A BOUNDARY—LAYER—POTENTIAL—FLOW INTERACTION MODEL FOR UNSTEADY AIRFOIL FLOWS

Hong—Ming Jang

ABSTRACT

The incompressible flows over a practical airfoil excuting a pitching motion were simulated by a boundary-layer-potential-flow interaction model. In this numerical model the boundary-layer flow was computed by a finite-difference scheme which made use of an interactive boundary condition and the potential flow was computed by an unsteady panel method involving a blowing-velocity distribution on the boundary, which accounted for viscous effects. After their calculations, both methods provided updated boundary conditions for each other. The calculations were repeated until the solutions converged.

After being developed, this model has been tested with the flows over airfoils excuting some kinds of pitching motions and the results demonstrate reasonable unsteady effects and justify the model. This model does not only simulate a wide range of airfoil flows but also may be a foundation for further exploring to the unsolved problems, such as unsteady boundary layer singularity, dynamic stall onset predictions, and unsteady-flow transition prediction etc.

INTRODUCTION

The effect of pitching motion of an airfoil on its stall behavior is of considerable interest to many practical applications including the blades of helicopter rotors and the wings of maneuvering aircraft. One example of dynamic stall process was described in Carr and Chandrasekhara[1], see Fig. 1, which demonstrates the flowfield structure as well as the lift and pitching moment variations when an NACA0012 airfoil performed one cycle of harmonic oscillation, $\alpha=15°+10° \sin\omega t$, at $\omega C/2U_\infty=0.15$, $Re=2.5\times10^6$, where C is the chord length, U_∞ the free-stream velocity, and Re the chord Reynolds number. This case shows that the pitching motion of the airfoil suppresses the trailing edge reversal region and induces the formation and shedding of a dynamic stall vortex from the leading edge so that the occurrence of stall is