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Numerical Study of an Airfoil with Riblets Installed Based on Large Eddy Simulation*

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Abstract:

The implicit large eddy simulation method is applied in a riblet drag reduction study of a low-speed airfoil. The numerical method is tested by a channel flow with streamwise riblets installed on one side. The mean velocity profile, root mean square of velocity and Reynolds shear stress match well with reference direct numerical simulation data. Next, numerical investigation is conducted on an airfoil called Eppler E374 at free stream Mach number 0.2, angle of attack 3° and Reynolds number 2.0×10^5. The simulated flow around the airfoil without or with a numerical trip is in good agreement with the experimental data. When isosceles triangle riblets are installed on the airfoil along the streamwise direction, the lift coefficient is increased, and the friction drag is decreased. The pressure distribution on the airfoil is slightly changed, corresponding to the increased pressure drag. The Reynolds stresses are greatly reduced by the riblets at locations of strong pressure gradient. The result of the power spectrum density of pressure shows that the high-frequency fluctuations are suppressed when the riblet film is installed on the airfoil, and the vortex structures in the boundary layer are also reduced.

Keywords:

large eddy simulation, streamwise riblet, airfoil, drag reduction, numerical trip

1. Introduction

Aerodynamic drag includes friction drag, induced drag and wave drag. Friction drag caused by turbulent flow plays an important role, accounting for approximately 50% of the total drag of a civil aircraft. Because the near-wall turbulent coherence structure is relevant to the high-friction drag of the boundary layer, flow control methods of suppressing the turbulence structure are usually employed to reduce the friction drag. The use of riblets is a passive flow control technique of friction drag reduction that restricts the streamwise vortex and suppresses the generation of hairpin vortex in the boundary layer; consequently, this technique reduces the Reynolds stress and decreases the momentum and energy loss inside the boundary layer. Many investigators are interested in the riblet technique because of its efficiency and implementability.

Experimental study is a common and convenient method to test the drag reduction effect of riblets. Vukoslavcevic et al. [1] studied the effect of riblets at $Re_\theta=10^3$ and found that the most efficient region for depressing the turbulent fluctuation is under 4% of the boundary layer height.

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