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Performance and Emission Characteristics of Reactivity Controlled Compression Ignition (RCCI) Engine with Diesel-Butanol and Gasoline Blends

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Abstract: Reactivity Controlled Compression Ignition, or RCCI, combustion in internal combustion engines offers a practical way to reduce emissions and increase fuel efficiency. This study investigates the environmental impacts of RCCI combustion using Indian fuel combined with butanol biodiesel. Through intensive testing and analysis, the study assesses the emissions performance, combustion characteristics, and environmental impacts of this novel fuel blend. The results demonstrate a notable decrease in particulate matter, greenhouse gas emissions, and other dangerous pollutants when compared to conventional diesel combustion. Additionally, butanol biodiesel, which is produced from sustainable feedstocks, has the potential to lessen the harm that conventional fossil fuels cause to the environment. The findings suggest that burning RCCI with Indian fuel and butanol biodiesel could encourage a more sustainable and ecologically friendly transportation sector, which would support environmental conservation initiatives.

Keywords: RCCI Engine, VCR,BTE,BSFC,EGT

I. INTRODUCTION

Reactivity Controlled Compression Ignition (RCCI) machines have surfaced as a promising technology in the hunt for more effective and environmentally friendly internal combustion machines. These engines can achieve high thermal efficiency and potentially lower harmful emissions such as nitrogen oxides (NOx) and particulate matter (PM). RCCI engines are a significant development in addressing the issues of air pollution and climate change, which are becoming increasingly pressing. However, the widespread use of RCCI engines is contingent upon the availability of suitable alternative fuels that can enhance their combustion characteristics and improve their environmental performance. Biodiesel Butanol, also referred to as butyl alcohol, is a four-carbon alcohol with the formula C4H9OH that has five isomeric structures (four structural isomers). Butyl or isobutyl groups joined to a hydroxyl group are the building blocks of all primary alcohols, ranging from straight-chain to branched-chain tertiary alcohols. Among them are tert-butyl alcohol, 1-butanol, isobutanol, and two stereoisomers of sec-butyl alcohol. Although it can be used as fuel, butanol is primarily used as a solvent and an intermediate in chemical synthesis. Butanol can be used as energy in internal combustion machines. It's more like gasoline than ethanol. Both can be produced from biomass (as" biobutanol") and reactionary energies (as" petrobutanol"). The Swiss company Butalco is working on developing genetically modified provocations in Europe to turn cellulosic accoutrements into biobutanol. Gourmet Butanol, a US- grounded company, is developing a process that uses fungi to convert organic waste into biobutanol.

The characteristics of isobutanol make it a desirable biofuel:
Because 98% of gasoline has a relatively high energy density and can be combined with gasoline in any ratio, it can "drop into" the existing infrastructure as a significant fuel replacement or additive.

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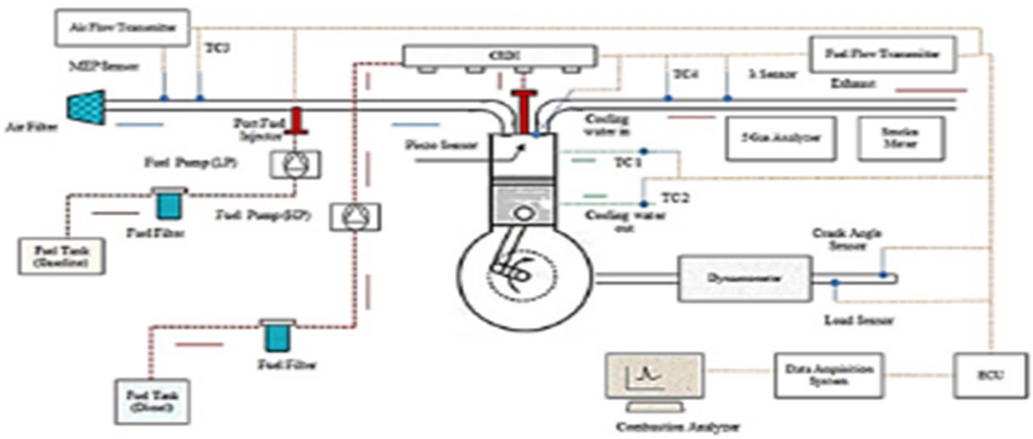
II. EXPERIMENTAL SET UP



A loading dynamometer of the eddy current type is connected to a four-stroke, single-cylinder, electric-start diesel engine with a variable compression ratio (VCR). The compression ratio can be changed without stopping the engine or altering the combustion chamber's geometry by utilizing a specially made tilting cylinder block arrangement. The equipment needed to measure combustion pressure and crank angle is included in the setup. There are interfaces for airflow, fuel flow, temperature, and load measurement. The setup's standalone panel box consists of an air box, two fuel tanks for the blend test, a manometer, a fuel measuring unit, transmitters for measuring the flow of fuel and air, a process indicator, and an engine indicator. Rotameters can be used to measure cooling water and calorimeter flow. With this configuration, VCR engines can be studied in terms of brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, and heat balance. The "Labview-basedEnginesoft" software package is available for online performance evaluation. A computerized diesel injection pressure measurement is an optional feature.

Table.2.1 Butanol Bio Diesel Properties.

Sr No	Properties	Scum Oil
1	Viscosity (mPa·s)	3.64
2	Specific Gravity	0.81
3	Calorific Value (KJ/KgK)	33,200
4	Flash Point (^{0}C)	35
5	Fire Point(^{0}C)	40

RCCI Engine Specifications

Product	VCR Engine Test Set up 1 Cylinder,4 Stroke Diesel Engine
Engine	Kirloskar Made 1 Cylinder,4 Stroke Diesel Engine, Water Cooled, Power 3.5 kW@1500 rpm,Bore 87 mm,Stroke 110 mm
VCR Arrangement	CR Change is accomplished with special features as below Compression Ratio can be changed without stopping the engine Without changing combustion chamber geometry & cylinder head It is furnished with specially designed tilting mechanism
Dynamometer	Eddy Current Water Cooled

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Load Indicator	Digital, Range0-50 Kg
Rotameter	Engine Cooling 40-400LPH
Calorimeter	25-250 LPH
Fuel Flow Transmitter	DP Transmitter
Air flow Transmitter	Pressure Transmitter

III. METHODOLOGY

Methodology adopted to control emissions from RCCI Engine.

1) RCCI engines can have their emissions reduced in a varietyof ways.
2) Choosing the right fuel at the main injector or port fuel injector.
3) Various chemicals that oxidized the unburned product were used.
4) Warming up the air coming in.
5) Applying pressure to the intake air entering the engine cylinder.
6) Timing of the variable valve.
7) The main injector's timing can be advanced or delayed.
8) To lower CO and HC in the current study, one or any of the appropriate approaches listed above may be applied.

IV. RESULTS AND DISCUSSION

1) Brake Thermal Efficiency:

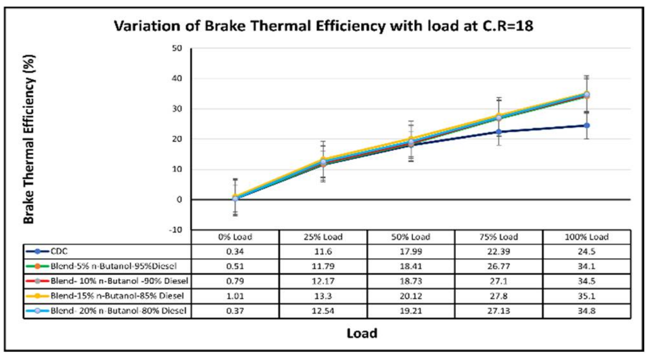

Fig.1 Load Vs Brake Thermal Efficiency

The figure shows various combinations of Brake Thermal Efficiency (BTE) with load. The efficiency of thermal brakes increases with load in all cases. Given that it consistently exhibits the highest efficiency among the blends under all load conditions, B15 seems to be the most efficient fuel blend in this data set. The least successful is always the CDC.

2) Brake Specific Fuel Consumption:

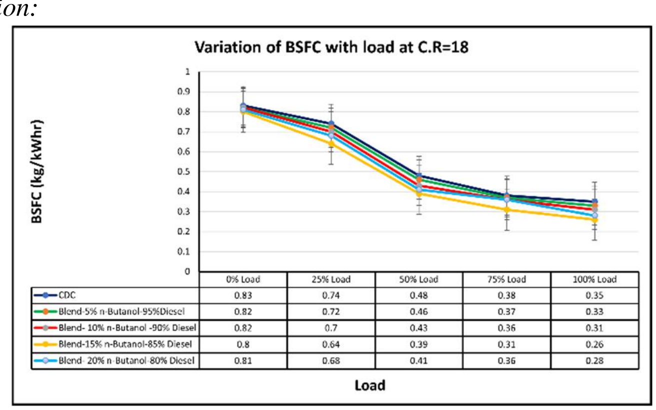

Fig 2.Load Vs Brake Specific Fuel Consumption

Figure 2 shows the load-dependent variation in specific fuel consumption. For all fuel blends, BSFC falls as the load rises. A lower BSFC, which is usually the consequence of a higher blend percentage, indicates better fuel efficiency, particularly at medium to high engine loads. B15 is consistently the best when it comes to lower BSFC. The BSFC is declining for a larger percentage of blends.

3) Brake Power:

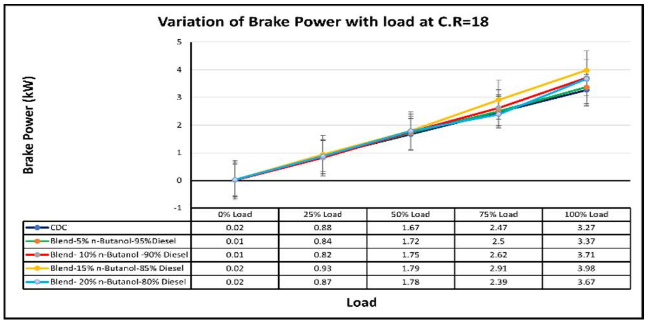

Fig.3 Load Vs Brake Power

The load variation with respect to BP at CR=18 is shown in Fig. 3. Diesel fuel was found to have the least amount of brake power when compared to other fuels. At increasing loads, all blends display higher parameter values; however, their performance varies. Blend 10 consistently shows a balanced trend, but Blend 15 shows higher values at peak loads, indicating potential issues in higher-load scenarios.

4) Emission Parameters:

a) CO Emissions:

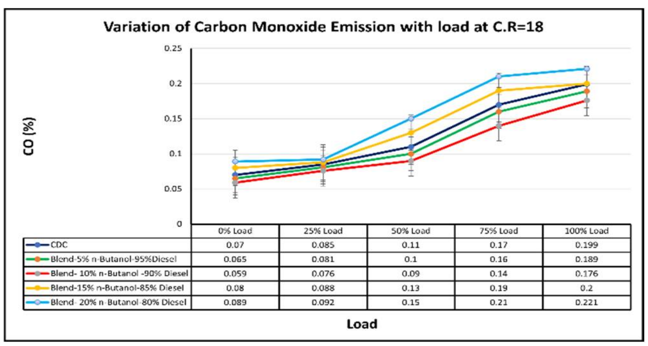

Fig.4 CO Emissions

The CO emissions for different fuel blends in relation to load are shown in Figure 4. With the lowest emissions at 0% load and the highest at 100% load, all fuel blends show a steady trend of increasing CO emissions as load increases. B5 consistently shows reduced CO emissions in comparison to the other blends. The data suggests that B5 is the fuel that lowers CO emissions the most across all load levels. It strikes a balance between environmental sustainability and operational efficacy.

b) CO2 Emissions:

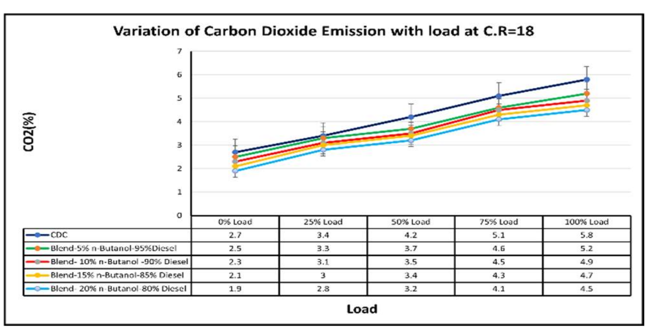

Fig 5. CO2 Emissions

Figure 5 illustrates how CO2 changes in response to loads. CO2 emissions generally increase with increasing load levels for all fuel blends. Emissions appear to decrease as the percentage of blending increases (B20 consistently shows lower emissions compared to CDC and other blends). As the blend percentage rises, the CO2 of B20 decreases by 1.9, 2.8, 3.2, 4.1, and 4.5 at load capacities of 0%, 25%, 50%, 75%, and 100%, respectively.

c) HC Emissions:

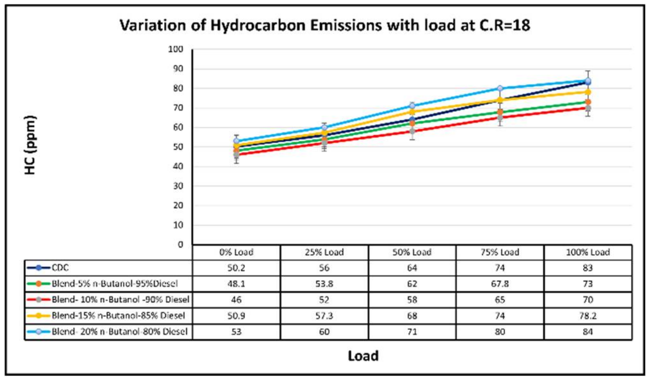

Fig.6 HC Emissions

Figure 6 predicts that as loads increase, hydrocarbon emissions will also increase. Fuel-rich combustion, crevice flows, valve overlap, misfiring, and flame quenching desorption are the main causes of hydrocarbon emissions. Emissions from CDC, B15, and B20 increase with increasing load; B20 has the highest emissions overall. Compared to other types, butanol B10 emits substantially fewer HC emissions. The graph shows that B5 and B10 lower the HC emission at any load variation.

5) Exhaust Gas Temperature:

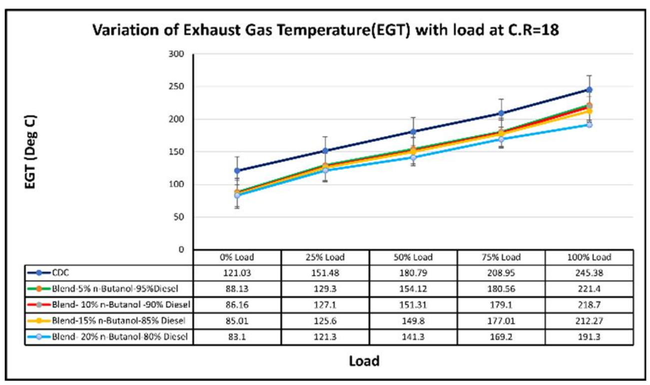

Fig.7 Exhaust Gas Temperature

As the blend concentration increases (from CDC to B20), the exhaust gas temperature decreases under all load conditions. This pattern suggests that higher blend concentrations might be linked to lower exhaust temperatures. This might indicate lower peak temperatures due to the properties of the blends or more efficient combustion.

V. CONCLUSIONS

The current experimental research project includes the characterization, performance, combustion, and emissions characteristics of RCCI engines that are powered by biodiesel blends. The results of the study were summarized as follows:

1) B15 enhances engine performance metrics, such as brake thermal efficiency, in comparison to diesel. This happened because of the fuel's inherent oxygen content, which makes fuels burn all the way through.
2) When compared to diesel, brake power rises with B15 while BSFC falls.
3) Emissions of hydrocarbons (HC) and carbon monoxide (CO) drop when B10 and diesel are compared at 3.71 kW brake power.
4) Compared to diesel, B20 lowered C02 emissions at 3.61 kW of brake power.

5) Compared to diesel, B20's brake power of 3.67 kW decreased CO2 emissions.
6) The exhaust gas temperature of the B20 is lower than that of the diesel.

Butanol biodiesel blends are a viable fuel substitute for RCCI engines with respectable combustion, emission, and performance characteristics, according to the discussions above. Blends of butanol biodiesel may therefore be a suitable alternative to fossil diesel fuel. Taking everything into account, B15 seems to be a superior alternative fuel choice.

VI. ACKNOWLEDGEMENT

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