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Rectangular Cavity Flowfield Effects on Stores in the Shear Layer

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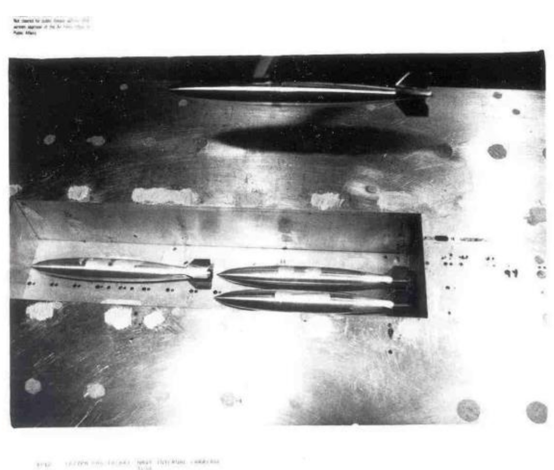
Abstract

In the late 1980 the US Air Force conducted a series of store separation wind tunnel tests from a generic cavity. The US Navy conducted a separate test distinguished by using horizontal traverses (rather than vertical) to examine the effects of the cavity flowfield on a bomb in the shear layer. This paper will describe how these wind tunnel test data can best be used.

1.0 Introduction

The US Air Force conducted a series of cavity wind tunnel tests [1] later known as WICS (Weapons Internal Carriage and Separation). A similar wind tunnel test was conducted by the US Navy [2] which tried to determine the critical conditions for store release from rectangular bays.



Figures 1 NICS Cavity Geometry

This test, known as NICS (Naval Internal Carriage and Separation) was unique, since it used horrizontal as well as vertical traverses of the store, particularly near the shear layer, to evaluate the how the stores could be safely released.

The MK-82 pitching moment C_{LM} as it traversed the longitudinal axis of the cavity at several different bay depths is shown in Figure 2. X/L=0 represnets the forward edge of the cavity, 1 the back end.

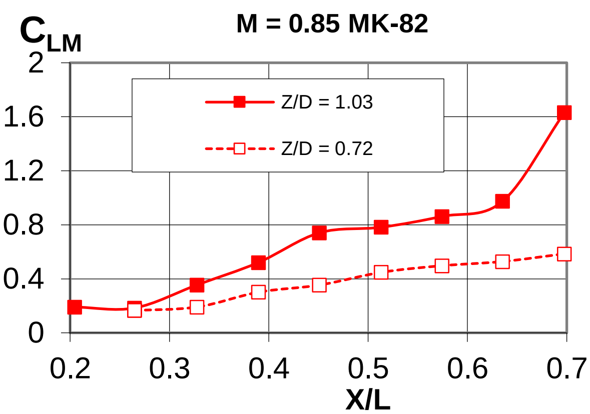


Figure 2 MK-82 C_{LM}

Note that the pitching moment increases by almost an order of magnitude from the front to the rear of the cavity.

Other wind tunnel test result for the NICS cavity are available [3].

2.0 Discussion

Cavity flow is fundamentally unsteady, but stores must be released and separated in a predictable manner. Previous research has looked extensively at the acoustics of the cavity as a measure of the unsteady flow. Other research has looked at the vertical position of the store within the cavity and the effect of this depth on the aerodynamic forces on the store.

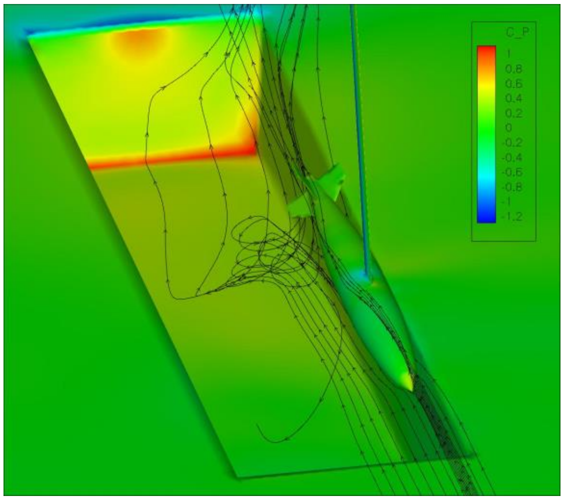


Figure 3 USM3D Solution

Wind tunnel test results use the quasi steady formulation to calculate trajectories. Some way of resloving wind tunnel data with unsteady CFD solutions would be valuable.

An attempt to match the NICS results was undertaken as a Trident project at the United States Naval Academy[4]. The cavity geometry and MK-82 bomb was modelled using a USM3D RANS solver. As may be seen in 4 there is good agreement with the trends, but a considerable discrepancy between the magnitudes predicted.

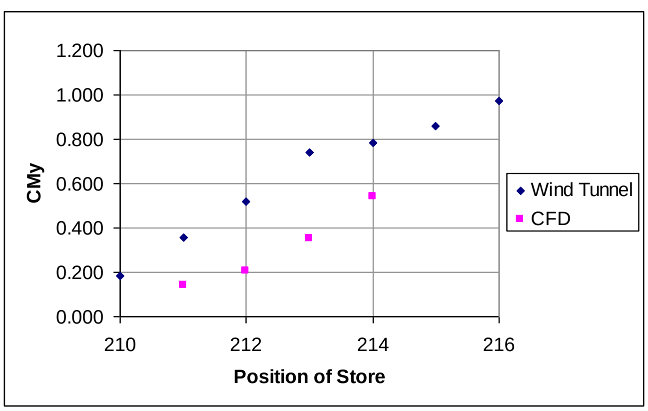


Figure 4 Pitching Moment Comparisons

Although CFD solutions for cavity flowfields are unsteady [5], previous store separation flight test data [6], [7] have shown excellent correlation with quasi steady wind tunnel data for stores released from bomb bays. This paper will address this issue.

3.0 Store Separation Workshop

The NICS wind tunnel test data base provides an excellent test bed for validation of CFD codes for cavity flowfields. If a code can be validated for a rectangular cavity, then modifications to the baseline geometry (curved edges, spoilers, blowing, fron and back wall slope) can be more readily designed.

3.1 Workshop Motivation

Store Release is a challenging engineering sub-discipline of Aircraft Stores Compatibility required to ensure that stores can be safely separated from an aircraft bomb bay. The difficulties of store release are best expressed by the many incidents where stores have damaged the releasing aircraft, sometimes fatally.

Early stores clearance effort involved progressive flight testing at increasingly challenging conditions until considered unsafe (usually observed by chase aircraft). This was obviously risky, time consuming and costly. The use of Captive Trajectory System (CTS) wind tunnel testing coupled with Six-Degree-of-Freedom (SDOF) computer codes to predict store release trajectories began in the 1970s with the aim of reducing the number of flight tests to the minimum required to validate the simulations.

SDoF codes have been developed by many government agencies and aerospace companies throughout the world.

However, veteran practitioners of the release simulation art have always been somewhat amused that no two codes give the same answer!

The complexities of such codes require an education difficult to obtain except by many years of practice as there are no widely available training opportunities. This dearth of training and awareness led to the establishment of the AIAC Store Separation workshop. Using previously published wind tunnel data [1,2,3] of a generic cavity and Mk-82 bomb (Figure 5).

Figure 5 MK-82 in Generic Cavity

The workshop represents an opportunity to benchmark current separation codes and provide an educational opportunity.

3.2 Workshop Description

3.2.1 Purpose: Determine Best Practice for Store Separation

1. CTS wind tunnel testing is useless for determining safe separation
   a) flight tests occur at different conditions
   b) ejector forces are different in flight
   c) mass properties may be different and should be measured
   d) aero coefficients are different – parametric variations
2. Why do we do use CTS?
   a) determine proper size and scope of grid test
   b) validate grid size
   c) reduce size of grid test
   d) make sure your pre-test predictions make sense
3. Purpose of the workshop
   a) See if different users of SDoF code get the same answers
   b) Compare various SDOF codes vs validated wind tunnel CTS and grid data
   c) Determine how wind tunnel testing for cavities could be improved
   d) share experience

3.2.2 How did the Workshop work?

Data provided to all participants

1. MK-82 Freestream Data at M = 0.95
2. MK-82 grid data for NICS cavity at M = 0.85
3. MK-82 mass properties
4, MK-82 initial conditions
5. MK-82 CTS trajectories (blind test no answers before predictions received)
6. Cavity Dimensions L = 15.73’ W = 4.33’ D = 2.925’ feet full scale
7. L/D=5.38
8. Cavity designed to fit 8 MK-82 bombs between the nacelles of the F-14 Bombcat (stealth design), Figures 6 and 7.

Figure 6 F-14 Tomcat Aircraft

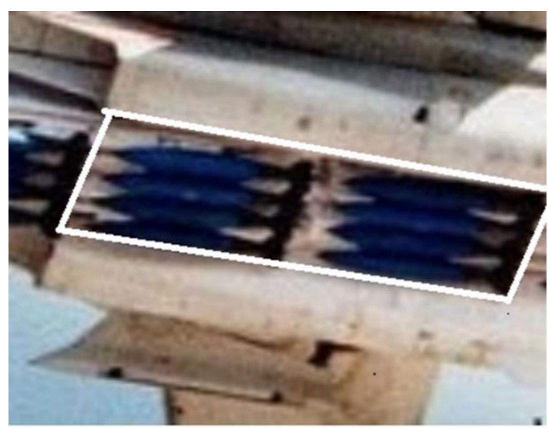


Figure 7 F-18 Bombcat

Requirements from all participants

1.Predictions of the trajectories (X, Y, Z, Psi, The, Phi) for the initial conditions provided

2.Determination of the miss distance between store and cavity wall.

3.Determination of the minimal ejector force that would ensue a safe trajectory.

3.3 Aerodynamic Data

3.3.1 Freestream Data

The original MK-82 freestream data from the cavity wing tunnel test are shown in Figure 8. For the store to fit inside the cavity the usual aft sting arrangement could not be used. The store was attached by a strut sting that had a significant effect on the pitching moment data at positive angles of attack. These data were therefore corrected by replacing the CN and CLM values for positive alphas by their negative equivalents.

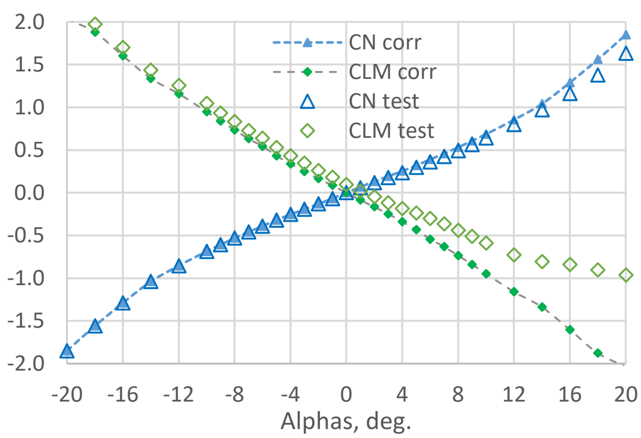


Figure 8 MK-82 Freestream Data

3.3.2 Grid Data

Grid data were available for three different store pitch attitudes. These were modified from the previously published data [2,3,4,8] to remove obvious errors and set the rolling moment C_{LL} to zero.

Figure 9 shows the pitching moment variation C_{LM} as a function of the displacement Z/D from the top of the cavity for the configuration shown in Figure 5. Note that pitching moments are total coefficients at the store for zero angle of attack. The pitching moment at -10 degrees angles of attack is almost +2.8 higher than its freestream value.

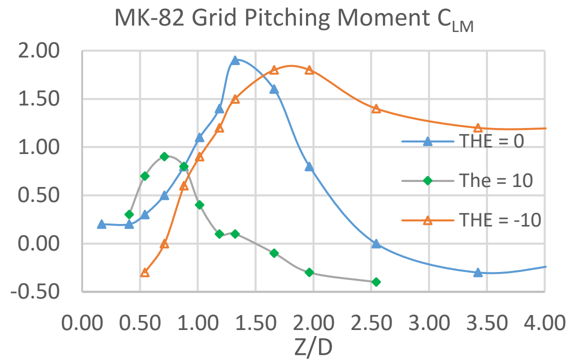


Figure 9 MK-82 Grid Data

Figure 10 shows the yawing moment variation C_{LM} as a function of the displacement Z/D.

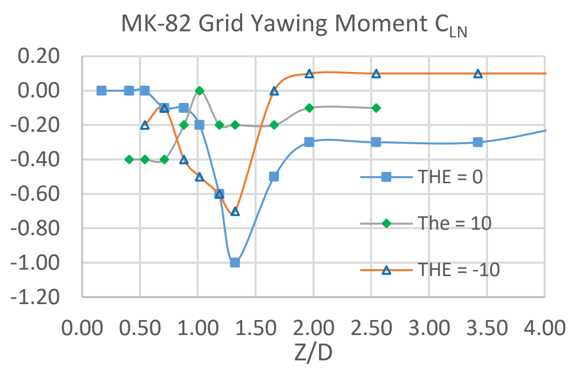


Figure 10 MK-82 Grid Data

4.0 Results for the AIAC 2017 Workshop

Trajectory simulations for the workshop performed by Australia using the ASTERIX [9] code are shown in Figure 11.

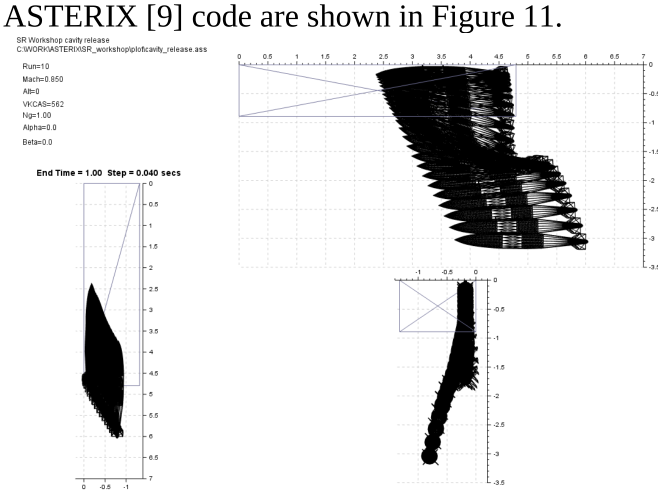


Figure 11 ASTERIX prediction

For gravity release the store is predicted to hit the side wall of the cavity.

This was the expected result, since the wind tunnel geometry violated the 10 degree fall line criteria [10].

Figure 12 MK-82 in Generic Cavity

5.0 Conclusions and Recommendations

Free stream and grid data have been made available for a MK-82 store in a generic cavity.

http://aiac.ae.metu.edu.tr/

These data may be used to determine how much difference there is in SDOF predictions using the same inputs.

It would be interesting to see how the prediction of the minimum ejector force necessary to clear the cavity would compare.

The MK-82 and generic cavity geometry could also be used to compare various CFD code's predictions.

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