A80-031

Ogive Cylinder Modified for Near-Minimum Side Moment

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Abstract

BODIES of revolution develop side moments at large angles of attack due to asymmetric vortices. A composite ogive cylinder model was designed to determine what modifications were necessary to suppress this moment. Low-speed wind tunnel tests, in which the geometry of the model was systematically varied, revealed that a simple afterbody step-down coupled with slight nose bluntness could reduce side moment to 10% of that on the unmodified model. Conventional models were then constructed to substantiate the results obtained with the composite model. The tests, conducted at three different velocities (85, 120, and 140 mph), resulted in a large reduction (90%) in side moment.

Contents

Efficient high-speed flight of missiles and aircraft necessitates the use of slender, pointed fuselage forebodies for aerodynamic drag minimization. However, these slender, pointed bodies develop significantly large side moments at high angles of attack[1-4] that can result in flight control problems. The alleviation of this problem is of particular interest to aircraft designers since these side moments can have a predominant effect on aircraft stall and spin characteristics. It is also of interest to the missile designer who contemplates the design of highly maneuverable guided missile configurations.[5] Generally, it is agreed that side moments on a symmetric body are produced by asymmetric vortices that develop at high angles of attack. The phenomenon is complicated by a switching effect; i.e., side forces have been observed to change direction with roll angle. Side forces and moments are relatively more severe at low velocities and gradually diminish as the velocity increases. Jorgensen[6] has measured side forces and moments on numerous configurations and has shown that body geometry has a strong influence on their magnitude. Therefore, it was felt that given sufficient freedom to vary body geometry, shapes could be evolved that would develop near-minimum side moment. A composite model of a 10-caliber ogive cylinder was fabricated and wind-tunnel tested in order to evaluate this hypothesis. This paper presents the results of that study.

A composite model (CPM) having a 3-caliber tangent ogive nose and a 7-caliber afterbody was fabricated in order to study the effect of geometry variation on side moment. The basic configuration, whose schematic is shown in Fig. 1a, has its component parts supported by a steel rod through the center. The parts may be disassembled by unscrewing the threaded nose cap. The base of the model is designed to contain a sting mounted, four component, strain gage balance. The composite nature of the model allows for extensive variation in geometry. Radical variations in geometry are shown in Fig. 2 of Ref. 8 in order to illustrate the model's utility.

Static force tests were conducted in the Edgewood Arsenal 28×40-in subsonic wind tunnel.[7] Normal force, pitching moment, side force, and side moment coefficients were measured in aeroballistic axes (nonrolling). All moments were referenced about the model base. Angles of attack from 0 to 90 deg were investigated. Preliminary tests revealed that the composite model, because of a lack of rigidity, could only be tested at tunnel velocities of less than 100 mph. Model vibrations above 100 mph were too severe to obtain good quality data. Consequently, intial tests were conducted at 85 mph because of the good performance of the model and balance system. Later tests were conducted on conventionally fabricated models at higher velocities.

Initially, the variation of the static stability coefficients with angle of attack and for roll angles (ϕ) of 0, 90, and 180 deg were evaluated for the CPM basic configuration (ogive cylinder shown in Fig. 1a). The lateral stability characteristics are presented in Fig. 2. The side moment and side force change sign with roll angle as expected.[4] Slight differences in the normal force and pitching moment coefficients with roll angle were obtained. However, these longitudinal stability data are not presented for the sake of brevity.

The initial runs showed that it was very time consuming to properly roll the composite model on its sting. Consequently, it was decided that further tests on the composite model would be conducted at a roll angle of 0 deg, and pertinent test results would be verified with conventional models at a later date.

Further wind tunnel tests, where the body geometry of the composite model was systematically varied, indicated that the side moment on the ogive cylinder was reduced by 90% when nose bluntness ($R/d = 0.1725$) and afterbody gap were introduced (see Fig. 3). Figure 1b is a schematic of the modified configuration. An in-depth discussion of how this configuration was evolved is given in Ref. 8.

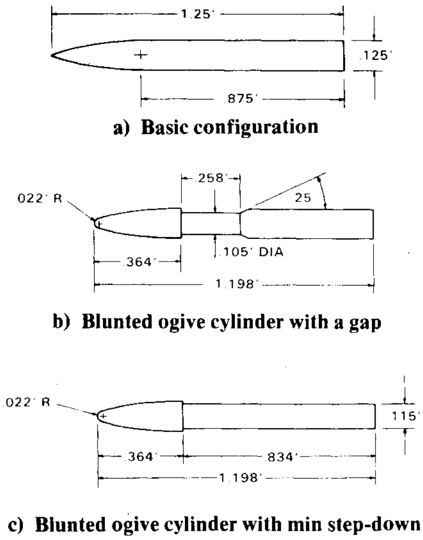

Fig. 1 Ogive cylinder models.

Received Sept. 28, 1978; Synoptic received July 6, 1979; revision received Nov. 5, 1979. Full paper available from National Technical Information Service, Springfield, Va. 22151, as N79-18955 at the standard price (available upon request).

Index categories: LV/M Aerodynamics; LV/M Dynamics and Control.

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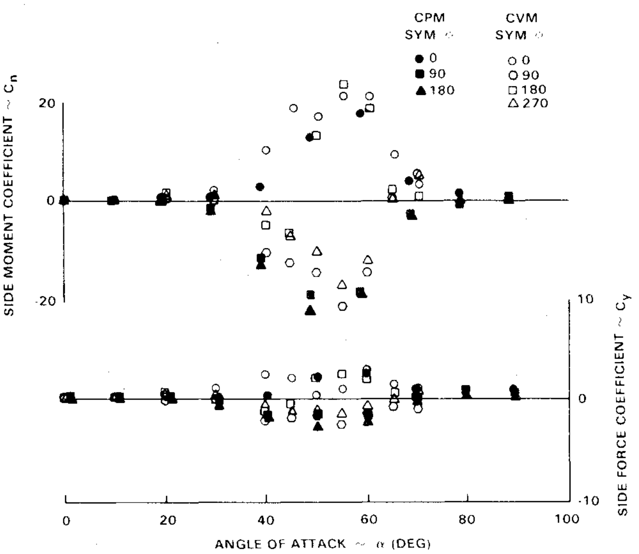

Fig. 2 Lateral stability characteristics of ogive cylinders (CPM, CVM), $V = 85$ mph.

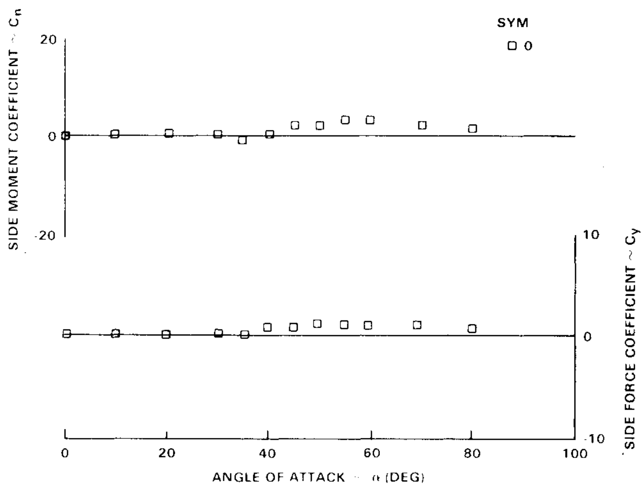

Fig. 3 Lateral stability characteristics of blunted ogive cylinder with gap (CPM), $V = 85$ mph.

Conventional models (CVM) made up of nose and afterbody sections were fabricated in order to evaluate test results obtained with the composite model. These models were also used to study the effect of roll angle and velocity variation. Roll angles of 0, 90, 180, and 270 deg were investigated at velocities of 85, 120, and 140 mph (the tunnel maximum velocity). The aerodynamic characteristics of the conventional ogive cylinder (CVM) were in good agreement with those obtained on the composite ogive cylinder. The lateral stability characteristics of the ogive cylinder (CVM) at 85 mph are presented in Fig. 2. The primary effect of increasing velocity was to cause the side forces and moments to change sign for $\phi = 90$ and 270 deg (see Ref. 8., Figs. 11-13).

The aerodynamic characteristics of the ogive cylinder with gap (CVM) also exhibited minimal side forces and moments at $V = 85$ mph. However, at higher velocities ($V = 120$ and 145 mph) the "fix" became ineffective (see Ref. 8, Figs. 17-18). It

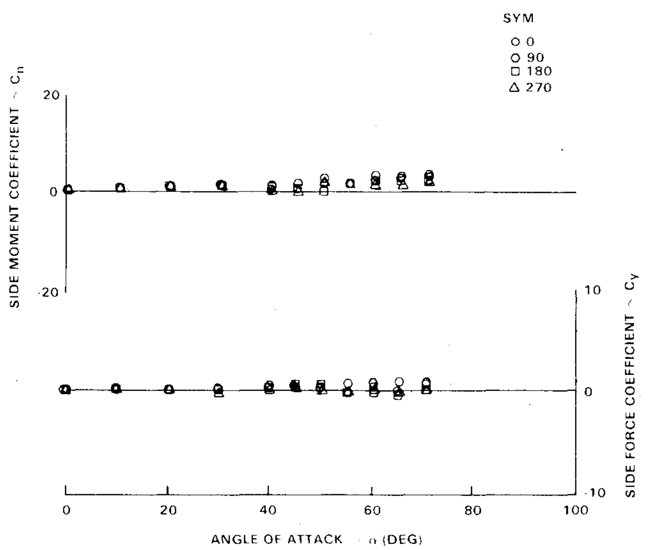

Fig. 4 Lateral stability characteristics of blunted ogive cylinder with minimum step-down (CVM), $V = 140$ mph.

was felt that the step-up (cone frustum) might be the cause of the increased side moments at $V \geq 120$ mph, and consequently, the cone frustum was eliminated. The resulting configuration consisting of a blunted ogive cylinder and continuous afterbody step-down (Fig. 1c) was effective at the three test velocities. The aerodynamic characteristics at $V = 140$ mph is shown in Fig. 4. These results are typical for the three test velocities.

Based on the results of this study, it was concluded that:

1) Side moment on an ogive cylinder can be minimized at low speed by nose blunting and afterbody step-down.

2) Proper design can result in side moment reduction on the order of 90%.

3) High-speed tests should be conducted to further evaluate the design.

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