Design and Analysis of Carburetor for efficient mixing of Air and Producer gas using CFD

Dayananda N P[1], Manjunath H S[2], Mohan Kumar B[3], Byregowda K C[4]
[1, 2, 3, 4] Department of Mechanical Engineering
[1, 2, 3, 4] Dr. Ambedkar Institute of Technology Bangalore, India

Abstract- *Currently no Producer gas carburetors are being sold commercially. So the development of the carburetor which will fulfill all the requirements of low energy density fuels is a need of the time. This thesis work is related to the design confirmation and mixing performance evaluation of the rectangular and Y- shaped producer gas engine carburetor for producer gas engine application. The factor, for example, Calorific value and flame temperature fluctuates with the air to fuel proportion deviations which affects the stoichiometry. A perfect stoichiometry gives complete combustion of mixture in combustion chamber without any release of green house gases, and with higher energy output. The stoichiometry is influenced by the blend stream varieties because of change in load, variation in composition, moisture and other factors; therefore it is vital to keep up stoichiometric air-fuel proportion by utilizing equipment like carburettor with perfect design configuration in shape and size. The advantage of this is that there is a complete combustion of fuel mixture; incomplete combustion leads to release of greenhouse gases which thus reduced air and sound pollution.*

Keywords- Air-fuel ratio, Carburettors, CFD, Producer Gas (PG),

I. INTRODUCTION

The world is facing a grave problem-energy crisis because of overuse of conventional fuels in automobile and power generation and various thermal applications. Imposition of emission norms by government regulating bodies to reduce environmental pollution lead to the search for cleaner burning fuel. The natural choice is an non-conventional energy sources. One of the non-conventional energy resources is a biomass. Biomass is an organic matter produced by plants, both terrestrial and aquatic and their derivatives. Energy from biomass can be acquired through the conversion technologies such as: Direct combustion, biochemical conversion and thermo chemical conversion. Thermo chemical conversion takes two forms: Gasification and liquification.

Gasification of biomass is a course of action associated with very high temperature of about 700-1000 ^{0}C and partial combustion wherein solid biomass typically in the form of small pieces of wood or agricultural waste is transformed into a combustible gas mixture. This combustible mixture is called as producer gas. The producer gas consists of mainly carbon dioxide, carbon monoxide, hydrogen and nitrogen gases.

The apparatus wherein producer gas is created is termed as gasifier. Generally there are two types of gasifiers which are available, one is fixed bed gasifier and another is fluidized bed gasifier. The former gasifiers can be further categorized in three types which are up draft, down draft and cross draft.

Producer gas resulting from biomass normally consists of 18-20% each of hydrogen (H_2) as well as carbon monoxide (CO), 2 % methane (CH_4) and rest like carbon dioxide (CO_2) and nitrogen (N_2) gases. The producer gas will be usually of lower calorific value which varies in the range of 4.5-4.9 MJ/Kg. Producer gas can be used in internal combustion operation like any other gaseous fuel like LPG, but the producer gas used should not contain any impurities and make sure that the gas is sufficiently neat and clean such that contaminant does not mount up in the intermediary channel to the engine cylinder. Producer gas can be used in both compression ignition (CI) as well as spark ignition (SI) engine by making slight changes in the engine configuration. For CI engine the fuel is dual mode, here one of the fuel is producer gas and other might be diesel so that a blend of this two should be used.

A SI engine with a single gas mode can also be used by mixing it with air in definite proportion. The power obtained from the producer gas internal combustion engine can be used remote places of villages where proper power supply is not possible and where it has abundant biomass resources. The power obtained here can vary between 20 KW to 50 KW, and depending on the requirement it can be expanded for industrial power generation installations. Use of producer gas in compression ignition engines where dual fuel operations is possible offers a maximum replacement of 80% diesel with an overall average replacement to 75% for smooth no restriction operation , which is not the case in single gas spark ignition engine operation wherein complete elimination of gasoline is possible. Due to the complete substitution of diesel by producer gas the focus is now shifting towards improving the SI engine which operates in a single fuel mode.

Objective:

The project outline involves:

- Theoretical Calculations where initial dimensions of the carburetor are arrived at.
- Conceptualization where different concepts of carburetor will simulate, review the simulation results and report
- Detailed Design of models which includes the iterative process of modeling, analyzing and optimization in order to achieve required conditions at outlet.

II. Literature review

Literature survey in the field of producer gas based engines primarily on use of producer gas for SI engines reveals modest research work accomplished since the inception of biomass/charcoal gasification system. This could be attributed to two reasons namely non-availability of standard gasification system that could generate consistent quality producer gas and other related to misconception about producer gas fuel.

The technology of biomass gasification has existed for more than seventy years. Subsequent to World War II, the technology did not gain popularity on two counts, the first reason being unrestricted availability of petroleum fuels the world over at low cost. The other reason being technological problems relating to the presence of high level of tar content in producer gas, which poses threat to engine operations.

Klimstra J et al, [1] conducted study on gasification technology and its use in IC engine. This could be attributed to the fact that Europe suffered most due to an oil crisis during World War II. Among the European nations, the Netherlands and Sweden account for greater amount of work in the field of gasification and use of producer gas for IC engines. Researchers at the BTG biomass technology group, the Netherlands have dealt at length on the theoretical and practical aspects of use of low calorific gases in internal combustion engines. The focus has mainly been on the gas mixture stoichiometry, gas temperature and pressure at the engine inlet and the flame speed. National Swedish Testing Institute of Agriculture machinery, Sweden has reported extensive work on the design and development of closed top charcoal and wood gasifiers for use with the reciprocating engines were mostly diesel engines mounted on trucks and tractors for operation in dual fuel mode. Swedish Riksdag (Parliament) bills (1930) also mention funding toward research activity for the use of producer gas in Military vehicles. Extensive research work also has been carried out to report comparisons between peak pressures attained using liquid fuels and using producer gas at various CR.

Mukunda H S et al, [2] has worked in the area of producer gas engine has been reported by Indian institute of technology, Mumbai. He has reported work on gas engine converted from a naturally aspirated diesel engine at CR of 11.5. The reason for limiting the CR cited to be the knocking tendency, however no experimental evidences are provided in support of it. On the combustion front Mukunda have worked extensively on the fundamental aspects of reactions of biomass char with air, CO_2 and water vapor and the flame propagation of producer gas and its components, namely CO and H_2 with air. It has been reported that the flame structure for CO-air mixer and H_2-air mixer is dominated by low activation energy reactions, which contribute nearly in equal proportions to the heat release.

Sridhar et al [3] have presented experimental and modeling aspects relating to the operation of high CR spark ignition Engines using producer gas. Kanitkar have reported on flame speed, temperature and limit of flame propagation for producer gas air mixer at ambient conditions. It is interesting to note down that almost every work needs for maintaining stoichiometry for producer gas operation. However, not much attention has been paid toward gas carburetors.

Jacob Klimstra et al [4] of N.V. Nederland Gasunie in which, some commercially available gas carburetors have been tested. It has been reported that air and producer gas being in gaseous state do not guarantee homogeneous mixture. Further the near equal proportion of gas and air mixer needed for stoichiometric mixer demands use of constant pressure regulator. The effect of use of the constant pressure regulators on the air-fuel ratio variations has been presented; steady and unsteady flow conditions in simple gas carburetor have been extensively studied.

Yoshishige Ohyama et al, [5] Literature survey on the air fuel ratio sensor and control system for maintaining air-fuel ratio at stoichiometric conditions shows that much work has been carried out by commercial establishments like BOSCH ,GmbH,TOYATO and HONDA in testing and developing reliable gas sensor mainly in the range of O_2 sensors, flammable gas sensor and toxic gas sensors.

Hepbum et al, [6] studied the effect of CO to H_2 ratio in the exhaust on the heated sensor. However, it is significant to note that much work on the control system has been done with a focus maximizing the efficiency of the three way catalytic converter, which has a peak performance at stoichiometric air to fuel mixture. Literally no work mention use of control system for maintaining of stoichiometry for producer gas based SI engines.

Berggren et al, [7] have developed an air fuel ratio controller using the throttle angle information along with some other signals. The main objective has been to evaluate the possibility of achieving finer air-fuel ratio control especially during transient conditions that involve sudden variations in the physical conditions inside the intake manifold due to fast throttle opening and closing. Platoon et al have presented information on non linear control of spark ignition engines for enhanced air-fuel ratio control system. Emphasis is placed on fast transient phases produced by simultaneous action on the throttle and the electronic fuel injection device. The primary aim here has been to achieve better performance for the air-fuel ratio regulation system, thereby improving engine efficiency and exhaust emissions during transient phases.

III. METHODOLOGY

3.2.1 FEA Methodology

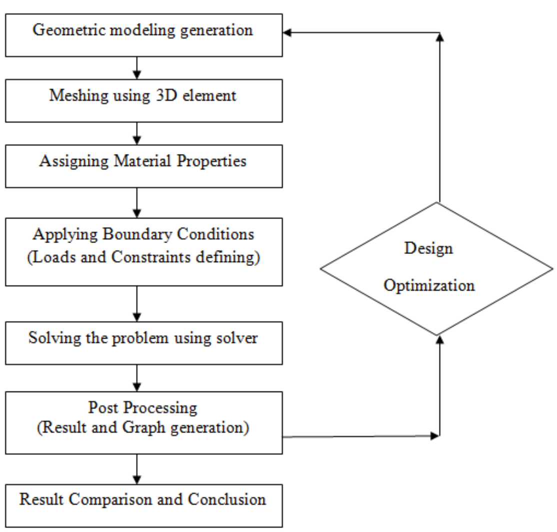

Fig 1: Flow chart of FEA Methodology

CFD Analysis:

CFD simulation analyses on carburetor are conducted using available ANSYS software package. Firstly the carburetor is modeled using CAD tool and then meshing of this 3D model is done with tetra elements. Then the boundary conditions and material properties are given in the pre processing stage. With a suitable solver the problem is solved and in the final post processing stage the results are analyzed. The carburetor is simulated with the above steps for different shapes and sizes, and for different flow rate of mixtures. All this results are tabulated and an optimized design case is figured out. In this project we considered two shapes of PG carburetor one is rectangular shaped and other Y shaped. These two cases are analyzed and the better one is furthered optimized in design of its shape to obtain the desired output result.

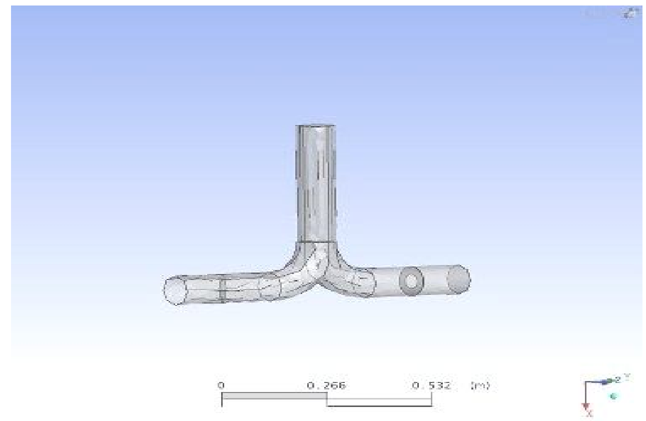

Fig 2: Three dimensional geometrical model of Y-shaped PG Carburettor

Three dimensional CFD computations on producer gas carburetor made have been able to capture the detailed functional features of fluid flow in the carburetor configurations considered and are found to be consistent. Turbulent model based on k-ε theory with a RANS code has been used for the CFD predictions of the producer gas mass fraction and the carburetor performance has been evaluated leading to bringing out of an optimal design of the PG carburetor.

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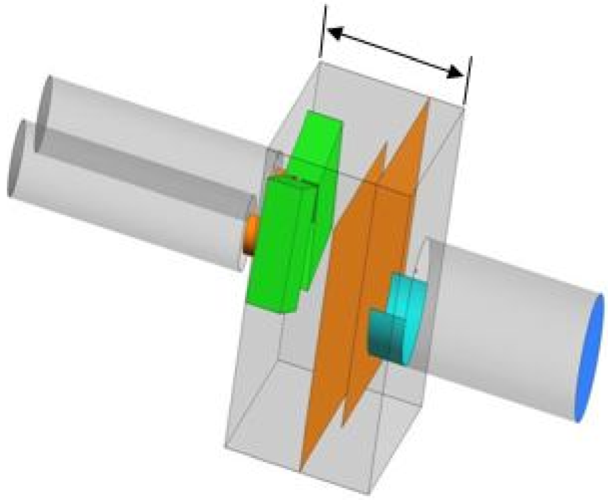

Fig 3: Three dimensional geometrical model of rectangular-shaped PG Carburettor

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III. RESULTS AND DISCUSSION

The analysis of the producer gas mass fraction and air mass fraction along the length of the geometry indicates the efficient mixing of air and producer gas. However, the complete mixing is not seen in Y-shaped geometry and in rectangular geometry mixing effectiveness is more than 90%. Flow induce pressure across the Y-shaped geometry is 30% less comparing in rectangular geometry.

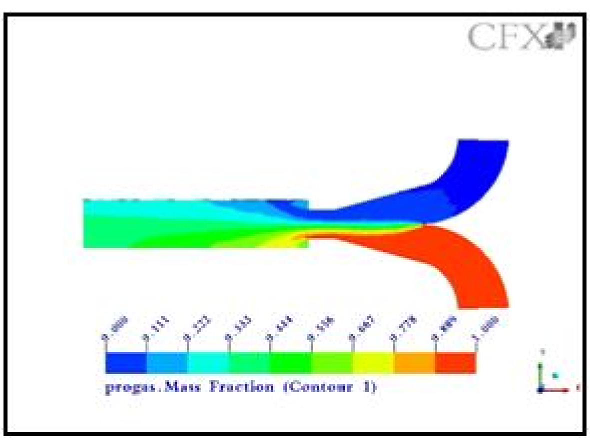

Fig 4: Air and producer gas mass fraction variation for Y model\

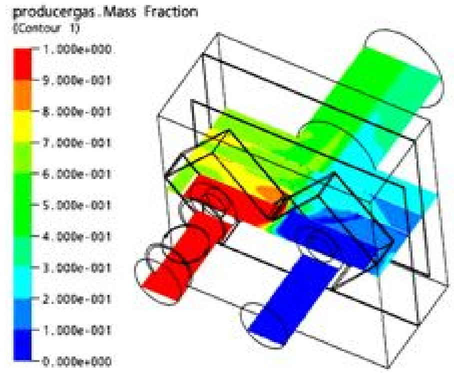

Fig 5: Air and producer gas mass fraction variation on a plane for a rectangular shaped model

Geometry comparisons for different sizes of carburetor are done. The design of the rectangular geometry carburetor has to be optimized in such a way that there is a proper amalgamation of producer gas and air, so that complete combustion is possible. Incomplete combustion leads to release of carbon monoxide which is a green house gases and it affects the environment severely.

By changing the dimensions of the carburetor one has to study the mass fraction of producer gas at the outlet. Here the length of mixing chamber is altered and the mass fraction of producer gas at outlet is noted down. We have done for three cases, that is for case 1 length is 120mm, case 2 it is 90mm and case 3 for 105mm. And the one with low variation in the air and PG mixing at the outlet is considered for design purpose. It is observer that one with 105mm length of mixing chamber has only 4% variation in the air and PG mixing at the outlet which is less than the other two cases and hence this mixture of producer gas and air at outlet is properly mixed for complete combustion.

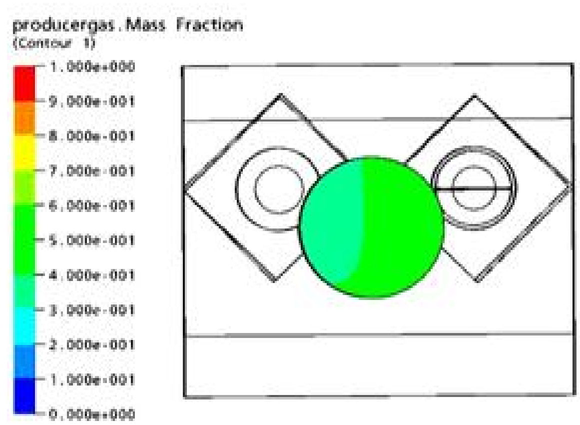

Fig 6: PG variation at outlet for 105mm length of mixing chamber.

IV. CONCLUSION

Three dimensional CFD computations on producer gas carburetor made have been able to capture the detailed functional features of fluid flow in the carburetor configurations considered. The CFX code used is an industrially established.

- A rectangular shape carburetor CFD result of indicates the sufficient mixing in the currently available geometry space. The mixing length of carburetor domain was sufficient for full mixing of producer gas with air, the rectangular geometry can work well for the engine applications.

- The Y-shape carburetor geometry mixing effectiveness of producer gas and air is not good enough, but pressure drop from inlet of air and producer gas to outlet is very minimal comparing with Rectangular and Cylindrical geometries.

- Rectangular geometrical configuration work fairly well in terms of mixing effectiveness comparing in Y-shape and cylindrical configurations. Pressure drop in Rectangular geometry is 92 Pa and in cylindrical geometry is 116 Pa. Out prints of geometrical dimensions of rectangular shape is very compact in size compared to other two configurations. A rectangular shape carburetor CFD result indicates consistent in comparing with other different geometrical configurations.

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