Subsonic Rolling Moments for Wing Roll Control of a Cruciform Missile Model

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Nomenclature

L_N = net rolling moment; clockwise rolling moment, positive, when viewed from rear
q = tunnel dynamic pressure
U = freestream velocity
α = body angle of attack
δ_d = wing differential deflection angle (each panel at δ_d) with respect to hing line; positive, when it produces positive rolling moment
ϕ = model roll angle, measured with respect to XY plane

Abstract

ONE of the main reasons for difficult roll control in the case of fore-wing controlled, cruciform missile-like configurations is the wing-tail interaction. Therefore the extent of wing shed vortex interaction with the tail is an important design factor. Some of the influencing parameters for this effect are the angle of attack, wing deflection angle, Mach number, and roll angle. The purpose of the present experiment is to determine the contribution of wing-tail interaction to overall roll controllability of a typical midwing controlled configuration. Force measurements were made at low speeds for both tail-off and tail-on configurations, at different wing deflection angles and angle of attack.

Contents

Some of the existing data[1,2] on wing-tail interaction were primarily obtained at supersonic speeds, over a narrow band of angle of attack. The present measurements cover a wide range of angle of attack and wing deflection angles. The experiments were conducted on a typical midwing controlled missile model and is a 25% scale model of the original configuration. The model geometry and its dimensions are shown in Fig. 1. The closed circuit wind tunnel has an effective working section of 1.14 × 0.87 m. The tunnel is capable of operating at a freestream Reynolds number of 0.328×10^6/m, corresponding to a maximum speed of 45.6 m/s. All the measurements were made at a tunnel speed of 45.6 m/s.

Force measurements were made using a main five-component internal strain gage balance and therefore measures the overall model normal force, pitching moment, sideforce, yawing moment, and rolling moment. However, only the rolling moment results are presented and discussed here. The strain gage balance specifically designed for this experimental program has a low design stress and therefore a stiff balance. The balance stiffness avoids any excessive oscillations in the strain gage channel outputs, which would otherwise require filtering of signals. The sting mountings along with the model were rotated approximately about the center of gravity of the model to vary the body angle of attack. The wing surfaces can be set at any angle of incidence, independently, using locking screws. A detailed description of the model construction can be found in Ref. 3. The estimated accuracy in the angle of attack and wing deflection setting was ±0.3 deg.

The output from the strain gage balance were connected to a computer controlled data logger for data acquisition and further processing to forces and moments. A scanning speed of 33 channels/s was used for all the five channels. Thirty samples were taken for a given angle of attack and wing deflection angle, at a particular tunnel speed.

Figure 2 shows the variation of rolling moment developed owing to the vertical wing pair deflection with angle of attack for different wing settings. The behavior of rolling moment is such that it shows a significant increase with angle of attack. Although the increase in rolling moment is moderate at low δ_d, it becomes pronounced at high δ_d. This behavior at any δ_d is mainly due to wing-wing and wing-tail interactions. The rolling moment variation with angle of attack for horizontal wing pair deflection, presents a different picture, as shown in Fig. 3. The rolling moment in this case decreases, with the angle of attack sometimes getting reversed at high angles of

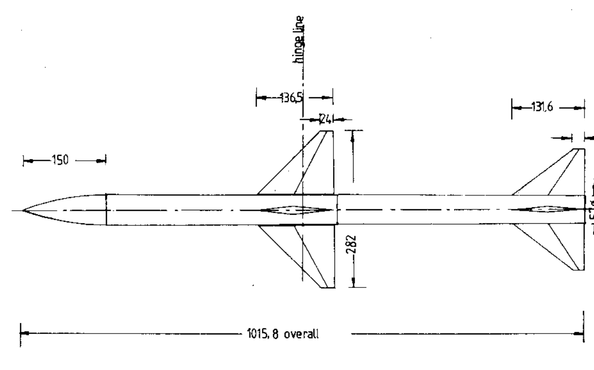

Fig. 1 General details of the model.

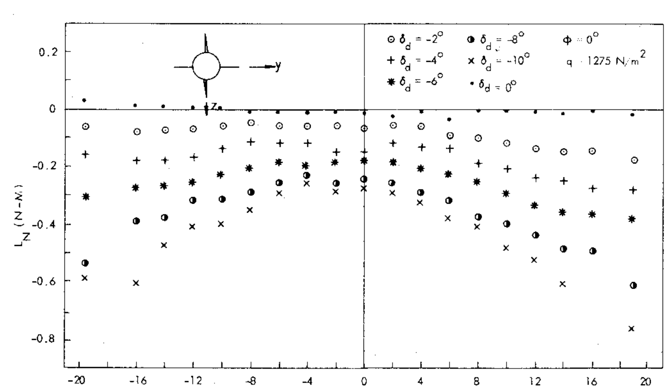

Fig. 2 Rolling moment variation with angle of attack for vertical wing deflection.

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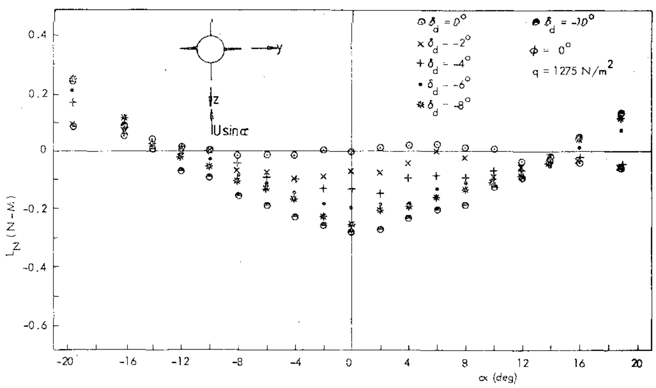

Fig. 3 Rolling moment variation with angle of attack for horizontal wing deflection.

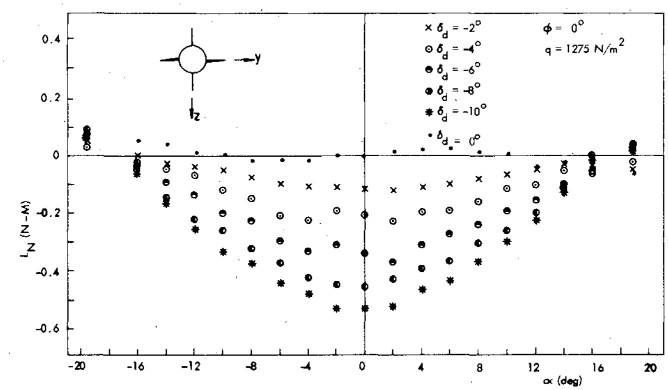

Fig. 5 Rolling moment variation for tail-off configuration (horizontal wing deflection).

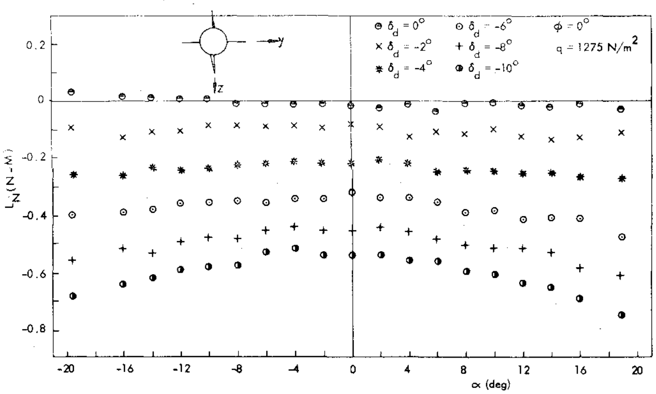

Fig. 4 Rolling moment variation for tail-off configuration (vertical wing deflection).

attack. Also, a strong asymmetry with respect to $\alpha = 0$ line is noticeable.

To assess the extent of wing-tail and wing-wing interaction, the rolling moment variation with angle of attack for tail-off configuration are presented in Figs. 4 and 5. A comparison of Fig. 4 with Fig. 2 shows the decrease in rolling moment due to the presence of tail. Although there is a reduction in rolling moment at low angles of attack (Fig. 2), the movement of wing- and body-shed vortices away from the tail substantially increases the rolling moment. In practice, this excessive rolling moment would roll the configuration much faster and hence is an important factor in the aerodynamic design. A similar comparison between Figs. 3 and 5 shows that the reduction in rolling moment, in the tail-off case, at higher angles of attack is primarily due to wing-wing interaction, although some reduction may also be due to wing stalling.[3] Also, the reverse roll at $\alpha = 19$ deg is almost equal to the rolling moment at $\alpha = 0$ deg, illustrating the severity of wing-tail interaction.

References

[1] Gur, I., Shiner, J., and Rom, J., "Prediction of Roll Controllability of Slender Cruciform Canard Configurations," AIAA Paper 78-1335, Aug. 1978.

[2] Edwards, S. and Hikido, K., "A Method for Estimating the Rolling Moment Caused by Wing-Tail Interference for Missiles at Supersonic Speeds," NACA RM-A53Hi8, 1953.

[3] Sekaran, V.G., "Prediction of Induced Rolling Moments in Slender Cruciform Canard Controlled Configurations at Moderately High Angles of Attack," Ph.D. Thesis, The Queen's University of Belfast, Northern Ireland, Feb. 1981.