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A PREDICTION METHOD OF THE STALLING FOR WINGS WITH REAR SEPARATION

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Abstract

In this paper, an approximate method is presented to compute aerodynamic characteristics of high aspect ratio and low sweep wings with rear separation at high incidences. The method utilizes a three dimensional linear lifting surface theory for inviscid flow and a two dimensional airfoil theory for viscous flow flow connecting both theory within an iteration techique for calculate lift, drag and pitching moment characteristics of wings.The computed model of airfoil used in viscid-inviscid iteration scheme with a higher order singularity panel method,including the boundary layer calculations and a displacement model forrear separation. An integralmethod is used in boundary layer calculations. The computed results comparison with data from other theory and exprimental as well. It has showed that the method is a little computational demand, fine converge and good accuracy approximate method, which is suitable to engineering computation.

I. Introduction

Ever since the science of aerodynamics exists, the predictión of the stalling for wings is an important and troublesome problem in design of aircraft. In order to predict the flow around the wing of an aircraft at high incidence and low speed, it is crucial to account for the viscosity effects, including separation.

Many numerical methods for computing aerodynamic characteristics of wing have developed. The general method for computing the three dimensional flow around the wing with rear separation would be a combination of a three dimensional panel method with a three dimensional boundary layer method and a three dimensional model of the separated flow region or even three dimensional Navier-Stokes question calculations. There are many problems in the details of such a method,and andmust expect that such a method will consume an enourmous amount of computer time which may be unacceptable for practical applications. So, it is reasonable to design an effective approximate method to compute aerodynamic characteristics of the wing.

A prediction method for computing the subsonic flow arounds with moderate to high aspect ratio and low sweep at high angles of attack has been presented by Jacob.k (ref.1).The method utilizes a three dimensional linear lifting surface method for inviscid flow and a two dimensional airfoil method for viscous flow at low Mach mumbers, including the boundary layer calculations and a displacement model for separation flow and a compressibility correction, connecting both methods within an iteration process. The total procedure allows for predicting the complete wing characteristics including maxium lift and post stall. But, the mathematical model of two dimensional airfoil theory in Jacob's method is very complex. The model brings aboute incommodious in numerical computation. Aaerodynamic characteristics of the flow around airfoil is used in this paper. The model is good responding aerodynamic characteristics of the flow around airfoil. The Thwaites' method is used to calculate the laminar boundary layer. The cebeci's rule is used to judge the transition of the boundary layer. The Green's Entrainment method is used to calculate the turbulent boundary layer. In final, a compressibility correction is applied to compute the aerodynamic characteristics of airfoil.

The modified method can predict aerodynamic characteristics of wing and airfoil. The computed results have showed that the modified method is a little computational demand, fine convergence and good accuracy approximate method, which is suitable to engineering computation. Using the method to compute a lifting curved line of wing, average times neede by an angles of attack is only haiy past two minutes CPU times on IBM4341 computer.

II. The Calculation Method

1. Description of the three dimensional lifting surface

For wings with moderate to high aspect ratio and low sweep, Jacob considered, except for the vicinity of the wing tips, the section flow of wing is approximately two dimensional.The vortex system is essentially determined by the spanwise lift distribution, which may be effected considerably by partial separation with a given wing and given oncoming flow.so, the vortex system is diffience between three dimensional wing and two dimemsional wing, and the reducing speed and the effective flow is difference, too.If the spanwise lift and the pitching moment of wing is known, the values and directions of effective basic flow at each section are computed by the linear lifting surface adversely applied. In the other words,if the values and directions of effective basic flow is known, the aerodynamic characteristics at each section of wing will be calculated from the predicted values or exprimental data of aerodynamic characteristics of airfoil.

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In iterative procedure, for given plane forms and geometrical angles of attack wing, the Truckenbrodt linear lifting surface theory is used to compute the first values of spanwise lift and the moment distribution of wing, and than the linear lifting surface theory is adversely applied to the computation of the downwash flow field. So, effective angle of attack at each wing section are gained. According to known effective angles of attack and Reynoids number, the corresponding second values of spanwise lift and the moment distribution of wing are gotten from predicted data or exprimental data of airfoil aerodynamic characteristics. Iteration is done again and again until covergence is reached.

2. Description of the airfoil section method

When flow over an airfoil, the simpler method employ a viscid-inviscid interaction scheme. In such procedures the viscous boundary layer calculation yieids sufficient information to effect appropriate displanementcorrections to the inviscid flow. and this calculation gives a new pressure distribution for use with the boundary layer calculation. the two computations are iteratively adjusted with respect to each other until some convergence criterion is satisfied. The above mathematical technique is of the direct type. Where the predicted inviscid flow velocity distribution provides an input to the boundary layer calculation Computed viscous displacement effects and the boundary layer separation point are then used to adjust the inviscid solution and so on. Modelling of the separated wake is achieved inviscidly in the manner of Dvovak and Maskew(ref.2), but as modified by Lu(ref.3), using a higher orde singularity panel method that the vorticity and sources distribtion in each panel is assumed linear with respect to the arc length of the panel. The sequence of this is as indicated in Figure 1.

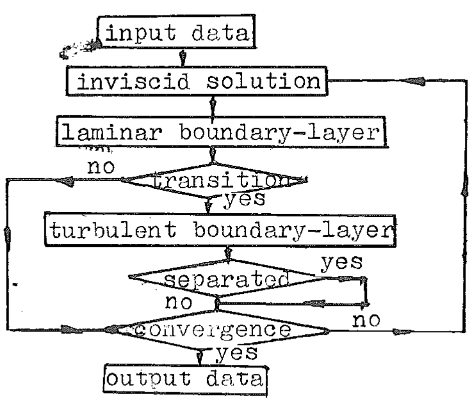

Figure 1. computed chart airfoil

For inviscid calculation, the airfoil profile is replaced by an inscribed polygon of vortex and source panels over which the vorticity and source varies linearly, achieving piecewise continuity between adjoining panels. The free shear layers used to model the airfoil wake are comprised of uniform strength vorticity panels. For boundary layer calculation, the laminar boundary layer portion were presented by Thwaites' method; and the turbulent portion were represented by Green's entrainment method The location of natural transition is obtained using the correlation of Cebeci. Details seen in ref.3.

The drag coefficient is estimated with following manner:no separating the drag is calculated with the Young-Squire formula at upper surface and under surface trailing edge point of the airfoil; when separatation occers the Young-Squiree formula is applied at separated point of upper surface and at trailling edge point of under surface adding contribution of pressure distribution separated region.

III. Results and Discussion

TO assess the predictive capability of the develop method, a number of comparisms with wind tunnel data and other theoretical data were made.

1. GA(W)-1 airfoil

The section was originally developed for general aviation purposes. Theairfoil is a 17% thick section with the maximum thickness lying at approximately 40% chord. The experimental data for the GA(W)-1 airfoil were obtained in the NASA Low Turbulence Pressure Tunnel. In Fig. 2 comparision is made between the lift,drag and pitching moment coefficient.

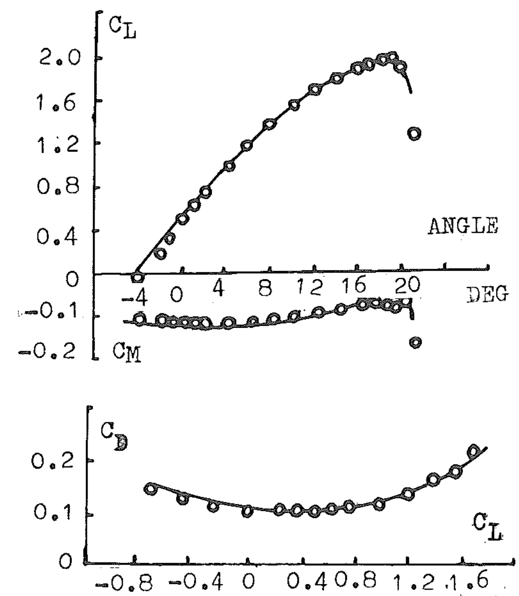

Figure 2. aerodynamic characteristics of GA(W)-1 airfoil

Fig.3 presents a comparison of calculated and experimental pressure distribution at 19.06 deg.,for $Re=6.3*10^6$,Ma=0.15.In this case, there is good agreement between the pressure distribution and the separation point is well predicted

2. N4412 airfoil

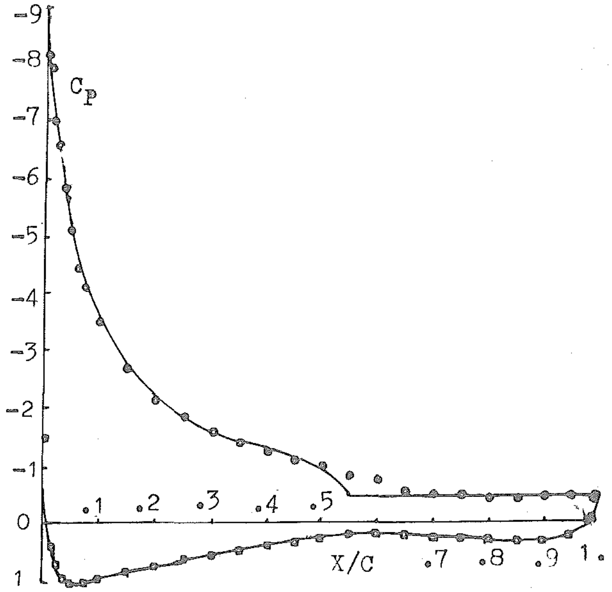

Figure 3. pressure distribution of GA(W)-1 at 19.06 deg.

This section is typical of many in general use. Theex experimental data were obtained in the NASA Low Turbulence Tunnel.

In Fig. 4, lift, drag and pitching moment coefficience characteristics are presented at $Re=6.3*10^6$, Ma=0.17, The predicted data the experimental data are in good agreement.

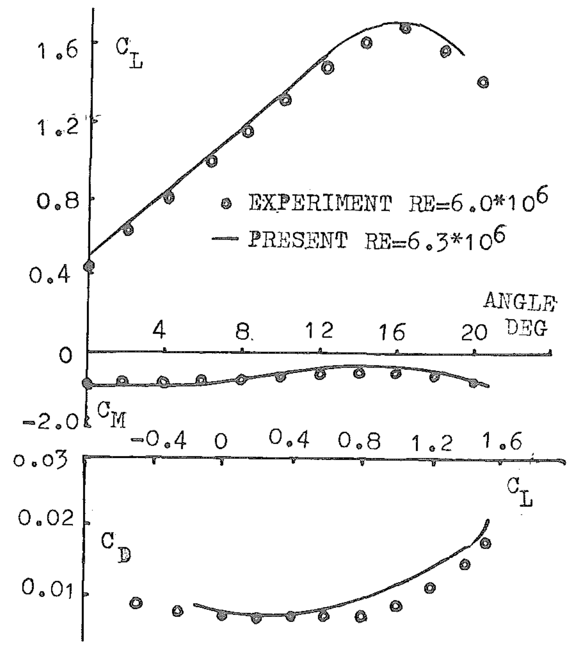

figure 4.aerodynamic characteristics of N4412 airfoil section

3.Rectangle wing with N4415 section

In fig.5, lift coefficient characteristics at two aspect ratio are presented for rectangle wing with N4415 section.Here,experimental data of two dimensional aerodynamic characteristics is used.Because the calculated values of N4415 section are overpredicted. One reason is considered that the Thwaites' method for N4415 with large curvature at leading edge is not possible to derive since it is a one-equation method. Figure 5 illustrate that the computed results is well agreement with experimental data than that in Jacob's paper.

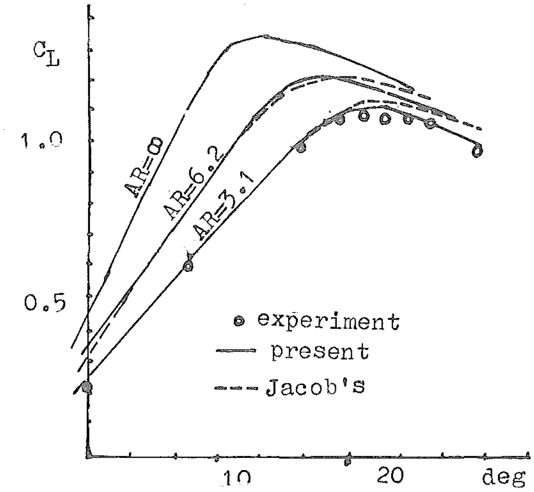

Figure 5. lift curve of rectangle wing at different aspect ratio

4.Tapered wing and sweep wing with N23012 section

In Fig.6,Fig.7,lift-drag characteristics are present for tapered and sweep wing with N23012 section,here experimental data of airfoil are used. Trend of curves at two figure is coincide with that in Jacob's

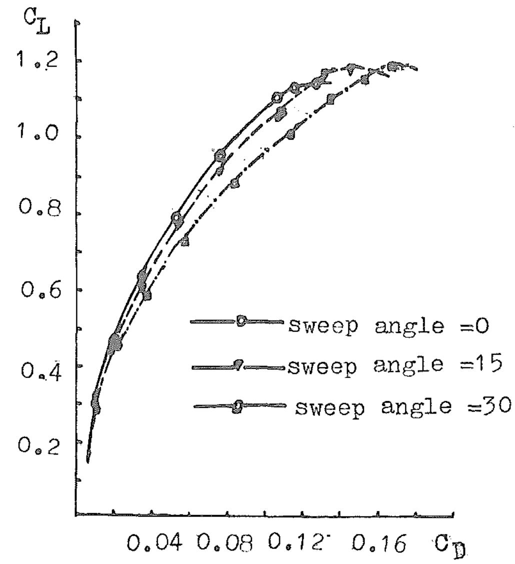

Figure 6.lift-drag characteristics of wing at different tapered wing

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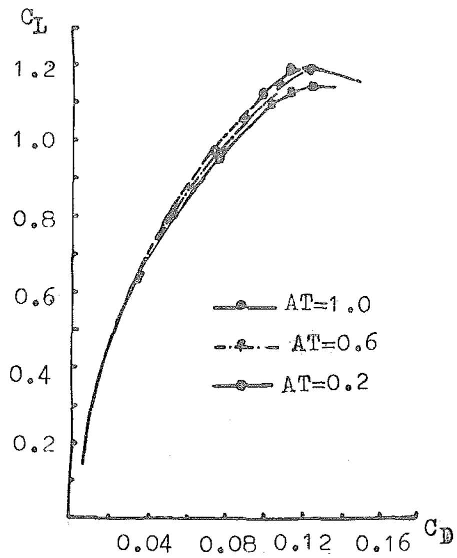

Figure 7.lift-drag characteristics of different sweep wing

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