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# Performance and Emission Analysis of Di Diesel Engine using Bio Diesel as Azolla Algae

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**Abstract:**
Continuous use of petroleum sourced fuels is now widely recognized as unsustainable because of depleting supplies and the contribution of these fuels to the accumulation of carbon dioxide and carbon monoxide in the environment. Renewable, carbon neutral, transport fuels are necessary for environmental and economic sustainability. In this work, diesel fuel is tested with standard piston byvarious load condition and studies' the performance and emission characteristics of dieselengine.Tthe production of AME azolla (algae) oil and also physical, chemical properties of AME was analyzed. The azolla algae oil was extracted algae methyl ester by transesterification process with suitable catalyst. The investigation was carried out the single cylinder four stroke, water cooled diesel engine with the conventional diesel fuel and the engine performance and emission, characteristics was analyzed in this project. The brake thermal efficiency of azolla biodiesel blend B25 is near to dieselfuel. The CO, HC and NOx emission are less when the percentage of biodiesel is increase

**Keywords:** $CO_2$, CO, RENEWABLE, TRANSESTERIFICATION, EMISSION.

## 1. INTRODUCTION

As there is an everlasting consumption of fossil fuels throughout the world which is depleting rapidly, there is the need to fulfill the ever increasing global energy demand that causes the intensive use of fossil fuels like coal, petroleum and natural gas. These fossil fuels represent more than 80% of the energetic resources. Also due to the adverse effect of gas emissions of these fuels on global climate change, research on fuel production is compelled to focus on finding alternative fuels to the existing fossil fuels. Due to their exhaustibility and indefensible environmental impact, both generated by their fossil origin, growing attention has emerged on renewable energy. It induced the researchers to tum into biodiesel which gives fewer emissions to the environment. Biodiesel shows potential alternativeness to consider it as an alternative fuel. Biodiesel obtained from oil crops is an. impending renewable and carbon neutral alternative to petroleum fuels. Unfortunately, biodiesel from oil crops, waste cooking oil and animal fat cannot realistically satisfy even a small fraction of the existing demand for transport fuels. The biodiesel produced from vegetable oil and animal fat using alcohol such as methanol, ethanol or butanol along with a catalyst. The production of biodiesel from microalgae was all year round and therefore, quantity of oil production exceeds the yield of the best oilseed crops, e.g. biodiesel yield of 58,700 l/ha for microalgae containing only 300/0 oil by wt., compared with 1190 l/ha for rapeseed or Canola, 1892 IIha for Jatropha, and 2590 IIhas for Karanj (Pongamiapinnata). Table 1 lists the typical oil yields from various sources. The rapid growthpotential and numerous species of microalgae with oil content in the range of 20- 50% dry. weight of biomass is the another advantage for its choice as a potential biomass. The exponential growth rates can double their biomass in periods as short as 3.5 h. Secondly, in spite of their growth in aqueous media, the algae need less water than terrestrial crops thus the load on freshwater sources is also reduced. Due to this reason, the microalgae can also be cultivated in brackish water on non-arable land, and therefore may not incur land use change, minimizing associated environmental impacts, without compromising the production of food, fodder and other products derived from terrestrial crops. According to' Chisti, 1 kg of dry algal biomass utilizes about 1.83 kg of CO2,.thus the microalgae biomass production can help in bio-fixation of waste CO2 with respect to air quality maintenance and improvement. Industries use vegetable oil and animal fat from poultry to produce the biodiesel. Also the research is focused on the production of biodiesel by using the high oil content crops. Microalgae that embody lots of unmatched advantages as non- food resources are vie~ed to be a promising feedstock of the third-generation biodiesel. Microalgae are unicellular, photosynthetic microorganisms; they have minimal nutrient requirements and are being used as source materials for a variety of products such as protein rich nutritional supplements, pharmaceutical chemicals and pigments. They also grow extremely fast, in comparison to plants and many microalgae strains are exceedingly rich in oil which makes them great candidates for the production of biodiesel. Using microalgae to produce biodiesel will not compromise production of human food, animal feed and other products as when oil crops are used.

## 2. OBJECTIVES AND METHODOLOGY

### 2.1. OBJECTIVES

- To identity the suitable macro algae plants.
- To identify the suitable method of extraction to get a maximum yield of algae oil.
- Based upon the literature survey azolla macro algae oil to be converted into algae methylester by using trans esterification process with suitable catalyst.
- To analyze of physical and chemical properties of azolla algae oil as per ASTM standards.

## 2.2. METHODOLOGY

- The collected macro algae was subjected into chemical solvent extraction method (Soxhlet apparatus) for 1 kg of dry powdered sample subjected into above apparatus with help of chloroform and methanol in 2: 1 ratio. Repeated at maintain a temperature 65°C bout 48 hours the fatty acid was extracted. The extracted fatty acid was converted into algae methyl ester by using trans esterification process.
- The experiment been carried out in Kirloskar TV 1, single cylinder, fourstroke, water cooled diesel engine with all necessary equipment to study the performance and emission characteristics .
- The experimental investigation was studied by the standard piston along with conventional diesel fuel.
- In bin-diesel has been extracted from azolla macro algae oil through trans esterification process and it has been blended with various proportions to conventional diesel fuel
- The experimental investigation of the engine has been carried out with various blends of bio-diesel and compared with standard piston along with conventional diesel fuel. In bio-diesel has been extracted from azolla macro algae oil through transesterification process and it has been blended with various proportions to conventional diesel fuel. The experimental investigation of the engine has been carried out with various blends of bio-diesel and compared with standard diesel fuel.

## 3. ALTERNATIVE FUELS

Probably in this century, it is believed that crude oil and petroleum products will become very scare and costly to find and produce. Gasoline and diesel will become scare and mostly costly. Alternative fuel technology, availability, and use must and will become more common in the coming decades.

All these years there have always been some IC engines fuelled with non-gasoline or diesel oil fuels. However, their numbers have been relatively small. Because of the high cost of petroleum products, some developing countries are trying to use alternate fuels for the vehicles.

Motivating the development of alternate fuels for the IC engine is concern over the emission problems of gasoline engines. Another reason for alternate fuel development is the fact that a large percentage of crude oil must be imported from other countries, which control the larger oil fields. As of now many alternate fuels have been used in limited quantities in automobiles.

### 3.1. Need of Biodiesel

- Increased environmental concerns, tougher clean air act standards &depletion of fossil fuels, necessitate the 'search, fora viable 'alternative fuel. Which is more environment-friendly? The use of vegetable oils such as palm, soybean, sunflower, peanut and olive as alternate fuels diesel engines dates back almost a' century. When Rudolf' diesel first. invented the diesel engine, he demonstrated the engine at the 1900 world exhibition in parts, employing peanutoil and said The use of vegetable oils for engine fuels may seem insignificant today. But such oils may become in course of time as important as petroleum and the coal tar products of the present time". In the 1930s and1940s, vegetable oils were used as diesel fuels in emergencies.
- Recently, because of increase in crude oil prices, limited 'resources of fossil fuels and environmental concerns, there has been a renewed focus on the use of vegetable oils, algae and animal fats as alternative fuel applications.

## 4. ALGAE OIL AS BIODIESEL

### 4.1. ALGAE

Algaeis the name given to a large and diverse group of oxygenic, phototrophic, eukaryotic microorganisms. Algae are eukaryotic, which means they have a nucleus. This differentiates them from Bacterial and photosynthetic Cyanobacteria. They are oxygenic phototrophs, meaning they use light as their energy Source for growth and produce oxygen as a byproduct, like plants. But what distinguishes algae from plants is that algae do not have any tissue differentiation. Plants can differentiate their tissues into roots, trunks, and leaves, all very different tissue types. In contrast, algae are composed of cells that are generally all the same. Despite the differences between plants and algae, many algal species are closely related to plants. But the algae are very diverse. Some algae, like Euglena, are close revolutionarily to single-celled protozoa than to plants.

### 4.2. MACRO ALGAE

Seaweeds or macro-algae belong to the lower plants, meaning that they do *not* have roots, stems and leaves. Instead they are composed of a thallus (leaf-like) and sometimes a stem and a foot. Some species have gas-filled structures to provide buoyancy. They are subdivided in three groups, the red, green and brownmacroalgae. In their natural environment, macro-algae grow on rocky substrates and form stable multi-layered, perennial vegetation capturing almost all available photons. Due to the fact that seaweeds are fixed to their substrate, values for maximum productivity may be 10 times higher fOI" a seaweed stand than for a plankton population, and can be as high as 1.8 kg C m $^{-2}$y -1. The maximum chlorophyll content is 3 g m-$^{2}$ illuminated surface, corresponding to an algal biomass of about10 kg m $^{-2}$. The productivity of plankton is much lower because most of the photons are absorbed or scattered by abiotic particles, and the algae are so thinly distributed. Commercial farming of' seaweed has a long history, especially in Asia. Approximately 200 species of seaweeds are used worldwide, about 10 of which are intensively cultivated, such as the brown algae Laminaria japonica and Undariapinnatifida, the red algae Porphyra, Eucheuma, Kappaphycus and Gracilaria, and the green algae Monostroma and Enteromorpha. Several species having a range of specific requirements for their living environment appear to be especially suited forlarge-scale cultivation (Table 5.2). These requirements are nutrients, salinity, temperature, light, depth, and currents. Factors that affect cultivation also include predation, growth of epiphytes, and pollution.

### 4.3. MICRO ALGAE

Microalgae are single-cell microscopic organisms which are naturally found in fresh water and marine environment. Their position is at the bottom of food chains. Microalgae are considered to be one of the oldest living organisms in our planet there are more than 50,000 species of micro algae species exist, but only30,000 are analyzedyet. They are thallophytes - plants lacking roots, stems, and leave that have chlorophyll as their primary photosynthetic pigment and lack a sterile covering of *cells* around the reproductive cells. While the mechanism of photosynthesis in these microorganisms is similar to that of higher plants, microalgae are generally more efficient converters of solar energy thanks to their simple cellular structure.

**Table.1. Oil content of Macro and Micro algae**

| FAME | Macro algae | Micro algae |
|---|---|---|
| | Oil(%) | Oil (%) |
| Palmitic | 14.0 | 9.8-32 |
| Stearic | 2.6 | 1.5-2.4 |
| Oleic | 41.3 | 8.2-14.9 |
| Linolenic | 88 | 14.4-21.4 |
| Arachidonic | 15.8 | 0.1-1.6 |

### 4.4. ALGAE AS FUEL IN INDIAN SCENARIO

Extensive work has been done by Indian scientists on utilization of microalgae for food and the pharmaceutical applications. The lists of organizations/institutions who are working on various aspects of microalgae such as microalgae collected from natural vegetation which is used for the production of biogas and bio fuel in India.

### 4.5. ADVANTAGES OF ALGAE

The advantages of culturing micro algae as a resource of biomass are:

Algae are considered to be a very efficient-, biological system for harvesting solar energy for the production of organic compounds.

Algae are non-vascular plants, lacking (usually-. complex reproductive organs. Many species of algae can be induced to produce particularly high concentrations of chosen, commercially valuable compounds, such as proteins, carbohydrates, lipids and pigments.

Algae are microorganisms that undergo a simple cell division cycle. The farming of microalgae can be grown using sea or brackish water.

Algal biomass production systems can easily be adapted to various levels of operational or technological skills.

The above advantage shows that algae to become a future source of fuel in India. To become a successful fuel the algae has to undergo various process from harvesting to cultivation in a manner to get the max output.

### 4.6. ALAGAE OIL EXTRACTION PROCESS

There are various methods to extract the oil from algae among them there are four methods are well known for extraction mechanical press, Solvent extraction, Supercritical fluid extraction and Ultrasonic assisted.

**Mechanical press**

Mechanical Press In this method, microalgae biomass is subjected to high pressure resulted ruptures cells wells and releases the oil. This method is easy to use and more importantly no solvent is required. In, this methods, extract a large percentage (70- 75%) of the oils out of algae biomass.

**Solvent extraction**

Algae oil can be extracted using chemicals. Organic solvents (such as benzene, cyclohexane, hexane, acetone and chloroform) mixed with macro algae bio mass they degrade microalgal cell walls and extract the oil because oil has a high solubility in organic solvents. Solvents used in this methods are relatively inexpensive, result are reproducible and Solvent is recycled. The oil extracts by this method is 60-70 %.

**Supercritical fluid extraction**

This method is more efficient than traditional solvent separation methods. Supercritical fluids have increased solvating power when they are raised above their critical temperature and pressure points. It produces highly purified extracts that are free of potentially harmful solvent residues, extraction and separation are quick, as well as safe for thermally sensitive products. This can extract almost 100% of the oils all by itself. In the supercritical fluid carbon dioxide ($CO_2$) extraction, C02 is liquefied under pressure and heated to the point that it has the properties of both a liquid and gas. This liquefied fluid then acts as the solvent in extracting the oil

**Ultrasonic assisted extraction**

This method based on Cavitation. Cavitation occurs when vapour bubbles of a liquid form in an area where pressure of the liquid is lower than its vapour pressure. These bubbles grow when pressure is negative and compress under positive pressure, which causes a violent collapse of the bubbles. If bubbles collapse near cell walls, damage can occur and the cell contents are released. This have advantage over other extraction method such as extraction time, is reduced, reduced solvent consumption,

### 4.7. AZOLLA ALGAE

Azolla, with about five extant species, is the only genus in the Azolla algae, a small family of ferns (which is sometimes combined with the genus Salvinia in the family Salviniaceae). The delimitation of species of Azolla and determination of their correct names is rather unsettled. The species reproduce primarily by budding off new plants. Sexual reproductive structures (described below) are usually absent, and without them it is very difficult to identify the species with certainty. Mosquito Ferns are sometimes mistaken for Duckweeds (Lemnaceae), a family of about five genera and 40 species of flowering plants, which are also tiny aquatic plants of worldwide distribution. Some species of Duckweeds are floating, whereas others are submersed in the water. Duckweeds are the smallest of all flowering plants, but they rarely produce flowers and seeds and, like Mosquito Ferns, reproduce mostly by budding off new plants. Mosquito Ferns (often "Mosquito-ferns") are also frequently called Azolla, Duckweed Fern, Fairy Moss (the plants have a moss-like appearance), Mosquito Plant and Water Fern. Species of Salvinia are more frequently called Water Ferns, so this name should be avoided. The name 'Mosquito Fern' is said to have arisen because thick mats of floating plants have a reputation for preventing mosquitoes from laying eggs. The curious genus name Azolla is based on the Greek azo, to drypollyo, to kill, an allusion to death from drought, which occurs should the plants lose their supply of water. Azolla species are diminutive, delicate, free-floating, annual plants. The extremely small leaves (technically 'fronds' in ferns), no larger than 2mm or 0.08 inch across, are alternately attached to the branching stems, often overlapping in tworanks. Mosquito Ferns are much reduced inform, and do not exhibit characteristic highly dissected ('ferny') foliage of most ferns. The leaves have an upper green (i.e. photosynthetic) lobe, which bears hydrophobic hairs, and a smaller, usually colourless lobe, which is buoyant and often submersed. Thread-like, unbranched roots are produced froni. the axils of branches. Under good conditions the plants can grow over each other in layers and develop mats up, to 5 cm (2 inches) thick. Most species of Azolla produce reddish pigments when stressed, for example by temperature extremes or feeding damage by herbivores, and this may result in a pinkish or reddish carpet of plants covering expanses of water. Azollafiliculoides has been called Red Water Fern because of the tendency to become reddish. Perhaps the most remarkable features of Azolla species is their symbiosis with a bacterial partner. The upper leaf lobes house the bacteria in a pouch on their lower side. This tightly integrated relationship is unique in the plant world. Ferns reproduce by spores, not seeds. Most fern species have just one kind of spore, but Azolla has two kinds, in reproductive structures termed sporocarps, which are developed at the junctions of the lower leaf lobes with the branches. Male sporocarps are minute (about 2mm or 0.08 inch in diameter) and produce male spores, which adhere to each other in clumps; female sporocarps are smaller than the male sporocarps,

**Figure.1. Photographic views of Azolla algae**

In China and Vietnam, particular strains of A. pinnata are cultivated in riceculturesystems, as discussed below. Whether such strains have been' domesticated'(changed genetically from wild ancestors), or simply represent selections of formsthat exist in the wild, is undetermined. Some recent success has been achieved in selecting and recombining more productive forms of fern-bacterium partnerships. Azolla is also analyzed for the cellulose, lignin, acid detergent fibre*(AD* F), neutral detergent fibre(NDF) and ether extract through Goering and Van Soest method. They found that Azollaconsists cellulose 15.19 ± 1.35%, lignin 9.27± *1.19%, ADF* 26.58 ± 2.3%, NDF 39.16 ± 1.56%, ether extract 5.05 ± 0.05% andnitrogen 4.47 ± 0.03 %. Due to lignin and cellulose it is prerequisite to pre-treat azolla to release fermentable sugars for yeast fermentation. Floating aquatic macrophytes are defined as plants that float on the water surface, usually with submerged roots. Floating species are generally not dependent on soil or water depth. Azolla are heterosporous free-floating freshwater ferns that live symbiotically with Anabaena azoIla, nitrogen-fixing blue - green algae. These planets have been of particular interest to botanists and Asian agronomists because oftheir association with blue-green algae and their rapid growth in nitrogen deficient habitats.

The genus Azollaincludes six species distributed widely throughout temperate, sub-tropical and tropical regions of the world. It is not clear whether thesymbiont the same in the various azolla species. Azolla consists of a main stem growing at the surface of the water, with alternate leaves and adventitious roots at regular intervals along the stem. Secondary stems develop at the axil of certain leaves. Azolla fronds are triangular or polygonal and float on the water surface individually or in mats. At first glance, their gross appearance is little like what are conventionally thought of as ferns; indeed, one common name for them is duckweed ferns. Plant diameter ranges from 113 to 1 inch (1-2.5 crn) for small species like Azollapinnata to 6 inches (15 cm) or more

## 5. EXTRACTION OF BIODIESEL FROM AZOLLA ALAGAE OIL

### 5.1 Transesterification process

Transesterification the process of using an alcohol (methanol, ethanol, propanal, or butanolthe presence of catalyst to chemically break the molecule of the raw re-newable oil into methyl or ethyl esters of the renewable oils with glycerolas by-product.

**Table.2. Materials requirement for Trans esterification process**

| SI.No | Description | Proportions |
|---|---|---|
| 1 | Azolla oil | 1000 ml |
| 2 | KOB(potassium hydroxide) | 6g |
| 3 | Methanol | 200 ml |

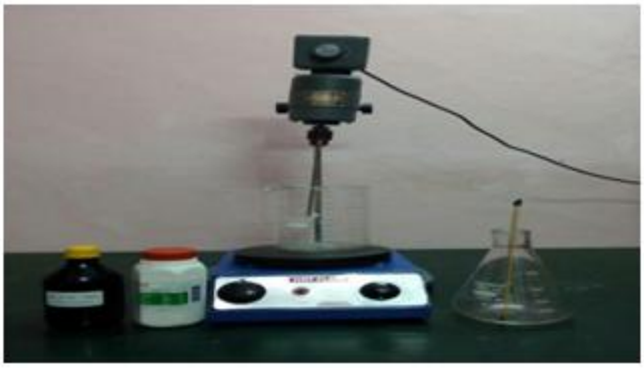


**Figure.2. Photographic view of biodiesel preparation plant (Transesterification process)**

### 5.8.2 Transesterification procedure

- The catalyst is dissolved into methanol by vigorous stirring in a flask.
- The oil is transferred into a round bottomed flask and is heated in a water bath at 7D$^c$ein water the prepared catalyst and alcohol mixture is added at first by constant stirring.
- The final mixture is stirred vigorously for 2 hours at 340K m ambient pressure in an etherification unit
- A successful transcsterification produces two liquid phases: ester and crude glycerol. Crude glycerol being heavier liquid is collected at the bottom of the flask after several hours of settling.
- Phase separation can be observed within 10min and can be completed within 2hours of settling in the separating funnel. Complete settling can take as long as 20 hours.
- Before collecting the oil in the separating funnel it is mixed water for distillation and easy phase separation
- The separating funnel should be shaken well by bubble washing for two to three times while the mixture is allowed for phase separation.
- Finally, after 20hours, complete settling of oil and glycerol will take place.
- The esterified oil is collected after few times of bubble washing.

Biodiesel is then extracted from azolla algae oil and the fuel properties weretested.

**Table.3. Properties of diesel and azolla biodiesel blends**

| Properties | Measurement Standards | Diesel | B25 | B50 | B75 | B100 |
|---|---|---|---|---|---|---|
| Specific gravity at 15/15°c | ASTM D1298 | 0.835 | 0.8422 | 0.8499 | 0.8522 | 0.8621 |
| Kinematic viscosity at 40°c(CSt) | ASTM D445 | 3.05 | 4.25 | 4.56 | 5.21 | 5.83 |
| Flash point (°c) | ASTM D92 | 45 | 72 | 78 | 82 | 96 |
| Fire point (°c) | ASTM D93 | 48 | 77 | 82 | 87 | 110 |
| Gross calorific value (kj/kg) | ASTM D240 | 43700 | 43386 | 43218 | 42890 | 42598 |
| Cetane number | ASTM D976 | 52 | 53 | 55 | 56 | 58 |

## 6. EXPERIMENTAL PROCEDURE

### 6.1 EXPERIMENTAL SETUP

This project work has been carried out using diesel fuel on a single cylinder, water cooled, 4-stroke, diesel engine.

Details of the engine specification are given in Table 6.1. Fuel flow rate is obtained on the gravimetric basis and the air flow rate is obtained on the volumetric basis. The engine was coupled to an eddy current dynamometer for load measurement and the smoke density was measured using an AVL smoke meter. $NO_x$ emission is measure with help of an exhaust gas analyzer. A VL Di gas analyzer is used to measure the rest of the pollutants. A VL combustion analyzer is used measure the combustion characteristic of the engine. A burette is used to measure the fuel consumption for a specified time interval. During this interval of time, how much fuel the engine consumes is measured, with the help of the stopwatch. The experimental set up is indicated in Figure 6.1

**Table.4. Speclflcation of the Test Engine**

| | |
|---|---|
| Type | Vertical, water cooled, Four stroke |
| Number of cylinder | I |
| Bore Diameter | 87.5 mm |
| Compression ratio | 17.5: 1 |
| Maximum power | 5.2Kw |
| Speed | 1500 rpm |
| Dynamometer | Eddy current |
| Injecting timing | 23 ° before TDC |
| Injection pressure | 220kgf/crrr' |

### 6.2 EXPERIMENTAL PROCEDURE

The engine was allowed to run with neat diesel at a various loads for nearly *10* minutes to attain the steady state constant speed c?nditions. Then the following observations were made.

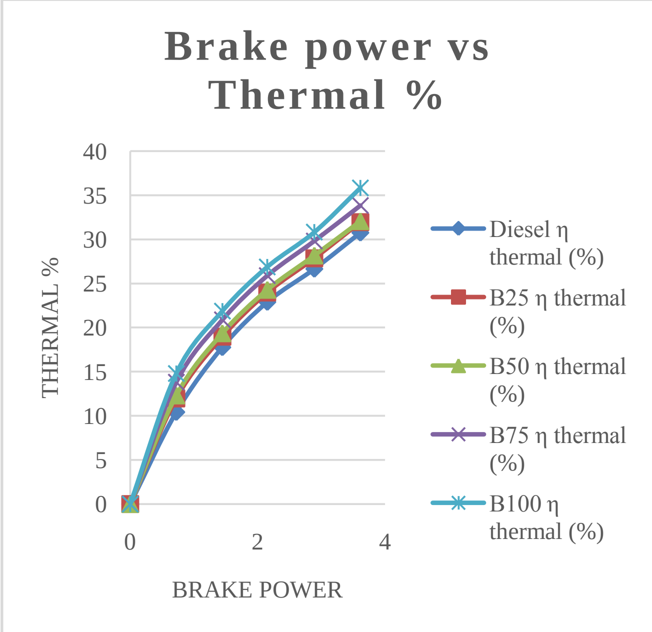
1. The water flow is started and maintained constant throughout the experiment.
2. The load, speed and temperature indicators were switched ON.
3. The engine was started by cranking after ensuring that thereis no load.
4. The engine is allowed to run at the rated speed of 1500 rpm rev/min for a period of 20 minutes to reach the steady state.
5. The fuel consumption is measured by a stop watch.
6. Smoke readings were measured using the AVL smoke meter at the exhaust output.
7. The amount of NO x was measured using AVL Di gas analyzer exhaust outlet.
8. The exhaust temperature was measured at the indicator by using a sensor.
9. Then the load is applied by adjusting the knob, which is connected to the Eddy Current Dynamometer.
10. Experiments were conducted with standard piston and standard fuel.

## 7. RESULTS AND DISCUSSION

The results of the experimental investigation earned out have been furnished hereunder.

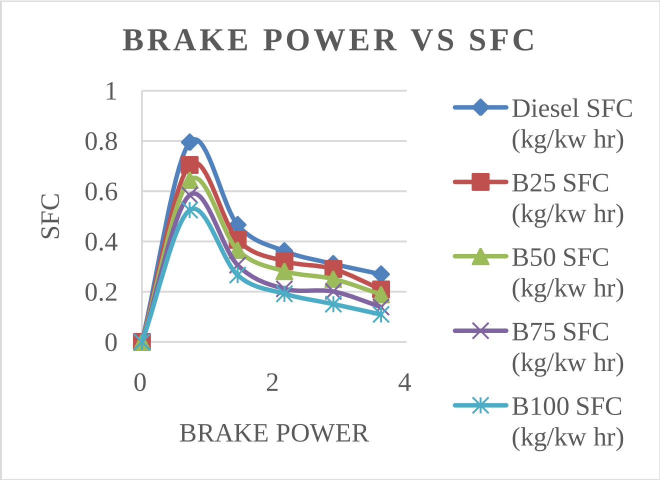
### a) Brake Thermal Efficiency

Figure 7.1 shows the variations of brake thermal efficiency against brake power for various bi dens of azolla biodiesel with constant speed 1500 rpm of theengine. From the figure It IS clearly observed that the brake thermal efficiency of blend B25 is nearly to diesel fuel at full load condition. The brake thermal efficiency of diesel at full load condition is 26.79. The lower brake thermal efficiency is due to reduction of calorific value and due to increase in fuel consumption. At full load condition the B25 blend of azollagives brake thermal efficiency of 26.24%. The brake thermal efficiency depends upon the combustion quality of the fuel. The decrease in values is due to poor combustion, low volatility, high viscosity and density.



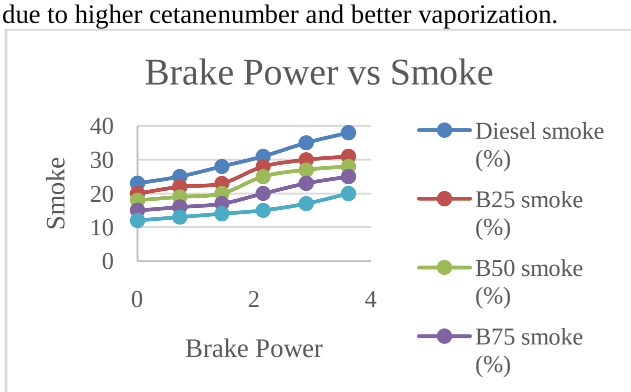

### b) Specific fuel consumption

Figure 7,2shows the variations of specific fuel consumption with brake power for diesel and azolla biodiesel blends. Brake power increases, SFC decreases. Among the diesel and various blends of azollabiodiesel, the diesel fuel shows the lesser specific fuel consumption. It has shown by the value of 0.3190 kg/kw-hr at full load condition.



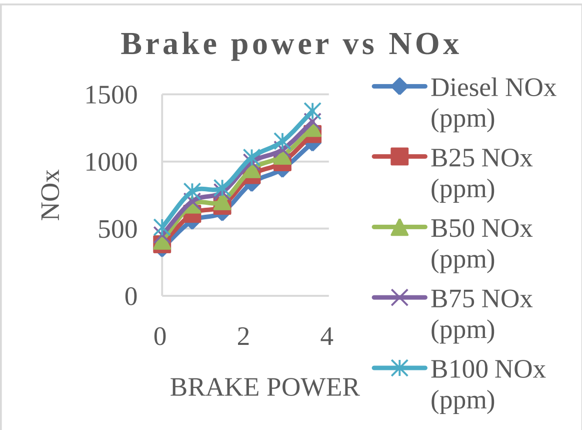

**c) Smoke density**

Figure 7.3 shows the variations of smoke density with brake power for various blends of azollabiodiesel and diesel fuel. From the figure all the biodiesel blends having higher smoke density when compare to diesel fuel. The blend 825 has lower smoke density when compare to other biodiesel blends. The smoke density of the blend B25, diesel fuel is 82HSU, 69.5HSU respectively at full load condition. This negative effect is mainly due to the high viscosity and poor volatility of azolla biodiesel caused poor injection and mixing characteristics and incomplete combustion, these can be overcome by preheating the azolla biodiesel better performance. This is due to shorter delay period of fuel blends. The shorter delay period is mainly due to higher cetanenumber and better vaporization.



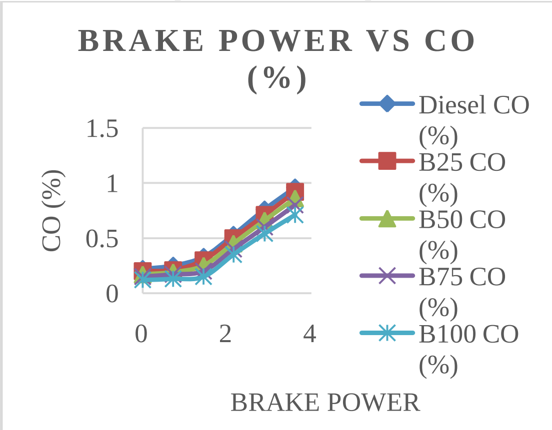

**d) Oxides of Nitrogen**

Figure 7.4 shows the variations of Oxides of Nitrogen with brake power for various blends of azolla biodiesel and diesel fuel. The NO" emission is observed by means of 1118 ppm for diesel and the blend 825 has 1050 ppm with full load. NO" emissions depend up on the oxygen concentration and the combustion time.



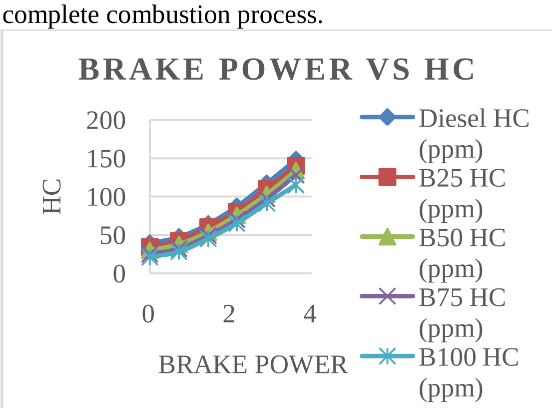

**e) Carbon monoxide**

Figure 7.5 shows the variations of Carbon monoxide with brake power for blend of azollabiodieseland B25 blend is 0.18, by % of volume at full load. The blend B25 has lower CO emission when compare to other biodiesel blends. At full load, the carbon monoxide emissions of the azolla biofuel decrease significantly. When compared with diesel. It is also observed that the carbon monoxide emission increase as the fuel air ratio becomes greater than the stoichiometric value. The carbon monoxide emission depends upon the oxygen content and cetane number of the fuel. The biodiesel has more oxygen content than the diesel fuel. So the biodiesel blends are involved in complete combustion process.




**f) Hydrocarbon**

Figure 7.6 shows the variations of hydrocarbon emission with brake power for various blends of azolla biodiesel and diesel fuel. The HCemission of the diesel fuel is 119 ppm and B25 has 106 ppm at full load. The HC emission of the blend B25 is 11 % decreases when compare to that of diesel fuel. This is because, at higher loads, when more fuel is injected into the engine cylinder, the availability of free oxygen is relatively less for the reaction. The hydrocarbon emissions of the biodiesel blends are lower than the standard diesel due to complete combustion process.




## 8. CONCLUSION

**The main conclusions of this study are;**

- By transesterification process the fuel (biodiesel) properties are near to diesel fuel. When biodiesel was used as fuel, increments in the engine efficiency were mainly caused by the higher mixture heating value of the biodiesel.
- The deterioration of the engine efficiency for biodiesel fuel was caused by the higher viscosity of the biodiesel. If the percentage of biodiesel is increased more than 25% then viscosity slightly increases. Therefore efficiency gets decreases. If the percentage of biodiesel is less than or equal to 25% then viscosity is optimum. So that B25 has maximum efficiency.
- The performance and emission characteristics of use of azolla algae biodiesel as engine fuel. A single cylinder compression ignition engine fuelled with azolla algae biodiesel

and its blends have been analyzed and compared to the standard diesel fuel. Based on the experimental results, the following conclusions were obtained.

- The brake thermal efficiency of azol1a biodiesel blends is slightly lower than that of diesel atfull load condition.
- The specific fuel consumption of B25 was minimum because of less fuel consumption. This isdue to the density of the biodiesel is little much lower than diesel.
- From the emissions test, it is observed that B 1 00 is more effective which has very Jess emissions when compared to other blends except for smoke emission.
- The emission of NOx, CO and HC are less when the percentage of bio diesel blend is increases. The biodiesel blend B 1 00 decreases the emission of NOx, CO, He by 17.8%, 57%, 25% respectively and smoke emission increases to 27.2%. This is because generally the vegetable oils have fewer emissions.

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