NILEST JOURNAL OF SCIENCE, TECHNOLOGY, AND MANAGEMENT (NIJOSTAM) VOLUME 3, ISSUE 1, NOVEMBER, 2024, pp. 109-119
eISSN: 3027-2580 www.nijostam.org

MODELING AND SIMULATION OF BIODIESEL AND BLENDS FROM JATROPHA-NEEM OIL IN COMPRESSION IGNITION ENGINES

[1]Oladele A.K, [1]Muhammad S.U. and [1]Solomon W.C.

1. Department of Mechanical Engineering, Nigerian Defence Academy, Kaduna, Nigeria

Correspondence: *ayodeji.oladele2020@nda.edu.ng*

ABSTRACT

While providing solutions to the emission of greenhouse gases through the use of biodiesels, several concerns have also arisen from the compatibility of such fuels with conventional diesel engines. The aim of this research is to model and simulate biodiesel and blends from Jatropha-Neem combination in Compression Ignition Engines. This article describes how a 4-cylinder compression ignition engine model was developed in Diesel R-K software interface with acknowledged specifications of an existing engine test bed using the Diesel R-K modeling software. Computed fuel properties of biodiesel and blends from Jatropha-Neem hybrid oil were obtained, their values were fed into simulated engine model. The simulation of engine recital in Diesel R-K established that the biodiesel and blends have properties that are considerably similar with petro diesel. The simulation of the biodiesel blend data revealed that the highest brake-specific fuel consumption was observed for JN B10, followed by JN B15, and JN B20. The highest brake mean effective pressure was achieved during the simulation of the CI engine performance with JN B100, JN B5 and JN B15 biodiesels correspondingly. The highest air-fuel ratio values were depicted by JN B100, JN B20 and JNB15 in descending order.

KEYWORDS

Biodiesel, Diesel R-K, Modeling, Simulation

ARTICLE HISTORY:

Received: June, 2024
Received: in revised: October, 2024
Accepted: November, 2024
Published online: December, 2024

INTRODUCTION

Biodiesel consists of fatty acids derived from alkyl esters that are produced when alkanols are catalyzed to mix with vegetable and animal fats in a transesterification reaction, according to Lomonaco et al. (2012). Hu et al. (2005) define biodiesel as the monoalkyl esters of long-chain fatty acids that are made from biological feed stocks that are sustainable. Numerous studies have been conducted in an attempt to identify sustainable solutions for the world's fuel dilemma and the environmental risk associated with the usage of fossil fuels. Using an engine cycle simulator, Bhave et al. (2004) worked on simulating a dual-fueled, multi-cylinder homogeneous charged compression ignition engine. They looked at how the octane number affected the multi-cylinder truck engine's emissions, combustion characteristics, and engine performance. Fuel for the homogeneous charged compression ignition engine consisted of branched chain octane, branching chain heptane, and straight chain heptane. The auto-ignition, in-cylinder pressure, carbon monoxide, nitrogen oxides and hydrocarbon predicted and experimental values showed a remarkable agreement, according to the authors.

Using constraint modeling techniques, Kakee and Pishgoogie (2011) identified the optimal valve timing scheme for spark ignition engines. Using GT Power software, a four-stroke spark ignition engine was modeled. To control input/output boundaries, the model was connected to MATLAB and Simulink. Sensitivity analysis and lowering engine-specific fuel usage were two uses for the model. It was established that engine performance has improved. At low engine speeds, the torque diagram in the VVT smoothed out and the torque rose with speed.

A comparative analysis of a one-dimensional simulation of blending biodiesel with fossil fuel was conducted by Rahim et al. (2012). As fuel, there were three types used: pure vegetable oil, 20% blend biodiesel, and 5% blend biodiesel. Ambient pressures, temperature, engine torque and power were compared using the fuel parameters from the GT Power software simulation. The engine's performance did not significantly change when it was run on 100% diesel and 5% biodiesel. Kolade et al. (2014) investigated the combined 1D/3D fuel injection combustion evaluations of diesel engines. It was determined that the injection not only significantly reduced combustion but also had a correlation with other issues, such as fuel efficiency, start-ability, noise from combustion, pollutants, and acceleration.

Higher brake thermal efficiency, according to Ong et al. (2014), smoothes out engine operation and increases fuel atomization, which improves air-fuel intermixing. Biodiesel offers superior ignition quality due to its greater cetane number compared to petro-diesel. Rahim et al. (2012) investigated how a diesel engine running on a 5% blend of biodiesel and diesel was affected by the temperature of the fuel. Prior to being entered into the GT Power database, the fuel's usual physical characteristics were measured. It was established that there were no biodiesel properties in GT Power's standard fuel database. The modeling and simulation of biodiesel from different feedstocks into a compression ignition engine was done by Kaisan et al. (2020). A four-cylinder CI engine was modeled using GT-suite software; the GT-power modeling tool was utilized to integrate the software with the known requirements of an existing engine test rig. The physical and chemical properties of biodiesel from various sources were retrieved and calculated from published sources. The modeled engine received data in the form of the average values of these attributes. Petro-diesel releases more carbon monoxide, NOx, and SOx emissions than biodiesel, according to a simulation of the engine. **SOx emissions were negligible for all biodiesels tested.**

Despite the significant findings of engine simulations, there remains a research gap in the simulation of biodiesel performance from different feedstocks in CI engines. Thus, this work examined the performance of biodiesel produced from blends of and Jatropha-Neem oil in a 4-cylinder compression ignition engine modeled in Diesel R-K. **While previous studies have focused on biodiesel blends from single feedstocks, there is limited research on binary or multi-feedstock biodiesel blends.** The goal of this study is to use Diesel R-K software to create a compression ignition engine model, validate the model and simulate the engine performance of biodiesel fuel made from the blend of Jatropha and Neem oils.

Diesel R-K Software

Diesel R-K software is an engineering standard engine model that top engine manufacturers, automakers, and their retailers have adopted. It has similar features and applications with other engine modeling soft wares such as GT power, WAVE and BOOST. According to Diesel R-K (2010), the software is also utilized in tiny engines, racing engines, power generating engines, and ship construction. A collection of modeling libraries is utilized in

Diesel R-K's simulation to assess crankshafts, fuel injection systems, lubrication systems, engine cooling structures, ignition and audibility, and power trains (Diesel R-K, 2010).

MATERIALS AND METHODS

A TD201 4-cylinder water-cooled TEC equipment compression ignition engine serves as the engine test bed. Table 1 displays the test rig model's specifications.

Table 1: Engine Model Specifications for TD201 Engine Test Bed

Parameters	**Specifications**
No. of stroke	4
Fuel ignition method	Diesel
Basic engine design	In-line
No. of cylinders	1
Cooling system	Liquid cooling
Cylinder bore	72mm
Piston stroke	85.8mm
Nominal speed	1900rpm
Compression ratio	9.5:1
Connecting rod length	153mm
No. of valves	2
Fuel pump pressure	500-800bar
Engine capacity	350cc

The diesel engine was simulated using Diesel R-K software's one-dimensional numerical analyses. A compression ignition engine was modeled (built) into the Diesel R-K software to match the test rig used in the testing process. This was done by using the modeling tool of Diesel R-K, engine cycle simulation for biodiesel/petro diesel fuels, and the engine specifications of the test rig used in the testing. The secondary data from the review was utilized to feed the model since biodiesel properties had to be measured before they could be entered into the simulation program.

RESULTS AND DISCUSSION

To examine engine performance characteristics, the modeled engine was simulated using the Diesel R-K software. These investigations were conducted using petro-diesel alone, biodiesel alone, and different mixtures of biodiesel and petro-diesel in the simulated engines. The Diesel R-K flow chart was shown in figure 1.

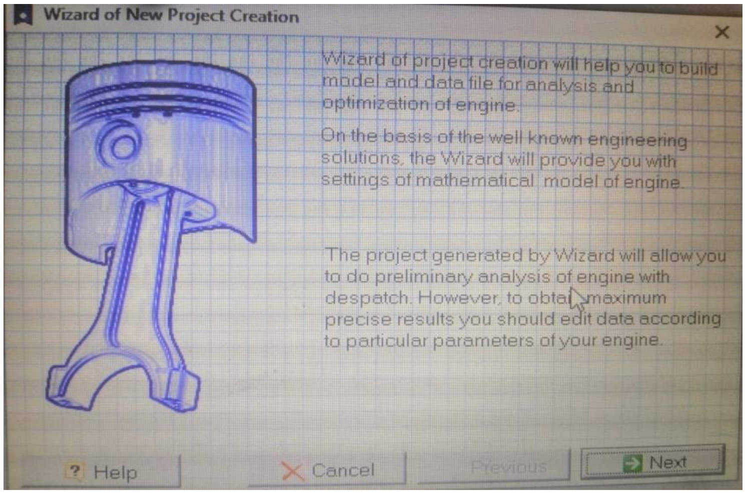

Figure 1: Diesel RK Interface for Creating a New Model

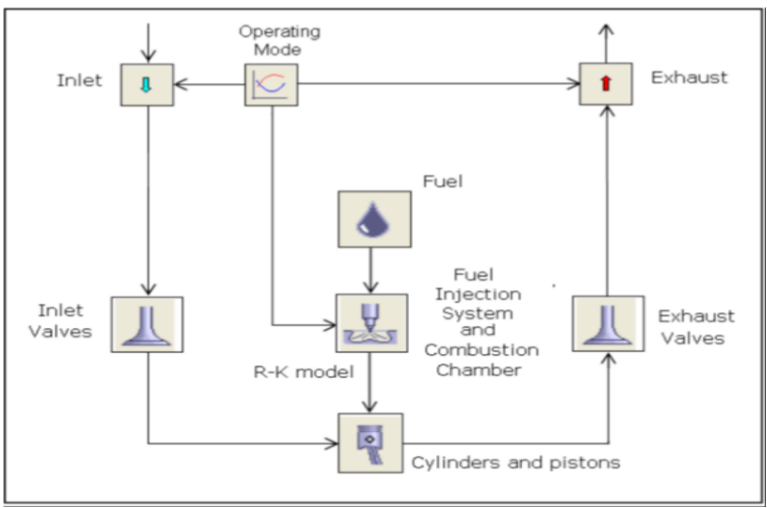

Figure 2: Diesel RK model operational arrangement

After developing the model, a simulation was conducted to evaluate engine performance. **Each fuel blend was used to simulate engine performance under controlled conditions**. All fuel samples, J-N-B0 (petro diesel), J-N-B5, J-N-B10, J-N-B15, J-N-B20, and J-N-B100 were used in the simulations.

Brake torque, Brake Mean Effective Pressure (BMEP), Indicated Mean Effective Pressure (IMEP), Specific Fuel Consumption (SFC), volumetric efficiency (eta V), thermal efficiency (eta T), air-fuel ratio (A/F), and other significant performance data were acquired.

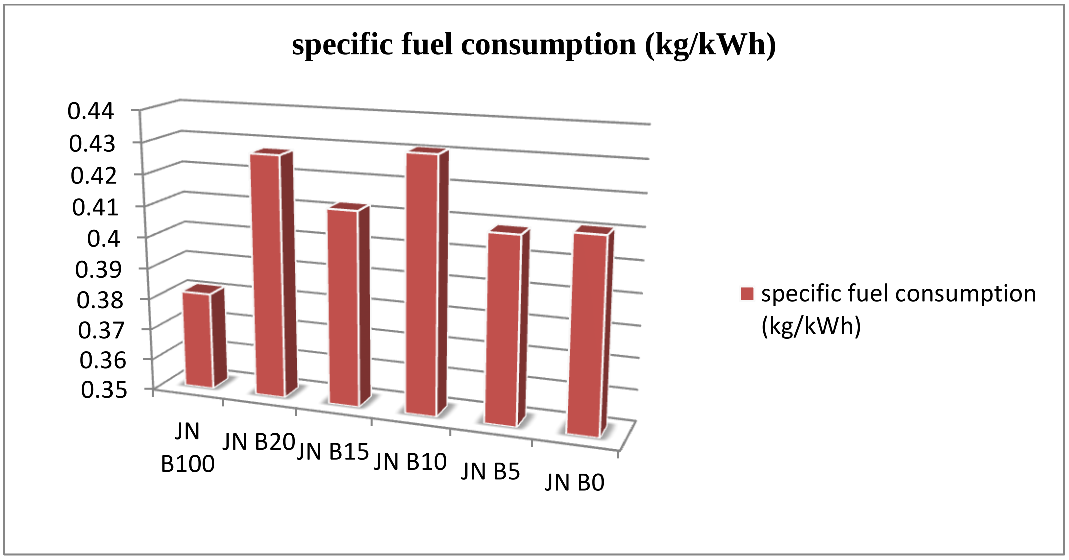

Figure 3: Specific Fuel Consumption of Engine Model

JN B10 has the greatest specific fuel consumption of 0.4308 kg/kWh, according to the simulation results. JN B100 showed the lowest figure, which was 0.3814 kg/kWh. Specific Fuel Consumption (SFC) **measures the amount of fuel consumed per unit of power produced, typically expressed in kg/kWh.** The SFC of JN B5 and JN B15 came the closest to the particular fuel consumption of 0.41083 kg/kWh provided by petrol diesel. Through the measurement of SFC parameters during real-time engine operations, these values were experimentally validated.

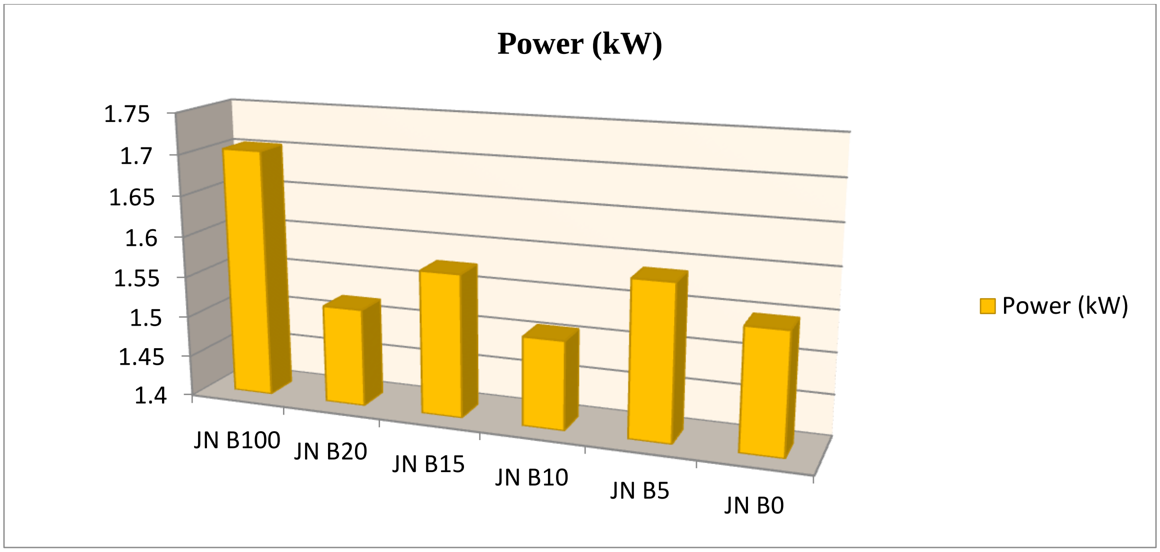

Figure 4: Chart showing simulated results of power

According to the simulated results, JN B100 had the most brake power (1.70kW), followed by JN B5 and JN B15 (1.59kW and 1.58kW, respectively), both of which were marginally more than petro diesel's brake power. Although it was noted that the simulations captured the maximum power values that could have been achieved for each fuel sample during engine operations, the real-time results will either confirm or refute this observation; moreover, they will demonstrate whether the power values that were recorded remained constant throughout the engine operation period.

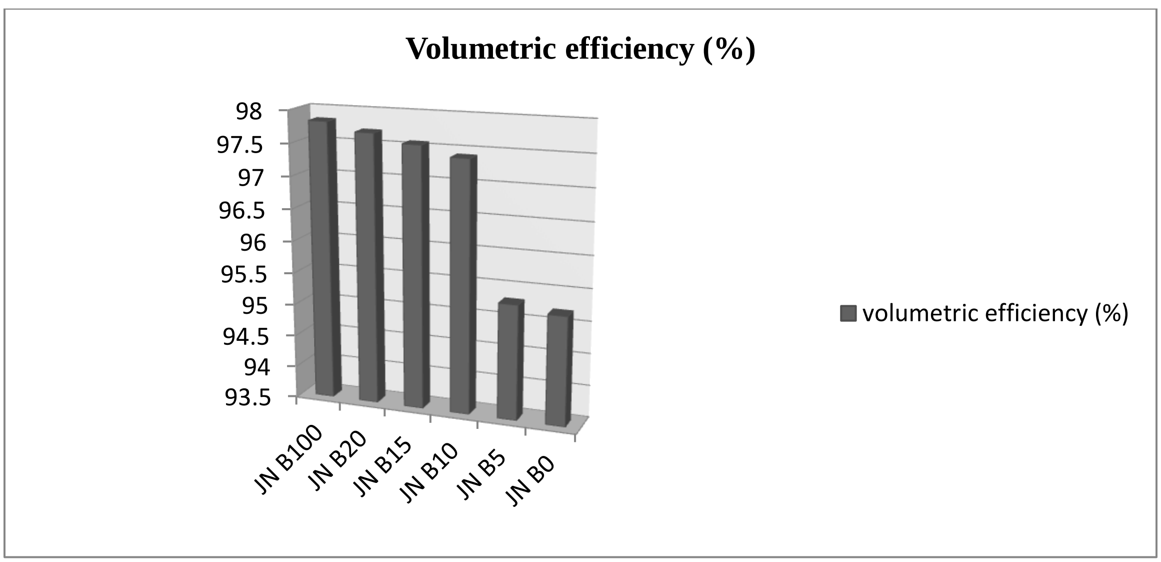

Figure 5: chart showing simulated values for volumetric efficiency

The efficiency with which an internal combustion engine (ICE) transports fresh air charge into and out of the cylinder is known as its volumetric efficiency. It is the ratio of the air volume sucked into the cylinder to the displacement (swept volume) of the cylinder. It is essentially an ICE's breathing capacity; an engine's power is determined in part by how much air it uses. In the simulations, JN B100 had the maximum volumetric efficiency of 97.83%, whereas petro diesel had the lowest volumetric efficiency (95.2%). Once more, the simulated values that were recorded here were the highest values that might have been acquired; the range of values that were obtained during real-time operations confirms or contradicts the simulated results.

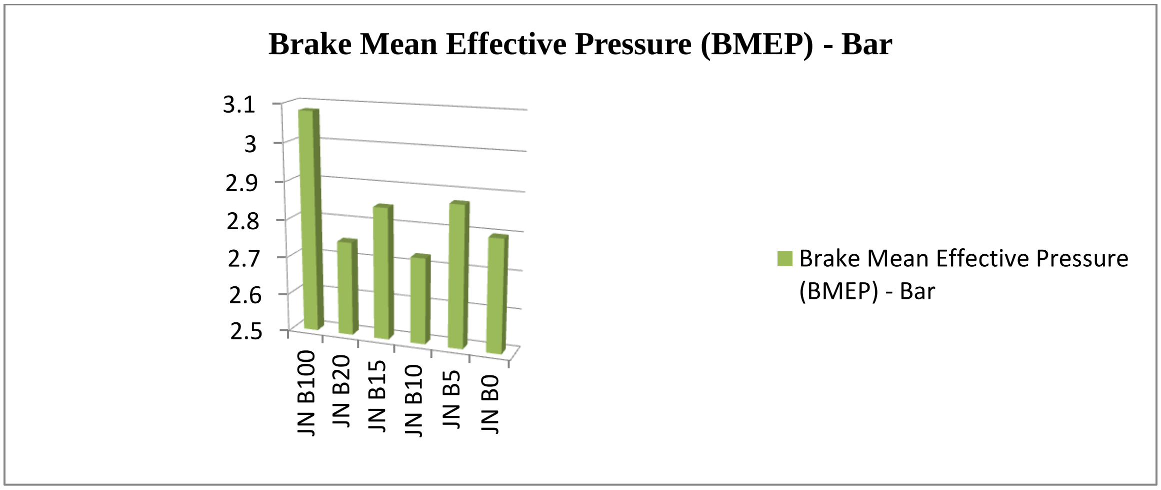

Figure 6: Chart showing simulated results for Brake Mean Effective pressure

An essential component of ICE operation, the Brake Mean Effective Pressure (BMEP) calculates the engine cylinder pressure needed to generate the observed power. It also shows engine efficiency independent of engine capacity or speed. Put simply, it shows how an engine produces torque effectively by utilizing its displacement. Comparing JN B0 (petro diesel) with JN B100, which had a BMEP of 3.08 Bar, the latter had a BMEP of 2.80 Bar. The BMEP of the blends JN B5 through JN B20 fluctuated in a reasonable manner, with JN B5 exhibiting the highest BMEP of 2.87 Bar. **The variations in torque output for each fuel blend contribute to the observed fluctuations in BMEP.**

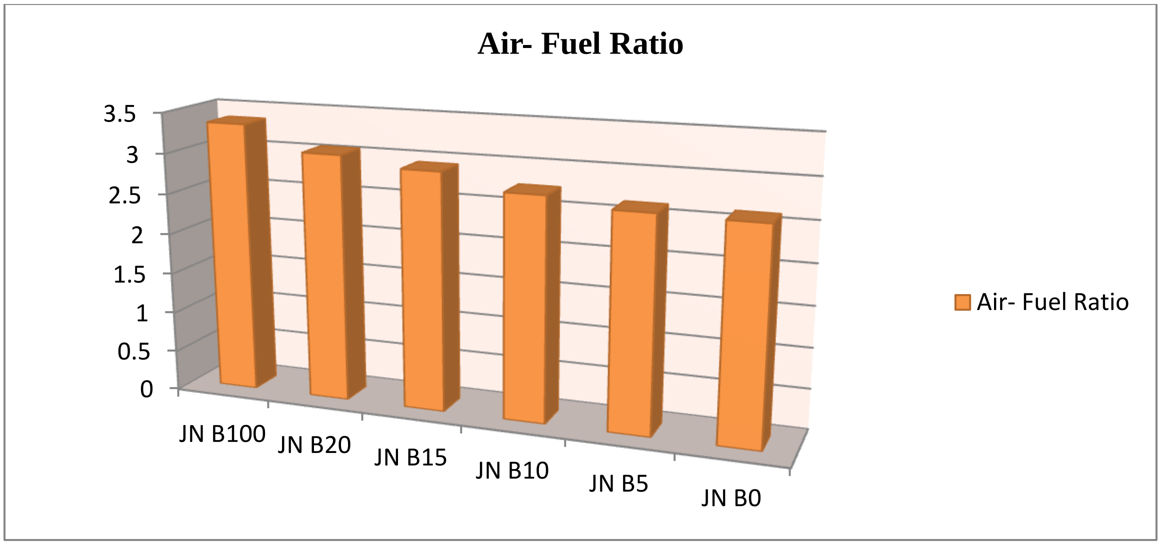

Figure 7: Simulation Results for Air-Fuel Ratio

The amount of air needed for every unit of fuel needed to produce a power stroke in an engine is known as the engine's air-fuel ratio. Air-fuel ratios are typically assumed to be ideal since a low or rich combination indicates potential engine hazards. JN B100 had an air fuel ratio of 3.35. The air fuel ratios of the blends JN B5 through JN B20 significantly range between the values noted for JN B0 and JN B100. Petro diesel (JN B0) was found to have an air-fuel ratio of 2.62 in the chart above; this value is inconsistent with the standard stoichiometric value for combustion because the characteristics of the TD201 test bed modeled into the Diesel R-K software includes modified devices such as a high pressure fuel pump having a pressure range of 500-800bar, significantly raising the pressure to about three to four times its normal capacity. This is to accommodate alternative fuels during performance testing.

For the engine test bed, it is to be noted that the cooling system was also upgraded to manage excessive heat resulting from the aforementioned design. Surprisingly, the graph indicates that the air-fuel ratio increases with increasing biodiesel concentration. A full-scale diesel engine that is turbocharged and runs on several cylinders is likely to have an air-fuel mixture of 15.9:1 to 17.4:1 in order to regulate exhaust emission and heat of combustion. Nonetheless, the engine model is a single-cylinder engine test bed.

CONCLUSION

The TD 201 TEC engine test bed was successfully modeled in the Diesel RK Engine software, the simulated results showed a good performance in terms of the brake power, brake thermal efficiency and specific fuel consumption. Inferences and interpretations were drawn; altogether, the simulated results proved the workability of the fuel samples making them viable alternatives to conventional diesel; the diesel RK software also showed reliability in the obtained results.

This simulation of the produced biodiesel was limited to the modeled TD201 engine test bed, it is recommended that the characteristics of other conventional engine models could be employed in the Diesel R-K engine software; likely, differential values might be observed for some engine parameters especially air-fuel ratio. The findings from this study could also form a basis for assessing behavioural characteristics of modified CIE engines where fuel pumps and fuel injectors are modified. For the produced Jatropha-Neem Biodiesel, real time performance evaluation could be conducted using the TD201 engine test bed. This will experimentally validate simulation results.

ACKNOWLEDGEMENTS

I wish to acknowledge my employer, Kaduna Polytechnic, Kaduna and the academic staff of my host department at Nigerian Defence Academy, Kaduna for their unwavering support throughout the period of this research.

REFERENCES

Bhave, A., Kraft, M., Montorsi, L., & Fabian, M. (2004). Modeling a dual fuelled multi cylinder HCCI engine using a pdf based engine cycle simulator. *SAE International, 01*(0561), 1-14.

Diesel R-K (2010). Diesel R-K Simulation Software. Retrieved from https://diesel-rk.com/Eng.

Hu, Q., Sommerfeld, M., Jarvis, E., Ghirardi, M., Posewitz, M., & Seibert, M. (2008). Micro algal tri-acyl-glycerol as feedstock for biofuel production: perspectives and advances. *Plant Journal*, *54*, 621-639.

Kaisan, M. U., Abubakar, S., Anafi, F .O, Umaru, S., Mohamed, S. P., Umar, U. A., Narayan, S., Mohamed, N. P., & Senophiyah, M. J. (2020). Modeling and simulation of biodiesel from various feedstocks into compression ignition engine. *Energy Recovery Processes from Wastes*, 101-113.

Kakee, A. H., & Pishgoogie, M. (2011). Determination of optimal valve timing for internal combustion engines using parameter estimation method. *International Journal of Automotive Engineering. 1*(2), 130-140.

Kolade, B., Morel, T., & Kong, S. (2014). Coupled 1-D /3-D analyses of fuel injection and diesel combustion. Retrieved from https://www.erc.wisc.edu/documents/13-GT-KIVA-Modeling-Meeting.pdf.

Lomonaco, D., Maia, F. J. N., Clemente, C. S., Mota, J. P. F., Costa Junior, A. E., & Mazzetto, S. E. (2012). Thermal studies of new biodiesel antioxidants synthesized from a naturally occurring phenolic lipid. *Fuel, 97*, 552-559.

Ong, H. C., Masjuki, H. H., Mahlia, T. M. I., Silitonga, A. S., Chong, W.T., & Leong, K.Y. (2014a). Optimization of biodiesel production and engine performance from high free fatty acid Calophylluminophyllum oil in CI diesel engine. *Energy conversion and Management. 81*, 30-40.

Rahim, R., Mamat, R., Taib, M. Y., & Abdullah, A. A. (2012b). Influence of fuel temperature on a diesel engine performance operating with biodiesel blend. *International Journal of Advance Sciences and Technology. 43*, 115-126.