A Review Paper on Performance and Emission Characteristics for CI Engine Fuelled With Mahua Oil Bio-Diesel and Diesel Blend Using Taguchi Method

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Abstract - *Because it outperforms diesel fuel while requiring little to no engine modification, biodiesel is a very beneficial fuel in the current environment. The production of biodiesel from mahua oil and its qualities are covered in the current study. Additionally, experimental research into the performance enhancement of biodiesel-fueled diesel engines is possible for various mahua oil biodiesel-diesel mixes and under various loads. For the experimental work, a single-cylinder, four-stroke CI engine is used. The experimental study will make use of Taguchi design with Minitab software to test various loads and blend ratios for braking power, specific fuel consumption, and break thermal efficiency and emission. As recommended by the programme, a series of tests have been carried out. Finally, the experiment is run on a CI engine using a combination of diesel and mahua-oil biodiesel to assess performance and emission parameters and optimise.*

Keywords: **Diesel, Bio-Diesel, Mahua Oil, CI Engine**

1. INTRODUCTION

Simply said, biodiesel is a liquid fuel made from vegetable oils and lipids that has combustion characteristics comparable to conventional petroleum diesel fuel. Straight vegetable oil, animal oil or fats, tallow, and used cooking oil can all be used to make biodiesel. When burnt, biodiesel emits much less emissions than diesel derived from petroleum and is biodegradable and nontoxic. An alternative fuel that is comparable to conventional or "fossil-petroleum" diesel is biodiesel. Transesterification is the method used to turn these oils into biodiesel. Oil crops including soybean, rapeseed, corn, and sunflower are the biggest potential supply of usable oil. Compressed air powers diesel engines. raises the temperature of the air inside the cylinder to a point where a fuel injection of atomized diesel ignites. 2-stroke and 4-stroke cycles were intended for diesel engines. At the moment, the globe is struggling with the crisis of running out of fossil fuels. According to the most recent World Energy Outlook (IEA, 2007a), China and India will be mostly responsible for the increase in global energy consumption in 2030 if governments continue with their current policies. The growth in primary energy consumption will require fossil fuels to supply around 84% of it. Fossil fuels, in particular, have a multitude of negative environmental effects, including air pollution, greenhouse gas emissions, and harm to ecosystems.

2. OBJECTIVE

- To determine whether mahua oil works in a diesel engine as an alternate fuel.
- Create and characterise the Mahua Oil Bio-Diesel after it has been prepared.
- Reduce emissions that cause pollution.
- To evaluate the efficiency and emission characteristics of a CI engine running on biodiesel-Mahua oil.
- To minimise the experiment, use Taguchi's L9 orthogonal array level. I've made the decision to implement 2-factor (Blend & Load) and 3-level designs in Minitab 16.
- To use Taguchi's approach to determine the CI engine that performs the best by examining the impacts of braking power, specific fuel consumption, and break thermal efficiency at various blends and loads.
- Through experiment analysis, engine performance, including break thermal efficiency, specific fuel consumption, break power, and exhaust emission, will be identified and optimised.

3. LITERATURE REVIEW

In 2018, Abhijeet Killol, Niklesh Reddy, Santosh Paruvada, S. Murugan [1] In this work, n-butanol is first mixed with Karanja methyl ester (KME) in modest amounts—5%, 10%, 15%, and 20%—and the blends are then analysed. The blends are identified as direct injection (DI) diesel engines with 4.4 kW of power at a constant speed of 1500 rpm (KBB5, KBB10, KBB15, and KBB20). At full load, it is discovered that the ignition delay of KME at 21.5 °CA is approximately 2 °CA shorter than that of diesel operation, but the addition of butanol to diesel results in a maximum delay period increase of 4 °CA. As the load grew, the combustion time increased as well. As the proportion of butanol in the mix grew, the combustion time at full load dropped. As the amount of butanol in the blend grew, the NO emission of the blends initially rose and then fell. The increased oxygen content of the blends, which is dominated by the effects of lower heat content and higher latent heat of vaporisation, is what causes the rise in NO emission. The NO emission is considerably reduced when DEE is added to KBB15.

In 2020, Abhishek Sharmaa, Nagendra Kumar Mauryaa, Yashvir Singhb, Nishant Kumar Singhc, Sandeep Kumar Guptad [2] done employing pongamia biodiesel mixed fuels into single-cylinder DI diesel engines. Additionally, the impacts of the Pongamia biodiesel mix %, fuel injection timing, and pressure on engine responses including BTE, UHC, NOx, and smoke emission were evaluated. The Taguchi factorial design matrix and the desirability technique were used in conjunction with the engine trials to forecast and optimise the input engine output response. The research has led to the following conclusions: BTE was found to be at its highest (31.057%) for the process parameters of 0% Pongamia biodiesel mix, 31 °bTDC fuel injection time, and 24 MPa injection pressure. UHC was shown to have a minimal value (33.835 ppm vol.) @ 19 °bTDC injection timing, 24 MPa injection pressure, and 40% mixing of Pongamia biodiesel. At the process parameter level with diesel, fuel injection time of 15 °bTDC, and injection pressure of 16 MPa, NOx was determined to be 520.4 ppm vol. At the level of process parameter with 40% Pongamia biodiesel blend, fuel injection timing of 31 °bTDC, and injection pressure of 24 MPa, the value of smoke was observed to be at its lowest. The generated models for the response factors, namely BTE, UHC, NOx, and Smoke, have R2 values of 0.962, 0.962, 0.953, and 0.819, respectively. It shows that the model that was created was statistically correct. At the highest engine operating parameter levels, confirmation experiments have demonstrated that the model value and experimental value are within a 95% confidence interval.

In 2015, C. Syed Aalam , C.G. Saravanan [3] The performance, emission, and combustion characteristics of a CRDI diesel engine powered by an ANP-mixed Mahua methyl ester blend were examined in this inquiry. Based on the results of the studies, the following findings were made: When compared to MME20, ANP-blended biodiesel (MME20+ANP50 and MME20+ ANP100) had a higher calorific value and a lower flash point. Because of its poorer heating value, biodiesel requires more gasoline. In comparison to operating with biodiesel, there is a significant decrease in fuel usage with the inclusion of aluminium oxide nanoparticles. With ANP added to the biodiesel blend, a little increase in BTE was seen. Because ANP serves as an oxygen buffer catalyst and contributes surface lattice oxygen for the oxidation of HC and CO, it decreased HC and CO emissions by up to 26.04% and 48% when compared to a biodiesel mix (MME20). In comparison to diesel fuel, NOx emissions rise when ANP and biodiesel are used in a mix. The inclusion of ANP raises the peak pressure. The ignition delay time is shortened by the inclusion of ANP. ANP is added, and this raises the rate of heat emission as well. When compared to plain diesel and biodiesel blend, the greater heat release rate is caused by the presence of ANP, which quickens the hydrocarbon combustion (MME20)

In 2019, Abhishek Sharmaa, Yashvir Singhb, Nishant Kumar Singhc, Amneesh Singlad [4] The Taguchi technique is used to calculate the ideal engine operating parameters and mathematical models (diesel fuel, FIT 19 °bTDC, FIT 18 MPa, and 60% engine load). The RSM approach was used to create a mathematical model and further improve engine responses. Experimental validation and discovery that the generated RSM models for BTE, Pmax, EGT, and UHC emission are within the required error range. The RSM model's composite desirability was 0.9024, making it an excellent predictor of the engine reactions discovered when jojoba biodiesel was taken into account. Using jojoba biodiesel blends as an alternative fuel reduces EGT and UHC emissions while improving BTE by moving the fuel injection timing forward by 2°bTDC in comparison to the factory settings and raising the FIP by 3.5 MPa from the manufacturer settings. In order to analyse the results, 3D surface and contour plots were used. The major effect charts demonstrate the influence of FIT, FIP, and jojoba biodiesel mixing on engine reactions (BTE, Pmax, EGT and UHC).

In 2019, A. Saravanan, M. Murugan, M. Sreenivasa Reddy, Satyajeet Parida [5] Rapeseed biodiesel (RA), Mahua biodiesel (MU), Dual biodiesel (RM), and their various mixes with diesel, were used to compare the performance of diesel engines (BL20,BL40, BL60 and BL80). The collected findings indicated that bio diesel (RA and MU) and mixes with diesel had greater brake-specific fuel consumption than diesel. The BL20 mix of biodiesel performed the closest to diesel of all the tested biodiesel blends, it was discovered. Diesel had a BSFC that was 8.18% lower than BL20. When compared to various biodiesel blends, it was discovered that the BL20 blend's braking thermal efficiency was at its highest but closest to diesel (i.e., 2.79% lower than diesel). The CO and HC emission was found to be lower than diesel for all tested biodiesel and blends. The CO and HC emissions from the BL20 mix were 20.66% and 8.56% less than those from diesel, respectively. Additionally, the B20 blend revealed the NOx emission whereas the NOx emission for all tested biodiesel and blends was greater than diesel. greater by 77% than diesel. For all of the tested biodiesel and the blends, the smoke opacity was measured at a lower value than diesel. The smoke opacity was 6.97% lower than diesel in the mix BL20, bringing it closer to that of diesel.

In 2020, Ranjeet Kumar Rai, Rashmi Rekha Sahoo [6] In the current investigation, three control parameters—compression ratio, load, and fuel mix percentages—were varied to maximise eleven response metrics, including T, BP, BMEP, BTE, BSFC, v, HJW, HGAS, NOx, HC, and CO emissions.

By creating an L16 orthogonal array, the Taguchi approach was utilised to design the trials and reduce the number of tests. The VCR engine's performance metrics, heat losses, and emission characteristics were studied in trials using diesel fuel based on Shorea robusta biodiesel at various compression ratios. The results showed that the compression ratio of 17 is thought to be the ideal value for these variables. The best performance characteristics, heat losses, and emission levels are obtained with an engine load of 10 kg on a VCR engine with a 30% blend of Shorea robusta biodiesel. The compression ratio is the least important control parameter, contributing just 12.45%, whereas engine load is the most important element, contributing 67.54%. The experimental findings and the results of the validation show good agreement. The experimental value of GRG and the anticipated GRG at the optimal configuration (A3B4C3) are 0.6897 and 0.7100, respectively. Additionally, there is a 0.0203 error between the experimental value of GRG and the anticipated value of GRG at the optimal configuration (A3B4C3).

In 2020, M. Udaya Kumar , S. Sivaganesan, C. Dhanasekaran, A. Parthiban [7] Based on experiments, the BTHE is roughly equivalent to diesel and Mahua oil methyl ester is blended with titanium dioxide to examine the special effects of titanium dioxide (TiO2) nano particles as additives for Mahua oil methyl ester on the performance, combustion, and emission characteristics of the CI engine (150 ppm). Carbon monoxide emissions are reduced when Mahua Oil Methyl Ester is combined with titanium dioxide (150 ppm), as opposed to the other blend. Higher NOx emissions are produced by mahua oil methyl ester mixed with titanium dioxide (75 ppm). When compared to other blends, the titanium dioxide (150 ppm) and methyl ester of mahua oil had lower NOx emissions. Overall, it has been shown that 150 ppm of titanium dioxide may be used as an addition, demonstrating the lower emission, well-matched performance, and distinctive combustion characteristics of Mahua Oil Methyl Ester.

In 2017, Arulprakasajothi Mahalingam , Yuvarajan Devarajan , Santhanakrishnan Radhakrishnan , Suresh Vellaiyan , Beemkumar Nagappan [8] According to the observation made after adding octanol to biodiesel blends of plain mahua oil at a ratio of 10% and 20% on a volume basis, CO emissions decrease as the amount of octanol in the blends increases. When compared to plain mahua oil biodiesel, M80O20 and M90O10 showed a 6.8% and 7.4% reduction in total CO emissions at all loads. Octanol content in the blends increases while HC emissions drop. When compared to plain mahua oil biodiesel, M80O20 and M90O10 showed a 5.1% and 5.7% reduction in total HC emissions at all loads. Octanol content in the blends increases as NOX emissions drop. When compared to plain mahua oil biodiesel, M80O20 and M90O10 showed a 4.8% and 5.4% reduction in total NOX emissions at all loads. Octanol content in the blends increases while smoke emissions drop. When compared to plain mahua oil biodiesel, total smoke emissions from M80O20 and M90O10 at all loads were reduced by 2.1% and 2.9%, respectively.

In 2020, Shakti Prakash Jena, Sankalp Mahapatra, Saroj Kumar Acharya [9] In this study, using the Taguchi method and grey relational analysis, we attempted to ascertain the effects of various input parameters, such as engine load, blend, and CR (different levels), on the performance (BTE), and emission parameters (NOx), of a CI engine operated with various blends of diesel and Karanja biodiesel. Following observations were made: With the use of Taguchi's L16 orthogonal arrays, the number of trials was decreased, and 16 tests with various combinations of input parameters were conducted. By giving the proper weighting variables, the grey relational analysis reduces numerous objective optimisations into a single objective optimisation issue. The best factor settings were reported using the Grey-Taguchi technique to be load at 100%, B20 mix, and CR 17.5. The input parameter with the greatest influence was found to be load. When using ANOVA to examine the relative influence of control variables on output responses, it was discovered that load contributed the most, at a rate of 40.33%.

In 2020, Sunilkumar S. Kattimani, S.N. Topannavar, Dr., M.M. Shivashimpi, B.M. Dodamani [10] On a VCR engine, which can operate on biofuel, the trials were performed using mixes of clean diesel and FOME biodiesel. The viscosity and density of biodiesel are comparable to those of diesel, and its C.V., or 39500 kJ/kg, is lower. To run on FOME biodiesel, the IC engine only requires minor or no engine setup changes. To minimise nitrogen oxides in the exhaust, modern techniques like EGR and CRDI can be applied. The atomization and vaporisation of fuel droplets occur at high injection pressures of 260 bar, leading to full combustion of the fuel with no emissions.

In 2018, Naushad Ahamad Ansari, Abhishek Sharma, Yashvir Singh [11] Of all the tested fuels, diesel had the highest BTE at 23obTDC. B30 blend exhibits the highest braking thermal efficiency (33.5%) of all the polanga biodiesel blends at 27obTDC. While NOx emissions rise with the proportion of biodiesel in the mix, B40 blend exhibits the lowest UHC emission of 24 ppm volume. Smoke opacity is decreased by delaying fuel injection time from 23obTDC to 19obTDC. At increasing fuel injection pressure, BTE rises.

In 2020, Tanmaya Agrawal, Raghvendra Gautam, Sudeekcha Agrawal, Vishal Singh, Manish Kumar, Saket Kumar [12] The Taguchi approach was utilised in this experimental inquiry to discover the best engine performance and emission characteristics, after which ANN and multiple regressions were used to find the mistake. The orthogonal array has been used as the foundation for 25 experimental runs. Blend%, Load, RPM, Calorific value, and Density were the input parameters. Only three parameters—

Load, Blend%, and RPM—were examined independently in Taguchi and multiple regression since the programme itself rejected the other two, which were density and calorific value of the fuel. For BTE, NO x, HC, and CO 2, the percentage errors varied by 4.6%, 1.26%, 2.96%, and 29.05%, respectively, however for BSFC and CO, the error margins were quite high. Thus, it can be said that ANN is a more effective method for making predictions. Additionally, by concentrating on the performance metrics, the Taguchi technique was used to identify the ideal operating circumstances. Thus, by running an engine configuration under these working circumstances, the greatest performance may be obtained from it.

In 2015, R. Sathish Kumar , K. Sureshkumar , R. Velraj [13] The synthesis, characterisation, and optimization of key process variables impacting the transesterification process of a novel biodiesel generated from M. zapota seed oil have been researched and reported in this experimental inquiry. The transesterification procedure was carried out using methanol and KOH as the catalyst. The four influencing factors taken into account for the Taguchi method optimization of biodiesel synthesis were the molar ratio of methanol to oil, catalyst concentration, reaction time, and reaction temperature. The yield rate for MZME is 94.83% under the experimentally found optimal parameters of 6:1 methanol to oil molar ratio, 1% (w/w) catalyst concentration, 90 min reaction duration, and 50 C reaction temperature. The two key process variables affecting the synthesis of bio diesel were determined to be catalyst concentration and the molar ratio of methanol to oil. The main characteristics of MZME are discovered to comply with EN 14214 biodiesel criteria.

In 2018, Abhishek Sharma, Naushad Ahmad Ansarib, Yashvir Singh, Ibrahim Mustefa, C.Vivekanandhan [14] A single-cylinder compression ignition engine with a direct-injection combustion chamber has had the effects of fuel injection pressure, fuel injection timing, control variables, and the effect of load torque examined with regard to toxic emissions, specifically NOx, as well as brake thermal efficiency. The impact that control parameters have on the response variables has been verified using the Taguchi approach. Utilizing the analytic techniques, the influence proportion of each and every control variable has been determined. Concluding remarks are made about the behaviour and componentry of the selected engine. Among the engine control parameters, fuel injection pressure has the greatest impact on engine brake thermal efficiency and exhaust emissions (NOx). With a disagreement percentage of under eight, the test results are quite comparable to the predicted extremes of acceptable conditions. It is important to conclude that the Taguchi technique is a reasonable, successful, and strategy for developing durable, effective, and standard-worthy devices for energy conversion.

In 2020, Navdeep Sharma Dugala, Gyanendra Singh Goindi , Ajay Sharma [15] Mahua and Jatropha biodiesel sample mixes with mineral diesel were created in various ratios, and their physicochemical characteristics were studied. The recent findings shown that the pre-treatment procedure may be effectively used to lower the free fatty acid value of biodiesels. In comparison to the other biodiesel samples (MB1 & JB1), MB2 and JB2 have better properties, and their physicochemical characteristics are also more similar to those of mineral diesel. All other samples' densities were determined to be within acceptable ranges, however B50 was found to exceed the ranges allowed by the various national and international regulations due to the greater biodiesel mixing ratio. Mineral diesel is added to Jatropha and Mahua biodiesel to improve both the physicochemical qualities and the cold flow characteristics of the blended dual biofuel. The pour and cloud points of dual biofuel samples were superior than those of solo biodiesel samples. Accordingly, the findings of this study showed that the B30 and B40 dual biofuel blends, which include 15% and 20%, respectively, of each biodiesel, may be tested in internal combustion engines to determine how well they operate and how much exhaust they emit.

In 2013, Horng-Wen Wu, Zhan-Yi Wu [16] For a diesel engine utilising a diesel/biodiesel blend, the ideal operating variables of high BTE and for low BSFC, NOX, and smoke have been discovered using H2 and the Taguchi technique with cooled EGR at the input port. The baseline diesel engine and the improved engine's combustion performance and emissions have also been compared. On the basis of the findings and discussion, the authors draw the following conclusions. Finding the ideal pairings was made easy by the Taguchi approach. With a 95% confidence interval, the predictions made using Taguchi's parameter design methodology are in good agreement with the confirmation findings, and this method also cuts the experiment's run time by 67%. NOX is more impacted by the EGR ratio (C) than other goals are. For each load, a combination of B20 (A2), 30% hydrogen (B3), and 40% EGR ratio results in the optimum BTE and BSFC, NOX, and smoke emissions (C3). The effectiveness of combustion is enhanced by this mixture. At different loads, the optimised engine performs better than the standard diesel engine in terms of BTE, cylinder pressure, heat release rate, and ignition delay. The ideal mix also lowers the BSFC. Additionally, the improved engine can reduce NOX and smoke emissions.

In 2020, Yuvarajan Devarajan, Beemkumar Nagappan, G. Mageshwaran, M. Sunil Kumar, R.B. Durairaj [17] This study evaluates the viability of replacing diesel fuel in compression ignition engines with biodiesel made from discarded grapefruit seed. To improve the ignition patterns, 10% of two antioxidants, BHA (butylated hydroxyanisole) and BHT (butylated hydroxytoluene), are added to diesel/biodiesel blends. The performance of the engine using the tested fuels is evaluated in various BPs and contrasted with diesel. The basic fuel's phase did not alter after the antioxidants were blended. The low viscosity of BHA and BHT enhanced fuel atomization, fuel-air mixing, and decreased BSFC with better BTE in diesel/biodiesel blends. The physio-chemical characteristics of diesel/biodiesel blends were enhanced by the addition of BHA and BHT, which led to a noticeable rise in in-cylinder pressure (ICP) and heat release rate (HRR). In order to reduce NO emissions for diesel/biodiesel blends, the catalytic activity of BHT and BHA increased the combustion reaction duration and decreased the combustion temperature. High injection fuel pressure and fuel atomization are produced by BD + D + BHT and BD + D + BHA's abundant oxygen availability. This energises the oxidation reaction and reduces smoke, HC, and CO emissions for diesel/biodiesel blends.

In 2020, M. Krishnamoorthi, S. Sreedhara, Pavan Prakash Duvvuri [18] This study looks at how injection factors affect a compression ignition (CI) engine that runs on syngas, diesel, and B20 (80% diesel, 20% biodiesel). In comparison to conventional diesel combustion (CDC) mode, particulate matter (PM) was decreased by 87% but brake thermal efficiency (BTE), hydrocarbon (HC), and oxides of nitrogen (NOx) were raised by 2.4%, 61%, and 71%, respectively. Increased fuel injection pressure improved mixture formation and decreased PM. The split fuel injection technique decreased NOx emissions. More CO has been seen during engine running in dual fuel (syngas and diesel) combustion, indicating that the majority of the syngas's CO was not oxidised during the combustion process. In comparison to CDC mode, HC, PM, and NOx were decreased by 29%, 77%, and 22%, respectively. BTE was increased by 1.5% and NOx was decreased by 29% in syngas and B20 mode (30% early injected mass) in comparison to CDC mode. It appears that syngas can be employed in stationary power generating compression ignition engines based on the advantages and disadvantages of this inquiry. This dual fuel mode has the ability to lower NOx and PM emissions while increasing CO emissions.

4. CONCLUSION

For the purpose of studying several research papers, I discovered that while numerous trials on various blends had been conducted in order to evaluate the performance of CI engines, relatively little work had been done on the engines' performance when employing the Taguchi technique. Method for Experiment Design play a crucial part in the I.C Engine's performance. Because of the right direction provided by the literature review, there are opportunities to increase the effectiveness and performance of the diesel engine. DOE and the Taguchi approach have been used in a variety of applications, therefore we will use them on a specific engine to improve performance and learn new things about it.

Finally, a CI engine, diesel, and a mahua bio-diesel/diesel blend are used to conduct the experiment.

In order to minimise the experiment, I will employ Taguchi's L9 orthogonal array level. In Minitab 16, I've chosen to construct a 2-factor (Blend & Load) and 3-level design.

Process Parameter chosen

1. Exhaust Emission
2. Break Power
3. Break Thermal efficiency
4. Specific Fuel Consumption.

Four test fuels in all were chosen for this inquiry.

- 100% Diesel fuel (**B0**)
- 10% Mahua oil Biodiesel and 90% Diesel fuel (**B10**)
- 30% Mahua oil Biodiesel and 70% Diesel fuel (**B30**)

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