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REVIEW OF RCCI ENGINE USING ALGAE BIODIESEL WITH ACETYLENE GAS

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Abstract: Energy security has become a major worldwide concern, prompting extensive research on cost-effective and environmentally benign alternatives. Renewable energy looks to be the only viable choice to fulfill future demands. Acetylene is well-known for its considerable flammability and low-cost non-crude oil derivative fuel availability. Microalgae appear to be a viable source of carbon-neutral biofuels due to their unique features. This review paper describes the performance of conventional diesel engines that use acetylene gas as the low reaction fuel (LRF) and algae biodiesel as the high reaction fuel (HRF) in reactive controlled compression ignition (RCCI). The focus is on improving and reducing emissions.

Keywords: Biofuels, Algae biodiesel, Acetylene gas, RCCI.

I. INTRODUCTION

The rise in environmental degradation as a result of the use of fossil fuels has boosted the demand for clean, sustainable energy sources. Biodiesel is a viable alternative to petroleum-based diesel in this aspect, as it cuts CO2 emissions and is renewable. India's crude oil demand is expected to be met by imports from other nations in 2030, according to estimates (1). Biodiesel is the most significant approach to reducing greenhouse gas emissions, and several studies suggest that using biodiesel from certain sources may cut greenhouse gas emissions by up to half compared to regular diesel fuel (2). Algae has gained international interest as a biodiesel feedstock because of its rapid growth rate, lack of competition with food and feed supplies, and capacity to collect CO2. A freshwater microalga was given vermicompost extract as a nutrition source to improve growth and lipid synthesis (Graesiellaemersonii MN877773) (3). A heterogeneous acid catalyst generated from the brewer's leftover yeast was used to make biodiesel (BSY). The catalyst's efficiency was tested by submitting it to sonochemical esterification of a low-value industrial waste product, palm fatty acid distillate (PFAD). The responses were carried out with ultrasound running at a constant frequency of 25 kHz. At 8 wt% catalyst, a 21:1 methanol to PFAD molar ratio, 65 °C, and 180 minutes of reaction time, an optimal methyl ester conversion of 87.8% was attained. Because of the strong single bond SO3H, the functional group linked to the catalyst showed good catalytic stability up to four cycles (4). The palm-fruit-bunch was used to make a new solid acid catalyst using an in-situ incomplete sulphonation carbonization process. The catalyst was then used in esterification and transesterification processes to create biodiesel from Calophyllum inophyllum (C. inophyllum) oil with a high free fatty acid (FFA) content. At 4 wt% catalyst, methanol to oil molar ratio of 21:1, and a reaction temperature of 60oC in 180 minutes, an optimal yield of 88.5 wt% methyl ester was obtained (5). There has been a lot of research done on the possibilities of utilizing algae to create oil for biodiesel manufacturing. Low molecular weight alcohols were used in the transesterification reaction, which was carried out in the presence of an acid, alkali, and enzymatic catalysts. Catalysts are also divided into homogeneous and heterogeneous categories [6]. Because of its high lipid content and ease of growing, Chlorella vulgaris offers a lot of promise for biodiesel conversion [7]. The Cu (H2PDC) (H2O)2 complex was used to perform a transesterification reaction of Spirulina algal oil with methanol to make biodiesel. Temperature, methanol-to-oil ratio, and catalyst concentration were all examined and tested as part of the reaction's operating parameters (8). Alternative renewable fuels reduce reliance on conventional fuels and reduce emissions dramatically. Alternative fuels have been studied by several researchers(9). A low-temperature combustion is a crucial approach to reducing greenhouse gas emissions, particularly NOx emissions, while improving engine efficiency (10). Acetylene is a colorless, garlic-scented gas that is made from calcium carbide (CaC2), which is derived from calcium carbonate (CaCO3). In a lime kiln, calcium carbonate is burned to around 8250 ° C to form calcium oxide (lime), which produces CO2. After that, calcium oxide is burned with coke in an electric furnace to make calcium carbide, which is then hydrolyzed to make acetylene. It can be utilized as an alternative fuel for internal combustion engines due to its fast flame rate and rapid energy release. It has a wide flammable range and requires very little ignition energy to ignite. In addition, acetylene has proven to be suitable for use in internal combustion engines when compared to a variety of other fuel properties (11). Because of their great efficiency and low

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emissions, RCCI (reactivity controlled compression ignition) engines, which combine the fuelling techniques of traditional diesel and gasoline engines, have gotten a lot of attention. In a typical RCCI engine, low-reactivity gasoline is supplied into the engine via the port fuel injection system and then premixed with air; high-reactivity diesel is immediately injected into the premixed gasoline–air charge. Because of the varied auto-ignition properties of these two types of fuels, research (12) found that by altering the gasoline to diesel fuel ratio, RCCI engine loads may be run over a wide range of 4.6 to 14.6 bar IMEP (indicated mean effective pressure). The usage of alternative and renewable fuels in RCCI engines has piqued the curiosity of certain academics. Natural gas [13, 14], methanol [15, 16–18], and ethanol [19] were utilised as low-reactivity fuels, while diesel was still used as a high-reactivity fuel.

II. ALGAE AS RAW MATERIALS

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Microalgae are microscopic organisms used for biofuel generation. The chemical composition of algae can be used to make a variety of biofuels such as Biodiesel, bioethanol, biobutanol, biomethane, jet fuel, biohydrogen bio-oil, bio-crude, and syngas (20). (21) used chloroform-methanol (2: 1 volume ratio) to extract lipids from microalgae. This is the so-called Forch method. In the Bligh and Dyer (22) method, lipid extraction and distribution are performed simultaneously. Because of their enhanced hardness and density, beads consisting of zirconia-silica, zirconium oxide, or titanium carbide can improve the disruption rates and extraction efficiency of microalgal cells Hopkins (23). Matthiache Valley (24) is a modified version of the Folch / Bligh and Dyer method. The above procedure provides better recovery of almost all major classes of lipids. Methyl tert-butyl ether (MTBE) is used as the solvent for lipid extraction and this method provides the most accurate lipidome profile. Levineetal (25) reported on in situ lipid hydrolysis and in situ supercritical transesterification (SCIST / E) methods for extracting lipids from moist algae biomass. Mechanical extraction methods that do not necessarily require solvent assistance include bead mill (26), expeller press method (27), microwave-assisted pyrolysis extraction (28), and also include ultrasonic-assisted extraction. The use of ionic liquid for algal lipid extraction is a novel and rapidly developing pre-treatment method. Various researchers have conducted an extensive study on ionic liquid extraction in microorganisms (29-34). There are impulse charging and hydrothermal liquefaction. Osmotic pressure is a unique and alternative strategy to competing with existing extraction processes that are deemed environmentally friendly and cost-effective (35). The use of calcium methoxide (36) as a heterogeneous catalyst in the manufacture of biodiesel from Euglena sanguinea microalgal bio-oil Bio-oil was recovered from Euglena sanguinea algae biomass that had been mass-cultivated. It was then processed and transesterified with a calcium methoxide catalyst under varied experimental circumstances, yielding an optimum of 94.83 percent. At present, solvent extraction methods are most commonly used for lipid extraction as they provide the highest lipid recovery (37). (38) explained how combining the models allows for fast analyses of the MFSP of algae-derived biofuels and insights into the best strategies to improve economic performance. At 300 °C, algae with lipid content of 20–25 percent had the best economic performance ($6 per gasoline-gallon-equivalent (GGE)).

A. BIODIESEL PRODUCED FROM ALGAE OIL

Transesterification is accomplished by combining warmed oil with alcohol in the presence of catalysts that accelerate the process. Following the extraction of algal oil, the esterification process might be catalytic, enzymatic, or non-catalytically catalysed. The quantity of free fatty acids (FFA) determines the type of catalyst utilised. As a by-product of this process, glycerol is generated, which separated using mechanical or electrical is stirring. During the refining process, water is also utilised to neutralise the Ph value of biodiesel. After the refining process, biodiesel is produced, which is a less viscous, clean, alternating fuel with a structure comparable to diesel. Mahendran et al. [39] made biodiesel from algal oil by dissolving 15 to 20 gms KOH pellets in a solution of alcohol (50 ml CH_3OH) and catalyst (10 ml H_2SO_4). The solution, together with 1L of algae oil, was heated to 50^0 C and agitated at 1500 rpm for one hour. Biodiesel was produced through the transesterification and evaporation processes. De Jesus et al. [40] used Chlorella pyrenoidosa microalgae as feedstock, 2-methyl tetrahydrofuran, or cyclopentyl methyl ether as a green solvent, and hydrochloric acid within the prescribed standard. Ranjithkumar et al. [41] derived biodiesel using CalophyllumInophyllum algae. 10– 20 gm pellets of KOH were dissolved into 100 ml of CH_3OH, 5 to 10 ml H_2SO_4 was added as a catalyst into the solution. Transesterification of dissolved solution and algae oil was administered at 65^0 C for biodiesel production. Lozano et al. [42] produced biodiesels, using a mixture of hydrophobic and hydrophilic with algae oil. In this way, 100% biodiesel yield was obtained after 120 min at 60^0C. Satputaley et al. [43] used a solvent extraction technique to obtain biodiesel from algal oil collected from the microalgae chlorella vulgaris. Transesterification of algal oil with KOH and CH_3OH yielded an 85 % biodiesel output.

III.PERFORMANCE AND EMISSION CHARACTERISTICS OF BIODIESEL

Yang et al. (44) investigated the dual fuel mode (Diesel and Methane) CI engine by altering the time of diesel injection in the RCCI combustion engine. The results show that efficiency is higher when compared to regular diesel fuel operation. Zheng et al. (45) investigated the combustion and emission traits of RCCI mode combustion using biodiesel as the HRF and n-butanol, 2,5-dimethylfuran, and ethanol as the LRF, all of which were injected using the port fuel injection system. NOx and soot emissions are reduced when biodiesel and ethanol are combined. SujeetKesharvani (46) demonstrated that using biodiesel blended with diesel improved engine performance by increasing BSFC and decreasing BTE. On the other hand, it minimizes pipe emissions like CO, CO2, and UBHC. Karthikeyan et al. [47] investigated the performance of the Kirloskar engine using biodiesel blends such as B20, B50, B75, and B100 made from S. Marginatummacroalgae. As a result of the presence of excess O2, lower body, and FFA, the B20 mix showed higher Heat rejection magnitude relation (HRR) and cylinder pressure (CP) in comparison to Diesel (BTE). There was no negative impact on the ignition delay. Karthikeyan et al. [48] investigated engine performance victimization biodiesel generated from S. MarginatumMacroalgae as B20, B50, 75, and B100. The experiment was carried out using a single-cylinder CI Engine with a 5.2 HP rating and a 1500 RPM speed. Due to the existence of inherent chemical element content, the study found that the mix magnitude relationship will increase BTE, Exhaust gas temperature (EGT) will increase, and Brake specific fuel consumption (BSFC) would decrease. Subramaniam et al. [49] investigated the performance characteristics of DIE victimization biodiesel blends generated from Azollapinnata alga as B10, B20, B30, B40, and B100 blends. The B20 blends had a greater BTE, lower CO, HC, Smoke, and specific matter, and a higher Nox emission based on one injection technique, Karthikeyan et al. [50] investigated DIE performance using a B20 mix produced from KappaphycusAlvarezil alga. When compared to DIE common injection, the pipe emission of PM and Nox was found to be reduced. Using B20 as a fuel reduces BTE by 0.75 percent, as per Rajat et al. [51], which is further improved by adding NPs. The oil from the transesterified Hevea Brasiliensis (52) was combined with diesel at percentages of 10%, 15%, and 20%. Biodiesel reduced NOx, HC, and CO emissions by an average of 16.06 percent, 9.46 percent, and 16.27 percent, respectively, with the addition of biodiesel. Hevea Brasiliensis might be a viable source for biodiesel production and can also be used as a fuel for diesel engines without requiring any engine changes, according to the results of the experiments. Biodiesel has several benefits over diesel, including lower CO, CO2, UHC, and PM emissions [53], and it is encouraging to use it as a diesel alternative because it is renewable and has similar properties [54]. KOH and Mg/AlNO3 (55) catalysts were used to transesterify mixed waste vegetable oil. The co-precipitation approach was used to make Mg/AlNO3 catalysts. Batch studies were carried out using the transesterification process at 50-80 °C, a 3:1-12:1 molar ratio of alcohol to oil, and a catalyst concentration of 0.5-2.0 wt. percent with varied reaction periods. The results show that KOH produces 93.12 percent biodiesel [0.75 weight percent KOH, methanol: oil molar ratio 8:1, reaction time 50 minutes, and reaction temperature 60 °C], while Mg/AlNO3 catalysts produce 87.26 percent biodiesel [1.75 weight percent Mg/AlNO3, methanol: oil molar ratio 12:1, reaction time 4 hours, and reaction temperature 60 °C]. (56) Using diesel fuel and alumina nanoparticle blended diesel fuel, determine the performance, emission, and combustion parameters of a diesel engine. Alumina nanoparticles are fully mixed with diesel fuel in mass fractions ranging from 25 ppm to 75 ppm. The brake thermal efficiency was raised by 2.1 percent based on the experimental findings. However, NOX and smoke levels are lowered by 9.31% and 15%, respectively.

IV.PERFORMANCE AND EMISSION CHARACTERISTICS OF ACETYLENE GAS

M. Sonachalam (57), The use of Acetylene as an Alternative Fuel in IC Engines shows that CO2 emissions are relatively low, while other pollutants such as NOx and SOx are insignificant when compared to CO2. This suggests that acetylene may be more potent and environmentally friendly than gasoline. In the reactivity-controlled compression ignition (RCCI) mode, the performance and reduction emissions of a conventional diesel engine by using low-reactivity fuel (LRF) as an acetylene gas and high-reactivity fuel (HRF) as B20 mahua biodiesel was improved. In terms of performance, emissions, and combustion characteristics, B20 mahua oil biodiesel blended with 4 LPM acetylene injection by 45° injector in RCCI mode combustion is found to be a better option to B20 mahua oil biodiesel combustion. T.Lakshmanan(58), compared to a baseline diesel operation, acetylene induction resulted in a small loss in thermal efficiency. The exhaust temperature, HC, CO, CO2, and smoke emissions were all lower than with a standard diesel engine. However, there is a considerable rise in NOx emissions in the exhaust. To sum up, we believe that acetylene will soon compete with hydrogen as an alternative fuel in internal combustion engines. By utilizing techniques such as TMI and TPI of gas, higher efficiency and reduced NOx emissions can be achieved. In a study of the applicability of acetylene in SI engines with EGR, Ashok Kumar et al. [59] found that emissions were dramatically reduced, on par with hydrogen engines, with only a small increase in thermal efficiency. Swami Nathan et al. [60] experimented with a CI engine using acetylene as a fuel in the HCCI mode with warmed take charge heating. The achieved efficiency was extremely close to those of diesel. NOx and smoke levels were dramatically lowered. The level of HC, on the other hand, was raised. Energy security has become a

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major worldwide concern, prompting extensive study into economically viable and environmentally beneficial alternatives. The impact of timed manifold injection of acetylene in the intake manifold of a diesel engine was investigated by Lakshmanan et al. [61]. Using an ECU, an optimal injection timing of 10 TDC and 90 CA duration was achieved. At full load, the performance was comparable to diesel. Because of the lean operation, nitrogen oxides, hydrocarbons, and carbon monoxide emissions dropped, although smoke emissions increased somewhat Renewable energy looks to be the only answer that appears to fulfill future needs,The performance characteristics of a CI engine in dual fuel mode were explored by Mahla et al. [62]. As a combustion source, a set amount of acetylene (12 lpm) and a diethyl ether mix with diesel (DEE10, DEE20, DEE30) were employed. Experiments demonstrate that adding diethyl ether enhances braking power and BTE by 20% without sacrificing brake specific fuel consumption; however, once this percentage is exceeded, performance diminishes and the engine knocks. In dual fuel mode, EGT is lower than in straight diesel mode.

V. CONCLUSION

Even though a variety of renewable energy sources are now being employed, the possibilities for manufacturing carbon-neutral biofuels from microalgae look to be promising due to their unique properties. The adoption of biodiesel has been observed to result in a considerable reduction in traditional fossil fuel usage as well as emissions. The high oil content and ease of growth of nature Algae feedstock can help India's biodiesel manufacturing. Its application and dependability are enhanced by advantages such as renewable energy, no extra land required, carbon neutrality, and the capacity to grow practically all water. Transesterification is used to produce biodiesel from algal oil. The use of biodiesel in combination with acetylene gas can improve engine performance by speeding up the BSFC and lowering the BTE. On the other hand, it lowers exhaust emissions.

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