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Effect of Compression Ratio on the Performance of the Diesel Engine Fuelled with Alternative Fuel

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Abstract

The availability of fossil fuels is reducing and the usage of these fuels affects the environment and causes climate change. Hence researchers working on alternative fuels which can be used as substitute for the fossil diesel. India is facing problem in disposing waste tires and tubes. However, we can produce tire pyrolysis oil (TPO) from the waste tires and tubes by pyrolysis process which can be used as fuel in diesel engine. In this work, we have used mixture of biodiesel and TPO as fuel in the diesel engine without making any modification in the fuel injection system. We have studied the effect of compression ratio on the performance and emissions of the engine fuelled with the fuel mixture. From the engine tests, we observed that the TPO can be used as an alternative fuel to the diesel in the diesel engine and the performance of the engine may be increased with the higher compression ratio.

Keywords: Alternative fuel, tyre pyrolysis oil, properties, engine tests, compression ratio

INTRODUCTION

In recent years, the world is facing two issues namely energy crisis and environmental degradation. Hence researchers working in this direction to overcome the problems associated with these issues. The biodiesel derived from non-edible oil is considered as an alternative fuel to the fossil diesel. The unscientific disposal of waste tyres and tubes degrades environment. The tyre contains synthetic rubber which causes environmental problem because it is not biodegradable.

As per a statistics India's waste tyres account for about 6-7% of the global waste tyre. In India, recycling and reusing of waste tyres is common, however it is estimated that 60% are disposed of through illegal dumping. According to a report, India is the second largest producer of reclaimed rubber and 90,000 metric tonnes of reclaimed rubber from waste tyres [1]. Also these materials take significantly much longer time as compared to biomass materials in case of photo degradation. However these materials can be disposed in controlled environment called pyrolysis. The value added by product of this pyrolysis process is a tyre pyrolysis oil which has properties similar to the fossil diesel. Figure1 shows the waste tyres.

Figure 1 Waste Tyres

The pyrolysis process is thermochemical decomposition of shredded tires carried out at higher temperature in a reactor vessel containing an oxygen-free atmosphere. The rubber is softened during this process and the rubber polymers break down into smaller molecules. These smaller molecules vaporize and can be condensed to get a liquid, called as tyre pyrolysis oil. The pyrolysis process is considered to give solution to waste disposal problem related to used tires [2].

Abdulkadir et al.[3] carried out pyrolysis of waste tire to produce tyre pyrolysis oil (TPO) by catalytic distillation. They reported that the characteristics of those light and heavy fuels were resembled to those of gasoline and diesel fuel [3]. Few researchers compared nitrogen sweeping pyrolysis with the vacuum pyrolysis with retorting. From their work they reported that longer vapor residence times lead to higher gas and coke yields and lower liquid yields [4].

Few researchers used the sensible heat of blast-furnace (BF) for the production of fuel oil and combustible gas from the pyrolysis of waste tire. They reported that the presence of BF slag greatly improved the production of derived-oil and increased the contents of H_2 and CO in pyrolysis gases [5].

Yunpu et al. reported that the microwave can be used for the pyrolysis of waste tyres. For the bio-oil production, they used microwave-assisted catalytic fast co- pyrolysis of waste and bamboo saw dusts. They reported that the optimal bamboo sawdust to waste tire ratio is 1:1, to get maximum yield of aromatic hydrocarbons [6]. Erick Ryoiti Umeki et al. reported that the specific gravity of the is 0.93 g cm^{-3} and the research octane number (RON) is similar to the RON for premium gasoline. They concluded that the blend properties highlight the complexity of the chemical interactions between the fuels [7]. M. N. Islam and M. R. Nahian reported that the distilled tire pyrolysis oil is similar to diesel fuel and able to replace diesel fuel in small engine. They observed that the brake specific fuel consumption of fuel mixture of diesel and TPO (DTPO 25) is close to the specific fuel consumption of diesel and suggested that the DTPO 25 blend can be directly utilized in diesel engine [8].

The cost of the biodiesel is higher than the diesel; however the cost of TPO is less. Hence in this work, we prepared the mixture of biodiesel and TPO and used as duel in the diesel engine to reduce the operating cost. The availability of the TPO is limited and hence it was used as partial substitute for the biodiesel. In India, honge oil has considerable potential for the biodiesel production and hence it was used as raw material for the biodiesel production. The honge biodiesel can be used as substitute for the diesel in the diesel engine [9]. Also it can be used as a pilot fuel in the dual fuel engine [10].

MATERIALS AND METHODOLOGY

In this work, biodiesel was produced from non-edible honge oil by a two-step transesterification process. The (TPO) commercially available was used in this work. The mixture of biodiesel TPO was prepared by mixing the fuels by 80: 20 ratio (volume ratio). The properties of the biodiesel were determined by ASTM and BIS methods. The fuel mixture was used as fuel in the diesel engine

The engine tests were carried out on a single cylinder naturally aspirated diesel engine without making any modifications in the fuel injection system. Table 1 provides technical details of the engine and eddy current dynamometer was used for loading the engine. The engine exhaust emissions were measured using an AVL make gas analyser. The necessary instrumentations were used to measure the engine performance parameters such as airflow, fuel flow, temperature and load measurement. The cooling water flowrate was controlled using rotameter. Figure 2 shows the experimental setup.

Table 1 Technical details of the engine

Engine	Single cylinder,4-Stroke, Naturally Aspirated Diesel Engine
Make	Kirloskar
Displacement	661 CC
Maximum Brake Power	3.5 kW at 1500 rpm
Rated Speed	1500 rpm
Compression Ratio	16.5 : 1 and 17.5 : 1
Load Sensor	Load cell, type strain gauge, range 0-50 Kg
Dynamometer	Eddy Current Dynamometer
Thermocouple Sensor	Type RTD
Thermocouple Range	0 – 1200 Degree C

Figure 2 Engine experimental setup

RESULTS AND DISCUSSION

The engine tests were conducted without making any modifications in the fuel injection system. Figure 3 shows the effect of fuel mixture on brake thermal efficiency at different compression ratios and at different loads. From the figure we observe that the compression ratio affects the thermal efficiency of the engine. The thermal efficiency of the engine with diesel is higher than the fuel mixture. However the higher compression ratio results in better thermal efficiency due to increase in combustion temperature which results in better vapourisation and atomization of the fuel mixture as compared to lower compression ratio.

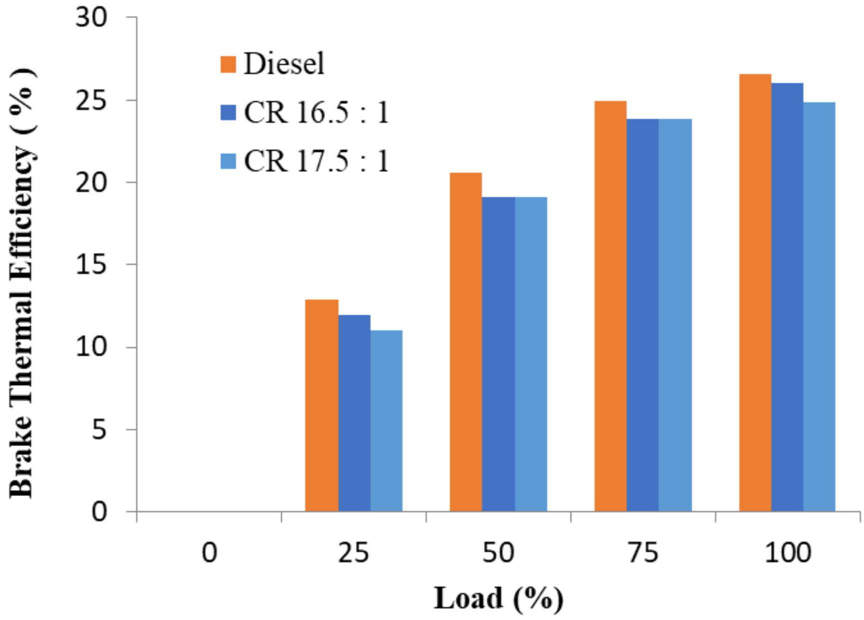

Figure 3 Effect of Compression Ratio on Brake Thermal Efficiency

The effect of compression ratio on the engine exhaust gas temperature (EGT) at different loads is shown in the Figure 4. From the figure, it is observed that the EGT of the fuel mixture is higher than the diesel and this is due to slow combustion of the fuel mixture which results in higher combustion temperature. The EGT of the diesel is lower than the fuel mixture. A slight variation in EGT at different compression ratio was observed.

Figure 5 shows the effect of compression ratio on the carbon monoxide (CO) emission of the engine at different loads. From the figure it is observed that the CO of the diesel is higher than the fuel mixture. The biodiesel contains oxygen in its molecular structure which results in better combustion of the fuel mixture. This reduces the formation of CO.

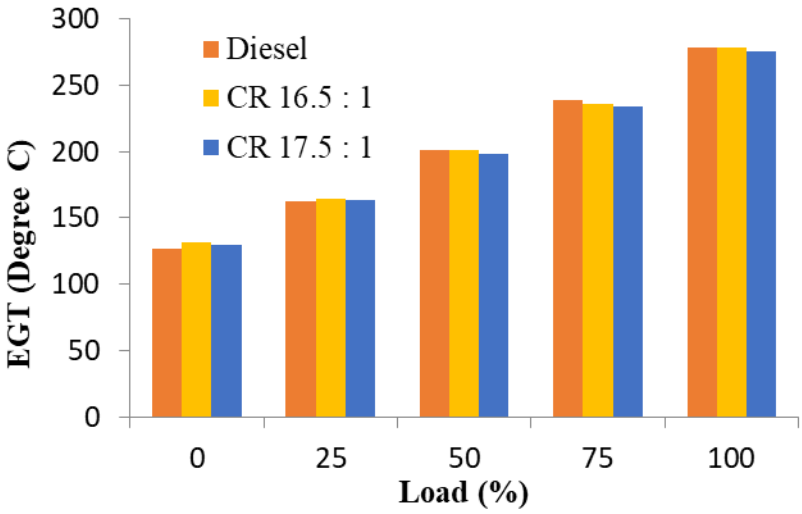

Figure 4 Effect of Compression Ratio on EGT

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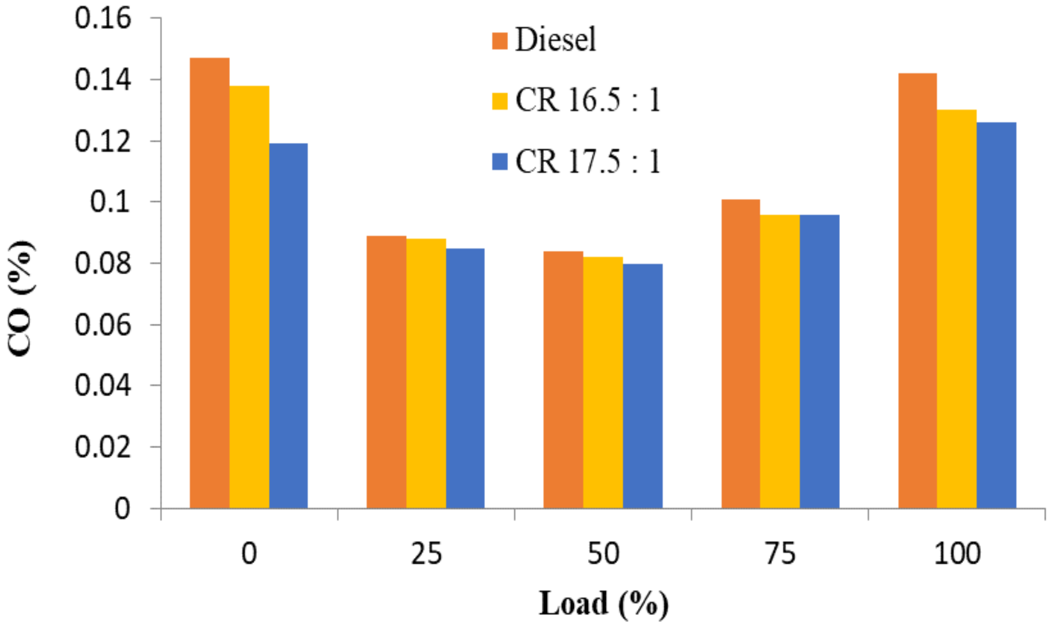

Figure 5 Effect of Compression Ratio on CO

The higher combustion chamber temperature causes lower CO emission due to higher combustion temperature which results in lower CO. The figure 6 shows the hydro carbon (HC) emission of the diesel engine with different fuels at different compression ratios. From the figure it is observed that diesel results in higher HC emission. The higher compression ratio of 17.5 :1 results in lower HC emission due to presence of oxygen in the molecular structure of the biodiesel.

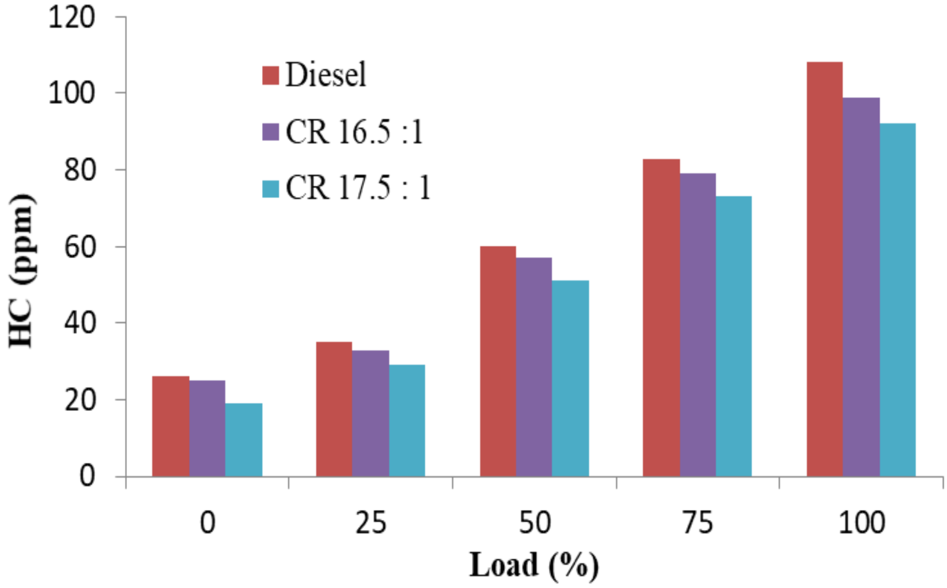

Figure 6 Effect of Compression Ratio on HC

The effect of compression ratio on the engine oxides of nitrogen (NO_x) with different fuels at different loads is shown in the Figure 7. From the figure, it is observed that the NOx of the fuel mixture is higher than the diesel and this is due to lower volatility and slightly higher viscosity of the fuel mixture. The NO_x emission of the engine with the compression ratio of 17.5 : 1 is lower than the other compression ratio. The NO_x emission of the diesel is lower than the fuel mixture.

Figure 8 shows the engine smoke emission with different fuels at different compression ratios and loads. From the figure it is observed that the diesel results in higher smoke emission. The compression ratio of 16.5:1 results in higher smoke emission and the compression ratio of 17.5:1 results in lower smoke emissions. The lower smoke emission is due to higher combustion chamber temperature which results in better combustion and lower smoke emission.

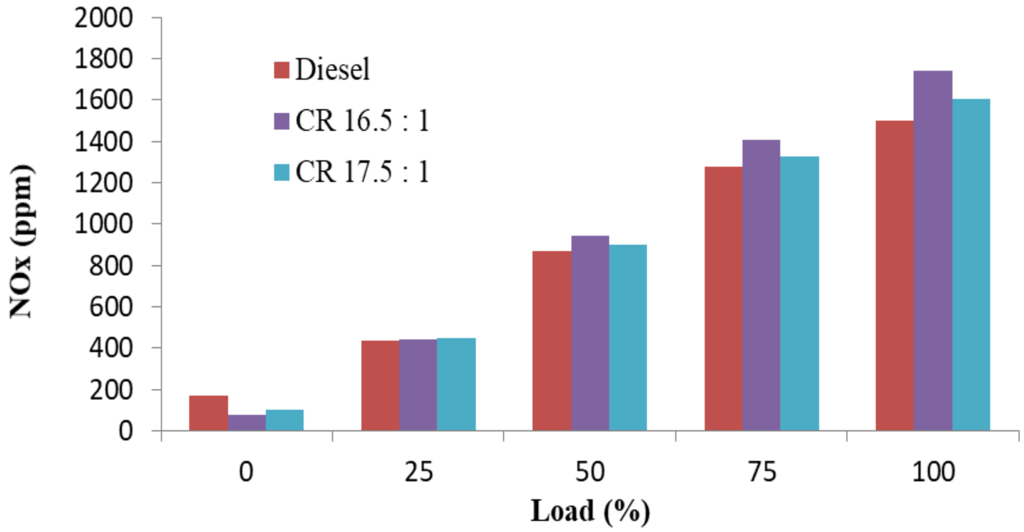

Figure 7 Effect of Compression Ratio on NO_x

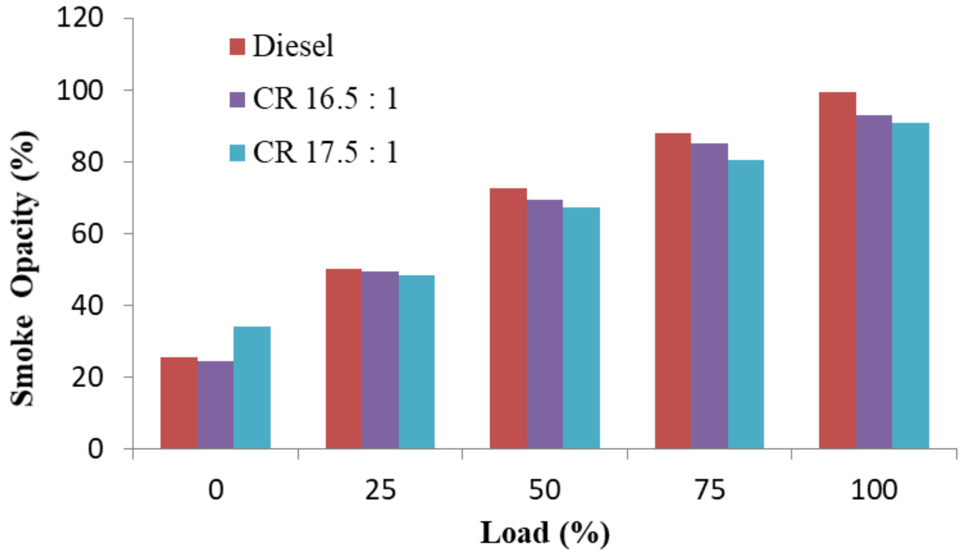

Figure 8 Effect of Compression Ratio on Smoke Opacity

CONCLUSION

The availability of fossil fuels is reducing and unscientific disposal of waste tyres and tubes affects the environment. Hence in this work we successfully used a fuel mixture of biodiesel and TPO as a substitute for fossil diesel in the diesel engine and without making any modification in the fuel injection system. The engine runs without any problem with the fuel mixture and the engine thermal efficiency is close to diesel. The compression ratio affects the performance of the diesel engine fuelled with the fuel mixture. From this work, we observed that the higher compression ratio results in better brake thermal efficiency and lower engine exhaust emissions. From this work, we suggest that the fuel mixture of biodiesel and TPO can be used as fuel in the diesel engine.

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