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EFFECT OF SWIRL INJECTOR ON HIGH SPEED FLOW USING SUPERSONIC COMBUSTOR

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Abstract- Mixing characteristics of swirl coaxial jet injector are investigated experimentally with a model of air injection in supersonic flow test facility with Mach number of 1.5. The injector, widely used in a high-performance combustor, the air is injected vertically for annular swirl flow. The swirl injector is placed at a distance of 25mm from inlet of the combustor. The cavities are used to discover the mixing of the air and fuel. Cavities having constant length to depth ratio of 5 with varying ramp angles of 15,20 and 30 degrees were used as the aft wall of the cavity. Wall static pressure were made by using of pressure transducer with various pressures 4bar and 5 bar. It was compared with and without injection. The swirl generator develops a pressure drop across the generator during the time of fuel is expelled in which pressure drops aids in enhancing the closure time of the injector. The swirl generator minimizes the volume of fuel remaining in the injector.

Keywords: Swirl injector, aft ramp angle, length to depth ratio.

I.INTRODUCTION

Air-fuel mixing is one of the major difficulty in high speed flow such as scramjet and gas turbine combustors. Injection of the fuel is placed an important role for the complete combustion. There are many injection methods were used to increase the mixing efficiency for complete combustion, (i.e) normal injection, angled injection, multi point injection and swirl injection. Swirl injection is one of the promising method to increase the air and fuel. The swirl injector have categorized into two (i.e) Liquid centered coaxial swirl injector and gas centered coaxial swirl injector. Gas centered swirl injectors are used in the combustion chamber of staged combustion engines for their high atomization performance and high efficiency propellant mixing

Strakey et al. [1] and Cohn et al. [2] performed cold flow tests and hotfiring tests by using several kinds of GCSC injectors, and developed design guidelines for GCSC injectors through understanding the injector characteristics. In addition, the correlation between cold flow and hot fire tests was observed with scaling methodology. The pump-fed systems are divided into a gas generator cycle and a staged combustion cycle based on how the turbine exhaust gas is used. combustion gas created from the gas generator(or pre-burner) is dumped overboard after driving the turbine in the gas generator cycle whereas it is routed into the combustion chamber to participate in the main combustion process in the staged combustion cycle.

Engines with staged combustion cycle provide higher performance than those with an equivalent gas generator cycle due to full utilization of the energy in the turbine exhaust gas [3,4].The objective of this work is to elucidate the interaction of large-scale coherent vortices within turbulent swirl flames in aGT-typical combustor by means of modern laser-based methods.In particular, novel high-speed laser techniques are applied for simultaneous measurements of flow field and flame structure with high temporal and spatial resolution, which provide detailed insights into the mechanisms of the interaction. The study uses aGT model combustor, which at certain operating conditions exhibits thermo-acoustic oscillations. These oscillations have been subject of numerous previous experimental studies, where several diagnostic techniques have been applied such as Raman spectroscopy,PLIF, and PIV at repetition rates between 5 Hz and 5 kHz.

Recent reviews of these works are provided by Boxx et al. [5] and Steinberg et al. In another work, where the same combustor was operated at a fuel-lean condition, Stöhr et al. have investigated the dynamics of lean blowout [6]. As an example for the development of gas turbine emissions the typical nitrogen oxide values (NO_x) in the exhaust gases are verified. Nitrogen oxides are basically produced if the nitrogen and the oxygen of the atmosphere reacts with each other. This process depends on reaction time, pressure and mainly the temperature in the flame, and the residence time in it. The production of "thermal NO_x" starts typically at temperatures above1500 °C and shows an exponential dependency to theTemperature [7].The objective of this paper is effect of swirl injector on supersonic flow using wall static pressure distribution.

The simple modification of the combustor geometry to achieve a lean primary zone and to reduce the residence time [8,9] to control the nitrogen oxide production leads to the excessive production of unburned carbon monoxide at low power requirements,as a consequence of an excessively lean primary zone and of the reduced residence time. Lightfoot et al. [10] studied the atomization mechanism of capital GCSC injectors and found relation between liquid intact length and momentum flux ratio.

II.EXPERIMENTAL METHOD

The test setup has an air compressor, reservoir, settling chamber,combustor,nozzle, cavity and discretized from this set up was swirl injector. There are two reservoir primary and secondary. Primary air is passed through pipelines and the flow is maintained by using pressure gauge. The pipe lines are connected with the settling chamber which connects the combustor and convergent-divergent nozzle. The convergent-divergent nozzle was designed for Mach number 1.5 with total pressure and temperature of 3.5 bar and 300K. Combustor, nozzle,cavities and swirl injector are fabricated by using mild steel. The exit diameter of the nozzle and combustor are same as 26 mm. The exit diameter of swirl injector is 3mm. The cavities are placed at the inlet section of the supersonic combustor. The swirl injector placed at a distance of 25mm from the inlet of the combustor. Inside portion of the injector has three blades that are fixed parallel to the flow at a degree of 45. Length and diameter of the cavities are constant of 15mm and 3mm and varying ramp angle are 15^0 $20^0$and 30^0 .Secondary reservoir is full of dry air and pipelines are connected to the common rail injector and flow of dry air is passed through swirl injector. The schematic diagram of swirl injector was shown in figure1.

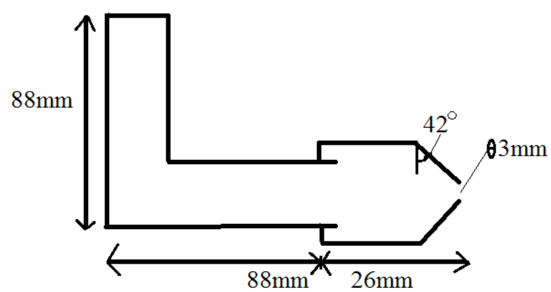

Figure 1. Schematic of swirl injector

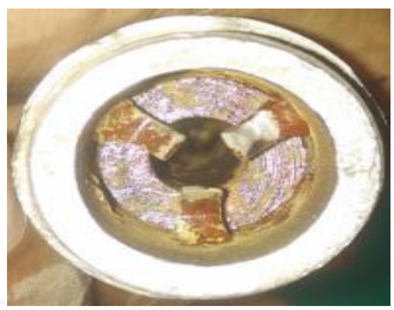

Figure 2. 3D view of swirl injector.

III. RESULT AND DISCUSSION

Wall static pressure distribution:

Wall static pressure distribution for various aft ramp cavity configurations were plotted against axial distance (x/L), where "x" denotes distance of the probe measured from inlet of the combustor and "L" denotes the total length of the combustor. The pressure probe was fitted at base of the entire combustor at a distance of 10 mm for every probe. Pressure measurement was made by using piezoelectric 16 channel pressure scanner. Adjustable pressure probes having 1mm diameter and it was connected to the transducer. Wall static pressure distribution was measured various aft ramp cavities 15^0, 20^0 and 30^0. The depth of the cavity were constant at 3mm. swirl injector was connected at a distance of 25mm from inlet of the combustor. Air is used as the injection fuel by using of common rail injection system. The various injection pressures were used 4 bar and 4.5 bar and it was compared with absence of injection. It was denoted as WOI.

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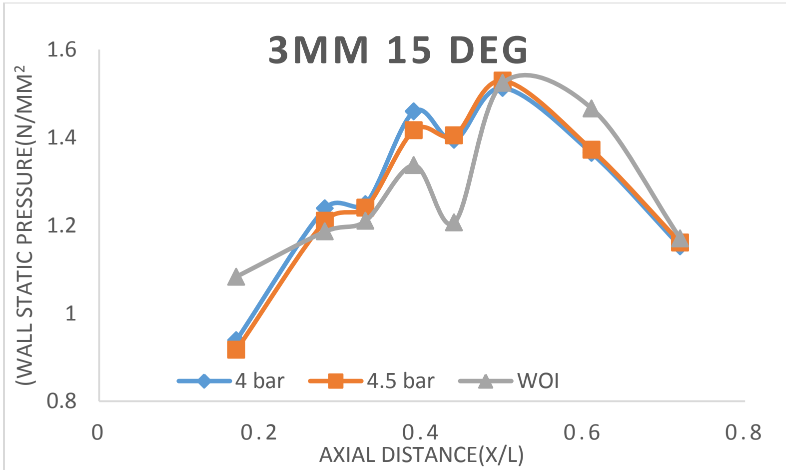
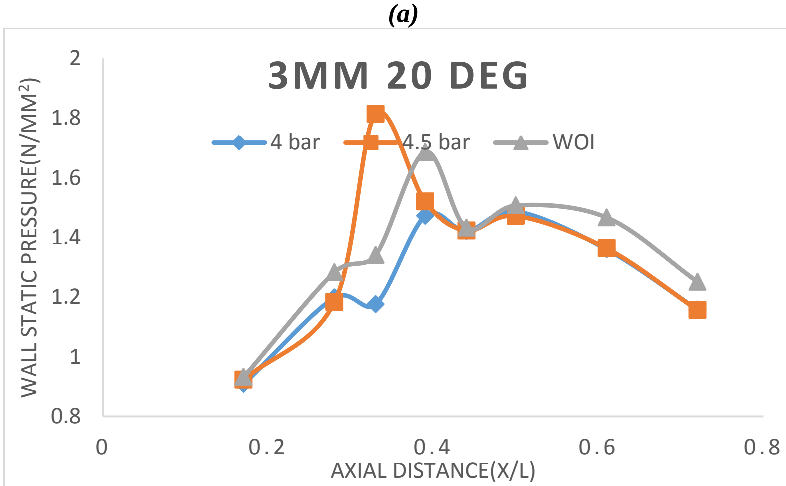
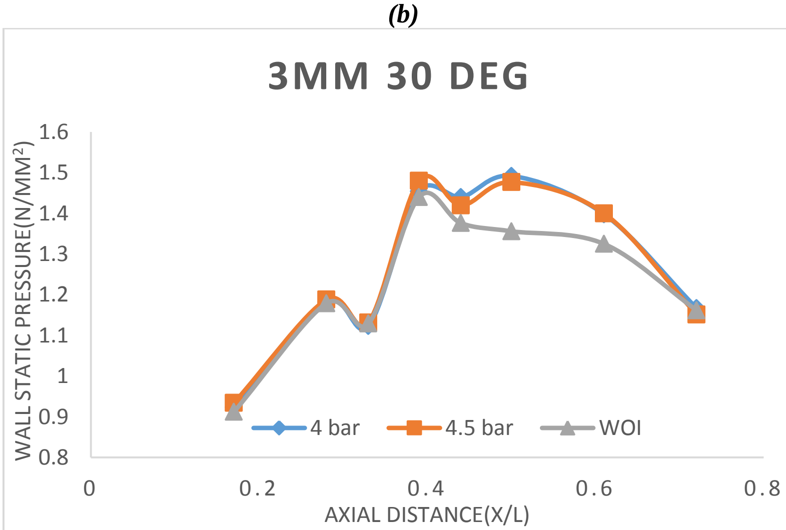


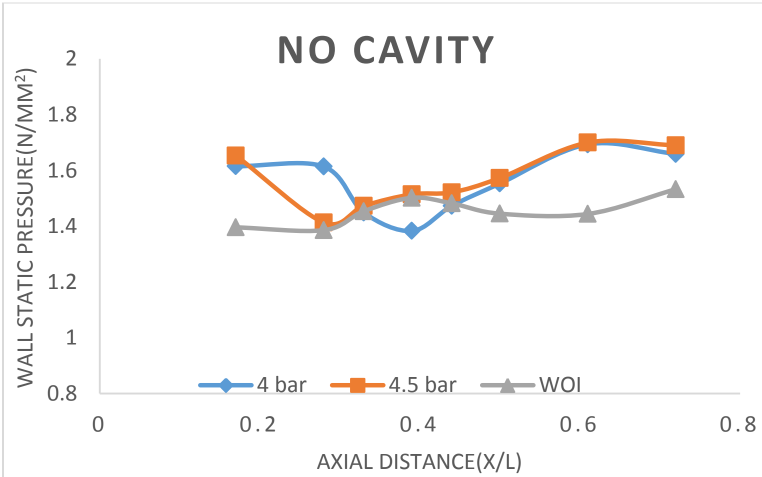
(a)



(b)



(c)



(d)

Fig3. Wall static pressure distribution for various cavity configurations.

From above plots for no cavity configuration there is no pressure difference using WOI. It seems to like almost uniform entire combustor region. From figure 1(d) shows that if increase the injection pressure the mixing is efficient in combustor region because of increasing pressure. The uniform pressure distribution was observed for both injection pressures at axial distance 0.61. The variation of pressure denotes the turbulence forms in entire cavity region. The peak pressure was observed at axial distance 0.39 from figure 1(c). The observation from 1(c) was the shear layer separates from the fore wall of the cavity and it creates strong shock from edge of the upstream and it reattaches at trailing edge of the cavity. The observation of this plot the strong recompression zone and longitudinal vortex was formed in the cavity region and there is no pressure variations for various injection pressure was observed by means of increasing ramp angles. From figure 1 (b) the high pressure was observed at the axial distance 0.39 and it was gradually decrease in the cavity region and it shows that the compression zone was produced because of bow shock. The uniform pressure was observed for minimum and maximum injection pressure from fig 1(a). From wall static pressure concluded that increasing ramp angles show more efficient than minimum ramp angle. And increasing ramp angles are also act as a effective flame holder and used to enhanced mixing by means of vortex generation.

IV. CONCLUSION

The effect of swirl injectors in supersonic combustor with Mach 1.5 was investigated experimentally. The experiments were carried out in a blow down type supersonic flow facility. Cavities of constant L/D ratio and varying ramp angles are used. Air is injected upstream of the cavity at various injection pressure. The wall static pressure was made by using of piezoelectric pressure transducer. The major conclusions from wall static pressure distribution the increasing ramp angle shows the enhanced mixing with minimum and maximum injection pressures. Another results were revealed from this experiment if using smooth surfaces in fore wall of the cavity shows better results and avoid more pressure losses.

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