Modeling Arbitrary NACA 4-Digit Airfoils with Kuethe Chow Vortex Panel Method

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This technical report presents a comprehensive numerical analysis of the aerodynamic characteristics of NACA 4-digit airfoils utilizing the Kuethe Chow vortex panel method. The airfoil surface is discretized into a series of panels, and the vortex panel strengths are computed to satisfy the imposed boundary conditions. The pressure distribution, lift, drag, and pitching moment coefficients around the airfoil are thoroughly examined and compared with experimental data obtained from wind tunnel tests. The results demonstrate a high degree of agreement with the experimental data, particularly when comparing the rate of change of coefficients. The Kuethe Chow method proves to be a valuable alternative to Computational Fluid Dynamics (CFD) for predicting the aerodynamic performance of airfoils.

Nomenclature

AoA	= *Angle of Attack*
CFD	= *Computation Fluid Dynamics*
Cp	= *Coefficient of Pressure*
Cmc/4	= *Coefficient of Moment about 25% chord point*
Cmac	= *Coefficient of Moment about aerodynamic center*
VPM	= *Vortex Panel Method*
MCL	= *Mean Camber Line*
TODO	

I. Introduction

NACA airfoils have been widely used in the aerospace industry due to their superior aerodynamic performance. Various numerical methods have been developed to accurately predict their characteristics, including the source panel method. However, this method is limited in its lack of circulation, thus unable to predict lift. The Kuethe Chow vortex panel method addresses this limitation by considering vortex shedding and circulation around the airfoil. Moreover, its computation time is significantly shorter than that of CFD, making it a valuable alternative for practical engineering applications.

II. Problem Statement

The Kuethe Chow vortex panel method represents an airfoil body as an infinitesimal summation of vortices forming a vortex sheet. This vortex sheet induces a circulation around the airfoil, which can be integrated to determine the lift produced on the airfoil via the Kutta-Joukowski theorem. This process is known as the Vortex Panel Method (VPM).

VPM can be applied to either the upper and lower surfaces of an airfoil or to the mean camber line (MCL) in conjunction with thin airfoil theory.

The accuracy of VPM is evaluated in this paper. Results are compared to experimental data referenced in the Perkins and Hage airfoil tables.

III. Program Setup

All code written for the analysis is done in MATLAB and referenced in the appendix.

Before defining the vortex, sheet and iterating across each panel, the geometry of the airfoil should be defined. The function "naca4digit" will accept a 4-character string and parse the digits into a struct containing all necessary parameters of the NACA 4-digit airfoil specified.

Once the geometry is defined, the program will iterate an angle of attack (AoA) list and run the "vortext_panel_method" function for each airfoil orientation. Flow characteristics are computed in this function using VPM and returned as an output struct to the main scope.

The main scope will iterate all flow characteristics for each AoA and finally determine the aerodynamic center of the NACA 4-digit airfoil.

a. naca4digit

b. vortext_panel_method

IV. Results

V. Conclusions

VI. Appendix

VII. References