INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & MANAGEMENT

ANALYSIS OF A CARBURETOR’S VENTURI UNDER DIFFERENT INCLINATIONS OF CHOKE VALVE AND THROTTLE VALVE

Santosh Kr. Sahu [1],Ashish Patidar [2]
[1] PG Research Scholar; [2] Assistant Professor
Patel College of Science and Technology, Indore (M.P) INDIA

ABSTRACT

Present research work is devoted to investigations in effect of inclinations of choke valve and throttle valve on the performance of venture section of a carburetor. For this purpose, a simulation approach is being adopted, under which a versions of a standard model of carburetor is designed and CFD analysis is done under different inclinations of choke and throttle openings. The results pointed out that the optimal opening angles for choke and throttle valve are 30 degree and 40 degrees, respectively.

Keywords: Carburetor, Venturi, Choke, Throttle.

INTRODUCTION

Spark ignition engines usually use volatile liquids. The preparation of the fuel-air mixture is accomplished outside the engine cylinder. The fuel droplets that stay in suspension also still evaporate and blend with air throughout suction and compression processes conjointly. Thus carburetion is needed to supply a flammable mixture of fuel and air in needed amount and quality. The process by which a combustible air-fuel is made before entering the cylinder is called carburetion and the device designed for this purpose is called carburetor. factors affecting this process are engine speed, vaporization properties of fuel, quality of inlet air, and design of carburetor.

To possess a prime quality carburetion the rate of the air at point of injection of fuel needs to be raised. To attain this, a venturi is provided within the path of air. Presence of extremely volatile hydrocarbons within the fuel additionally ensures prime quality carburetion. The pressure and temperature of the encompassing air conjointly affects the technique of carburetion. Higher part air temperature increases the vaporization of the fuel and therefore an additional homogenous mixture is produced. Designs of the carburetor, its intake system combustion chamber also have an effect on the uniform distribution of mixture to numerous cylinders of the engine. Considering above mentioned facts present research work is devoted to investigations on carburetors considering variations in operating conditions. For this purpose a simple carburetor is targeted, and its performance is evaluated by varying the openings of choke and throttle. The applied approach for this purpose is simulation approach, under which CFD of system is accomplished with the help of well-known software ANSYS 14.0.

Following are the objectives of present research work.

a) Modeling of carburetor;
b) Evaluation of throat pressures and throat velocities of carburetor with different openings of choke valve; and
c) Evaluation of exit pressures and velocities of carburetor with different openings of throttle valve; and

LITERATURE REVIEW

Table 2.1 shows the summary of research contributions made by different researchers in the field of carburetion.

Table 2.1: Research Contributions in the field of Carburetion

S. No	Researcher (Year)	Contribution
1.	Szybist & Splitter (2017)	During this study, a group of three fuels was designed to hold Ron nearly constant (RON=99.2–100) and to vary S (S=0, 6.5, and 12). These fuels were operated at the knock-limited spark advance (KLSA) at nominal engine loads of 10, 15, and 20 bar indicated mean effective pressure (IMEP) in a single cylinder SI engine with side-mounted direct injection supplying, at λ=1 stoichiometry. At every load

		condition, the intake manifold temperature was swept from 35 °C to 95 °C to change the temperature and pressure history of the charge. At the 10 bar IMEP condition, knock resistance was reciprocally proportional to S, with the S=0 fuel being the foremost knock resistant. As load increased the trend reversed and knock resistance became proportional to fuel S, with the S=12 fuel mbeing the foremost knock resistant. The fuel S knock resistance reversal with load is attributed to dynamic fuel ignition delay. At enlarged load, intermediate temperature heat release (ITHR) for the S=0 fuel was observed many crank angles before spark command, and ITHR magnitude was proportional to intake temperature. As intake temperature continued to extend, the S=0 fuel transitioned from ITHR to lowtemperature heat release (LTHR) before spark command. At the best load and intake temperature, 20 bar IMEP and 95 °C, the S=0 fuel exhibited distinct LTHR and negative temperature coefficient (NTC), and the intermediate S value fuel (S=6.5) exhibited distinct ITHR behavior several crank angles previous to spark command. However, for all tested conditions, the S=12 fuel exhibited neither ITHR nor LTHR. To understand the measured trends, chemical kinetic modeling was accustomed elucidate the fuel-specific dependencies on in-cylinder pressure–temperature history. An island of cold reactivity was identified at temperatures between 700 K and 825 K and at pressures above 17 bar. The dimensions and magnitude of this island was found to be fuel-specific, decreasing with increasing S. The combined findings illustrate the commonality and utility of fuel S, ITHR, LTHR, and NTC across a good range of conditions and the associated implications of fuel S in boosted trendy gasoline direct injection SI engines relative to the ron and MON tests.
2.	Krishna & Mallikarjuna (2016)	The present study focuses on the evaluation of the impact of engine parameters on the characteristics of a GDI engine by CFD analysis. The analysis was administrated at 3 engine speeds (2000, 3000, and 4000 rev/min), at 3 compression ratios (10, 11, and 12) and at 3 fuel injection pressures (200, 300, and 400 bar). The equivalence ratio of the in-cylinder mixture was maintained at 0.75 altogether the higher than cases. Finally, it is discovered that, the turbulent kinetic energy and tumble ratio were additional sensitive to the engine speed than to alternative parameters. The fuel injection pressure was found to play a significant role in getting combustible mixture close to the spark plug at the time of spark. Additionally, a low heat unleash rate occurred at the engine speed of 4000 rev/min compression ratio of 10 and fuel injection system pressure of 200 bar.
3.	Sharma (2015)	This paper investigates the effects of using argon (Ar) gas to mitigate the spark ignition engine intake air to reinforce the performance and prevent the emissions chiefly nitrogen oxides. The input variables of this study embody the compression ratio, stroke length, and engine speed and Ar concentration. Output parameters like TE, volumetric efficiency, heat unleash rates; brake power, exhaust gas temperature and emissions of Nox, CO_2 and CO were studied during a thermal barrier coated SI engine, beneath variable Ar concentrations. Results of this study showed that the inclusion of Ar to the input air of the thermal barrier coated SI engine has considerably improved the emission characteristics and engine's performance among the range studied.
4.	Elfasakhany (2015)	During the research work, combustion and emission characteristics of methanol, ethanol and gasoline along with blends were investigated. Results showed that when the test vehicle was fueled with ethanol-methanol-gasoline blends, the

		concentrations of CO and UHC emissions were considerably reduced compared to the neat gasoline. Methanol-gasoline blends given the lowest emissions of CO and UHC among all test fuels. Ethanol-gasoline blends showed a moderate emission level between the neat gasoline and ethanol-methanol-gasoline blends, e.g., ethanol-gasoline blends conferred lower CO and UHC emissions than those of the neat gasoline however higher emissions than those of the ethanol-methanol-gasoline blends. Additionally, the CO and UHC decreased and CO2 rose when ethanol and/or methanol contents multiplied in the fuel blends. Furthermore, the consequences of emulsified fuels on engine performance were investigated and results showed that methanol-gasoline blends presents the best volumetric efficiency and torque; ethanol-gasoline blends provides the best brake power, whereas ethanol-methanol-gasoline blends showed a moderate level of volumetric efficiency, torque and brake power between each methanol-gasoline and ethanol-gasoline blends; gasoline, on the opposite hand, showed the lowest volumetric efficiency, torque and brake power among all test fuels.
5.	Sulaiman *et al.*(2013)	This paper analyzes the characteristics of single cylinder SI ICE fueled by LPG. Above all, torque and engine speed were examined with using the universal dynamometer in WOT condition beneath stable condition. In additional the fuel consumption has been measure to identify that fuel is more sensible for SI ICE. SI engine fueled by LPG has slightly reduced on power output up to 4compared to ULP. However, engine fueled by LPG scale back on specific fuel consumption (SFC) to 28.38 %. Additionally, LPG engine have low energy price than ULP engine with distinction up to 47.40 %.

Gaps in the Research

Following are the gaps identified from the survey of available literature.

a) There is almost nil research available which tells about optimal opening angle of choke valve; and

b) There is very limited research available which tells about optimal opening angle of throttle valve.

On the basis of these gaps objectives of present research work are being decided.

SOLUTION METHODOLOGY

Present section tells about the details of analytical approach and software used to solve the research problem. In the present research work focus is being made on k-ε model to yield desired results. For the purpose of model development for CFD analysis, ANSYS 14.0 is used. Details of the k-ε model and software used in research work are presented in upcoming sub sections.

k-ε Model

K-epsilon (k-ε) turbulence model is a very famous model used in the field of computational fluid dynamics for simulating mean flow characteristics for turbulent flow conditions. It is a two equation type of model which offers a general description of existing turbulence by means of two transport equations. Following are the details of variables obtained through k-ε model:

1. The first transported variable is called turbulent kinetic energy (k), which determines the energy in the turbulence; and
2. The second transported variable is used for determining the rate of dissipation of kinetic energy. This variable is called turbulent dissipation (ε).

Details of the model are as follows (Mierka *et al.*, 2006):

In the framework of eddy viscosity models, the hydrodynamic behaviour of a turbulent incompressible fluid is governed by the RANS equations for the velocity u and pressure p.

$$\frac{\partial u}{\partial t} + u\,.\nabla \mathrm{u} = -\nabla \mathrm{p} + \nabla.\left((\mathrm{V} + \mathrm{V_T})[\nabla \mathrm{u} + \nabla \mathrm{u^T}]\right), \qquad \nabla.\mathrm{u} = 0 \tag{3.1}$$

Where ν depends only on the physical properties of the fluid, while V_T is the turbulent eddyviscosity which is supposed to emulate the effect of unresolved velocity fluctuations u′.
If the standard k − ε model is employed, then

$$V_T = C_\mu \frac{k^2}{\varepsilon} \tag{3.2}$$

…where k is the turbulent kinetic energy and ε is the dissipation rate. Hence, the above system is to be complemented by two additional convection-diffusion-reaction equations for computation of k and ε.

$$\frac{\partial k}{\partial t} + \nabla.\left(ku - \frac{V_T}{\sigma_k}\right) = P_k - \varepsilon \tag{3.3}$$

$$\frac{\partial_\varepsilon}{\partial_t} + \nabla.\left(\varepsilon u - \frac{V_T}{\sigma_\varepsilon}\nabla\varepsilon\right) = \frac{\varepsilon}{k}(C_1 P_K - C_2\,\varepsilon) \tag{3.4}$$

…where

$$P_k = \frac{V_T}{2}|\nabla u + \nabla u^T|^2 \tag{3.5}$$

…and ε is responsible for production and dissipation of turbulent kinetic energy, respectively. The default values of the involved empirical constants are as follows: $C\mu = 0.09$, $C_1 = 1.44$, $C_2 = 1.92$, $\sigma_k = 1.0$, σ" = 1.3.

ANSYS

ANSYS is a very popular analysis tools, developed by ANSYS Inc., USA for simulating problems of structural analysis, thermal analysis, computational fluid dynamics, modal analysis, harmonic analysis, transient dynamics, buckling, and other categories. The software also offers the facility to develop simple models. With the help of inbuilt library, one can find out the properties of materials. ANSYS also include a set of models to solve complex problems of engineering, sciences, and other applications. In present research work ANSYS 14.0 version is being used. Following are the salient features of the software:

- Provides excellent simulation facility;
- Offers different types of complex analysis like modal, transient, etc;
- Provides different approaches to solve a problem with different inbuilt models;
- Facilitates in modelling of simple parts;
- Separate modules for different analyses purposes like structural, modal, etc; and
- Better graphics facilities.

CASE STUDY

Present section tells about the details of implementations of research tool on the case problem, and presents the problem analysis and solution which includes model formulation and solution of the model, the details of which are presented in upcoming sub sections.

Problem Analysis and Formulation

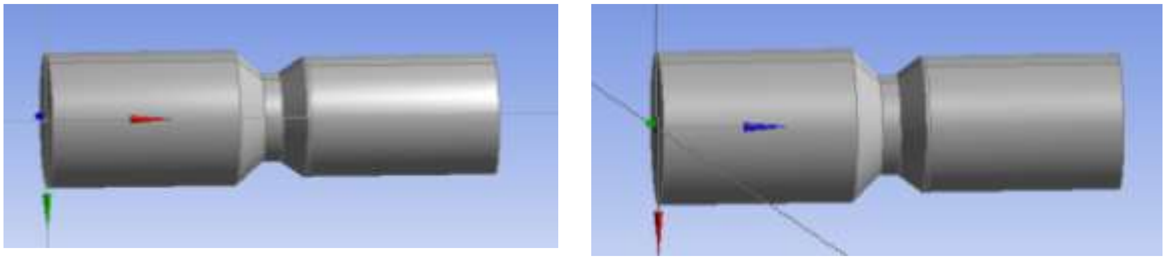
This section portrays the details of model formulation and approach used to solve the model, the stepwise procedure of which is presented below.

a) First of all, with the help of survey of available literature, dimensions of carburetor’s venture section were identified. Research shows that yet there are many types of carburetor available, but the performance evaluation of simple carburetor’s venture can be dictated into other parameters. For this purpose, venture section of simple carburetor was selected. Details of venturi section are presented as follows.

Table 1: Details of Venturi Section of a Simple Carburetor *(Kumar et al., 2014)*

S.No	Dimension	Value (mm)
1.	Total length of venture tube	150
2.	Inlet diameter	52
3.	Diameter of choke plate (expert opinion)	49
4.	Throat diameter	34
5.	Outlet diameter	46
6.	Diameter of throttle valve (expert opinion)	43
7.	Length of throat	6
8.	Length of the inlet part	63
9.	Length of the outlet part	63

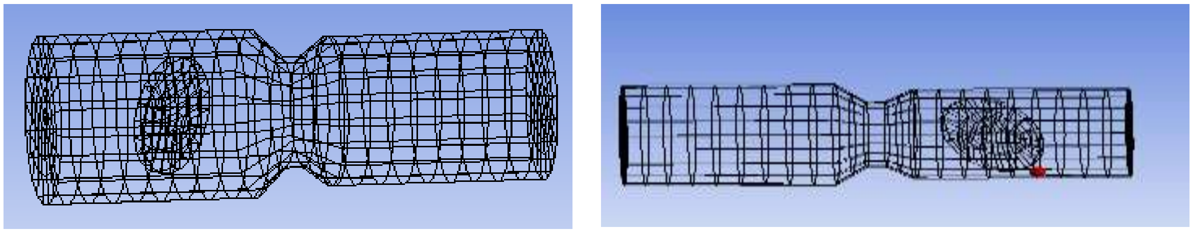
b) From above mentioned data models of venturi was developed in the simulation software ANSYS 14.0. In present research work, choke angles were taken as 30°, 45°, 60°, 75° and 90° and throttle angles were taken as 30°, 35°, 40°, 45°, 50°, 55°, 60°, 65°, 70°, 75°, 80°, 85° and 90°, respectively. Figure given below shows the models of venturies considering both the cases.



(a) Venturi considering Choke **(b) Venturi considering Throttle**

Figure 1: Models of Venturies

c) In next stage, meshing of was carried out. Following figure shows the meshed venturi sections.



(a) Venturi considering Choke **(b) Venturi considering Throttle**

Figure 2: Meshed Venturi Sections

d) Following are the details of meshing parameters.

Table 2: Details of Meshing Parameters

S.No	Parameter	Venturi considering Choke	Venturi Considering Throttle
1.	Nodes	1866	1874
2.	Elements	1463	1467
3.	Mesh Element Type	Coarse	Coarse
4.	Method	Automatic	Automatic

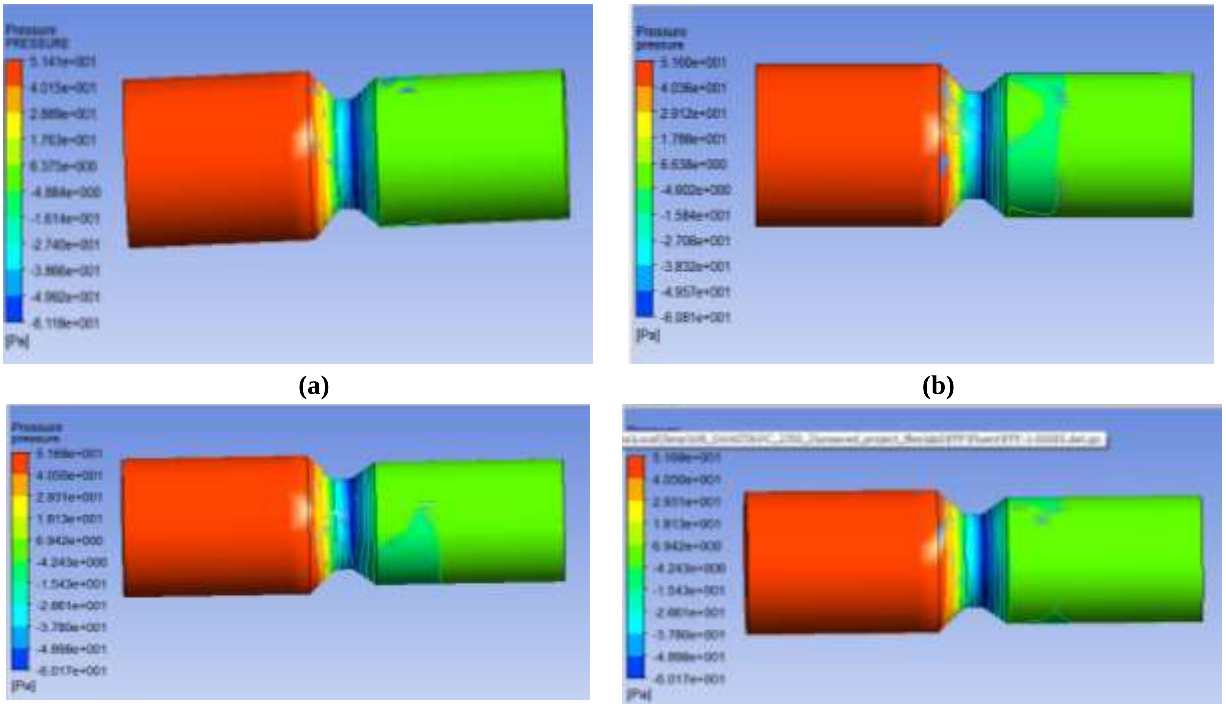
e) In next stage, CFD analysis for different models was carried out, under which pressures and velocities at the exit of throat section and after throttle were investigated. For the purpose of analysis, operating pressure was chosen as 101235 Pa. The working fluid was considered as air.

RESULTS AND DISCUSSION

Present section is devoted to results of the research work and associated discussion made, the details of which are present in upcoming sections.

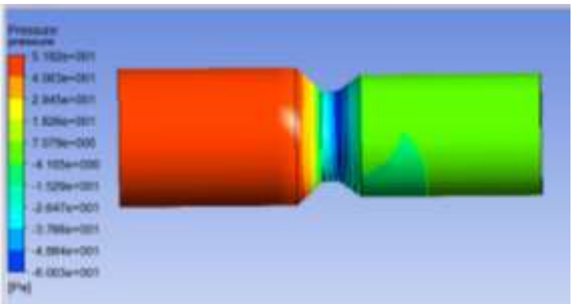
Results

Following are the results of pressures obtained by changing angles of choke.



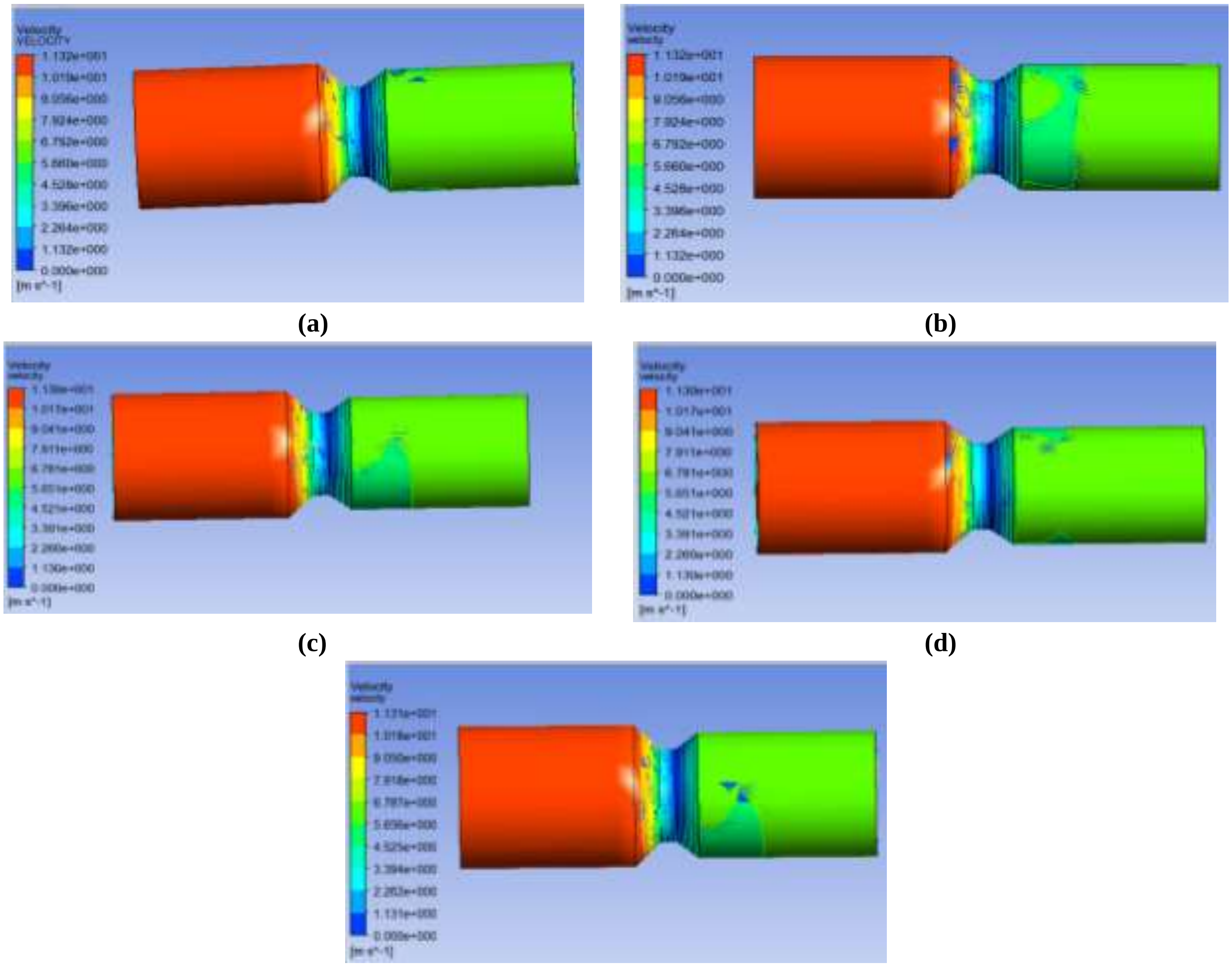
(a) **(b)**

(c) **(d)**



(e)

Figure 3: Pressures at Different Choke Angles



(a)
(b)
(c)
(d)
(e)

Figure 4: Velocities at Different Choke Angles

Table 5.1 shows the summary of above mentioned results.

Table 3: Summary of Results for Variation in Choke Angles

S.No	**Choke Angle (degrees)**	**Pressure** (at throat) (Pa)	**Velocity** (at throat) (m/s)
1.	30	-4.992E+001	1.132E+000
2.	45	-4.957E+001	1.132E+000
3.	60	-4.896E+001	1.130E+000
4.	75	-4.896E+001	1.130E+000
5.	90	-4.884E+001	1.131E+000

Negative signs in pressure column show that the gauge pressures are less than operating pressure (101325 Pa). Therefore in order to get static pressure or absolute pressure, these values were added with operating pressure, and following results were obtained.

Table 4: Variations in Static Pressure with Choke Angles

S.No	**Choke Angle (degrees)**	**Static Pressure** (at throat) (Pa)
1.	30	101275.1
2.	45	101275.4
3.	60	101276
4.	75	101276
5.	90	101276.2

Graphical representation of above mentioned results is as follows.

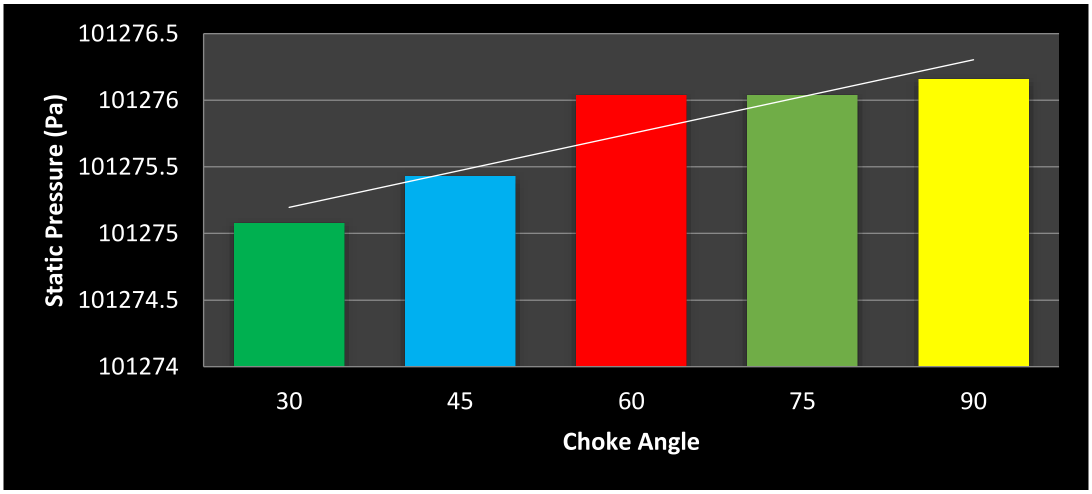


Figure 5: Variations in Static Pressures at Throat with respect to Choke Angles

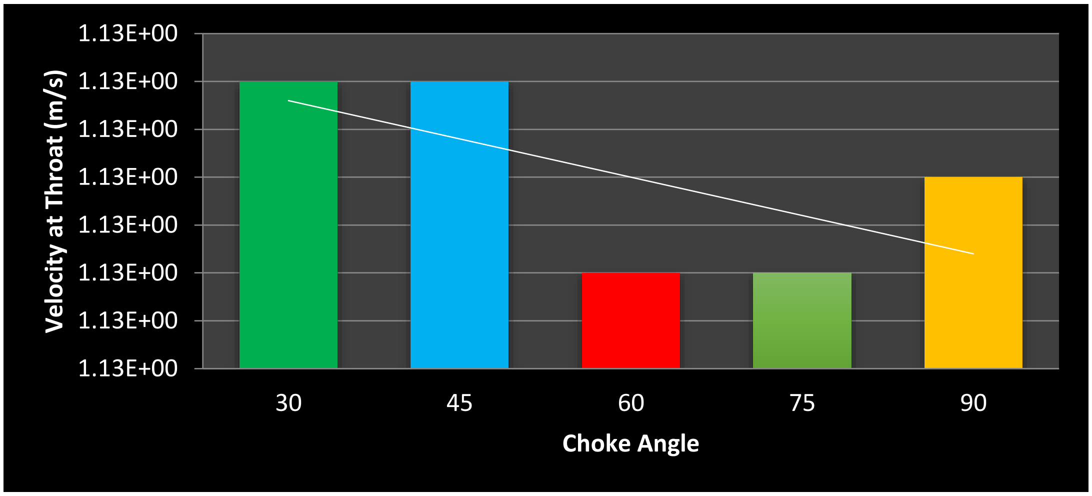
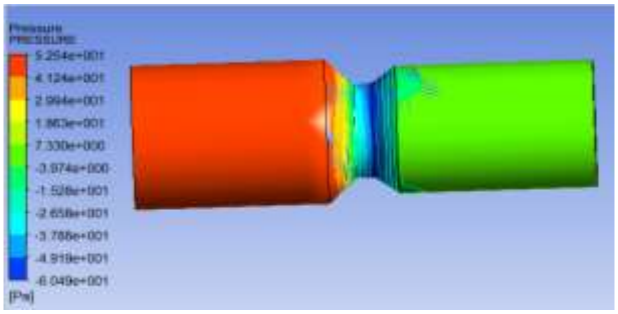
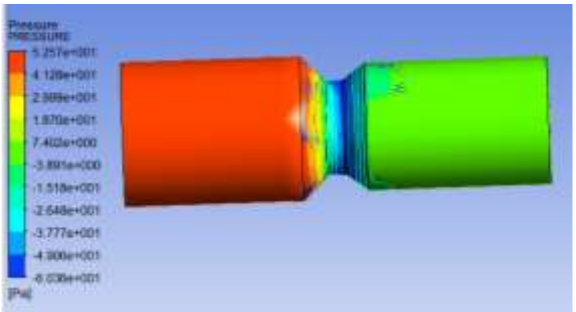


Figure 6: Variations in Velocities at Throat with respect to Choke Angles

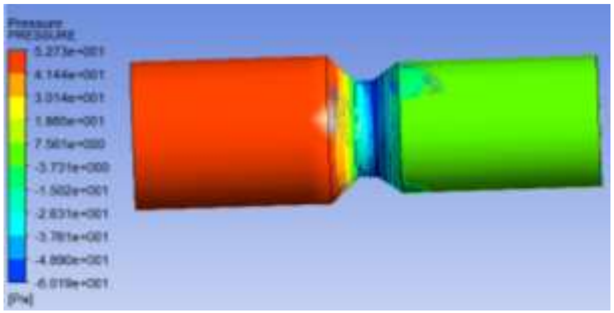
Following are the results of pressures obtained by changing throttle angles.



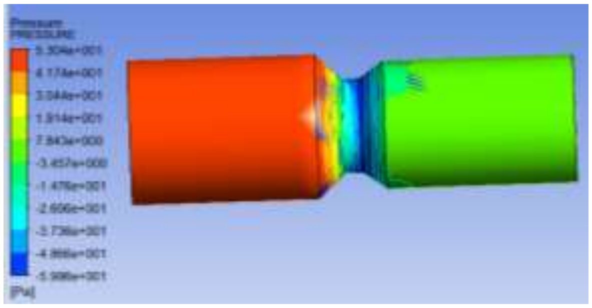
(a) 30 Degrees



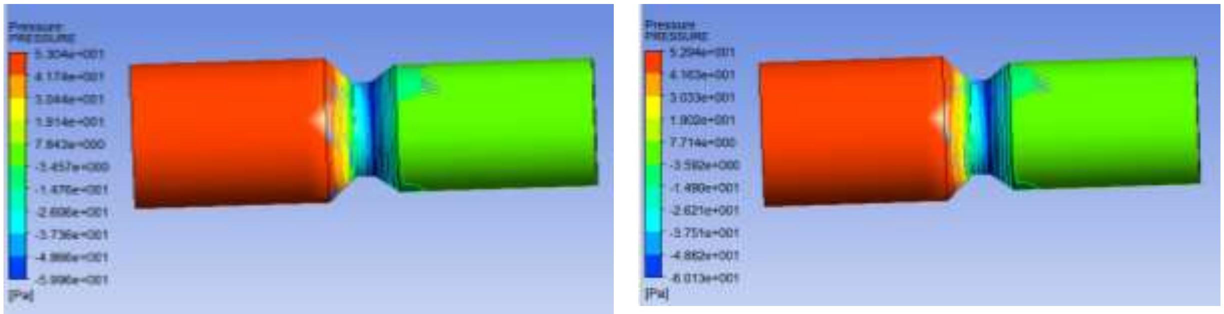
(b) 35 Degrees



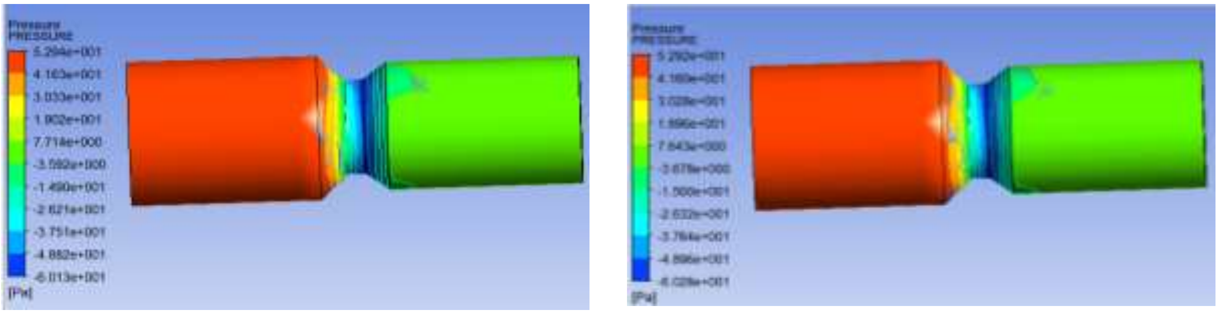
(c) 40 Degrees



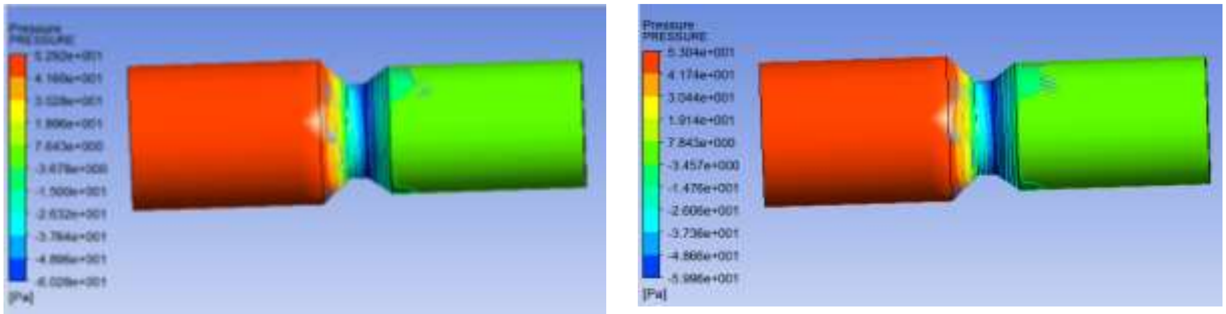
(d) 45 Degrees



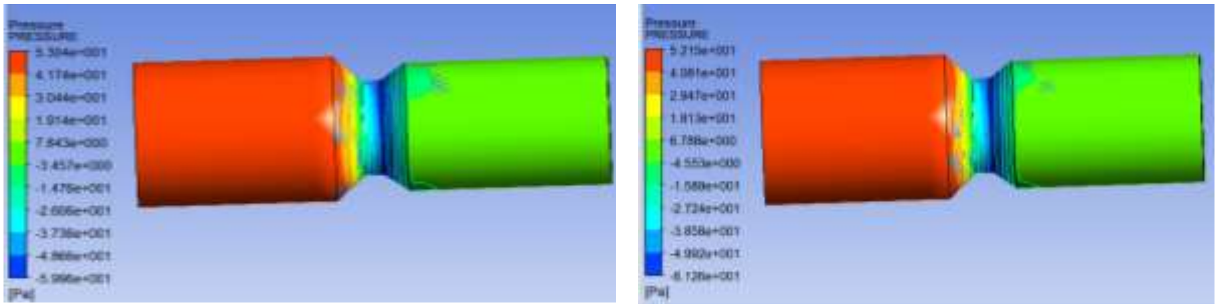
(e) 50 Degrees **(f) 55 Degrees**



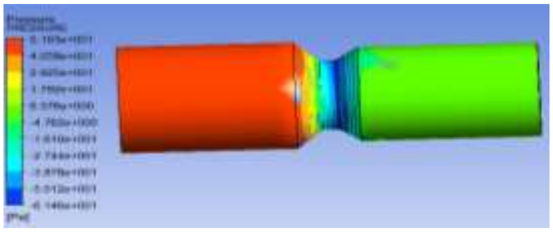
(g) 60 Degrees **(h) 65 Degrees**



(i) 70 Degrees **(j) 75 Degrees**



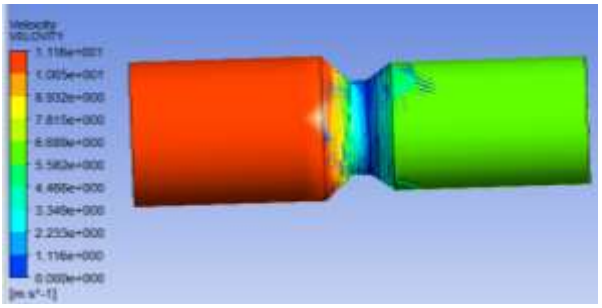
(k) 80 Degrees **(l) 85 Degrees**



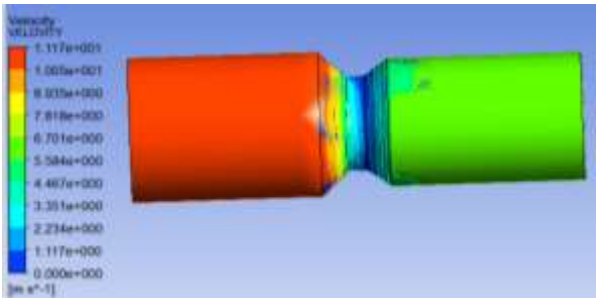
(m) 90 Degrees

Figure 7: Pressures at Different Throttle Angles

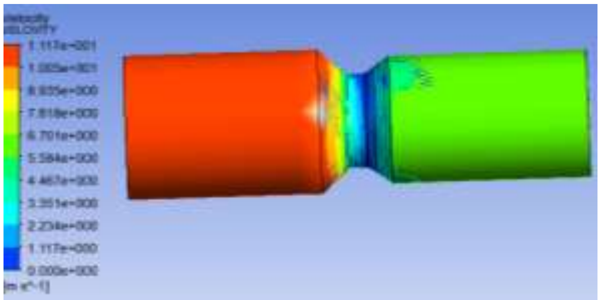
Following are the results of velocities obtained by changing throttle angles.



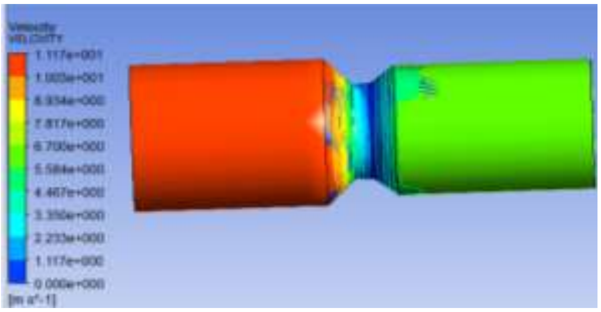
(a) 30 Degrees



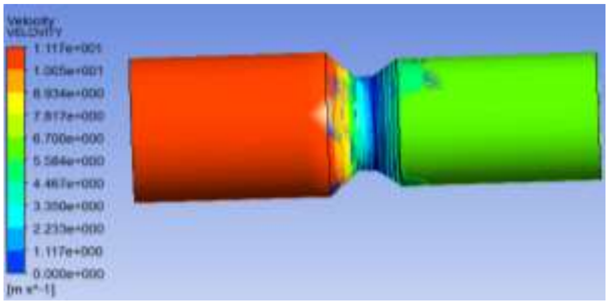
(b) 35 Degrees



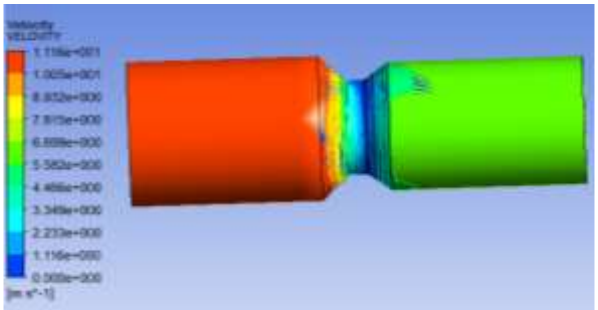
(c) 40 Degrees



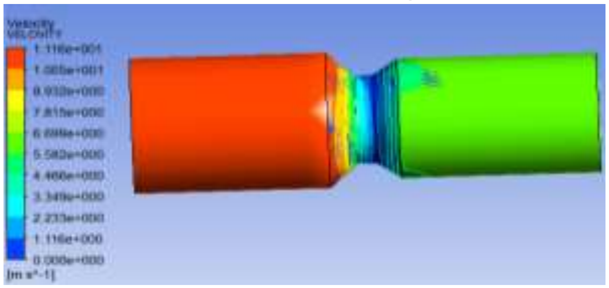
(d) 45 Degrees



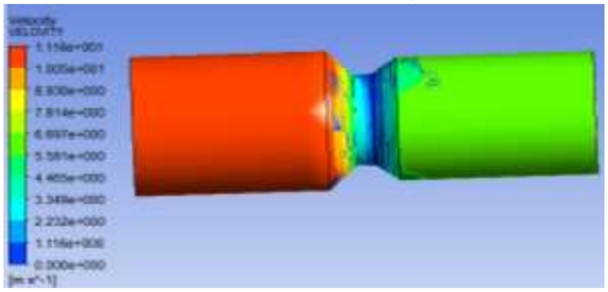
(e) 50 Degrees



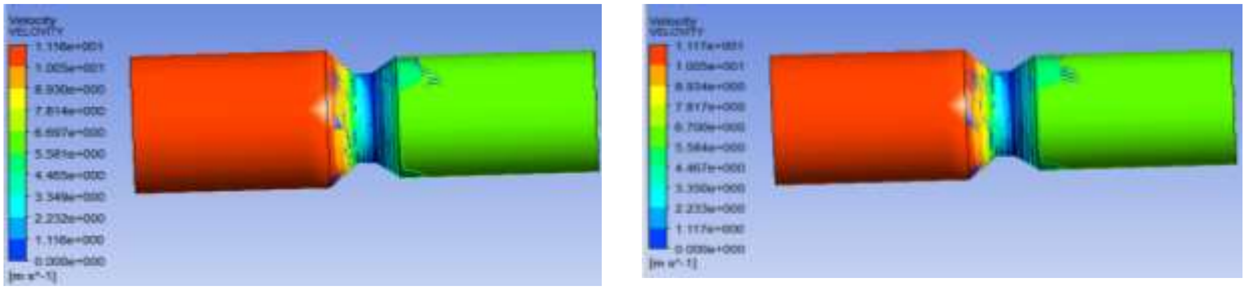
(f) 55 Degrees



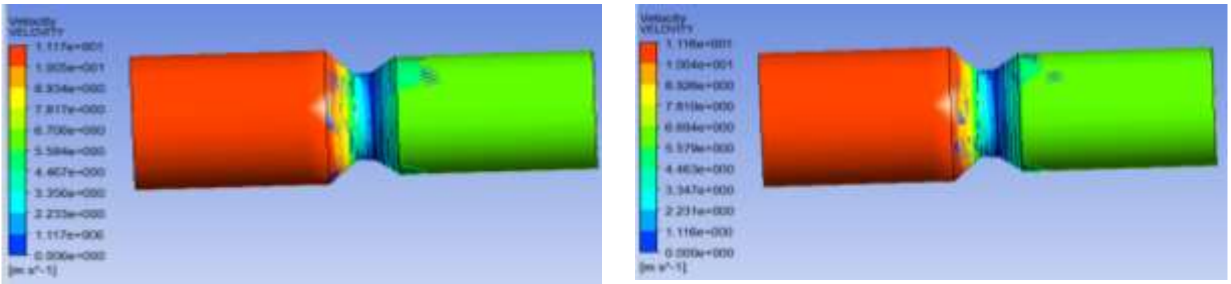
(g) 60 Degrees



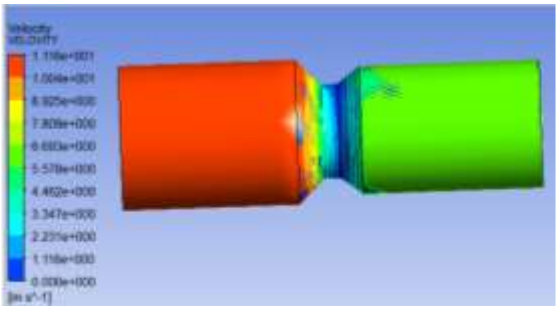
(h) 65 Degrees



(i) 70 Degrees **(j) 75 Degrees**



(k) 80 Degrees **(l) 85 Degrees**



(m)90 Degrees

Figure 8: Velocities at Different Throttle Angles

Summary of above mentioned results is as follows.

Table 4: Summary of Variations of pressure and velocity with respect to Throttle Angles

S. No	**Throttle Angle** (degrees)	**Pressure** (after throttle) (Pa)	**Velocity** (after throttle) (m/s)
1.	30	-3.974E+000	5.582E+000
2.	35	-3.891E+000	5.584E+000
3.	40	-3.371E+000	5.584E+000
4.	45	-3.457E+000	5.584E+000
5.	50	-3.457E+000	5.584E+000
6.	55	-3.592E+000	5.582E+000
7.	60	-3.592E+000	5.582E+000
8.	65	-3.678E+000	5.581E+000
9.	70	-3.678E+000	5.581E+000
10.	75	-3.457E+000	5.584E+000
11.	80	-3.457E+000	5.584E+000
12.	85	-4.533E+000	5.579E+000
13.	90	-4.762E+000	5.578E+000

In this case also negative signs in pressure column show that the gauge pressures are less than operating pressure (101325 Pa). Therefore in order to get static pressure or absolute pressure, these values were added with operating pressure, and following results were obtained.

Table 5: Static Pressure Variation in Choke Angles

S.No	**Throttle Angle** (degrees)	**Static Pressure** (after throttle) (Pa)
1.	30	101321.026
2.	35	101321.109
3.	40	101321.629
4.	45	101321.543
5.	50	101321.543
6.	55	101321.408
7.	60	101321.408
8.	65	101321.322
9.	70	101321.322
10.	75	101321.543
11.	80	101321.543
12.	85	101320.467
13.	90	101320.238

Graphical representation of above mentioned results is as follows.

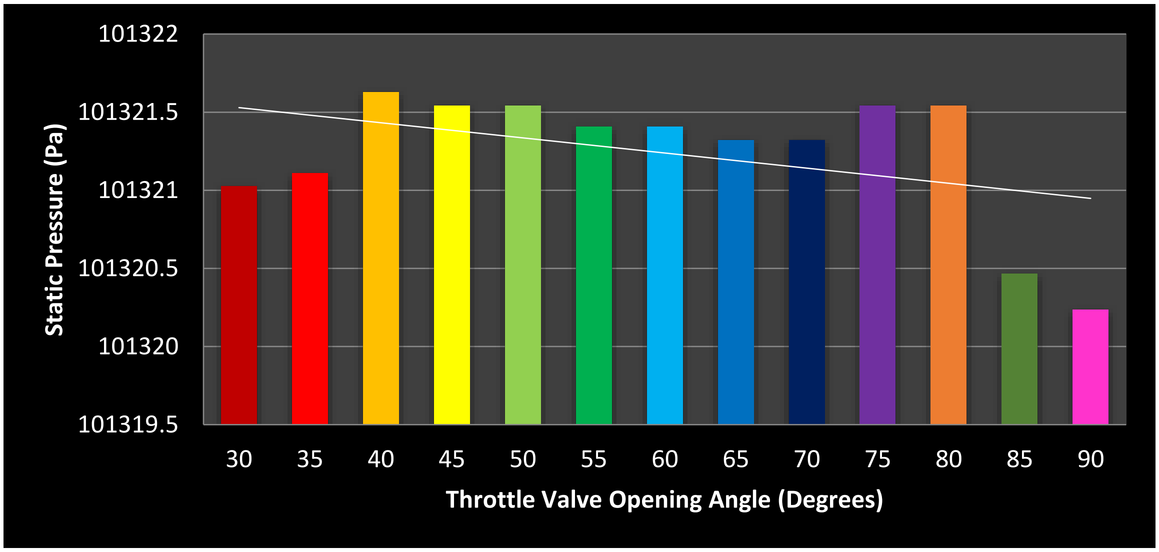


Figure 5.7: Variations in Pressures at Throat with respect to Throttle Angles

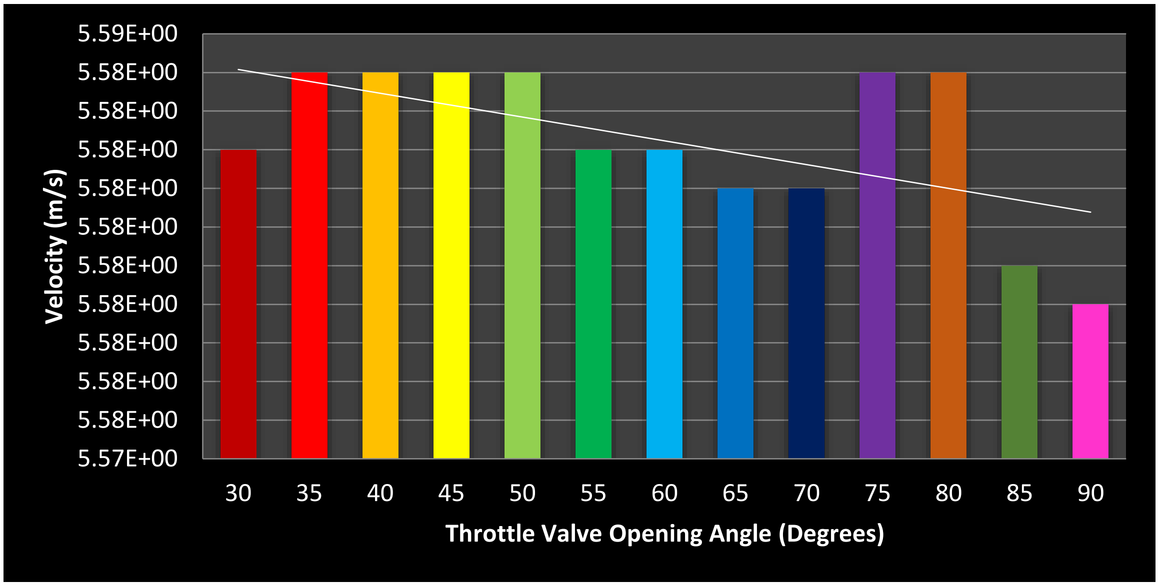
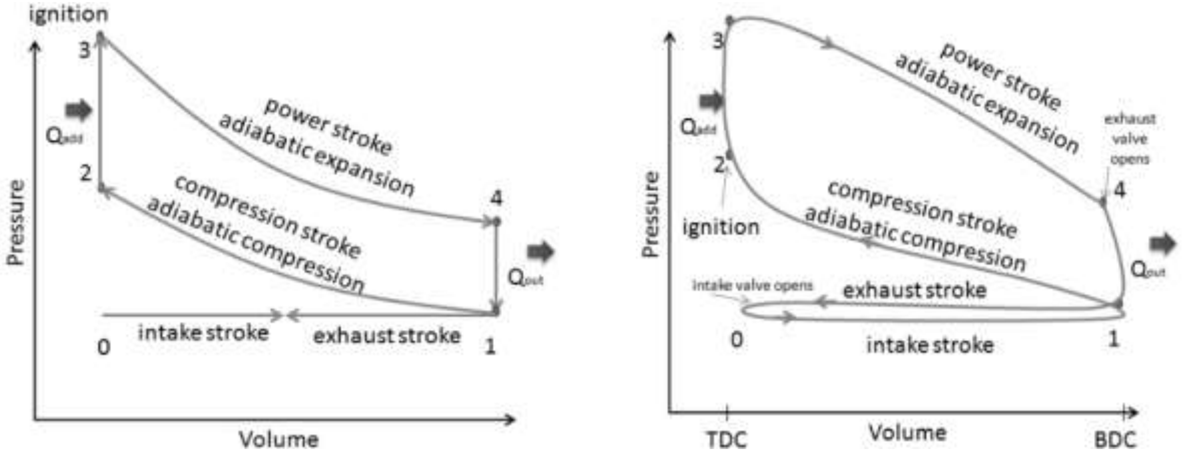


Figure 9: Variations in Velocities at Throat with respect to Throttle Angles

5.3 Discussion

We know that at throat section of the venturi, a requirement of minimum pressure and maximum velocity exists. This is because, at throat section due to lower pressure fuel reaches, and if the velocity of air at this section is higher, rapid formation along with rapid removal of air fuel mixture from that vicinity will take place. Considering this fact, chock angle which offers lowest pressure with greatest velocity should be considered. In research analysis, chock angles 30 degree shows the least value of static pressure as compared to other angles. In case of velocity value for this angle, greatest values out of all combinations, is obtained. Second best option is 45 degree chock angle, because at this choke angle, velocity is same as that of 30 degree choke angle and pressure is somewhat higher than previous case. Above this angle, one can find considerable deviations the values of static pressure and velocity of air. Considering trend line also, one can analyze that out of the available options best choke angle is 30 degree.

Figure 5.9 shows hypothetical and actual Otto cycles.



(a) Hypothetical Otto Cycle **(b) Actual Otto Cycle**

Figure 10: Hypothetical and Actual Otto Cycles

From above figures one can analyzed that in case of hypothetical Otto cycle, intake and exhaust both takes place at constant pressure (atmospheric pressure), which in case of actual Otto cycle intake takes place at a pressure below atmosphere, while exhaust takes place at a pressure above atmosphere. These two processes create unwanted loss of work, which should be reduced. The area covered between suction and exhaust can be reduced, if air fuel mixture from the carburetor enters at a pressure equals to atmospheric or at least near atmospheric. Therefore considering above mentioned fact, one can analyze that throttle angle 40 degree offers maximum pressure as well as velocity. After this angle, angles, 45 degrees and 50 degrees can be considered as good options. Trend lines drawn on both the figures also show that both pressure and velocity of air decrease with the increase in throttle angles.

CONCLUSION, LIMITATIONS AND FUTURE SCOPE OF THE RESEARCH

Present conclusion tells about conclusions drawn, limitations and future scope of the research, the details of which are presented in upcoming sections.

Conclusion

Following conclusions are being drawn from the research work.

1. At throat section, static pressure increases and velocity decreases with increase in choke angle;
2. After throttle valve, both static pressure and velocity decrease with increase in throttle angle;
3. Out of analyzed options, best angles for choke valve are 30 degree and 45 degree, respectively; and
4. Out of analyzed options, best angles for throttle valve are 40 degree, 45 degree and 50 degree, respectively.

Limitations and Future Scope of the Research

Following points indicate the limitations of present research work.

1. The research work is limited to investigations on a particular element of carburetor;
2. The research work is limited by investigations on a precise set of properties; and
3. The research work is limited to investigating a compact set of angles of venture.

On the basis of limitations, future scope of the research can be dictated through following points.

1. A vast research considering complete assembly of carburetor can be initiated;
2. A detailed research involving a broader set of properties can be undertaken; and
3. A more detailed research considering all the possible combinations of angles, length ratios, diameters, and other parameters can be initiated.

REFERENCES

1. Elfasakhany Ashraf (2015).Investigations on the effects of ethanolemethanolegasoline blends in a spark-ignition engine: Performance and emissions analysis. *Engineering Science and Technology, an International Journal*, 18 713-719.

2. Krishna, A. S., &Mallikarjuna, J. M. (2016). Parametric analysis of a 4-stroke GDI engine using CFD. *Alexandria Engineering Journal*.

3. Kumar Jay, Singh Jaspreet, Kansal Harsh, Narula Gursimran Singh, and Singh Prabhjot (2014). CFD Analysis of Flow using Venturi. *International Journal of Research in Mechanical Engineering and Technology*, 4 (2), 214 – 217

4. Sharma, T. K. (2015). Performance and emission characteristics of the thermal barrier coated SI engine by adding argon inert gas to intake mixture. *Journal of advanced research*, *6*(6), 819-826.

5. Sulaiman, M. Y., Ayob, M. R., &Meran, I. (2013). Performance of single cylinder spark ignition engine fueled by LPG. *Procedia Engineering*, *53*, 579-585.

6. Szybist, J. P., & Splitter, D. A. (2017). Pressure and temperature effects on fuels with varying octane sensitivity at high load in SI engines. *Combustion and Flame*, *177*, 49-66.