Investigation to Assess the Performance of Homogeneous Charged Compression Ignition Engines

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Abstract
As the need of clean and green sources of energy is increasing with growing industrial requirement and population as the reserves of conventional fuel reserves are depleting exponential different countries are now taking lead in creating many reforms in order to achieve energy independence. In view of this objective several advance combustion technologies have now been developed, HCCI combustion engines being one of them. Several challenges are still restricting the use of this combustion technique over conventional internal combustion engine modules ie SI and CI engines few of such challeges includes flexibility in using different fuels, controlling the combustion rates, meeting the autoignition needs of the fuel, limited working range of such engines. Present work studies suitability of ethanol as working fuel in HCCI engines on different loading condition, since the autoignition temperature of ethanol based fuel will be higher test was conducted by preheating the charge on different engine loads to check the working domain of HCCI engine along with to easily attain the autoignition point use EGR is also tested along with the nature of emissions in terms of NOx and unburned hydrocarbon emissions.

Keywords: HCCI engine, EGR, Combustion, Autoignition, Emissions

1. Introduction

With the exponential increase in energy, demand globally has caught the eyes of people from various fields to look for better and sustainable sources of energy to meet elementary energy needs. Automotive fuels are among major contributing elements for the power sector and focus is shifted to look for alternate options of conventional petroleum sources, which must be comparable with them in terms of energy and emission outcomes. Energy demand is rapidly increasing with economic and industrial development and two third of primary energy sources are being accounted from fossil fuels as it can be seen from figure 1. Almost 50% of total global energy consumption is consumed by US, China and India out of which almost 86 % of total consumption is derived from fossil fuels like oil, coal and natural gas [7].

The above data of energy consumption looks horrifying when the scenario is viewed in terms of growing world population which caused rise in the need of many applications including mobility, consumption and transportation, if the current practice of fuels is continued global pollution and drastic degradation of air quality as well as all other type of pollutions will reach to next level. Thus, requirement for cost efficient and clean sources of energy is perceived for a healthy and safer environment as burning of conventional fossil fuels leads emission of green house gases. Typically GHG emissions consist of 76% CO_2 as can be seen from the figure 2 in addition to this other constituents includes fluorinated gases, hydrofluorocarbons, sulphur hexafluoride and perfluorocarbons. Among various sectors which consumes energy includes industries, electricity, agriculture, transportation etc [8].

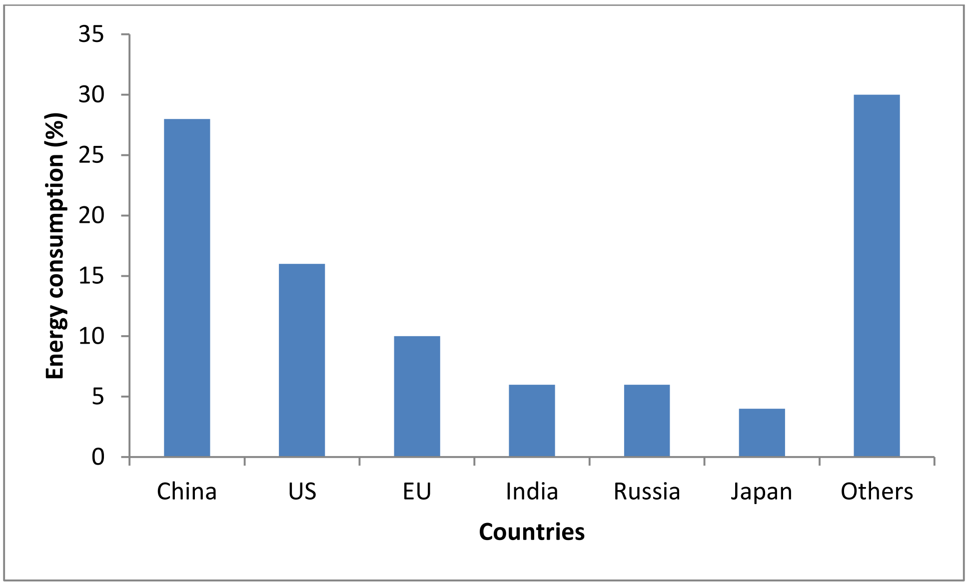

Figure 1 Global energy consumption

Transportation sector alone shares 14% of GHG emissions of total GHG emission by all the other sectors. Even after numerous efforts to create awareness, researching for advance combustion techniques and several emissions related laws and policies being implemented transport sector is still among major GHG emission contributing sectors [1]. Road transport accounts for detrioriting air quality due to the formation of pollutants like NOx, particulate matter, soot, carbon monoxide and many more. Transport sector alone contribute almose 58% of global NOx emissions and nearly 75 % of total particulate matter emissions. As discussed since the rate of energy consumption is increasing massively which is resulting in the depletion of crude reserves, thus need for meeting the energy requirement from non conventional energy source has become essential [2]. Some of such sources include solar, tidal, geothermal wind and biomass, all of these energy sources cause very low emissions but the major problem faced in implementing these sources includes contionous availability and complications in transportation of this form of energy. Some factors which inspires the use of alternative sources of energy includes decrease in CO_2, particulate matter and soot emissions, going for energy independence and switching to th fuel sources that includes agricultural wastes, scrap tyres biomass, algal and alcohol compounds [3].

Researches are continuously being carried out to contribute and looking for the solution for decreasing the emissions and increasing the effectiveness of combustion techniques, for achieving these objectives many alternative fuels and combustion technologies have been developed over last 20 years [4]. Combustion technology like stratified charged compression ignition, stratified charged spark ignition, low temperature combustion and homogenous charge compression ignition (HCCI) have been developed. HCCI engines use ultra lean homogenous air fuel mixture for auto ignition, recent studies have shown that HCCI is capable to be operated with multifuels and biofuels [5].

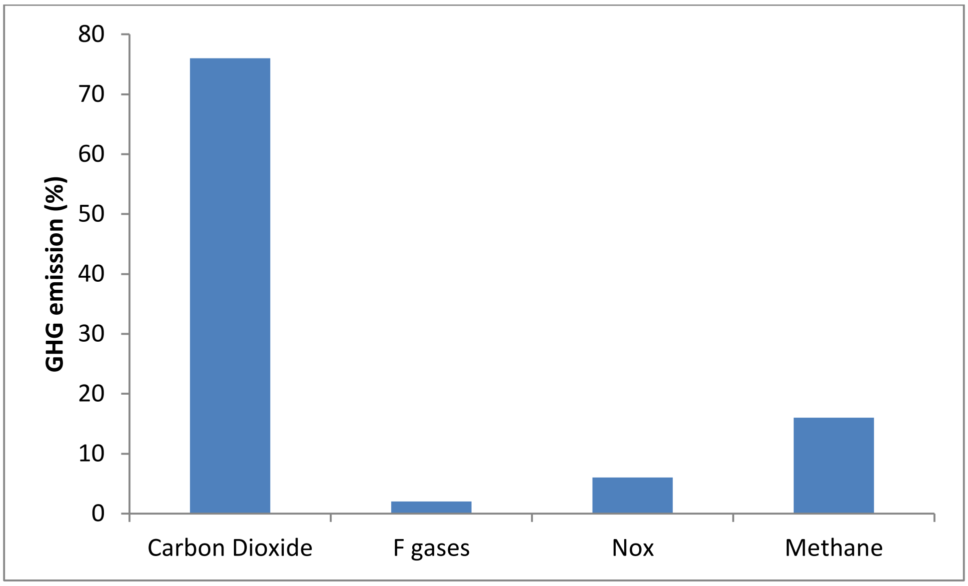

Figure 2 Constituent of GHG emissions

Operation in HCCI engine is similar to SI engine where a homogenously mixed charge is prepared and like CI engine autoignition of that mixture takes place, thus many works in the past compared the combustion process of HCCI, CI and SI engines on various parameters like ignition method, ignition point, throttle loss, compression ratio etc. Due to greater amount of air in HCCI operation, combustion in it is at relatively lower temperature thus lower formation of NOx and due to greater availaibility of oxygen reduction in CO and particulate matter emissions [6]. Similar to the evaluation of performance of HCCI some challenges are brought into discussion in few studies challenges like controlled auto ignition, cold start, phase control, temperature range.

Onishi et al [9] worked with homogenously mixed residual and fresh charge, in this study higher values of EGR is used to realize the autoignition of gasoline that lead to reduced emission and more economic fuel consumption but this method has limited the range of different load operation. Noguchi et al [10] worked to enhance the autoignition of homogenous charge in HCCI with active radicals to achieve smooth combustion to improve comsumption of fuel with lower unburnt hydrocarbons. Thring et al [11] has studied the effect of air fuel equivalence ratio and EGR content on the operation range of HCCI and has found that it gets difficult to control the autoignition with increase in EGR. Saqaff [12] worked on reducing the exhaust gast temperature by reducing exhaust port area by 1 to 8 % and found a significant reduction in exhaust temperature with reduced fuel consumption. From exhaustive review of the work carried out in past it can be observed that HCCI has competitive outcomes compared with SI and CI engines with lower NOx and HC emissions, present work will be based on studying the flexibility of fuel that can be used in HCCI arrangement which is found challenging so far.

2. Material and Method

A single cylinder 4 stroke diesel engine is used which employed air cooling working on constant speed (1500 rpm), engine has 4.4 kW with 662 cc swept volume. With the help of external mixture formation the test engine is converted to work as HCCI engine. The intake air is heated at steps of 10 ^{o}C starting from 130 ^{o}C. An anemometer is used to measure the air flow, a PNP type sensor is used to measure the engine speed which is connected near the flywheel. Before testing the engine for various study parameters autoignition temperature diesel ethanol blend fuel is found. For comparison purpose initial the engine was operated on diesel at 20, 40, 60, 80 and 100% load and reference data of the engine is obtained later with PFI technique setup is converted to HCCI but since the autoignition temperature of ethanol based fuel will be more inlet air was preheated with a heater.

3. Results

3.1. Indicated Thermal Efficiency

The working range of HCCI engine was found to be limited by two operating measures, the upper working range is limited by higher knock occurrence while the lower limit is decided by the increased misfire during ignition. Since the fuel required at loading condition below 60% and air intake temperature less than 150 °C is very less which results in lesser heat release and it result in lower gas temperature and more unburned hydrocarbons and CO realse. In contrast to that when the engine load is increased along with air intake temperature greater amount of fuel is delivered which resulted in higher heat realease and thus uncontrolled rise in pressure inside the cylinder lead to greater noise and set the upper limit of working domain for the current configuration. It can be observed that efficiency has increade upon increasing the engine load and inlet charge temperature.

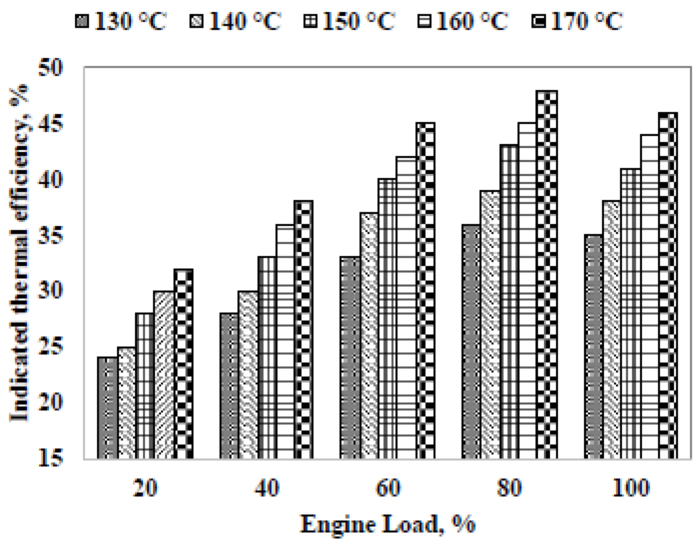

Figure 3 Indicated thermal efficiency vs Engine load

3.2. Exhaust Gas Temperature

It is very difficult to control the combustion of HCCI setup, exhaust gas recirculation is studied. Different percentage of EGR were circulated backin this case and its effect resulted in decrease of NOx emission but due to which it was found that amount of unburned hydrocarbon emissions were increased thus it is required to find an optimal point to which EGR can be circulated.

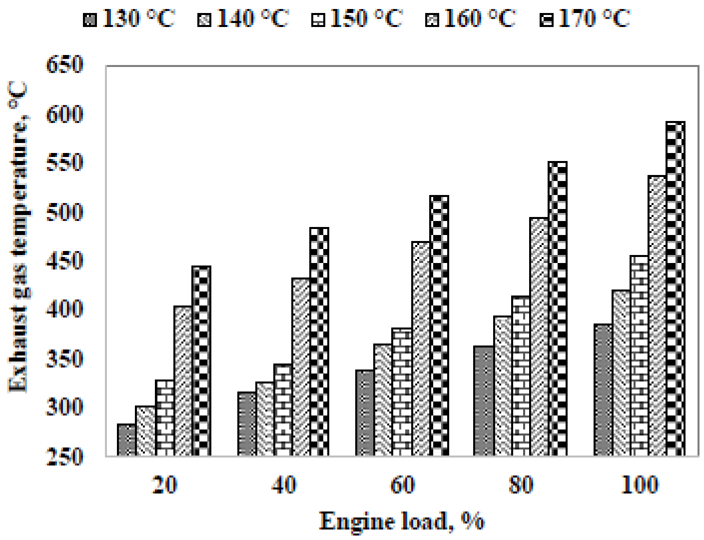

Figure 4 Effect of Exhaust gas temperature vs Engine load

4. Conclusion

In perspective on this goal a few development ignition advances have now been created, HCCI burning motors being one of them. A few difficulties are as yet confining the utilization of this ignition method over show inside combuston motor modules ie SI and CI motors not many of such challeges remembers adaptability for utilizing various fills, controlling the burning rates, meeting the autoignition needs of the fuel, constrained working scope of such motors. Study analysed the variation of indicated thermal efficiency and exhaust gas temperature with respect to engine load and intake charge temperature. Present work examines appropriateness of ethanol as working fuel in HCCI motors on various stacking condition, since the autoignition temperature of ethanol based fuel will be higher test was led by preheating the charge on various motor burdens to check the working space of HCCI motor alongside to effectively accomplish the autoignition point use EGR is additionally tried alongside the idea of discharges as far as NOx and unburned hydrocarbon outflows.

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