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EXPERIMENTAL STUDY OF DECAY OF PRESSURE ALONG THE JET AXIS OF THE CONVERGENT DIVERGENT NOZZLE WITH SECONDARY INJECTION FOR VARIOUS ANGLE AND PRESSURE

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Abstract— **This experiment deals with the study of mixing characteristic of supersonic flow through a convergent divergent nozzle with secondary injection of different angles and various pressure by measuring the total pressure along the nozzle jet axis until it reaches the atmospheric pressure. The primary jet was supersonic and the secondary jet (co flow) is highly sonic. Now-a-days the effect of mixing of fuel and air mixture in the combustion chamber of the scramjet engine is quite interesting problem in the field of propulsion. This is because of the supersonic flow in the combustion chamber of the scramjet engine. Hence the requirement of immediate mixing of fuel and air mixture in the combustion chamber is important .This problem can be slightly solved by injecting the fuel in various angles with various proportion of pressure with respect to primary supersonic flow through the nozzle. Hence while analyzing the data got from this experiment it is understood that the time and distance taken for the proper mixing or decaying of secondary injected sonic flow and primary supersonic flow with atmospheric pressure along the jet axis is less compared to non secondary injected and secondary injection which is parallel to the flow.**

Keyword— divergent nozzle, secondary sonic jet, pressure, Shadow graph ,primary supersonic jet.

Introduction

Jet flows due to their vast applicability in various fields, required to be controlled for a particular application. By controlling the jet flow field, the performance of various system can be improved greatly. For example, many technological applications such as fuel air mixing in combustion chamber, reducing infrared signature and noise level of the jet of a missile or launch vehicle, thrust vector control, and gas dynamic lasers require to control on the mixing of jet flows. Here, control may be defined as the ability to modify the jet flow mixing characteristic to achieve engineering efficiency, the technological ease economy, adherence to standards, and so on. The extensive research has done on circular jet as well as non circular jets in the past decades. The enhanced mixing if elliptical jets compared to their circular counterpart is due to the generation of azimuthal vortices of continuously varying size generated at the nozzle exit.Gutmark et al observed better mixing performance and spreading rate of the elliptical jet relative to rectangular and circular jet in the subsonic and super sonic flow regime. Quinn showed the mixing in an elliptical jet issuing from elliptical nozzle and in round jets. With this mind, the present study aims at studying the mixing characteristic of circular jet along the jet axis in the presence of secondary with different angles such as 45degree, 90degree and 60degree for different NPR.

Experimental Details

Jet flow facility:

The experiment was conducted in the open jet facility in Propulsion laboratory at Rajalakshmi Engineering College, Chennai, Tamilnadu. The compressed air to the settling chamber was supplied continuously from the storage tank through a control valve. To reduce the flow disturbance caused by the control valve the mixing length of 1m is placed between the valve and the settling chamber. The flow is then allowed to pass to the settling chamber. The desired nozzle pressure ratio was achieved by controlling the settling chamber pressure (P_0),because the back pressure was the atmospheric pressure (P_a) in to which the jet was discharging. The jet axis pressure is measured using a PSI pressure transducer. The transducer had 8 pressure ports with capability of measuring pressure simultaneously through all the ports using a menu driven user friendly software provider by the manufacture. The transducer measures an average of 150 samples per second. The pressure measurement accuracy of the transducer was specified to be 0.15% on a full scale. The pressure measurement were conducted using a pitot probe mounted on the 3D traverse with least count of 1mm in translation. The probe mounted on the traverse measured the pressure along the jet axis (X-axis).The effectiveness of jet controls in weakening the shock cells were also analyzed using shadowgraph optical flow visualization technique.The high speed jet facility is shown below.

Result and discussion

It is well established that the supersonic jet core is highly dominated zone. Thus the axial pressure values for 50%0f secondary flow corresponds to primary flow and flow without secondary injection is noted. The graphs were plotted for the axial distance from the exit of the CD nozzle with respect to the pressure values for the corresponding distance.

Centre-line pitot pressure decay:

The centre line pressure decay for flow without secondary injection is showed in figure below.

Settling chamber pressure: 3bar

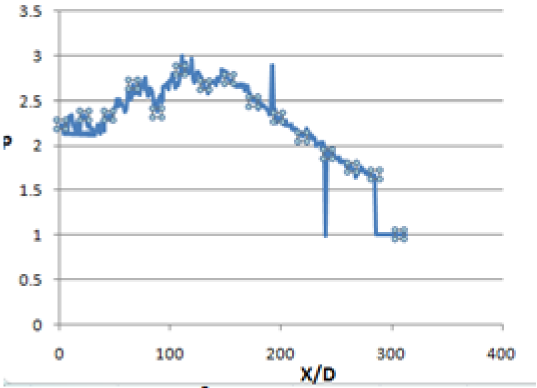
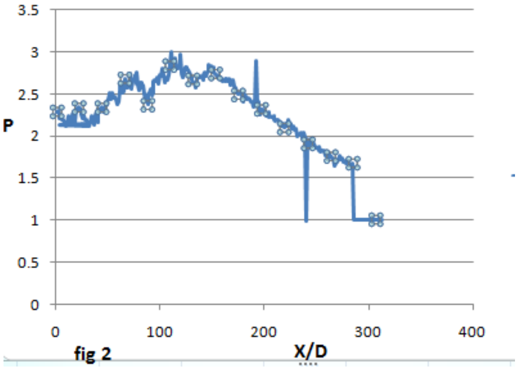
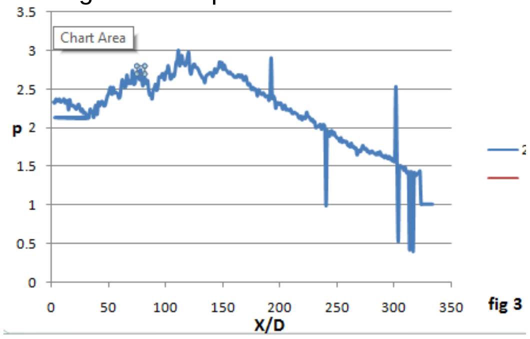


fig 1

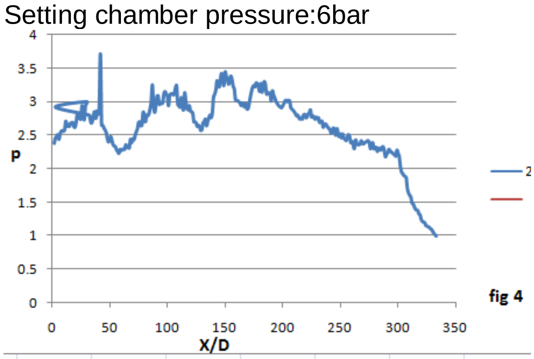
Setilling chamber pressure:4bar



Settling chamber pressure:5bar



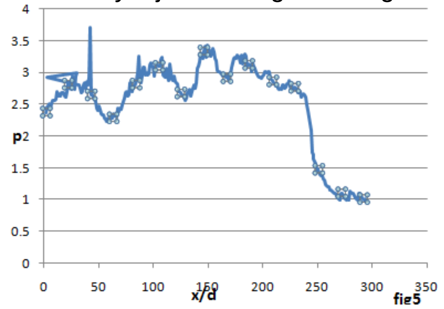
Setting chamber pressure:6bar



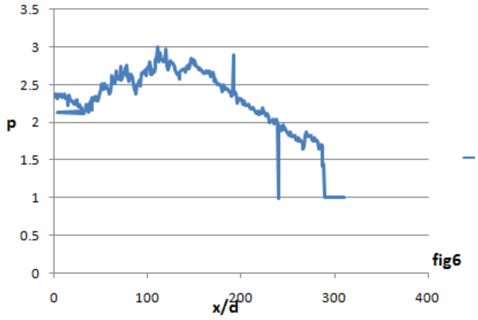
Flow with secondary injection:

Secondary injection pressure: 3bar

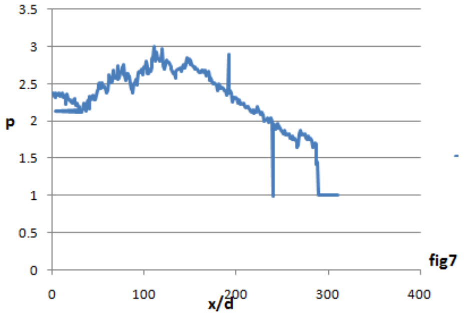
Primary flow inlet pressure: 6bar
Secondary injection angle: 90deg



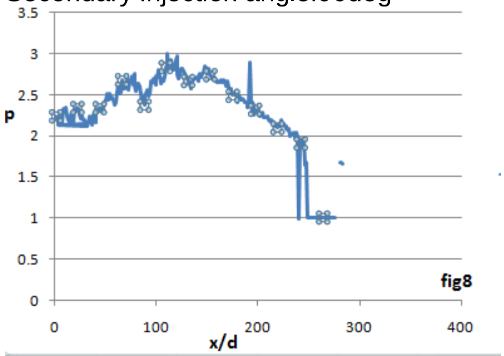
Secondary injection pressure:2.5bar
Primary flow inlet pressure:5bar
Secondary injection angle:90deg



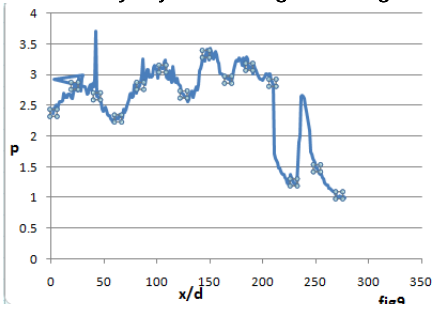
Secondary injection pressure:2bar
Primary flow inlet pressure:4bar
Secondary injection angle:90deg



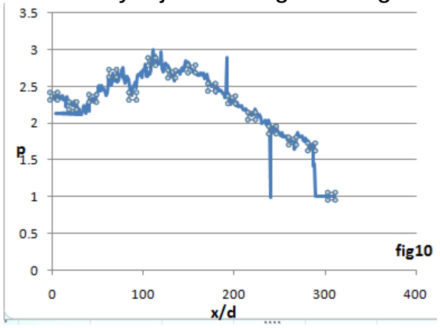
Secondary injection pressure:1.5bar
Primary flow inlet pressure:3bar
Secondary injection angle:90deg



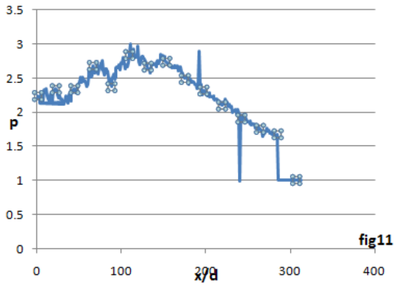
Secondary injection pressure:3bar
Primary flow inlet pressure:6bar
Secondary injection angle:60deg



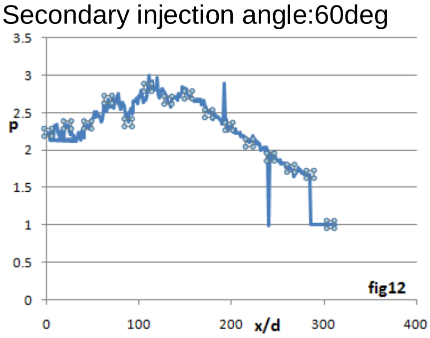
Secondary injection pressure:2.5bar
Primary flow inlet pressure:5bar
Secondary injection angle:60deg



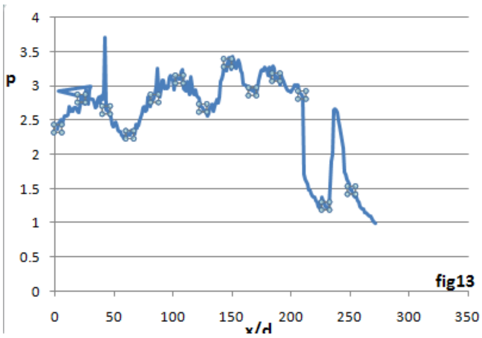
Secondary injection pressure:2bar
Primary flow inlet pressure:4bar
Secondary injection angle:60deg



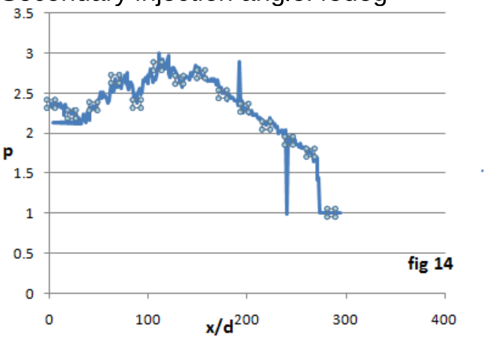
Secondary injection pressure:1.5bar
Primary flow inlet pressure:3bar
Secondary injection angle:60deg



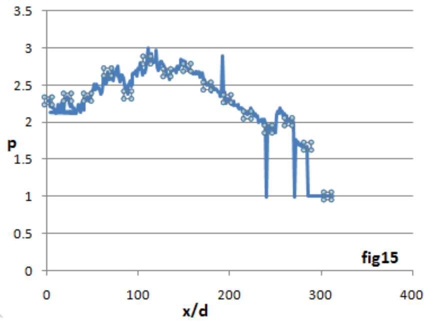
Secondary injection pressure:3bar
Primary flow inlet pressure:6bar
Secondary injection angle:45deg



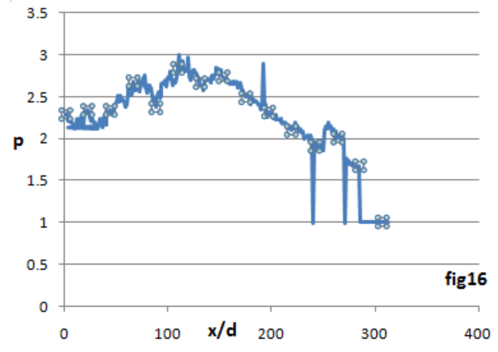
Secondary injection pressure:2.5bar
Primary flow inlet pressure:5bar
Secondary injection angle:45deg



Secondary injection pressure:2bar
Primary flow inlet pressure:4bar
Secondary injection angle:45deg



Secondary injection pressure:1.5bar
Primary flow inlet pressure:3bar
Secondary injection angle:45deg



While analyzing the graphs from fig1 to fig 16, it is noted that the distance taken to mix with atmospheric pressure for 50% of secondary injection with respect to main flow is less than the distance taken for the non secondary injected flow.

Optical flow visualization:

The shadowgraph optical flow visualization method was employed to analyse the prevailing in the jet with or without control at different NPRs. For control jets, visualization was carried out.

The visualization image for the jet with settling chamber pressure is equal to 6 bar is showed in figure below.

Settling chamber pressure:6bar
Non secondary injection:

fig16

Settling chamber pressure:6bar
Secondary injection pressure:3bar
Secondary injection angle:90deg

fig17

Settling chamber pressure:6bar
Secondary injection pressure:3bar
Secondary injection angle:45deg

fig18

Settling chamber pressure:6bar
Secondary injection pressure:3bar
Secondary injection angle:60deg

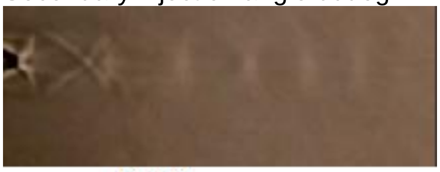


fig19

When analyzing the image got from the shadowgraph visualization ,it is understood that ,for 6bar pressure there is six visible shock cells in the visualization image. further ,it is interesting to see that there is a oblique shock at the exit of the nozzle. Though, the first shock cell is longer and having high strength. The shock cell followed by the first shock cell having less strength and shorter. This indicates that the mixing happens gradually.

When analyzing the image of the secondary injected flow it is seen that the shock strength gets disappear immediately. It indicates that the mixing happens immediately.

Conclusion:

Thus the study of mixing characteristic for with and without secondary injection with the help of pressure decay along the jet axis and shadowgraph technique. From that, it is understood that The decay or mixing of supersonic flow with atmospheric pressure attain very rapidly in flow with secondary injection compared to the non secondary injection flow.

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