A Study of VCR Diesel Engine Fuelled with Marotti Bio-diesel Using CFD

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ABSTRACT:

Straight vegetable oils are non-conventional in nature and can be directly used as fuels in diesel engines. However, their high viscosity and poor volatility lead to reduced thermal efficiency and increased CO, smoke density and HC. Transesterification is one of the methods, by which viscosity could be reduced drastically and the fuel could be adopted for conventional compression ignition engine. This transesterified vegetable oil is popularly known as Bio-diesel (or) Vegetable Oil Methyl Ester (VOME). In our work, an experimental study has been conducted to measure the engine

combustion

characteristics marotti (Hydnocarpus

performance,and emission of Wightianus) bio-diesel (methyl ester of marotti oil) and its mixtures with conventional diesel fuel. The same work has been extended by using CFD technique. The results for the same has been compared and presented. The Marotti bio-diesel or Marotti oil Methyl Ester (MOME) has been produced using Methanol (CH3OH) as solvent and sodium hydroxide (NaOH) as base catalyst during the transesterification process. The MOME has been mixed with the base (conventional) diesel in the ratio of 10:90, 15:85 and 20:80. The performance, combustion and emission characteristics of these mixtures on the VCR with the compression ratio of 14:1, 16:1 and 17:1 have been investigated and compared the experimental results with the conventional diesel engine. The multi-fuel capability is increased by the VCR engines since they can improve the low load operation and capability of starting. The CFD analysed the feasibility of the VCR engine design for the process of opening the exhaust valve during the compression strokes of various compression ratios. The

model is modified so that the simulationof 14:1 and 17:1 are similar. The second valve opening at the 17:1 would be developed on their initial opening of the stroke. The fuel is injected when the valve of the exhaust is closed, by which the BSFC would be increase. The p-test is used for testing the actual and predicted results. The result shows that the HRR is lower for the 20% blend of the Marotti oil bio-diesel with a compression ratio 16:1. The CFD used for the compression stroke performance modification. The Marotti oil blend of 20% have better performance by the reduction of the BSFC and increased in BTE. Compared to the diesel engine, MOB20 has longer duration of combustion and lower ignition delay.

Keywords: Bio-Diesel, Marooti Oil, Tranesterification Process, CFD.

1. INTRODUCTION

Energy is required for our basic needs of life such as for cooking food, lighting, communication and transporting. The energy can be in forms such as chemical, heat, nuclear, kinetic, light, potential and electrical energy. The United States gets 81% of its total energy from oil, coal, and natural gas, all of which are fossil fuels. The above items depend on those fuels to heat our homes, run our vehicles, power industry and manufacturing, and provide us with electricity. The major energy source during the pre-industrial epoch was wood, later coal becomes the major source due to the discovery of the steam engine. Afterward, the internal combustion engine was discovered, the popular fuel source are natural gas, petrol and diesel. Fossil fuels are widely used for meeting the demand of rising energy which leads to the greenhouse gas emissions continuous increment. The energy supply should be sustainable and secure since it has become an essential part of our life. The convenient source of energy is disbursed profoundly which leads to environmental pollution. Also, the supplies of these sources are affected which leads to scarcity, therefore these conventional sources of energy are imported. By importing the energy sources, the direct investment of foreigners is happening and it creates the crisis of energy. Increasing in need of energy and derisory energy resources, the irreconcilability problem arises. In this century, the priority for the clean, secure and sustainable energy source is required, due to the energy supply lacks. The world energy demand in 2018, grew by 2.9% where it will reach 740 million terajoules (a 30% growth) by 2040. The worldwide energy usage could be triple when comparing the year from 1980 to 2050. But in 2020 the consumption of energy globally reduced by 4% due to the restrictions of transport and lockdown measures for the COVID-19 crisis. International Energy Agency (IEA) shows that during the year 2040 there will be a 30% increasing pattern of energy in the consumption compared with the present year. In the world total energy consumption, two-thirds of energy is consumed by China and India in the Asian non-Organisation for Economic Co-operation and Development (OECD) countries. The potential growth of a nation can drops 1 to 2% due to incompetent and improper energy systems which are proved by a World Bank study. Table 1 indicates the fatty acid composition of Marotti seed.

Table 1: Fatty Acid Compositions of Marooti Seed

Oleic acid	49.1 to 61.9%
Stearic acid	14.4 to 24.1%
Palmitic acid	13.6 to 16.2 %
Linoleic acid	2.3 to 15.8 %
Arachidic acid	0.8 to 3.4%
Myristic acid	0.2 to 2.6%

2. LITERATURE SURVEY

The development of biomass in China was studied by Wang Jianxin *et al.* (2007). The ethanol-gasoline mixture was distributed since the development of bio-diesel was under. In order to lower the emissions of soot, the ethanol was blended with the diesel. Direct blending, dual-fuel system and online blending, the methods for the blending of ethanol with diesel were discussed. Also, the investigation for the blending of different methods such as ethanol-fossil diesel, bio-diesel and fossil diesel and ethanol-diesel was passed out. The ignition and emanation of these blends were discussed and the result shows that the reduction in PM and soot emission was greater in the ethanol-bio-diesel blend compared with other blends. The ethanol-fossil diesel blending application was more difficult than the ethanol-gasoline blending. The highest smoke reduction was obtained when using the ethanol-diesel blends. The bio-diesel feedstock in Indonesia for the vegetable oil bio-diesel was discussed by Fritriyanti Mayasari & Rinaldy Dalimi (2014) for many latent crops. The issues in feedstocks such as productivity, competition with food, market price, conversion of the bio-diesel efficiency, potential, supply and crop resistance during the change of climate were stated. The bio-diesel was obtained from the palm, coconut, jatropha, soybean, Reutalis Trisperma and rapeseed oils. The issues of these oils were discussed and the results show that the best feedstock for bio-diesel production in Indonesia were the Reutalis Trisperma, Jatropha and palm oils. Siddharth Shorot & Kumar Gaurav (2019) reviewed the production of bio-diesel from mutton waste fat based on the livestock and the comparison with the conventional feedstock was carried out. Haq Nawaz Bhatti *et al.* (2008) proposed the bio-diesel production from the waste tallow both chicken and mutton fats. The gas chromatographic analysis was used in the transesterification process. Sulphuric acid acted as the acid catalyst whereas for the base catalyst potassium hydroxide was used. The result shows that the saturated fatty acids were in higher percentage in mutton and lower percentage of unsaturated fatty acids. Fatty acids of 97.25% and 98.29% was identified in mutton and chicken fat respectively. Fuel properties were recommended for both highly suitable fats which form the bio-diesel of higher yield. Shirneshan *et al.* (2014) investigated the performance of the bio-diesel produced from the waste cooking oil. Central composite rotatable design of 5-level three-factor engine with four-cylinder was used for the experiment. The Response Surface Methodology (RSM) was used for the analysis of the optimization of the statistical data and the surface plots for various impacts of the input parameter such as CR, BR, and bio-diesel blends on the output parameters such as BTE, BSFC, emissions of NO_X, CO, HC and carbon dioxide. Dan Moldovanu & Nicolae Burnete (2013) produced the bio-diesel and the conventional CI engine was operated with blends of bio-diesel with diesel using CFD technique. After the simulation was done, all the necessary data were extracted and processed in order to be presented in a traditional way. Kesong Zhang *et al.* (2019) calculated the pressure curves in different operation conditions fit the measured data reasonably well. The oxidation mechanism could reproduce the main characteristics including combustion phase and NO_X emission of diesel combustion in different cases.

OBJECTIVE:

The objectives of this project are to use the example of biofuels to demonstrate the way that multiple objectives are developed in energy and environmental policy. Bio-fuels are promoted as replacements for transport fuels, but biofuel policy is also geared towards socioeconomic goals such as agricultural subsidy and strategic goals such as security of energy supply.

3. RESULTS AND DISCUSSIONS:

Table 2: Various Properties of Neat Diesel, Marotti oil Blends and Neat MOME

S. No	Properties	Diesel	B100 (Neat MOME)	MOB20	MOB15	MOB10
1	Density (kg/m^3)	840	865	845	843	842
2	Kinematic Viscosity (cSt at 40°C)	3.9	5.21	4.46	4.34	4.19
3	Calorific Value (MJ/kg)	43.00	34.60	39.88	41.33	41.79
4	Flash Point (°C)	56	162	110	108	105
5	Fire Point (°C)	70	183	135	125	116

As per standards, the properties of various assortments of Marotti oil with diesel and MOME (Marotti Oil Methyl Ester) are determined and are summarized in Table 2.

Table 3: VCR Engine Specification

Description Details	Specification Details
Bore/ Stroke/ Connecting rod Length	87.5 mm/ 110 mm/ 263 mm
Engine Speed	1800 rpm
Compression ratio	**14:1,16:1,17:1**
No. of Nozzles	3
Injection timing – Duration of Injection	9° bTDC/21°
Fuel-Injected	0.621 g

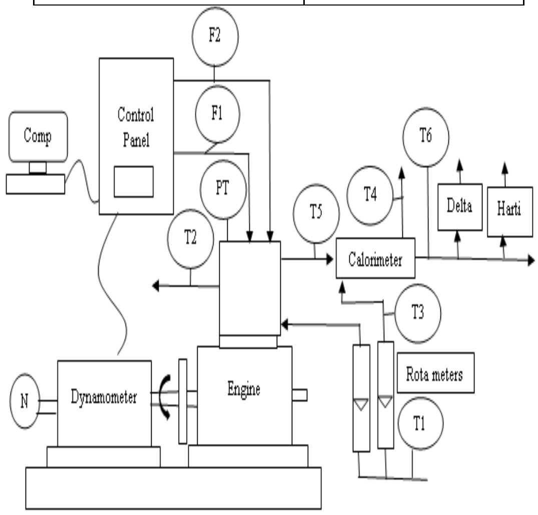

Figure 1: Line Diagram of Conventional CI Engine with VCR

Hartri - SM-Hartridge smoke meter
DELTA - 1600S- Exhaust 5 Gas analyser
N - RPM decoder
PT - Pressure transducer
T6 - EGT after calorimeter
T5 - EGT before calorimeter
T2 - Outlet engine jacket water temperature
T4 - Outlet calorimeter water temperature
T1andT3- nlet water temperature
F2 Air intake DP unit
F1 Fuel flow Differential Pressure (DP) unit

Figure 1 shows that the line diagram of VCR conventional engine. The experiment is carried out in the VCR engine with different compression ratios. The best brake thermal efficiency is obtained by using different conditions of loads at 1500 RPM speed of the engine. After the stable condition of the engine, only the records are recorded. The engine of variable compression ratio is started using the diesel fuel and the engines are allowed to warm up. After the initial warming end, the temperature of the water is cooled to 60 deg C. Then the output parameters such as BTE, BSFC, mechanical efficiency, EGT, BP are measured for the different loads for the diesel, Marotti oil Bio-diesel (MOME), blends of Marotti of 10, 15 and 20%. Gas analyser (AIRREX HG-540) is used for the measurement of the exhaust emissions which will occur during bio-diesel combustion. The various sensors produces data which are collected, stored and analysed using the IC Engine Soft, a computerized data acquisition system.

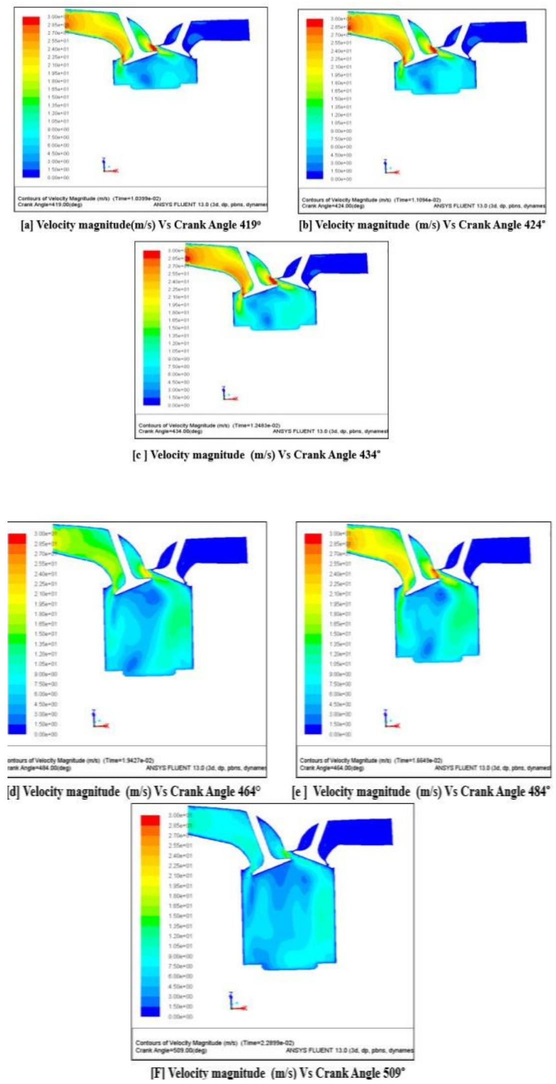

Figure 2: Model of VCR engine velocity magnitude vs [a] Crank angle 419˚ [b] Crank angle 424˚ [c] Crank angle 434˚ [d] Crank angle 464˚ [e] Crank angle 484˚ [f] Crank angle 509˚

Table 3 illustrates the features and specifications of the VCR engine Ramachandran *et al.* (2018), Satyam & Kalapala Prasad (2020), Banapurmath (2009). The sector model corresponds to 1/6 of all the overall ignition chamber taken into account, diminishing the computing time. Mexican hat-based ignition chamber is used for the VCR engine's computing performance and the results are shown in Figure 2. ANSYS CFD code is used for evaluating the performance replication. Usually, the VCR engine with turbulence modelling such as the Reynolds Averaged Navier-Stokes (RANS) is used. The RNG k-Ɛ is utilized since it is especially appropriate for VCR engine modelling.

The boundary conditions used in computational fluid dynamics (CFD) are

- Intake conditions
- Symmetry conditions
- Physical boundary conditions
- Cyclic conditions
- Pressure conditions
- Exit conditions.

CFD modelling is used to investigate the different flow characteristics in CI engine using the commercial fluid flow analysis. The numerical solution in terms of generated head across the stage closely followed the experimental single stage head and flow curve which validated the modelling technique. Generally during the factory acceptance testing of CI engine, only net residual thrust loads acting on the bearing are measured. Therefore, in order to further validate the theoretical model, it was considered to be important to compare the calculated radial pressure distribution and rotation factor profile with the CFD results. Subsequently, the calculated rotation factor and pressure profiles were plotted against the CFD values. It is clearly evident that the calculated values are very well supported by the CFD results.

4. Conclusions:

The result shows that the Marotti oil blend of 20% have better performance by the reduction of the BSFC and increased in BTE. Compared to the diesel engine, MOB20 has longer duration of combustion and lower ignition delay. The HRR is lower for the 20% blend of the Marotti oil bio-diesel with a compression ratio 16:1. The

CFD used for the compression stroke performance modification. The value of predicted and actual R^2 indicates the model is fitted significantly. The NO_X emission is reduced by the performance of the brake power and CR and fuel injection pressure. The result shows that the Marotti oil bio-diesel can be used for the conventional engine with reduced emissions and without any further modifications.

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