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To study performance characterization and validation using ANN of Microalgae Biofuel using ZnO as an additive and diesel fuel on single cylinder diesel engine

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ABSTRACT: India is looking at renewable alternative fuel sources to reduce its dependence on foreign crude oil. As India imports 80% of the oil it uses, it has been hit hard by increasing costs and uncertainty. In this study microalgae biodiesel have been proposed as an alternative fuel for powering existing diesel engine. The present study is proposed to investigate experimentally, the performance and emission analysis of microalgae biodiesel in a stationary single cylinder VCR diesel engine and compare it with diesel fuel. The microalgae biodiesel will be blended with the diesel fuel in different proportions. The brake thermal efficiency (BTE), brake power (BP), brake specific fuel consumption (BSFC) and brake mean effective pressure (BMEP) will be measured for different blends at constant speed and various loads. Separate tests will be conducted for pure diesel and biodiesel blends. A comparative study will be carried out on the basis of different performance and emission curves. Performance and emission analysis will be done for different blends with nanoparticles as additives and pure diesel at various loads and constant speed. Impact of blended microalgae biodiesel 08%, B16%, B20%, B24%, B30% with 5% of ZnO on the performance and emission of diesel engine will be investigated. This fuel will be examined with varying loads and the obtained results of performance and emission characteristics will be compared to that of 100% diesel.

KEYWORDS: Biodiesel, crude oils, microalgae, diesel engine, emission, nano particles.

I. INTRODUCTION

Biodiesel refers to a vegetable oil or animal fat-based diesel fuel consisting of long chain alkyl (methyl, ethyl, or propyl) esters. Biodiesel is typically made by chemically reacting lipids (e.g., vegetable oil, soybean oil, animal fat (tallow) with an alcohol producing fatty acid esters. There has been plenty of research done so far on emission testing and biodiesel production. Research in the area of biodiesel has shifted towards making it more economical feasible by lowering production costs and increasing the energetic yields from various feedstock. Where the research has lacking is in relation to the better characterization of the performance of these fuels in all possible diesel applications. The goal of this work is to determine the usefulness of biodiesel in a single cylinder diesel engine. So our aim of study is mainly to conduct engine testing to evaluate performance, emission and combustion characteristics. In the present study the tests will be carried out at different loads, at constant speed without any modification in engine. The effect of different blends on brake thermal efficiency, brake power, brake specific fuel consumption and on brake mean effective pressure will be studied.

II. LITERATURE REVIEW

[1] In the paper of 'Prafulla D. Patil, Shuguang Deng' titled as 'Optimization of biodiesel production from edible and non-edible vegetable oils.' in 2009 states that Two step and one step transesterification methods are best suitable for non-edible oils and edible oils, respectively for the production of biodiesel. Further research and development on some advanced methods such as supercritical methanol process, in situ alkaline transesterification and microwave method is necessary. Kinetic study, long-term run, and analysis using biodiesel fueled engine is also recommended. [2] 'A. Murugesan, C. Umarani, T.R. Chinnusamy, M. Krishnan, R. Subramanian, N. Neduzchezha in' with title 'Production and analysis of bio-diesel from non-edible oils: A review' stated that As per the analytical method reported in literature high performance liquid chromatography method is suitable to analyze the reaction intermediates and products of transesterification reaction. Economic feasibility study shows that the bio-diesel obtained from non-edible oil is cheaper than that from edible oils. [3] 'A.E. Atabani, A. S. Siliton, H. C. Ong, T. M. I. Mahli, H. H. Masjuki, Irfan Anjum Badruddin, H. Fayaz' With name of paper 'Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production' talk about the Production of biodiesel from non-edible oil resources can play a vital role in helping to overcome the land problem as its can be grown in marginal and waste land are as for high yield. Moreover, the issue of food versus fuel for edible oil sources will make non-edible oil feed stocks as alternative fuels for diesel engines. Therefore, the demand for non-edible oil sources is expected to increase sharply in the near future. Some of non-edible feedstock for biodiesel production includes *Jatropha curcas*, *Pongamia pinnata*, Rubberseed, *Madhuca indica*, *Calophyllum inaphyllum*, *Sterculia foetida*, etc. However, it must be pointed out that global biodiesel feedstock should not rely on certain sources as it could bring harmful influence in the long run. [4] Indu Ambat and et al talk in the paper that Based on various feedstock stated non- edible oils, algal oils, animal fats are promising sources for biodiesel production. In supplementary to that more investigation is needed to overcome some challenges related with non-edible feedstock such as non- edible sources require a large amount of methanol, whereas algal sources need more financial investment, and mixed culturing of algae. Having title 'Recent advancement in biodiesel production methodologies using various feedstock: A review' [5] In the paper of 'Hwanam Kim, Byungchul Choi' with the title of 'The effect of biodiesel and bioethanol blended diesel fuel on nanoparticles and exhaust emissions from CRDI diesel engine' talk about The engine performance under biofuel-blended diesel fuels was similar to that under D100 fuel; the slightly higher fuel consumption was due to the lower calorific value that was based on the biofuel mixture. The use of biodiesel– diesel blends reduced the THC and CO emissions but increased NO_x emissions, as the oxygen content of the fuel increased. Smoke emissions were reduced by 50% with the use of bioethanol-diesel blends. [6] In the title of paper 'Effects of alumina nanoparticles in waste chicken fat biodiesel on the operating characteristics of a compression ignition engine' by 'Naresh Kumar Gurusala V Arul Mozhi Selvan' said that The BSFC for all the WCFME diesel fuel blends were found higher when compared to the neat diesel due to lower calorific value of the biodiesel blends. The BTE increases when the alumina nanoparticles concentration in the fuel blend increases due to the better combustion characteristics of the nano-fuel blends. The carbon monoxide and hydrocarbon emission was lower for the WCFME-diesel fuel blends when compared with the diesel. The NO emissions were slightly increased with the increasing alumina concentration due to the higher combustion pressure and temperature of the fuel blends. The smoke emissions were found lower about 65 % when using the alumina nanoparticles compared to the neat diesel.

[7] 'Mehrdad Mirzajanzade h, Meisam Tabatabaei, & et al' in their research work title as 'A novel soluble nano catalysts in diesel– biodiesel fuel blends to improve diesel engines performance and reduce exhaust emissions' reported that All pollutants i.e., NO_x, CO, HC and soot were reduced by up to 18.9%, 38.8%, 71.4% and 26.3%, respectively, in B20 (90 ppm) compared to neat B20. The innovated fuel blend also increased engine performance parameters i.e. power and torque by up to 7.81%, 4.91%, respectively and decreased fuel consumption by 4.50%. [8] 'C. Syed Aalam, C.G. Saravanan' in their paper talk about Brake thermal efficiency (BTE) increases with the load for both Mahua biodiesel blend (MME20) and ANP- blended MME20. Significant reduction in HC emissions when replacing diesel fuel with biodiesel addition of aluminum oxide nanoparticles reduces the hydrocarbon emissions, because ANP supplies the oxygen for the oxidation of hydrocarbon and CO during combustion with the title as 'Effects of nano metal oxide blended Mahua biodiesel on CRDI diesel engine' [9] In the title of research work 'Effect of a zinc oxide nanoparticle fuel additive on the emission reduction of a hydrogen dual- fuelled engine with *Jatropha methyl ester* biodiesel blends.' by 'Syed Javed, Y. V. V. Satyanarayan a Murthy, M. R. S. Satyanarayan a, Rajeswara Reddy R1, K. Rajagopal' said that NO_x emissions are reduced with the inclusion of nanoparticles. HC emissions mainly depend on nanoparticle size and H₂ flow rates. With the presence of ZnO nanoparticles in blends of pure JME, the CO emission increased, and higher H₂ flow rate supplemented the CO emission. [10] In the paper of 'Hariram Venkatesan, Seralathan Sivamani, Srinivasan Sampath, Gopi V, Dinesh Kumar M' with title 'A Comprehensive Review on the

Effect of Nano Metallic Additives on Fuel Properties, Engine Performance and Emission Characteristics' talk about the Addition of nanoparticles plays a major role in improving the fuel properties and enhancing the performance of CI engine as well as reducing the exhaust emissions. Addition of nanoparticles increases BTE which depends upon the base fuel used, amount of nanoparticle added, how well they are mixed with the base fuel, and operating condition of the CI engine. Nanoparticles like Al_2O_3 , Al, CNT and CeO_2 shows good results as additives with diesel and biodiesel blends in all aspects. ZnO also gives better results but, more amount of ZnO should be added than other nanoparticles to get an equivalent performance and the use of ZnO as fuel additive increases the cost of fuel. [11] In the year of 2017 'Vishal Saxena, Niraj Kumar, Vinod. Kumar Saxena' done a research and come to the conclusion that It was also suggested that improving engine design through additional swirling effect produced by providing slots on the piton or by changing the injector nozzle geometry (increasing number of holes in a nozzle) gives high injection pressure, which reduces the fuel droplet diameter and maintains better spray patterns. Besides this the fast vaporization of fuel inside the cylinder promotes complete combustion of fuel which results in higher engine efficiencies and lower specific fuel consumption with reduced emission levels in the title 'A comprehensive review on combustion and stability aspects of metal nanoparticles and its additive effect on diesel and biodiesel fuelled C.I. engine' [12] 'D. Yuvarajan, M. Dinesh Babu, N. BeemKumar, P. Amith Kishore' studied in the title 'Experimental investigation on the influence of titanium dioxide nanofluid on emission pattern of biodiesel in a diesel engine.' That HC, CO and Smoke emissions for MOME, MOMET100 and MOMET200 is lesser than diesel at all working conditions owing to its inbuilt oxygen content. NOx emissions for MOME, MOMET100 and MOMET200 are higher than diesel at all working conditions owing to longer delay period of biodiesel causing higher fuel ignition temperature. The addition of TiO_2 nanofluid in (base fuel) mustard oil methyl ester results in reduction in HC, CO and smoke emissions at all loads owing to its improved oxidation capability, enhanced thermal conductivity and the catalytic effect. NOx emissions for MOMET100 and MOMET200 are significantly reduced by adding TiO_2 nanofluid to MOME owing to the combined effects of heat absorption by water molecules and reduction in ignition delay due to catalytic effect of nano fluids. [13] 'Gnanasikamani Balaji And Marimuthu Cheralathan' in the research title 'Influence Of Alumina Oxide Nanoparticles On The Performance And Emissions In A Methyl Ester Of Neem Oil Fuelled Direct Injection Diesel Engine' said that The brake thermal efficiency, increased by 4.23% and NO emissions, reduced by 7.81% for MENO+ALN200 blend compared to neat biodiesel. The NO, HC, CO, and smoke emissions were reduced by adding nano additive to the neat biodiesel. The performance parameters like brake thermalefficiency increased and brake specific fuel consumption decreased by adding nano additive. This nano addition is a simple and easy method for simultaneous performance improvement and NO reduction. [14] 'Anjuman Shaheen, Shazia Sultana, & et al' Said in the heading 'Assessing the Potential of Different Nano- composite (MgO , Al_2O_3-CaO and TiO_2) for Efficient Conversion of Silybum eburneum Seed Oil to Liquid Biodiesel' that MgO showed the promising results; highest conversion efficiency was achieved 91%, using MgO followed by Al_2O_3-CaO and TiO_2 at 0.1% catalysts loading. The optimized experimental variables were; alcohol oil molar ration (1:3), temperature (700 C), reaction time (3 hrs) and stirring rate (600 rpm) using reflux transesterification route. Considering the encouraging results and finding of this study Silybum eburneum was strongly recommended as an economically feasible potential feedstock for biodiesel production as renewable energy on industrial scale. [15] In the year 2018 'I. Ors, S. Sarıoc, A.E. Atabanic, S. Unalan, S.O. Akansu' do study on 'The effects on performance, combustion and emission characteristics of DICl engine fueled with TiO_2 nanoparticles addition in diesel/biodiesel/n- butanol blends' and said that The nano-particle additive of TiO_2 has not substantially affected the blends properties. n-butanol has strongly affected some of the important properties of fuel blends such as density, kinematic viscosity, pour point, cloud point, cold filter plugging point and flash point. Besides, n-butanol improved cold flow properties of fuel blends. The maximum brake engine torque and power values are recorded for all tested fuels at approximately 1400 rpm and 2800 rpm, respectively. The addition of TiO_2 to B20($B20+TiO_2$) increased the engine brake torque and power for about 10.20% compared to B20 blend. In addition, brake engine torque and power for B20But10+ TiO_2 is approximately 9.74% higher than B20But10. The brake specific fuel consumption decreased 27.73% and 28.37%, respectively (Compared to B20 and B20But10). It can be concluded that the addition of TiO_2 in the fuel blend has positively affected engine performance. [16] 'Varatharaju Perumal, M. Ilankumara n' said in the title 'The influence of copper oxide nano particle added pongamia methyl ester biodiesel on the performance, combustion and emission of a diesel engine' that PME has performed inferior in fuel qualities regarding BTE and BSFC due to its lower calorific value. Catalytic behavior of CuO had improved the BTE and BSFC significantly while it was mixed with pongamia biodiesel. A significant reduction in greenhouse gases of CO, HC, NOx and smoke has been observed as experimental result. CuO act as a catalyst and oxygen booster when mixed with PME blend which enhances combustion characteristics and hence a considerable reduction in smoke and NOx emission takes place. [17] A. Prabu in his paper title 'Nanoparticles as additive in biodiesel on the working characteristics of a DI diesel engine' said that The addition of nanoparticles in biodiesel decreases the ignition delay and accelerates earlier initiation of combustion which results in the lower heat release rate and cylinder pressure at the full load condition. The NO

emission drastically reduced for the B20A30C30 test fuel with percentage reduction of 30%, when compared with B100 due to the combined effect of Alumin and Cerium oxide nanoparticles. [18] A. Praveen & et al presented a paper 'Performance and emission characteristics of a diesel engine using Calophyllum Inophyllum biodiesel blends with TiO₂ nanoadditives and EGR' and said that Characterization of TiO₂ nano particles such as XRD, SEM and EDX analysis confirms the TiO₂ nano particles were in the anatase phase and average size in the range of 30-40 nm. The brake thermal efficiency of B20+20%TiO₂, B20+20%TiO₂ + 20% EGR fuels were increased by 3.1%, 2.5%, respectively, and decreased by 1.8% for B20 + 20%EGR fuel compared to the B20 fuel sample at full load condition. [19] Hakan Caliskana, Kazutoshi Mori done a research in the paper 'Thermodynamic, environmental and economic effects of diesel and biodiesel fuels on exhaust emissions and nano-particles of a diesel engine' and said that the most of the exhaust emissions (except NO_x) are directly proportional to engine load. If the engine load increases, the exhaust emissions (except NO_x) increase too. The maximum CO₂ and NO_x emissions rates are generally determined for BDF100 biodiesel fuel, while the minimum ones are calculated for the JIS#2 diesel fuel. On the other hand, the maximum CO and HC emissions rates are generally computed for the engine load. BDF100 has less carbon and more oxygen molecules compared to diesel fuels. So, if the engine is fueled with the BDF100, it is better to operate it at higher engine loads for the better soot concentration and better environmental protection. On the other hand, if the engine is fueled with the JIS#2, BDF20 and BDF50, the best environmentally effective operation condition is low engine loads. [20] K.Vinukumara in his paper 'Biodiesel with nano additives from coconut shell for decreasing emissions in diesel engines' said that EDAX are used to identify the C, O, Al, Si, K and Ca elements in coconut shell nano particles and TEM is used to find the particle size of coconut shell, nano particles with an average particle diameter of 20 nm was observed. The invented fuel blends of 20%BD80%DF with CS fuel at maximum load 18.56% decreased in nitrogen oxides compared to 100%DF. For all loads CO and CO₂ emissions are reduced in 20%BD 80%DF with CS fuel. CS nanoadditive blended biodiesel-diesel blends also increased engine performance and increase in SFC. The CS nano particles is blended with biodiesel- diesel blends is an safest technique which increases engine performance and reduction in emissions and no more engine modifications is required. [21] Yingqun in the title of paper 'Biodiesels from microbial oils: Opportunity and challenges' said that Microbial oils are of a bio-renewable feedstock for biodiesel production without compromising food and water supply. It can be produced from various carbon sources by microorganisms, which also can be efficiently cultivated and harvested via assorted technologies and pathways. However, developed large-scale microbial oils-biodiesel production faced with much more limitations and challenges. In this regard, some solutions forwards should be urgently exploited and designed for future industrialization, including development of cheap carbon sources, screening and modification of oleaginous microorganisms, exploitation of high- efficiency cell wall breaking and oil extraction technology and development of novel microporous catalysts and regeneration technique.

[22] V. Ananthia and et al talk in the paper title 'Comparison of Integrated Sustainable Biodiesel and Antibacterial Nano Silver Production by Microalgal and Yeast Isolates' that In conjunction with microalgae and yeast usage for biodiesel production, the present study broadens its exploration towards silver nanoparticle synthesis by avoiding many prudential steps. Remarkably, for the first time we propose the feasible production of biodiesel and silver nanoparticle synthesis from microalgal and yeast isolates under single fermentation processes. Utilization of the oleaginous isolates for silver nanoparticle synthesis along with biolipid accumulation, afforded a possible track by producing sustainable The physicochemical properties of both microalgal and yeast based biodiesel were found within the specified biodiesel standards limit (EN 14214, ASTM, IS 15607). These results therefore highlight the possibility of microbial lipids produced by the present study as a valuable renewable energy source and can eventually obviate fossil fuels in internal combustion engines. The crystalline spherical shaped AgNPs of size between 2.0 to 7.3 nm was extracellularly synthesized from the cell free supernatants of microalgal and yeast isolates. [23] Lijie Zhang and et al said in the title 'Cultivation of microalgae using anaerobically digested effluent from kitchen waste as a nutrient source for biodiesel production' that Applying diluted ADE- KW to cultivate microalgae was feasible, and the 1/15 dilution ratio providing optimal biomass production (Chlorella sorokiniana SDEC-18: 0.42 g/L, Scenedesmus SDEC-8: 0.55 g/L) was recommended. More photosynthetic flow of carbon and energy from protein and carbohydrate changed into the biosynthesis of lipid/TAG under the stress of phosphorus limitation as well as high organic carbon in ADE- KW. Additionally, the microalgae could gain desirable properties for production of an ideal biodiesel. The biomass and lipid productivity in ADE- KW with addition of K₂HPO₄ were both promoted significantly: by factors of 2.27 and 1.08, respectively, compared with the corresponding condition without added K₂HPO₄. [24] Indu Ambat and et al talk in the paper that Based on various feedstock stated non- edible oils, algal oils, animal fats are promising sources for biodiesel production. In supplementary to that more investigation is needed to overcome some challenges related with non-edible feedstock such as non- edible sources require a large amount of methanol, whereas algal sources need more financial investment, and mixed culturing of algae. Having title 'Recent advancement in biodiesel production methodologies using various feedstock: A review' [25] Maria Vazquez and et al talk in the paper title 'Selection of

microalgae with potential for cultivation in surfactant-stabilized foam' that Major influence of each specific algal species on the production of stable, algal-enriched foam for a given surfactant has been proven and exemplified for several microalgal species of different nature and with known or potential commercial applications by analyzing of the following parameters: 1) foamability, 2) microalgal partitioning, and 3) foam stability, 4) The inherent growth characteristics of each microalgal strain were also considered for the final evaluation of the potential of the different strains to be cultivated in a foam-bed photobioreactor. [26]In the paper of 'Niraj B Dole , Rahul B Barjibhe' titled as 'Character traits of Hybrid Bio-Fuel as performance and exhaust emissions in a Diesel Engine' in 2022 states that On a single cylinder, four-stroke diesel engine, Undi oil biodiesel blends were used, and the results were compared to diesel fuel, Biodiesel and its mixes have been proved to have lower EGT than diesel in all scenarios. – Because biodiesel has a lower viscosity than diesel, spray generation in the combustion chamber is enhanced, resulting in a less dominating diffusion combustion phase. Because of its higher efficiency, B20 could eventually replace diesel fuel. B20 also has a lower BSFC value. CO, CO₂, HC, NO_x, and O₂ emissions are also significantly lower in B20 than in diesel. It may be possible to use undi biodiesel after more plantings have been completed, making it economically viable.

III. CRITICAL DISCUSSION ON LITERATURE REVIEW

- Production methodology of biodiesel from edible and nonedible oils was explained and optimization is done by various researchers. They concluded that further research and development on some advanced methods such as super critical methanol process in situ alkaline transesterification and micro wave method is necessary. (1,2,4)
- Biodiesel properties are analyzed by researchers and concluded that Biodiesel can be considered as feasible alternative substitution fuel for Diesel engine without any modification. (5)
- Further, many researchers added Nanoparticles in biodiesel blends to enhance properties to improve performance and reduce emissions of CI engine. They concluded that addition of nanoparticles plays a major role in improving the fuel properties and enhancing the performance of CI engine as well as reducing the exhaust emissions. (3,10,11,20,21,23,24,25)
- Many researchers used specific nanoparticles like CNT, Al₂O₃ etc. CNT as fuel borne nanoparticles additives in the diesterol fuel blend contributes for cleaner combustion and significantly reduces the harmful exhaust gas emissions. (6,7)
- CuO act as a catalyst and Oxygen booster when mixed with PME blend which enhances combustion characteristics and hence a considerable reduction in smoke and NO_x emission takes place. (16)
- By adding Alumina nanoparticles, exhaust gas temperature reduces as the Nano additive concentration is increased no matter the engine speed. The NO emissions were slightly increased with the increasing Alumina concentration due to higher combustion pressure and temperature of the fuel blends. The smoke emissions were found lower about 65%. When using the Alumina nanoparticles compared to the neat diesel. (8, 9, 12,13, 14, 15, 16,17, 19)
- With the presence of ZnO nanoparticles in blends of pure JME, the CO emissions increased and higher H₂ flow rate supplemented the CO emission (18) and the BJE is 2-3% more with B20 added with 50 and 100 ppm of ZnO compared to the diesel fuel (22).
- The addition of TiO₂ nano fluid in base fuel mustard oil methyl ester results in reduction in HC, CO and smoke emissions as all loads owing to its improved oxidation capability, enhanced thermal conductivity and the catalytic effect (22). The calophyllum inophyllum methyl ester nano emissions are promising alternatives fuel for diesel engine for significant reductions in exhaust emissions and improved performances compared pure calophyllum inophyllum biodiesel without any major modifications (24).
- Microbial oils are of a bio-renewable feedstock for biodiesel production without compromising food and water supply. Additionally, the microalgae could gain desirable properties for production of an ideal biodiesel. Advanced biofuels such as drop in microalgae, and electro biofuels have been extensively investigated as alternatives to conventional plant based biofuels (24, 25).

IV. CONCLUSION

Microalgae utilization for biofuel production is undoubtedly desirable all over the world. Though this approach is energy efficient and environment friendly, experts are still looking for an innovation that can boost the microalgae biofuel yield from primary stage to end product as well as shift the whole process towards a cost effective fuel solution. Hence, this review was emphasized on the synergistic effect of nano additive (ZnO) enhanced microalgae biofuel for mercantile approach and fuel-yield extension. Application of various forms of nano additives in different phases on microalgae growth to biofuel demonstrated an excellent outcome that may project revolutionary improvement of commercial microalgae biofuel. However, the sustainability analysis of stepwise production rounds for microalgae biofuel still presented a bare need of further research and innovative concepts.

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