Boundary layers transition measurement over an airfoil by using PIV with high magnification

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1. Introduction

Boundary layer velocity vectors over a 16% elliptic airfoil at a Reynolds number of $3 \times 10^5$ were measured by using a two dimensional particle image velocimetry with high magnification. To see the inside of the thin boundary layer in detail the magnification factor was increased up to about 60 pixels/mm by inserting extension tube between the lens and CCD camera. Surface mount hot film sensor was also used to determine boundary layer transition from laminar to turbulent or relaminarization from turbulent to laminar by inspecting intermittency factors. The experimental results indicates that as angle of attack increases boundary layer transition position moves toward leading edge on the suction side while laminar boundary layer remains unchanged on the pressure side with smooth surface condition. On the contrary, turbulent boundary layer on the pressure side of trip surface condition is relaminarized as angle of attack increases causing early laminar boundary layer separation. This verifies that the results revealed in previous research concerning lift curve slope higher than $2 \pi \alpha$ at low angles of attack and lower than $2 \pi \alpha$ at high angles of attack, which is quite different from the case of conventional airfoils. From the comparison between velocity profile shapes and intermittency factors, boundary layer shape factors can be a good measure in determining transition even though there exists pressure gradient along the airfoil surface.

This paper focuses on the boundary layer velocity profiles and boundary layer transition positions over an airfoil, since boundary layer transition is directly related to boundary layer separation. Measurements were taken in a subsonic wind tunnel by using PIV with high magnification and surface mount hot film sensors.

2. Experimentation

Tests were conducted in a low-speed wind tunnel at Korea Aerospace Research Institute (KARI), of which the test section is 1 m wide, 0.75 m high, and 2 m long. The maximum achievable wind speed is 110 m/s and the turbulence intensities for empty test section condition are 0.12% in stream wise direction and 0.15% in vertical and lateral directions. The cross sectional shape of the airfoil was an ellipse whose major axis, the chord length ($c$), was 200 mm and the minor axis 32 mm. The span of the model was 990 mm yielding the aspect ratio of 4.95. The model was constructed of aluminum and its surface was coated with thin black vinyl to reduce scattering of laser light for PIV. The Reynolds number based on the chord was $3 \times 10^5$ with the free stream velocity ($U_0$) of about 25 m/s. The angle of attack was varied from $-16^\circ$ to $16^\circ$ with the increment of $1^\circ$.

A two dimensional PIV system was used for the flow field measurements around the airfoil surface to investigate boundary layer velocity profiles. In addition to the velocity profile measurement, intermittency factors were measured by using surface mount hot film sensors.

3. Results

Boundary layer transition on an elliptic airfoil was studied both by PIV and by surface mount hot film. From PIV measurement, velocity profiles were measured and shape factors were calculated. From surface mount hot film sensor measurement, intermittency factors were computed. The comparison between velocity profiles and intermittency factors shows a good agreement in distinguishing boundary layer transitions. It can be concluded that the wake asymmetry in a low angle of attack range which was reveled in the previous research are caused from the different flow regime i.e. laminar or turbulent between suction and pressure sides as angle of attack increases.