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ORIGINAL ARTICLE

An experimental study on premixed charge compression ignition-direct ignition engine fueled with ethanol and gasohol

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Abstract This paper investigates the combustion, performance and emission characteristics of a partial Premixed Charge Compression Ignition-Direct Injection (PCCI-DI) Engine with premixed fuels ethanol and gasohol (90% gasoline and 10% ethanol by volume) along with direct injection of diesel fuel into the combustion chamber. The experiments were conducted in a four stroke, naturally aspirated, air cooled, constant speed diesel engine with 20% premixed fuels from no load to full load condition. The addition of premixed fuel enhances the air fuel mixture strength and for that the combustion duration is decreased in dual fuel operation. From this experiment it was observed the 70% and 67% reduction in smoke emission from premixed gasohol and ethanol fuel when compared to neat diesel operation. In addition to that, the oxides of nitrogen emissions were reduced to 30% and 24% for premixed gasohol and ethanol fuel. In particular, premixed gasohol reduces the smoke and oxides of nitrogen emissions more than the ethanol and also, significant increase in brake thermal efficiency was noted in 20% premixed gasohol and ethanol in dual fuel mode, when compared to neat diesel operation.
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1. Introduction

The day to day challenges facing today is the increased emissions which is the environmental challenge. The new combustion concept, namely Homogeneous Charge Compression Ignition (HCCI), has taken the advantage of the working principles of both the Spark Ignition (SI) and Compression Ignition (CI) engines. Here, the mixture preparation is like an SI engine and the combustion is like a CI engine. The HCCI engine operates at nearly constant volume combustion, resulting in high thermal efficiency and improved fuel economy. Lower Oxides of Nitrogen (NOx) could be achieved due to the localized mixture being relatively lean by homogeneous nature [1]. Particulate emission can be reduced significantly due to homogeneous charge combustion. Even though HCCI has the advantage of a high emission reduction potential and improved fuel economy, it has many challenges such as obtaining the homogeneous mixture and controlled auto ignition [2]. Many institutes have already studied HCCI, but

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only a few of them performed experiments using biodiesel as a potential alternative fuel [3].

HCCI is a strategy that has shown the possibility of both lower emissions and lower fuel consumption than SI combustion. However, HCCI combustion can be sensitive to changes in fuel composition. SI engines use a homogeneous air-fuel mixture that is compressed and subsequently ignited by an electric spark. CI engines compress the air charge to a higher level than SI engines and then the fuel is injected into the air, which is hot enough after compression to ignite the fuel. This results in a highly inhomogeneous mixture. It has been shown that an engine can be run using a combination of the SI and CI strategies, by utilizing a homogeneous mixture, but relying on the compression to ignite the mixture. The HCCI concept involves premixing of fuel and air prior to its induction into the cylinder then igniting the fuel–air mixture through the compression process. The combustion occurring in an HCCI engine is fundamentally different from that in an SI or CI engine. HC and CO emissions in HCCI are normally higher than their equivalent of diesel engines. However, reducing HC and CO emissions from HCCI engines is easier than reducing NOx and soot emissions from diesel engines. High HC and CO emissions in HCCI are mainly due to low in-cylinder temperature caused by lean-burn or high-dilution combustion. This can result in incomplete combustion and decrease of post-combustion oxidation rates inside the cylinder. As the charge is made leaner by decreasing fueling or increasing EGR rates, the production of HC and CO is dominated by incomplete bulk-gas reactions.

A lot of researches have been performed in this field [1–10]. However, this concept has major challenges such as combustion initiation and combustion duration control. To overcome these difficulties a lot of work has been carried out in the field of HCCI mode by varying inlet air heating [1], Variable Compression Ratio (VCR) [2] and Variable Valve Actuation (VVA) [9] to alter the effective compression ratio and to trap the residual gases respectively. The Exhaust Gas Recirculation (EGR) rates are also varied to reduce the heat release rate and as a result to control the combustion at higher loads [6]. In addition, the additives were further added to the fuel to boost the physical and chemical properties.

The fuel injection is one of the key parameters to achieve the HCCI mode. The combustion processes that take place inside a diesel engine are essentially dependent on the way in which the fuel is injected into the combustion chamber. The most important criteria are the timing and duration of the injection, the degree of atomization and the distribution of the fuel inside the combustion chamber, the timing of ignition, the mass of fuel injected relative to the crankshaft rotation, and the total amount of fuel injected relative to engine load [10].

An experiment on diesel fuel vaporizer is conducted to prepare the homogeneous diesel vapor air mixture by mounting diesel fuel vaporizer in the intake system. The above investigation reduces the oxides of nitrogen emissions by more than 75% for diesel vapor induction with 10% Exhaust Gas Recirculation compared to the conventional mode of operation [6]. The effects of premixed gasoline fuel and direct injection timing on partial HCCI were analyzed. The results exhibited a significant reduction of oxides of nitrogen and smoke emissions with slight increase in carbon monoxide and unburned hydrocarbon emissions. To overcome this difficulty a premixed PCCI combustion concept is undertaken.

Many different strategies have been formed from this basic idea and they have different names such as Controlled Auto-Ignition (CAI), Low Temperature Combustion (LTC) and Premixed-Charge Compression Ignition (PCCI) [11–20]. The HCCI operates much better and has no flame front, which results in low in-cylinder temperatures, and hence, low NOx formation. The load in an HCCI engine is controlled by the amount of fuel, allowing unthrottled operation. This reduces the pumping losses and decreases the fuel consumption [5].

Even though HCCI combustion can provide emissions and fuel consumption benefits compared to SI combustion, it is still important to investigate the effect of fuel consumption. To overcome these difficulties a PCCI Combustion concept is undertaken for reducing the oxides of nitrogen and soot emissions. The PCCI mode of operation involves the preparation of a premixed charge outside the cylinder. A partial amount of the total fuel supply is injected into the intake manifold where it is mixed with the intake air and the mixture enters the combustion chamber and the rest of the fuel is injected as usual. The premixing of the fuel with the intake air raises the equivalence ratio of the charge entering, and hence the overall non-homogeneity is reduced in the combustion chamber [17].

The port injection of diesel fuel is very difficult for the environment is too cold for the fuel to vaporize. In the diesel engine, the combustion and emission characteristics are greatly influenced by the quality of atomization and, in particular, by the fuel–air mixture present in the combustion chamber. Various methods were tried to achieve proper vaporization of the fuel in the intake manifold. Processes such as hot and cold EGR, preheating the air and large premixing chamber were utilized. Each process has its own set of advantages as well as disadvantages [7]. For example, preheating the air will not only increase the fuel atomization rate, but also decrease the air density, thereby drastically affecting the volumetric efficiency. Hot EGR, if employed, will increase the fuel vaporization, but it would also raise the net chamber temperature, thereby increasing the chance of NOx production, and hence the EGR quantity would necessarily require an automatic control mechanism if it is to be used under different loaded conditions [5].

The performance and emission characteristics of the engine with a PCCI mode and its results were compared with the conventional diesel mode operation. The results of the experimental investigations were analyzed and it was found that the PCCI mode operation results in a better performance than the conventional engine. The reductions in emissions were the primary area of investigation and the area of interest. It is involved in testing the feasibility of a PCCI concept in achieving the simultaneous reduction of NOx and smoke [8].

The present work deals with the study of performance, combustion and emission characteristics of PCCI concept in a direct injection diesel engine with port fuel injection of ethanol and gasohol fuel. The partial premixing is achieved by using two injectors, namely the main injector and an auxiliary injector. In this experimental work a stationary four stroke, single cylinder, constant speed, air cooled diesel engine was adapted to operate in premixed charge compression ignition mode with port fuel injection technique. The experiments were conducted with a 20% premixed gasohol and ethanol fuel in

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