International Journal of Fluids Engineering.
ISSN 0974-3138 Volume 7, Number 1 (2015), pp. 1-12

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Enhancement Of Mixing Using Delta Tab

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ABSTRACT

Forced mixers are used to enhance the efficiency of the working unit and to reduce the jet mixing noise in turbo fans and in jet engines. A new idea is implementing a delta tab in the flow field. It is well known fact that when a solid strip kept normal to the flow, usually at the exit of any duct or nozzle generates a pair of counter rotating transverse vortices (with the axis of rotation along the tab) which become stream wise soon after shedding that can affect the flow development significantly. The size of vortices plays a dominant role in the near field and far field of the mixing. The smaller the size of the vortex, the better is its mixing promoting efficiently, and also small vortices are highly stable and can travel longer distances compared to the larger vortices. With this aim in the present investigation rectangular strip and triangular strips are used as Tabs. These tabs are placed normal and at an angle to the flow. The flow modifications by the presence of these tabs are studied at different velocities.

INTRODUCTION

Jet is defined as a continuous fluid flow issuing from a duct into a medium of lower speed fluid where width-to-axial distance is a constant. As the jet fluid travels away from its origin, it slows down due to mixing with the stagnant ambient fluid entrained and inducted into the jet field. This is due to the boundary layer at the nozzle exit which develops roll-up structures, or ring vortices, that grow in size when they move downstream, due to the entrainment of ambient fluid into the jet stream. Thus, mass flow at any cross-section of the jet progressively increases along the downstream direction. Hence, to conserve momentum the center line velocity decreases with downstream distance [1, 2]. The resulting centerline velocity decay is proportional to the gradient across the shear layer and is a strong function of the distance downstream of jet exit. The vast quantity of knowledge presently available and the continuous research currently being carried out stand testimony to the importance of jet flows, and can find numerous systems where the ability to enhance the mixing characteristics of a jet will greatly improve their performance. For example, by increasing the rate of mixing between air and fuel, the efficiency of a combustion cycle may be improved. Forced mixers are used to improve the performance (thrust and SFC) and to reduce jet-mixing noise of turbofan engines. Therefore every effort has been made to enhance the mixing from forced exhaust mixers [3, 4]. A lobed type of forced mixer induces rapid mixing by enhancing the stream wise vorticity and increasing the interfacial area. Lobed mixer effectiveness can be further enhanced through the introduction of smaller scale mixing devices. For the design of these mixing devices it is important to keep in mind, that the devices have to produce smaller scale vorticity, but with an acceptable pressure loss [5, 6].

The most notable work on the effect of tabs and tab like devices on the jet flow field is that a significant increase in the centerline velocity decay caused by the tabs. However, they could not detect such vortex motion using wool tufts, which led to the inference that the effect was likely to be due to the "circumferential variations in flow angle produced by the tabs."

EXPERIMENTAL SET UP & METHODOLOGY

(a) OPEN JET FACILITY

The experiments were conducted in an open jet facility. A schematic diagram of the open jet test facility is shown in fig 1. High pressure air enters the settling chamber through a tunnel section with a gate valve followed by a pressure regulating valve and a mixing length. The settling chamber is connected to the mixing length by a wide angle diffuser. The flow is further conditioned inside the settling chamber by closely meshed grids. The test model was fixed at the end of settling chamber with "O" ring sealing to avoid leaks. During the runs the settling (stagnation) chamber temperature was the same as the ambient temperature and the back pressure was the ambient pressure of the ambient to which the jets were discharged.

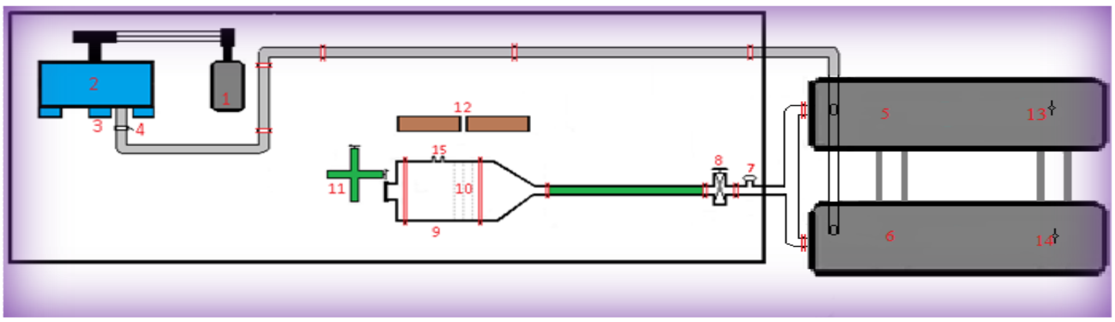


Fig.1 Layout of the open jet facility

1. 20 Hp induction motor
2. Reciprocating compressor
3. Activated charcoal filters
4. Non-return valve
5. Storage tank 1
6. Storage tank 2
7. Pressure gauge
8. Pressure regulating valve
9. Stagnation chamber
10. Screens
11. Traversing system
12. U-tube manometers
13. Safety valve 1
14. Safety valve 2
15. Two pressure ports

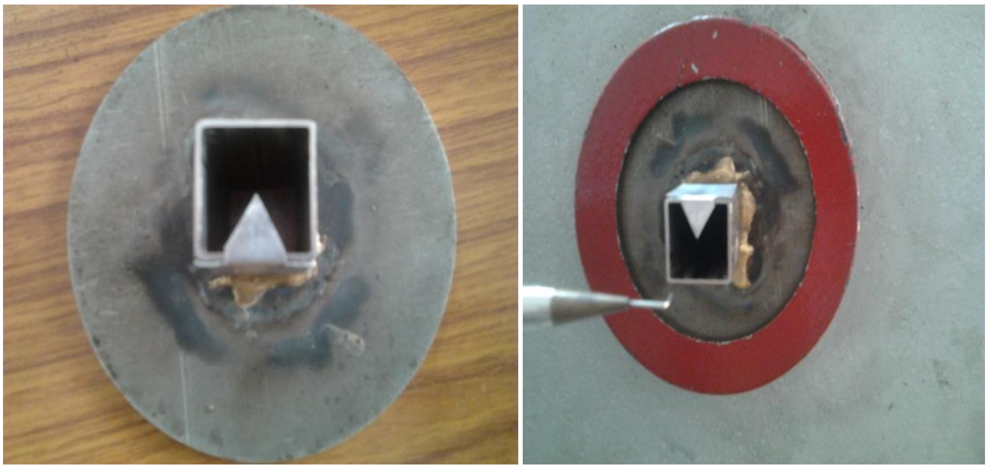


Fig.2 Delta tab arranged to open jet facility

The experiment is carried out in a free open jet facility, before conducting the experiment the experimental set is calibrated. And after fix the nozzle of orifice at the end of the settling chamber with "O" ring seal to avoid leaks and operate the pressure regulating valve slowly and controlling the flow rate, so that the head difference in the manometer (connected to the stagnation chamber) to show the difference required to generate the flow with required Mach number, keeping the pitot probe at the centre of the jet exit. Connecting the probe to another manometer. Due to the flow of air through the pitot probe there will be head difference in the manometer. Calculating the corresponding Mach number and following the same procedure for various Mach numbers.

CALCULATIONS

The head difference in U-Tube manometer for corresponding inlet Mach number can be calculated by using the following steps.

Calculation of head Mach number:

From the gas tables for M = 0.1, from the isentropic relation:

Corresponding Pressure ratio is, $(P_{atm}/ P_{stag}) = 0.9930$

We know that, $P_{gauge} = P_{absolute} - P_{atmospheric}$ …………………. (1)

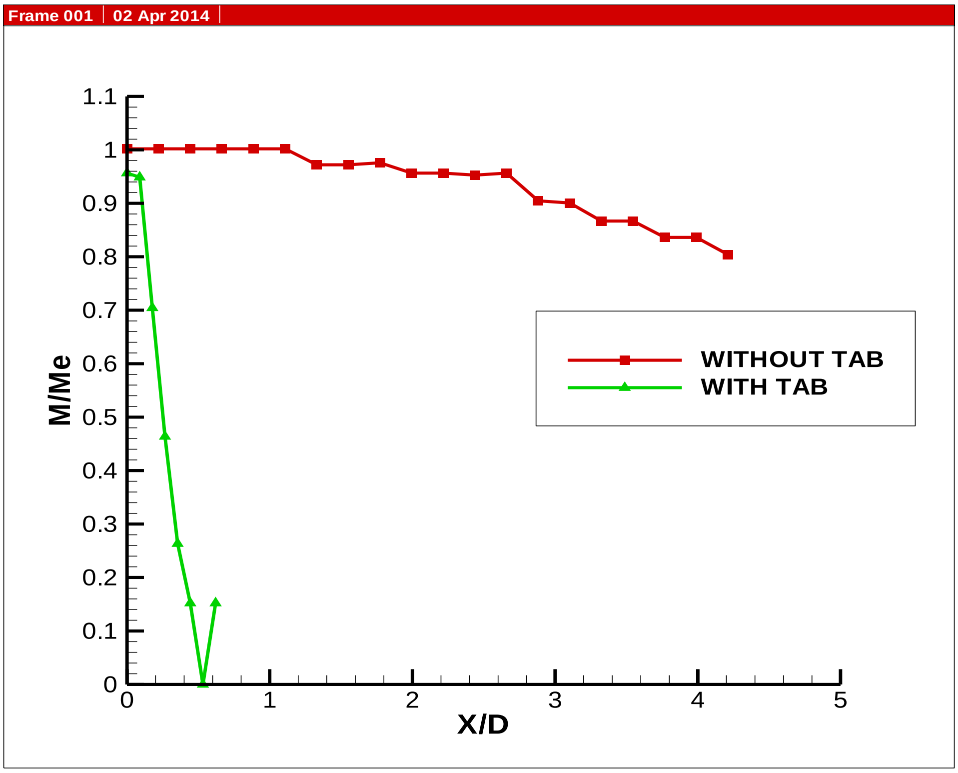
$P_{gauge} = 709.27\ N/m^2$ $[P_{atm} = 101325\ N/m^2]$

We know that, $P_{gauge} = \rho gh$

For Water: h = 7.23 cm and For Mercury h = 0.5 cm

RESULTS & DISCUSSION

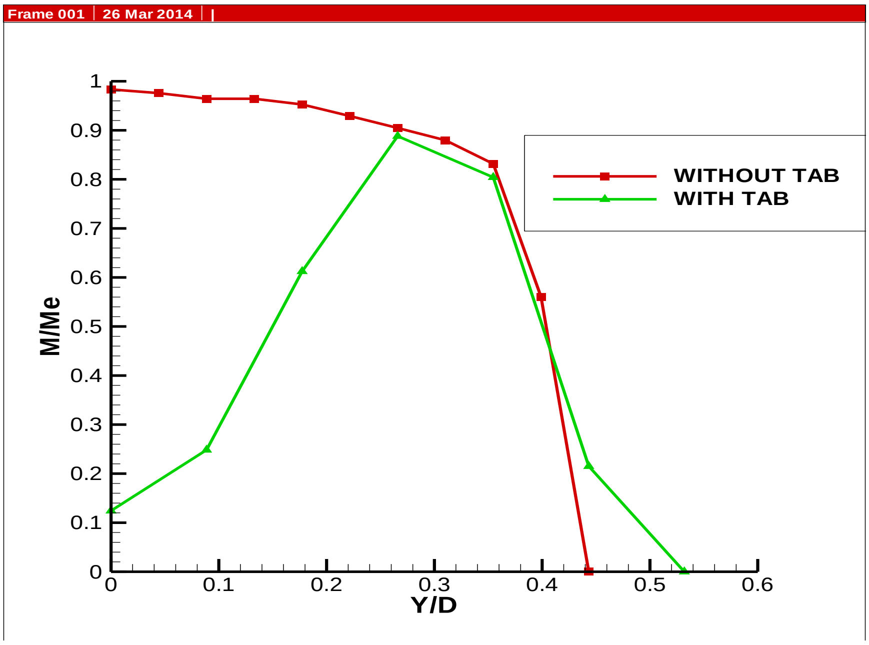
CENTER LINE MACH NUMBER DECAY



Graph: 1. Centerline Mach number decay for Mach 0.3 jet

The Mach number (M/Me) variation along the axial distance (X/D) for jet Mach number 0.3 is shown in graph.1. For the uncontrolled jet coming from a square duct, the core extends up to about X/D= 4.0 for the Mach number 0.3. But when the delta tab is introduced, taking the core as the axial extent at which the characteristic decay begins, it is seen that the core ends as early as X/D less than 0.5 for Mach 0.3 jet, surprisingly a drastic change has taken when delta tab is introduced in axial direction to jet [7]. Hence the usage of delta tab is much more dominant to promote mixing.

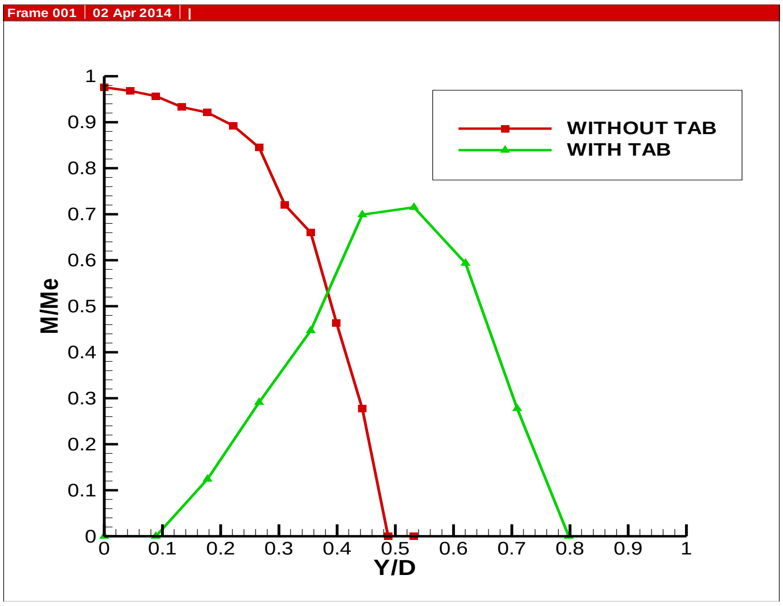
MACH NUMBER PROFILE
AXIAL DISTANCE X=10mm VARIATION IN Y- DIRECTION



Graph: 2. (a).Mach number profile for mach 0.3 jet

The graph 2 (a) presents the radial Mach number variation of plain jet. The variation of Mach number in the plane perpendicular to the tab (X–Y plane) and along the tab (X–Z plane) at various axial locations is presented in graphs 2(b) and 2(c), respectively. The extent of potential core for the controlled jet, normal to the tab(Y-direction), can be observed in graph 2 (b). For the plain jet the potential core extends up to Y/D= 5 as seen from. (b), whereas for the controlled jet the extent of the potential core in the Y-direction is only up to Y/D =1:0 and no such characteristic thereafter, as seen in graph 2(a), (b) and (c) without tab . It can be easily seen in graphs 2 (a), (b) and (c), that the duct with tab causes the jet to spread asymmetrically, being wider in the plane perpendicular to the tab [8, 9].

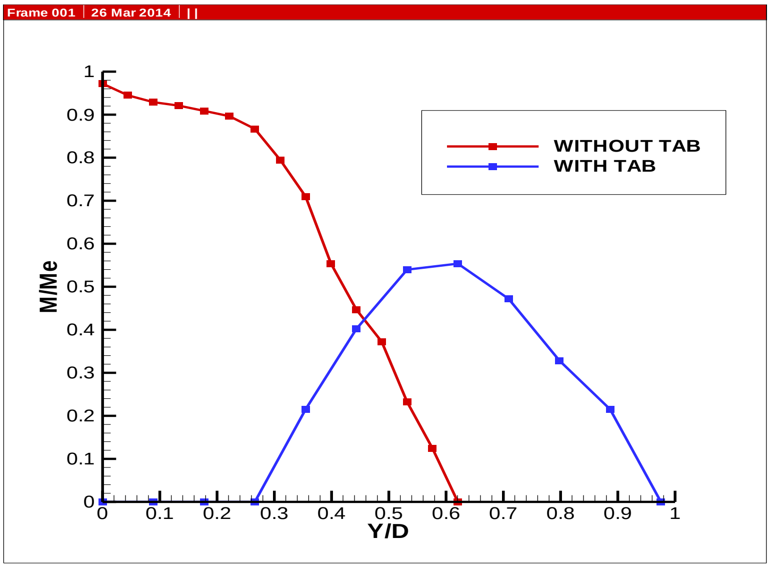
AXIAL DISTANCE X=20mm VARIATION IN Y- DIRECTION



Graph: 2(b).Mach number profile for mach 0.3 jet

The graph is plotted by moving the pitot probe axially X=20 and varying in radial direction by 1 mm [10]. Introduction of tab promotes mixing in radial direction as well as shown in graph 2(b).

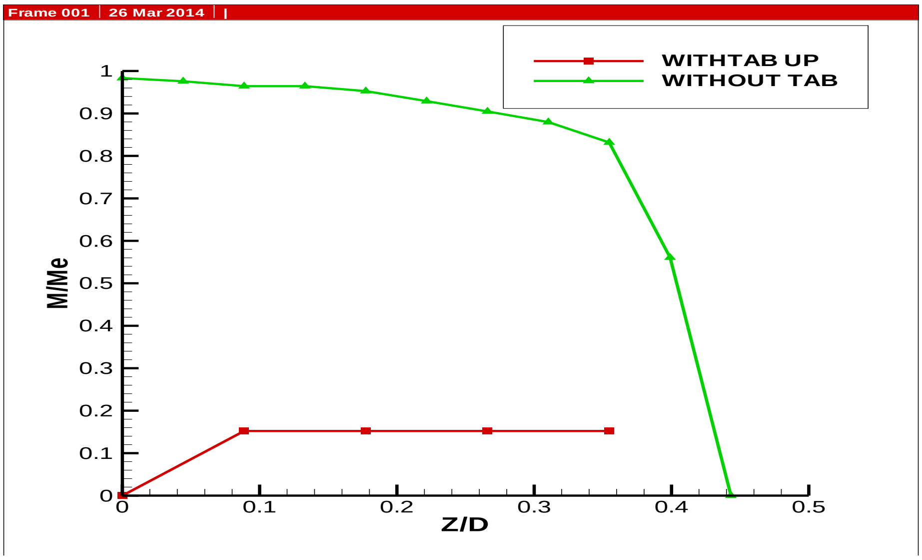
AXIAL DISTANCE X=30mm VARIATION IN Y- DIRECTION



Graph: 2(c).Mach number profile for mach 0.3 jet

The graph is plotted by moving the pitot probe axially X=30 and varying in radial direction by 1 mm. Introduction of tab promotes mixing in radial direction as well, as shown in graph 2(c). By moving axially through some distance the air from the duct mixes with the atmospheric air.

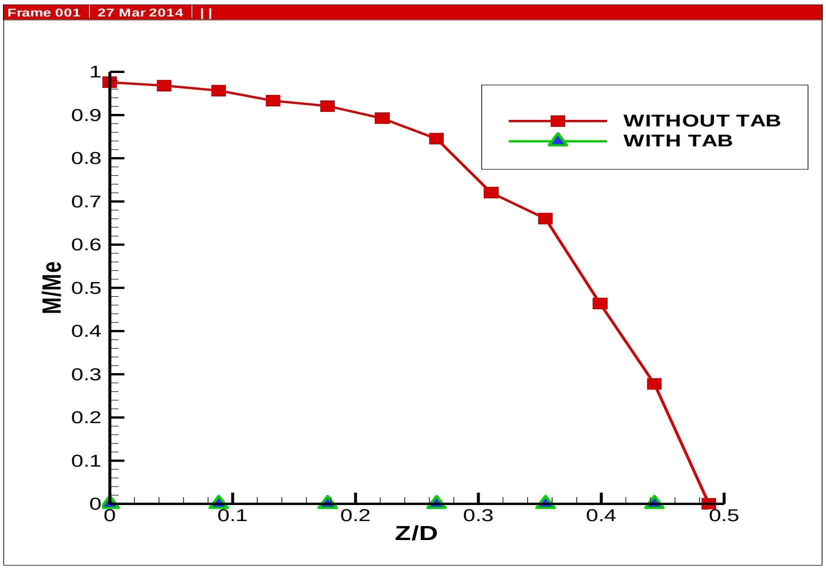
AXIAL DISTANCE X=10mm VARIATION IN Z- UP DIRECTION



Graph: 3(a).Mach number profile for mach 0.3 jet

Here the graph is plotted by moving the pitot probe axially X=10mm and varying in Z direction by 1mm. The presence of tab in Z-UP direction shows how much dominantly a delta tab creates mixing [11, 12]. The velocity increased to some value and remained constant, because exactly behind the tab a high pressure is attained in turn loss in velocity. Hence mixing is enhanced.

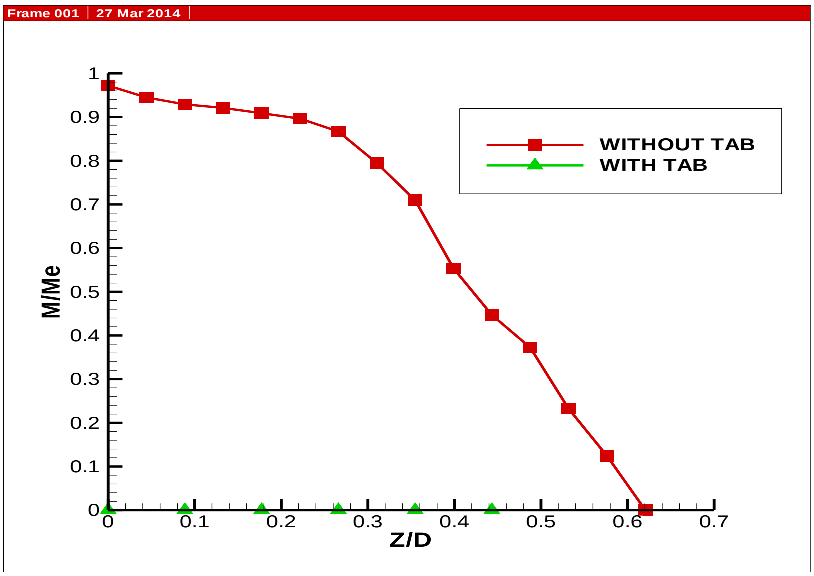
AXIAL DISTANCE X=20mm VARIATION IN Z- UP DIRECTION



Graph: 3. (b).Mach number profile for mach 0.3 jet

Here as the pitot probe moves axially X=20mm and variation in Z-UP direction by 1mm, the air from the square duct completely mix with the ambient air as shown in graph 3(b).

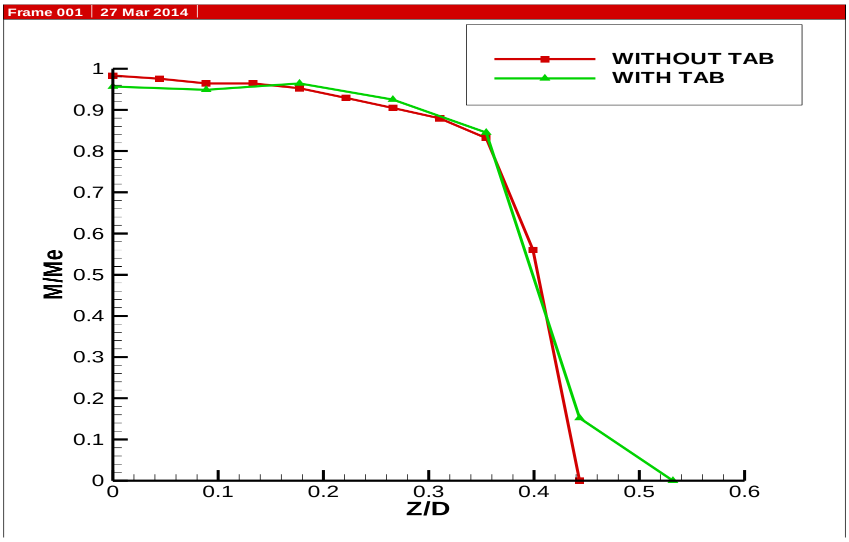
AXIAL DISTANCE X=30mm VARIATION IN Z- UP DIRECTION



Graph:3.(c) Mach number profile for mach 0.3 jet

Here as the pitot probe moves axially X=30mm and variation in Z-UP direction by 1mm, the air from the square duct completely mix with the ambient air as shown in graph 3(c).

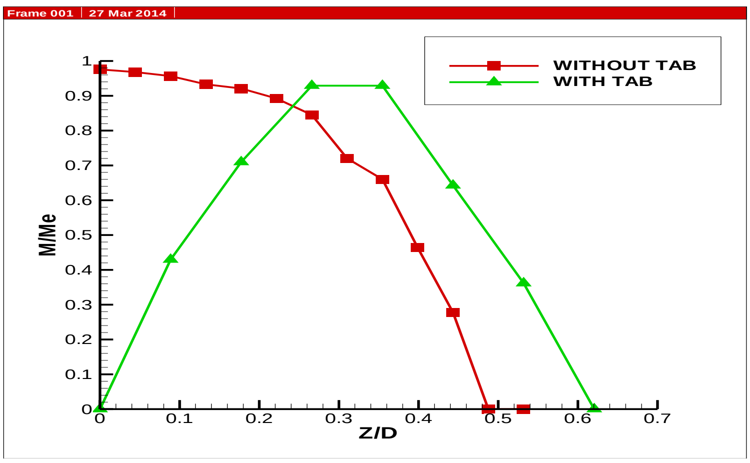
AXIAL DISTANCE X=10mm VARIATION IN Z- DOWN DIRECTION



Graph :4 (a).Mach number profile for mach 0.3 jet

In Z-DOWN direction, due to absence of tab the radial characteristic decay is similar as the jet without control as shown in graph 4(a).

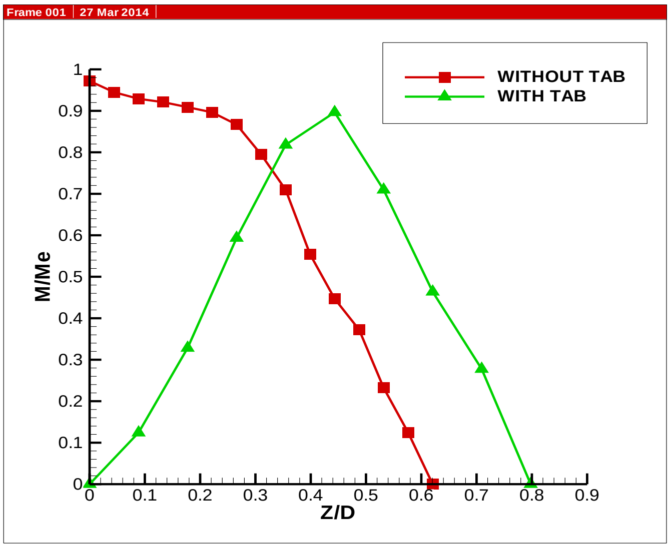
AXIAL DISTANCE X=20mm VARIATION IN Z- DOWN DIRECTION



Graph :4 (b) .Mach number profiles for mach 0.3 jet

In Z-DOWN direction, due to absence of tab the radial characteristic decay is similar as the jet without control as shown in graph 4(a). But as the pitot probe moves axially X=20mm, the effect of tab which promotes mixing is shown in graph 4(b).

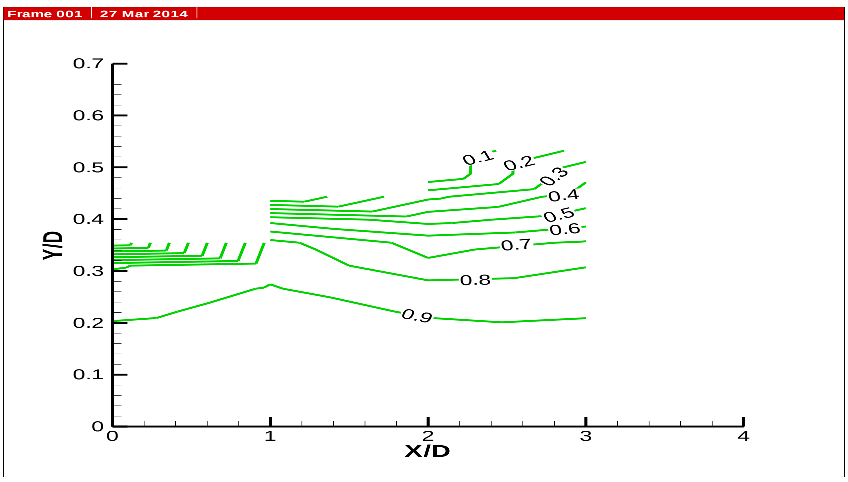
AXIAL DISTANCE X=30mm VARIATION IN Z- DOWN DIRECTION



Graph :4(c).Mach number profile for mach 0.3 jet

In Z-DOWN direction, due to absence of tab the radial characteristic decay is similar as the jet without control as shown in graph 4(a). But as the pitot probe moves axially X=30mm, the effect of tab which promotes mixing is shown in graph 4(c).

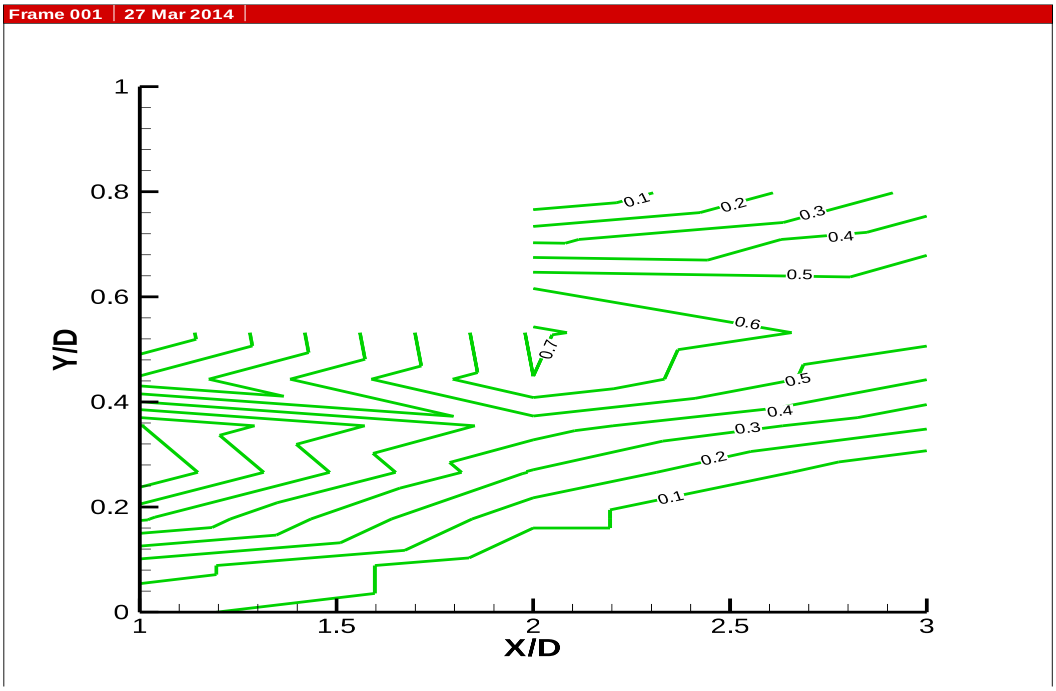
REPRESENTATION OF ISO MACH CONTOURS WITHOUT TAB



Graph:5(a) ISO MACH CONTOURS FOR MACH 0.3 JET

A comparison of the Iso-Mach contours at the same axial stations for the plain and tab controlled jets clearly illustrates the effect introduced in the flow field by the presence of tab at each operating condition. It is seen from the contour plots that the tab controlled jets grow fast in the plane normal to the tab and slowly in the plane of the tab at all the operating conditions investigated. At the exit of the nozzle, the jet lines are very nearer, when tab is not placed. As move axially through some distance, we find mixing i.e., jets lines expand. This is much more enhanced when delta tab is placed.

REPRESENTATION OF ISO MACH CONTOURS WITH TAB



Graph 5(b) ISO MACH CONTOURS FOR MACH 0.3 JET

It is seen from the contour plots that the tab controlled jets grow fast in the plane normal to the tab and slowly in the plane of the tab at all the operating conditions investigated.

Conclusion

The flow mixing characteristics of delta tab were investigated by conducting experiments using wind tunnel and jet facility. delta tab is very much effective in influencing the central line characteristics which is a direct indication of mixing and enhancement compared to the without tab case, and it makes jet to grow wider in the plane normal to it and narrow in the plane of tab. so this indicates a symmetric jet made asymmetric by the presence of tab. These features are attained only by the presence of tab because this delta tab sheds small scale vortices of different sizes which are beneficial in promoting the mixing.

REFERENCES

1. **Yoshio Yajima** 1994, ”The Effect of Stream wise Vorticity of Jet Behavior,” ASME Fluids Engineering Division Summer Meeting, Lake Tahoe, Nevada, June 19-23, Turbulence Control Session
2. **AshishVashishtha** 1995, “Use of Stream wise Vorticity to Increase Mass Entrainment in a Cylindrical Ejector,” AIAA Journal, Vol. 33, No. 9, 1641.
3. **E. Rathakrishnan** 1999, “The Effect of Mean Velocity Variations on Jet Noise,” Journal of Fluid Mechanics, 26, 186-197.
4. **R. Kalimuthu** 1987, “Vortex Induction and Mass Entrainment in a Small-Aspect-Ratio Elliptic Jet,” Journal of Fluid Mechanics, 179, 383-405.
5. **Khalid M. Sowed.**1987, “Vortex Induction and Mass Entrainment in a Small-Aspect-Ratio Elliptic Jet,” Journal of Fluid Mechanics, 179, 383-405.
6. **G. K. Suryanarayana 1991**, “Control of Jet Structures by Crown-Shaped Nozzle Attachments,” In 29th Aerospace Sciences Meeting, Reno, Nevada**.**
7. **Stephen A. Whitmore** 1992, “The Role of Stream wise Vorticity in the near-field entrainment of round jets,” Journal of Fluid Mechanics, vol. 245, 643-668.
8. **V.L. Zhdanov, H.D,** 1989, “An Experimental Study of Forced Stream wise Vertical Structures in a Plane Mixing Layer,” JIAA Stanford University.
9. **Sang Joon Lee** 1996, “Innovative Jet Flow Control: Mixing Enhancement Experiments,” AIAA Paper 96-0308.
10. **C.C.L. Yuan.et.al** 1995 “Jet Mixing Control Using Excitation from Miniature Oscillating Jets,” AIAA Journal, Vol. 33, No. 2, pp. 365-368.
11. **W.R. Quinn.et.al** 1994 “Mixing Enhancement by and Noise Characteristics of Stream wise Vortices in an Air Jet,” AIAA Journal, Vol. 32, No. 3, pp. 464-471.
12. **W.R. Quinn.et.al** 1993, “Stream wise Vorticity Generation and Mixing Enhancement in Free Jets by ‘Delta-Tabs’,” AIAA Shear Flow Conference, Paper No. 93-3253.
13. **G.JNathan.et.al** 1994, “The Effect of Enhanced Stream wise on the Mixing and Acoustic Characteristics of an Air Jet,” AIAA Journal October.
14. **K. B. M. Q. Zaman.et.al** 1994, “Control of an Axisymmetric Jet Using Vortex Generators,” Physics of Fluids, Feb., vol. 6 (2), 778-793.
15. **Anatoli Tumin.et.al ,** 1995, “Use of Stream wise Vorticity to Increase Mass Entrainment in a Cylindrical Ejector,” AIAA Journal, 33, 9, 1641