

Research on the Effect of Aerodynamic Interference between the Wing-Horizontal Tail Configuration on the Aerodynamic Characteristics of the SU-30MK2 Aircraft

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Abstract

The paper presents a method for calculating the effect of aerodynamic interference between the wing and horizontal tail on the aerodynamic characteristics of the Su-30MK2 aircraft, based on a theoretical model of the wing-horizontal tail configuration. The study separately determines the lift coefficient and the derivative of the lift coefficient with respect to angle of attack for the wing and horizontal tail; these quantities are then corrected using interference coefficients and the effect of the flow field downstream of the wing. The comparative plots at $M = 0.1, 0.5, 1, 1.5$, and 2 show that the interference effect is most pronounced in the negative angle-of-attack range from approximately -10° to -5° and continues to affect the lift coefficient at positive angles of attack. This provides a basis for improving the accuracy of aerodynamic-characteristic calculations, longitudinal trim, and studies of the stability and control of the Su-30MK2 aircraft.

Keywords — Su-30MK2; aerodynamic interference; wing-horizontal tail; flow inclination angle; lift coefficient.

I. INTRODUCTION

In aircraft aerodynamic research, determining the characteristics of individual components is not sufficient to fully describe the flow state of the entire aircraft. For a conventional aerodynamic configuration, the wing generates lift while simultaneously modifying the flow and producing a non-uniform velocity field downstream of the wing. When the horizontal tail is located within this flow field, its effective angle of attack differs from the geometric angle of attack, thereby changing the lift, moment, and trim capability of the aircraft. This is the fundamental mechanism of wing-horizontal tail aerodynamic interference.

This study formulates a method to successively determine the lift curve slopes of the wing and horizontal tail of the Su-30MK2 aircraft; calculates the interference factors; and determines the horizontal tail efficiency factor along with the average downwash angle behind the wing. Subsequently, the horizontal tail lift coefficient is recalculated to account for interference effects, and the angle of attack marking the onset of aerodynamic interference is identified

II. METHODOLOGY

Calculation of the Lift-Coefficient Derivatives of the Wing and Horizontal Tail

Standalone Wing Lift Curve Slope C_{ykp}^α

The wing of the Su-30MK2 aircraft is a straight-tapered wing, characterized by straight leading and trailing edges, with the root chord parallel to the tip chord. According to the Su-30MK2 technical documentation, the critical Mach number is $M_{kp} = 0.85$.

Subsonic case ($0 < M < M_{kp}$)

$$C_{ykp1}^\alpha = \frac{C_{ykpH}^\alpha}{\sqrt{1 - M_\infty^2}}$$

Case $M_{kp} \leq M_\infty \leq 1.2$

$$C_{ykp2}^\alpha = 57.3\lambda \left(\frac{C_{ykp}^{\alpha^0}}{\lambda} \right)$$

Supersonic Case $M_\infty \geq 1.2$

$$C_{ykp3}^\alpha = \bar{C}_{ykp} \frac{4}{\sqrt{M_\infty^2 - 1}}$$

Figure 1 shows that the lift-coefficient derivative of the wing increases with increasing M for $M \leq 1$ and gradually decreases for $M \geq 1$. The maximum value of the wing lift coefficient is 5.4779 at $M = 1$.

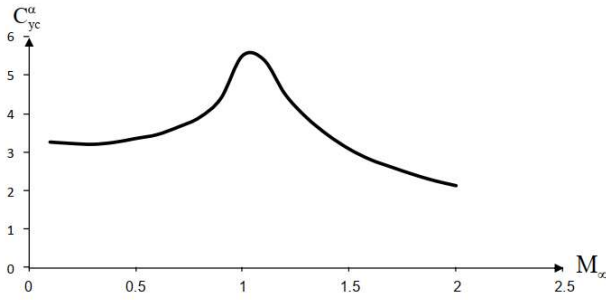


Figure 1. Wing lift curve slope versus Mach number

Lift-coefficient derivative of the isolated horizontal tail C_{ydn}^α

For $M_\infty < 0,85$, we have:

$$C_{ydn}^\alpha = \frac{C_{ydnH}^\alpha}{\sqrt{1-M_\infty^2}}$$

For $M_{kp} \leq M_\infty \leq 1,2$, we have:

$$C_{ydn}^\alpha = 57,3\lambda \left(\frac{C_{ydn}^{\alpha^0}}{\lambda} \right)$$

For $M_\infty > 1,2$, we have:

$$C_{ydn}^\alpha = \bar{C}_{ydn} \frac{4}{\sqrt{M_\infty^2 - 1}}$$

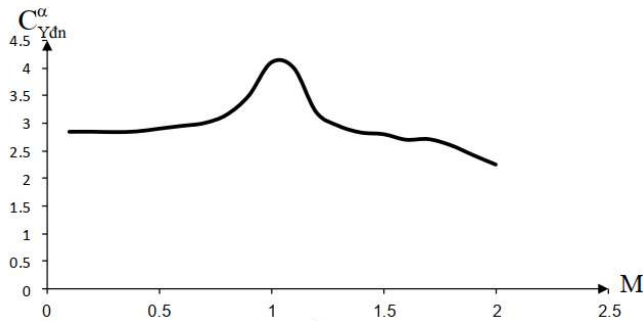


Figure 2. Horizontal tail lift curve slope versus Mach number

Figure 2 shows that the lift-coefficient derivative of the horizontal tail increases with increasing M for $M \leq 1$ and gradually decreases for $M \geq 1$. The maximum value of the wing lift coefficient is 3.6328 at $M = 1$.

Interference coefficient of the wing and fuselage. Assuming that the aircraft fuselage has a circular cross-section with diameter $D_c = 2.142$ m and $l_c = 14.7$, the ratio is obtained as follows. Yielding the ratio $\frac{D_c}{l_c} = 0,1457$

$$\Rightarrow (k_\alpha + \Delta k_\alpha)_c = 1,32$$

Interference coefficient of the horizontal tail and fuselage

The fuselage cross-section at the wing attachment is

assumed to be elliptical.

$$(k_\alpha + \Delta k_\alpha)_{dn} = \frac{1,2}{1 + 0,2 \frac{h_{dn}}{B_{dn}}} (k_\alpha + \Delta k_\alpha)_{tron}$$

$$\Rightarrow (k_\alpha + \Delta k_\alpha)_{dn} = 1,52.$$

Horizontal tail efficiency factor η_{dn}

$$\eta_{dn} = 1 - \varepsilon^\alpha$$

where: $\varepsilon^\alpha = \frac{d\varepsilon}{d\alpha}$ - Derivative of the average downwash angle

with respect to the angle of attack at the horizontal tail behind the wing

Calculation of the Horizontal-Tail Lift Coefficient C_y

Determination of the horizontal-tail lift coefficient

Since the horizontal tail typically features a symmetric airfoil section $\alpha_{0r,dn} = 0$. Given the isolated horizontal tail area $S_{r,dn}$ and the freestream dynamic pressure q_∞ the horizontal tail lift coefficient without considering the wing-induced downwash effect is expressed as:

$$C_{y,rdn} = C_{y,rdn}^\alpha \left[\alpha (K_\alpha + \Delta K_\alpha)_{dn} + \varphi_{dn} (K_\varphi + \Delta K_\varphi)_{dn} \right]$$

where: $C_{y,rdn}^\alpha$ - Isolated horizontal tail lift curve slope;

The first term determines the horizontal tail lift coefficient in its neutral position ($\varphi_{dn} = 0$), while the second term represents the lift coefficient increment accounting for the horizontal tail deflection angle.

Replacing the angle of attack with the effective angle of attack and accounting for flow retardation yields:

$$C_{y,rdn} = C_{y,rdn}^\alpha \left[(\eta_\alpha - \varepsilon_0) (K_\alpha + \Delta K_\alpha)_{dn} + \varphi_{dn} (K_\varphi + \Delta K_\varphi)_{dn} \right] K_v$$

When the horizontal tail is in its neutral position $\varphi_{dn} = 0$, neglecting the influence of the wing downwash angle yields:

$$C_{y,rdn} = C_{y,rdn}^\alpha \alpha (K_\alpha + \Delta K_\alpha)_{dn} K_v = C_{y,rdn}^\alpha \alpha \cdot 1,52 \cdot 0,9 = 1,368 C_{y,rdn}^\alpha \alpha$$

Determination of the Critical Angles of Attack for Wing-Horizontal Tail Interference Onset

As the airflow passes over the wing at a velocity of V_∞ , the wing generates lift while inducing a downward air velocity component V_y perpendicular to the freestream direction. This alters the flow direction by an angle ε known as the downwash angle. For the Su-30MK2 aircraft, at certain angles of attack, the flow downstream of the wing is deflected and passes through the horizontal tail region, thereby altering its aerodynamic characteristics. However, this phenomenon does not occur across all angles of attack. Therefore, when evaluating interference effects induced by the downwash angle, it is necessary to determine the specific angle of attack threshold at which aerodynamic interference is initiated for this particular

aircraft.

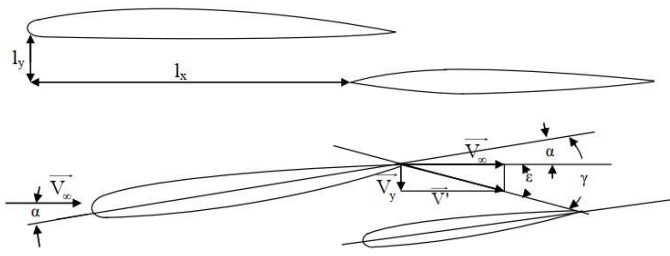


Figure 3. Model for determining the critical angle of attack for the onset of wing-horizontal tail interference on the Su-30MK2 aircraft

For the following values:

$$\begin{cases} l_x = 5,577(\text{m}) \\ l_y = 0,67 (\text{m}) \end{cases}$$

The wing root chord length is $b_{0c} = 6,561(\text{m})$ and the horizontal tail root chord length is $b_{0dn} = 5,249 (\text{m})$.

Determination of the angle γ corresponding to the onset of aerodynamic interference for a given angle of attack α and wing downwash angle ϵ :

$$\gamma = \alpha + \epsilon = 8^\circ = 0,14 (\text{rad})$$

Determination of the horizontal-tail lift coefficient with interference

The lift coefficient of the horizontal tail, taking into account the interference effect of the wing-horizontal tail configuration, is determined by the following equation:

$$C_{y, \text{dn}} = C_{y, \text{dn}}^\alpha (\eta \alpha - \epsilon_0) (K_\alpha + \Delta K_\alpha) K_v = 1,368 C_{y, \text{dn}}^\alpha [(\eta \alpha - \epsilon_0)]$$

To clarify the interference effect, the study directly compares $C_{y, \text{h}}(\alpha)$ of the horizontal tail for two cases: with and without the influence of the flow downstream of the wing. The cases are investigated at $M = 0.1, 0.5, 1, 1.5$, and 2 . This comparison makes it possible to identify changes in both the lift coefficient magnitude and the slope of the curve with angle of attack.

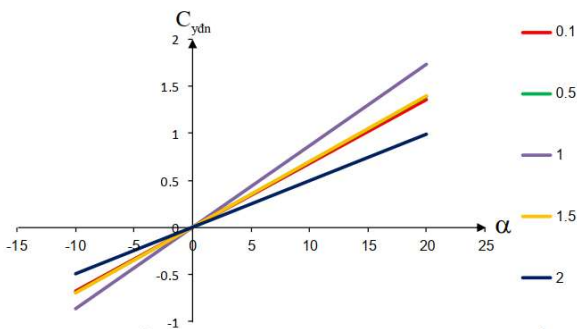


Figure 4. Horizontal-tail lift coefficient as a function of angle of attack without considering the interference effect of the wing-horizontal tail configuration

Figure 4 shows that the isolated horizontal tail lift coefficient, without considering interference effects, increases linearly with increasing angle of attack within the range $-10^\circ \leq \alpha \leq 20^\circ$. The slope of the curve decreases progressively

with decreasing Mach number for $M \leq 1$ and increases for $M \geq 1$.

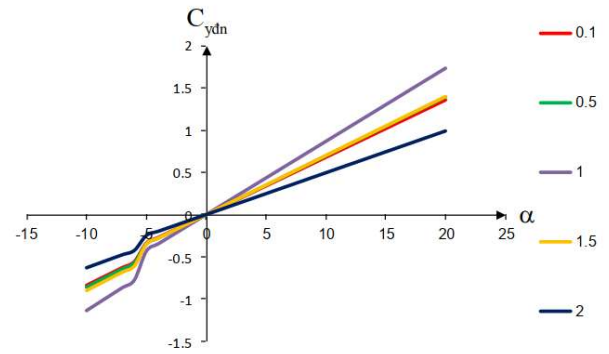


Figure 5. Horizontal-tail lift coefficient as a function of angle of attack without considering the interference effect of the wing-horizontal tail configuration

Figure 5 shows that the isolated horizontal tail lift coefficient, accounting for interference effects, increases with angle of attack in the range of $-10^\circ \leq \alpha \leq -5^\circ$ and increases linearly in the range of $-5^\circ \leq \alpha \leq 20^\circ$. The slope of the curve decreases progressively with decreasing Mach number for $M \leq 1$ and increases for $M \geq 1$. Specifically, the horizontal tail lift coefficient with interference effects is lower than that without wing-horizontal tail interference in the angle of attack range from $-10^\circ \leq \alpha \leq -5^\circ$. This clearly illustrates the impact of wing-horizontal tail interference on the aerodynamic characteristics of the horizontal tail at angles of attack where interference occurs. This reduction is attributed to the wing-induced downwash, which deflects the downstream airflow downward by a certain angle. Consequently, the effective angle of attack reaching the horizontal tail is reduced, thereby decreasing its lift coefficient

III. CONCLUSIONS

The study has established and presented a procedure for determining the effect of aerodynamic interference of the wing-horizontal tail configuration on the lift characteristics of the Su-30MK2 aircraft using a theoretical model. When interference is taken into account, the lift coefficient of the horizontal tail decreases compared with the case without interference within the affected angle-of-attack range, most notably over $-10^\circ \leq \alpha \leq -5^\circ$. The results confirm the need to account for the flow field downstream of the wing when determining the aerodynamic characteristics of the wing-horizontal tail configuration, particularly when the results are used for longitudinal trim, stability, and control calculations.

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