Supersonic Flow over a Cruciform Configuration at Angle of Attack

Anthony M. Agnone*
New York University, Antonio Ferri Laboratories, Westbury, New York

Abstract

EXPERIMENTAL data of the flow about a cruciform configuration is compared with an inviscid finite difference Euler code, SWINT, to assess its predictive capabilities, accuracy, and limitations. Surface pressure distributions and overall aerodynamic coefficients are in good agreement with the computed values using the SWINT code for angles of attack up to 20 deg at Mach 2.7.

Contents

SWINT is an inviscid flowfield prediction code which treats conventional type missiles by approximating the fins as thin surfaces in meridional planes.[1] The code semi-empirically models the cross-flow separation on the leeward surfaces of the body, which occurs at moderate to high angles of attack. The limitations and accuracy of this analysis are considered herein. The aerodynamics of the configuration are also reported.

The experiments,[2] were conducted with a 1.905-cm-diam model, Fig. 1. A Mach-2.7 blowdown wind tunnel facility was operated at the three stagnation pressures (0.11, 0.45, and 1.24 MPa) and with ambient-temperature air. The purpose of the tests was to assess the Reynolds-number effects on the aerodynamic coefficients. Tests at low Reynolds numbers ($Re_D = 0.19\times10^6$ and 0.38×10^6) were subsequently conducted with a pressure and force instrumented model 3.831 cm in diam.[3]

The measured pressure distributions along the most windward ray of the body, shown in Fig. 2, for the cross configuration ($\phi = 45$ deg) are in excellent agreement with the SWINT code for angles of attack less than 20 deg. At higher incidences, the body shock interacts with the ventral fin, subsonic flow regions appear in the fin-body juncture regions on the windward side, and the flow on the leeward surfaces of the body and fins separates. The SWINT code does not handle these situations.[2]

The pressure variation around the cylindrical portion of the body, at an axial station upstream of the fins, is compared with SWINT in Fig. 3. On the leeward surfaces, the measured data for angles of attack greater than 10 deg show cross-flow separation and the occurrence of a cross-flow shock. Axial pressure distributions at three radial locations (6, 37.5, and 62.5 percent of the fin span) on the windward side of one fin are compared in Fig. 4 with the calculated values for $\alpha = 15$ deg and $\phi = 45$ deg. The agreement with the available data is good. The fin shocks appear to be detached at about 40% of the span.

Presented as Paper 84-0507 at the AIAA 22nd Aerospace Sciences Meeting, Reno, NV, Jan. 9-12, 1984; received July 3, 1985; synoptic submitted Nov. 27, 1985. Full paper available from the AIAA Library, 555 West 57th St., New York, NY 10019; microfiche—$4.00; hard copy—$8.50. **Remittance must accompany order.**

*Associate Professor of Applied Science. Associate Member AIAA.

Force-and-moment coefficients of the configuration, measured with a five-component balance, have been reported.[3] The normal force coefficient, C_N, of the configuration were also determined by integrating the fin's surface pressures, and the results are compared in Fig. 5 with the SWINT code and slender body theory[4] with coefficients adjusted to best fit the present data. The normal force coefficient is slightly dependent on the fin roll angle for $\alpha > 40$ deg.

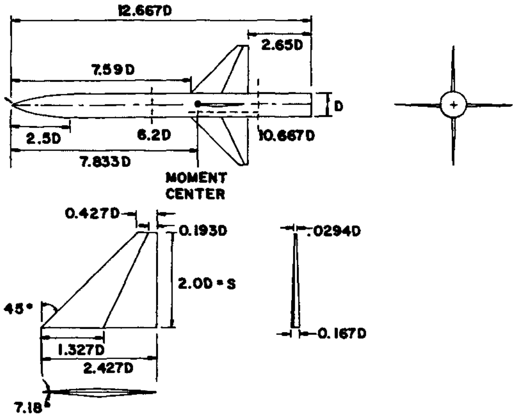

Fig. 1 Geometry of cruciform configuration.

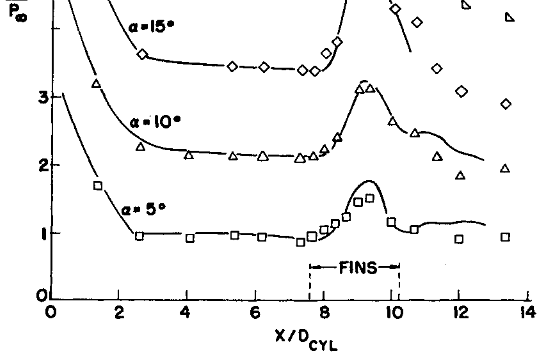

Fig. 2 Pressure distributions along the most windward ray for $\alpha > 20$ deg. (Ordinate zero reference is shifted up by 1 for each successively increasing $\alpha =$ constant curve.)

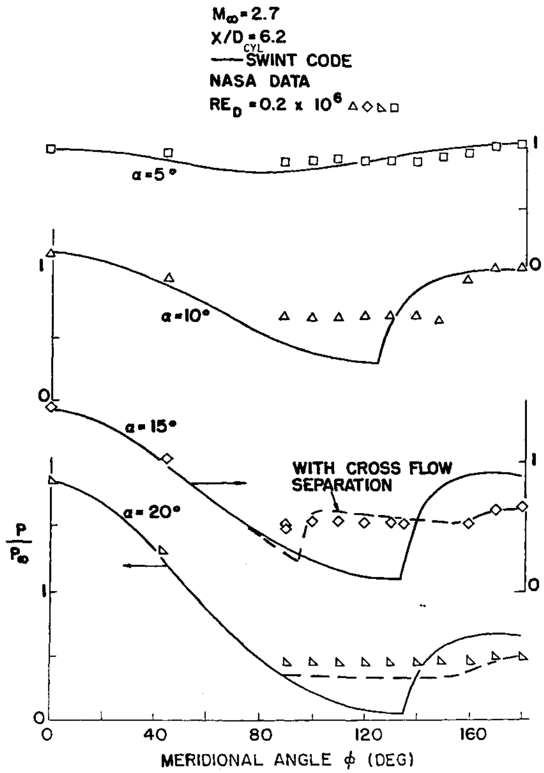

Fig. 3 Circumferential pressure distributions on cylinder at an axial station ($x/D_{cyl} = 6.2$) upstream of the fins.

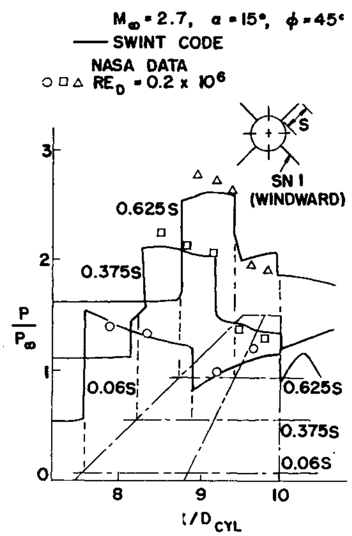

Fig. 4 Static pressure along three spanwise stations of the windward surface of fin #1. (Ordinate zero reference is shifted up by 0.5 units for each successively increasing spanwise station.)

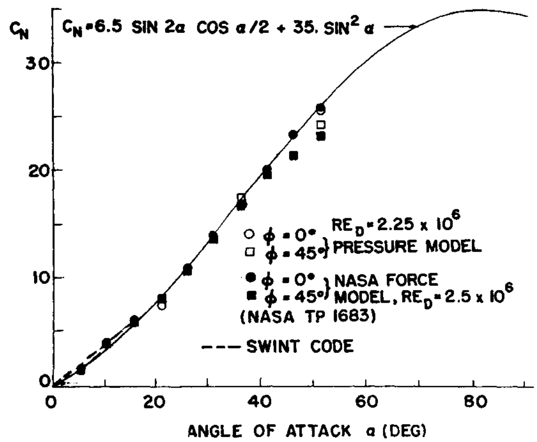

Fig. 5 Normal force coefficient of cruciform configuration.

Conclusions

The SWINT code has been shown to accurately predict body and fin surface pressures and aerodynamic coefficients on a cruciform configuration for incidences less than 20 deg. This was found to be the largest angle of attack for which the code could be used to compute the flow field. The cross flow separation modeling technique used in the SWINT code yields good pressure distribuitions on the leeward surfaces. At higher incidences, locally subsonic flow and very strong expansions occur in the regions of the fins. Also, the detached fin shocks merge with the bow shock. The SWINT code is not capable of handling these situations.

Acknowledgments

The research presented here was sponsored by the Department of the Army, US Army Research Office, under Contract DAAG29-83-K-0115. The experimental program was conducted under the sponsorship of the NASA, Langley Research Center, Hampton, Virginia, under NASA Grant NSG 1303. The author gratefully acknowledges R. Stallings (NASA LRC) for the low-Reynolds number data and Dr. A. B. Wardlaw of the Naval Surface Weapons Center, Maryland, for supplying the SWINT code.

References

[1]Wardlaw, A. B. Jr., Hackerman, L. B., and Baltakis, F. P., "An Inviscid Computational Method for Supersonic Missile Type Bodies—Program Description and User's Guide," Naval Surface Weapons Center, Dahlgren, VA, NSWC TR 81-459, Dec. 1981.

[2]Agnone, A. M., "High Angle of Attack Aerodynamics of a Cruciform Missile," AIAA Paper 84-0507, Jan. 1984.

[3]Stallings, R. L. Jr., "Effects of Reynolds Number on the Aerodynamic Characteristics of a Cruciform Wing-Body Configuration," AIAA Paper 79-0301, Jan. 1979.

[4]Jorgensen, L. H., "Estimation of Aerodynamics for Slender Bodies Alone and with Lifting Surfaces at α's from 0° to 90°," *AIAA Journal,* Vol. 11, March 1973, pp. 409-412.