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A Review Paper Based On the Investigation of Catalytic Fuel Reformer for Diesel Engine

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***Abstract:*-- Diminishing of fossil fuel sources, steep rise in fuel price, growing of demand and environmental hazards shove the worldwide researcher's to seek the possible alternative fuels for internal combustion engines. It is necessary to reduce consumption of the fossil fuel due to negative effects on environment. Particularly search of suitable alternative fuel for compression ignition engine is very important because of their wide application. Therefore scientist and researchers all over the world working hard to utilize the new technologies that allowed the re-cyclic and reuse of the waste material as a source of energy.**

In this research work, a catalytic fuel reformer is designed and fabricated with suitable size. The waste engine oil is selected as an alternate fuel for the compression ignition engine. Cracking the waste engine oil in the catalytic fuel reformer, the catalyst such as alumina, fly ash, red mud and zeolite 4A are selected. The waste engine oil has to be cracked with each catalyst individually.

Index Terms:- Diesel engine, reformers and catalysts

1. INTRODUCTION

Compression ignition engines plays a vital role in modern transportation and power generation sector owing to their higher thermal efficiency, excellent fuel economy and low emissions of unburned hydrocarbon and carbon monoxide (CO). Nonetheless, these engines greatly affect the environmental aspects because of their high NOx and particulate matter emission. Moreover, the ever-quenching petroleum reserves and stringent emission norms followed worldwide nowadays has put serious doubt on the usability of diesel engine in future. Therefore, a lot of the research is now concentrated towards finding an alternative fuel source with better performance and emission characteristics.

In the method of utilizing the alternative fuel in the compression ignition engine, dual fuel mode is one of the best methods available. In the dual fuel mode for compression ignition engines, gaseous high-octane fuel is usually inducted with the intake air through the inlet manifold (giving a largely premixed fuel–air mixture). The gaseous mixture is compressed as in a conventional diesel engine. A small amount of liquid high-cetane fuel, which is injected near the end of the compression stroke, using pilot, initiates the combustion of the gas–air mixture. The gaseous fuel, which acts as the primary fuel, comprises nearly 90% of the total fuel used. Commonly used gaseous fuels for dual fuelling include natural gas (NG), biogas, producer gas, liquefied petroleum gas (LPG), hydrogen and alcohols. NG has a high octane number and therefore it is suitable for engines with relatively high compression ratio. As it is composed primarily of methane, homogeneous air fuel mixtures formed in such dual fuel mode can be ignited and burned over a wide flammability range.

2. REVIEW

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3. PRESENT INVESTIGATION

Many researchers have attempted to produce alternative fuel sources which is similar the properties and performance of petroleum based fuels. The alternative fuel sources to petroleum should be technically viable, economically competitive, environmentally acceptable and easily usable. There are several types of waste fuel sources such as vegetable oils, trees, plastics, tires, etc., which are known as alternative fuel sources. However, they cannot be used as engine fuel without purification and being converted into the required fuel to be used since they have many adverse effects on living beings and the environment.

4. SURVEY Of DUAL FUEL DIESEL ENGINE

Nirendra N. Mustafi et al. investigated the influence of dual-fuel combustion on the performance and exhaust emissions of a DI diesel engine fueled with natural gas (NG) and biogas (BG). The engine was operated at a constant speed of 1750 rpm and at two different loads: low (∼3 Nm) and high (∼28 Nm), which were about 10% and 85% respectively of the torque generated in the engine at 1800 rpm. In this work study, the pressure and the rate of heat manufactured were evaluated experimentally in order to study the combustion characteristics and their effects on exhaust emissions consist of particulate matter for single-fuel (diesel) and dual fuel combustion modes. In the dual fuel mode, the peak cylinder pressure of the engine was found to be similar to diesel at 75% of the rated output of the engine. About 28–30% greater maximum net heat release rates were obtained for NG and biogas fueling respectively compared to diesel fueling.

5. WASTE ENGINE OIL

OrhanArpa et al., investigated the desulfurization of diesel-like fuel (DLF) produced from waste lubrication oil, and the effects of desulfurized fuel on engine performance and emissions. They produced the DLF by using a fuel production system and applying the pyrolitic distillation method. After generating the DLF, oxidative desulfurization proccess was applied at 50 oC temperature in order to decrease the amount of sulfur in the DLF. They named it as a low sulfur diesel-like fuel (LSDLF). The LSDLF and a commercial diesel fuel were used in a diesel engine to examine their effects on engine performance and emission parameters. The performance and emission test results is shows that torque, mean effective pressure and brake thermal efficiency for the LSDLF were slightly higher while brake specific fuel consumption, exhaust temperature and emissions of SO_2, CO and NOx appeared to be lower than that of the commercial diesel fuel.

6. CATALYSTS

T. Bhaskar, et al., studied the recycling of waste lubricant oil from the automobile industry to be the best alternative to incineration. The Silica, alumina, silica–alumina consist of iron oxide catalysts were manufactured by the wet impregnation process and used for the desulphurization of waste lubricant oil into fuel oil. The extent of sulfur removal increases in the sequence of Fe/SiO_2-Al_2O_3, Fe/Al_2O_3, Fe/SiO_2 and this might be due to the presence of smaller crystalline size (7.4 nm) of Fe_2O_3 in Fe/SiO_2 catalyst. Gas chromatography with the thermal conductivity detector analysis confirms the availability of of H_2S in gaseous products. In addition, Fe/SiO_2 catalyst facilitated to the formation of lower hydrocarbons by cracking higher hydrocarbons (<C40) present in the waste lubricant oil.

7. METHODOLOGY

Identify the cheaper catalysts for cracking the waste engine oil from useful resources.
Selection of suitable catalysts like alumina, fly ash, red mud and zeolite 4A.
To analyze the characteristics of the pyrolysis gas produced from the catalytic fuel reformer.
Preparation of catalyst pellets.
Alumina and zeolite 4A catalyst are commercially available in the form pellets whereas fly ash and red mud samples are collected and pellets are prepared. The fly ash samples are collected from Neyveli Lignite Corporation, Tamilnadu. The fly ash sample was allowed to the shaker. The shaker had three different sizes of sieves. It took out the core particles present in the fly ash and the powder form of fly ash were collected. The NaOH was added as the bonding material into the sieved fly ash. Then the fly ash was prepared in the shape of pellets. The size of the pellets was approximately 20 to 30 mm diameter. The pellets are subjected into the oven and heated the pellets about 80 oC for the period of one hour. Then the dried pellets were left to cool in the room temperature. The red mud samples were collected from

aluminium plants located in different sites from India and the same procedure is repeated to prepare the red mud catalyst.

Cracking of waste engine oil into useful forms of energy to CI engine by using a catalytic fuel reformer.Waste engine oil has to be cracked with each catalyst individually.

F. The experiment is conducted in two parts.

In the first part of the experiment, the output of the catalytic fuel reformer is condensed using condenser to study the characteristics of the reformed waste engine oil.

In the second part of the experiment, the catalytic fuel reformer is installed with the diesel engine and the output of the catalytic fuel reformer is connected to the intake air manifold of the engineThe temperature of the catalytic fuel reformer is set to 150 oC initially and the engine is run at different load conditions. Then the temperature of the catalytic fuel reformer is set to 300 oC and the same procedure is repeated.

8. REFORMING FUNDAMENTALS

On-board catalytic partial oxidation reformer converts diesel fuel into H_2-rich reformates:

Diesel Fuel + Air → Reformate

$$CH_2 + 0.5 (O_2 + 3.8 N_2) \rightarrow H_2 + CO + 1.9 N_2 + Heat$$

9. TYPES OF REFORMER TECHNOLOGY :

i. Steam methane reforming
ii. Partial oxidation
iii. Auto-thermal reforming
iv. Methanol reforming
v. Catalytic cracking of methane
vi. Ammonia cracking
vii. Novel reformer technologies

i. Steam Methane Reforming :

Catalytic steam reforming of methane is a well recognized, commercially available process for hydrogen production in the United States, most hydrogen today is manufactured via steam reforming of natural gas. Hydrogen production is completed in several steps: steam reforming, water gas shift reaction and hydrogen purification. The steam reforming reaction is endothermic and requires external heat input. Economics favor reactor operation is completed at pressures of 3-25 atmospheres and temperatures of 700°C to 850°C.

$$CH_4 + H_2O \rightarrow CO + 3\ H_2 \quad \Delta h = +206.16 \text{ kJ/mol } CH_4$$

ii. Auto Thermal Reforming :

Auto thermal reformers combine some of the best features of steam reforming and partial oxidation systems. Several companies are manufacturing small auto thermal reformers for converting liquid hydrocarbon fuels to hydrogen in fuel cell systems

In auto thermal reforming a hydrocarbon feed (methane or a liquid fuel) is reacted with both steam and air to produce hydrogen – rich gas. Both the steam reforming and partial oxidation reactions take place. For example, with methane with the right mixture of fuel, air and steam, the partial oxidation reaction supplies all the heat needed to drive the catalyst steam reforming reaction.

$$CH_4 + H_2O \rightarrow CO + 3\ H_2 \quad \Delta h = +206.16 \text{ kJ/mol } CH_4$$

$$CH_4 + \tfrac{1}{2}\ O_2 \rightarrow CO + 2\ H_2 \quad \Delta h° = -36 \text{ MJ/kmol } CH_4$$

iii. Methanol Steam Reformer:

Methanol is liquid fuel that can easily stored and transport as compare to hydrogen. Because it can be readily steam reformed at moderate temperatures (250-350°C), methanol has been used as a fuel for fuel cell vehicles. Experimental fuel cell vehicles with onboard methanol reformers have been demonstrated by Daimler Chrysler, Toyota and Nissan. In addition, small hydrogen production systems based on methanol reforming are in commercial useAlthough these technologies are being developed for fuel processors on board fuel cell vehicles, it has also been suggested that hydrogen are manufactured by steam reforming methanol at refueling stations.

10. DESCRIPTION OF CATALYTIC FUEL REFORMER

The catalytic fuel reformer consists of several components such as fuel tank, control panel, reactor, thermocouple, stirrer, fuel storage tank. The fuel tank is used to supply the waste engine oil into the catalytic fuel reformer. The catalytic fuel reformer has a cylindrical shape with inner diameter of 15 cm and the length of 45 cm. The reactor was designed and fabricated to heat the waste engine oil immersed with the catalyst. It includes an electrical heating unit which can be used to heat the waste engine oil with catalyst upto 1000 oC. The electrical heater panel consists of resistance heater and a voltage control which is used to adjust the heating rate. The heating control is performed by the control panel. The stirrer is used to mix the waste engine oil with catalyst uniformly and also to distribute the temperature uniformly.

11. CATALYST USED IN THE CATALYTIC FUEL REFORMER

11.1. Alumina Catalyst :

Aluminum oxide, Al2O3 is a major engineering material. It is combination of mechanical properties as well as electrical properties leading to a wide range of applications. It has high hardness, excellent dielectric properties, refractoriness and good thermal properties make it the material of choice for a wide range of applications. Aluminum oxide is made in Claus process for converting hydrogen sulfide waste gases into elemental sulfur in refineries. It is necessary of dehydration of alcohols to alkenes. Aluminum oxide serves as a catalyst support for many industrial catalysts, such as those used in hydro-desulfurization and some Ziegler-Natta polymerizations.

11.2. Fly Ash Catalyst :

Coal fly ash is a particulate material produced from the combustion of coal in thermal power plants. Ash contamination poses a serious threat to the environment. The confirmed presence of heavy metals in fly ash their bioactivity and biotoxicology, first of all, their mobility can cause significant environmental problems. Contamination during disposal of fly ash, as well as interaction of fly ash and heavy metals in the environment is very limited

11.3. Red Mud Catalyst :

Red mud is the waste by-product of the Bayer process used to extract pure Al2O3 from bauxite ores for the production of aluminium metal. Disposal of red mud waste is a major issue to the environment, it associates with considerable safety hazards problems like space requirement and pollution created by red mud waste. Red mud mainly contains Fe2O3 and considerable amount of SiO2, Al2O3 or TiO2, hence it is necessary to develop a technology for the recovery of at least some of the important chemicals.

12. FUNCTION OF CATALYTIC FUEL REFORMER

Catalytic fuel reformer is used to crack the waste engine oil into useful energy in the form of gaseous state. The output of the catalytic fuel reformer is connected to the intake air manifold of the engine. The gas produced from the catalytic fuel reformer mixes with the intake air and inducted into the combustion chamber. The temperature and property of the gas enhance complete combustion in the combustion chamber.

Waste engine oil is selected as the alternate fuel to use in the catalytic fuel reformer. The pellet form of catalysts selected to use in the catalytic fuel reformer is alumina, fly ash, red mud and zeolite 4A. The catalytic fuel reformer is performed with each catalyst individually. First the catalytic fuel reformer is filled with catalyst and maintained with a temperature of 150 oC constantly. After the catalytic fuel reformer reaches the temperature of 80 oC, the waste engine oil is allowed to the catalytic fuel reformer gradually. 500 ml of the waste engine oil is used for a cycle to conduct a load test of the engine.

13. EXPERIMENTAL PROCEDURE

The engine was allowed to run with sole diesel at a constant speed of 1500 rpm. During the investigation, the temperature of the lubricating oil and temperature of the engine cooling water were held constant to eliminate their influences on the results. The engine was allowed to run for 15 to 20 minutes to attain study state condition to reach the cooling water temperature of 70°C and lubricating oil temperature of 65°C. Then the following observations were made twice for concordance. It consists of two parts of work. The first part of work is without fuel reformer and the second part of the work is with fuel reformer.

The catalytic fuel reformer has a cylindrical shape with inner diameter of 15 cm and the length of 45 cm. The reactor was designed and fabricated to heat the waste engine oil immersed with the catalyst. It includes an electrical heating unit which can be used to heat the waste engine oil with catalyst upto 1000 oC.

- Exhaust gas temperature, °C
- Measurement of smoke density using AVL smoke meter,
- Measurement of oxide of nitrogen using AVL exhaust gas analyzer,
- Combustion parameters are measured by AVL combustion analyzer
- After completing the experiments with diesel fuel, the experiments were conducted with catalytic fuel reformer with four different phases.

Phase – I : Alumina catalyst
Phase – II : fly ash catalyst
Phase – III : red mud catalyst
Phase – IV : Zeolite 4A catalyst.

For every phase the experiments is conducted with all loads and same procedure is carried out.

14. RESULTS AND DISCUSSIONS

The experimental investigations were conducted using catalytic fuel reformer with four phases. In phase – I alumina is used as catalyst in the fuel reformer, in phase – II fly ash is used as catalyst, in phase – III red mud is used as catalyst and phase – IV zeolite 4A is used as catalyst in the catalytic fuel reformer. The catalytic fuel reformer is connected in a standard DI diesel engine with various brake power at rated speed of 1500 rpm and standard injection timing of 23°bTDC to conduct the experimental investigation. The optimization for each phase was done based on the performance and emission characteristics. In each phase of work various parameters such as smoke density, oxides of nitrogen, hydrocarbon, carbon monoxide and brake thermal efficiency against the brake power of the engine were drawn and compared. It is important to compare the results obtained by with and without catalytic fuel reformer to ascertain performance and emission for DI diesel engine.

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