

Flow past a Yawed Rectangular Cavity in Transonic and Low Supersonic Flows

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DOI: 10.2514/1.40729

The effect of yaw on the steady and unsteady pressure measurements along the floor and walls of a rectangular cavity with a length-to-depth ratio of 5 was investigated. Statistical analyses were carried out on the pressure outputs to determine modal frequencies, amplitudes, and phase relationships. Rossiter's empirical formula was found to give good estimates of the frequencies of the acoustic tones for moderate yaw angles up to 20 deg, which was the highest value tested. The dominant acoustic mode was a function of the yaw angle, and it switched over to a higher mode when the yaw angle exceeded a critical value. At $M = 0.84$ and $M = 1.11$, the aft wall pressure distributions and acoustic mode amplitudes showed a very different behavior with changes in yaw angle for transonic and supersonic Mach numbers.

Nomenclature

C_p	=	pressure coefficient
D	=	cavity depth
f	=	frequency
k	=	constant
L	=	cavity length
M	=	freestream Mach number
n	=	mode number
p	=	pressure
St	=	Strouhal number
U	=	freestream velocity
W	=	cavity span
α	=	constant
ψ	=	yaw angle

I. Introduction

STORES carriage inside an internal weapons bay can reduce drag, enhance maneuverability, and minimize the radar cross section of military combat aircraft. However, the flowfield associated with a cavity presents a number of challenges for the safe carriage and release of stores. The large nose-up pitching moments experienced by stores on traversing the pressure gradients inside the cavity may endanger the parent aircraft because of the possibility of collision when stores are released. In addition, the unsteady flow can generate self-sustained oscillations as a result of shear layer instability and acoustic tone coupling. The intense sound field that is produced can exceed 170 dB. The structural integrity of stores, as well as the aircraft, is a matter of concern, and numerous investigations have been reported in the past two decades. The studies are mainly concentrated in three areas: experimental, theoretical and semi-empirical, and

computational fluid dynamics (CFD) (Reynolds-averaged Navier–Stokes, large-eddy simulation, direct numerical simulation, etc.). Review articles on these subjects are given by Komerath et al. [1], Chokani [2] and Grace [3].

Most of the investigations have been carried out on rectangular cavities at zero yaw angle, and the parameters investigated are Mach number, Reynolds number, cavity length L , depth D , and span W ratios. A CFD study of the steady flowfield inside a yawed cavity has been reported by Baysal and Yen [4] for supersonic flows at a yaw angle $\psi = 45$ deg. They showed that the flow is dominated by a large vortex that grows in size from the separating side wall to the impinged side wall. The vortex rotates in both the vertical and horizontal planes. The separation and reattachment lines on the floor display a more complex topology than the unyawed cavity. Wind-tunnel studies have been conducted at the Langley 0.3-Meter Transonic Cryogenic Tunnel on a rectangular cavity at $\psi = 15$ deg. Plentovich et al. [5] give static results of the pressure distributions along the longitudinal centerline of cavities with various L/D ratios showing the effects of Mach number and Reynolds number. Unsteady results showing the mode shapes for $\psi = 0$ and 15 deg are given by Tracy and Plentovich [6].

At moderate yaw angles, the frequency of the acoustic tones generated inside the cavity can be predicted quite accurately using Rossiter's [7] empirical formula. Rossiter's vortex model [7] has been shown by Bilanin and Covert [8] and later by Tam and Block [9] to give similar results as the Heller and Bliss [10] oscillating shear layer model.

In Rossiter's [7] model, the degree of vorticity concentration, and hence circulation of the vortex that impinges on the cavity aft wall, is a function of the cavity length L . For an unyawed cavity with a sufficiently large L/D ratio, so that the shear layer has gone through the stages of linear growth, instability, nonlinear saturation, and finally coherent or large structure formation, Rossiter [7] provided a satisfactory model that synchronizes the vortices and acoustic waves to form a coupled system. However, in the case of the yawed cavity when the shear layer from the separating sidewall has not developed sufficiently to generate vortices, the Heller and Bliss [10] model gives the possible mechanisms of the generation of the longitudinal acoustic waves. It should be noted that the acoustic waves will be weakened as the yaw angle increases because the shear layer is increasingly less developed.

The present paper presents results showing the effect of yaw on the cavity floor and wall pressure distributions. The acoustic modes are identified from statistical analysis and the yaw angle at which the

Presented as Paper 6234 at the 26th Applied Aerodynamics Conference, Honolulu, HI, 18–21 August 2008; received 1 September 2008; revision received 27 May 2009; accepted for publication 29 May 2009. Copyright © 2009 by the American Institute of Aeronautics and Astronautics, Inc. All rights reserved. Copies of this paper may be made for personal or internal use, on condition that the copier pay the \$10.00 per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923; include the code 0021-8669/09 and \$10.00 in correspondence with the CCC.

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