Dynamic Derivatives for Missile Configurations to Mach Number Three

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Abstract

AN extension of aerodynamic prediction methodology[1] for tactical weapons to compute dynamic derivatives, including Magnus, pitch damping, and roll damping moments, is discussed. The methodology is applicable to general wing-body-tail configurations for Mach numbers to about 3 and small angles of attack. Predictions agree with experiment to about ±25%. The CDC 6600 computer program calculates the static and dynamic derivatives in less than a minute per case (one configuration, one Mach number, one angle of attack). The computer program and methodology are available to government facilities and their contractors through Refs. 2 and 3.

Content

This synoptic discusses the application of a general design methodology for tactical weapons. These weapons include guided missiles and projectiles and unguided ordnance such as free-fall bombs, unguided rockets, and spin-stabilized projectiles. Typical geometries may consist of general shaped bodies with up to two sets of lifting surfaces. The body may be pointed, spherically blunted, or truncated. It may have up to two slope discontinuities along the nose followed by a cylindrical afterbody with a boattail or flare at the aft end. The wings may have biconvex or double wedge planforms (or modifications thereof) and the wings may have sharp or blunt leading and trailing edges. The planform may be swept and the wing thickness to chord ratio may vary along the span.

Previously, operational requirements for these weapons dictated Mach numbers 0 to 3 and angles of attack up to about 20 deg with only secondary interest outside these regions. Future requirements indicate higher Mach numbers and angle of attack as well as nonaxisymmetric body geometries. This synoptic deals only with the lower spectrum of the operational requirements.

The overall approach to developing a general tactical weapon design code has been threefold: a) utilize existing state-of-the-art approximate analytic schemes where possible; b) modify these approximate schemes or develop new methods if feasible; and c) utilize existing empirical or develop new empirical techniques as a last resort. This overall approach was dictated by a tradeoff between accuracy and minimum computational time and cost. It was felt an all-empirical methodology such as that of Ref. 4 would not be accurate enough whereas an exact numerical procedure would be too costly, both in development and computer execution time for most design applications.

Received July 5, 1977; revision received Oct. 7, 1977. Full paper available from National Technical Information Service, Springfield, Va. 22151, as N77-28096 at the standard price (available upon request).

Index categories: LV/M Aerodynamics; LV/M Configurational Design; Computational Methods.

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Figure 1 summarizes the methods used to compute the dynamic derivatives. The body-alone roll damping, pitch damping, and Magnus moments were calculated empirically by the method of Ref. 5 throughout the Mach number range. The wing and interference roll and pitch damping were calculated by lifting surface theory in subsonic flow and by 3-D thin-wing theory in supersonic flow. In transonic flow, these aerodynamics were assumed to vary in direct proportion to the normal force coefficient. For wing-body configurations, it was assumed the configurations would be rolling slow enough so the Magnus moment could be neglected. For details of the theoretical development, the reader is referred to Ref. 2.

Two cases are chosen to indicate the comparison of the current methodology with experiment. The cases are the Army-Navy finner missile and an exploratory development concept for a Navy guided projectile listed as Navy research model in Fig. 2. The aspect ratio of the finner tail fins is 3 whereas that of the research model is 6.1. Roll damping comparisons are shown in Fig. 3 and pitch damping in Fig. 4. Two points need to be made regarding these calculations. First of all, reasonable agreement is shown with experiment throughout the Mach number region with the exception of transonic flow. Second, the dropoff in lift caused by the standing shock wave on the tail in transonic flow causes the roll damping and pitch damping to exhibit this same phenomena due to the assumption that the damping derivatives vary in accordance with the normal force coefficient in this Mach regime. The experimental data were too scarce to verify this, but indications are that the roll damping and pitch damping do not change so drastically as does lift for thick lifting surfaces. Further development is needed for transonic Mach numbers.

It is interesting to note that the experimental roll damping wind tunnel data of Ref. 6 agreed with other experimental data and theoretical approaches (Ref. 7) and with the present theory; however, the pitch damping data of Ref. 6 was somewhat lower than that of other experimental data (Refs. 8 and 9) and the present theory. It was mentioned in Ref. 6 that

COMPONENT \ MACH NUMBER REGION	SUBSONIC	TRANSONIC	SUPERSONIC
BODY ALONE ROLL DAMPING MOMENT	EMPIRICAL		
WING AND INTERFERENCE ROLL DAMPING	LIFTING SURFACE THEORY	EMPIRICAL	LINEAR THEORY
BODY ALONE MAGNUS MOMENT	EMPIRICAL		
WING AND INTERFERENCE MAGNUS MOMENT	ASSUMED ZERO		
BODY ALONE PITCH DAMPING MOMENT	EMPIRICAL		
WING AND INTERFERENCE PITCH DAMPING MOMENT	LIFTING SURFACE THEORY	EMPIRICAL	LINEAR THEORY

Fig. 1 Methods used to compute dynamic derivative.

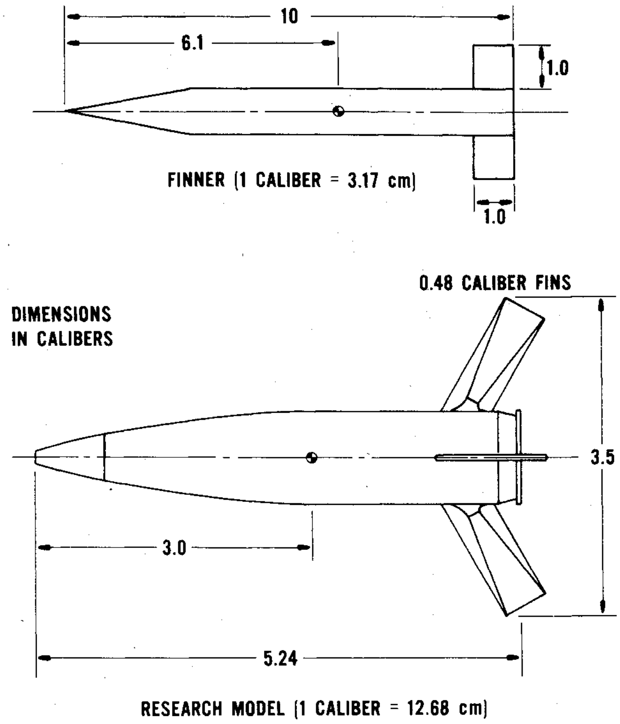

Fig. 2 Body-tail configurations.

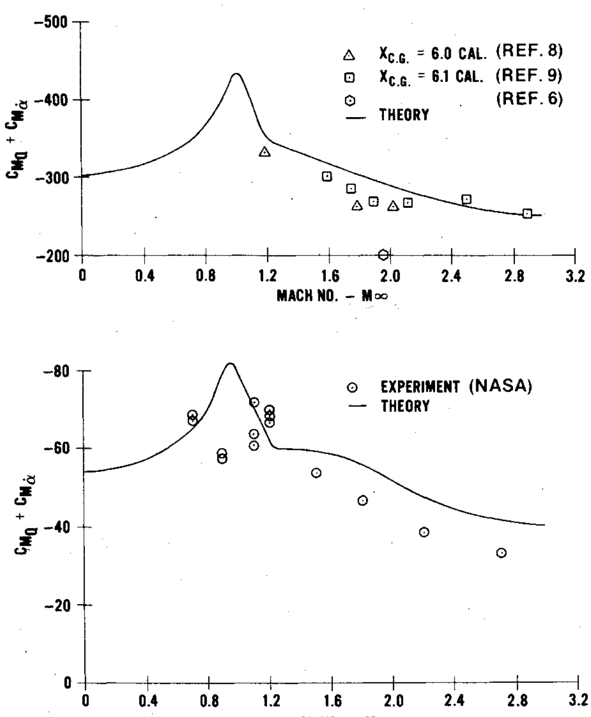

Fig. 3 a) Roll damping coefficient for Army-Navy finner; b) roll damping of Navy research model configuration.

at angles of attack less than 6 deg, strut inteference was encountered and it is suspected this is the probable cause of the disagreement.

In summary, a general design code for tactical weapons has been developed which computes lift, drag, pitching moment, Magnus moment, roll damping, and pitch damping moments from Mach number 0 to 3 and angles of attack to about 15 deg. Comparison of the overall methodology with experiment for several configurations indicates accuracies of ±10% can be obtained for static aerodynamics and ±25% for dynamic aerodynamics.

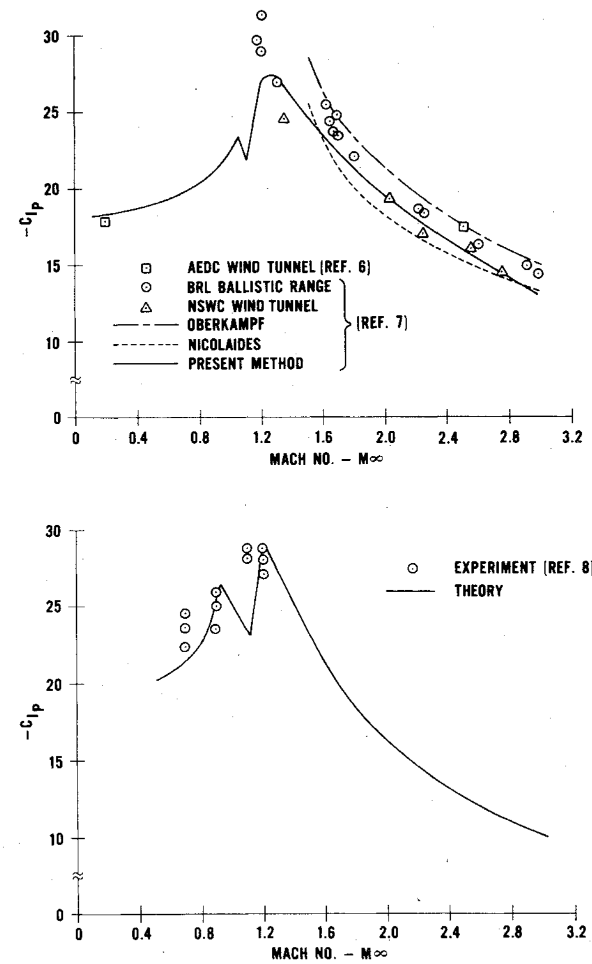

Fig. 4 a) Pitch damping of Army-Navy finner; b) pitch damping of Navy research model configuration.

Acknowledgment

This research was jointly sponsored by Naval Sea Systems Command, Naval Air Systems Command, Office of Naval Research, and Army Missile Command.

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