

ABSTRACT

Energy is a vital factor that decides the growth and social development of a country. Fossil fuels contribute a lot of energy and are crucial to the current energy situation. The demand for petroleum-based fuels has sharply increased as a result of the rapid growth of industrialization and motorization. The rapid rise in oil consumption, unpredictable oil prices, declining oil reserves and higher levels of harmful emissions, the current petroleum-based fuel can't be used for all energy purposes. The scientific community has now been compelled to concentrate on the use of biofuels for compression ignition (CI) engines.

The most popular technology in the automotive industry is Internal Combustion (IC) engines. Conventional diesel engines have been in use in commercial vehicles and passenger cars for more than half a century. Methyl or ethyl ester of fatty acids is a kind of alternative energy source that is generally called bio-diesel, which is made from unused and used vegetable oils and animal fats. Like petroleum diesel, bio-diesel can be used as a straight fuel for IC engines due to its similar physical and chemical properties. A bio-diesel blend can be made by blending bio-diesel with conventional diesel in any ratio and it can run on IC engines like petroleum diesel and almost requires no modifications.

To explore the performance characteristics of an IC engine, the experimental work was carried out in a single-cylinder, 4-stroke water-cooled Direct Injection (DI) diesel engine running at a constant speed of 1500 rpm. The work started with the synthesis of bio-diesel from rapeseed (*Brassica napus*) and linseed (*Linum usitatissimum*) oil. The oils from the seeds were extracted through mechanical pressing and solvent extraction process and the extracted oils were transformed into Rapeseed Bio-diesel (RB) and linseed bio-diesel (LB) through transesterification process. The produced bio-diesels

were examined for both physical and chemical characteristics by following ASTM standards. The chemical characteristics of the bio-diesel were analyzed using Fourier Transform Infrared Spectroscopy (FTIR) and Gas Chromatography-Mass Spectrometry (GC-MS).

In the IC engine, the experimental work was carried out by using conventional diesel as a fuel without changing the engine operating parameters and design. Furthermore, the engine was operated with five different ternary bio-diesel blends produced by the combination of rapeseed bio-diesel, linseed bio-diesel and diesel. The blend RLD10 (5% RB + 5% LB + 90% diesel), RLD20 (10% RB + 10% LB + 80% diesel), RLD30 (15% RB + 15% LB + 70% diesel), RLD40 (20% RB + 20% LB + 60% diesel) and RLD50 (25% RB + 25% LB + 50% diesel) were prepared and used for analysis with the objective of analyzing performance, emissions and combustion characteristics in an engine at variable load.

The study also investigated the performance of 10% ternary bio-diesel blends with the addition of copper oxide (CuO) nanoparticles. Four different nano bio-diesels were prepared with the addition of different dosages of CuO nanoparticles and named as RLD10CU25 (5% RB + 5% LB + 90% diesel + 25 ppm CuO), RLD10CU50 (5% RB + 5% LB + 90% diesel + 50 ppm CuO), RLD10CU75 (5% RB + 5% LB + 90% diesel + 75 ppm CuO), RLD10CU100 (5% RB + 5% LB + 90% diesel + 100 ppm CuO). The performance parameters evaluated include Brake Thermal Efficiency (BTE), Specific Fuel Consumption (SFC), Total Fuel Consumption (TFC), mechanical efficiency, Indicated Mean Effective Pressure (IMEP) exhaust gas emissions includes carbon monoxide (CO), carbon dioxide (CO₂), hydrocarbons (HC) and oxides of nitrogen (NO_x) and smoke. The combustion characteristics such as in-cylinder pressure and heat release rate (HRR) of the optimum fuel blend (RLD10CU75) and diesel have also been conducted.

The interaction of load and dosage of CuO with ternary bio-diesel blends on the emission and performance of the diesel engine was investigated through Response Surface Methodology (RSM). The first stage experimental outcomes revealed that the ternary blended bio-diesels showed lower BTE with increased BSFC. But the use of bio-diesel resulted in the reduction of CO, HC and smoke.

According to the findings, adding nano CuO to bio-diesel improved BTE at all loads. In comparison to the same bio-diesel blends and diesel, at maximum load, there were appreciable increases in BTE up to 13.88%. The SFC of all bio-diesel blends with additives was lower than that of neat diesel. Compared to ternary blend and conventional diesel, it was shown that the ternary blend with CuO greatly reduced the emissions of CO, HC, NO_x and smoke. At higher load, compared to diesel, a reduction of 31.97 to 39.53% CO, 9.09% to 12.12% HC, 2.52% to 3.98% NO_x and 23.08% to 42.31% smoke was obtained from ternary nano bio-diesel. In comparison to diesel, the addition of 75 ppm CuO with 10% ternary blend emits 6.17% more CO₂. According to the combustion characteristics of the engine, the combustion of RLD10CU75 is better than the conventional diesel fuel.