INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title : CHARACTERISTICS OF CAVITIES DURING START TRANSIENT AND ESTABLISHED FLOW CONDITIONS AT SUPERSONIC MACH NUMBER

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SHORT ABSTRACT

Supersonic combustion ramjet engine (scramjet) is being considered as a viable propulsion system for hypersonic cruise missiles, transport passenger vehicles for long-range operation, faster inter-continental travel and in the first stage of Two Stage To Orbit (TSTO) vehicle of low cost access to space. Some of the programs to demonstrate scramjet technology include Kholod of Russia, SCRAM, X43, X51 of USA, Hyshot and Scram Space Experiments by Australia. Recently, India has successfully demonstrated scramjet powered flight technology in 2016. The major challenges in the design of scramjet engine are; cowl opening mechanism for air intake under high dynamic pressure, material selection to endure high temperature effects and supersonic combustion. Although the concept of scramjet engine appeared to be straightforward, achieving supersonic combustion remains a formidable task due to the presence of chemical kinetics, high temperature and pressure, equivalence ratio, mixing rate, etc. Among which perhaps, mixing, flame holding and sustained combustion in high-speed supersonic flows, are the key problems due to compressibility effects. In order to overcome these challenges, several doable solutions have been proposed by many researchers amongst cavity assisted (with respect to length-to-depth ratio-L/D) supersonic combustion is proposed due to its simplicity and ability to reduce total pressure losses and drag as compared to other active or passive devices. For some L/D ratios, cavity shear layer is influenced by the acoustic feedback mechanism resulted in oscillation which can be used for efficient mixing whereas, in other L/D ratios, the cavities are acoustically stable with large recirculation zone that can be utilized for flame holding. In this background, it is proposed to concentrate on the geometrical modifications of the cavities to study either the mixing or the flame holding purposes and understand cavity flow physics. This is the theme of the thesis where the flow physics of various fundamental cavities are experimentally studied at supersonic speed. The core objective of the work involves fundamental

studies of shallow rectangular cavities of various L/D ratios ranging from 1 to 10 to characterize its behavior at supersonic speed.

The background of the work is with respect to scramjet engine, its design issues and importance of cavity flow field in terms of mixing and flame holding at supersonic Mach numbers. With a detailed review of the literature pertaining to high speed mixing layer flows, different injection strategies, the cavity flow physics (in terms of oscillation and its suppression mechanisms) are presented. The fabrication of the convergent divergent nozzle, test section and various cavity geometries along with the calibration of nozzle along with the instrumentation, measurement schemes and the data reduction are integral part of experimental setup and data processing. The transient starting process and associated pressure spectra of the cavities along with mode switching phenomena are elaborately presented using Shadowgraph images and unsteady pressure sensors. The transitional cavities (1 ≤ L/D ≤ 3) are studied using time resolved Schlieren images (125000 fps with the shutter speed of 3.5 microseconds) and unsteady pressure measurements. The modes/tones from FFT are compared with modified Rossiter relations and the flow features around the cavity and their dynamics are captured. Further, shear layer vortex dynamics and wave propagation inside the cavity for an elapsed time of 8μs are studied. They are correlated to mode/tone of the cavity. From unsteady signals, coherence, cross correlation, spectrogram and wavelet transform are derived to understand the physics of the transitional cavities. The studies on the open cavities (L/D = 4 and 5) deal with the characteristics such as vortex motion inside the cavity, waves dynamics as a consequence of shear layer vortex both inside and outside the cavity. The mode switching phenomena are studied through high-speed Schlieren images and unsteady pressure measurements. The studies further brought out the flow physics through derived parameters like coherence, cross correlation, spectrogram and wavelet transform. Similarly, flow features and analyzes of transition from open to close rectangular cavities (6 ≤ L/D ≤ 10) are studied and presented. The flow chart highlighting the overview of the thesis is shown in following figure.