfoil, concentrating towards the upper surface of the airfoil to capture the laminar separation and subsequent turbulence. Two Reynolds numbers are studied at Re=3×10^3 and 1×10^4 with Mach number is M∞=0.5, and AoA changing from α=0° to 12°. At Re=3×10^3, the flow is basically laminar with a critical AoA around α=9°. According to the mean streamlines in Figure 1, we can see that the flow is attached upstream the apex and separated after the apex when α<9° and fully separated from the leading edge when α≥9°. When the Reynolds number is increased to Re=1×10^4, the turbulence develops gradually with the increase of AoA (as shown in Figure 2). The critical AoA changes from around 9° at Re=3×10^3 to a value between 4° and 5°. At α=4°, the flow upstream the apex is attached but a relatively large separation zone is developed downstream the apex (shown in Figure 3) and the separated shear-layer breaks into 3-D vortex structures in the wake region (shown in Figure 2). At α=5°, two small separation
zones can be observed upstream and downstream the apex respectively. Compared with the case of $\alpha=4^\circ$, the breakup of the shear-layer is delayed and the fluctuating intensity is reduced, probably due to the reduction of size of the downstream separation zone. With the further increase of AoA, the fully separated flow is observed and turbulence is developed above the airfoil. The detailed analysis of flow physics around the critical AoA is on-going.

![Figure 1: Mean velocity and streamlines at $Re=3\times10^3$ ($\alpha=6^\circ$~$12^\circ$)](image1)

![Figure 2: Instantaneous iso-surfaces of $Q=10$ at $Re=1\times10^4$ ($\alpha=4^\circ$~$6^\circ$)](image2)

![Figure 3: Mean velocity and streamlines at $Re=1\times10^4$ ($\alpha=4^\circ$~$6^\circ$)](image3)

**REFERENCES**
