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Aerodynamic Characteristics of a Combat Aircraft in the Clean Configuration Using Computational Fluid Dynamics

Le Thanh Nguyen[#1], Duc Dung Nguyen[#2], Trung Duc Pham[#3]

[#] *Faculty of Aircraft - Engines, Air Force Officer's College, Khanh Hoa, Viet Nam*

[1]thanhmbdc @gmail.com

Abstract—
This paper presents the development of a three-dimensional aerodynamic model and a computational fluid dynamics (CFD) procedure for a combat aircraft in the clean configuration, without external weapon or fuel-store attachments. The aircraft geometry is developed in SolidWorks and coupled with ANSYS CFX to define the computational domain, mesh, and boundary conditions. Compressible-flow calculations are performed at an altitude of 4 km, Mach numbers of 0.4 and 0.8, angles of attack from 0° to 21°, and a zero sideslip angle. For the clean configuration, the lift coefficient Cy varies with angle of attack in three characteristic stages. At Mach 0.4, Cy increases approximately linearly up to 15°, then increases more slowly until about 18°, after which it decreases. At Mach 0.8, the corresponding transition points are approximately 10° and 20°. Local supersonic regions and shock waves appear on the wing at Mach 0.8, causing earlier boundary-layer separation and reducing the maximum lift coefficient and critical angle of attack compared with Mach 0.4. The obtained results characterize the baseline aerodynamic behavior of the aircraft without external attachments.

Keywords— *Computational Fluid Dynamics; Ansys CFX; Clean Configuration; Aerodynamic Characteristics; Lift Coefficient; Mach Number; Angle of Attack.*

I. INTRODUCTION

In aircraft research and operation, determining aerodynamic characteristics as functions of angle of attack and Mach number is essential for evaluating lift generation and the operating limits of an aircraft. The reliability of numerical results depends on the geometric model, computational mesh, boundary conditions, and convergence procedure. Therefore, a clearly defined CFD model and a systematic aerodynamic assessment of the clean aircraft configuration are required to characterize its aerodynamic behavior under different flow conditions.

Several approaches can be used to determine aerodynamic characteristics, including analytical methods, physical aerodynamic methods, experimental methods, and numerical methods. The numerical approach based on computational fluid dynamics was selected in this study because it enables the flow field and aerodynamic characteristics to be evaluated under controlled operating conditions [1], [2].

The objective of this study is to establish a CFD model for the aircraft in the clean configuration, determine the lift behavior over an angle-of-attack range of 0°–21°, and examine the influence of Mach number on the pressure field, lift development, and critical angle of attack.

II. NUMERICAL MODEL

A. Computational Procedure

The computational procedure consists of three main stages: (1) development of the three-dimensional aircraft model; (2) numerical simulation over angles of attack from 0° to 21° at Mach numbers of 0.4 and 0.8; and (3) analysis and interpretation of the calculated aerodynamic characteristics.

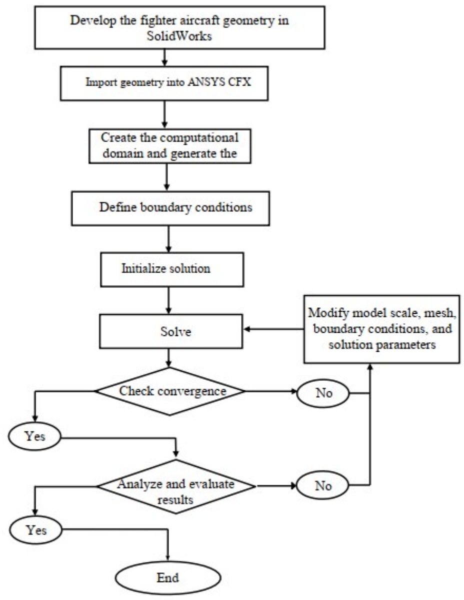

Fig. 1. Computational procedure for the simulation problem.

B. Geometric Model Development

The three-dimensional aircraft model was developed in SolidWorks at a scale corresponding to the actual aircraft dimensions. The clean configuration, without external weapon or fuel-store attachments, was selected as the only configuration investigated in this study. The model geometry was then imported into ANSYS CFX for construction of the computational domain and numerical solution.

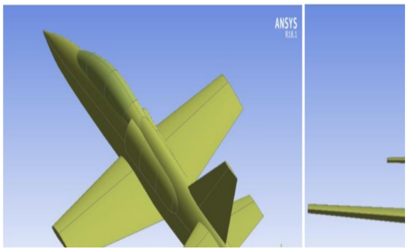

Fig. 2. Three-dimensional model of the aircraft in the clean configuration.

C. Computational Mesh

Mesh generation is a critical step in CFD simulation because the accuracy of the numerical results depends strongly on mesh quality. A finer mesh can represent the flow field more accurately, but it also increases computational time and hardware requirements. Therefore, different mesh densities were considered to select an appropriate computational mesh for the clean aircraft configuration, providing a reasonable balance between numerical accuracy and computational efficiency.

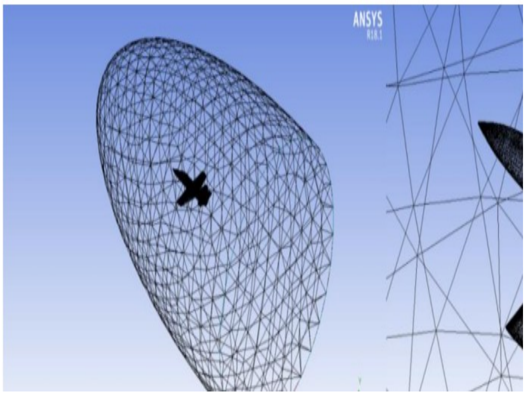

Fig. 3. Computational domain and mesh for the clean aircraft configuration.

D. Boundary Conditions and Computational Range

– The aircraft structure is assumed to be perfectly rigid, and aeroelastic deformation is neglected.

– The atmospheric parameters tH, pH, aH, and ρH are taken at an altitude of H = 4 km.

– Compressible air flow is considered at Mach numbers M = 0.4 and M = 0.8.

– Heat exchange between the flow inside the engine components and the external environment or aircraft surface is neglected.

– Aerodynamic characteristics are evaluated over an angle-of-attack range of $\alpha = 0°–21°$, with a zero sideslip angle $\beta = 0°$.

III. RESULTS AND DISCUSSION

A. Pressure Field at Mach 0.4

The CFD pressure field for the clean aircraft at Mach 0.4 and an angle of attack of 5° is shown in Fig. 4. The pressure distribution over the aircraft surface reflects the aerodynamic loading generated by the compressible flow and the selected angle of attack.

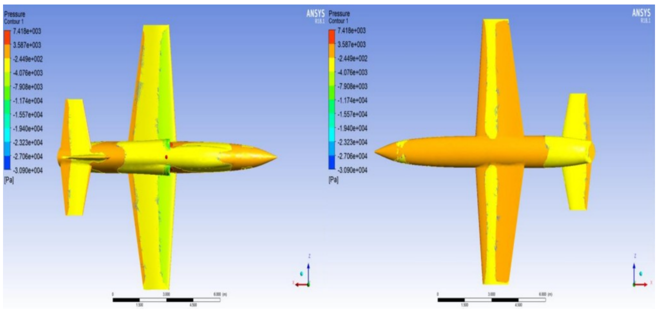

Fig. 4. Pressure field of the aircraft at Mach 0.4 and an angle of attack of 5°.

B. Pressure Field at Mach 0.8

At Mach 0.8, the pressure field changes more significantly. Local supersonic regions and shock waves appear on the wing, modifying the pressure distribution and promoting earlier boundary-layer separation on the upper wing surface.

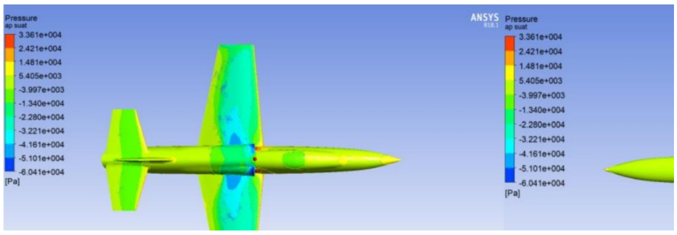

Fig. 5. Pressure field of the aircraft at Mach 0.8 and an angle of attack of 5°.

C. Lift Coefficient as a Function of Angle of Attack

Figure 6 presents the variation of the lift coefficient Cy with angle of attack for the clean configuration. At Mach 0.4, Cy increases approximately linearly from 0° to 15°, increases more slowly from 15° to 18°, and begins to decrease when the angle of attack exceeds 18°. At Mach 0.8, Cy increases approximately linearly from 0° to 10°, then increases more slowly from 10° to 20°, and begins to decrease above 20°.

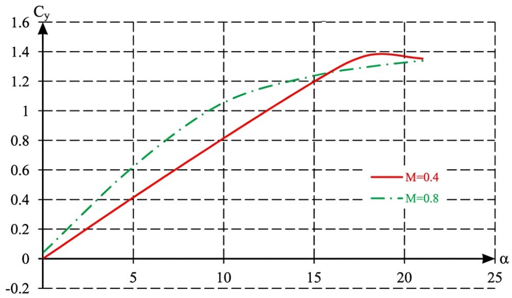

Fig. 6. Lift coefficient Cy as a function of angle of attack α for the clean configuration.

The increase in Mach number to 0.8 causes local supersonic flow and shock waves to develop over the wing. The resulting earlier boundary-layer separation reduces the maximum lift coefficient and the critical angle of attack compared with Mach 0.4. These results demonstrate the sensitivity of the clean aircraft aerodynamic characteristics to compressibility effects and establish the main aerodynamic trends over the investigated flight range.

IV. CONCLUSIONS

A CFD simulation procedure using SolidWorks and ANSYS CFX was established to assess the aerodynamic characteristics of a combat aircraft in the clean configuration.

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The lift coefficient Cy was evaluated over angles of attack from 0° to 21° at Mach 0.4 and Mach 0.8. The results show three characteristic stages in the variation of Cy with angle of attack. At Mach 0.8, local supersonic flow and shock waves promote earlier boundary-layer separation and reduce the maximum lift coefficient and critical angle of attack compared with Mach 0.4. The results provide a consistent aerodynamic baseline for the aircraft configuration without external attachments and support further aerodynamic analysis under other operating conditions.

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