Experimental And Cfd Simulation Of Producer Gas Carburetor

Sanjay.M.R[1], *B.Yogesha*[2] *and N.K.S.Rajan*[3]

1. Assistant Professor & 2.Professor **Dept. of Mechanical Engg, Malnad college of Engineering, Hassan.**

3. Principal Research Scientist, **CGPL, Dept. of Aerospace Engg, IISc, Bangalore.**

Email: sanjaymrgech@gmail.com, mcemrs@gmail.com

Points to be presented in paper

- **Introduction**
- **Geometric modelling and meshing**
- **Governing equation and the boundary conditions**
- **CFD Analysis**
- **Experimental and CFD Simulation Results**
- **Conclusion**

ABSTRACT:

Presently there is no Producer gas carburetor available commercially. Some of the concepts evolved have not been optimized and are not standardized as well. In this view, development of the carburetor which will fulfil all the requirements of low energy density fuels is a need of the time. Design of a carburetor for producer gas application with special reference for reduced loss of pressure is taken up to generate the optimal fuel–air mixture to meet different load conditions of the engine as well as for varying operating conditions of producer gas reactor. A specially designed producer gas carburetor is comprehensively analysed for its mixing performance and response with a CFD modelling. The model is made up of a mixer chamber that has the essential orifices for air and fuel (producer gas) inlets to generate stable stoichiometric mixture at near to ambient conditions using the induction of the engine as the driving pressure differential for the flow, and tested for a case of engine of 15 kW capacity. The CFD simulations are carried out followed with experimental studies to validate the analysis. The results show a consistency in the experimental data and the modelling has provided a good insight into the flow details and has paved way in optimization in the geometrical design to get a good mixing efficiency.

Keywords: *air/fuel ratio, carburetor, computational fluid dynamic, turbulence, producer gas.*

1. INTRODUCTION

Mixing devices for gases used in gas engines generally referred to as carburetor, for mixing air and gaseous fuels are commonly attached to the intake manifold of an internal combustion engine. In gas carburettor the mixing of air and gaseous fuels needs to be in a proper ratio for particular demand of the engine. In the current state of technological advances, it is recognized that Biomass is one of the viable and sustainable renewable resources and new technologies emerging out of biomass based gasification systems find a significant role in bridging the energy crisis. The advanced biomass gasification systems are known to generate producer gas as the combustible fuel that is clean enough to be used in Direct Injection gas engines. However in order to adapt standard gas engines few of its components need modifications before they are used in the biomass power plants.

Since this area is an emerging one and the technology has not been disseminated to the scale of driving market it is essential that specialized components that require modification need be studied. Carburetor is one of the important components in such Category and it is identified that additional research work is to be carried out in establishing a design procedure for this application. [3]. the work presented here is an effort in this regard.

Air/fuel ratio characteristic exert a large influence on exhaust emission and fuel economy in Internal Combustion engine [4]. With increasing demand for high fuel efficiency and low emission, the need to supply the engine cylinders with a well-defined mixture under all circumstances has become more essential for better engine performance. Carburetors are in general defined as devices where a flow induced pressure drop forces a fuel flow into the air stream [1]. An ideal carburetor would provide a mixture of appropriate air-fuel (A/F) ratio to the engine over its entire range of operation from no load to full load condition. To ensure proper performance, Carburetors should be reproducible and have unequivocal adjustment procedures.

CFD software used for cold flow analysis is CFX 14.0.The k-ε turbulence model is most commonly used and is considered to be the best model between computational time and precision [2]. The geometric model is built using Ansys ICEM CFD 14.0.

2. GEOMETRIC MODELLING AND MESHING

Some of the prime factors considered in designing the carburetor are simplicity and ruggedness as basic requirements that would achieve reproducible and good performance. The air and fuel flow through orifices entering into a mixing chamber of the carburettor enables to produce stoichiometric ratio with good mixing of air and gas. Carburetor is being designed to have air and fuel flow near ambient conditions of working pressure. The Fig.1 shows Dimension and 3D model of producer gas carburetor. The carburetor is as shown in the Fig.2 and it has orifices at air and fuel inlets such that the A/F ratio at ambient flow condition should maintained stoichiometry for a 15 kW engine. The amount of fuel flow inside the carburettor is controlled by butterfly valves which are located prior to the air and fuel inlet orifices. The pressure balancing electronic control module drives suitably the butterfly valve with the help of a DC motor that brings the valves for a null pressure differential across the manifolds of the fuel and air. In a practical system, the variation of air-fuel ratios are indicated by a differential pressure sensor and the valve movements are controlled based on this feedback towards maintaining the stoichiometric air-fuel ratio. A detailed concept of the first generation carburetor based on this working principle is brought out in earlier reported work [1, 2]. A reported work [3] also mentions the need for homogeneity in mixing and maintenance of the air-fuel ratio in the gas carburetors. In order to overcome the problems associated with the use of zero pressure regulators and to maintain the stoichiometry A/F mixture, carburettor uses the orifices at both air and gas lines. Orifices are designed based on the mass flow rate of the gas required for IC engine. Fig.3 shows the orifice meter for air and fuel control. Continuous hexahedron meshed model considered for CFD analysis and which is shown in Fig.4, with 50 thousand computational nodes.

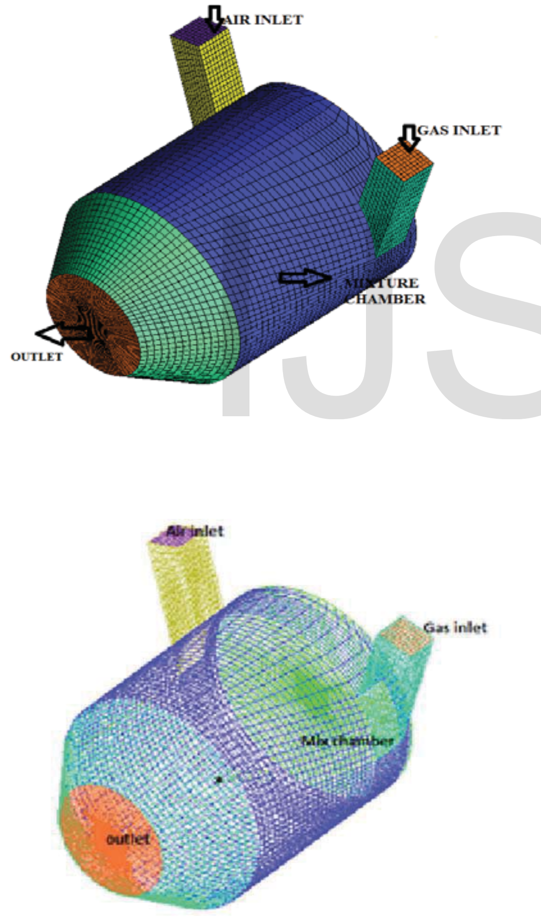


Fig 4: Geometric and Structured Mesh Model of Producer gas Carburetor

3. GOVERNING EQUATION AND THE BOUNDARY CONDITIONS

For the present flow analysis the 3D RANS equations have been considered. The Reynolds-Averaged Nervier-Stocks Equations are solved for steady, single phase and viscous flow.

Mass conservation: $\frac{\partial \overline{u_j}}{\partial x_j} = 0$

Momentum Conservation:

$$\frac{\partial}{\partial t}(\rho \bar{U}_i) + \frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j) = -\frac{\partial \bar{p}}{\partial x_i} - \frac{\partial}{\partial x_j}(\bar{\tau}_{ij} + \rho \overline{u''_i u''_j})$$

A 3 Dimensional RANS code having up winding implicit scheme and k-ε approach for turbulence is used for obtaining numerical solution. The Equations are solved for steady incompressible flow. The boundary and initial conditions used include (a) no slip at the walls; (b) Assigned mass flow rate and pressures at inlet and outlet ports.

4. CFD ANALYSIS

As mentioned earlier, primary concept of this carburetor is taken from the earlier reported work [1, 2]. This work addresses the geometrical and design optimization of this design concept. The CFD simulations are carried out on the carburetor geometric models as shown in Fig.4. The air and fuel pass through inlet ducts of size 25mm X 25 mm. The air inlet is kept tangential and fuel inlet radial to the cylindrical mixing chamber. Air and fuel enter into the mixing chamber through orifices of sizes of 28 mm and 26.5 mm diameters; respectively. From the analysis, it can be seen that the mixing of fuel and air in the carburetor is occurring fairly well and rendering the variation in mass fraction at the exit nearly to be within 2% considered to be good enough for a premixed combustion in the engine. The velocity at outlet is designed to be below 10m/s, Re works out to be 35055 and pressure drop across the carburetor is found be about 125 Pa. In the previous works on carburetor analysis it is noticed that there is considerable pressure drop at the outlet. Efforts are made to reduce the pressure drop and to achieve the proper mass fraction by changing the air and fuel inlet position (15°, 30°and 45° with respect to the original tangential position).

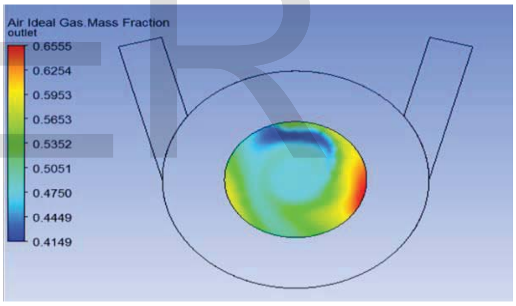
AIR INLET POSITION	GAS INLET POSITION
Tangential	Tangential
15°	15°
	30°
	45°
30°	30°
	45°
45°	45°

Table.1: This represents different positions of air and fuel inlets for which the analysis is carried out

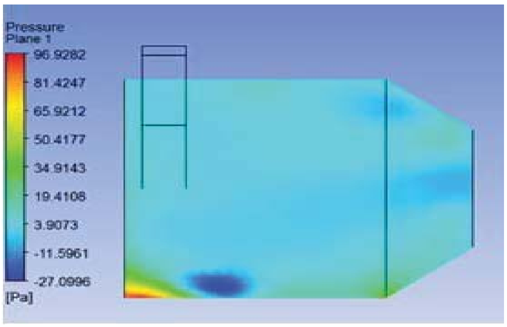
5. EXPERIMENT AND CFD SIMULATION RESULTS

Fig.2 shows the assembled view of the carburetor and schematic view of the Test Rig setup. Engine simulating experimental set up consists of two blowers which are fixing at suction and forced mode. The setup so as to achieve nearly producer gas engine working conditions. The fig.5 shows the pressure controller timing diagram indicating, when there is a rise in pressure difference between the two inlets of the carburetor, due to changes in the load, there is a corresponding change in the input voltage from the pressure sensor to the pressure controller circuit. The ECM takes corrective action by actuating the motors thereby valves connected to the inlets thereby regulating zero pressure difference across the two inlets; this in turn maintains the stoichiometry. The potentiometer output changes accordingly and the data is acquired using the DAQ system.

From all results shown in Table.3 one can notice that for air and fuel inlet angles 15°-15° is suitable to obtain the desired mixing and the pressure drops is considerably low has better results when compared to all other cases and is in the order of 69 pa. The Fig.6 shows the air ideal mass fraction and the pressure variation along length of the carburetor for different air and fuel inlet positioned at 15°-15° consider full mass flow condition and without valve control.



a) Air ideal gas mass fraction



b) Pressure variation along length of carburetor

Fig.6: Air ideal gas mass fraction and pressure variation plots of carburetor for Air inlet and gas inlet positioned at 15°

6. CONCLUSION

The work is carried out with an objective to achieve optimum design for a carburettor for engine application with fuels of low energy contents, mentioned earlier. 3-D CFD simulations made have been able to capture the detailed functional features of fluid flow in the carburetor configurations considered. The results obtained from the computational studies provide a good insight of its functional behaviour.

Turbulent model based on k-ε model with a RANS code has been used for the CFD predictions of the fuel and air mass fractions and the carburettor performance has been evaluated. The outcome has brought out an optimal design of the carburettor that can be used for prototype testing and qualifying tests. The results indicate that there is a good mixing of the constituent gases in the geometries considered and the optimization has allowed to have reduced pressure drop of about 25 Pa. This optimization has paved a way in overcoming multiple hardware building and testing and has allowed to get enhanced performance of the prototyping model that could lead to blend suitably for the engine applications specified. Apart from the reduction in the cost function of the design, this approach has led to provide performance border lines in the possible geometrical options giving an edge over the empirical design approach and manage to meet the constraints of the applications. These aspects of this work are considered to provide a design alternative in bridging the technology gap in the area of low energy fuel based engine applications.

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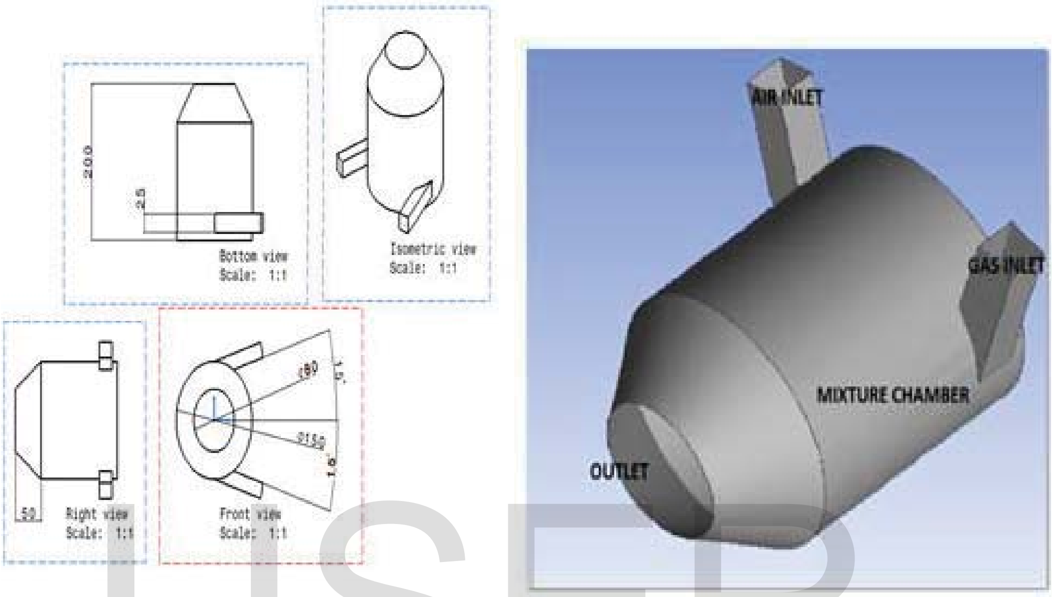

Fig 1: Dimensions and 3D- model of producer gas carburetor

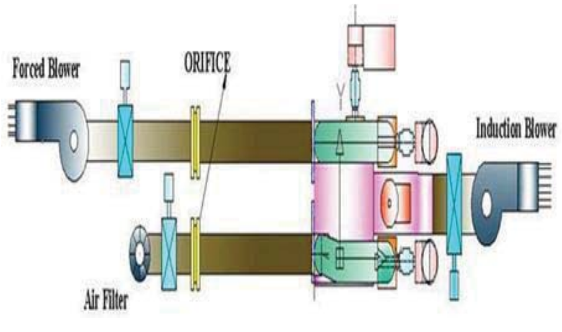

Fig 2: Assembled view of the Test Rig Setup

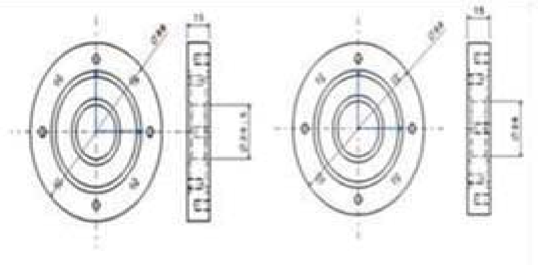

Fig 3: Flow control for gas carburetor
A) Air control B) Fuel control

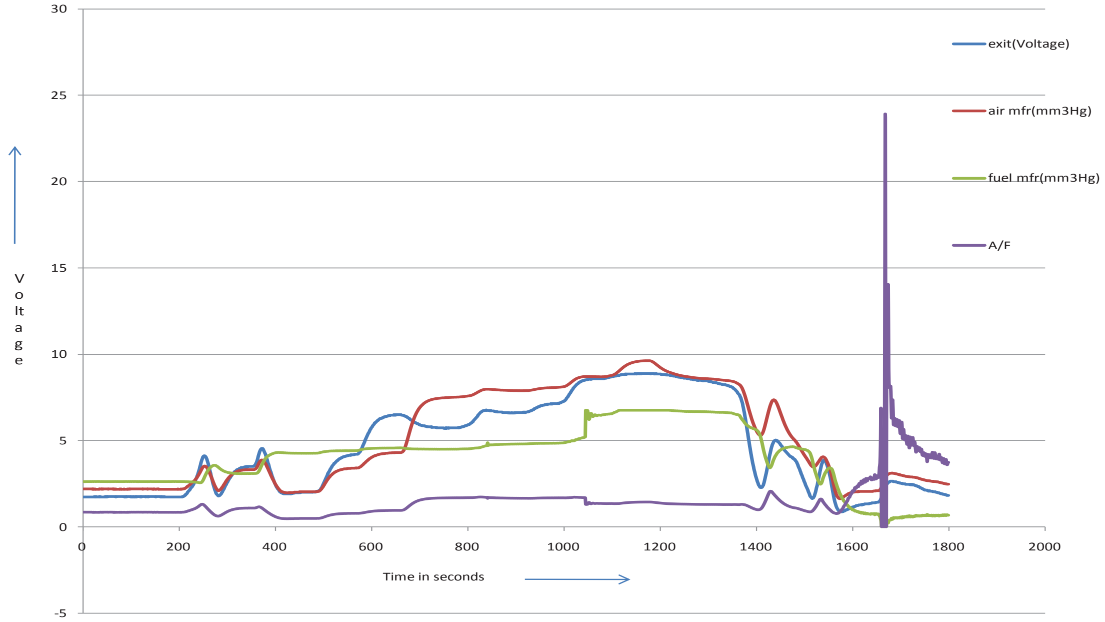

Fig.5 Pressure controller timing diagram

Table .2: Experimental Engine Simulation data

Sl no	ΔP across venturi meter (air side) g/s	ΔP across venturi meter (PG side) g/s	ΔP across Air Orifice in mm of water column	ΔP across PG Orifice in mm of water column	Absolute pressure (carburet or outlet) mm of water column	Air flow rate g/s	Fuel flow rate g/s	A/F ratio
1	68	10	25	6	102	27.62	9.423	2.931
2	68	20	25	10	102	27.62	13.32	2.074
3	68	30	25	13	99	27.62	16.32	1.692
4	68	40	25	19	99	27.62	18.85	1.465
5	68	50	25	22	97	27.62	21.07	1.311
6	68	60	25	25	95	27.62	23.08	1.196
7	68	70	25	30	95	27.62	24.93	1.108

Table.3: Comparison Chart obtained by CFX analysis for different air and fuel inlets

AIR INLET POSITION	**GAS INLET POSITION**	**AIR IDEAL GAS MASS FRACTION**	**PRESSURE DROP ALONG THE LENGTH (Pa)**	**RESULTS**
Tangential	Tangential	0.4972	199.4658	Good mixing, relatively very high pressure drop
15°	15°	0.5352	**69.8316**	**Optimal result with least pressure drop**
15°	30°	0.4529	121.3155	Not proper mixing, higher pressure drop
15°	45°	0.4647	128.1975	Not proper mixing, very high pressure drop
30°	30°	0.6148	144.3209	Not proper mixing, considerably high pressure drop
30°	45°	0.5472	189.5497	Good mixing, very high pressure drop
45°	45°	0.5277	169.6418	Good mixing, considerably high pressure drop