Analysis of Different types of Supersonic Diffuser Profile

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Abstract: In this framework of world, our necessity is to evolve more optimize design and more precise in which there is less energy consumption and less energy loss. Energy is basic need of daily life as it is well known energy can't be created only can be transformed to another form with great efficiency so main objective of this Work is to find optimum geometry of thermal device which transforms energy from one form to another. The main aim of this project is to compare the supersonic diffuser profile by design the diffuser of type of Constant rate of Pressure change and Constant rate of Momentum change by using design analysis found in the literature and compare the result in the last to show the best efficient profile for the supersonic diffuse. All graphs are studied individually and in the last part of Work and thus optimum profile is chosen by studying the generated result. It is expected that this paper described within will be useful for those wishing to model or design diffuser different profiles and contributes to the further understanding of related investigations

Keywords: *Diffuser, Momentum, Pressure, Velocity, MATLAB.*

1. **Introduction**

A diffuser is a device which decrease the flow velocity by increasing the cross sectional area. Diffuser is a pipe or we can say that tube of varying cross sectional area which are used for direct or modify the flow of a fluid. Diffuser also used for to control of the flow rate, speed, direction, mass, shape, and the steam pressure that emerges from them [5].

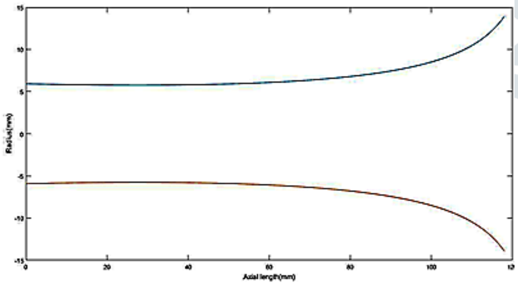

Fig.1: Profile of Simple Diffuser.

Mathematical modeling will be done and comparison of designed diffuser profile will be done, which is produced by the under the flowing method.

(i) Constant Velocity change (dv/dx)

(ii) Constant Pressure change (dp/dx)

(iii) Constant rate of momentum change [d(mv)/dx]

dv = Change in volume

dx = Change in the length of diffuser

dp = Change in pressure

d(mv) = Change in momentum

By performing mathematical modeling and by MATLAB coding we will generate the diffuser profile. By using M.Abdulhadi's [1] equation for supersonic diffuser and after generating equation in mathematical form and the result of these mathematical equation used in the MATLAB for generating the profile of CPC, CRMC and CVC after it will be compared by the profiles generated by considering skin friction coefficient and based on results the optimize profile will be chosen.

2. Mathematical Relations

During this work calculation will be done mainly for the area variation, pressure variation, temperature variation and variation of Mach number. In this Work all the relation in differential form will be developed so that profile of geometry can be analyzed step by step and by proceeding in same way all data set like pressure, temperature, area and Mach number at each differential part will be generated and finally by using MATLAB an excel sheet for data set will be generated, where all properties changes will be found for profile of diffuser [2].

Assumptions:-

a) Fluid flow is isentropic

b) Flow is steady.

c) Air as a fluid. (γ=1.4)

d) Flow is one Dimensional.

After calculation the following differential set of equation generated:

(i) Constant pressure change with respect to axial length:

$$\frac{dP}{dx} \Rightarrow \lambda \qquad (1)$$

$$\frac{dA}{A} = \left[\frac{dP}{P} * \left(\frac{1 - M^2}{\gamma M^2}\right) + 2(1 - M^2)\frac{fdx}{D_h}\right] \qquad (2)$$

$$\frac{dV}{V} \Rightarrow \left(\frac{1}{M^2 - 1}\right)\frac{dA}{A} \qquad (3)$$

$$\frac{dT}{T} \Rightarrow -(\gamma - 1)\frac{M^2 dV}{V} \qquad (4)$$

$$\frac{dM}{M} = (1 + 0.2M^2)\frac{dV}{V} \qquad (5)$$

(ii) Constant velocity change with respect to axial length:

$$\frac{dV}{dx} = \lambda \qquad (1)$$

$$\frac{dA}{A} \Rightarrow 2.8M^2\frac{fdx}{D_h} - (1 - M^2)\frac{\lambda.dx}{V} \qquad (2)$$

$$\frac{dp}{p} = -\{1 + (\gamma - 1)M^2\}\frac{\lambda dx}{V} - \frac{dA}{A} \qquad (3)$$

$$\frac{dT}{T} \Rightarrow -\frac{0.4M^2}{1 + \frac{(\gamma - 1)}{2}M^2}\frac{dM}{M} \qquad (4)$$

$$\frac{dM}{M} = \frac{1 + \frac{\gamma - 1}{2}M^2}{(M^2 - 1)}\frac{dA}{A} - \frac{\left(1 + \frac{\gamma - 1}{2}M^2\right)2.8M^2}{(M^2 - 1)}\frac{fdx}{D_h} \qquad (5)$$

(iii) Constant rate of momentum change with respect to axial length:

$$\frac{d(\dot{m}V)}{dx} = \lambda \qquad (1)$$

$$\frac{dV}{V} = \frac{1}{M^2 - 1}\left(\frac{dA}{A}\right) \qquad (2)$$

$$\frac{dA}{A} = \left[2.8\, M^2\frac{fdx}{Dh} - \{1 - M^2\}\left(\lambda.\frac{dx}{\dot{m}}.V\right)\right] \qquad (3)$$

$$\frac{dp}{p} = -\{1 + (\gamma - 1)M^2\}\frac{\lambda dx}{\dot{m}V} - \frac{dA}{A} \qquad (4)$$

$$\frac{dM}{M} = \frac{\left(1 + \frac{\gamma - 1}{2}M^2\right)}{(M^2 - 1)}\frac{dA}{A} - \frac{\left(1 + \frac{\gamma - 1}{2}M^2\right)}{(M^2 - 1)}2.8M^2\frac{fdx}{Dh} \qquad (5)$$

3. Result & Discussion

After develop differential set of equations by help of MATLAB profile of diffuser, temperature, pressure, velocity and Mach no. will be developed and will be compared to find best geometrical profile with minimum losses.

Case 1:

Constant pressure change with respect to axial length:

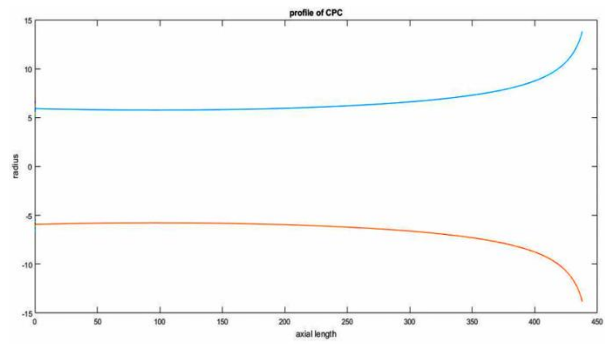

Fig.2: Constant pressure change diffuser profile

This is the profile generated by the MATLAB according to given input set of equations. By the profile it is clear that the length of diffuser is 438mm.

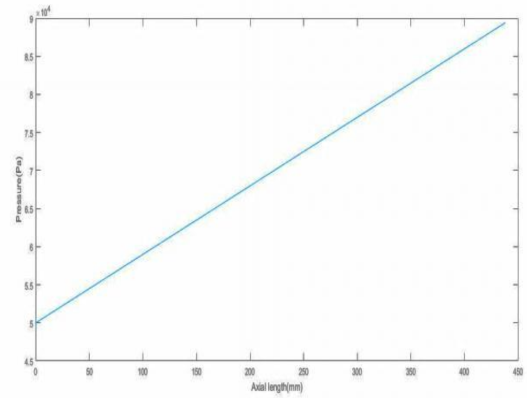

Fig.3: Static Pressure Variation

The rise in the pressure is the common feature of the diffuser and in the isentropic diffusion there is the continuous rise in the static pressure which is shown by the above graph.

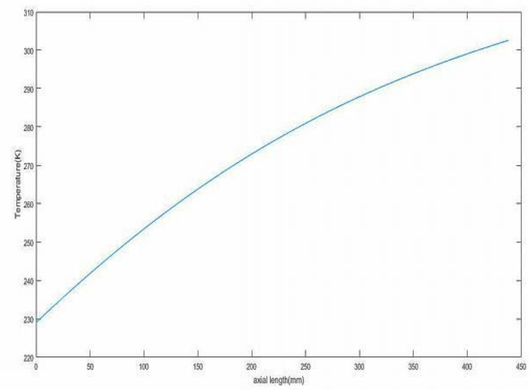

Fig.4: Static Temperature Variation

The graph shows the temperature variation along axial length of diffuser. The initial temp is about 230 K and at the exit of diffuser the temperature is 302 K.

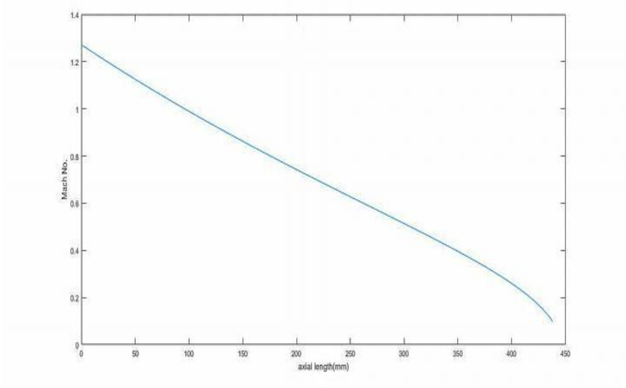

Fig 5: Mach No. Variation

This graph shows the variation of Mach no. along length of diffuser, in diffuser Mach no. at inlet is 1.28 and fluid expands till its value becomes 0.1.

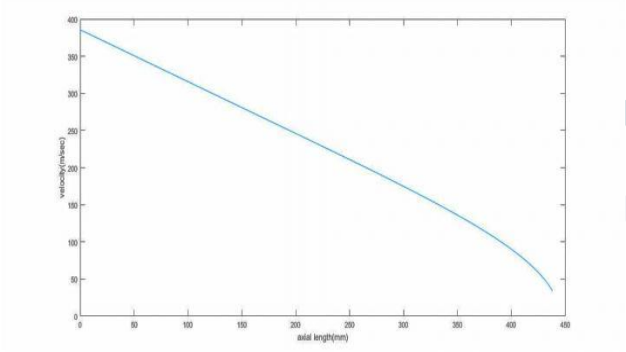

Fig 6: Velocity variation

The velocity in diffuser will decrease because of increase in pressure energy of fluid, the initial velocity of fluid at entrance of diffuser is 385(m/s) whereas at exit of diffuser the velocity of fluid is 34 (m/s).

Case 2:

Constant velocity change with respect to axial length:

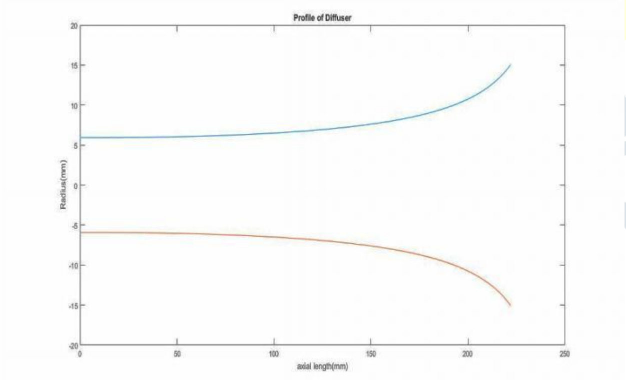

Fig. 7: Constant velocity change with friction profile

Above profile shows Supersonic diffuser profile assuming constant velocity initially radius of profile is of conversing type and after a minimum section i.e. Throat Radius is of diverging type of following theoretical concept of Supersonic diffuser profile.

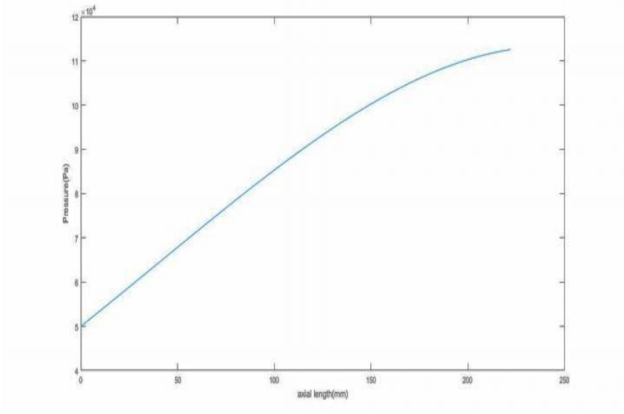

Fig.8: Static Pressure variation

Pressure variation with friction at the inlet pressure is near about 5.9 Pa and at the outlet the pressure is 15 Pa. As we know that Pressure is increase in the diffuser which is shown by the above graph.

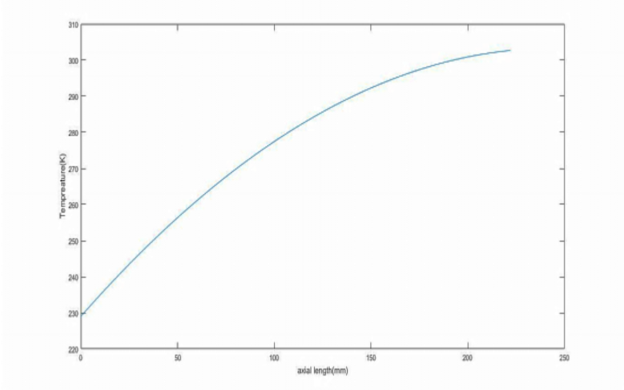

Fig.9: Static Temperature variation

as the pressure increase, Temperature also increase as it follow the ideal gas equation in above figure at the inlet of the diffuser the temperature of gas is 229 k and at the out let of the diffuser it is 302 k

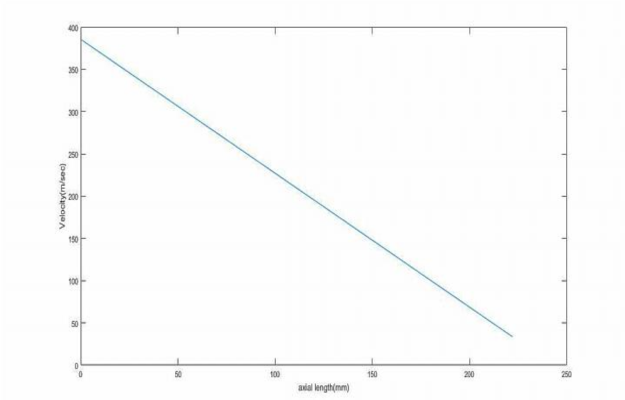

Fig 10: Velocity variation

Velocity variation is almost linear with respect to the axial length of the diffuser considering the friction because our formulation is based on constant velocity change with axial length of diffuser.

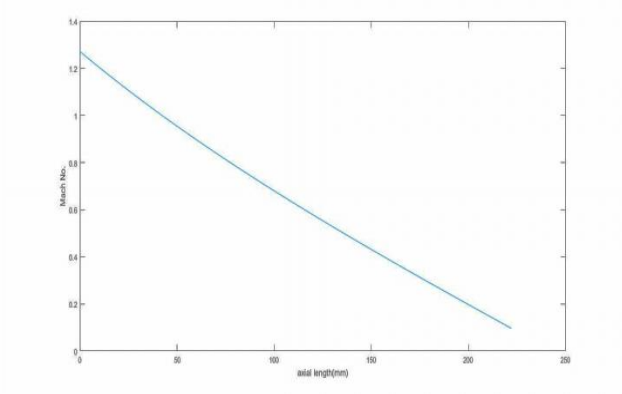

Fig.11: Mach No variation

As shown in above graph change in Mach number considering the friction at the inlet of diffuser the value of Mach number is 1.2 and at the outlet it is .09.

Case 3:

Constant rate of momentum change with respect to axial length:

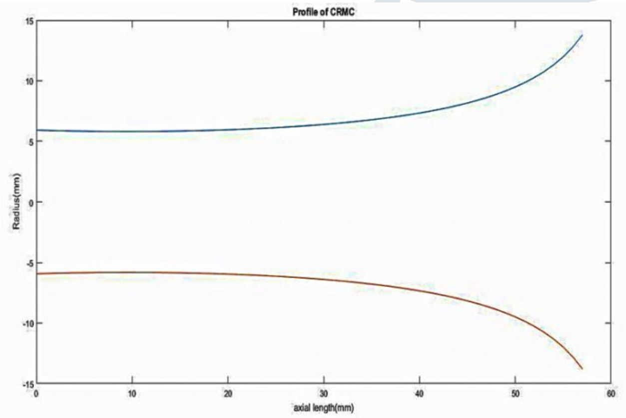

Fig.12: Constant rate of momentum change profile

Above figure shows the profile of CRMC considering friction here as we show in this graph radius of profile is of converging type and after a minimum section (throat) radius is of diverging type by following theoretical concept of Supersonic diffuser profile.

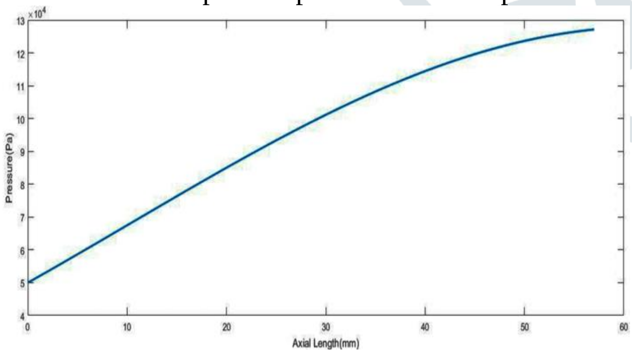

Fig.13: Static Pressure variation

The inlet of diffuse pressure is 1.3 Pa and the outlet it is near about 3.2Pa. As the velocity is slow down which results in the increase in pressure which is shown by the above graph.

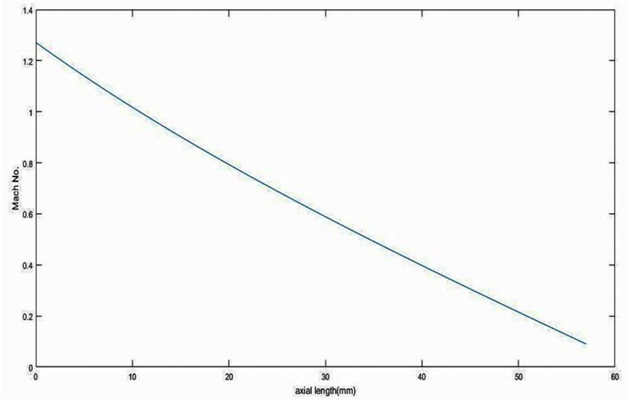

Fig.14: Mach number variation

Graph shows the change in Mach number as the velocity decrease and pressure increase so Mach number decrease at the inlet of the diffuser the Mach number value is 1.27 and at the outlet the value of Mach no. is .09.

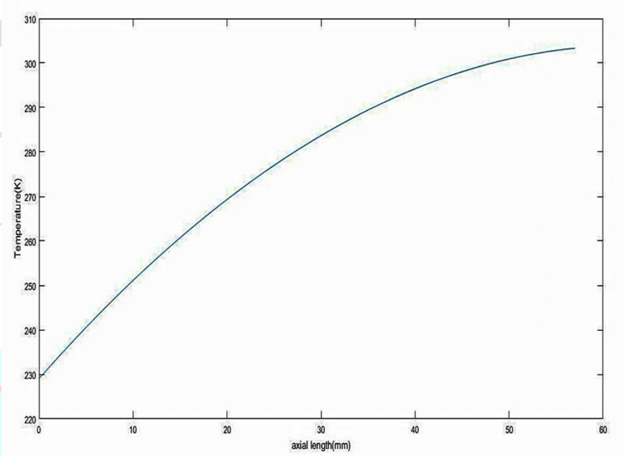

Fig.15: Temperature variation

As cross sectional area of supersonic diffuser changes due to that temperature increase and at the inlet the value of temperature is 229k and at the outlet value is 303k.

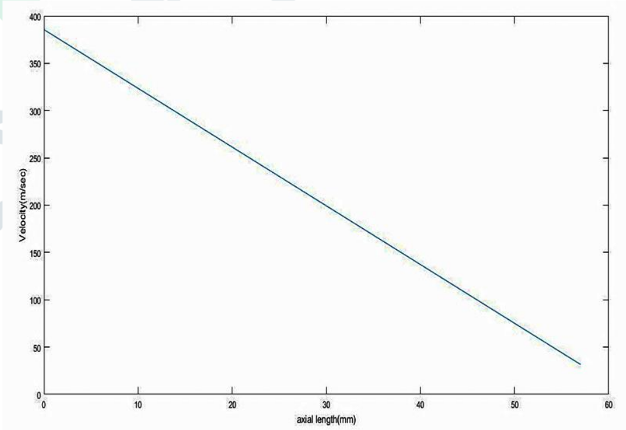

Fig.14: Velocity variation

The change in velocity flow velocity decrease by increase of cross section area which result in decrease in velocity at the inlet the velocity is 385 m/s and the outlet the value of velocity is 31 m/s.

4. Conclusion

Constant pressure change diffuser profile is worst design diffuser in practical situation as seen by the table and graph that this profile has maximum geometry dimensions which is not practically possible.

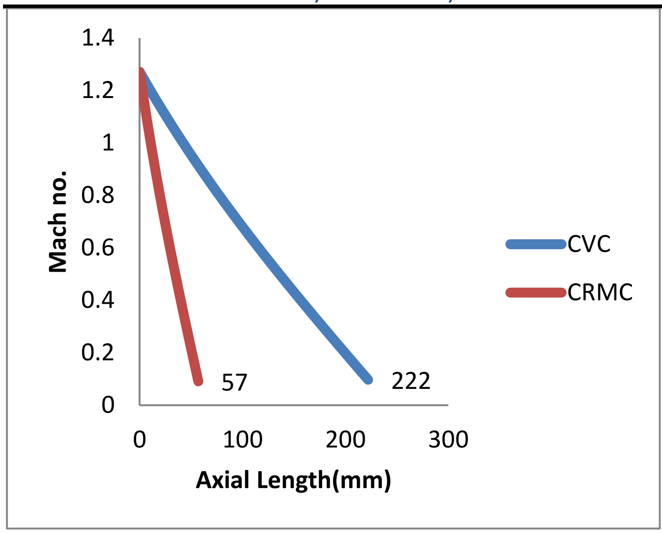

Fig.15: Comparison of Mach number between CVC profile and CRMC profile

As it is clear constant pressure change profile is not acceptable from design point of view. Now two profiles are being considered either CVC or CRMC profile. In both we get our desired Mach number but main difference here is axial length of both diffusers. For the desired Mach number the length of constant velocity diffuser is 222 mm and by the calculation performed of CRMC diffuser the length is 57 mm. So on the basis of this we conclude that material saving, economic point of view and operation point of view the CRMC is the best option. We know that more the length more the complexity in the flow more losses and more friction that way we choose always optimum profile which is obtain in the CRMC diffuser. So considering the length and Mach No. at the outlet CRMC give us better result than CVC in small length than CVC ,our optimum profile is CRMC.

5. References

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