Experimental investigations on the interaction between impinging shock and cavity shear layer

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In Scramjets, cavities are one of the means to facilitate controlled fuel-air mixture, stabilize the flame, and prevent blowout, ensuring sustained and efficient combustion. Cavity flameholders are used extensively in supersonic flow stabilization owing to their minimal system complexity, small total pressure losses, minimal impact on the supersonic core flow, reduced drag and aerodynamic heating [Liu et al. (2019), Liu et al. (2020)]. Supersonic cavities and the associated noise, especially the Rossiter modes, have been widely investigated in the literature. In the context of scramjet isolators, cavity flow field cannot however be studied in isolation, without considering the shock waves impinging on them. There are few works addressing cavity flows with impinging shock [Karthick (2021)], but they only report time averaged flow features. The understanding of the dynamics of the interaction of shock with cavity shear layer is very limited. Recently, based on 2-dimensional detached eddy simulations, some time-resolved aspects of the interaction between impinging shock and cavity shear layer were reported [Kirit et al. (2014)]. There are no detailed experimental studies or high-fidelity 3-dimensional computations on the dynamics of such flows, to the best of our knowledge.

With the broad objective of understanding the dynamics of oblique shock and cavity shear layer interactions, with particular focus on the effect the shock has on the shear layer shedding, mixing and cavity acoustics, as well as the effect of shear layer dynamics on the shock reflection, experimental investigations are initiated with the isolator facility at IIT Madras. The present paper reports the initial phases of the work, consisting of time resolved schlieren and cavity surface pressure data. The tests are carried out for a free stream Mach number of 2.2, generated by a contoured nozzle. The isolator test section has a dimension of 330 x 100 x 33 mm. The cavity has a length (L) of 38 mm and a depth (d) of 9.5 mm (L/d = 4). The leading edge of the cavity is at 147 mm from the inlet of the test section. Shock generators of various angles (6^{o} and 12^{o}) are used to generate oblique shocks. These shock generators can be traversed such that the point of impingement of the shock over the cavity can be varied.

Figure 1a shows an instantaneous schlieren image of the baseline case, i.e, the Mach 2.2 flow over the cavity with no impinging shock. The various flow features are marked. Figure 1b shows the normalized power spectral density of ‘undisturbed’ pressure signal upstream of the cavity leading edge on the top wall as well as that of the pressure signal on the bottom wall of the cavity. Four significant Rossiter modes are observable, with the mode having 11.5 kHz being the dominant. Figure 2 shows a schlieren image of the flow field with the placement of a 6^{o} shock generator. The placement of the shock generator is such that a started flow field will have the oblique shock impinging at a distance of 15 mm downstream of cavity leading edge, and the expansion fan at the rear end of the shock generator impinging downstream of the cavity trailing edge. However, in the shown image, the supersonic flow field is not started, despite the shock generator being thinner than that permitted by second throat considerations. The span of the shock generator is reduced to 70 mm so as to reduce the frontal area, and experiments are underway with the reduced span shock generator. Further details will be discussed in the full-length paper and the presentation.

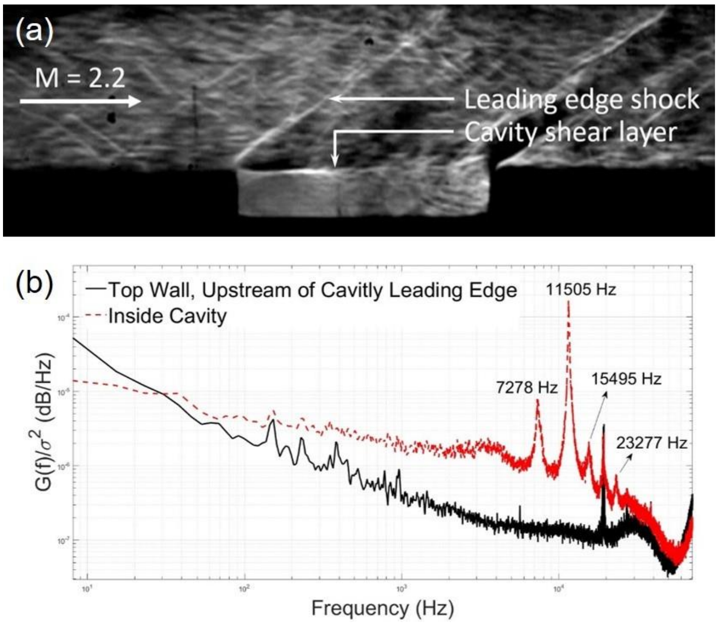

Figure 1**:** Flow field over cavity (baseline case) (a) Instantaneous Schlieren Image, (b) Power spectral density of pressure signals upstream of cavity and inside the cavity

Figure 2: Instantaneous schlieren image of the unstarted flow with shock generator

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