CFD ANALYSIS OF CARBURETOR FOR DIFFERENT POSITIONS OF AERODYNAMIC SHAPE THROTTLE VALVE AND FUEL NOZZLE ANGLE

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ABSTRACT

Carburetor plays an important role in SI engine performance which supplies combustible fuel-air mixture by mixing the right amount of fuel with air before admission to the cylinder at different speed and loads. One of the important factors that affect the fuel consumption is the design of the carburetor. The carburetor provides required pressure drop with the venturi shape of the carburetor throat. Currently, alternative fuels like LPG, CNG, etc. are gaining attention all over the world because of their eco-friendly nature. So the design of the carburetor is important. Literature shows that to get a better economy and uniform distribution of fuel air mixture, it is required to design the carburetor with an effective analytical tool or software. Main objective of this work is to find pressure drop and velocity profile for different aerodynamic shape throttle valve angle and at best fuel discharge nozzle angle with help of CFD (Ansys) analysis on a carburetor and analyze for optimum design of a carburetor.

Keywords: *Carburetor Design, CFD, Fuel Air Mixture, Fuel Nozzle Angle, SI Engine, Throttle Valve*

1. INRODUCTION

The process of forming a combustible fuel-air mixture by mixing the right amount of fuel with air before admission to the cylinder of the engine is called carburetion and the device doing this job is called carburetor. All carburetors work on the Bernoulli's Principle which states that the velocity of a fluid increases, when the pressure drops. Within a certain range of velocity and pressure, the velocity increases with drop in pressure. However, this linear relationship only holds within a certain range. Carburetor has to accelerate from rest, to some speed. It depends upon the air flow demanded by the engine speed and the throttle butterfly valve setting. According to Bernoulli theorem, air flowing through the throat of the carburetor will be at a pressure less than atmospheric pressure, and related to the velocity. This pressure drop is mainly achieved by giving venturi section in carburetor throat. There has been plenty of research done on analysis of different positions of throttle valve and fuel discharge nozzle angles of simple carburetor. There has been also more work carried out of air intake pressure and fluid flow analysis through carburetor body to improve function and design of carburetor. Less work has been found in literature regarding the application of aerodynamic shape throttle valve in the simple carburetor of Spark Ignition engine and its effects i.e. pressure changes and velocity of intake air and fuel mixture in throttle body of carburetor using CFD analysis. Which is mainly done in this research work.

1.1 CFD Methodology Used

CFD may be used to determine the performance of a component at the design stage, or it can be used to analyses difficulties with an existing component and lead to its improved design. For example, the pressure drop through a component may be considered excessive: The first step is to identify the region of interest: The geometry of the region of interest is then defined. If the geometry already exists in CAD, it can be imported directly. The mesh is then created. After importing the mesh into the pre-processor, other elements of the simulation including the boundary conditions (inlets, outlets, etc.) and fluid properties are defined. The flow solver is run to produce a file of results which contain the variation of velocity, pressure and any other variables throughout the region of interest. The results can be visualized and can provide the engineer an understanding of the behaviour of the fluid throughout the region of interest. This can lead to design modifications which can be tested by changing the geometry of the CFD model and seeing the effect.

2. TOOL USED TO INCREASE PERFOMANCE OF CARBURATOR

2.1 The NACA Four Digit Airfoil Series

The first family of airfoils designed using this approach became known as the NACA Four-Digit Series. The first digit specifies the maximum camber (m) in percentage of the chord (airfoil length), the second indicates the position of the maximum camber (p) in tenths of chord, and the last two numbers provide the maximum thickness (t) of the airfoil in percentage of chord. For example, the NACA 2415 airfoil has a maximum thickness of 15% with a camber of 2% located 40% back from the airfoil leading edge (or 0.4c). Utilizing these m, p, and t values, we can compute the coordinates for an entire airfoil using the following relationships:

1. Pick values of x from 0 to the maximum chord c.
2. Compute the mean camber line coordinates by plugging the values of m and p into the following equations for each of the x coordinates.

$$y_c = \frac{m}{p^2}\left(2px - x^2\right) \qquad \text{from } x = 0 \text{ to } x = p$$

$$y_c = \frac{m}{(1-p)^2}\left[(1-2p) + 2px - x^2\right] \qquad \text{from } x = p \text{ to } x = c$$

Where,
x = coordinates along the length of the airfoil, from 0 to c (which stands for chord, or length)
y = coordinates above and below the line extending along the length of the airfoil, these are either y_t for thickness coordinates or y_c for camber coordinates
t = maximum airfoil thickness in tenths of chord (i.e. a 15% thick airfoil would be 0.15)
m = maximum camber in tenths of the chord
p =position of the maximum camber along the chord in tenths of chord.

3. Calculate the thickness distribution above (+) and below (-) the mean line by plugging the value of t into the following equation for each of the x coordinates.

$$\pm y_t = \frac{t}{0.2}\left(0.2969\sqrt{x} - 0.1260x - 0.3516x^2 + 0.2843x^3 - 0.1015x^4\right)$$

4. Determine the final coordinates for the airfoil upper surface (X_U, Y_U) and lower surface (X_L, Y_L) using the following relationships.

$$x_U = x - y_t \sin\theta$$
$$y_U = y_c + y_t \cos\theta$$
$$x_L = x + y_t \sin\theta$$
$$y_L = y_c - y_t \cos\theta$$
$$\text{where } \theta = \arctan\left(\frac{dy_c}{dx}\right)$$

Following aerodynamic shape throttle valve is generated in ANSYS R18.0 for the close position using NACA airfoil with help of above equations and we have considered 5% thickness of airfoil.

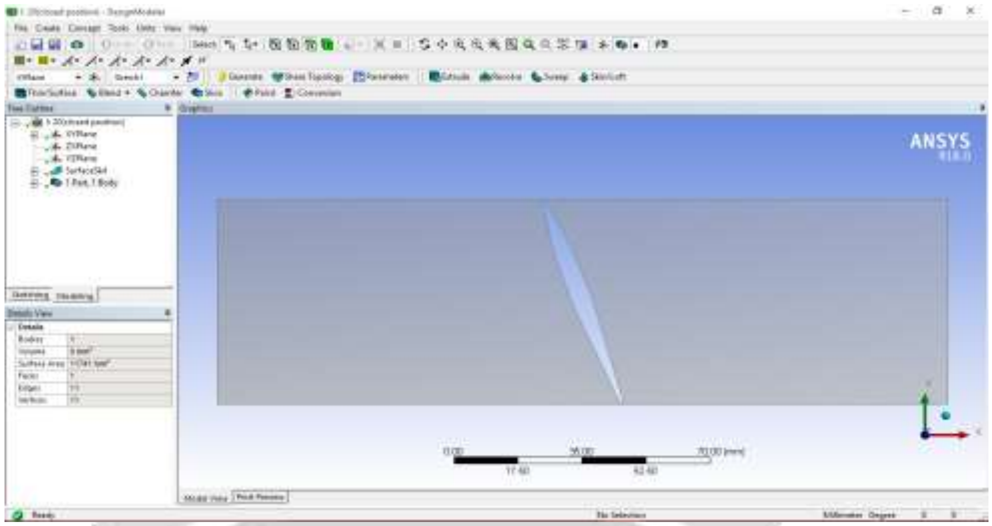


Fig 1 Close condition of aerodynamic shape of throttle valve

2.1.2 Meshing of Carbrator parts

The geometry and the mesh of a carburator domain is generated using Ansys Workbench. An unstructured mesh with tetrahedral cells is used for the zones of Throttle plate as shown in Fig. a total of 11972 elements are generated for the carburator throttle plate. Mesh statistics are presented in Table.

Table 1 Mesh statistics are presented

No. of Nodes	36610
No. of Elements	11972
Type of Element	Tetrahedral

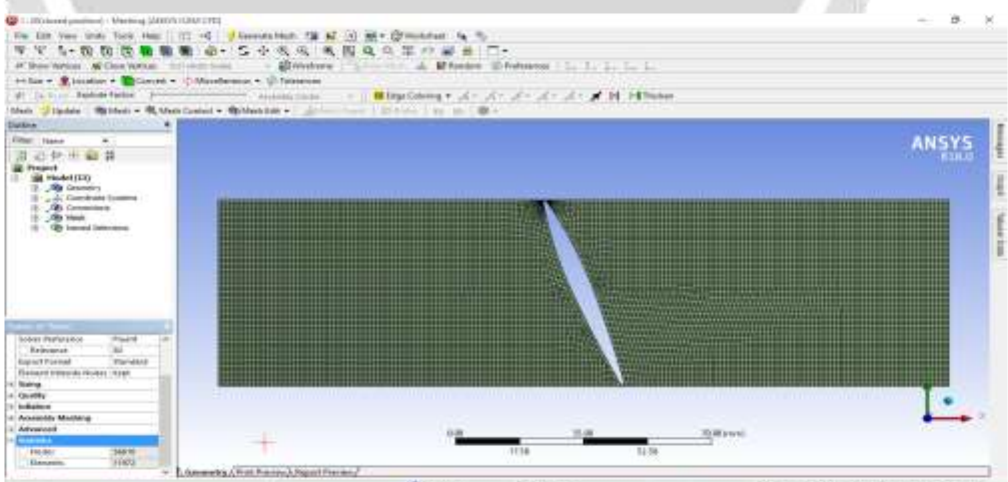


Fig 2 Part mashing in Close condition

3. RESULTS AND DISCUSSION

The inlet air was assumed to enter the carburetor at normal temperature and the pressure was taken to be 1 atm. The following are results of the analysis of the carburetor for different angles of the throttle plate.
Fig. 3, 5, 7, 9, 11, 13 indicates the pressure at the throat of the venturi when the throttle valve is 25º, 30º, 50º, 60º, 80º and 90º respectively. It is seen from Fig. 11 shows that the pressure at the throat section has decreased gradually with the increase in the throttle valve angle. It is minimum (3.867 X 10^2 Mpa) at 80º and maximum (7.718 X 10^2 Mpa) at 30º throttle valve position. As shown in fig 4, 6, 8, 10, 12, 14 with the increase in the throttle valve angle from 25º to 90º, the air velocity has increased, consequently the pressure at the throat section has decreased. This has a greater effect on the mixture strength. With the increase in pressure drop at the throat section, amount fuel entering into the throat section increases and makes the mixture progressively uniform.

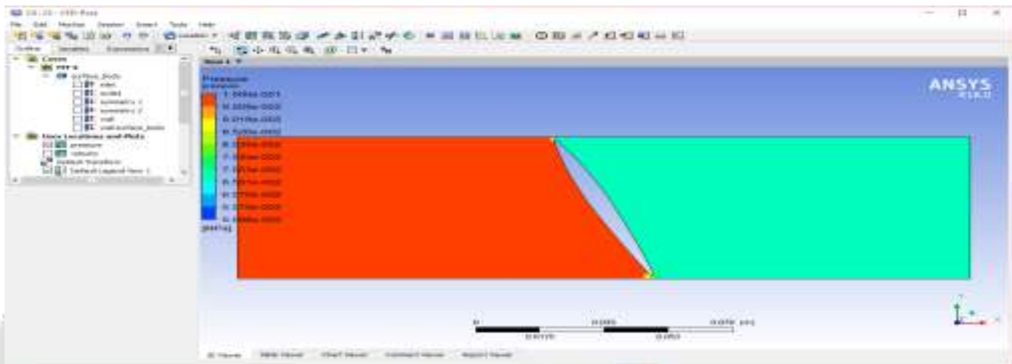


Fig. 3 Pressure Distribution in throttle angel 25°

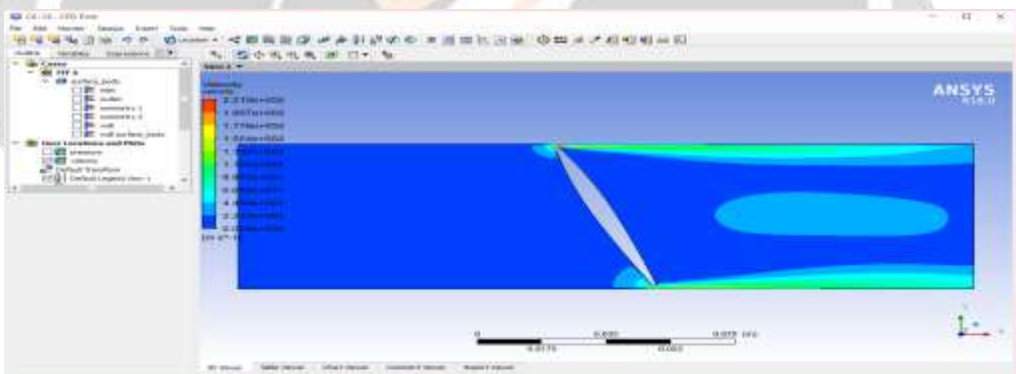


Fig 4 Velocity Distribution in throttle angel 25°

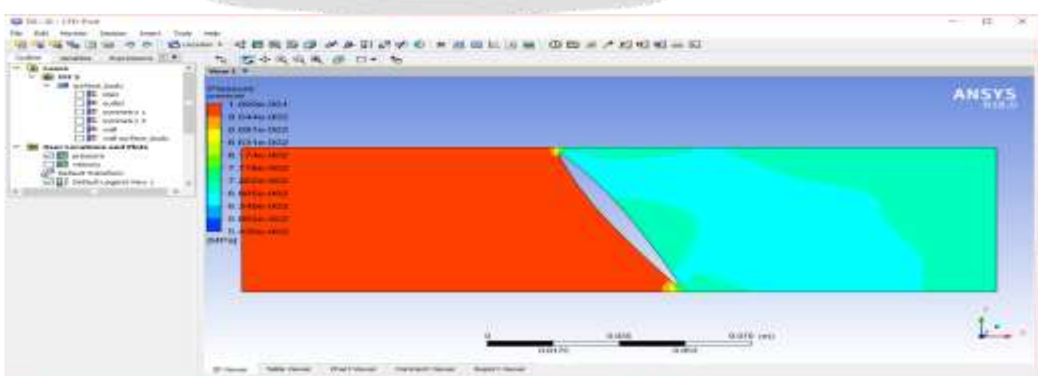


Fig 5 Pressure Distribution in throttle angel 30°

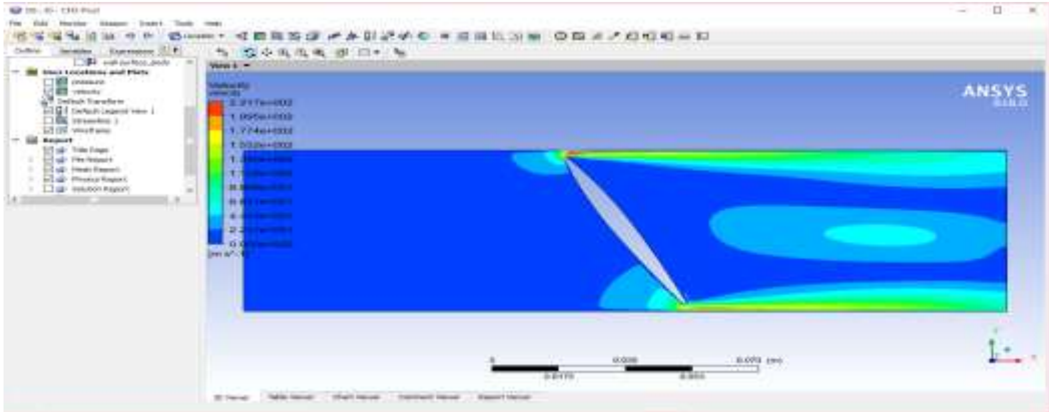


Fig 6 Velocity Distribution in throttle angel 30°

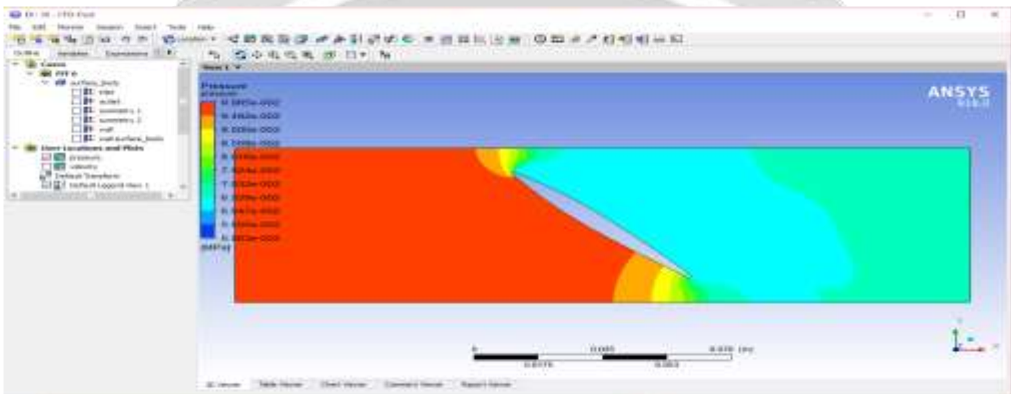


Fig 7 Pressure Distribution at Throttle angle 50^0

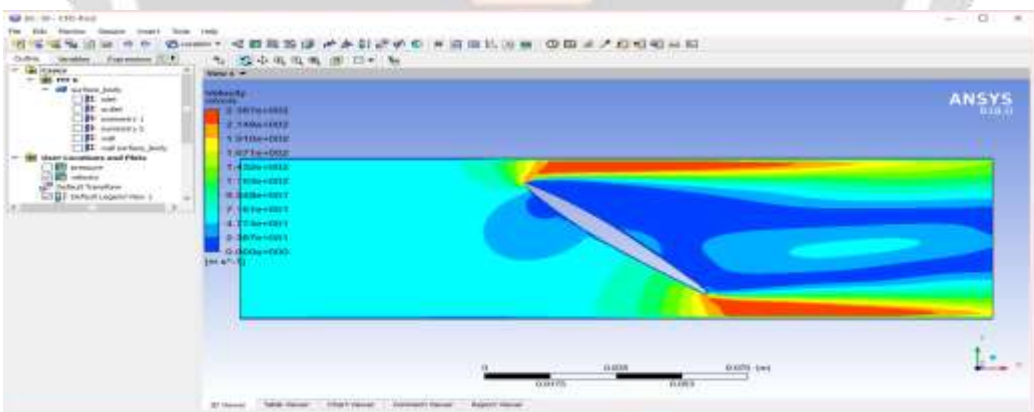


Fig 8 Velocity Distribution at Throttle angle 50^0

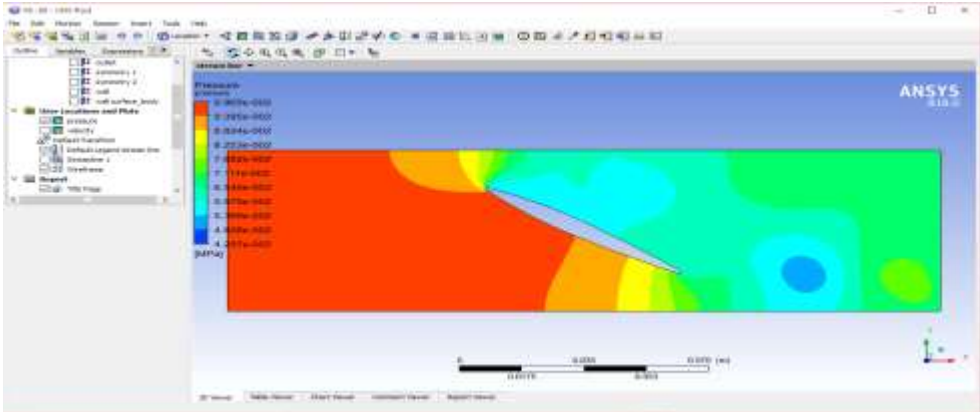


Fig 9 Pressure Distribution at Throttle angle 60^0

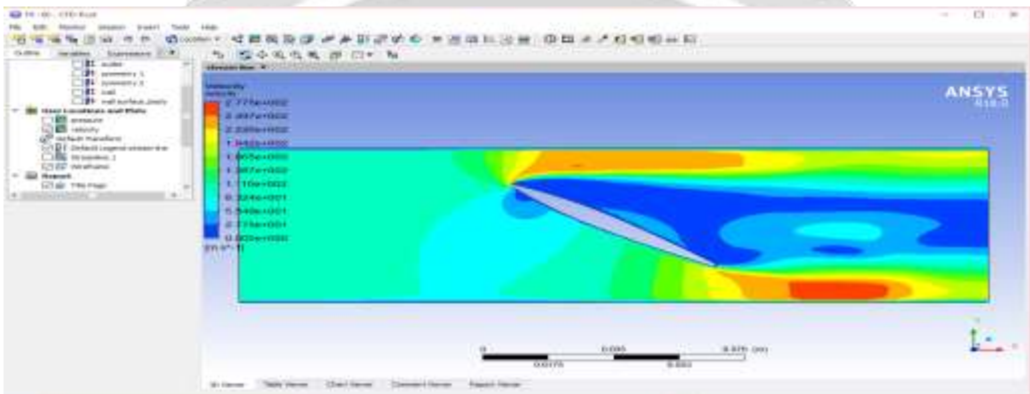


Fig 10 Velocity Distribution at Throttle angle 60^0

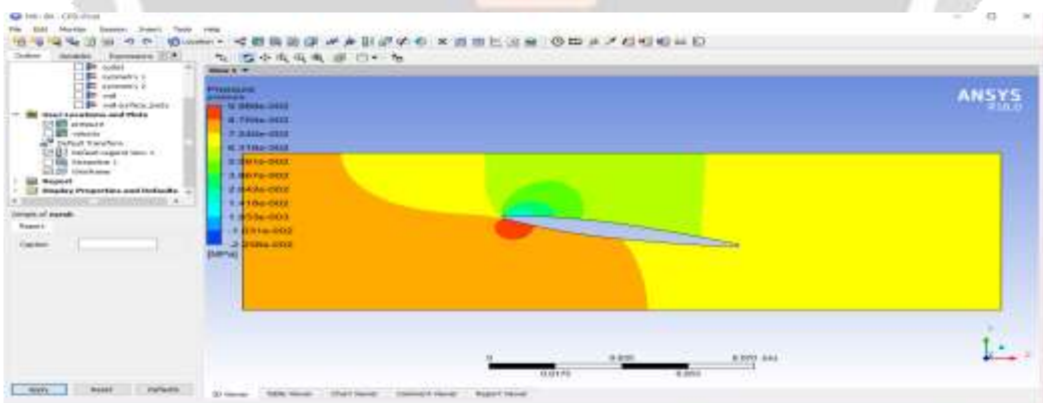


Fig 11 Pressure Distribution at Throttle angle 80^0

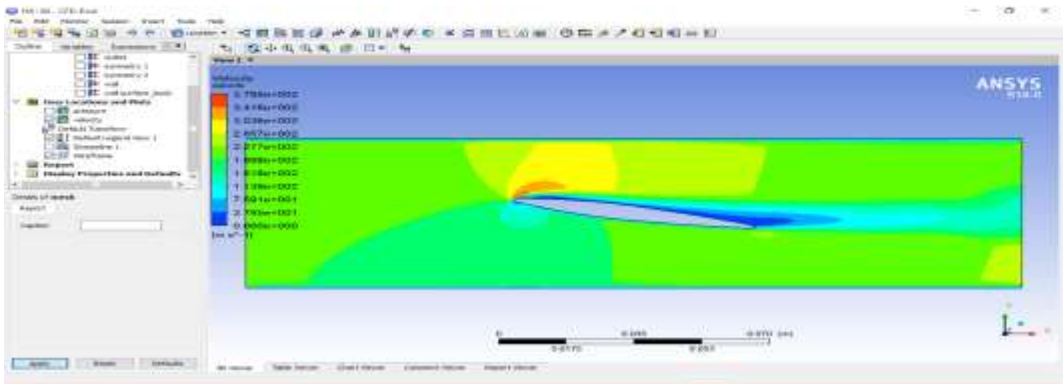


Fig 12 Velocity Distribution at Throttle angle 80^0

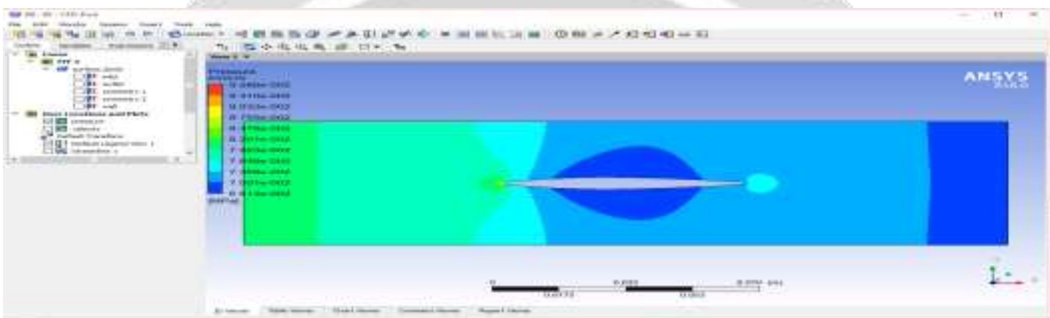
v 

Fig 13 Pressure Distribution at Throttle angle 90^0

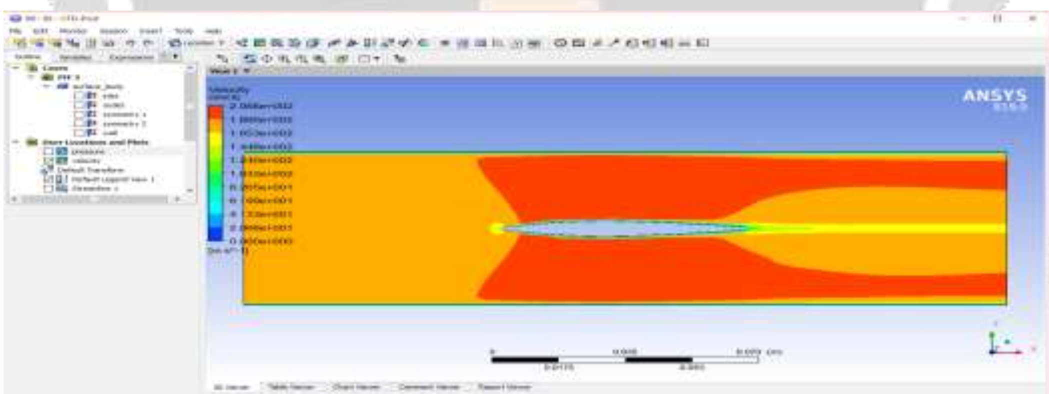


Fig 14 Velocity Distribution at Throttle angle 90^0

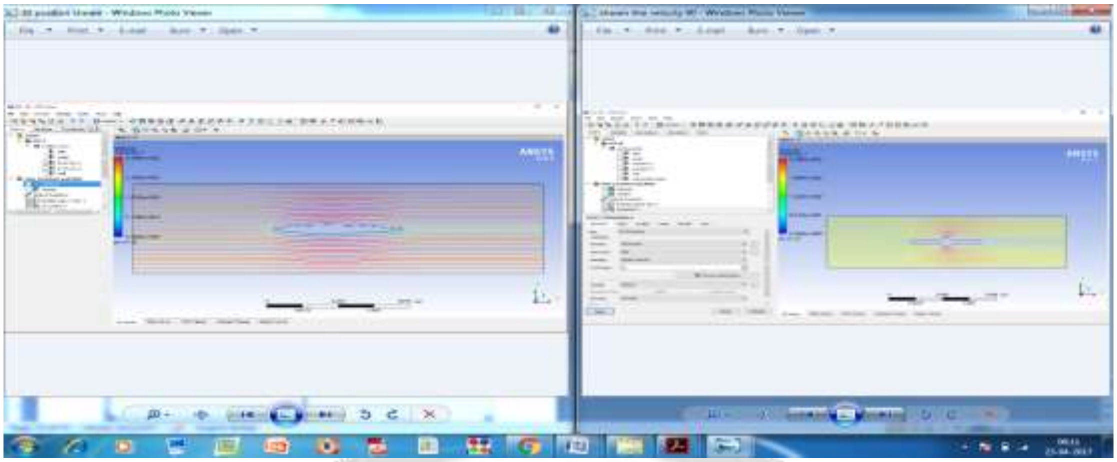


Fig 15 Velocity Streamlines for aerodynamic Shape & Flat Plate Throttle Valve at 90^0

As shown in above figure 15 comparision of velocity stream lines for aerodynamic shape and flat plate throttle valve is given which shows that in aerodynamic shape throttle valve more uniform streamlines is obtain with higher velicty and less pressure compare to flat plate throttle valve. In the table 2 and 3 Maximum pressure and velocity obtained in CFD analysis of aerodynamic shape throttle valve at different angles respectively given. In which we get increase in veloctiy as throttle angle increases and maximum velocity is obtained at 80^0 throttle valve angle. Howevver velocity at 90^0 throttle valve is slightly decreased but more uniform velocity streamlines is obtained at that angle of throttle valve which shows more uniform air fuel mixture is obtained.

Table 2 Maximum Pressure Distributions in Aerodynamics shape

Sr No	Angle	Pressure (Mpa)
1	30°	7.718×10^2
2	50°	7.524×10^2
3	60°	7.111×10^2
4	70°	5.675×10^2
5	80°	3.867×10^2
6	90°	7.93×10^2

Table 3 Maximum Velocity Distributions in Aerodynamics shape

Sr No	Angle	Velocity (M/S)
1	30°	1.108×10^2
2	50°	1.193×10^2
3	60°	1.665×10^2
4	70°	1.994×10^2
5	80°	2.277×10^2
6	90°	1.241×10^2

4. CONCLUSION

When the flow inside the Carburator was analyzed for different angles, it was found that the pressure decreased with the increase in opening of the throttle plate. Because when the throttle plate opening increases then the flow of air through the venture increases. But as obtained from the analysis above the pressure at the throat the throat also decreases with increase in opening of the throttle plate so the flow of air from the float chamber into the throat increases.

The pressure at the throat of the venturi when the throttle valve is 25º, 30º, 50º, 60º, 80º and 90º respectively. The pressure at the throat section has decreased gradually with the increase in the throttle valve angle. It is minimum (3.867×10^2 Mpa) at 80º and maximum (7.718×10^2 Mpa) at 30º throttle valve position.
With the increase in the throttle valve angle from 30º to 90º, the air velocity has increased, consequently the pressure at the throat section has decreased. This has a greater effect on the mixture strength. With the increase in pressure drop at the throat section, amount fuel entering into the throat section increases and makes the mixture progressively uniform.
The Velocity streamline is uniform in aerodynamic shape by Comparing to existing flat plate throttle valve to aerodynamic throttle valve design, mixing of air fuel is also uniform, reduced unborn fuel ratio and increase the efficiency of carburator.

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