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Compression ratio effect on Diesel Engine working with Biodiesel (JOME)-Diesel blend as fuel

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Abstract

Continuous increase of energy demand in domestic and industrial sectors increases the pollution problems due to huge usage of fossil fuel. To overcome this problem it is necessary to develop an alternate and renewable source of energy which has less impact on environmental pollution. The wide varieties of plant based vegetable oils available are suitably converted to use in diesel engines as an alternative fuel. In this paper an attempt has been made to investigate the effect of compression ratio (CR) on performance characteristics of diesel engine with 20% Jatropha oil methyl ester (JOME) mixed with 80% diesel to form as B20D80 blend fuel (BF). Experiments were conducted on a variable compression ratio (VCR) engine at compression ratio of 14, 16, 18 and 20 for BF and at 14 and 20 for diesel fuel to compare the results. The performance parameters like brake thermal efficiency, BSFC, volumetric efficiency, CO, CO_2 HC, NO_x and smoke intensity were measured and analyzed. It was observed that the increase in compression ratio, performance of engine increased appreciably with less BSFC for blend fuel. From the emission results, it was also observed that CO, HC, NO_x and smoke density reduces significantly but a slight increase in CO_2 as the compression ratio increases.

Keywords: Performance, VCR engine, biodiesel, JOME, blend fuel, emissions.

Introduction

Vegetable oils have improved ignition quality, because of their long molecular chain, and low cetane number due poor volatility. As the oxygen content in the vegetable oils is high, its calorific value low. However, due to their large molecular mass and chemical structure viscosity and carbon residue are higher[1]. The flash point of vegetable oils is higher compared to neat diesel, which indicates much safer to store. Due to higher density of vegetable oil the cold point is higher, which indicates problems of thickening or even freezing at low ambient temperatures. Low volatility of vegetable oils makes slow evaporation when injected into the engine compared to diesel[2]. Depending upon the composition, vegetable oils have cetane number of about 35 to 50 which is very close to the diesel value[3].

Development of treatment devices increases the problem of emission to a large extent while allowing the combustion process optimization for maximum fuel efficiency[4]. By using raw Jatropha oil as the primary fuel found that slightly reduced thermal efficiency, higher smoke emissions and increased hydrocarbon, carbon monoxide emissions. Dual fuel operation with Jatropha biodiesel engine results in good thermal efficiency and low smoke emissions, particularly at high power outputs[5, 6]. At full load condition considerable improvement in the performance parameters as well as exhaust emissions were observed. The performance of VCR engine with marula oil as fuel is very close to that of diesel at 80% of load for compression ratio of 16:1[7,8]. The performance and emission characteristics of diesel engine affects significantly with the compression ratio. Variable compression ratio provides complete vaporization of fuel at higher pressures in the engine, hence the combustion and optimal compression ratio can improves fuel economy, performance and to reduce tail pipe emissions of the engine[9-11]. The objective of the present study is to compare the performance and emission characteristics of a four stroke Variable Compression Ratio, water cooled diesel engine at constant speed, using B20D80 blend fuel (BF) for different compression ratios.

Material and Methods

Preparation of Biodiesel: In this study Jatropha oil is selected to make biodiesel. Raw oil is filtered and heated to 105^0C temperature. Methanol of 120 ml and 2ml of H_2SO_4 per liter of oil is added and heated with stirring at 60^0C for ten minutes in a closed conical flask. The mixture is allowed to settle in a decanter, and then glycerin is separated from methyl ester. *Sodium Methoxide* is prepared by mixing 200 ml of methanol (20% by vol.) and 6.5 grams of NaOH per liter of oil. This solution is added to the oil, stirred continuously at 60^0C and allowed to settle in decanter. The collected Jatropha oil methyl ester is bubble washed with water to remove soaps and heated. The properties of biodiesel produced are equivalent to fissile fuel[12-14].

Experimentation: Four stroke single cylinder Variable Compression Ratio (VCR) diesel engine is used for experimental work. Experiments were conducted at compression ratios of 14, 16, 18 and 20 with BF and for diesel fuel at 14 and 20. During the test, performance, exhaust emissions and smoke density parameters were measured by using appropriate instruments and analyzed to compare the results.

Results and Discussion

Performance analysis: Brake thermal efficiency (η_{Bth}) and *BSFC*: The figure-1 shows the effect of CR with brake thermal efficiency and *BSFC*. The observation is that the brake thermal efficiency is increased with increase in compression ratio for all fuels at all loads. For blend fuel, the brake thermal efficiency is always less, when compared to diesel because of lower calorific value of biodiesel. The increase in brake thermal efficiency is observed as CR increases, due to better mixing of biodiesel at higher temperature causes complete combustion of fuel.

The observation is that *BSFC* decreased with increasing of brake power and compression ratio and the BSFC for blend fuel is 2.4% higher as compared to diesel at maximum load for CR of 20:1. The BSFC is 18.23% less with increasing CR from 14:1 to 20:1 for the blend fuel at full load operation. Maximum brake thermal efficiency of 24.5% is obtained at minimum BSFC of 0.38 for blend fuel at compression ratio of 20:1.

Volumetric efficiency (η_{vol}): The CR effect on volumetric efficiency is shown in figure-2. The volumetric efficiency is decreased with increase in load as well as CR, and at 20:1 CR. The volumetric efficiency of blend fuel is less by 0.9% compared to that of diesel at maximum load with increase in CR from 14:1 to 20:1 the volumetric efficiency decreased by 3.1% for blend fuel at maximum load. The residual gas left in the clearance volume at high pressure and temperature causes to decrease volumetric efficiency.

Emission analysis: Carbon monoxide (**CO**): The effect of CR on CO with brake power is shown in figure-3. The observation is that CO emission decreased with increasing both CR and brake power. The blend fuel CO emission is 32.6% less compared to diesel at CR 20:1 for blend fuel at full load. At higher CR, combustion rate of fuel increases due to higher temperature and adequate turbulence is created in the combustion chamber to complete combustion, hence the emission of CO decreases.

Carbon dioxide (CO_2): The effect of CR on CO_2 emission with brake power is shown in figure 4. It is observed that CO_2 emission increased with increasing CR for all the loads. Further it is observed that CO_2 emission increased with increase in brake power. At 20:1 CR the CO_2 emission of blend fuel is 3.2% higher compared to that of diesel at maximum load. At higher compression ratio CO_2 emission is 28.6% higher for blend fuel at maximum load due to improved combustion rate of bend fuel.

Unburnt hydrocarbon (**HC**): The CR effect on HC emission with brake power is shown in figure-5. It is observed that the emission decreased with increase in CR for all loads. The blend fuel emission is 26.7% less compared to that of diesel at maximum load for 20:1 CR. The HC emission of blend fuel at maximum load is 54.3% decreased with increase in CR, this is due to the presence of oxygen molecules present in the blend fuel improves the combustion.

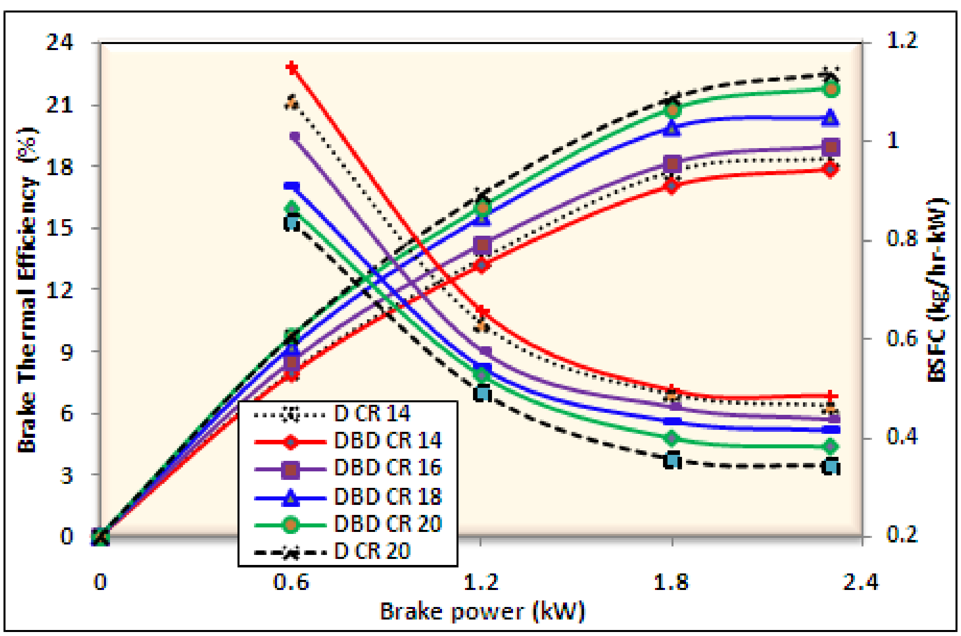

Figure-1
Effect of η_{Bth} and BSFC with load

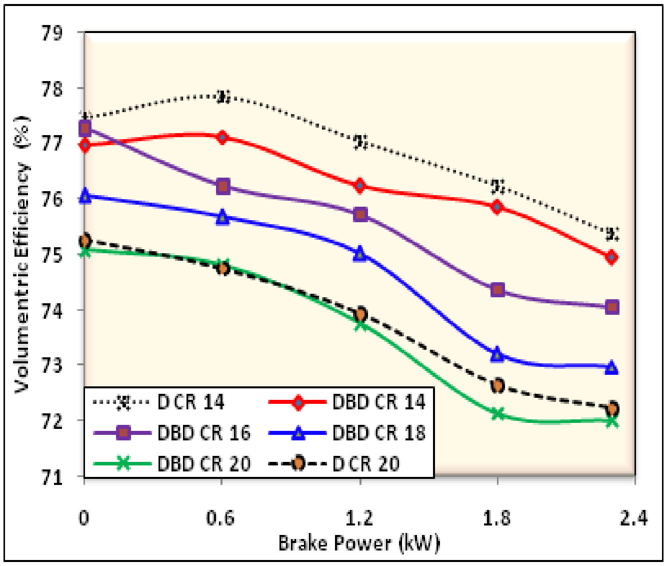

Figure-2
Effect of η_{vol} with load

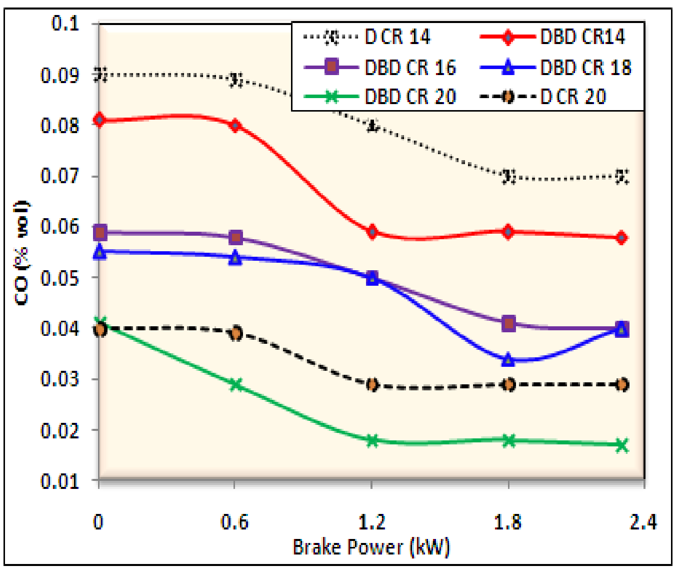

Figure-3
Effect of CO with load

Nitrous oxide (NO_x): The effect of CR on NO_x emission with respect to brake power is shown in figure-6. The observation is that the NO_x emission increased with increase in CR for all loads. The blend fuel NO_x emission is 9.8% less compared to that of diesel at maximum load for 20:1 CR. NO_x emission of 63.2% increased for blend fuel at maximum load and increasing in CR. Production of NO_x depends upon the maximum temperature in the cylinder and concentration of oxygen. It is observed that the oxygen concentration in exhaust gas at higher CR is less, hence lower the NO_x formation.

Smoke density: The effect of CR on smoke density with brake power is shown in figure-7. The observation is that the smoke density is decreased with increase in CR up to the brake power of 1.8kW and increased thereafter. For blend fuel smoke is 9.2% less compared to diesel at maximum load for 20:1 CR. The blend fuel smoke emission is 20.11% and lower for maximum load by increasing CR from 14:1 to 20:1. This is due to better oxidation of fuel at higher temperature and pressure attained at higher CR.

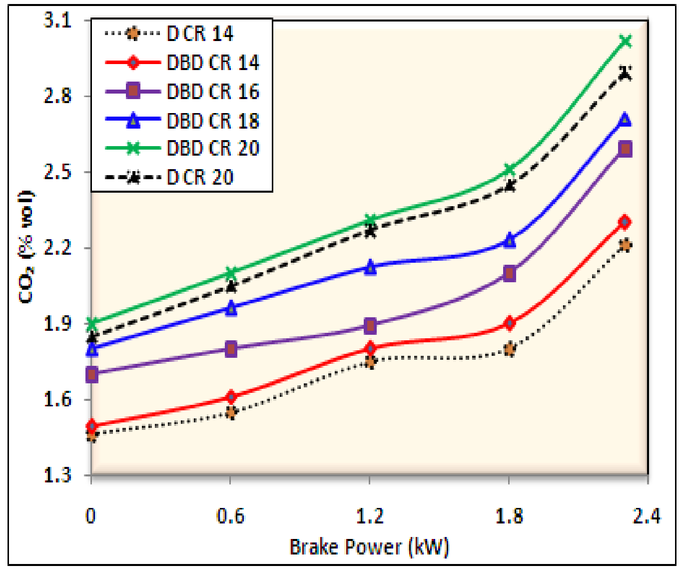

Figure-4
Effect of CO_2 with load

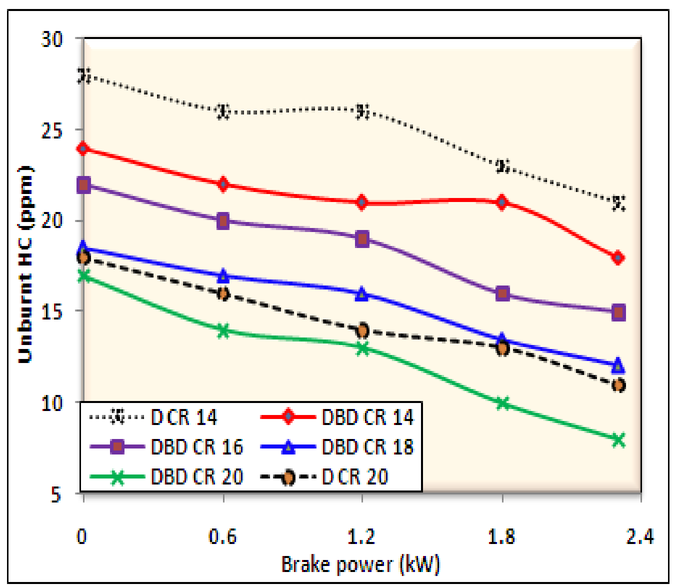

Figure-5
Effect of HC with load

Conclusion

Based on the experiments conducted on diesel engine with 20% biodiesel blended with 80% diesel, the following conclusions were drawn:

Maximum brake thermal efficiency is obtained at minimum BSFC for blend fuel at compression ratio of 20:1. Due to complete combustion of blend fuel CO, smoke density and hydrocarbons are minimum level where as NO_x and CO_2 are at higher level for compression ratio of 20:1. Blend fuel of biodiesel B20D80 revealed that a significant improvement in performance and emissions reduction of the engine at higher CR compared to pure diesel operation.

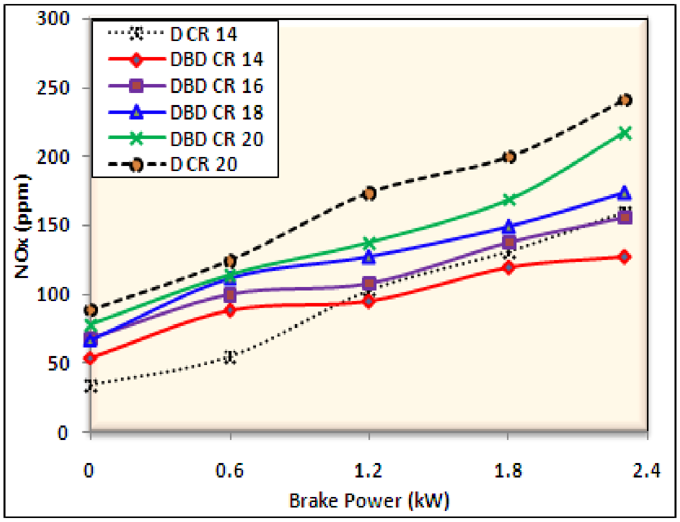

Figure-7
Effect of smoke density with load

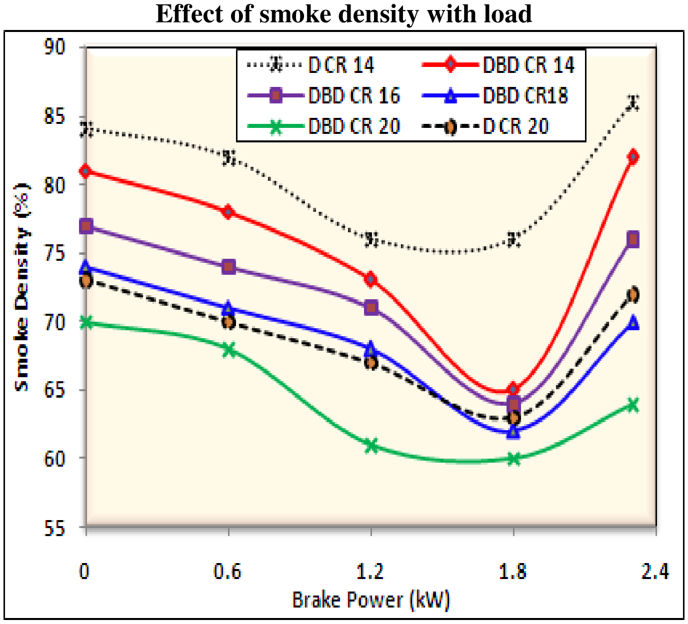

Figure-6
Effect of NO_x with load

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