Effect of Chevron on Transonic Nozzle

[1]A. Usha Bharathi [2]B. Balamanikandan [3]J. Blessing Sam Paul [4]V. Naveen Sundar [5]J. Vikash
[1]Asst. Professor, [2] [3] [4] [5]U.G. Student,
Department of Aeronautical Engineering, Jeppiaar Engineering College,
Chennai, India.

Abstract **- Chevrons are used in jet engine nozzle to reduce the noise level at the exhaust by smooth mixing with the cooler air. Nozzle and nozzle with chevron model was designed at different penetration length as 40%, 50%, 60% of external diameter and the models are analysed by CFD. The effect of chevron in the nozzle has been analysed along the axis and across the axis of the nozzle for penetration length of 40%. From the result, it can be observed that by implement the chevron in the transonic nozzle the efficiency of the engine is not compromised.**

Keywords— Chevrons, penetration length, transonic nozzle.

I. INTRODUCTION

Nozzles are used to increase the velocity to get more thrust and also control the direction of fluid flow. In nozzle, the static energy is converted into kinetic energy because of this noise will produced. So it is necessary to reduce the noise at exhaust the nozzle. It is the one by implementing the chevron on the exit section of the nozzle for smooth mixing cold and exhaust air. First the chevron was occur in early art design on pottery and rack carving. The major fact of implementing chevron to the aircraft jet engine is to reduce aircraft noise in order to reduce impact of surrounding vicinity. The basic principle of chevron is that the hot air from the exit mixes with cooler air, the edges serve to smooth the mixing which minimize noise-creating turbulence. One of the successful implementation of chevron nozzle to the aircraft engine is Boing747-8 which is powered by GEnx-2B67which have a saw tooth pattern. Chevron penetration has a strong impact on centerline decay and noise[1]. A higher chevron count with a lower level of penetration yields the maximum noise suppression for low and medium nozzle pressure ratios. And found that chevron nozzle to be free from screech unlike regular nozzles[4]. James and Brown[1] told that chevron length was not a major impact on either flow or sound, when chevron count and penetration were kept constant. James and Brown[5] shows that the impact of chevrons on the azimuthal structure of the fluctuating axial velocity is small at cold and hot jet condition.

II. MODEL

Chevrons are used to minimize the sound at the exit of the jet engine. The chevrons are designed in the nozzle to analyse the effect of chevrons in the nozzle flow.Nozzles are created at different penetration length as 40%, 50%, 60% of external diameter of the nozzle shown below in figure 1.The nozzles tested were designed in CATIA software. Nozzles are created at constant count as six chevron for each nozzle and the penetration length will vary. The dimensions of the nozzle without chevron as shown below,

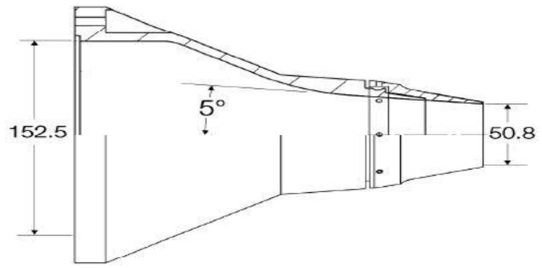
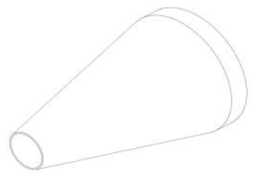


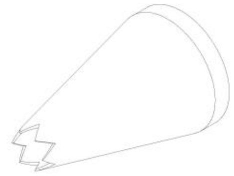
Figure 1:Overall nozzle showing mounting scheme for different chevron nozzle. Linear dimension are in mm

Nozzle ID	No. of chevrons	Length[mm]	Diameter at exit[mm]
Model 1	0	0	50.8
Model 2	6	20.32	50.8
Model 3	6	25.4	50.8
Model 4	6	30.48	50.8

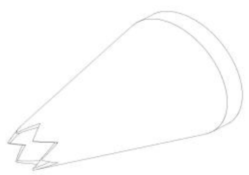
Table 1: Parameters of chevron nozzles tested



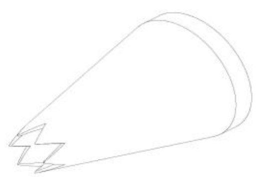
MODEL 1



MODEL 2



MODEL 3



MODEL 4

ISSN: 2278-0181
Vol. 4 Issue 04, April-2015

III. MESHING

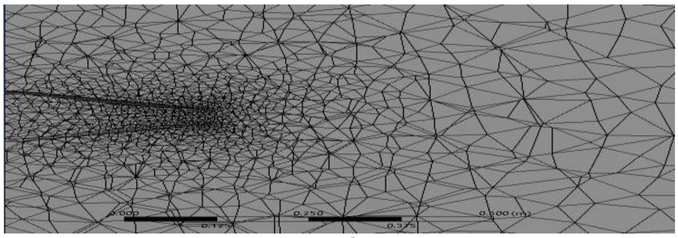
Meshing was done using ANSYS Fluent software. A circular domain has been created around the model. The length of the domain is one hundred times of external diameter of nozzle without chevron. The diameter of the domain is twenty times of external diameter of nozzle without chevron. A tetrahedral coarse mesh has been used.

Nozzle ID	No. of Nodes	No. of elements
Model 1	9965	55321
Model 2	9979	53493
Model 3	10265	55240
Model 4	9994	53670

Table 2

Analysis are done with the Density-based solver since the flow is compressible. The inlet condition are taken as pressure inlet and the outlet condition as pressure outlet. The pressure difference at the inlet condtion is taken as Mach 0.9 for nozzle without chevron and chevron nozzle at different penetration length.

The below diagram shows that the cut section view of the mesh of the nozzle without chevron and chevron nozzles



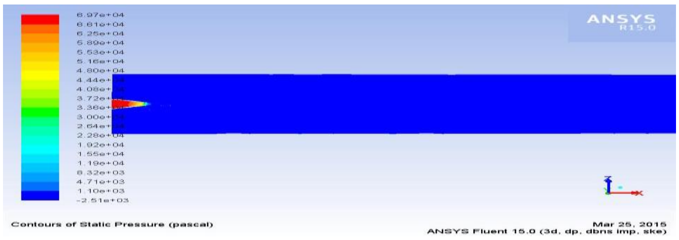
MODEL 1,2,3,4: Mesh cut section view

III. RESULTS AND DISCUSSION

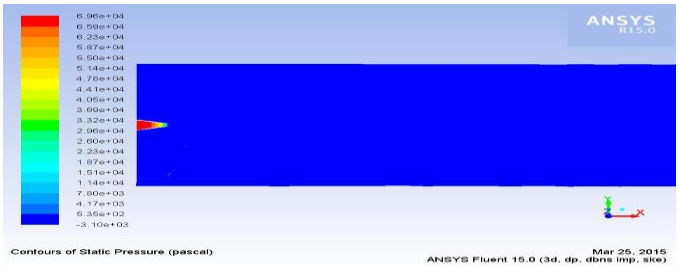
The analysis was carried out for nozzle without chevron and chevron nozzles in CFD software. And the results are taken in the form of graph and images and compare the results in the comparision graph and the conclusion were taken from the graph we shown below. Graphs are plotted in both along the axis and across the axis.

Contours of Static Pressure

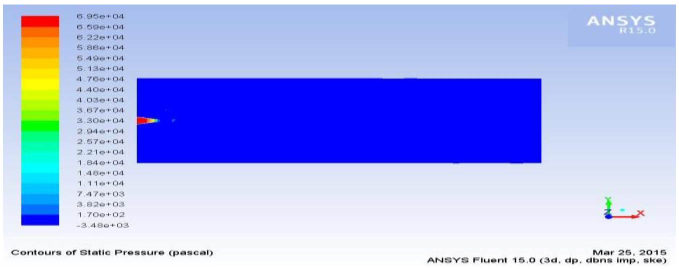
Contours of static pressure for all the four models are shown in figure. From the figure, we could see that static pressure of the flow of each model attain the optimum condition at the exit. It maximum at the entry of the nozzle and gradually decreases and attain optimum condition at the exit.



Model 1 – Baseline Round Nozzle



Model 2 – 40% penetration length of external diameter

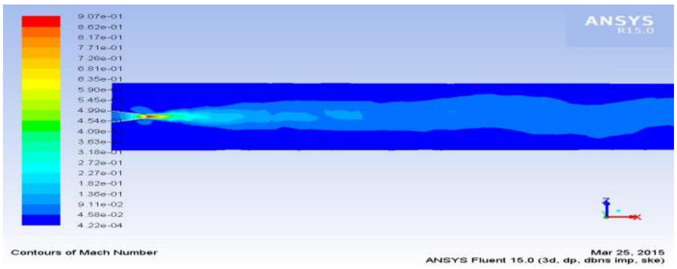


Model 3 – 50% penetration length of external diameter

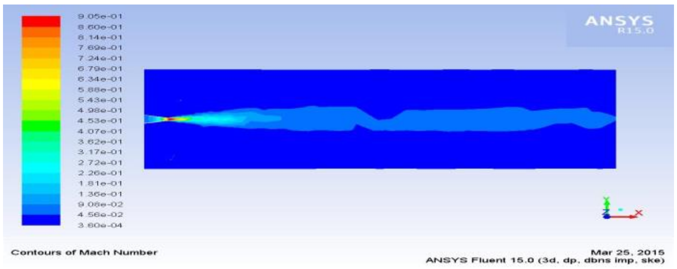
Model 4 – 60% penetration length of external diameter

Contours of Mach Number

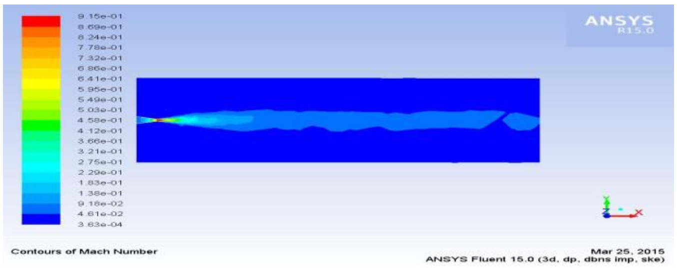
Contours of mach number for all the four models are shown in figure 16. From the figure, we could see that mach number of each model attain the 0.9 at the exit. It reaches transonic speed.



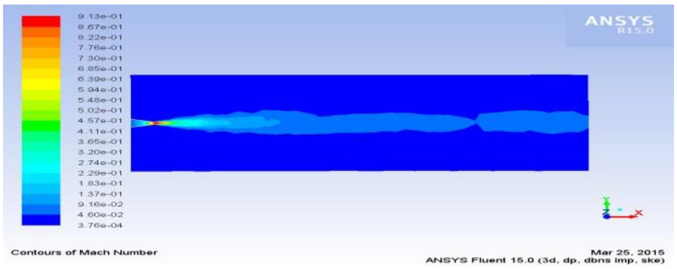
Model 1 – Baseline Round Nozzle



Model 2 – 40% penetration length of external diameter



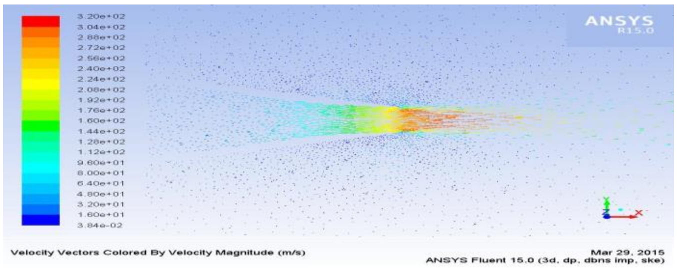
Model 3 – 50% penetration length of external diameter



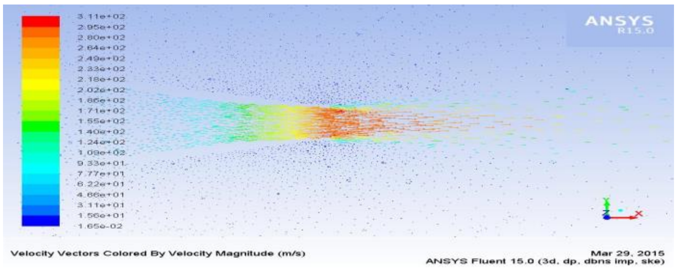
Model 4 – 60% penetration length of external diameter

Vector

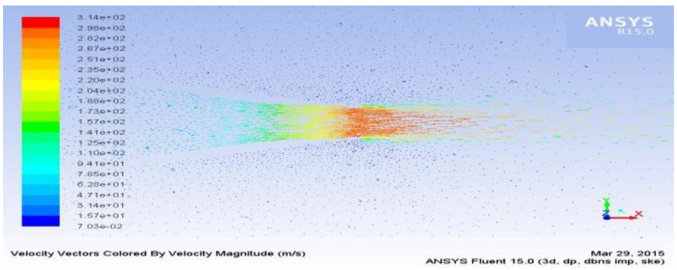
Velocity vector for all the four models are shown in figure . From this image we can observe the direction of the flow from the entry of the nozzle to the exit of the nozzle. The vector image of the baseline round nozzle and different penetration length chevron nozzle as shown below,



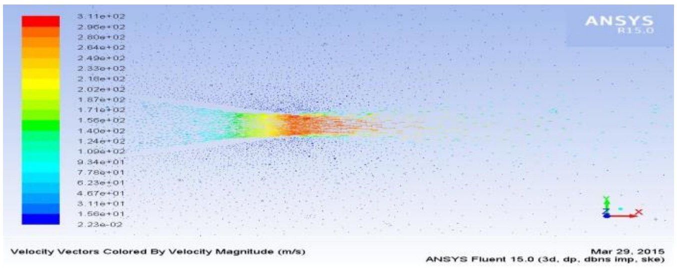
Model 1 – Baseline Round Nozzle



Model 2 – 40% penetration length of external diameter



Model 3 – 50% penetration length of external diameter



Model 4 – 60% penetration length of external diameter

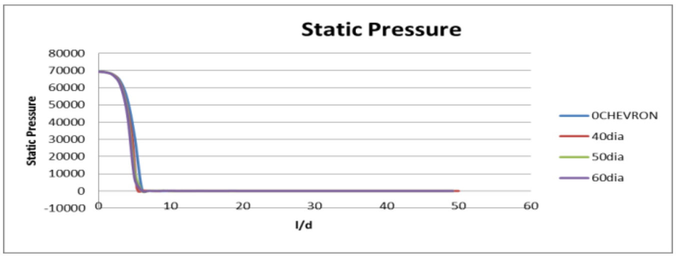
Graph

For getting the better and accurate result, we draw the rake along the axis and across the axis, and compare the results taken from the graph and also we draw several rake at different points across the axis and make the comparision over the nozzles. We take the results of static pressure, velocity,
Mach number and density and compare for the baseline round nozzle and different penetration chevron nozzles.

Along the axis:

Static pressure

Here we show the static pressure along the axis, the comparision for baseline round nozzle and different penetration length chevron nozzle are shown,

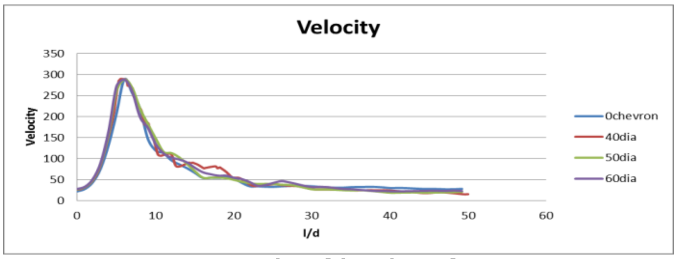


Static Pressure[along the axis]

Here the static pressure for the baseline round nozzle and the different penetration chevron nozzle follow the same pattern. So the chevron has not have any affect on static pressure of the flow through the nozzle.

Velocity

Here we show the velocity along the axis, the comparision for baseline round nozzle and different penetration length chevron nozzle are shown,

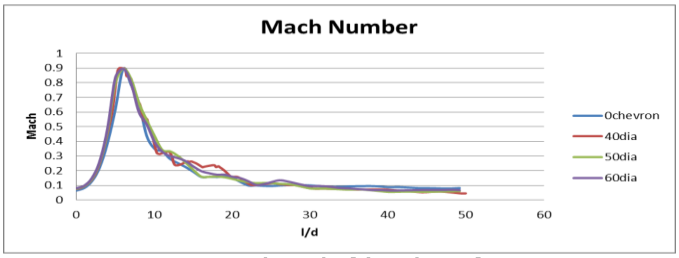


Velocity[along the axis]

Here the baseline round nozzle and the chevron nozzle follow the nearly the same velocity pattern. All the nozzles attains nearly 290m/s. From this result, you can clearly tell that the chevron nozzle does not affect the velocity of the flow.

Mach number

Here we show the mach number along the axis, the comparision for baseline round nozzle and different penetration length chevron nozzle are shown,

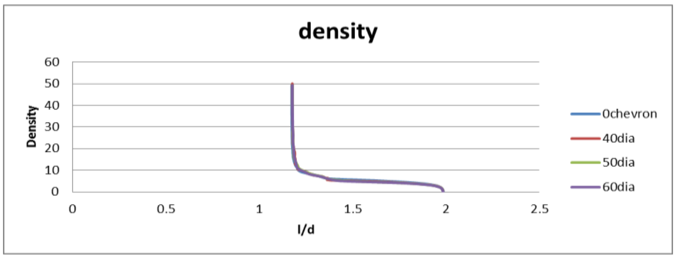


Mach Number[along the axis]

Here the baseline round nozzle and the chevron nozzle follow the nearly the same mach number pattern. All the nozzles attains nearly reaches the mach number of 0.9. From this result, you can clearly tell that the chevron nozzle does not affect the mach number of the flow.

Density

Here we show the density along the axis, the comparision for baseline round nozzle and different penetration length chevron nozzle are shown,

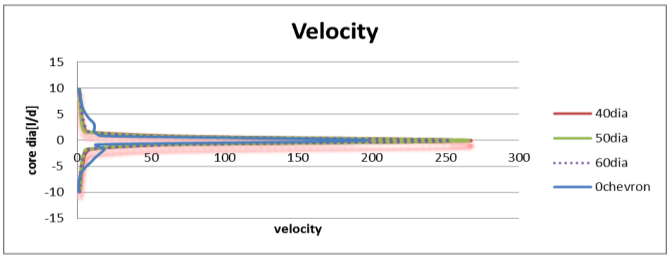


Density[along the axis]

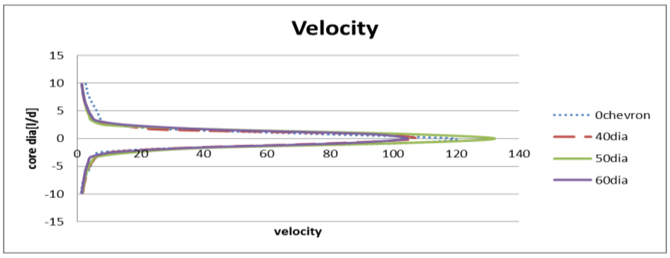
Here the baseline round nozzle and the chevron nozzle follow the nearly the same density pattern. From this result, you can clearly tell that the chevron nozzle does not affect the density of the flow.

Velocity

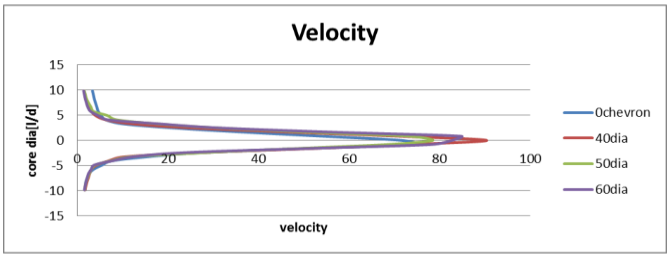
The comparision graph across the axis at different distance are shown,



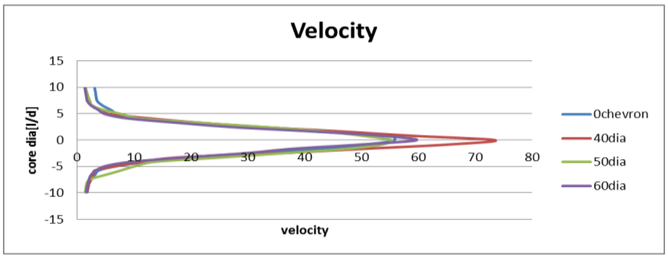
VELOCITY ACROSS 0.35m



VELOCITY ACROSS 0.55m



VELOCITY ACROSS 0.75m

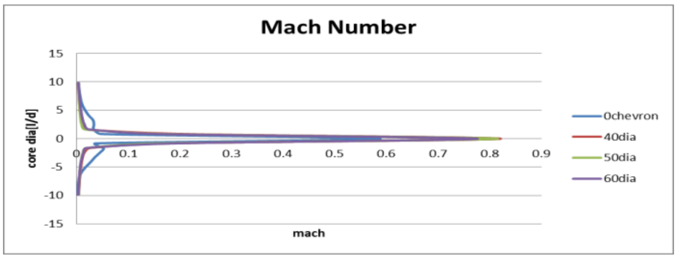


VELOCITY ACROSS 0.95m

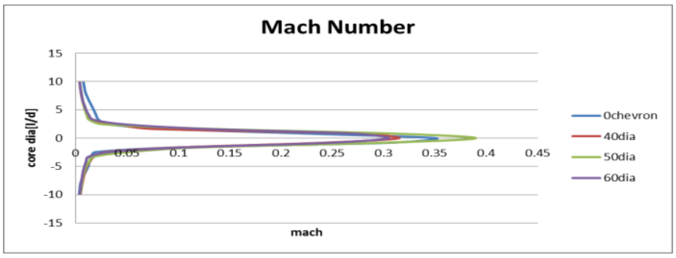
From this result, the velocity at different penetration length chevron nozzle has approximately the same value. Eventhough there is a small difference in the magnitude, the chevron has no affect on the flow.

Mach number

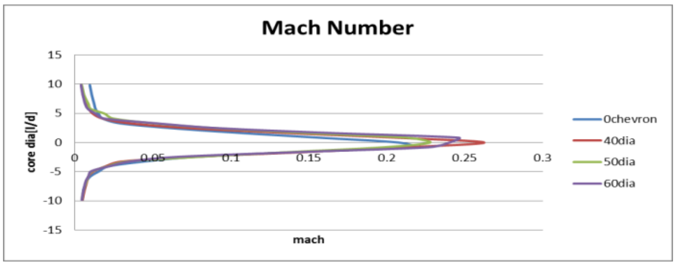
The comparision graph across the axis at different distance are shown,



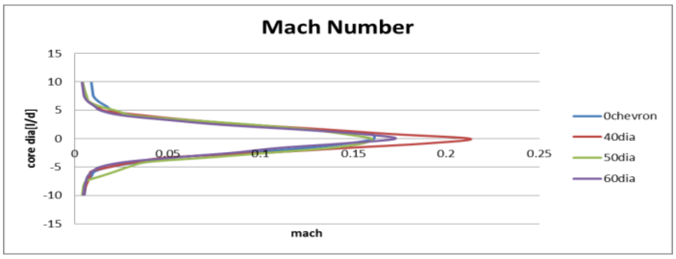
MACH NUMBER ACROSS 0.35m



MACH NUMBER ACROSS 0.55m



MACH NUMBER ACROSS 0.75m

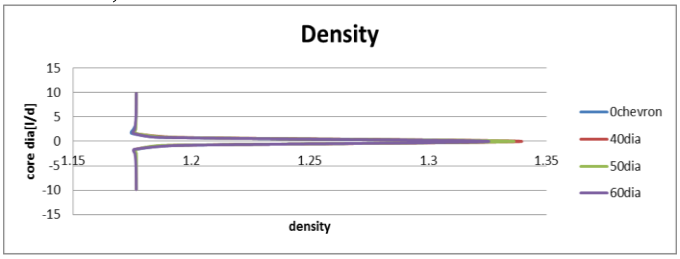


MACH NUMBER ACROSS 0.95m

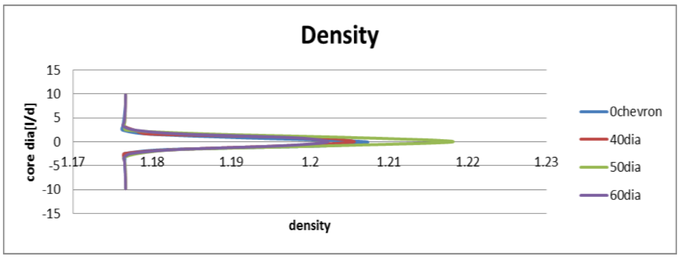
From this result, the mach number at each different has approximately the same value. Eventhough there is a small difference in the magnitude, the chevron has no affect on the flow.

Density

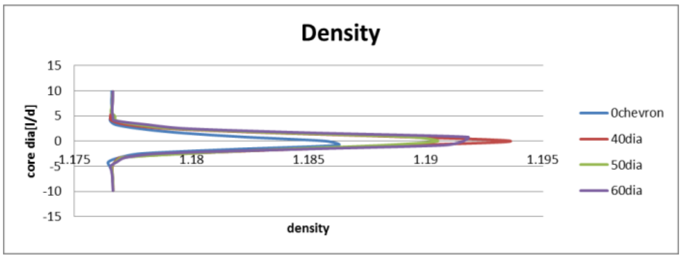
The comparision graph across the axis at different distance are shown,



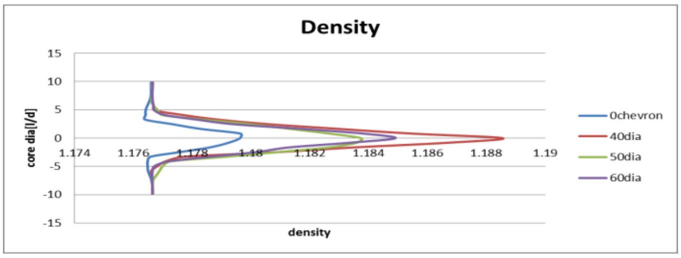
DENSITY ACROSS 0.35m



DENSITY ACROSS 0.55m



DENSITY ACROSS 0.75m



DENSITY ACROSS 0.95m

From this result, the density at each different has approximately the same value. Eventhough there is a small difference in the magnitude, the chevron has no affect on the flow.

IV. CONCLUSION

Chevrons are used to reduce the noise level at the engine exit. In this research, the implementing of chevron does not make any effect on the convergent nozzle. From the result, the static pressure of chevron nozzle attain the optimum condition like the baseline round nozzle. So the chevron nozzle does not affect the flow. The mach number of the chevron nozzle attains the same mach number of baseline round nozzle as 0.9. The velocity of the chevron nozzle follow the same pattern as the baseline round nozzle. So the chevron does not have any effect on the flow.

V. REFERENCE

1. James Bridges and Clifford A. Brown " Parametric Testing of Chevrons on Single Flow Hot Jets"
2. James Bridges and Clifford A. Brown "Acoustic Efficiency of Azimuthal Modes in Jet Noise Using Chevron Nozzles"
3. Vance Dippold III "CFD Analyses and Jet-Noise Predictions of Chevron Nozzles With Vortex Stabilization"
4. Steven J. Massey, Alaa A. Elmiligui, Craig A. Hunter, Russell H. Thomas, S. Paul Pao and Vinod G. Mengle "Computational Analysis of a Chevron Nozzle Uniquely Tailored for Propulsion Airframe Aeroacoustics"
5. P.S.Tide and K.Srinivasan " Effect of Chevron Count and Penetration on the Acoustic Characteristics of Chevron Nozzles"
6. Vinod G. Mengle, Robert W. Stoker, Leon Brusniak, Ronen Elkoby and Russell H. Thomas "Flaperon Modification Effect on Jet-Flap Interaction Noise Reduction for Chevron Nozzles"
7. James Bridges, Mark P. Wernet and Franco C. Frate"PIV Measurements of Chevrons on F400-Series Tactical Aircraft Nozzle Model"
8. N.Kathikeyan , B.T.N.Sridhar "Studies on effect of jet shapes in the coaxial supersonic jet spreading rates"
8. Seung-Cheol Baek, Soon-Bum Kwon, Byeong-Eun Lee, "An Experimental Study of Supersonic Dual Coaxial Free Jet" KSME International Journal, Vol. 17 No. 12, pp. 2107~2115, 2003.
9. J. Philip Drummond, "Enhancement of Mixing and Reaction in High-Speed Combustor Flow fields", International Colloquium on Advanced and Analysis of Combustion, 1997, Moscow, RUSSIA.
10. Nicholas J. Georgiadis and Dimitri Papamoschou, "Computational Aeroacoustis Conference and Exhibit, 12-14 May 2003, Hilton Head, South Carolina.
11. Nevin Celik, Daniel W. Bettenhausen and Ryan D.Lovik, "Formation of Co-Axial Jets and Their Downstream Development".
12. Vinod G. Mengle, Ronen Elkoby, Leon Brusniak and Russell H. Thomas "Reducing Propulsion Airframe Aeroacoustic Interactions with Uniquely Tailored Chevrons: 2. Installed Nozzles"
13. Michael J. Doty, Brenda S. Henderson and Kevin W. Kinzie "Turbulent Flow Field Measurements of Separate Flow Round and Chevron Nozzles with Pylon Interaction Using Particle Image Velocimetry"