EXPERIMENTAL INVESTIGATION PERFORMANCE ON A VARIABLE COMPRESSION RATIO ENGINE USING MAROTTI BIODIESEL, COMPARING RESPONSE SURFACE TECHNIQUES AND COMPUTATIONAL FLUID DYNAMICS MODELING

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Abstract.

We obtain fossil fuels from burning or decomposing dead organisms, which are natural processes. Crude oil, coal, and natural gas are a few of the more well-known fossil fuels. In order to obtain fossil fuel, more dangerous gases are burned, which causes social and environmental problems like global warming and air pollution. In this case, biodiesel is viewed as an alternative to clean, environmentally friendly renewable energy sources. This study focuses on Marotti oil, a biodiesel fuel substitute for diesel engines with variable compression ratios (VCR).Computational fluid dynamics (CFD) software from ANSYSsoft is used to simulate a variable compression ratio engine while changing the relevant parameters. When Marotti oil is applied to automobiles, issues like a cooking injector, lubrication, a gumming filter, etc. are resolved. Results are assessed based on emission and performance. Response Surface Method (RSM) is used in the planning of the experiment to select the sequence factors. The improved and increased nitrogen oxides enable important parameters like the combustion ratio, fuel injection pressure, and start of injection to perform as intended.By reducing carbon dioxide and hydrochloride, which increases thermal energy, Marotti oil is used. It is evident that biodiesel-based fuel is environmentally friendly and improves engine performance.

Keywords: Response Surface Method, fuel, natural fuel, environmental situation, Marotti oil.

AIMS AND BACKGROUND

In recent times Biodiesel is considered the alternative for diesel engines. It is obtained from animal fat and vegetable oil. Certain biodiesel fuels are obtained from the esterification process. Marotti oil is one such oil that is obtained from non-edible oil through the esterification process of Biodiesel[1]. The Marotti oil obtained from the esterification process of biodiesel can be used for vehicle engines because they are considered an alternative to petroleum. Because biodiesel fuels are renewable they are eco-friendly. The biodisesl fules are non-toxic and biodegradable. They also reduce the discharge of harmful pollutants from vehicle engines, such as the emission of carbon-di-oxide will be reduced by 80%, and zero percent emission of sulfur. Biodiesel fuel has the unique feature of cetane number through which helps in noise reduction[2]. A recent study reported that biodiesel fuel usage in the vehicle engine will extend the engine's life due to high lubrication and output power unaffected by biodiesel fuels. The Indian state government is taking the initiative to develop biofuel companies in the country. The company setup will be based on the central government's guidelines. In India, Marotti oil is highly found in the state of Kerala. They are suitable for biodiesel production. Marotti is a tree that is primarily found in Kerela. This Marotti oil has an ancient history because it has its medicinal value[3,4]. Various experiments have been carried out for biodiesel production using Marotti oil through the oil's influencing parameters[5]. One of the critical parameters of Marotti oil is the optimum parameter which is analyzed through performance evaluation. The botanical name of Marotti oil is *Hydnocarpus laurifio* which belongs to the family of Flacourtiaceae. The fruit which seeds inside it contains almost 63% of Marotti oil[6]. The oil is extracted from the seed through a steam distillation process. Marotti oil has high medicinal value. Some of the significant fatty acids found in the oil are hydnocarpic acid, cyclopentene fatty acids, chaulmoogric acid, garlic acid. The oil's fatty content may vary from 2 to 6% - the Marotti oil with fat content less than 3% alkaline esterification for biodiesel fuel production. The Marotti oil with 4.5% nt fatty content must go through a two-step esterification process. Table 1 shows the fatty acid content of Marotti oil[7].

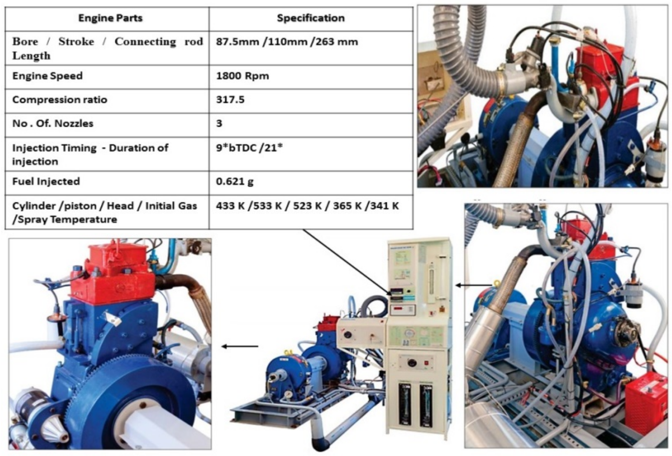
Table 1. Fatty acid profile of Marotti oil

Fatty Acid	Acronym	Molecular weight	Weight in oil (%)
Palmiticacid	16:1	256.42	1.9
Hydnocarpicacid	16:2	2.54.46	48.6
Chaulmoorgricacid	18:2	282.45	37.2
Gallic acid	18:3	280.43	12.4

It was found that biodiesel is obtained from edible oil. Still, in India's case, Biodiesel is obtained from non-edible seeds such as the Marotti, Neem, Mahua, etc. all these can be used for biodiesel production[8]. Marotti biodiesel has low brake thermal power, high smoke density, etc. It can be found that Marotti biodiesel can be used for DI diesel engines without any alterations to its present condition. In general, the biodiesel from punnakka oil and Marotti oil are suitable substitutes for diesel based on their performance and are preferable too, since the oils are non-edible[9,10].In this present study, the RSM is used to examine the impact of the DI diesel engine's injection factors based on the performance and emission. The authors concluded that the desirability methodology of the RSM was an effective and easiest optimization procedure. Taguchi Design Of experiments planning is utilized to examine the split injection approach for an internal combustion engine working in the ignition Partially premixed combustion method. Thermochemical synthesis of carbon-sequestered material into engine and biofuels emission characteristics. Green gas biofuels' energy outlook in the coming years.[11] This demonstrated that algae were the most efficient and cost-effective Carbon dioxide sequestering compared to terrestrial vegetation in an environmentally acceptable and cost-effective manner with concurrent wastewater cleanup.[12]The authors have concluded that the Taguchi technique was possible and proved to be an efficient way for parametric studies[13]. Owing to the increased humidity level of carbon sources, thermal compression was favored over pyrolysis for biofuel production. Algae-based fuels emit fewer greenhouse gases and have a higher energy content.[14] It assists researchers, conservationists, and industry professionals in assessing the effect of algae-based bio-energy on sustainable energy and the ecosystem.

EXPERIMENTAL

The performance analysis of the engine is complicated due to certain factors which are closely associated with the engine performance. The modeling process of the Computational Fluid Dynamicsengine gives a detailed description of the toxin formation and operational cycle. While modeling the engine, one should keep in mind the engine's efficiency through the performance and the lesser emission of harmful pollutants. In this research, ANSYS^{soft} is used to model the cylindrical stream through which the ignition and implementation can be assessed. In recent times ANSYS^{soft} is used in Computational Fluid Dynamic software engines and Marotti biodiesel which altogether heps in the time needed to design the grid for engine modeling. The current study's primary purposeis to examine the utilization of waste potatoes from food industries as a precursor for bioethanol. Potato starch produced from waste potatoes was utilized as an economical source for biomass, and bioethanol was produced by fermentation. A genetic algorithm is used for analyzing the optimum parameters (Fig. 1).



Engine Parts	Specification
Bore / Stroke / Connecting rod Length	87.5mm /110mm /263 mm
Engine Speed	1800 Rpm
Compression ratio	317.5
No . Of. Nozzles	3
Injection Timing - Duration of injection	9*bTDC /21*
Fuel Injected	0.621 g
Cylinder /piston / Head / Initial Gas /Spray Temperature	433 K /533 K / 523 K / 365 K /341 K

Fig.1.Engine specifications

PARTICIPATORY RESEARCH METHODOLOGY

In this present research, a VCR engine with Marotti biodiesel is used. Figure 1 illustrates the features and specifications of the Variable Compression Ratio (VCR)engine. The sector model corresponds to 1/6 of the overall ignition chamber taken into account, diminishing the computing time. Figure2 describes the VCR engine's computing performance where the Mexican hat-based ignition chamber is used. The ANSYS Computational Fluid Dynamic.

code is used for evaluating the performance of the engine replication. Usually, the VCR engine with turbance modeling such as the (Reynolds averaged Navier–Stokes) RANS is used. In this present study, the RNG k–ε is utilized since it is especially appropriate for Variable Compression Ratio (VCR) engine modeling.

In this process, an *n*-heptane mechanism with a SAGE is used for combustion simulation. One of the critical reasons for selecting *n*-heptane is mainly due to the H/C % of the chosen *n*-heptane, close to the VCR biodiesel engine. The VCR engine is made of 168 reactions and 42 species to form NO_x.

The critical parameters considered in the process are the start of injection, fuel injection pressure, compression ratio, exhaust gas recirculation, and the influence of these mentioned parameters for the VCR engine's performance. Table 2 describes the performance of implementation and emission of the chosen parameters. The RSM layout of experimentation has been designed for mathematical experiments that are based on the model

Table 4.Values of *p* for model terms of ANOVA analysis

Parameters source	Sum of squares	Factors Df	Mean square	*F* value	p-value Prob > F
Model	2737.345	16	195.5223	904.9312	< 0.0001
A- blend ratio	373.6356	2	373.6345	1729.234	< 0.0001
B- compression ratio	458.6778	2	458.6787	2122.845	< 0.0001
C- injection time	312.9334	2	312.9398	1448.376	< 0.0001
D- injection pressure	232.412	2	232.410	1075.634	< 0.0001
AB	8.4623	2	8.4623	39.19165	< 0.0001
AC	38.9393	2	38.9345	180.2077	< 0.0001
AD	16.4836	2	16.4898	76.28834	< 0.0001
BC	106.8133	2	106.8234	494.3411	< 0.0001
BD	10.5687	2	10.5656	48.88456	< 0.0001
CD	87.70387	2	87.70456	405.991	< 0.0001
blend ratio ^2	230.0123	2	230.0222	1064.544	< 0.0001
compression ratio ^2	308.9198	2	308.9165	1429.709	< 0.0001
injection time ^2	879.9589	2	879.9582	4072.577	< 0.0001
injection pressure ^2	77.92665	2	77.92682	360.6599	< 0.0001
Residual	3.024978	16	0.216096		
Lack of fit	1.762243	12	0.176292	0.55823	0.7928
Pure error	1.26276	8	0.31597		
Total	2740.423	22			

BSFC AND CR IMPACT ON VCR ENGINE

Figure 6 illustrated the collaborative impacts compression ratios and the start of injection on Soot, NOx, and peak pressure. The injection start has been improved from 0° to 30°, BTDC, leading to a reduction in soot emissions and an improvement in NO_x emissions and peak pressure. It is observed that an improvement in the compression ratio in conjunction with the improved BSFC leads to the rise of NO_x emissions and peak pressure, although a reduction in the compression ratio compared with BSFC. The models are significant, such as the values of p are not more than 0.05. The simulation evaluation of RSM is demonstrated in Table 5. This could be because as the compression ratio is improved, it grows in-cylinder pressures and temperature, which will enhance flame temperatures.

Table 5. Simulation evaluation of RSM

Description	BSFC	NO_x	Break power
R^2	1.222032	0.987451289	0.998896245
AdjustedR^2	0.968716	0.985354796	0.997792823
Predicted R^2	0.952212	0.989510234	0.995575674
Adequate precision	50.76423	82.56930145	110.2173466

intake mixes. This mixture of reduced oxygen content and diminished flame temperatures reduces NO_x emissions. From the graphs, it can be inferred that the combination of enhanced brake power and minimal EGR leads to superior NO_x emissions and superior in-cylinder pressures but extremely minimal emissions of break power soot.

CONCLUSIONS

Biodiesel is considered an alternative to renewable energy sources that are cleaner and harmless to the environment. In this research for VCR diesel engines Marotti oil is used as an alternative biodiesel fuel instead of diesel. The VCR engine simulation is done with ANSYS fluent CFD, where the parameters involved are altered.From the current study, the following conclusion may be drawn. Compression Ratio, Fuel Injection Parameters, and Break Power were all found to have increased performance. The improvement in break power improved the performance of NO_x, and peak pressure through the implementation of soot decreased. But this situation differed when the execution of EGR increased. It ultimately reduces the performance of the NO_x and peak pressure with an increase in soot. Alteration in the factors such as the brake power, EGR, NO_x, CR will not decrease the soot. The NO_xvalue remains the same based on the condition of the peak pressure. The interface consequences of Exhaust Gas Recirculation × Break Power, Exhaust Gas Recirculation × Nitric Oxide, are significant on soot, Nitric Oxide, and peak pressure. Although the combination of Compression Ratio and Brake Specific Fuel Consumption had a considerable influence on soot and EGR, it had no meaningful effect on Nitric Oxide. The application of Response Surface Methodology aided in determining the best performance with the required percent of effectiveness. The operation factor obtained from the parameter is 1691% in EGR, 13.69 BTDC in BSFC, 1153.15 bar in break power, and 14.25 in $NO_x$with an interest of 0.95.

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