

ABSTRACT

Ever-increasing conventional fuel costs and negative impact on environmental conditions are the twin crises that cause worry in the present world. Growing countries like India and China are grappling with the trouble of meeting the ever-increasing vehicle population, depending on fossil fuels, legal requirements, and limited resources. To reduce the dependency on fossil fuels and stringent emission norms enforce the use of renewable fuels for a diesel engine. At present, some of the alternative fuels like biodiesel, alcohols (ethanol, methanol, and butanol), Liquefied Petroleum Gas (LPG), hydrogen, acetylene, and Compressed Natural Gas (CNG) are in the line to replace the fossil fuels for IC engines.

Vegetable oil is a potential energy resource and is used as an alternative fuel. However, it has some concerns when using in CI engines, such as clogging in the injector, poor thermal efficiency, low energy value and high viscosity. To resolve this issue, the neat vegetable oil is converted into biodiesel through a transesterification process to drop the oil viscosity. The biodiesel form of Kapok oil is called kapok methyl ester (KME). The KME can be directly used as an alternative fuel in CI under most operating conditions without the need for any modification. At the beginning of the investigation, the KME is extracted and its physical properties are tested as per the ASTM fuel standards. In this work single cylinder direct injection with Variable Compression Ratio (VCR) engine with Exhaust Gas Recirculation (EGR) is utilised.

At the first stage of the investigation, the kapok methyl ester was blended with diesel at various concentrations such as KME10, KME20,

KME30 and KME40 for knowing the impact of KME fuel blend in CI engine. The test was conducted at standard conventional operating points. This test result was considered a base reading. From this test, it was observed that the Brake Thermal Efficiency (BTE) of kapok methyl ester was lower than diesel, showing a drastic reduction in Carbon monoxide (CO) and Hydrocarbon (HC) emissions. Also, it is noticed that NO_x emission was higher for kapok biodiesel as compared to diesel fuel. Among the different fuel blend, it was observed KME20 fuel blend close performance with diesel fuel along with lower engine-out emissions. Hence, the KME20 blend was elected as the optimum blend for further trails.

To enhance the thermal efficiency of KME20 blend, the Compression Ratio (CR) was modified in the test engine. The investigation was performed by decrement and increment of compression of the CI engine. The standard compression ratio of the test engine was 18:1, which was varied to 17:1, 19:1 and 20:1. The engine performance was effectively increased, and CO and HC emissions were marginally reduced using KME20 blend at a high CR of 19. But there was a penalty that NO_x emission was further increased.

To overcome this issue, a nanoparticle was chosen as a better option to reduce NO_x emission as well as slightly increase the performance parameter. In the present investigation, Cobalt chromite (CoCr₂O₄) was chosen as a Nano additive for the KME20 blend because it has a high oxygen content. The nanoparticles were added in various proportions, namely 20 ppm, 40 ppm, 60 ppm and 80 ppm with the optimum KME20 blend. Meanwhile, the Injection Timing (IT) also varied for increasing the residence time of fuel in the cylinder, so that sufficient time is available to make a homogenous mixture preparation. From the investigation, it was found that the NO_x emission was significantly reduced along with an optimum reduction in HC, CO and smoke emissions. The dual effect of nanoparticle addition and

varying the IT of the KME20 blend was also noted to be a remarkable improvement in combustion characteristics such as peak cylinder pressure and Heat Release Rate (HRR).

For the further evaluation process, the Injection Pressure (IP) was changed from the standard IP of 220 bar to elevated IP of 240 bar, 260 bar and low IP of 200bar. Due to higher penetration length and homogeneous formation, IP of 240 bar was noticed to be better than other IP. Also, IP of 240 bar displayed a drastic reduction in emission parameters than its rivals. Combustion efficiency of $\text{CoCr}_2\text{O}_4+\text{KME20}$ was improved for advanced IT of 25°bTDC and high IP of 240 bar at peak load conditions.

At the final stage of research work, the EGR technique was adopted with Nano additive blend of KME20. By this method, the burnt gases were partially supplied along with air which leads to suppression of the cylinder temperature and combustion temperature, thereby reducing the NO_x emission. From the results, the effect of $\text{CoCr}_2\text{O}_4+\text{KME20}$ with various percentages of EGR (5%, 10% and 15%) on engine characteristics was studied. The result of BTE for 80 ppm $\text{CoCr}_2\text{O}_4+\text{KME20}$ at different flow rate of EGR 0%, 5%, 10% and 15% was 31.5%, 30.8%, 29.91% and 29.1%, respectively as related to 29.69% for diesel. This research concluded that the direct injection of CI engine led to enhanced performance, combustion and remarkable reduction in emission characteristics fuelled with $\text{CoCr}_2\text{O}_4+\text{KME20}$ at injection timing of 25°bTDC and injection pressure of 240 bar.