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# Experimental Investigation of Effect of Compression Ratio on Performance and Emission Characteristics of a Diesel Engine

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**ABSTRACT:** Concerns about health risks from harmful emissions, rising fuel prices, and fuel depletion have all been linked to the use of fossil fuels in internal combustion engines. A variety of organic materials, including plants, algae, and biowaste, are used to make biodiesels. In order to support industrial aspects in India, the current work proposes to study the engine behavior of a single cylinder DI diesel engine using bio-fuel made from Jatropha oil and waste derived fuel. With varying compression ratios of 17.5:1, 16.5:1, and 18.5:1, tests were performed to examine engine characteristics such as heat release rate, peak pressure, ignition delay, and brake thermal efficiency for both part load and rated load. According to experimental results, engines that run at a compression ratio of 18.5:1 are more efficient when using blends of jatropha and waste derived fuel

## I. INTRODUCTION

The global energy crisis has become a pressing issue, impacting economies, societies, and the environment. As fossil fuel reserves dwindle and climate change accelerates, the requirement for sustainable and innovative energy solutions has never been more critical [1]. The energy crisis is characterized by rising energy prices, supply shortages, and increased demand for energy resources. Factors contributing to this crisis include geopolitical tensions, natural disasters, and the ongoing effects of the COVID-19 pandemic, which have disrupted supply chains and energy production [2]. As countries strive to recover economically, the demand for energy continues to surge, leading to heightened competition for limited resources [3]. This is happening due to excessive usage of fossil fuels, the adverse effect of combustion of fossil fuel on human being and environment etc. Different generations of biofuels are shown in figure 1.

Fossil fuels are the primary source of greenhouse gas (GHG) emissions, which are the leading contributors to climate change. The burning of coal, oil, and natural gas releases carbon dioxide ($CO2$) and other harmful pollutants into the atmosphere, resulting in global warming and severe weather patterns [4]. The Intergovernmental Panel on Climate Change (IPCC) has warned that if we do not transition away from fossil fuels, we could face catastrophic consequences, including rising sea levels, extreme heatwaves, and increased frequency of natural disasters. Moreover, the extraction and transportation of fossil fuels have devastating impacts on ecosystems [5]. Oil spills, coal mining, and fracking can lead to habitat destruction, water contamination, and loss of biodiversity [6]. For instance, oil spills can devastate marine life, while coal mining can result in soil erosion and the destruction of landscapes. These environmental consequences not only harm wildlife but also affect human health and livelihoods, particularly in communities that depend on natural resources for their survival. Overall, it can be understood that the energy crisis is a multifaceted problem exacerbated by the reliance on fossil fuels, which have severe negative impacts on the environment [7]. Addressing this crisis requires a collective effort to shift towards sustainable energy solutions that prioritize ecological health and the well-being of future generations. The time to act is now, as the consequences of inaction will only deepen the challenges, we face in securing a sustainable and healthy planet [8][9].

The oil produced from tyre pyrolysis is a complex mixture of hydrocarbons, resembling conventional fuels like diesel and gasoline [10]. Key characteristics of tyre pyrolysis oil include: The energy content of pyrolysis oil can range from 30 to 40 MJ/kg, making it a potent energy source [11]. The viscosity of the oil can vary, affecting its handling and combustion properties [12]. The oil contains a variety of organic compounds, including aliphatic and aromatic

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hydrocarbons, which can be further refined for specific applications. Utilizing tyre pyrolysis oil as an alternative fuel offers several environmental advantages [13]:

- Waste reduction: The pyrolysis process helps in managing the growing problem of tyre waste, diverting it from landfills and reducing environmental pollution.
- Lower emissions: When combusted, tyre pyrolysis oil generally produces fewer greenhouse gases and pollutants compared to traditional fossil fuels.
- Resource recovery: The process not only generates fuel but also recovers valuable materials like carbon black, which can be reused in various applications.

This research paper explores the utilization of biodiesel and waste tyre derived fuel blend, examining their performance and emission parameters. The combination of these two fuels presents a promising alternative to conventional diesel, potentially enhancing engine efficiency while reducing harmful emissions. The analysis includes the benefits and challenges associated with this dual fuel system, as well as its impact on engine performance metrics and environmental outcomes.


**Fig.1 Different generation of biofuels**

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## II. TEST FUELS

The alternative fuel can be majorly classified as first-generation biofuels, second generation biofuels and third generation biofuels [14]. Biofuels have emerged as a sustainable alternative to fossil fuels, offering a renewable source of energy that can help mitigate climate change and reduce greenhouse gas emissions [15]. Many studies explore the various types of biofuels, including their production methods, characteristics, and performance metrics, specifically focusing on brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) [16][17] [18]. Understanding these parameters is crucial for evaluating the viability of biofuels in internal combustion engines. In this work biodiesel derived from Jatropha oil and its blend with waste derived fuel has been considered as alternative to diesel fuel.
The core of the biodiesel production process is transesterification, which involves the following steps:

- Mixing: The feedstock is mixed with an alcohol (usually methanol or ethanol) and a catalyst (commonly sodium hydroxide or potassium hydroxide).
- Reaction: The mixture is heated and stirred, allowing the triglycerides in the feedstock to react with the alcohol. This reaction produces fatty acid methyl esters (biodiesel) and glycerol.
- Separation: After the reaction, the mixture separates into two layers: biodiesel (top layer) and glycerol (bottom layer).

Tyre pyrolysis is a thermochemical process that breaks down used tyres into various valuable products, including pyrolysis oil, carbon black, and syngas. The process involves heating the tyres to high temperatures (typically between 300 °C to 600 °C) in the absence of oxygen, which prevents combustion and allows for the breakdown of complex hydrocarbons present in the rubber.

## III. EXPERIMENTATION

One method to address the issue of scrap tires is through biological processing or recycling. Thermochemical conversion plants can be used to turn these used tires into carbon material and energy. JME and TPO, the test fuels, were sourced from a commercial enterprise. A single-cylinder diesel engine with a maximum power productivity of 4.4 kW was used for the research. The experimental setup layout is depicted in figure 2.

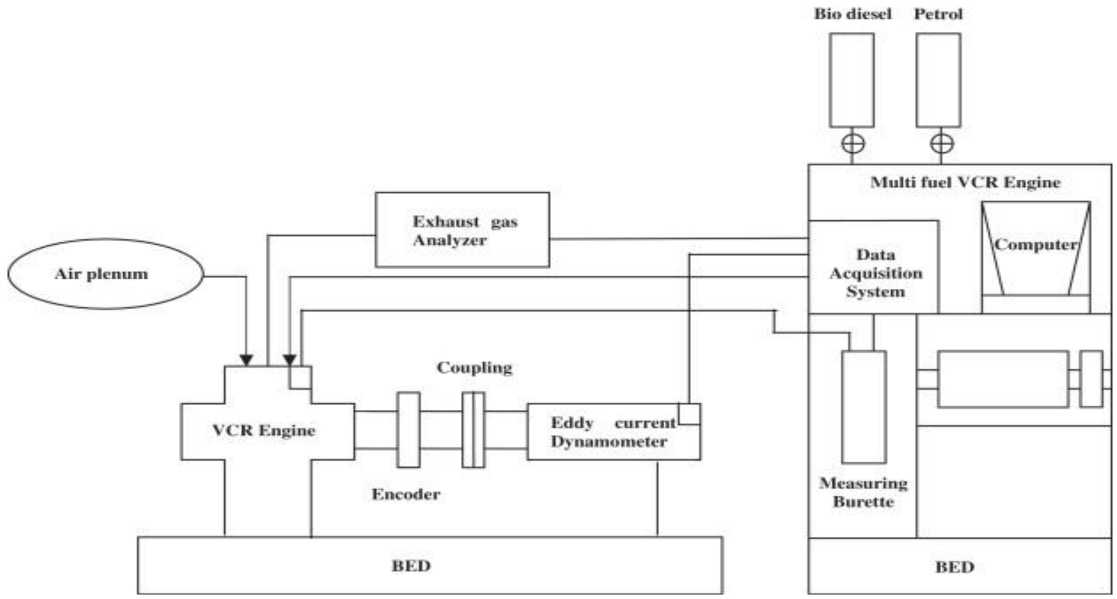


**Fig.2 Schematic diagram of the set up**

In order to obtain a baseline analysis, diesel was used for the first set of tests, followed by the blend fuel operation. Diesel was used to start the experiments, and once the engine had warmed up, it was switched to biodiesel and then biodiesel

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with waste tyre derived fuel operation at the initial injection timing of 23 ˚CA bTDC (as specified by the engine manufacturer) in order to collect reference data. Additionally, experiments with the different compression ratio at standard injection timings. By adding or removing shims, the number of shims installed beneath the pump's plunger was changed, changing the initial injection timing. A probe inserted into the engines' exhaust was used to measure the emissions of HC, CO, O2, and NO using a AVL instruments gas analyzer. A type-K thermocouple coupled to an Energy combustion analyzer was used to measure the exhaust temperature. Using a 2000 ml fuel reservoir set on a 5000 gm Ohaus digital balance, fuel consumption was calculated. A digital stop watch was used to measure the amount of time that had passed. The standard operating procedure for all runs was to put the engine under the desired load for about ten minutes in total, with the exhaust temperature and emissions readings being taken after about eight minutes. Diesel fuel at room temperature was used for the diesel tests.

## IV. PERFORMANCE PARAMETERS

Brake thermal efficiency (BTE) is a measure of the efficiency of an engine in converting the heat from fuel into useful work [19]. It is defined as the ratio of the brake power output to the heat input from the fuel. Higher BTE indicates better engine performance and fuel utilization. Generally, shows comparable or slightly higher BTE than petroleum diesel, attributed to its higher cetane number and better combustion characteristics [20]. Brake specific fuel consumption is a measure of the fuel efficiency of an engine, defined as the amount of fuel consumed per unit of power produced. Lower BSFC values indicate better fuel efficiency. Figure 3 illustrates how, a engine gives output when it is operated with biodiesel-acetylene in dual fuel mode operation. The BTE is calculated by multiplying the fuel's lower heating value by the power output to mass flow rate ratio [21].

Between all the fuels used in this study, diesel had the highest BTE value, 29.9% at rated BP. At rated BP, it was 29.8, 29.8, 29.9, and 31.4% for the different compression ratio, respectively. When two different fuels with different densities and calorific values are blended, the engine's BTE rises with the appropriate term. Figure 4 shows about the amount of energy goes in waste without utilizing for useful form of work.

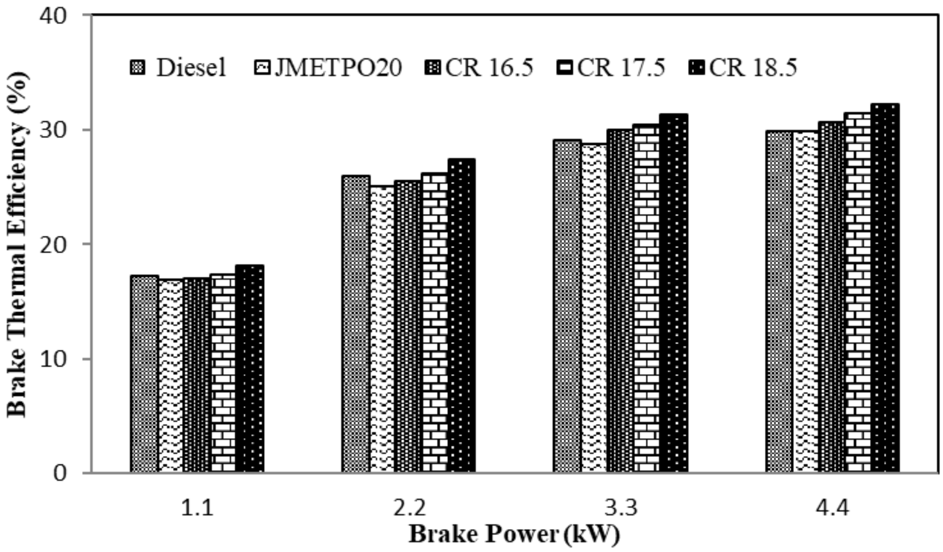


**Fig. 3 Load Vs BTE**

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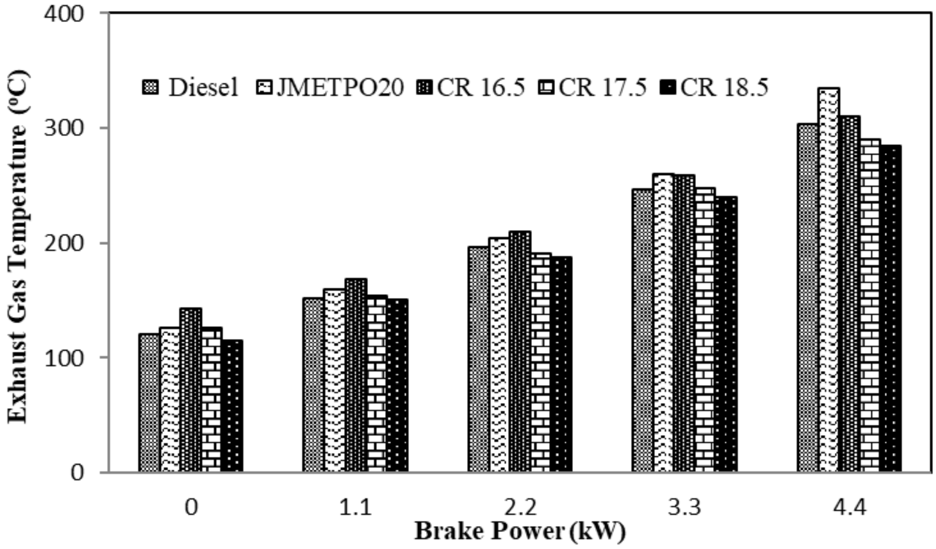


**Fig. 4 Load Vs EGT**

## V. EMISSION PARAMETERS

Nitric oxide is a precursor to nitrogen dioxide (NO2), which contributes to the formation of ground-level ozone [22]. The impact of biodiesel blends on NO emissions is complex and can vary based on the blend ratio and engine type [23]. Generally, lower NO emissions are observed with biodiesel blends due to the lower combustion temperatures associated with biodiesel. However, some studies report increased NO emissions at higher biodiesel concentrations, suggesting that the combustion characteristics of biodiesel can influence NO formation. It should be mentioned that the majority of vegetable oils have trace amounts of proteins that contain nitrogen [24]. Through combustion, this tiny quantity of nitrogen, in addition to atmospheric nitrogen, produces additional NOx emissions. This could be one of the reasons why vegetable oils emit more NO than diesel fuel.

The result of incomplete combustion is these emissions. Carbon monoxide is a colorless, odorless gas that is harmful to human health and the environment [25]. Studies have shown that biodiesel blends generally result in lower CO emissions compared to conventional diesel [26]. The oxygen content in biodiesel facilitates more complete combustion, leading to reduced CO formation. However, the extent of CO reduction can vary depending on the biodiesel blend ratio and the engine operating conditions.

The incomplete burning of working fuel within the combustion chamber is indicated by the emission of HC. HC emissions for various blends at 75% load for a range of fuel injection temperatures are displayed in Fig. 5. As the preheating temperature increases, the amount of HC emissions decreases. This is because the JME contains oxygen molecules, which promote better combustion within the engine's cylinder. As the compression ratio rises from 16.5 to 18.5, the HC emission for blend decreases, as seen in figure. Hydrocarbon oxides, including unburned hydrocarbons, are a significant contributor to air pollution and smog formation [27]. Biodiesel blends typically exhibit lower HC emissions due to improved combustion efficiency. The presence of oxygen in biodiesel enhances the oxidation of fuel, resulting in fewer unburned hydrocarbons. However, some studies indicate that higher blends of biodiesel may lead to increased HC emissions under certain conditions, highlighting the need for further research.

Smoke opacity is a measure of the particulate matter emitted during combustion, which can affect air quality and visibility [28]. Biodiesel blends have been shown to reduce smoke opacity compared to conventional diesel fuel. The higher cetane number and lower aromatic content of biodiesel contribute to more complete combustion, resulting in lower particulate emissions [29]. However, the reduction in smoke opacity can vary depending on the specific biodiesel blend and engine settings [7].

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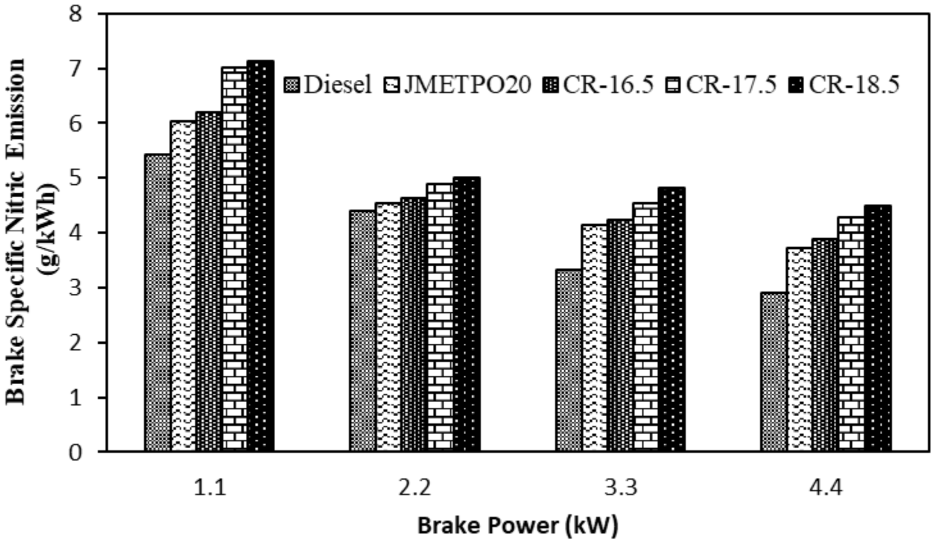


**Fig. 5 Load Vs NO**

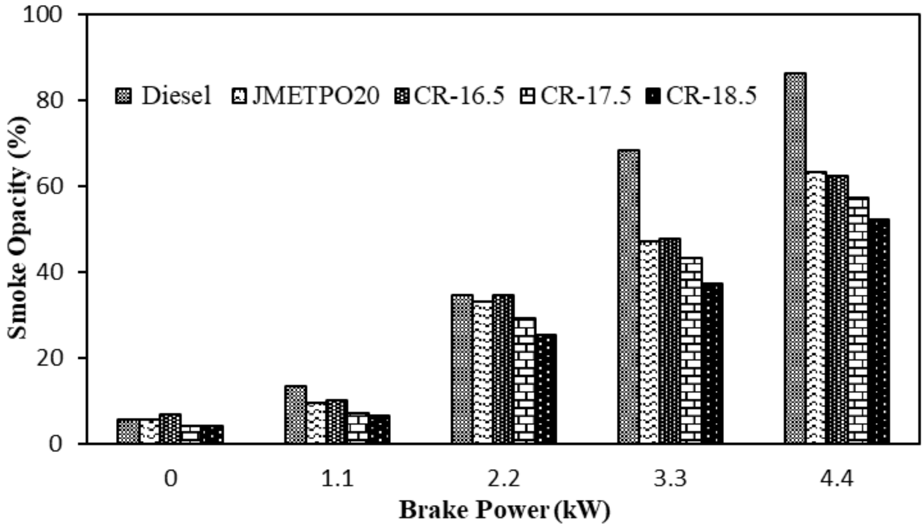


**Fig. 6 Load Vs Smoke Opacity**

## VI. CONCLUSION

The performance of biofuels in terms of brake thermal efficiency and brake specific fuel consumption varies significantly based on the type of biofuel and the engine configuration. While biofuels present a promising alternative to fossil fuels, ongoing research and development are essential to optimize their performance and integration into existing energy systems. Understanding these performance metrics is crucial for assessing the potential of biofuels in reducing reliance on fossil fuels and achieving sustainability goals. tyre pyrolysis oil represents a sustainable alternative fuel that can contribute to energy diversification and waste management. As technology advances and the demand for cleaner energy sources increases, tyre pyrolysis oil could play a significant role in the transition towards a more sustainable energy future.

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