Design and Development of Fuel Vaporizer for HCCI Engine

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Abstract— the world is becoming more enthusiastic about exploring the Automobile. Researchers all over the world are developing new technologies every single day that can help us to look far beyond in Automobile. We require devices which can help us to look faraway objects in Automobile. The idea of Fuel vaporizer has been around for many year. There had to be a way to get a Fuel vapor and air mix into place, for combustion, in converted steam engines. There are over 650 version of fuel vaporizer on the books. We all know that vaporizer in many variations, but have the design and development that if the speed of the engine is increased, the specific consumption is also increases. A fuel vaporizer unit for HCCI Engine includes a heat exchange medium. Vaporizer enclosure is provided with an electric Heater for heating the heat exchange medium during cold weather to assist in heating the fuel vaporizer to the time the engine reaches operating temperature. After Design the fuel vaporizer, we are analyzing to the CFD analysis of Fuel vaporizer, so the use of the fuel vaporizer according to the design, a quick & through combustion is attains & this at high speed as well. This system can there by improve fuel Economy & reduced Emissions over Vehicle Operating Entirely from Liquid Fuel. This system also offers improved safety by not allowing Fuel vapor & Fresh air to mix prior to entering the intake manifold of the engine.

Key words: Diesel Fuel Vapors, Fuel Vaporizer, Air-Fuel Mixture, Vapor Combustion, Reduced Emission

NOMENCLATURE

- a, Heat transfer surface area per unit length of tubing, for internally finned tubing (a,), for smooth tube (n,)
- A, Heat transfer surface area [m'] ;
- A_m, Mean Conduction surface area (M^2);
- C_p, Specific heat (kJ kg-1 K^{-1})
- D, Tube outer diameter (mm)
- Di, Tube inside diameter (mm)
- FN, Constant flow area criterion
- G, Mass velocity [kg m^{-1}
- h, Heat transfer coefficient [W m-'K-l];
- k, Thermal conductivity [W m-' K-l] ;
- L, Llength of flow path in heat exchanger (m)
- LMTD, Log mean temperature difference (K)
- N, Number of tubes in each pass of heat exchanger
- NTU, Number of heat transfer units;
- /IP, Pressure drop [Pa]
- P, Pumping power [W]
- Pr, Prandtl number ;
- Q, Heat transfer rate (w)
- Re, Reynolds number
- R_f, Fouling factor (m^2kW^{-1})
- T, Tube wall thickness [m];
- ΔT_i, Inlet temperature difference between hot and cold streams [K]
- u, Flow velocity [m SC']
- U, Overall heat transfer coefficient ($Wm^{-2}K^{-1}$)
- ε , Heat exchanger thermal effectiveness;
- v, Kinematic viscosity [m2 s-l].

I. INTRODUCTION

In a CI engine, the charge is heterogeneous leading to non-uniform combustion and hence pollutants such as PM and NOx are emitted in large portions. Hence a solution is required to reduce these pollutants [1]. In HCCI technology, the homogeneous mixture of fuel and air are compressed to the point of self-ignition. Similar to the gasoline engines, HCCI engines also premixes the fuel-in air charge to prepare a homogeneous mixture. HCCI engines inject the air-fuel mixture during the intake stroke. Even though HCCI engines uses the charge similar to that of an SI engine, the combustion process is similar to that of a CI engine where temperature and density of the charge raises due to compression and on reaching the self-ignition temperature the charge combusts. In HCCI engines the process of combustion is spontaneous and all the charge within the combustion chamber burns simultaneously unlike the CI engines. HCCI approach enables the engine to have a high compression ratio and rapidly burn the air-fuel mixture near TDC which results in high thermal efficiency. HCCI technology can reduce the fuel consumption by 16-32% .The indicated results show noticeable improvement in the charge homogeneity if the external mixture preparation technique is used.

II. FUEL VAPORIZER

Fuel Vaporizer is an external device consisting of heaters to vaporize the pilot fuel (diesel) so that it mixes homogeneously with air thereby forming a homogeneous mixture leading to uniform combustion.

Diesel fuel has very low volatility and is highly viscous.

These two properties are the main drawbacks leading to formation of heterogeneous air-fuel mixture .In order to reduce the viscosity and increase the volatility of diesel, it has to be pre-heated to a certain temperature or vaporized so that vapors can mix easily with air leading to the formation of homogeneous mixture and in turn leading to homogeneous combustion.

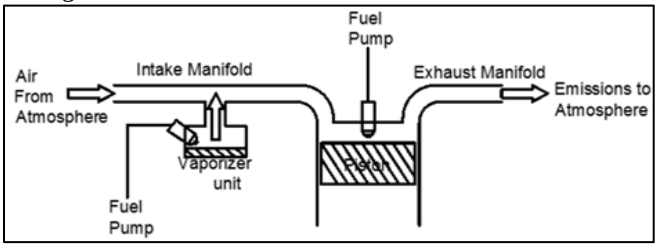

Fig. 1: Fuel Vaporizer System

III. DESIGN STEP OF FUEL VAPORIZER

Before going into the actual design procedure of fuel vaporizer for HCCI Engine.

1) Design process step
2) Identify application (temperature , heat load , mass flow rate etc.)
3) Decide on construction type
4) Evaluate L.M.T.D , q and F
5) Determine dimensions
6) Evaluate heat transfer co-efficient on hot side
7) Evaluate heat transfer co-efficient on cold side
8) Determine over all heat transfer co-efficient
9) Determine dimension – iterate
10) Check power consumption

A. Basic Equation

1) Mass flow rate of air

= Area of cross section of the tube * velocity of air

2) Evaluate L.M.T.D, q and f

Here,

$$\Delta T_{1}= Th_i - Th_0$$

$$\Delta T_2= Th_i - Th_0$$

$$\Delta Tl_m=\frac{\Delta T1-\Delta T2}{\ln *\frac{\Delta T2}{\Delta T1}} (^{\cdot}c)$$

Correction factor (f):

$$P=\frac{to-ti}{Ti-ti},\ R=\frac{Ti-To}{to-Ti},\ F=P/R$$

F_t normally should be greater than 0.75 for the steady operation of the exchangers. Otherwise it is required to increase the number of passes to obtain higher F_t values.

3) Determine Fuel vaporizer dimension

Select tube material, decide the tube diameter (ID= id, OD = o d), its wall thickness (in terms of BWG or SWG) and tube length (L). Calculate the number of tubes (N_t)

Heat transfer area (A) = $N_T(\pi D_O)L$

– Assume tube Diameter and length Outer Diameter (D_O) = 22 mm, Inner Diameter (D_I) = 19 mm
– The heating surface area for a tube also equals (π D_I L) Where D_i and L represent the inside take diameter and length respectively

$$\text{Length of Tube (L)} = \frac{A}{U\theta m}$$

4) Determine over all heat transfer co-efficient

$$Q = U*A*\Delta T_M$$

Where,

Q= heat load
U=Over all heat transfer coefficient
A= Heat transfer area

Assume a reasonable value of overall heat transfer coefficient (U). The value of U with respect to the process hot and cold fluids can be taken from the books.

So, here the overall heat transfer coefficient of heater is 10-20 BTU/hr-ft^2-f

5) Calculate pressure drop (ΔP_s)

Pressure drop for flow across the tube bundle (frictional loss) (PΔs) and (ii) return loss (PΔrs) due to change of direction of fluid. Total pressure drop:

$$\Delta P_s = \Delta Ps + \Delta P_{rs}$$

With the help of above equations, various parameters were found out. The 3-D model of Fuel vaporizer was made in CREO 2.0.

Below Figure (2) shows the view of Fuel vaporizer and cross section views.

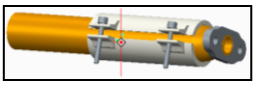

Fig. 2: 3D View of fuel vaporizer

IV. EXPERIMENTAL SETUP

It consists of a fuel introduction system, fuel vaporizer and engine.

A. Fuel Vaporizer

A fuel vaporizer is a device consisting of heaters that are used to vaporize the diesel. The main purpose of the vaporizer is to vaporize the diesel fuel so that it mixes homogeneously with air to obtain better combustion characteristics to attain HCCI. The fuel vaporizer comprises of a rod heater, copper coils inside which the fuel flows, two band heaters that provides additional heating to completely vaporize all the pilot fuel(diesel) entering the copper coils.

S. No.	Component used	Specification
1	Copper coil	Dia=3mm
2	Band heater	250w
3	Insulating material	Asbestos rope
4	Temp. Controller	250·c

Table 1: Fuel vaporizer specification

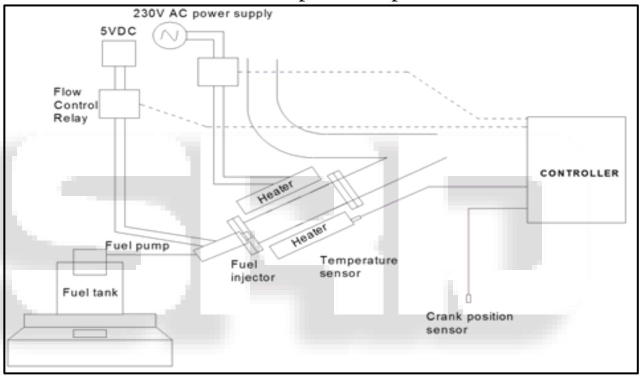

Fig. 3: Block diagram of fuel vaporizer

1) Engine

The fabricated fuel vaporizer is coupled directly to the air intake manifold of the naturally aspirated HCCI engine.

Engine	Kirloskar (AVI)
Dynamometer	Eddy Current , Water Cooled
Bore	87.5
Stroke	110
Displacement	661
Compression Ratio	17.5
R.P.M.	1500
H.P.	5.2

Table 2: Engine test specification

Fig. 4: Test Engine

V. EXPERIMENTATION PROCEDURE

Initially the conventional engine (CI) is started normally. It is allowed to run for some time to attain steady state condition. Then the pilot fuel (diesel) is allowed to pass through the vaporizer .When the engine attains steady state, the quantity of fuel from the main fuel pump is adjusted and the engine is made to run mainly on the fuel vapors supplied from the vaporizer. In short, the engine is started in CI mode and is shifted to HCCI mode.

VI. RESULTS AND DISCUSSIONS

The engine was tested for its performance by varying the load and the results are illustrated below.

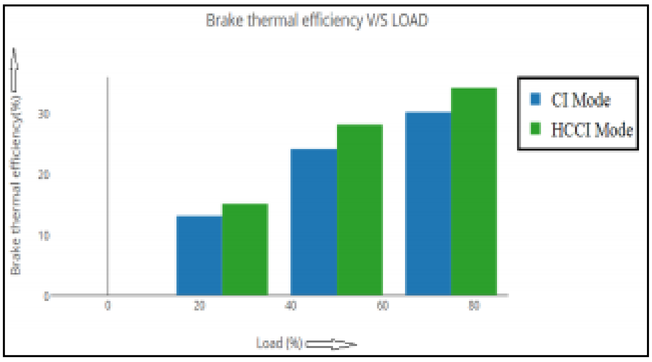

Fig. 5: BTE vs Load

- CI Mode: Conventional engine without fuel vaporizer
- HCCI Mode: Conventional engine with fuel vaporizer From the Figure-5, it is evident that BTE has increased considerably on coupling with the fuel vaporizer.

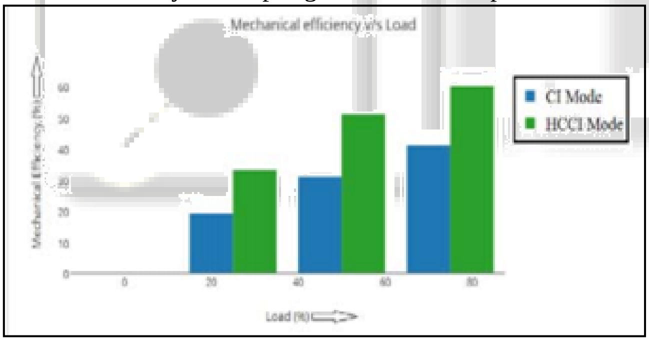

Fig. 6: Mechanical Efficiency vs load\

- CI Mode: Conventional engine without fuel vaporizer
- HCCI Mode: Conventional engine with fuel vaporizer From Fig 6, it is evident that the mechanical efficiency increases with load on coupling the vaporizer.

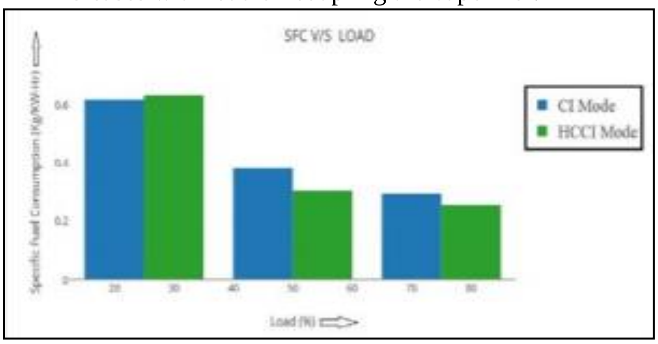

Fig. 7: SFC vs load

- CI Mode: Conventional engine without fuel vaporizer
- HCCI Mode: Conventional engine with fuel vaporizer From Fig 7 it is evident that the SFC decreases on coupling with the fuel vaporizer.

VII. CONCLUSIONS

In the present work, combustion characteristics of HCCI using pilot fuel (diesel) vapors were investigated for different values of engine load. By using diesel vapors the air fuel mixture obtained is homogeneous and this is the best of all methods to obtain a homogeneous mixture. However the experiment was conducted to mainly determine the performance characteristics and no effort was done to determine the concentration of pollutants in the exhaust.

On the vaporizer to the conventional CI engine the following results were obtained:

- Brake thermal efficiency has been increased by 3-7%.
- b. Mechanical Efficiency has been increased by 15-20%.
- Specific Fuel Consumption (SFC) has been reduced by 10-15%.

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