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Passive Control of Transonic Cavity Flow

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ABSTRACT

The unsteady turbulent flow over an open cavity is characterised by large pressure fluctuations on the walls of the cavity as well as radiated noise. The pressure fluctuations inside the cavity may excite the local structure and could possibly couple with the main structural modes of the aircraft [1]. Passive control methods, which involve manipulating the cavity geometry, have shown to be effective in suppressing cavity noise [2,3]. Regardless of the numerous experimental efforts on cavity flow control, only a limited number of computational studies have been reported in the literature. It is therefore the objective of this paper to conduct CFD studies for a range of passive control methods and gain better understanding of cavity flow physics and its prediction.

In this direction, computations using Detached Eddy Simulation (DES) have been undertaken for a cavity with length-to-depth (L/D) ratio of 5 at Mach 0.85. Flow control devices include a leading edge flat spoiler, leading edge transverse rod and 53° slanted aft wall. Slanting the rear wall of the cavity is known to reduce at the amplitude of Rossiter's modes as well as the broadband noise levels [4]. However, none of Rossiter's modes were completely suppressed.

Results for a leading edge transverse rod and flat spoiler suggest that noise suppression is due to the displacement of the shear-layer spanning the cavity, therefore reducing the interaction with the aft cavity wall (Figure 1). Sound Pressure Levels (SPL) across the cavity floor suggest reductions of 5dB can be obtained (Figure 2(a)). At the cavity mouth, the reduction in SPL near the aft wall was the same as on the cavity floor (Figure 2(b)).

It was anticipated that vortices shed from the transverse rod would energise the shear layer and so prevent it's break down. Looking at iso-surfaces of Q-Criterion (Figure 3), it can be seen that the vortices shed from the transverse rod lose structure after approximately 25% of the cavity length. A detailed account of the flow control effects will be presented in the final paper.

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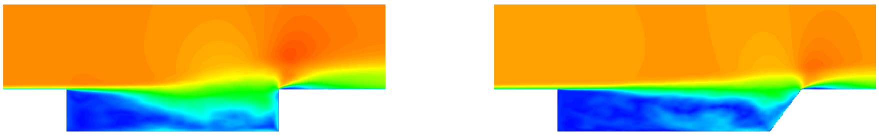
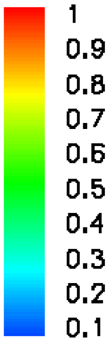
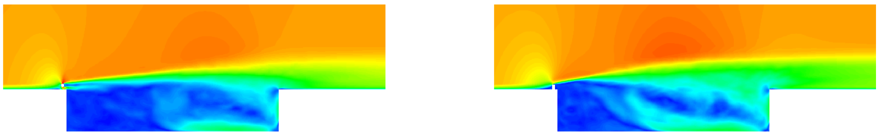


(a) Clean Cavity

(b) Slanted Aft Wall

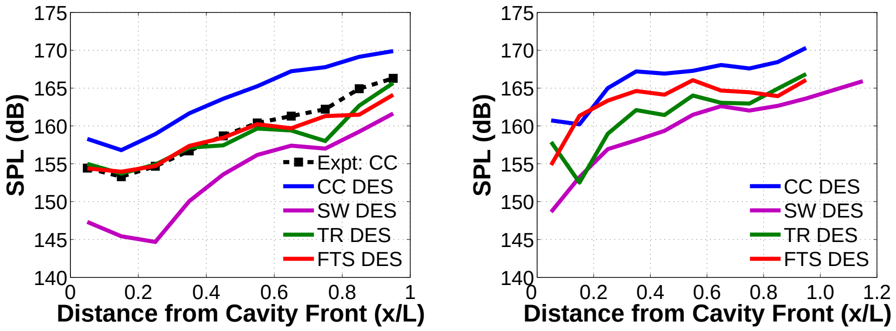




(c) Transverse Rod

(d) Flat Spoiler

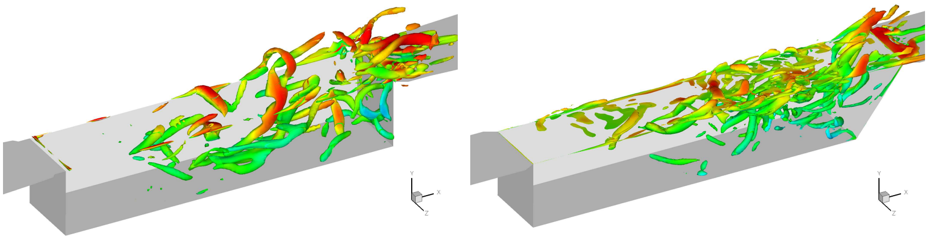
Figure 1: Averaged mach contours at the mid-plane of the cavity.



(a) Cavity Floor

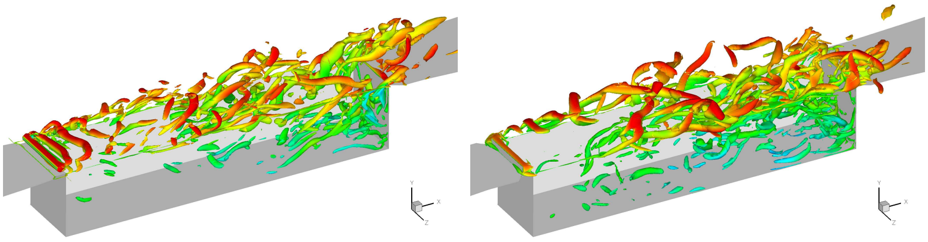
(b) Cavity Mouth

Figure 2: SPL's along the cavity centerline for the clean cavity (CC), slanted aft wall (SW), leading edge transverse rod (TR) and leading edge flat-top spoiler (FTS).



(a) Clean Cavity

(b) Slanted Aft Wall



(c) Transverse Rod

(d) Flat Spoiler

Figure 3: Iso-surfaces of Q-criteria for clean cavity and passive flow control devices.