Computational Analysis of Intake System for Biogas Fuelled SI Engine

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Abstract - For the use of Biogas as a fuel in the SI engine some modifications are done. The improvement of flow strategy is implemented in the intake system of the engine to produce better biogas engine performance. The intake system for air-fuel mixture is studied, designed, simulated and analyzed with ANSYS-CFX and CFD-Post code. A venturi with an inlet for air at nozzle convergent section and for biogas at throat with providing an accelerating device for maintaining flow of biogas is done. In CFD analysis the effect of flow of air-fuel mixture with the contours of pressure, velocity, kinetic energy and streamlines are studied. Form that results the effect of break power, air/fuel ratio, bsfc at the speed 1000rpm, 3000rpm, 5000rpm and 7000rpm are studied. In this study it is found that the break power at the respected speed are 0.96kW, 1.7kW, and 2.7 kW, 5.3kW resp. Whereas the specified speed of standard petrol engine comes near about same as that of biogas speed at 7000rpm.

Keywords: CFD; Intake System; Venturi; Biogas

I. INTRODUCTION

As the population and economic growth increase, most of developing countries facing the increasing demand of energy. Energy saving and emission reduction are two world wild problems. In order to meet the increasing demand on the performance of internal combustion engine and satisfy the more and more restricted emission regulations, the power, reliability, life cycle, emissions and fuel economy in IC engine need to be further improved. In order to meet the energy requirements, there has been growing interest in alternative fuels like biodiesels, methyl alcohol, ethyl alcohol, biogas, hydrogen and producer gas to provide a suitable fuel substitute for internal combustion engines. Biogas has been a major source of energy and it is also a renewable source of energy. The biogas is easily developed under specific climatic and socio-economic conditions and the cost of production of biogas is very low. Also 60-80% methane gas is present in the biogas; hence we can use the biogas as a fuel in the SI engine.

II. NEED FOR ANALYSIS

Air/fuel ratio exerts a large influence on exhaust emission and fuel economy in IC engine. With increasing demand for high fuel efficiency and low emission, the need to supply the engine cylinders with a well-defined mixture under entire range of operation from no load to full load condition 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. But the conventional carburettors are especially designed and developed for liquid fuels like gasoline. Their main functions of conventional carburetors are carburetion and mixing the fuel with air properly apart from acceleration. But biogas being a gaseous fuel requires the intake system only for mixing the fuel with air properly.

III. DESIGN OF INTAKE SYSTEM

The basic function of carburetor is to provide required air fuel ratios at all loads and speeds. To achieve this function, throat diameter and the jet diameter must be calculated with most care. Venturi type of Biogas mixer was designed and fabricated for selected Hero Honda Engine. A mixer is capable for providing a stoichiometric air fuel ratio for overall operating conditions of the engine to operate.
smoothly. The mixing device has to ensure the provision of a constant air/fuel ratio irrespective of the actual amount sucked into the engine, irrespective of the butterfly valve position. This is achieved by adequate design of the mixing device, whether a venturi mixer or a suction-pressure controlled mixing valve.

A suitable mixture for a biogas engine should be a venturi with the accelerator cone being tapered as a curve of suitable radius and the diffuser cone angle. The biogas is fed into the venturi through a single opening at throat portion. The simple slider is attached to the throat for controlling the fuel flow which is operated as the accelerating device. Venturi mixers utilize the velocity increase and subsequent pressure reduction in a flow through a tube with a contraction. The pressure at the smallest cross-section area is a function of the air velocity, hence the air volume Fuel gas enters and mixes with the airstream at the smallest cross-section (the bottleneck).

An almost constant air/fuel ratio is thus achieved. The cross section area of biogas entrance, the diameter of the biogas entrance to be selected such that the engine performance will be optimum. With this information, an intake system or a mixer comprising of basic venturi is designed as shown in figure. The basic venturi model and the designed assembly of the intake system is given as fallows,

\[ P_2 - \text{Pressure at venturi throat} = P_{2g}, \]
\[ V_1 & V_2 - \text{Velocities at venturi inlet & throat resp.,} \]
\[ \rho_a & \rho_g - \text{Densities of air & biogas= 1.2629 & 1.16 resp.,} \]
\[ P_{1g} - \text{Gas pressure at inlet} = P_{atm} = 101337.3 \text{ N/m}^2, \]
\[ V_{1g} - \text{Gas velocity at inlet} = 0, \]
\[ V_{2g} - \text{Gas velocity at throat,} \]
\[ A_g - \text{Area of gas passage,} \]
\[ d_1 & d_2 - \text{diameters of gas entrance in mm,} \]
\[ m_g & m_a - \text{mass of gas & air resp. in kg,} \]

The \( d_1 \) is the outer diameter which is constant i.e. 6.50 mm and the value of \( d_2 \) changes as per the engine speed. Due to the accelerating device the values of \( d_2 \) are 5.79mm, 5.65mm, 5.51, 5.09mm, 4.82, 4.45mm, 2.68mm, 2.16mm resp. as the speed varies from 1000rpm to 8000rpm.

IV. SOFTWARE MODELLING AND ANALYSING OF VENTURI SECTION:

The software “AutoCAD2011”, “CATIA V5R16” and “ANSYS CFX and CFD-Post” are used for drafting, modeling and analyzing the intake system respectively. The model of the venturi is given as,
CFD Stands for Computational Fluid Dynamics. It is a numerical tool to solve the equations of Fluid Dynamics by suitable methods which can capture the essential physics of the fluid. The numerical schemes that are used for discretization of the equilibrium of equations for fluid, i.e. the Navier-Stokes equations can be one out of Finite Difference Method, Finite Volume Method or Finite Element Method. The general purpose CFD software ANSYS CFX and CFD-Post is used to analyze performance of designs. ANSYS CFX and CFD-Post are supported in Release 12.0 of ANSYS Workbench, which is built on a new framework while leveraging the strength of ANSYS core applications, solvers, and associated tools with a new workflow and simulation project management capability.

After making model for analysis the part where the fluid comes in contact of venturi only those parts have to be taken for analyzing purpose. In this paper the analysis of air and biogas mixture at different speed i.e. 1000rpm, 3000rpm, 5000rpm and 7000rpm are done. While making all the procedure of analysis for air and biogas fluid the contours of Static pressure, Velocity, Streamlines and kinetic energy are given as fallows,

V. RESULTS

From this analysis we got the flow related values such as pressure, velocity. The results for model of the intake system which is made and manufactured for the SI Engine at N=1000rpm, 3000 rpm, 5000rpm and 7000rpm have been found in the following table,
TABLE 1. RESULTS OF INTAKE SYSTEM FOR CFD ANALYSIS

<table>
<thead>
<tr>
<th>N rpm</th>
<th>P2-P1</th>
<th>V1</th>
<th>V2</th>
<th>V2g</th>
<th>3 D Streamline Velocity m/s</th>
<th>Turbulence KE m²/s²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>-25.84</td>
<td>2</td>
<td>21.6</td>
<td>18</td>
<td>16.3</td>
<td>0.08</td>
</tr>
<tr>
<td>3000</td>
<td>-205.66</td>
<td>6</td>
<td>30.4</td>
<td>24</td>
<td>29.7</td>
<td>0.71</td>
</tr>
<tr>
<td>5000</td>
<td>-400.966</td>
<td>11</td>
<td>33.1</td>
<td>25</td>
<td>41.2</td>
<td>3.56</td>
</tr>
<tr>
<td>7000</td>
<td>-1007.76</td>
<td>16</td>
<td>34.4</td>
<td>25</td>
<td>68.7</td>
<td>6.34</td>
</tr>
</tbody>
</table>

By using above result from software and the following equations the remaining terms have been found. The sample calculations are as,

\[ m_{a} = \rho_{a} A_{a} V_{2g} \text{ (act)} \]  
\[ Q = A_{1} V \]  
\[ m_{a} = \rho_{a} Q \]  
\[ BP = m \times \eta \times CV \]  

The result table by calculating all values is given in the following table,

TABLE 2. RESULT TABLE BY CALCULATION

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>N rpm</th>
<th>Q (x10⁻³ m³/s)</th>
<th>m_a (x10⁻⁴ kg/s)</th>
<th>m_g (x10⁻⁴ kg/s)</th>
<th>BP (KW)</th>
<th>T (Nm)</th>
<th>A/F Ratio</th>
<th>bsfc (gm/kWhr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1000</td>
<td>1.132</td>
<td>1.42</td>
<td>14.3</td>
<td>0.96</td>
<td>9.23</td>
<td>10.1:1</td>
<td>528.60</td>
</tr>
<tr>
<td>2</td>
<td>3000</td>
<td>3.366</td>
<td>2.59</td>
<td>42.51</td>
<td>1.76</td>
<td>5.61</td>
<td>16.4:1</td>
<td>528.64</td>
</tr>
<tr>
<td>3</td>
<td>5000</td>
<td>5.609</td>
<td>4.06</td>
<td>70.84</td>
<td>2.76</td>
<td>5.28</td>
<td>17.4:1</td>
<td>528.63</td>
</tr>
<tr>
<td>4</td>
<td>7000</td>
<td>7.853</td>
<td>7.83</td>
<td>99.18</td>
<td>5.33</td>
<td>7.27</td>
<td>12.7:1</td>
<td>528.63</td>
</tr>
</tbody>
</table>

From this result table the break power and the torque values are calculated and also the air/fuel ratio and bsfc calculated.

VI. CONCLUSION:

The study has demonstrated the possibility of implementation flow management strategy in improving the biogas engine performances, through a system called advanced intake system. This approach is simpler and cheaper compared to improvement on combustion chamber. The research provided an example how the flow management strategy may improve the engine performance without major modification. It is shown in the study that the intake system is capable in increasing the engine performance. The combination of venturi with accelerating device is produced well effect of engine. The break power at the speed 1000rpm, 3000rpm, 5000rpm and 7000rpm are 0.96kW, 1.7kW, and 2.7kW, 5.3kW resp. which shows that the analysis part is concluded. Besides producing cleaner emission, the biogas operation also reduces operational cost on the vehicle. It promises a green and sustainable source of energy. In the overall, the study has provided a simpler, cheaper and effective alternative to improve the biogas engine performance by implementing a pressurized and turbulent mixture proper A/F ratio.
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