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# Design and analysis of nozzle for reducing noise pollution

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***Abstract:***
***Background**: In aircraft applications, engine and nozzle are the two main components which produce high level of noise. The engine noise is predominantly occurred due to piston and otheractuation of subcomponents. Whereas the noise due to nozzle is occurred by mingling of air streams at various temperature and speed.*
***Methods**: In this project study, chevron nozzle is studied which is used in aircraft application. And also, theoretical analysis is performed to obtain effective design parameters of chevron nozzle. Hence, Various design of chevron nozzle is modelled by SOLIDWORKS software. The end shape of nozzle is changed such that saw tooth triangular shape is modified by various dimensions and shape. Then, the designed various nozzle is analyzed by ANSYS FLUENT software. In this project, Acoustic power and velocity of those models are calculated and compared for getting efficient model.*
***Results**: Chevron V-v with 30 deg inclination model produces minimum acoustic power and maximum velocity. Acoustic power of V-v with 30 deg inclination angle produce 141dB acoustic power and 762 m/s velocity.*

***Key Word**: Chevron nozzle; CFD analysis; Aircraft engine; Acoustic power.*

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## I. Introduction

In recent times, researchers have been working mainly with the aim to minimize the noise pollution in the Air craft systems [1]. The air craft engine and nozzle are two systems causes to large amount of noise pollution. To minimize the noise in the nozzle, the chevron nozzle is commercialized which has saw tooth pattern at its end edge [2]. The triangular shaped cut outs along the trailing edge of nozzle leads to reduce the jet plume length. Whereas chevron improves mixing at the required level and reduces the noise of jet. Jet noise continues to be the dominant noise component, especially during take-off. A great deal of effort has been dedicated to the development of practical passive flow control techniques for jet noise reduction. Thrust penalties associated with these designs must be minimized, before they can be used in commercial aircraft engines. Acoustic studies reveal that addition of chevrons to the nozzle reduces the sound pressure level reasonably with acceptable reduction in performance. The understanding of the fundamental mechanisms responsible for the acoustic benefit and the influence of various geometric parameters of chevrons are not clear. Parameters such as, the number of chevron lobes,the lobe length and the level of penetration of the chevrons into the flow have been investigated over a variety of flow conditions. Although experiments are necessary and provide useful data for validating the computations, they are expensive and can supply relatively limited amount of information. Hence it is desirable to have reliable CFD capabilities to quickly evaluate preliminary designs for noise reduction.Callendar et al [3] explored overall sound pressure level of nozzle by varying an angle of chevron blade and measured effective frequency. The researcher also performed analysis by varying number of lobes and levels of penetration to provide insight into the effects of geometric parameters on the acoustic noise [4]. Bridges J et al [5] developed relationships between chevron geometric parameters, flow characteristics, and far-field noise. Both cold and hot conditions have been run at acoustic mach number 0.9. Four comparative studies have done and identified that chevron length is not influencing parameter on either flow or sound. Kochet al [6] predicted mean flow and acoustic measurements by changing pattern on the core nozzle. Engblom et al [7] presented numerical predictions for single-stream chevron nozzle flow performance and far field noise production are presented. This methodology is applied to a set of sensitivity cases involving varying degrees of chevron inward bend angle relative to the core flow, for both cold and hot exhaust conditions. Pierre et al [8] achieved jet noise reduction levels at high power setting conditions. Calkins [9] designed and tested a full-scale variable geometry chevron for the fan-nozzle exhaust whose shape change is driven by a shape memory alloy actuator.

In this project work, it is proposed to evaluate the performance of different profiles of chevron nozzle. Different chevron nozzle design is modeled in using SOLIDWORKS software and analyzed in ANSYS CFD to evaluate acoustic performance. The flow parameters such as pressure, acoustic power, velocity is evaluated to find the most efficient shape of chevron.

## II. CAD Modelling

**Geometric Details:**

In this study, Chevron lobe profile are varied to study their effect on the overall sound pressure levels. In general, chevron penetration can be defined as the difference to the tip radii of the chevron, is kept zero for allnozzle profiles for the present study. The various chevron nozzle selected for the analysis are mentioned below:

a) A baseline round nozzle without chevrons
b) Half circle shape nozzle
c) Chevron –Triangular shape nozzle
d) Chevron –Triangular with bend angle
e) Chevron V-w shape nozzle
f) Chevron –V-v shape nozzle
g) 30 deg inclination W shape (smooth inner side)

**CAD Model:**

The parametersuch as chevron count, chevron length (mm), bent angle (deg) and exit diameter (mm) are changed for various chevron profile which are illustrated in Table 1. Also, CAD models of different chevron profile are shown in Fig. 1-7.

**Table 1.** Geometric details of the nozzle

| S. No | Nozzle | Chevron count | Chevron length (mm) | Bent angle (deg) | Exit diameter (mm) |
|---|---|---|---|---|---|
| 1 | Base line | 0 | - | - | 50 |
| 2 | Chevron-Triangular | 6 | 20 | 10 | 50 |
| 3 | Chevron V-w | 4-4 | 20-5 | - | 50 |
| 4 | Chevron–Triangular | 6 | 20 | - | 50 |
| 5 | Chevron –V-v | 10-10 | 15-7 | - | 50 |
| 6 | W shape (smooth inner side) | 6 | 20 | - | 50 |
| 7 | Half circle | 12 | 5 | - | 50 |

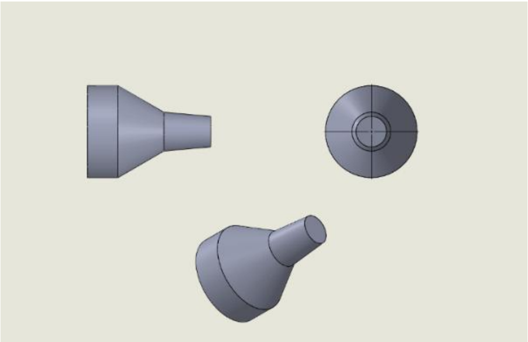

**Fig. 1.** Model of baseline nozzle

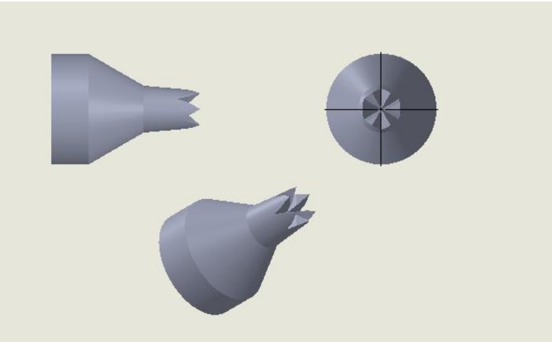

**Fig. 2.** Model of triangular with bend angle shape gap nozzle

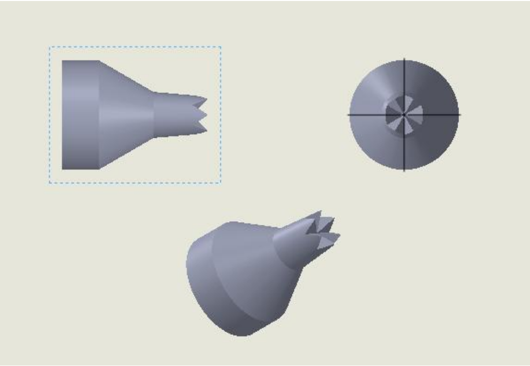

**Fig. 3.** Model of triangular without bend angle shape gap nozzle

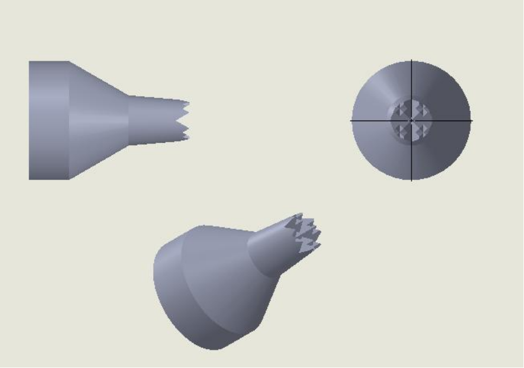

**Fig. 4.** Model of Chevron V-w shape inclined cut nozzle

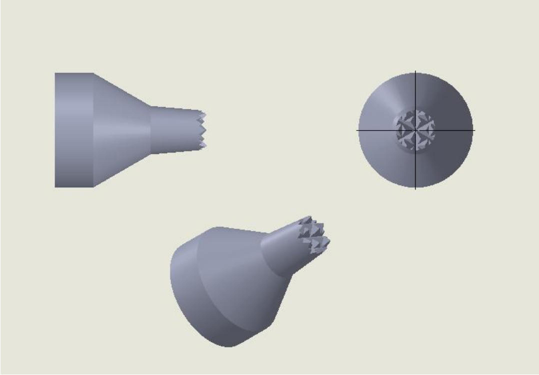

**Fig. 5.**Model of Chevron V-v shape gap nozzle nozzle

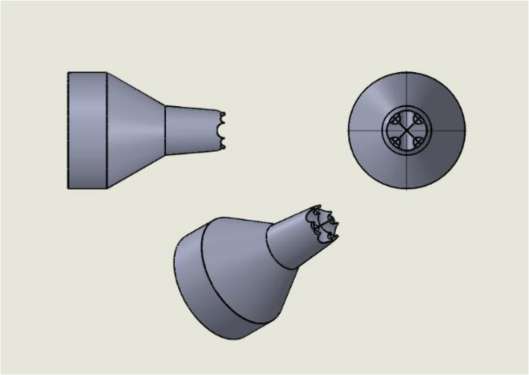

**Fig. 6.**Model of Chevron W smooth inner shape gap

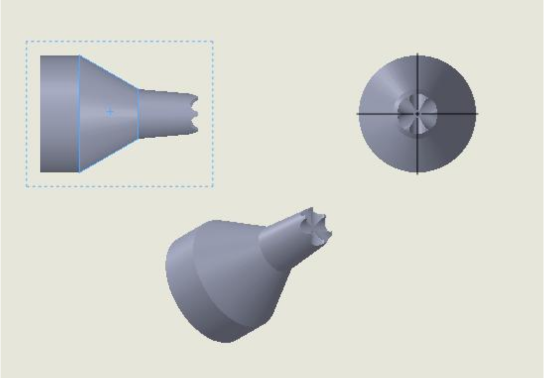

**Fig. 7.** Model of half circles shape gap nozzle

## III. CFD Analysis

In this study, CFD analysis is performed to evaluate the acoustic power and velocity profile of the various chevron nozzle designs to find the effective design parameters. Simulations have been performed for jets, with stagnation temperature of 300K. The inlet pressure is considered as 1555000Paand outlet pressure is 24500 Pa.

## IV. Results and discussion

The baseline nozzle model and the chevron nozzle models designed by SOLIDWORKS. And analyzed virtually by ANSYS CFD. In ANSYS CFD software, as convergence is an iterative process, successive Iterations are performed by the CFD solver to obtain the acoustic power, velocity distribution. The result of the CFD solver namely the acoustic power and velocity distribution has been taken from the CFD-post (result) in the CFD tool. The procedure is repeated for the successive six models for further simulation.

### Baseline nozzle model

The result of the CFD solver namely the acoustic power and velocity distribution of the baseline nozzle model are shown in the Fig 8 and 9. It is seen that acoustic power is more concentrated at the trailing edge of chevron nozzle and is about 142 dB. The velocity profile clearly shows that there is uniform distribution of velocity at the trailing edge with the amount of 480 m/s.

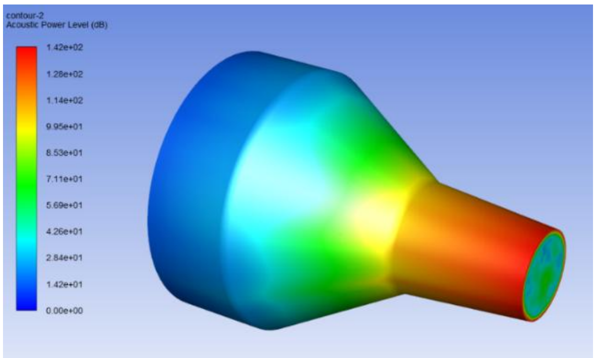

**Fig. 8.** Acoustic power of the baseline design model

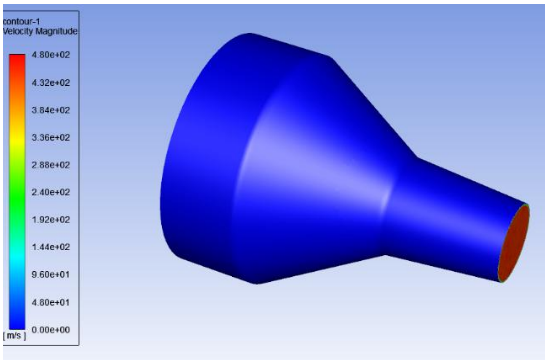

**Fig. 9.**Velocity of the baseline design model

### Chevron triangular with bend angle shape gap nozzle model

The result of the CFD solver namely the acoustic power and velocity distribution of the Chevron Triangular with bend angle shape gap nozzle model are shown in the Fig. 10 and 11. The acoustic power increased to 152 dB for this profile. Also, velocity distribution is non uniform and increased to 797 m/s.

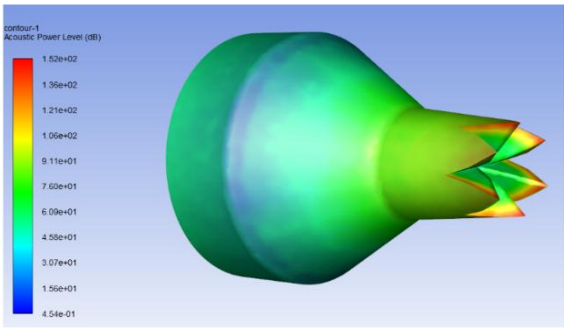

**Fig. 10.** Acoustic power of the Chevron Triangular with bend angle shape gap model

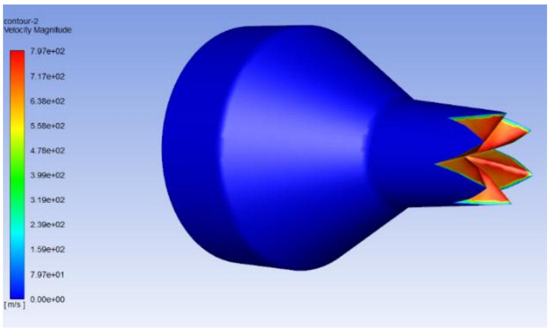

**Fig. 11.** Velocity of the Chevron Triangular with bend angle shape gap model

### Chevron triangular shape without bend angle gap nozzle model

The result of the CFD solver namely the acoustic power and velocity distribution of the Chevron Triangular with bend angle shape gap nozzle model are shown in the Fig.12 and 13. In this model, the acoustic power and velocity are considerably reduced to 145 dB and 711 m/s respectively.

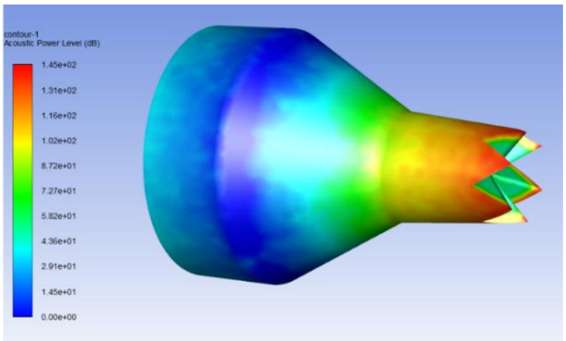

**Fig. 12.** Acoustic power of the Chevron Triangular shape without bend angle gap model

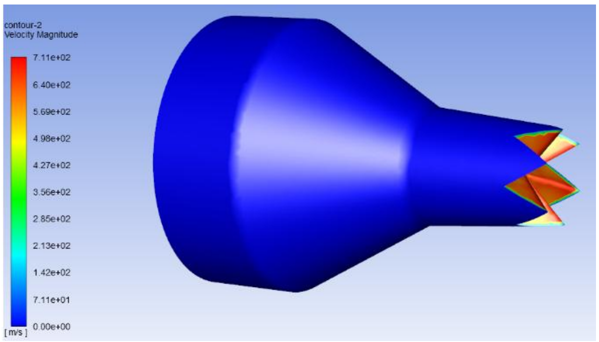

**Fig. 13.** Velocity of the Chevron Triangular without bend angle shape gap model

### Chevron v-w shape gap nozzle model

The result of the CFD solver namely the acoustic power and velocity distribution of the Chevron V-w shape gap nozzle model are shown in the Fig.13 and 14. The contour plots clearly indicate that there is decrement in the acoustic power and velocity compared to previous models.

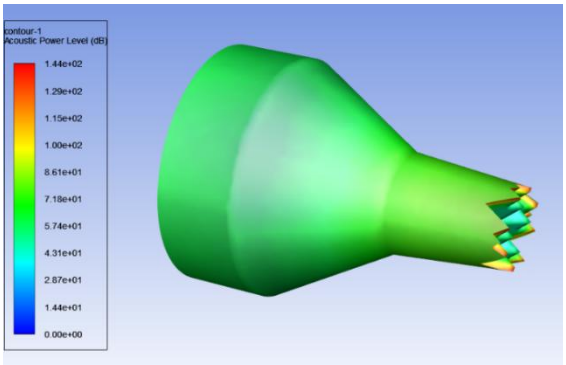

**Fig. 13.** Acoustic power of the Chevron v-w shape gap model

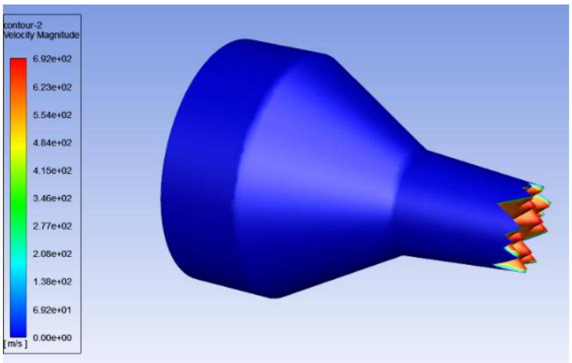

**Fig. 14.** Velocity of the Chevron v-w shape gap model

### Chevron w smooth inner shape cut model

The result of the CFD solver namely the acoustic power and velocity distribution of the Chevron w smooth inner shape gap nozzle model are shown in the Fig. 15 and 16. The concentration of velocity at the trailing edge is less and is about 691 m/s.

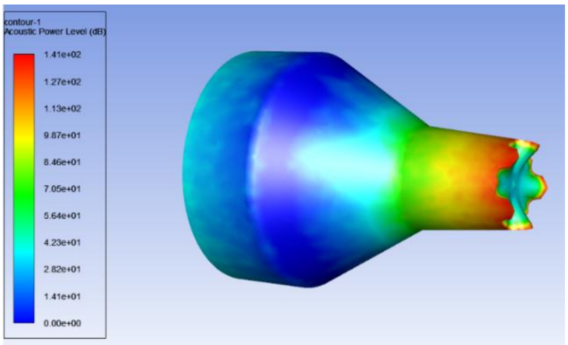

**Fig. 15.** Acoustic power of the Chevron w smooth inner shape cut model

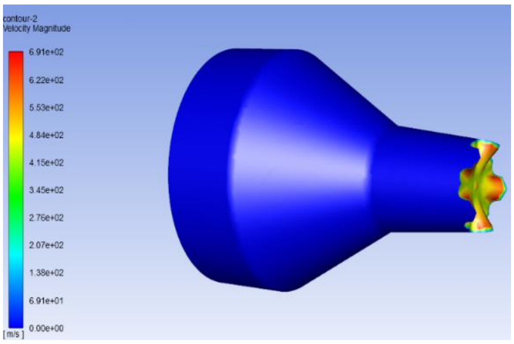

**Fig. 16.** Velocity of the Chevron w smooth inner shape cut model

### Chevron half circle shape cut model

The result of the CFD solver namely the acoustic power and velocity distribution of the Chevron half circle shape gap nozzle model are shown in the Fig. 17 and 18. The maximum velocity of 795 m/s can be seen at the trailing edge. However, the acoustic power is moderately less.

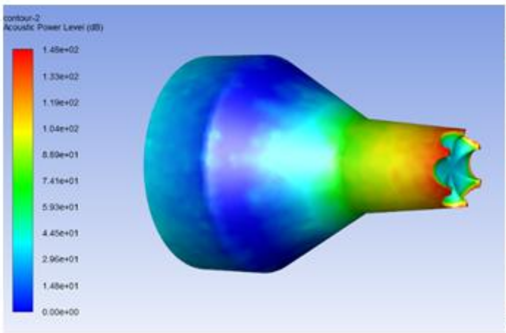

**Fig. 17.** Acoustic power of the Chevron Half circle shape cut model

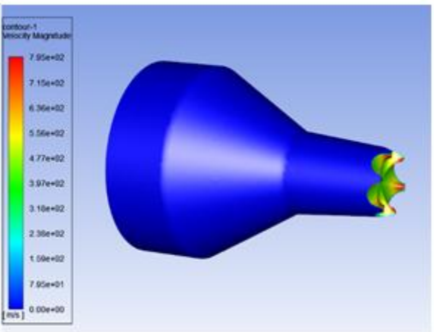

**Fig. 18.** Velocity of the Chevron Half circle shape cut model

**Chevron V-v shape inclined cutmodel**

The result of the CFD solver namely the acoustic power and velocity distribution of the chevron V-v shape inclined cut model are shown in the Fig. 18 and 19. The contour plots depict the maximum velocity and minimum acoustic power compared to other nozzle profiles.

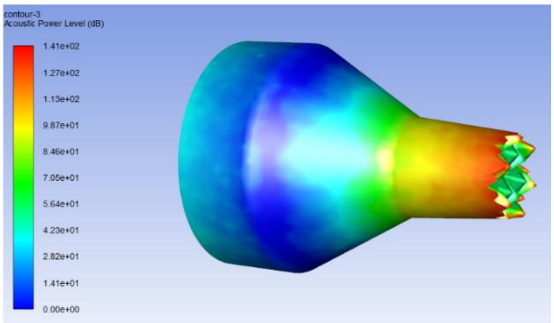

**Fig. 19.** Acoustic power of the Chevron V-w inclined shape cut model

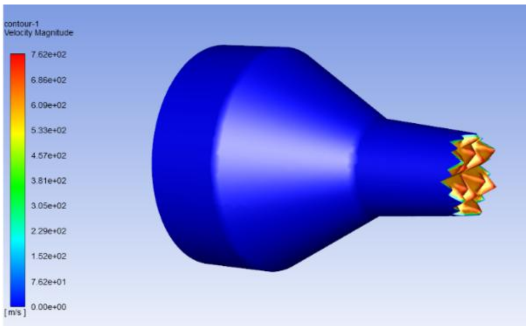

**Fig. 20.** Velocity of the Chevron V-w inclined shape cut model

Fig. 21 and 22 shows the acoustic power and velocity of chevron nozzle models. The major deviation in the acoustic power can be seen when the chevron nozzle profile is modified. Chevron-triangular profile exhibits high acoustic power which is not advisable. Rather than the chevron V-v model experiences less amount of acoustic power and also displays maximum velocity at the trailing edge compared to other chevron nozzle profile.

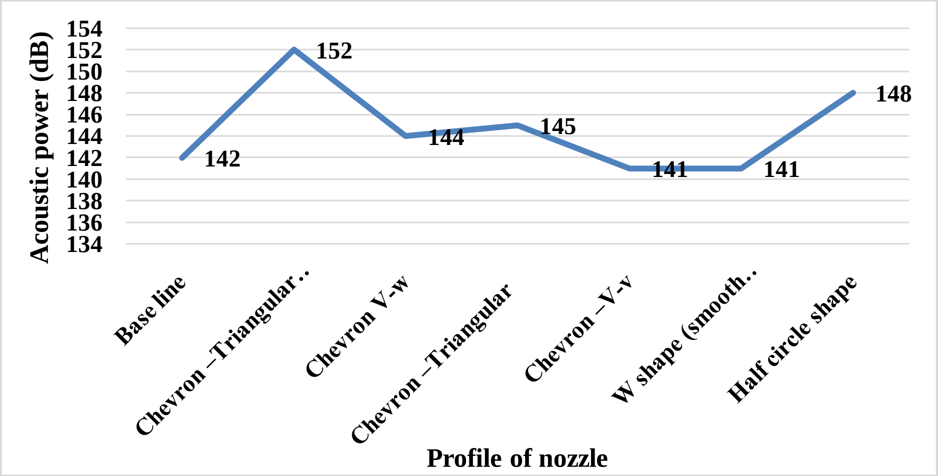

**Fig. 21.** Acoustic power for chevron models (dB)

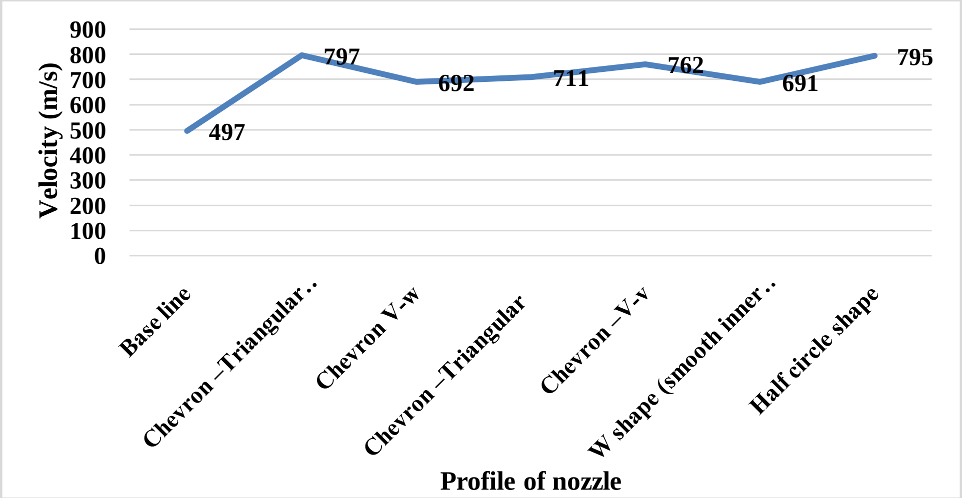

**Fig. 22.**Velocity for chevron models(m/s)

## V. Conclusion

In this project work, different chevron nozzle designs have been considered to identify the effective performance of chevron nozzle. Hence, theoretical analysis is performed to evaluate the acoustic performance and velocity at the trailing edge of chevron nozzle using ANSYS CFD. The results suggested that chevron-V-v nozzle profile experiences very low acoustic power of 142 dB and very high velocity of 762 m/s at the trailing edge. From the theoretical fluid analysis, it is recommended that chevron-V-v nozzlewith 30 deg inclination angle can be used in the aircraft engine as it provides effective performance.

## References

[1]. Callender, B., Gutmark, E., and Martens, S., "A Far-Field Investigation into Chevron Nozzle Mechanisms and Trends," AIAA Paper 2003–1058, 2003.

[2]. Mabe, J.H., Cabell, R.H., and Butler, G.W., "Design and Control of a Morphing Chevron for Takeoff and Cruise Noise Reduction," AIAA Paper 2005–2889, 2005.

[3]. Callender, B., Gutmark, E., and Martens, S., "A PIV Flow Field Investigation of Chevron Nozzle Mechanisms," AIAA Paper 2004–191, 2004.

[4]. Callender, B., Gutmark, E., and Martens, S., "A Near-Field Investigation into Chevron Nozzle Mechanisms," AIAA Paper 2003–3210, 2003.

[5]. Bridges, J. and Brown, C.A., "Parametric Testing of Chevrons on Single-flow Hot Jets," AIAA Paper 2004–2824, 2004.

[6]. Koch, L. D., Bridges, J., and Khavaran, A., "Mean Flow and Noise Prediction for a Separate Flow Jet with Chevron Mixers," AIAA Paper 2004–189, 2004

[7]. Engblom, W., Khavaran, A., and Bridges, J., "Numerical Prediction of Chevron Nozzle Noise Reduction using WIND-MGBK Methodology," AIAA Paper 2004–2979, 2004.

[8]. Loheac, P., Julliard, J., and Dravet, A., "CFM56 Noise Reduction with the Chevron Nozzle," AIAA Paper 2004–3044, 2004.

[9]. Calkins, F.T. and Butler, G.W., "Subsonic Jet Noise Reduction Variable Geometry Chevron," AIAA Paper 2004–190, 2004.

[10]. Henderson, B.S., Kinzie, K.W., Whitmere, J., and Abeysinghe, A., "The Impact of Fluidic Chevrons on Jet Noise," AIAA Paper 2005–2888, 2005.

[11]. Henderson, B.S., Kinzie, K. W., Whitmere, J., and Abeysinghe, A., "Aeroacoustic Improvements to Fluidic Chevron Nozzles," AIAA Paper 2006–2706, 2006.

[12]. Harrison, S.A., Gutmark, E.J., and Martens, S., "Jet Noise Reduction by Fluidic Injection on a Separate Flow Exhaust System," AIAA Paper 2006–2547, 2006.

[13]. GRIDGEN Version 13, User Manual, Pointwise, Inc., Bedford, Texas, 1998.

[14]. Bush, R., Power, G., and Towne, C., "WIND: The Production Flow Solver of the NPARC Alliance," AIAA Paper 98–0935, 1998.

[15]. Nelson, C.C. and Power, G.D., "CHSSI Project CFD-7: The NPARC Alliance Flow Simulation System," AIAA Paper 2001–0594, 2001.

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