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Evaluating the Aerodynamic Impact of Wing-Horizontal Tail Interference on the Su-27 via ANSYS

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Abstract- This paper investigates the aerodynamic interference of the wing-horizontal tail combination on the Su-27 using ANSYS. Full-scale numerical simulations at a 10 km altitude reveal that interference occurs exclusively at negative angles of attack, depending on flight speed. Here, wing airflow alters the flow field over a portion of the horizontal tail, modifying the aircraft's lift, drag, and aerodynamic efficiency. This study resolves high-precision computation challenges by identifying the specific tail segment affected by the downwash angle, enabling accurate lift and drag coefficient calculations to reliably serve research and flight training.

Keywords: Su-27, aerodynamic interference, ANSYS, wing-horizontal tail combination, downwash angle, flow field.

I. INTRODUCTION

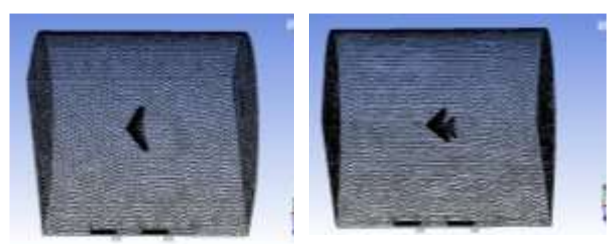
The Su-27 aircraft consists of multiple distinct parts, each exhibiting a unique aerodynamic profile and flow behavior. When integrated into the complete airframe, the airflow from one section inevitably interacts with adjacent structures. This dynamic alters the overall flow topology and redistributes surface pressure, causing the performance of individual parts to deviate from their isolated characteristics. This phenomenon, known as aerodynamic interference, can be either detrimental or beneficial: negative interference increases drag and degrades efficiency, whereas positive interference minimizes drag and enhances overall aerodynamic performance.

Aerodynamic interference on the Su-27 aircraft occurs across the wing-fuselage, wing-vertical tail, and wing-horizontal tail combinations. Within the scope of this study, the paper focuses on a specific aspect: the aerodynamic interference of the "wing-horizontal tail" combination. Because interference characteristics related to the generation of vortices during component integration are highly complex, investigation via ANSYS numerical simulation software is the optimal solution to provide accurate visual representations and characteristic graphs, serving as a scientific basis to comprehensively analyze the aircraft's aerodynamic behavior.

II. METHODOLOGY

Geometric Modeling and Meshing

The investigation process using ANSYS software begins with constructing the full-scale models of the wing, the horizontal tail, and the wing-horizontal tail combination of the Su-27 aircraft. The outer boundary is constructed with sufficiently large dimensions to ensure that the investigation process is not affected by the outer boundary layer interacting with the surveyed elements. The meshing process is performed automatically using the Fluid Flow (CFX) tool within the ANSYS 15 software suite. The surface mesh and spatial mesh structures for the isolated wing model and the wing-horizontal tail combination model are illustrated in Figure 1a and Figure 1b, respectively.



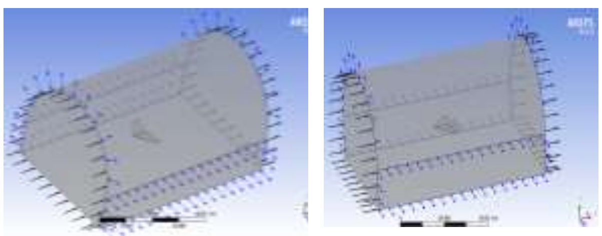
(a) (b)

Figure 1: Automatic modeling and meshing using Fluid Flow (CFX) in ANSYS 15 for the Su-27: (a) Wing model; (b) Wing-horizontal tail model

Inputting Boundary Parameters and Problem Setup

Upon completing the meshing, the inner boundary, outer boundary, outlet, and inlet parameters are inputted into the full-scale computational model. To facilitate the interference investigation problem, the isolated wing, isolated tail, and wing-tail combination models are set up with synchronized boundary conditions.

Specifically, the surveyed altitude is fixed at 10 km. The outer boundary condition is established as an undisturbed free-stream flow, and the inner boundary condition as a no-penetration flow. The process of establishing geometric boundary parameters for the model is visually demonstrated in Figure 2.



(a) (b)

Figure 2: Visual demonstration of boundary condition parameters for the Su-27 computational models:

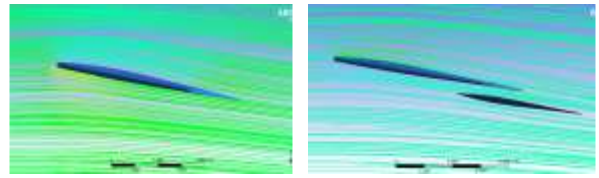
(a) Wing model; (b) Wing-horizontal tail model

III. RESULTS AND DISCUSSION

Visual Representation of the Flow Field Around the Model

From the computational models constructed with actual dimensions, the software extracted visual representations of the airflow to clearly determine at which angles of attack the aerodynamic interference phenomenon occurs.

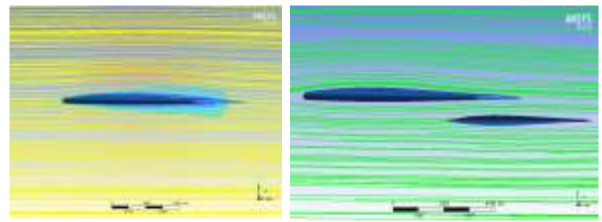
Through the images obtained at positive angles of attack and at an angle of attack of α= 0o, the interference phenomenon completely does not occur directly for the wing-horizontal tail model. At this point, theoretical interference is merely the mutual interaction between the wing and the fuselage, and subsequently the fuselage and the horizontal tail, with the wing not directly impacting the horizontal tail.



(a) (b)

Figure 3: Airflow fields around the isolated wing model and the wing-horizontal tail combination model at α= 10o:

(a) Wing model; (b) Wing-horizontal tail model

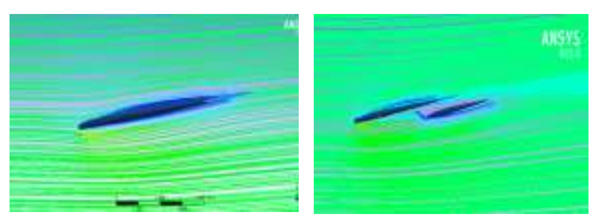


(a) (b)

Figure 4: Airflow fields around the isolated wing model and the wing-horizontal tail combination model at α= 0o:

(a) Wing model; (b) Wing-horizontal tail model

Conversely, observing the flow field images at a negative angle of attack of α= -10o, the aerodynamic interference phenomenon of the wing-horizontal tail combination is distinctly apparent. The flow passing over the wing directly influences the flow reaching the horizontal tail; the flow direction behind the wing is altered compared to the incoming free-stream flow, subsequently washing over a portion of the horizontal tail.



(a) (b)

Figure 5: Airflow fields around the isolated wing model and the wing-horizontal tail combination model at α= -10o:

(a) Wing model; (b) Wing-horizontal tail model

This visual manifestation of the altered flow direction perfectly aligns with the aerodynamic theory regarding the downwash angle and pressure redistribution.

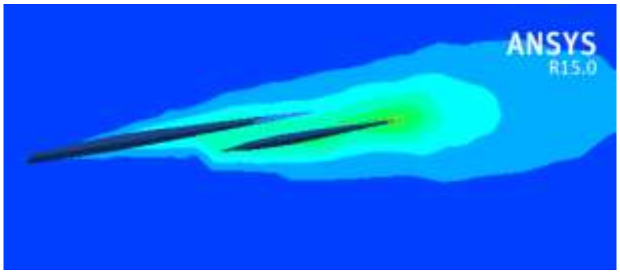


Figure 6: Airflow and pressure distribution in the wing-horizontal tail model at α= -10o

Evaluation of Lift and Drag Characteristics Extracted from the Software

The computational process supported by ANSYS operates automatically and independently; synthesizing the collected data points establishes a system of characteristic graphs.

Regarding the combined graph for the entire aircraft, the lift coefficient curve of the wing-horizontal tail combination exhibits a slight deviation at the beginning of the graph at an angle of attack range smaller than -5o. This characteristic is clarified through the visual simulation images from the software: the portion of the flow exhibiting a downwash angle practically only reaches and impacts a segment of the horizontal tail. Consequently, the lift coefficient of the horizontal tail only alters and degrades locally within the area segment affected by the disturbed flow, rather than neutralizing the entire lift generated across the horizontal tail surface.

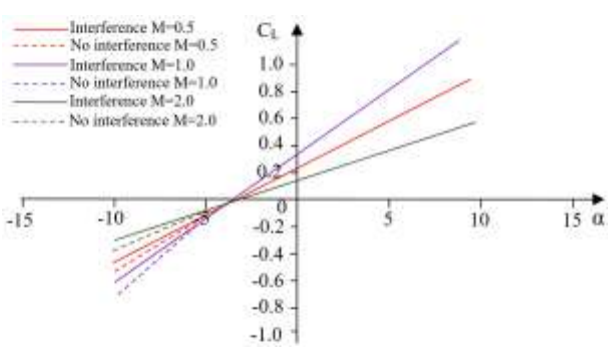


Figure 7: Combined graph of lift coefficient versus angle of attack

In terms of drag characteristics, at negative angles of attack, the aerodynamic interference between the wing and the horizontal tail produces a positive aerodynamic effect that reduces the overall drag. Specifically, the drag coefficient at Mach 0.5 remains low due to subsonic flow characteristics, which lack the shockwaves that trigger a sharp drag increase in the transonic (Mach 1.0) and supersonic (Mach 2.0) regimes.

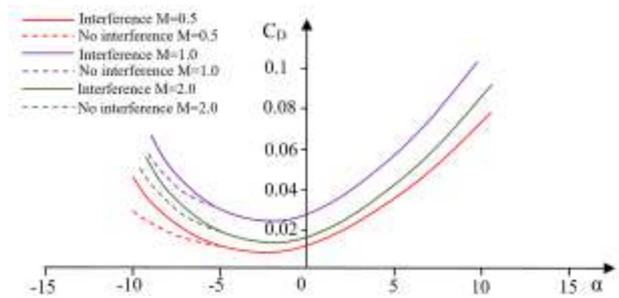


Figure 8: Combined graph of drag coefficient versus angle of attack

IV. CONCLUSION

By integrating the Su-27 wing-horizontal tail combination model into the ANSYS software for full-scale investigation under standard boundary conditions, the main conclusions drawn include:

- The Su-27 aircraft undeniably experiences the aerodynamic interference phenomenon within its wing-horizontal tail combination. This phenomenon occurs at negative angles of attack depending on the flight speed, rather than happening across all various angles of attack.
- When the interference phenomenon takes place, its effect does not impact the entire surface but only influences a portion of the horizontal tail, altering the actual angle of the airflow reaching that surface area. This subsequently modifies the horizontal tail's lift coefficient, the drag coefficient, and the drag polar curve of the aircraft.
- The calculation method using ANSYS support suite holds a significant advantage in constructing visual simulation images and automating the calculation sequence to rapidly yield precise parameter results. In computational scenarios requiring high precision, the

application of software helps explicitly identify the tail area segment affected by the downwash angle in order to segment and calculate the lift coefficient most accurately, reliably serving research and flight training purposes.

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