Investigation on Biogas Operated Intake Device

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Abstract— One of the major problems for the successful application of biogas as a motor fuel for SI (Spark Ignition) engines are the modifications that are required into the engine as well as intake system. To overcome this problem, a new intake device has to design. With the use of this new intake device, the engine will be effectively run on biogas. Intake system for petrol operated SI engine is an combination of number of devices like Air cleaning device, Fuel hoses, Air/Fuel mixing device and Intake manifold. For safe, clean, and reliable operation of combustion devices depends to a large degree on the exact control of the fuel/air mixing process prior to ignition. This intake system is not directly used for biogas operated SI engine because the properties of biogas and petrol are different. For that purpose a new intake device will be designed to mix the air/ fuel in proper proportion for safe and clean burning of mixture and better performance of biogas operated SI engine. In that Intake Device inlet diameter remains constant while throat diameter, convergent angle, gas hole diameter and Number of holes are varied. This device has a better control on quantity of air and fuel (Biogas) which is coming into the mixing device, quantity of air and Fuel (biogas) has been controlled with the help of accelerating device it is an combination of many parts but there are two main parts which are more useful for controlling air and Fuel are piston valve and jet needle. The aim of this study is to optimize the throat diameter of intake device, number of gas holes and proper mixing of charge by using control device before the combustion process.
Key words: Biogas; Intake Device; SI Engine

I. Introduction

All kinds of vehicle engines work with fuels produced from petroleum. However, petroleum stocks in the world are limited and expected to be exhausted in about 41 years. Limited energy sources warn of a potential lack of energy in the future. Depletion of fossil fuels and environmental considerations has led engineers and scientists to anticipate the need to develop a clean, renewable and sustainable energy device [3]. The renewable sources such as hydro, wind, solar and biomass are gaining more and more importance in terms of research and development as well as implemented devices. 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 [1, 4]. To overcome the problem of limited source of petrol, biogas can be used as a fuel for the petrol engine.

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. It is widely used in rural communities in the developing countries to serve energy needs for cooking and for limited industrial use. Biogas can also be used as an alternative fuel for internal combustion engines like SI engines. To run the SI engine on biogas some modifications are required to be done in engine device as well as intake device. The strong reason behind need of modification in SI engine to suit for biogas is that petrol and biogas fuel properties are not identical. Hence the SI engine without modification will not perform optimum on biogas fuel. [2].

Therefore the study proposes to design the modified intake device for biogas operated SI engine. The carburetor is to be redesigned to cope up with the problem and be able to use a biogas as a fuel by volume.

II. Literature review

1) Mardani.2004 developed the intake device for improvement of performance of compressed natural gas spark ignition engine. Also he was improves the flow strategy in the intake device of the engine to produce better Compressed Natural Gas engine performance. Three components were studied, designed, simulated, developed, tested and validated in this research. The components are: the mixer, swirl device and fuel cooler device. The work included design and fabrication of the engine test rig, the CNG fuel cooling device, fitting of instrumentation and measurement device for the performance testing of both gasoline and CNG modes. The overall improvement on engine performance of power and torque was about 11% and 13 % compared to the original mixture.
2) Arali et al. 2011design and analyse the fuel intake device for biogas operated spark ignition engine. Improving the biogas engine performance by implementing the pressurised turbulent flow,due to this pressurised flow the volume of flow increase. This causes improve the volumetric efficiency and the turbulence will increase the homogeneity of mixture also improve the flame propogation speed. They focuses on the design and analysis of the fuel intake device as economical devices without major modification.
3) Yuksel et al. 2003 designed the intake device for ethanol-gasoline blend as a fuel in SI engine. By using ethanol–gasoline blend, the availability analysis of a spark-ignition engine was experimentally investigated. Sixty percent ethanol and fourty percent gasoline blend was exploited to test the performance, the fuel consumption, and the exhaust emissions. It had been found that such type of ethanol-gasoline blends have some advantages over gasoline, such as better anti-knock characteristics and reduction of CO and UHC emissions.
   In the study, the carburetor was redesigned to solve the phase problems of fuel and be able to use a 60% alcohol–gasoline blend by volume. Carter type of carburetor had been replaced and made a special type of carburetor which was having two float chambers, one for ethanol and other for gasoline fuel.

As a result of this study, it is seen that a new dual fuel device could be serviceable by making simple modifications on the carburetor and these modifications would not cause complications in the carburetor device.

4) Phan Minh Duc et al.2007 study and experimental investigation of a small IDI biogas premixed charge diesel dual fuelled CI engine used in agricultural applications. Engine performance, diesel fuel substitution, energy consumption and long term use have been concerned. The attained results show that biogas–diesel dual fuelling of this engine revealed almost no deterioration in engine performance but lower energy conversion efficiency which was offset by the reduced fuel cost of biogas over diesel. The long term use of this engine with biogas–diesel dual fuelling is feasible with some considerations.
5) Banapurmath et al. 2008 made comparative performance studies of a 4-stroke CI engine operated on dual fuel mode with producer gas and Honge oil and its methyl ester (HOME) with and without carburetor In order to meet the energy requirements they found that there has been growing interest in alternative fuels like biodiesels, methyl alcohol, ethyl alcohol, biogas, hydrogen and producer gas to provide a suitable diesel oil substitute for internal combustion engines. They use biomass energy for CI engine, solid biomass can be converted into a mixture of combustible gases, and subsequently utilized for combustion in a CI engine.
6) Pikunas et al. 2003 made study on influence of composition of gasoline – ethanol blends on parameters of internal combustion engines also they investigate experimentally and compare the engine performance and pollutant emission of a SI engine using ethanol–gasoline blended fuel and pure gasoline. They found that the heating value of blended fuel increases or decreases with percentage of ethanol added to it, when ethanol–gasoline blended fuel is used, the engine power and specific fuel consumption of the engine slightly increase CO emission decreases dramatically as a result of the leaning effect caused by the ethanol addition HC emission decreases in some engine working conditions; and CO_2 emission increases because of the improved combustion.
7) LimSoo King et al. 2014 can use gasoline –ethanol blends for internal combustion engine and he tested various percentage of ethanol blends for various compression ratios for example 10%, 20%, 30% and 40% ethanol of blended fuels in a variable-compression-ratio engine. After that study they found that the increase of ethanol content increases the octane number, but decreases the heating value. The 10% addition of ethanol had the most obvious effect on increasing the octane number. Under various compression ratios of engine, the optimum blend rate was found to be 10% ethanol with 90% gasoline.
8) Sachin Singla et al. 2015 studied for a better performance of an internal combustion engine, design of intake manifold is one of the important factor. It is required that equal mass of air fuel mixture is delivered to each cylinder of the engine. Unequal distribution of charge reduces the efficiency of the engine. Presented study aims at the design modification of the intake manifold so that almost equal velocity can be obtained at the end of each runner. For the study purpose Intake manifold of Maruti Wagnor was used. Experimental study was conducted on the manifold and variation in outlet velocity and outlet pressure was recorded at different inlet velocities. Further, three dimensional drawing of the intake manifold was made and CFD simulation was conducted using ANSYS FLUENT. Two models were studied by making some modifications in the actual manifold and thus an improved manifold design was suggested. Results show that nearly equal velocity was obtained at all the runner outlet and flow velocity at outlet 1 increased by 16%, and velocity in other outlets improved by approximately 5% to 7% as compared to actual model.

III. PROBLEM FORMATIOM

The problem under study aims to improve the biogas engine performance by implementing a suitable intake device. In SI engine the air and fuel is mixed in carburetor and the homogenous mixture of air and fuel is then admitted into the combustion chamber. The fuel used for this engine is petrol which is in the form of liquid. Air comes through the air filter and fuel comes from fuel tank into the float chamber of carburetor and gets mixed with each other into throat of carburetor. This Inlate Device is specially designed for the stable liquid phase fuels. If it is need for fuels like biogas, it cannot be effectively used for the biogas. The major problem with the biogas as a fuel for SI engine is phase difference, the biogas exists in the form of gaseous phase. Besides, biogas is required to be stored at high pressure in the tank and when high pressure biogas comes to the intake manifold large amount of fuel is entered into the combustion chamber due to high pressure. So as to overcome these problems, the intake device is needed to be designed for biogas fuel.

A. Problem Definition

An intake device is to be designed and analyzed for biogas operated SI engine. For the same, analytical and computational approaches are to be used and optimum results are to be found out. From the results the optimized intake device is to be designed for biogas operated engine.

IV. OBJECTIVE

- To design analytically the intake device and fluid flow for biogas operated SI engine.
- To prepare CAD models of designed intake device, using suitable CAD modeling software
- To analyze computationally the CAD models of intake device, using suitable CFD package.
- To compare the results from analytical and computational findings for optimum results.
- To optimize of the intake device for biogas operated SI engine.

V. PLAN OF WORK

The project work is organized as follow

A. Introduction

This includes the brief introduction of dissertation work which covers introduction of previous work, relevance, need of intake device design, proposed work, objectives of study, expected outcomes and methodology and organization of dissertation work.

B. Literature Survey

This includes literature survey and theoretical study of SI engine terms, engine performance parameters, biogas as a fuel for SI engine, intake device and intake system, literature review and findings of literature reviews.

C. Design & Mathematical Analysis of Intake Device

This deals with the actual analytical work carried covering comparison of results with standard design.

D. Modeling & CFD Analysis of Intake Device

This deals with design of intake device, using suitable modeling software and CFD analysis of intake device.

E. Results & Findings

This concludes the dissertation with summery of dissertation, findings and graph of thst results, conclusion of dissertation, limitations due to scope defined and scope of future work.

VI. DESIGN & MATHEMATICAL ANALYSIS OF INTAKE DEVICE

After study of intake device a new intake device with specific dimensions are made with the help of modelling software like CATIA. Analytical design of intake device comprising of design of mixing device, venturi design analysis has been done.

A. Mixing Device (Venturi Mixer)

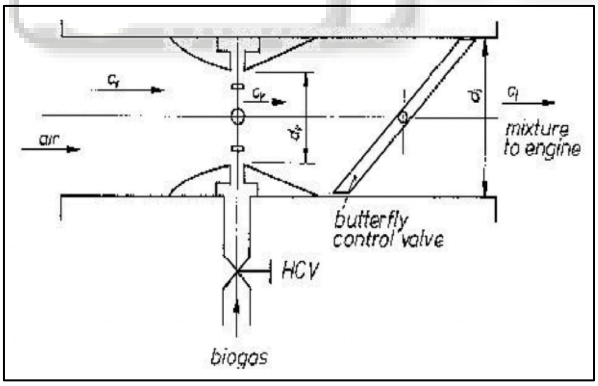

Fig. 6.1: Venturi Mixer with Gas Supply through Several Bores

1) C1 = Velocity at mixer inlet,
2) Cv = Velocity at venture contraction,
3) di = Diameter of mixer/engine inlet,
4) dv = Diameter of venture contraction
5) Ci = Velocity of mixture at engine inlet,
6) dg = Diameter of gas inlet nozzle.

B. Intake Device Design

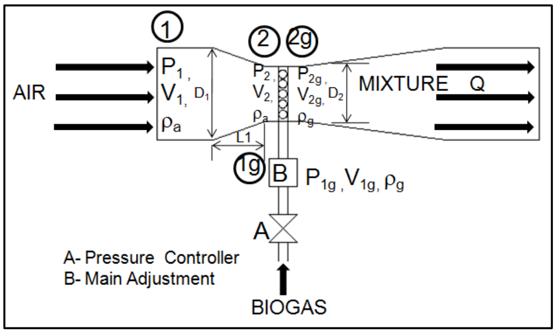

Fig. 6.2: Venturi Mixer with a Single Gas Inlet Nozzle

Notations & their units used in design:
D and L – bore and stroke of engine (m)
η th – Thermal efficiency of engine,
η v- Volumetric efficiency of engine,
N- Speed of engine (rpm),
B.P. – Brale Power (kW),
Q- Discharge of air through venturi,
D1 & D2- Diameters of venturi inlet & throat resp.,
A1 & A2- Areas of venturi inlet & throat resp.,
P1- Pressure at venturi inlet =Patm= N/m2,
P2- Pressure at venturi throat =P2g,
V1 & V2- Velocities at venturi inlet & throat resp.,,
ρ a & ρ g- Densities of air & biogas
P1g- Gas pressure at inlet =Patm= N/m2,
V1-Gas velocity at inlet,
V2g- Gas velocity at throat,
Cd- discharge co-efficient of venturi ,
Datum at inlet Z1= Datum at throat Z2,
Datum of gas at inlet Z1g= Datum of gas at throat Z2g,
Ag- Area of gas passage,
n & d2- Number & diameter of holes for gas entrance resp.,
mg & ma- mass of gas & air resp.,
C.V.g- Calorific value of biogas= kJ/kg, [2, 10]

VII. MODELING & CFD ANALYSIS OF INTAKE DEV

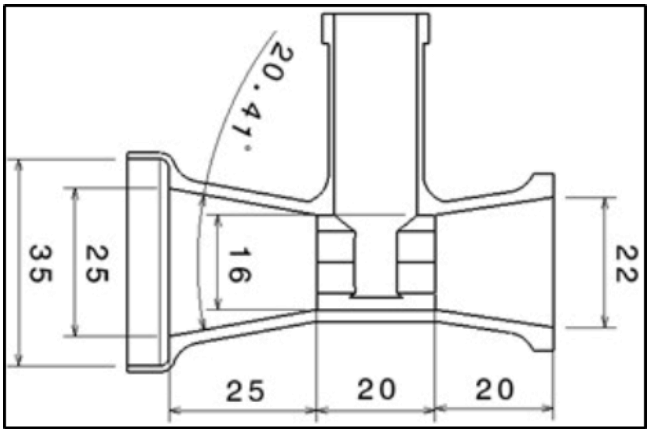

Fig. 7.1: Actual Intake Device

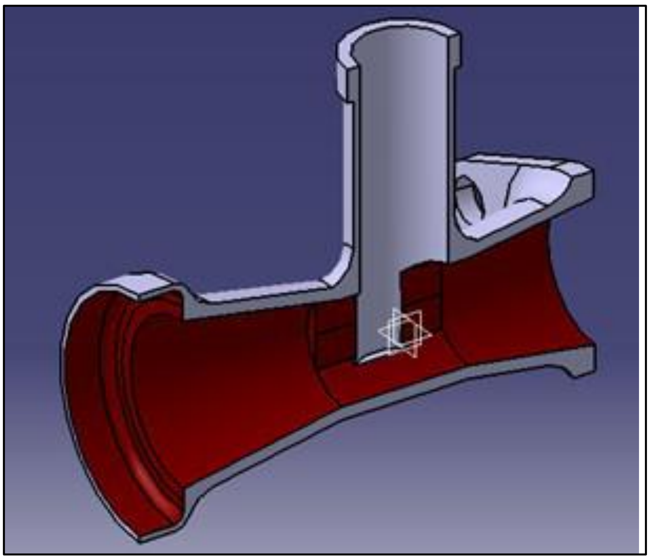

Fig. 7.2: CAD Model of Final Intake Device

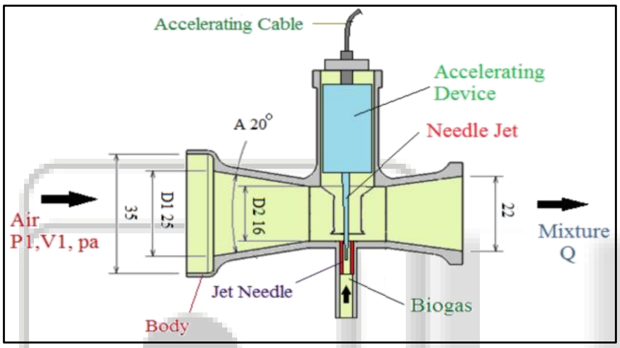

Fig.7.3: Actual Intake Device with Dimensions

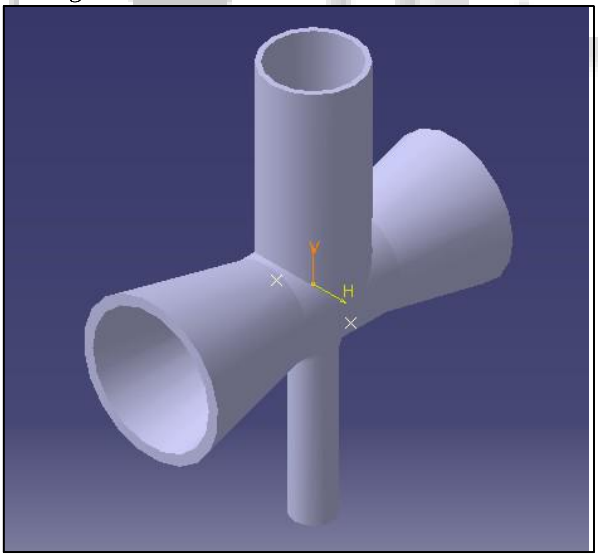

Fig. 7.4: CFD Domain

A. Methods of CFD Analysis

CFD study for computational fluid dynamics is the numerical tool to solve the equations of fluid dynamics by suitable methods which can compute the essential physics of the fluid. The numerical schemes that are used for discretization of the equilibrium of the equations for fluid, which is Navier-Stokes equations, can be one of the following.

a) Finite Difference Method
b) Finite Volume Method
c) Finite Element Method

VIII. Conclusion

The research 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 & 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 throat diameter 16 mm, convergent angle 200, hole diameter 3 mm and one gas hole produced as much as 8 to 15 % increase in power output of few other combinations. The overall implementation of this advanced intake system is proven to improve the power output 11.5% and torque 15.5 % compared to average values of the same of other combination. However, this figure, still approximately 15 % lower compared to that of gasoline mode.

In the overall, the study has provided a simpler, cheaper and effective alternative to improve the biogas engine performance by implementing a proper pressurized and turbulent mixture of A/F ratio.

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