

IMPACT OF HETEROGENOUS ACID CATALYST ON DIESEL ENGINE PERFORMANCE AND EMISSIONS USING CHLORELLA - SP BIODIESEL.

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering Degree in
Mechanical Engineering.

by

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DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **KILAPARTI SRIKAR (37150098), KOLLI PRUDHVI (37150100)** who carried out the project entitled "**IMPACT OF HETEROGENOUS ACID CATALYST ON DIESEL ENGINE PERFORMANCE AND EMISSIONS USING CHLORELLA - SP BIODIESEL.**" under my / our supervision from _____ to _____.

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ABSTRACT

Biodiesel have a possible to Interchange standard Diesel oil in C.I Engine. Biodiesel is utilized in unadopted diesel engines. The transesterification of biodiesel is the combination of oil and alcohol with facilitate of catalyst. Catalysts are classified as alkali, acid, enzymes and heterogenous acid or base catalyst. Feed stocks with higher fatty acids treated with acid catalyst so as to avoid saponification. In this experiment we are using "Sulfonated Activated Carbon" as heterogenous acid catalyst due to its high surface area and acidic nature. Oleum 20 is used to sulfonate the "Coconut Shell" activated carbon. The biodiesel is engine tested to show significantly reduce in emissions such as CO, HC, CO₂, NO_x, O₂. However, there is a slight Increment in NO_x emissions. Sulfonated activated carbon increases the reusability in transesterification.

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LIST OF ABBREVIATIONS

ACRONYM.	EXPANSION.
CI	Compressed Ignition.
SO ₃	Sulphur Trioxide.
T.B.H.Q.	Tertiary Butylhydroquinone.
AOME	Algae oil methyl ester
CO	Carbon monoxide.
HC	Hydrocarbon.
CO ₂	Carbon dioxide.
NO _x	Nitrogen Oxides.
O ₂	Oxygen.
BTHE	Brake Thermal Efficiency.
BP	Brake power.
SFC	Specific fuel consumption.
D.I	Direct Injection.
DLU	Dynamometer Loading Unit.
PPU	Piezo Powering Unit.
RPM	Rotations per minute.
S1	Sample 1.
S2	Sample 2.
S3	Sample 3.
S4	Sample 4.

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CHAPTER - 1

INTRODUCTION

1.1 ALTERNATIVE FUELS.

Alternative fuels are derived from sources aside from fossil oil. Most are made domestically, reducing our dependence on foreign oil, and a few are derived from renewable sources. Often, they manufacture less pollution than gas or diesel.

Ethanol is made domestically from corn and different crops. It produces less gas (GHG) emissions than gas or diesel.

Electricity is made domestically from a range of sources like coal, fossil fuel, atomic power, and renewable. Powering vehicles with electricity causes no piping emissions, however generating electricity will manufacture pollutants and greenhouse gases.

Biodiesel is diesel derived from vegetable oils and animal fats. it always produces less air pollutants than petroleum-based diesel.

Natural gas may be a fuel that's plentiful within the U.S. It produces less air pollutants and GHGs than gas.

Propane, additionally known as liquefied fossil oil gas (LPG), may be a domestically abundant fuel. It produces less harmful air pollutants and GHGs than gas.

Hydrogen will be made domestically from fossil fuels (such as coal), atomic power, or renewable resources, like hydropower. cell vehicles high-powered by pure H emit no harmful air pollutants.

1.2 BIOFUELS.

Bioenergy is energy derived from biofuels. Biofuels square measure fuels made directly or indirectly from organic material – biomass – together with plant materials and animal waste.

Overall, bioenergy covers roughly 100 percent of the overall world energy demand. ancient unprocessed biomass like fuelwood, charcoal and animal dung

accounts for many of this and represents the most supply of energy for an outsized range of individuals in developing countries WHO use it chiefly for preparation and heating.

More advanced and economical conversion technologies currently permit the extraction of biofuels from materials like wood, crops and waste matter. Biofuels will be solid, gassy or liquid, despite the fact that the term is commonly employed in the literature in a very slim sense to refer solely to liquid biofuels for transport.

Biofuels could also be derived from agricultural crops, together with standard food plants or from special energy crops. Biofuels may be derived from biology, agricultural or piscary product or municipal wastes, also as from agro-industry, food business and food service by-products and wastes.

A distinction is formed between primary and secondary biofuels. within the case of primary biofuels, like fuelwood, wood chips and pellets, organic materials square measure employed in AN unprocessed type, primarily for heating, preparation or electricity production. Secondary biofuels result from process of biomass and embrace liquid biofuels like fermentation alcohol and biodiesel that may be employed in vehicles and industrial processes.

Bioenergy is especially employed in homes (80%), to a lesser extent in business (18%), whereas liquid biofuels for transport still play a restricted role (2%).

Even though the assembly of liquid biofuels for transport has big speedily in recent years it presently represents only one of total transport fuel consumption and solely 0.2 to 0.3% of total energy consumption worldwide.

1.2.1 TYPES OF BIOFUELS.

The most widely used liquid biofuels for transport are ethyl alcohol and biodiesel.

Ethanol could be a form of alcohol that may be created victimization any feedstock containing vital amounts of sugar, like sugar cane or sugar beet, or starch, like maize and wheat. Sugar will be directly hard to alcohol, whereas starch initial has to be regenerate to sugar. The fermentation method is analogous thereto want to create wine or brewage, and pure ethyl alcohol is obtained by distillation. the most producers are Brazil and therefore the USA.

Ethanol will be mixed with gasoline or burned in nearly pure type in slightly changed spark-ignition engines. A l of ethyl alcohol contains close to two thirds of the energy provided by A l of gasoline. However, once mixed with gasoline, it improves the combustion performance and lowers the emissions of carbon monoxide gas and oxide.

Biodiesel is created, primarily within the European Union, by combining oil or fat with AN alcohol. Biodiesel will be mixed with ancient fuel or burned in its pure type in compression ignition engines. Its energy content is somewhat but that of diesel (88 to 95%). Biodiesel will be derived from a large vary of oils, together with oilseed, soybean, palm, coconut or rosid dicot genus oils and thus the ensuing fuels will show a bigger style of physical properties than ethyl alcohol.

Diesel engines also can run on vegetable oils and animal fats, as an example used cookery oils from restaurants and fat from meat process industries.

The production processes for each bioethanol and biodiesel yield further by-products like animal feed.

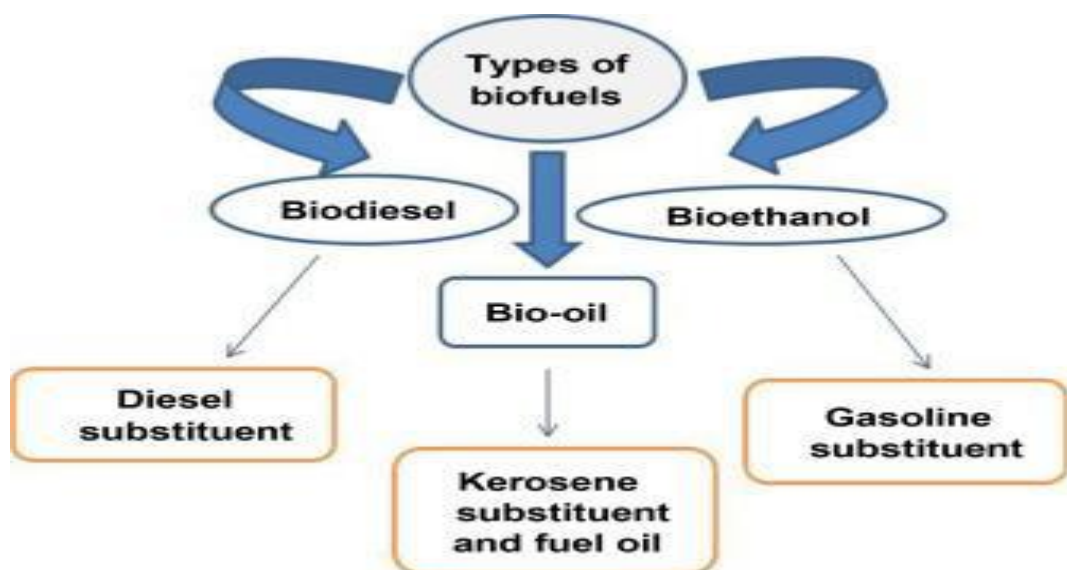


Fig.1.1: Types of Biofuels.

1.2.2 BASED ON GENERATIONS.

- First Generation.
- Second Generation.
- Third Generation.

- Fourth Generation.

In Our Project, we are mainly focusing on “Third Generation Biofuel”.

The term third generation biofuel has solely recently entered the thought it refers to biofuel derived from algae. Previously, algae were lumped in with second generation biofuels. However, once it became apparent that algae square measure capable of abundant higher yields with lower resource inputs than different feedstock, several instructed that they be moved to their own class. As we'll demonstrate, algae offer variety of benefits, however a minimum of one major disadvantage that has prevented them from changing into a runaway success.

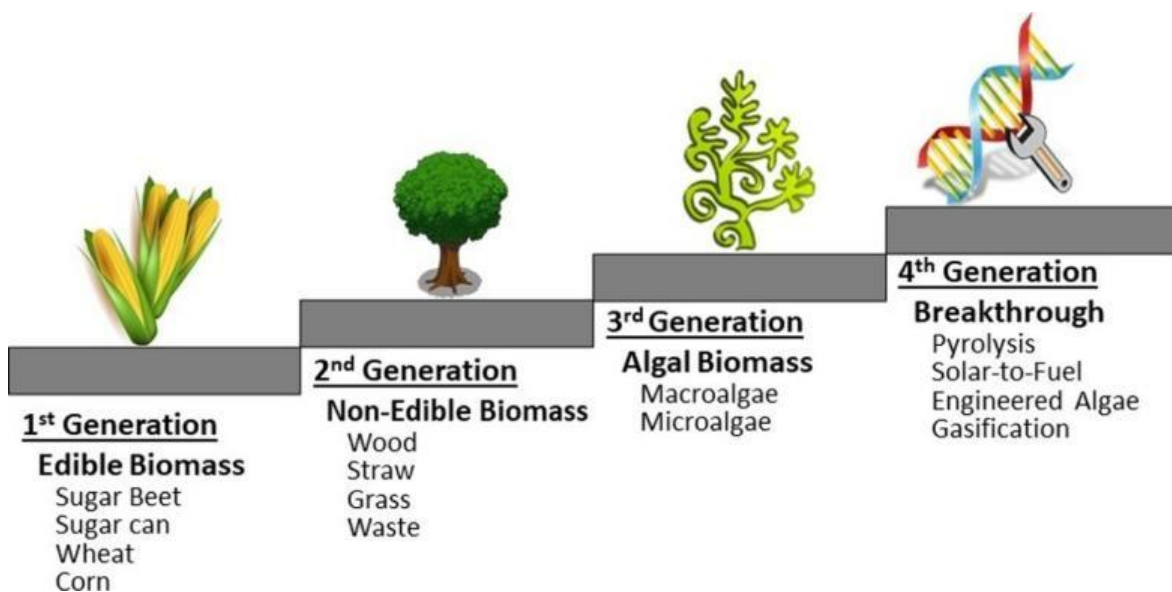


Fig.1.2: Based on Generations.

1.2.3 FUEL POTENTIAL OF THIRD GENERATION BIOFUELS.

When it involves the potential to provide fuel, no feedstock will match algae in terms of amount or diversity. the variety of fuel that algae will manufacture results from two characteristics of the being. First, algae manufacture associate degree oil that may simply be refined into diesel or maybe sure parts of fuel. a lot of significantly, however, could be a second property in it are often genetically manipulated to provide everything from grain alcohol and alcohol to even fuel and diesel oil directly.

Butanol is of nice interest as a result of the alcohol is exceptionally the same as fuel. In fact, it's a virtually identical energy density to fuel associate degree an

improved emissions profile. till the appearance of genetically changed algae, scientists had an excellent deal of issue manufacturing alcohol. Now, many commercial-scale facilities are developed and square measure on the brink of constructing alcohol and a lot of common biofuel than grain alcohol as a result of it's not solely similar in some ways to fuel, however conjointly doesn't cause engine harm or maybe need engine modification the method grain alcohol will.

The list of fuels that may be derived from algae includes:

- Biodiesel
- Butanol
- Gasoline
- Methane
- Ethanol
- Vegetable Oil
- Jet Fuel

Diversity isn't the sole factor that algae have going for it in terms of fuel potential. it's conjointly capable of manufacturing outstanding yields. In fact, algae are accustomed manufacture up to 9000 gallons of biofuel per acre, that is 10-fold what the simplest ancient feedstock are able to generate. people that work closely with algae have instructed that yields as high as twenty thousand gallons per acre square measure gettable. In step with the America Department of Energy, yields that square measure ten times beyond second-generation biofuels mean that solely 0.42% of the U.S. acre age would be required to come up with enough biofuel to fulfill all of the U.S. needs. only if the U.S. is that the largest shopper of fuel within the world, that's voice communication one thing regarding the potency of algal-based biofuels.

1.2.4 CULTIVATION OF THIRD GENERATION BIOFUELS.

Another favorable property of alga is that the diversity of how during which it is often cultivated. algae are often mature in any of the subsequent ways that.

- Open Loop System.
- Closed Loop System.
- Photobioreactors.

Open pools – These square measures the best systems during which algae is mature during a pond within the exterior. they're straightforward and have low capital prices, however square measure less economical than different systems. they're conjointly of concern as a result of different organisms will contaminate the pool and probably harm or kill the algae.

Closed-loop systems – These square measures the same as open ponds, however they're not exposed to the atmosphere and use a sterile supply of greenhouse emission. Such systems have potential as a result of they will be able to be directly connected to greenhouse emission sources (such as smokestacks) and so use the gas before it's each free into the atmosphere.

Photobioreactors – These square measure the foremost advanced and so most tough systems to implement, leading to high capital prices. Their blessings in terms of yield and management, however, square measure incomparable. they're closed systems.

Note that each one of the systems mean that algae square measure able to be mature virtually anyplace that temperatures square measure heat enough. this implies that no farm land want be vulnerable by algae. Closed-loop and photobioreactor systems have even been employed in desert settings.

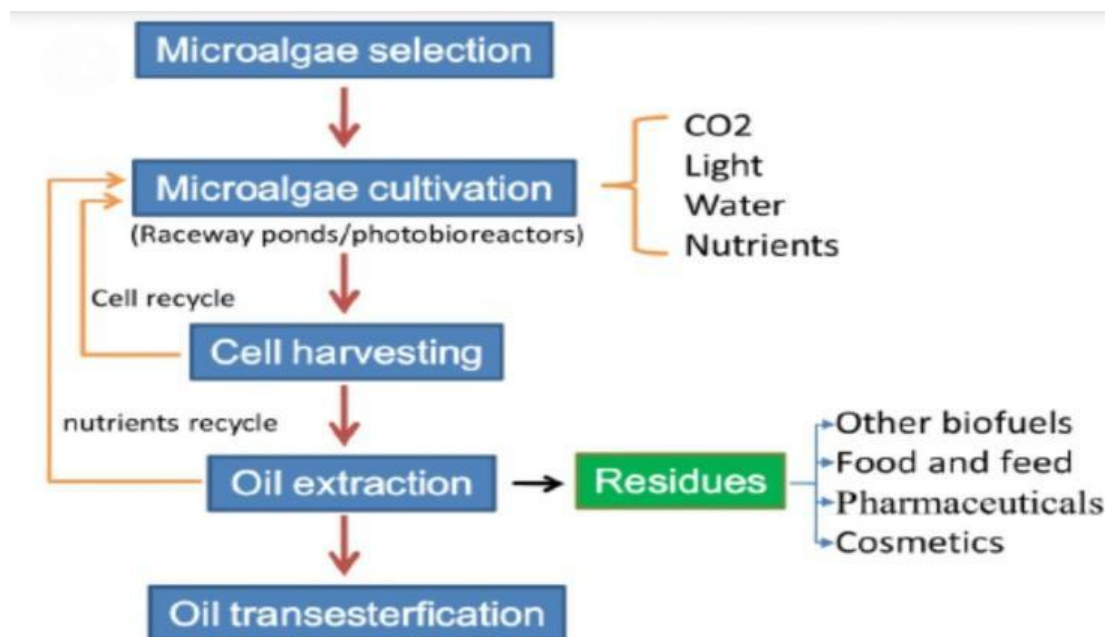


Fig.1.3: Microalgae Cultivation.

1.3 BIODIESEL.

Biodiesel may be a clean burning different fuel created from domestic, renewable resources. This biofuel may be a mixture of carboxylic acid alkyl radical esters made of vegetable oils, animal fats or recycled greases. wherever on the market, biodiesel is utilized in compression-ignition (diesel) engines in its pure kind with very little or no modifications.

Diesel engines these days solely remotely correspond the engine that applied scientist designed. His engine was an initio designed to run on coal dirt. Moreover, for the primary few decades, they may run on the subject of something that will burn. while late because the 1970's, automotive diesel engines were very tolerant once it involves the fuel they may use. Today's diesel engines area unit way more economical and cleaner than the first versions, partially as a result of they run on a narrowly outlined fuel. It permits the engine manufactures to tune the equipment for improved potency. Biodiesel and fuel area unit terribly similar in their physical and chemical characteristics. they're similar enough that trendy diesel engines will run on biodiesel.

We can mix Biodiesel with fuel at any magnitude relation. We can discover biodiesel blends like B20, that is two hundredth biodiesel and eightieth diesel, at truck stops and gas stations. mixing biodiesel with fuel ends up in a fuel that burns cleaner than diesel alone. everybody has seen those black clouds, or soot, gushing from the exhaust of a diesel truck once it's beneath load. However, after we mix biodiesel with diesel, the soot is reduced, and dirty diesels will become clean diesels.

Biodiesel is created through a method within which organically derived oils area unit combined with alcohol (ethanol or methanol) within the presence of a catalyst to make alkyl group or alkyl radical organic compound. The biomass-derived alkyl group or alkyl radical esters is mingling with typical fuel or used as a neat fuel (100% biodiesel). Biodiesel is made of any oil, animal fats, waste vegetable oils, or microalgae oils.

There are a unit 3 basic routes to biodiesel production from oils and fats:

- Base catalyzed trans-esterification of the oil.

- Direct acid catalyzed trans-esterification of the oil.
- Conversion of the oil to its fatty acids and so to biodiesel.

There are a unit a spread of oils that area unit accustomed manufacture biodiesel, the foremost common ones being soybean, rapeseed, and oil that frame the bulk of worldwide biodiesel production. alternative feedstock will return from waste oil, jatropha, mustard, flax, sunflower, oil or Temp.

Animal fats as well as animal oil, lard, yellow grease, chicken fat and animal oil by-products could contribute a little share to biodiesel production within the future, however it's restricted in provide and inefficient to lift animals for his or her fat. genus Jatropha may be a tiny pest- and drought -resistant bush that's capable of being full-grown on marginal/degraded land and produces seeds that yield many times additional oil per acre than soybeans.

Biodiesel is mingling in any proportion with mineral diesel. a biodiesel mixes or is utilized in its pure form. a bit like crude diesel, biodiesel operates within the compression ignition (diesel) engine, and basically needs little or no or no engine modifications as a result of the biodiesel has properties kind of like mineral diesel. It is keeping a bit like mineral diesel and therefore doesn't need separate infrastructure.

The use of biodiesel in typical diesel engines ends up in substantial reduction within the emission of turn hydrocarbons, carbon monoxide gas, and particulates. There are a unit presently an outsized variety of existing biodiesel production plants globally, and an outsized variety beneath construction or planned to provide the growing world demand.

Among different feedstocks, algae hold monumental potential to produce a non-food, high-yield, non-arable land use supply of biodiesel, alcohol and element fuels. Microalgae are grabbing biofuel attention as a result of on associate acre-by-acre basis, microalgae will manufacture one hundred to three hundred times the oil yield of soybeans on marginal land and with salt water. Microalgae is that the quickest growing photosynthesizing organism and is capable of finishing a whole growing cycle each few days.

1.3.1 NEED FOR BIODIESEL.

- Easy to Use as No vehicle modifications or special fueling equipment — just pump and go.
- Power, Performance and Economy Proven performance and economy make biodiesel a renewable winner.
- Emissions & Greenhouse Gas Reduction With lower exhaust emissions biodiesel is helping to reduce pollution and improve health. Lower CO₂ emissions help reduce the impacts of global warming.
- Energy Balance & Security Biodiesel production and use at home, biodiesel helps reduce the need for foreign oil.
- Toxicity, Biodegradability, Safety & Recycling Less toxic than table salt, biodiesel has minimal environmental impact. With a high flash point, biodiesel is safer to handle and store than petroleum diesel. When made from used oils and fats, biodiesel helps ensure proper recycling of former waste products.
- Economic Development Biodiesel helps communities by keeping energy dollars at home.

1.3.2 PROPERTIES OF BIODIESEL.

Table 1.1: Properties.

Property	ASTM method	Diesel	Biodiesel [B100]	Ethanol	BEB 2.5	BEB 5	BEB 7.5
Flash point [°C]	D93	58	159.5	13.5	156	153	142
Kinematic viscosity at 40°C [mm ² s ⁻¹]	D445	2.85	5.26	1.2	4.92	4.51	4.13
Density at 20 °C [kgm ⁻³]	D1298	842.5	873.2	789	869	862	858
Calorific value [MJkg ⁻¹]	D240	43.4	39.85	27	39.6	39.2	38.7
Cetane index	D976	47	59	8	56	53	49
Carbon content [% mass]	D5291	86.7	76.1	52.2	76.0	74.8	73.7
Hydrogen content [% mass]	D5291	12.8	12.7	13	12.1	12.2	12.2
Oxygen content [% mass]	D5291	—	11.2	34.8	11.9	13.0	14.1

1.3.3 WHY LOWER EMISSIONS IN USAGE OF BIODIESEL?

- Can reduce the consumptions of fossil fuels.
- Reduces CO, CO₂, NO_x emissions.

- Less Pollution.
- Burns fully.
- No Aromatics.
- High Cetane and Octane value.
- Complete CO₂ cycle.

1.3.4 ADVANTAGES OF BIODIESEL.

- Produced from Renewable Resources.
- Can be Used in Existing Diesel Engines.
- Less Greenhouse Gas Emissions (e.g., B20 reduces CO₂ by 15%).
- Grown, Produced and Distributed Locally.
- Cleaner Biofuel Refineries.
- Biodegradable and Non-Toxic.
- Better Fuel Economy.
- Reduced Foreign Oil Dependence.
- Improved Air Quality.
- Biodiesel is Undoubtedly a Safer Alternative to Fossil Fuels.
- Biodiesel Could Possibly End Energy Crisis and Energy Politics.

1.3.5 DISADVANTAGES OF BIODIESEL.

- Variation in Quality of Biodiesel.
- Not Suitable for Use in Low Temperatures.
- Biodiesel Could Harm the Rubber Houses of Some Engines.
- Biodiesel is Way More Expensive than Petroleum.
- Use of Petroleum Diesel to Produce Biodiesel.
- Monoculture refers to the practice of producing the same crop over and over again rather than producing different crops.
- Clogging in Engine.
- Increased use of Fertilizers.
- Regional Suitability.

1.3.6 APPLICATIONS.

- In Automobile industry.

- In Aviations.
- In cooking.
- Energy Generations.
- Clean oil Spills and Grease.

1.4 WHAT IS AN ALGAE?

“Algae is a term that describes a large and incredibly diverse group of eukaryotic, photosynthetic life forms. These organisms do not share a common ancestor and hence, are not related to each other (polyphyletic).”

Algae are organisms that grow in aquatic environments and use light-weight and CO₂ to make biomass. There are two classifications of algae: macroalgae and microalgae. Macroalgae, that are measured in inches, are the big, multi-cellular protocist usually seen growing in ponds. These larger protocist will grow in an exceedingly form of ways that. the most important cellular protocist are referred to as seaweed; an example is that the big brown algae plant, which might be over a hundred feet long. Microalgae, on the opposite hand, are measured in micrometers and are little, animate thing protocist that unremarkably grow in suspension inside a body of water.

Microalgae have long been recognized as doubtless sensible sources for biofuel production due to their comparatively high oil content and speedy biomass production. Microalgae grow terribly quickly compared to terrestrial crops; the follow of protocist culture may be performed on non-arable lands exploitation non-potable saline water and waste water. Thus, use of microalgae as another biodiesel biofuel feedstock is gaining increasing interest from researchers, entrepreneurs, and therefore the general public.

1.4.1 POTENTIAL FOR USE AS AN ALGAE BIOFUEL.

Algal biomass contains 3 main components: carbohydrates, proteins, and lipids/natural oils. as a result of the majority of the natural oil created by microalgae is within the sort of triacylglycerol, that is that the correct of oil for manufacturing biodiesel, microalgae area unit the exclusive focus within the algae-to-biodiesel arena. additionally, to biodiesel, microalgae can even be won't to generate energy in many alternative ways in which. Some protocist species will

turn out H₂ gas underneath specialized growth conditions. The biomass from alga can even be burned almost like wood or anaerobically digestible to supply gas biogas to get heat and electricity. protocist biomass can even be treated by shift to get crude bio-oil.

1.4.2 MICROALGAE AS SUPPLY OF BIOFUELS.

Microalgae are unit one in every of the foremost promising candidates for excess of biofuels attributable to their straight forward, cheap and easy cultivation system. They grow simply with basic nutritional needs like air, water and mineral salts with lightweight because the sole energy supply. They grow on liquid media, therefore numerous waste product can even be used, which may be expeditiously remediated by alga not to mention biofuel production.

The optimum use of sunshine energy through chemical action is incredibly expeditiously done by microalgae. They possess higher chemical change levels and growth rates and may be used for the assembly of desired biofuels. they'll contain appreciable amounts of lipids that are unit in the main part within the thylakoid membranes. Their biofuels are unit non toxic and extremely perishable. basically, nonparasitic chloroplasts and are the top of minimizing structural part. they need high greenhouse emission sequestering effectiveness thereby, reducing GHG emissions.

They scale back nutrient load in waste product as they'll utilize element and chemical element gift in agricultural, industrial and municipal waste product attributable to their phytoremediation acumen. they'll be cultivated in areas like sea-coast, desert, and so on, that isn't appropriate for agricultural plants and not competitor with cultivatable land. Their cultivation is freelance of seasons as they'll be cultivated around the year and have smallest environmental impact. The cultures may be expedited to supply high yields through technological interventions of biotechnology, artificial biology, metabolic engineering, then on as protocist systems are unit promptly pliant.

The biofuels from algae are unit numerous in nature. supermolecule part of biomass is employed for bioethanol production, whereas protocist oil for biodiesel and also the residual biomass may be used for paraffin, fuel gas or fuel production. The biomass when biofuel production will more be used as supply of

the many added product like omega-3 fatty acid (EPA), omega-3 fatty acid (DHA), nutraceuticals, supermolecule supplements, medical specialty, biocontrol agents, fertilizers, animal feed and cultivation.

1.4.3 TYPES OF ALGAE.

Algae can be categorized into seven major types, each with distinct sizes, functions, and color. The different divisions include:

Euglenophyta (Euglenoids).

Chrysophyta (Golden-brown algae and Diatoms).

Pyrrophyta (Fire algae).

Chlorophyta (Green algae).

Rhodophyta (Red algae).

Paeophyta (Brown algae).

Xanthophyta (Yellow-green algae).

1.4.4 PROSPECTS OF ALGAE AS BIODIESEL FEEDSTOCK.

Among SCO (Single Cell Organisms), algae area unit as promising as yeast and bacterium. variety of attention-grabbing factors are attributed to the current reality. they're wide obtainable and may be grown up anywhere with sensible consistencies, thereby limiting any competition with edible vegetable oils. in contrast to several energy crops, algae will have up to one hundred times a lot of oil content. in theory, depending on the strength, algae species will manufacture up to a yield of 20,000 gallons of feedstock per acre of land.

Table one presents a short time projection of fuels from alga. By 2014, below 3-D of the world standard fuels production are going to be substituted by biofuels of ancient origin. This share represents a market size of over \$120 billions. Biofuels from algae feedstock can potentially replace a better share of fossil fuels used as automobile fuels than the opposite sources. The calculable market sizes for algae are \$425 billions, that is over double the expected market size for different ancient biofuels.

Thus, the algae choices stand a market worth as many billions of greenbacks. Similarly, there is a unit potentiality that these prospects would even step up in the long run. as an example, one shows a comparable biodiesel yield per acre of farmland for various crops, with algae because the most promising feedstock. whereas the yields of most typical vegetable oils are below a thousand gallons per acre, the yield from algae feedstock reaches 5000 gallons per acre, indicating enormously a way higher prospect. Low land mass is needed to provide vast amount of oil for industrial biodiesel production. as an example, a recent study projected the algae biodiesel to be capable of meeting the United States diesel demand with solely 25% of the cropland exploited for this purpose. This has robust tendency to eliminate the problems of food shortage and connected worth hike that area unit sometimes associated with massive scale exploitation of agricultural land for biofuels production. While biodiesel is taken into account the most gettable fuel-produced from algae, different vital fuels will equally be produced, therefore enhancing their exploitation potentials.

Fuels like methane, hydrogen, plant product and Bio gasoline are often generated from algae. The biomass-residues area unit applicable as property feedstock for combustion. different vital areas of applications for algae include environmental management and production of different products. algae derivatives have glorious bioremediation properties and thus appropriate for treating waste and waste matter water through the removal of poisons and nutrients. Pigments, nutraceuticals and even fertilizers will with success be made from algae. It may be seen that, manufacturing oil from algae and after biodiesel also as different product is taken into account extremely economical by many authors. The processes of cultivation, oil extraction and final conversion into biodiesel area unit primarily like those of different edible crops like soy, flower and palm. These facts may be attributed to big factors resulting in the escalated growth-rates for the algae species around several places within the world. it's notably vital to notice that, in contrast to different crops, algae are often cultivated even in harsh conditions, including salty and waste matter receiving areas. throughout their growth, the algae species need extended quantity of part carbon dioxide. This issue implies that, they will be used for cheaper mode of CO₂ sequestration from

stationary sources like oil and gas facilities and connected industrial power plants. In fact, algae cultivation is often thought-about multi-beneficial.

However, there are a unit bound difficulties preventive algae exploitation compared to different crops. These embody state of affairs awareness (i.e., lack of full knowledge of their prospects, particularly within the developing world where analysis is limited), poor data of the foremost cost-feasible cultivation technique and issue in characteristic the foremost affordable algae strain with higher oil content, having quickest growth rate with no harvest home challenges. different challenges are; algae production needs vast land mass and water and cold flow problems with cyberspace biodiesel. Some macro blue-green alga species also are unsafe to kinsmen, particularly once exposed through recreational activities or drinking contaminated water.

1.4.5 PERCENTAGE OF LIPID CONTENT IN MICROALGAE.

Table 1.2: Percentage of Lipid Content.

S.No.	Microalgae	Oil content (% dry weight)
1	<i>Botryococcus braunii</i>	25-75
2	<i>Chlorella</i> sp.	28-32
3	<i>Cryptocodinium cohnii</i>	20
4	<i>Cylindrotheca</i> sp.	16-37
5	<i>Dunaliella primolecta</i>	23
6	<i>Isochrysis</i> sp.	25-33
7	<i>Monallanthus salina</i>	>20
8	<i>Nannochloris</i> sp.	20-25
9	<i>Nannochloropsis</i> sp.	31-68
10	<i>Neochloris oleoabundans</i>	45-47
11	<i>Nitzschia</i> sp.	45-47
12	<i>Phaeodactylum tricornutum</i>	20-30
13	<i>Schizochytrium</i> sp.	50-77
14	<i>Tetraselmis sueica</i>	15-23

1.4.6 ADVANTAGES OF ALGAE BIOFUEL.

- Algae grows at higher efficiency levels than other biofuel crops.
- Algae is more productive than other forms of biomass.
- Algae is a renewable resource.
- Algae produces viable hydrocarbons for numerous products.
- Algae is something that almost anyone can grow.

- Algae can grow in virtually all waters.
- Algae biofuels work with our current distribution system.
- Algae growth helps us to curb our greenhouse gas emissions.

1.5 ROLE OF HETEROGENOUS ACID CATALYST ON BIODIESEL.

Various solid acid catalysts like resins, sulfated metallic element and metal oxides, heteropoly acids, sulfated polyaniline, metal complexes, and zeolites are utilized as heterogeneous catalysts on the biodiesel production reactions. In general, they're most well-liked over consistent catalysts in the main as a result of they'll be simply isolated from reaction medium by filtration and simply reused. However, there are a unit negative aspect that compromise the employment of heterogeneous catalysts at the commercial scale.

Heterogeneous acid catalysts area unit synthesized as insoluble salts or solid matrices of high extent containing an energetic dopant, in most times via sol-gel processes, precipitation or impregnation ways. Currently, biodiesel production processes using heterogeneous chemical change need additional severe operating conditions than those employed in the consistent ones (i.e., higher temperature and pressure). sadly, thanks to the presence of water or glycerin generated throughout the reaction, the action risk is usually gift, which could contaminate the biodiesel and cut back the period of the catalyst. finally, toward be used on the biodiesel production at industrial scale, the heterogeneous catalyst ought to move, stable throughout the reaction, simply redeemable, and reusable while not activity loss.

Actually, the drive to develop heterogeneous catalysts aims at the biodiesel production being price saving and lowering the generation of environmentally undesirable wastes. These aspects will minimize the environmental impact of the processes and reduce the assembly prices, widening the scope of raw materials, an important issue for biodiesel producing.

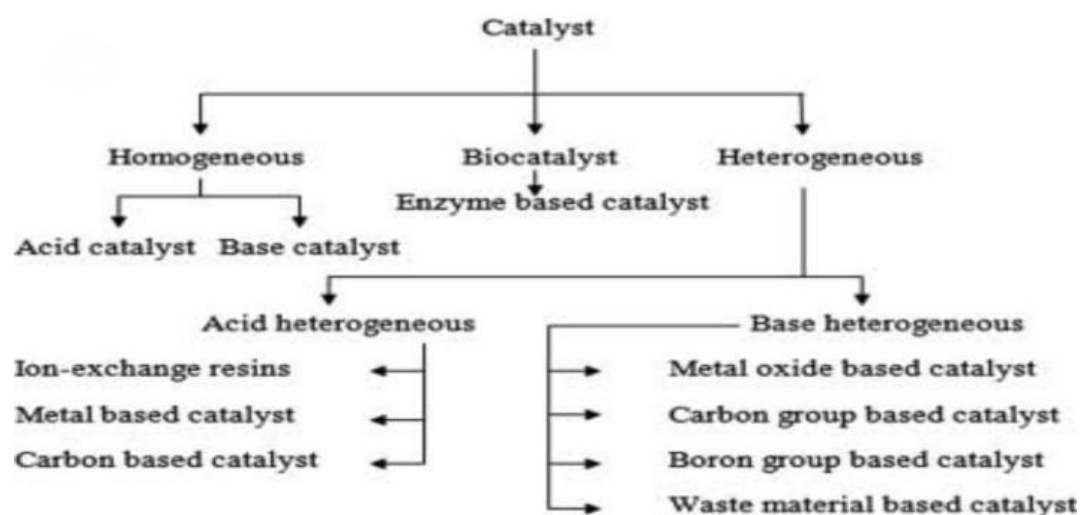


Fig.1.4: Catalyst.

CHAPTER - 2

LITERATURE REVIEW

- Exploration of performance and emissions characteristics of Gossypium arboreum biodiesel on diesel engine. S.Ganesan ,Obulareddy Yuvatejeswar Reddy, Kontham Jyotiraditya Reddy, Phadatare Rahul b.
- We have observed that, broadly speaking, the Gossypium arboreum oil, combined with diesel oil, provides a superior efficiency and a substantial reduction in CO₂ emissions, making it the perfect choice for Gossypium arboreum oil blends GAOB20 and GAOB30.
- Impact of nano additives in DI diesel engine to investigate performance and emission characteristics by using biodiesel blended with diesel. Senthilkumar Jayapalan, a), Ramesh Bapu, b), Dharani Kumar, c), Kanishkar, d), Jayaprakash Venugopal), Anish Mariadhas, f), Ganesan Subbiah, g) 1 School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India. 2 Department of Mechanical Engineering, Chennai Institute of Technology, Chennai, India. 3 Department of Mechanical Engineering, Sathyabama Institute of Science and Technology. Chennai, India.
- The experimental investigation of combustion, performance and the emission characteristics of wheat germ oil and its blends have been performed on DI diesel engine and has been completed, the following conclusions have been drawn. The CO₂ emissions are lower for all the diesel-biodiesel blends and the maximum reduction of CO₂ emission is for sample 6 (70%diesel+30%biofuel+30 ppm TiO₂). The percentage reduction is more than 35% compared to diesel
- Influence of CNG emissions in copper coated catalytic converter in 4-stroke S.I. engine. Hemanandh Janarthanam, a), Lilly Mercy Jayaraman, Ganesan Subbiah, Devaraj Rangabashiam, Sridhar Raja, Rakesh Kumar Reddy, Swamy Saran
- The stainless-steel wire mesh coated copper (which is the metal catalyst agent) by using electroplating which provides high conductivity, withstand to higher temperatures (thermal resistance) and flexible. This coated SS-304

wire mesh is reduced the emissions such as CO₂, HC, NO_x, CO from the bike.

- Investigations on the impact of EGR with a modified combustion chamber for CI diesel engine using biodiesel Vemuri Sai Srikanth, a) S.Ganesan, b), K. Vijaya Kumar Reddy
- In the present work the experiments are conducted with suitable bio diesel, piston geometry and EGR design. With these the investigations are conducted out on four stroke single cylinder water cooled, computerized test rig of CI diesel engine The BSFC for RPOME 15% EGR is decreased about 8% compared standard engine. This is owing to proper air fuel mixing in the combustion geometry. The BSFC for RPOME 15% EGR is decreased about 8% compared standard engine. This is owing to proper air fuel mixing in the combustion geometry.
- Multi-objective Optimization of VCR Diesel Engine Performance and Emissions Fueled with Diesel-Lime Steam Oil Blends using Grey Relational Analysis. Ganesan Subbiah, a), Sathish Kumar, b), Devaraj Rangabashiam, c), Hemanandh Janarathanam, d), Venkatesan Sorakka Ponnappan, e), Beemkumar Nagappan, f), K.S. Sreenivasan.
- Grey relational Analysis mainly deals with the objective to "optimize a response which is influenced by several independent variables." Homogeneous combustion catalysts are those additives which are dissolved into diesel fuels homogeneously to play a catalytic role during the combustion process of the engine. The lemon Distilled oil would be one of the safe alternate fuels in future. Based on the ANOVA results, the parameter of Nano catalyst CeO₂ composition shows 62 % followed by Biodiesel blend 16%, BP 11% and Injection Pressure with 9%. CeO₂ composition shows the major contribution of engine performance and Lemon grass oil blend shows the second most significant affecting parameter.
- Influence of nano catalyst on performance of DI diesel engine with blends of Citronella oil using Taguchi approach S. Ganesan, a) J. k.S.Sridhar raja, b) N.Beem kumar, c) J.Hemanandth, d) G.senthilkumar, e) K.S. Sreenivasan, f) R.Rajasekar.

- This study investigated diesel engine emissions characteristics under various engine process parameters such as Citronella oil, injection pressure, brake power and ZnO were tested. The main effects plot for both mean of signal to noise ratio the optimized combination is found for various engine performance and emissions. The experimental data shows that at this combination the engine performance is comparable to that of diesel. The emissions are less than that for diesel.
- Optimum design of catalytic converter to reduce carbon monoxide emissions on diesel engine Rajasekar Rajendran. a), Logesh, Praveen, Ganesan Subbiah School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India.
- Catalytic converter design and modification of catalytic materials can be an alternative to overcome the high air pollution problem from the automotive transportation sector especially particular carbon Monoxide and NOx exhaust emission from diesel engine. The use of zirconium and alumina coated as catalyst in the catalytic converter was significantly able to increase the reduction of carbon Monoxide and NOx exhaust emissions. The increase of catalyst cell amount decreased the concentration of carbon Monoxide and NOx exhaust emission. Optimum design of catalytic converter was able to reduce exhaust emission.
- Performance and Emission Analysis of Waste Cooking Oil as Green Diesel in 4S Diesel Engine Hemanandh Janarthanam. a), Venkatesan Sorakka Ponnappan, Ganesan Subbiah, Purushothaman Mani, 'Suman, Rajesh School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India.
- The emissions with Hydrotreated Waste cooking oil as fuel showed a reduction in CO, HC, CO₂, NO_x, Smoke, brake specific fuel consumption and increase in Brake thermal efficiency when compared with Petro diesel as fuel. Thus, the above experiments help us to conclude that, 100% hydrotreated waste cooking oil can be used as fuel directly without any modification in the engine leading to lesser emissions and better performance of the diesel engine.

- Performance and emission characteristics of diesel engine using waste plastic oil with Nhexanol as an additive S. P. Venkatesan, a) J. Jeya Jeevahan, b), J. Hemanandh ,c), S. Ganesan, d), R. Rajakavieswaran, e), V.Saravanan, f) School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India.
- This research study gives the solution to plastic waste management and alternate fuel to diesel. The waste plastic oil is extracted from the plastic waste by the pyrolysis process to which zeolite is used as a catalyst. From the experimental results, the blend having the volume percentage of 50% of diesel, 30% of waste plastic oil and 20% of n-hexanol has shown better performance among the other blends. From the experimental test, the following conclusion is drawn: (1) Among the tested fuel it was observed that D50WPO30H20 blend shows better performance among all other blends and therefore the brake thermal efficiency of that blend found to be 1.265% and 14.285% increases when compared with pure diesel and WPO at full load. (2) When compared with pure diesel and WPO, NO_x emission was found to 4.04% and 8.96% lower when the engine runs with D50WPO30H20 blends. (3) Smoke emission was found to be 30% lower than diesel and 40% lower than WPO when the engine power sourced with the D50WPO30H20 blend.
- Performance and emission characteristics of bio fuelled CI engine using palm oil and waste cooking oil S. Ganesan, a) K. Vijai Anand, b)S.Sridhar raja, c) J. Hemanandh, d) N.Beem kumar, e) k Shivan Srivastava, f), Shone Biju, g) School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India. Faculty of Engineering and Technology, Jain (Deemed-to-be-University), Bengaluru, India
- It is observed that there is an increment of 55% in the SFC, 9% increase in break thermal efficiency, 76% decrement in hydrocarbon emission, 10% reduction in emission of Carbon dioxide and 22% increase in the emission of oxides of nitrogen. Reduction of NO_x emissions with low viscous biofuel using exhaust gas recirculation technique Rajasekar Rajendran a), Paul Udayan Gomez b), Mohammed Javed c), and Ganesan Subbiah d) School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India It was concluded that BE-3 with 75% diesel,

20% LG, 5% DEE and 500ppm of pyrogallol with 25% EGR was considered to have better performance and emission characteristics when compared with the other two blends.

- Taguchi Based Optimization of Diesel Engine Parameters with Blends of Lemon Grass oil with ZnO S. Ganesan, a) S.P. Venkatesan, b), N.Beem kumar, c), M. Purushothaman, d), J. Hemanandh², e), J. Senthilkumar, f), G. Senthilkumar, g) School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India 3 Faculty of Engineering and Technology, Jain (Deemed-to-be-University), Bengaluru, India
- The activation energy of Zinc oxide acts to burn off carbon deposits within the engine cylinder at the wall temperature and prevents the deposition of non-polar compounds on the cylinder wall results reduction in HC emissions. The tests revealed that Zinc oxide nanoparticles can be used as additive in diesel-biodiesel blend to improve complete combustion of the fuel and reduce the exhaust emissions significantly., it was observed that the multi-response parameters are optimized using grey relational analysis and converted into a single response. To analyze the experimental data Taguchi 's methodology was used. The main effects plot for both mean of average grey grade and signal to noise ratio the optimized combination is found to be A3B1C3. In this particular combination it is predicted from the experimental data that the engine performance is comparable to that of diesel, moreover the emissions are less than that for diesel
- Effect of nano additives in engine performance and emission characteristics using biodiesel fuel Ganesan Subbiah, a), Hemanandh Janarthanam, b, Purushothaman Mani, c, Sridhar Raja, d, Periya Sakthivel, e), 6Sakthivignesh, f), Sreenivasan, g) School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India Department of Mechanical Engineering, MNM Jain Engineering College, Chennai, India
- For better BTHE, we need to operate the engine under the conditions A1B3C1D3. x for low Specific fuel consumption and CO, the engine has to be operated under the condition A3B3C1 D1 and A3B2C1D2. x for low HC, an experiment should be conducted with MgO in 45 ppm, BP in 3KW, 200

bar of injection pressure, L.B in 10% and for NO_x, with MgO in 15 ppm, BP in 4.4 KW, 200 bar of injection pressure and L.B in 10%.

- Emission and performance analysis of thermochemical conversion of bio-oil using waste animal fat. Hemanandh Janarthanama), Sridhar Raja Sundara Raju Kachupalli, Senthil Kumar Jayapalan, Ganesan Subbiah, Purusothaman Mani, Velkumar and Siva Adithya School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India.
- The emissions of CO increased with increasing load. It was noted that there was a marginal difference between the pure diesel and the bio-oil produced. The CO emission from B10 oil was less compared with pure diesel. $\frac{3}{4}$ It was observed that the HC emission was nominal for B10 when the engine was operated with 80% load. $\frac{3}{4}$ The B10 blend emitted relatively lower amount of CO₂ for all load conditions as compared to diesel. It was noted that the CO₂ emission was almost equal to diesel emission up to 50% load but it marginally decreased after 50% load.
- Detailed study on the influence of silicon oxide on emission characteristics of VCR diesel engine with blends of camelina biodiesel. Ganesan Subbiah, a), Venkatesan Sorakka Ponnappan, b), Hemanandh Janarthanam, c), Devaraj Rangabashiam, d), K.S. Sridhar Raja, e), Vikash Reddy, f), Sathish Kumar.
- Addition of additives lowered the harmful emissions significantly with a trivial increase in NO_x emissions to the sample 1 compare with other samples Blends. For Better BTHE, BTHE of Diesel compared with S1, S2, S3, S4, S5, S6 Finally Diesel produces 4% more BTHE than S1. Hence Diesel has more BTHE than prepared samples. x For Better Specific fuel consumption, the results show that almost all the sample having same specific fuel consumption. there are no significant changes at all break powers x For Lower HC, the result shows that S5 produces high than the diesel all other bio diesel samples produce less in all break powers.
- Experimental investigation of catalytic convertor using jute and Kevlar composite in VCR engine. S. Ganesan, a) M. Purushothaman, b) S.P. Venkatesan, c) K. Vijai Anand, d) J. Hemanandh2, e), Senthilkumar, f)

K.S.Sreenivasan, g) School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India 3 Department of Mechanical Engineering, MNM Jain Engineering College, Chennai, India

- The result successfully showed significant reduction in NO_x values with maximum reduction. The values were compared with that of diesel and graphs of BTHE, SFC, NO_x and other components were plotted against BP. Thus, it can be concluded that the NO_x emission is much lesser than the standards set. Also, Kevlar and Jute fiber does shows effect in decreasing the remaining emissions such as hydrocarbon, carbon monoxide and carbon dioxide as change taken place in the NO_x. The values of HC, CO and CO₂ obtained in the result shows slight variation at the time of varying the loads and these values are less than the values that are obtained after combustion of the pure diesel from test results obtained after testing, we can say the maximum reduction had obtained at the sample 1 among all the samples the emissions such as the HC, CO, CO₂ and NO_x are greatly reduced at the sample 1 and also less than the diesel combustion values.
- Experimental and synthesis of chicken slaughter waste biodiesel in DI diesel engine. Hemanandh Janarthanam, a), Ganesan Subbiah, Sridhar Raja, Senthilkumar Gnanamani, Amarjit Roy, Vineet Chougale. School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India. Jeppiaar Mammallan Engineering College, Chennai, India.
- The biofuel produced has a low emission rate and a decline in the fuel price. Biochar is produced as a by-product during the experiment that could be used as bio-fertilizer due to the rich nitrogen content to improve the soil quality in comparison with pure diesel, it was found that the blend produces less HC emission than with a yield of 9.68% at 100% load condition
- Environmental emission control in CI engine using hydro treated bio-fuel in India. Hemanandh Janarthanam a), Venkatesan Sorakka Ponnappan, Purushothaman Mani, Ganesan Subbiah, Shanjiit, Tejual Krishna Department of Mechanical Engineering, Sathyabama Institute of science and Technology, Chennai, India.
- The results showed that Jatropha oil gave less emission and enhanced performance when compared with refined palm olein oil and Petro diesel.

The emissions of CO decreased by 14.26% and 28.57% for HTRPMB100 and HTJATB100 respectively. The HC emissions of HTJATB100 and HTRPMB100 reduced by 57.5% and 52.6 % respectively.

- Experimental Investigation and Characterization of HDPE & LDPE Polymer Composites. S. Ganesan, J. Hemanandh, K. S. Sridhar Raja, and M. Purusothaman
- This work provides possible solution for the management of wood wastes generated from wood industry and municipal wastes. In order to remove the presence of impurities content in the wood wastes and to reduce the size, sieving has been carried out and size is reduced to 180 microns. To remove the moisture content from sawdust, heating of sawdust is carried out in an electric oven for three hours. Here the testing results revealed that the untreated sawdust show fewer mechanical properties than chemically treated sawdust.
- Influence of nerium based catalytic converter in DI diesel engine for emission reduction using avocado oil. J. Hemanandh , M. Purushothaman, S.P. Venkatesan, S. Ganesan, Shivam Gautam, Subham Kandoi School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India.
- It can also be observed that the amount of HC, CO, NOx for biodiesel blends at all load conditions is significantly reduced as compared to diesel. The CO and HC emissions have been found to increase with the added load for all the biodiesel blends. The nerium based catalytic converter is played an important role which can increase or decrease the emission parameters of the engine
- Vehicle Emission Analysis by using Refined Sunflower Oil as Alternate Fuel and Varying the Injection Timing in Diesel Engine. J. Hemanandh , S. Ganesan, C. Sathya Sai Puneeth and G. Venkata Sai Naga Manikankata Tejesh Dept. of Mech. Engg., Sathyabama University, Chennai, India.
- The results show that engine temperature decreases at higher loads by 2°, NOx and CO decreases and there was a marginal increase in HC and the exhaust temperature. The experiments conducted showed that the refined

palm-olein biodiesel, when blended with diesel by varying the pressure, resulted in desired pattern of emissions.

- Investigation of Sapindus seed biodiesel with nano additive on single cylinder diesel engine. S. Padmanabhan, T. Vinod Kumar, M. Chandrasekaran & S. Ganesan to cite this article: S. Padmanabhan, T. Vinod Kumar, M. Chandrasekaran & S. Ganesan Investigation of Sapindus seed biodiesel with nano additive on single cylinder diesel engine.
- A nano additive of Cerium oxide used to oxygen catalyst on these biofuel blends and to improve the cetane number for enhanced combustion This study also resulted in, the Sapindus seed oil is another new alternative in biofuel category which is atmosphere friendly.
- Study of Annona squamosa as alternative green power fuel in diesel engine Devaraj Rangabashiam & H. Suresh Babu Rao & Ganesan Subbiah & Mohanavel Vinayagam.
- In this study, the nano biochar derived from sugarcane was added with custard seed biodiesel (CBD) at different concentrations of 25 and 50 ppm to assist the emission and performance pattern of a compression ignition engine. The study monitored harmful gases, namely, hydrocarbon (HC), carbon monoxide (CO), nitrogen oxide (NO), and smoke as emission parameters and investigated brake specific fuel consumption (BSFC) and brake thermal efficiency (BTHE) as performance parameters is analyzed at diverse loads by altering the concentration the biochar with CBD and compared with diesel.

CHAPTER - 3

AIM AND SCOPE OF PRESENT INVESTIGATION

3.1 AIM.

The primary aim of this paper is to study the emissions and performance characteristics of direct injection Diesel engine using AOME blend synthesized by ALGAE oil. Brake thermal efficiency (BTHE) and Specific fuel consumption (SFC) are also studied.

3.2 SCOPE.

The scope of this work is to analyze performance of the engine at different rated power was evaluated in terms Specific Fuel Consumption (SFC), Brake Thermal Efficiency (BTHE) and emissions characteristics such as HC, CO, CO₂ and NO_x of AOME. The algae-bio oil trans esterified with facilitate of heterogenous catalyst and blend with petroleum diesel and TBHQ antioxidants. The biofuel is tested in DI Diesel engine. The engine was permitted to run at no load condition in the beginning, and the test blend was added and the emission and performance characteristics for the sample were recorded.

CHAPTER – 4

MATERIALS AND METHODS

4.1 EXPERIMENTAL SETUP.

A single cylinder, constant speed, Direct Injection engine was used to evaluate the engine performance and emission characteristics of Chlorella-SP biodiesel. The diesel runs under different load conditions at a constant speed of 1500 rpm with the different blend proportions. The diesel engine was directly attached with an eddy current dynamometer for varying the loads from no load (0%) to full load (100%). Based on the engine power, the engine load is varied from no load condition of 0%, 25%, 50%, 75% and full load condition of 100%. The engine loads are varied manually with help of an eddy current dynamometer. Air flow rate was measured with an air drum fitted with a calibrated orifice and the fuel flow was measured using volumetric calibrated burette method. For fuel flow measurement, two fuel tanks were used; one is filled with pure diesel while trans esterified Chlorella-SP biodiesel is filled in another fuel tank. An AVL smoke meter was attached for measuring the smoke opacity and exhaust gas temperatures. The test rig was installed with AVL indimicro software to obtain various readings and results during operation. A five-gas analyzer was used to measure the emission characteristics such as HC, CO, CO₂, O₂ and NO_x values from the exhaust gas. The performance and emission tests were conducted at the compression ratio of 17.5 and with rated power.

The test was carried out for different blend proportions of Chlorella-SP biofuel blended with the pure diesel fuel. The performance analysis of the engine at different rated power was evaluated in terms Specific Fuel Consumption (SFC), Brake Thermal Efficiency (BTHE) and emissions characteristics such as HC, CO, CO₂ and NO_x. Figure 4.1 shows the photographic view of the experimental set up used in this study.



Fig.4.1: Experimental Setup.



Fig.4.2: Engine Testing Lab.

Table 4.1: Specifications of the Test Engine.

Engine Type	Single Cylinder, 4 Stroke, Water Cooled Engine
	Stroke 110mm, Bore 87.5mm, 661 cc
Power	5.20 KW @ 1500 rpm
Compression ratio	17.5
Injection variation	0-25 deg bTDC
Dynamometer	Eddy current, Water cooled with Loading unit
Fuel tank	15 Liters , Dual compartment with fuel metering

4.2 ENGINE TESTING SOFTWARE.

EngineSoft is LabVIEW based software package developed by Apex Innovations Pvt. Ltd. for engine performance monitoring system. EngineSoft can serve most of the engine testing application needs including monitoring, reporting, data entry, data logging. The software evaluates power, efficiencies, fuel consumption and heat release. It is configurable as per engine set up. Various graphs are obtained at different operating condition. While on line testing of the engine in RUN mode necessary signals are scanned, stored and presented in graph. Stored data file is accessed to view the data graphical and tabular formats. The results and graphs can be printed. The data in excel format can be used for further analysis.

4.3 TEST RUN WITH COMPUTERIZED MULTI CYLINDER ENGINE SETUPS.

- Ensure that all the nut bolts of engine, dynamometer, propeller shaft, bass farms are property tightened.
- Ensure that sufficient lubrication oil is present in the engine sump tank This can be checked ty marking on the level stick.
- Ensure sufficient fuel in fuel tank. Remove air in fuel line, if any.
- Switch on electric supply and ensure that PPU (Piezo powering unit AX-409), DLU (Dynamometer loading unit AX-155). Load indicator und Voltmeter are switched on.

- Start Computer and open "ICEngineSoft" (Double click "ICEngineSoft" icon on the desktop) Select: File| Configure| Product.
- In "Configure the product" window select "Load Default".
- Under "Select File" choose your Setup from drop down menu.
- Under "Set Parameters" study the parameters under Engine Sensors, Combustion and Performance tabs Click on "OK".
- Changing the Parameters.
- If any parameter is to be changed Click "New/Change". Change the parameter under respective tabs After all changes click "Save & Apply". Click "OK" to save changes.
- Click "OK" again to reconfigure changes.
- Reconfiguring the graphs.
- Select File| Configure Graph Under "Configure" the Graphs window "Select a Configuration" from the drop-down menu.
- Study the preset configuration of X axis, Y axis. graph ranges, for the selected graphs. Click "CLOSE & SET". Configure the necessary parameters, ranges, as required. Click "SAVE" and then "Close & SET".
- Note three vertical tabs viz. Combustion Performance Report Under Vertical Combustion tab horizontally following tabs are available: Combustion, Cylinder Pr. PV, Log PV and RPR etc. Similarly, under other vertical tabs we get more horizontal tabs. Start water pump. Adjust the flow rate of "Rotameter (Engine)" to 900-1000 LPH and "Rotameter (Colorimeter)" to 200-250 LPH by manipulating respective globe values provided at the rotameter inlet. Ensure that water is flowing through dynamometer at a pressure of 0.5 to 1 Kg/cm². (For Hydraulic dynamometer at a pressure of 1.5 to 2 Kg/cm²).
- Keep the DLU knob at minimum position. Change the Fuel cock position from "Measuring".
- Tank". Start the engine by starter keys switch and allow it to run at idling condition for 4-5 minutes.

4.4 ONLINE DATA ACQUISITION.

- Click toggle switch Move to "Start/Stop" the device communication. Green color indicates ON condition Click toggle switch *Measurement" to Start/Stop data acquisition. Green color indicates ON condition.
- Ensure that Speed, Temperatures and Manometer reading are correctly displayed on the PC. These readings should tally with those displayed on the engine panel.
- Increase the load on the engine by rotating knob on the DLU and confirm the load reading on the indicator and computer are same.
- Gradually increase throttle to full open condition and load the engine simultaneously maintaining engine speed at 2000-2600 RPM.
- Wait for steady state for 3 minutes and ensure that RPM & Load is constant during this period. Change the Fuel cock position from "Tank" to "Measuring". Click "Log on" on. The fuel metering in ON for next 60 seconds. During first 30 seconds enter engine. Water flow, calorimeter jacket cooling water flow in LPH Click "OK" after recording fuel reading. Enter the file name under which the records to be stored. The first reading data is now saved. Change the Fuel cock position from "Measuring " to "Tank".
- Gradually decrease the load to the increase speed in steps of 500 RPM up to 4000 RPM maximum and repeat the data logging for each observation.
- After finishing all the readings simultaneously decrease the load on the engine by DLU. Gradually decrease throttle to full down condition.
- Click toggle switch "Measurement" to Stop data acquisition in PC (Green color indicates ON condition). Click toggle switch "Mode" to Stop the device communication.
- Click: File|Data|Close. Stop the engine by pressing engine stop starter keys. Allow the water to circulate for about 5 minutes for engine cooling and then Stop the pump.
- Click: File|Data|Open. on PC, Select the File under which the readings are stored and click "OK". To view next readings, click "Next Data". The results are displayed on all the three screens.

- Report Printing Click "Report" tab to Performance generating Report Enter File name in "Report File" Select Combustion Report. the Report Requirements viz. Result Data, Observation Data, Graph Only OR Graph and Table. (Note: If "Graph and Table") options Selected.
- Combustion Report, the size of the output file for printing otherwise it becomes too big. However, it can be viewed in Excel) Click: File|Data|Close. after Printing & checking. Click "Exit" and then Shut Down the computer.

4.5 SMOKEMETER.

To take the readings from Smoke meter to ADCS Software kindly follow these steps: -

- Kindly fill the details (Engine No, Model, Engine Type, Engine Speed). In respective text boxes given on the form. If you didn't check "Vehicle details" check box in Master data entry form all the Textboxes related to (Engine No, Model, Engine Type, and Engine Speed) become disabled.
- Click on "Connect button" to connect the PC with equipment and wait for 5-10 second. If the readings are not coming it shows the message in red color "Unable to Communicate with Equipment" kindly Check the following:
- Be sure that Smoke meter model name display on screen is same as your Smoke meter if not kindly Master the model in Data Entry Form".
- Check the COM port settings with PC and the Software in "Master Data Entry form".
- RS232 Cable for smoke meter is working property and connected with equipment.
- Readings are coming with equipment and display on remote of smoke meter.
- According to "Time interval settings" in selection box, readings are automatically saves in database.
- After taking the readings click on "Disconnect button". it disconnects the communication with equipment and show the message "Disconnected".
- Report: Click on report button to take the rear of the test.
- Print: Click on print button to take the printout of screen as bitmap image.

- Export to MS Excel Sheet: To export data in excel sheet click on "EXPORT TO EXCEL" button When pressing export button, a excel file is generated at path "C: \AVLFolder\" The file name of excel file is same as test date and VIN no (Tuesday, January 06, 2009).
- Close button: click on close button to exit from current active window or screen, it takes time to close, so wait for 10-15 seconds for form window to close.



Fig.4.3: Smoke Meter.



Fig.4.4: Linearity Test.

4.6 GAS ANALYZER.

To take the readings from Gas analyzer to ADCS Software kindly follow the steps:

- Kindly fill the details (Engine No, Model, Engine Type, Engine Speed) in respective text boxes given on the form.
- Click on "Connect button" to connect the PC with equipment and wait for 2-3 minutes. if the readings are not coming it show the message in red color CO, HC power not communicating kindly check the following.
- Be sure that gas analyzer settings in "MAHA Euro" mode.
- Connect to COM port settings with PC and the software.
- RS232 Cable is working properly and connected with equipment.
- Readings are coming with equipment and display on panel.
- After 6 seconds readings are automatically saved in database and status bar strip moving according to readings save in database.
- After taking the readings click on "Disconnect button". it disconnects the communication with equipment and show the message Saved Database.
- Click on report button to take a part of the test.
- Print: Click on print button to take the printout of screen as bitmap image.
- Export to MS Excel Sheet: To export data in windows sheet click on "EXPORT TO EXCEL" button. When pressing, export button excel File is generated in a path C:\AVLFolder file name of excel file is same as Test Date and VIN no (Tuesday, January 06, 2009_ 23).
- Close button: click on close button to exit from current active window screen.



Fig.4.5: Five Gas Analyzer Reading.



Fig.4.6: Five Gas Analyzer.

4.7 PROCEDURE.

The micro algae strain used as feed feedstock is chlorella species renamed as Chlorella - SP. Oleum 20, activated charcoal from coconut shell. 20% free SO₃ is maintained at 150 degrees Celsius in microwave oven for 15 hours under nitrogen stream. Following the method reported in the literature 1 gram of solid charcoal his mixed with 16.5 ML of fuming sulfuric acid. then washed with distilled water for 30 minutes continued with the distilled hot water at 80 degrees Celsius resulting slurry

material dried it at 110 degrees Celsius over following the method reported in literature the microalgae oil is trans esterified by the prepared sulphonated activated charcoal of 5wt% and methanol: oil ratio of 9:1 at 65 degrees Celsius after 4 hrs of transesterification giving AOME of 94%.



Fig.4.7: Algae Biodiesel.

The trans-esterified biodiesel is made in to four samples S1, S2, S3, S4 of petroleum diesel blends off 10%, 20%, 30%, 40% off volume respectively. Each sample is a total of 400 ml blend.



Fig.4.8: Petroleum Diesel.



Fig.4.9: Test Samples S1, S2, S3, S4.

Each sample is under the influence of 30 PPM of TERTIARY BUTYLHYDROQUINONE. **tert-Butylhydroquinone (TBHQ, tertiary butylhydroquinone)** is a synthetic aromatic organic compound which is a type of phenol. It is a derivative of hydroquinone, substituted with a *tert*-butyl group. Copper launch become greater excessive with inside the neat biodiesel which evidenced that TBHQ retarded the corrosion procedure as a corrosion inhibitor. One of the main regulations associated with the use and commercialization of biodiesel is its bad oxidation stability. Compared to diesel fuel, biodiesel is greater at risk of oxidation or auto-oxidation in the course of long-time period garage and its instability is proportional to the quantity of unsaturated fatty acids derived from the uncooked substances generally used for acquiring the biofuel.



Fig.4.10: Teritiary Butylhydroquinone from Sigma Aldrich.

Oxidation approaches are extended with inside the presence of air (exposure to water and oxygen), heat, mild and pro-oxidants (hydroperoxides and hint metals). As a consequence, adjustments with inside the bodily and chemical traits of biodiesel occur, consisting of a boom in viscosity, density and polymer content, which bring about the formation of gums and sediments. Inside the engine, the latter might also additionally cause clear out blocking, injector fouling, deposit formation with inside the engine combustion chamber and corrosion of engine components

CHAPTER – 5

RESULTS, DISCUSSION AND PERFORMANCE ANALYSIS

The engine's performance and emission analysis were carried out when fueled with algae oil biodiesel for four different volumetric fuel blends with petroleum diesel at different loads and compared with diesel fuel operation.

5.1 EMISSIONS.

Biodiesel has been shown to possess a bonus over petroleum-based diesel in terms of

emissions composition. Combustion of biodiesel emits nominal to no SO₂ emissions, less polyaromatic hydrocarbons, soot, and CO. Combustion potency is outlined because the ratio of the energy free in combustion to the upper heating worth of the fuel. This potency can be optimized through changes of the air body of water to the burner which may conjointly impact final emission composition. Combustion potency is additionally a operate of the exhaust temperature and therefore the exhaust concentration of CO₂. High concentrations of CO₂ indicate that combustion goes towards completion and most of the fuel is being consumed. The stack temperature is directly associated with the amount of settled soot and scale on the warmth transfer surfaces. With larger buildup of soot, the conductive heat transfer constant of the surfaces drops and additional helpful heat is lost within the tack. For these reasons, it's vital to tune burners to maximize CO₂ concentrations within the stack whereas minimizing the number of smokes made.

5.2 NOX EMISSIONS.

Nitrogen Oxides (NO_x) are a bunch of extremely reactive gases, that include compounds starting from nitrous to acid. These compounds are primarily discharged in truck, car, station and off-road instrumentality exhaust. Nox gases kind when nitrogen and oxygen from the air react at the very high temperatures and pressures inside a combustion cylinder, which might reach up to 4000°F and 300PSI (Johnson, 2015). In the direct injection ICE fuel is sprayed into the cylinder and forms small droplets. Oxygen interacts at the boundary surface between the air and therefore the fuel droplets wherever the localized temperature within the

fuel drop exceeds that needed to make NO_x gases. usually, a high quantity of oxygen and heat can lead to high levels of NO_x formation. These conditions are typically found in diesel engines as a result of they run at a lean air-fuel mixture and at high compression ratios. fuel produces less NO_x than gas throughout combustion, however with the implementation of chemical action converts in gas high-powered vehicles, diesels engines release additional NO_x gases to the setting.

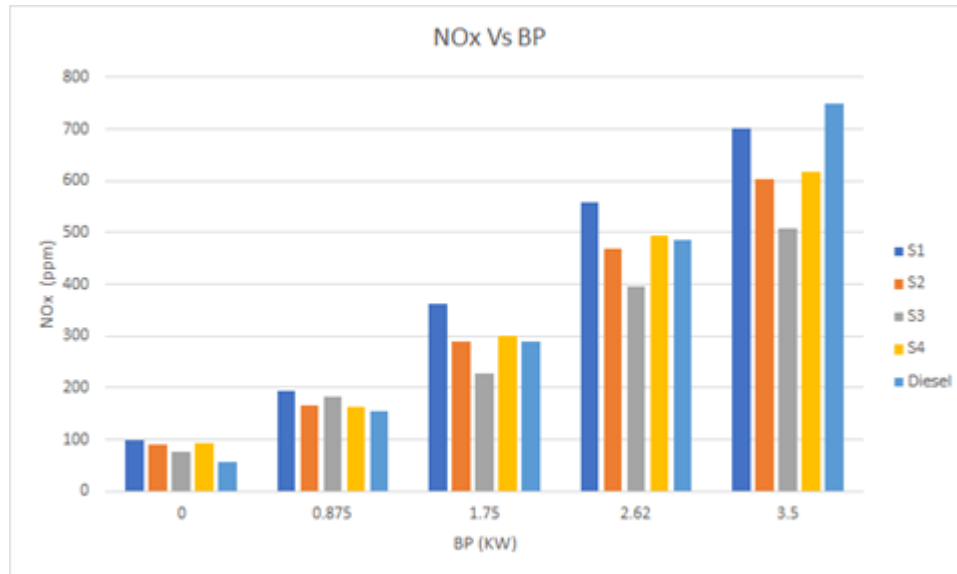


Fig.5.1: NO_x Vs BP.

Table 5.1: NO_x Emissions of S1, S2, S3, S4, Diesel with loads.

BP(KW)	0	0.875	1.75	2.62	3.5
S1	98	195	361	558	702
S2	91	167	289	470	604
S3	76	183	228	395	508
S4	92	164	300	495	617
Diesel	56	156	289	485	750

Figure 5.1 displays the change in NO_x emissions with BP (KW) for S1, S2, S3, S4, Diesel. NO_x emissions for S1, S2, S3, S4 are significantly lower than diesel emissions. S3 out of all samples has recorded least NO_x emissions at every load

conditions. there is a decreasing trend with increasing blend content up to 30 percentage. S1 has the highest NOx content but, it is lower than diesel.

5.3 CO EMISSIONS.

Carbon monoxide results from the unfinished combustion wherever the chemical reaction method doesn't occur fully. This concentration is essentially smitten by air/fuel mixture and its highest wherever the excess-air issue (λ) is a smaller amount than one.0 that's classified as wealthy mixture. It is often caused particularly at the time of beginning and instant acceleration of engine wherever the wealthy mixtures are needed. within the wealthy mixtures, because of air deficiency and chemical concentration, all the carbon cannot convert to carbon dioxide and be shaped CO concentration. though CO is made throughout operation in wealthy mixtures, a little portion of CO is additionally emitted below lean conditions due to chemical kinetic effects.

Diesel engines are lean combustion engines that have a systematically high air–fuel quantitative relation ($\lambda > 1$). So, the formation of CO is bottom in diesel engines. None the less, CO is made if the droplets in a very ICE are large or if insufficient turbulence or swirl is made within the combustion chamber.

Carbon monoxide is an inodorous and colorless gas. In humans, CO within the air is inhaled by the lungs and transmitted into the blood. It binds to hemoprotein and inhibits its capability to transfer oxygen. looking on CO concentration within the air, as so resulting in asphyxiation, this could have an effect on the operate of various organs, leading to impaired concentration, slow reflexes, and confusion.

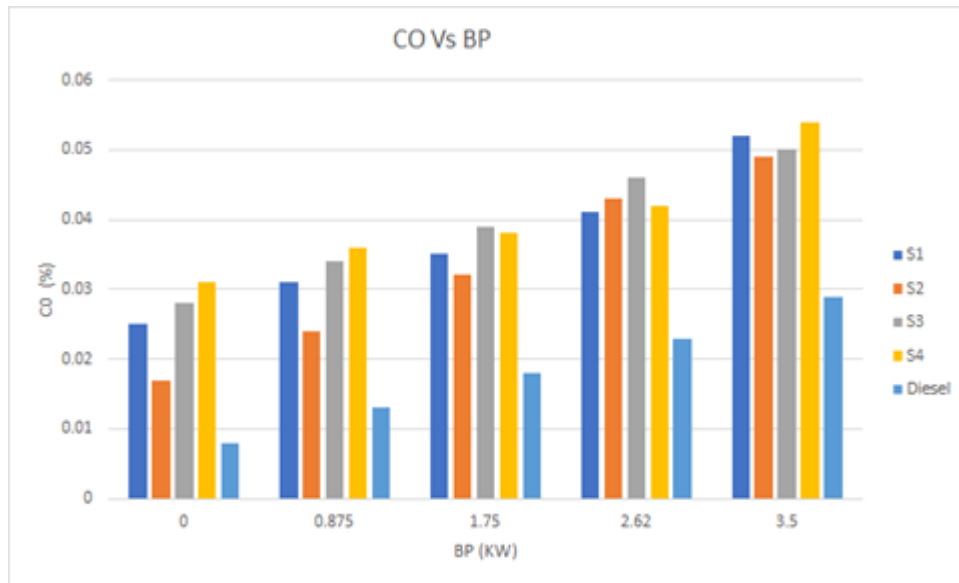


Fig.5.2: CO Vs BP.

Table 5.2: CO Emissions of S1, S2, S3, S4, Diesel with Loads.

BP(KW)	0	0.875	1.75	2.62	3.5	
S1	0.025	0.031	0.035	0.041	0.052	
S2	0.017	0.024	0.032	0.043	0.049	
S3	0.028	0.034	0.039	0.046	0.05	
S4	0.031	0.036	0.038	0.042	0.054	
Diesel	0.008	0.013	0.018	0.023	0.029	

Figure 5.2 displays the comparison of CO emissions with BP (KW) for S1, S2, S3, S4 diesel. CO emissions are formed due to air fuel equivalent ratio, injection pressure, fuel type, speed. Every sample has slightly higher CO emissions than diesel emissions.

5.4 O₂ EMISSIONS.

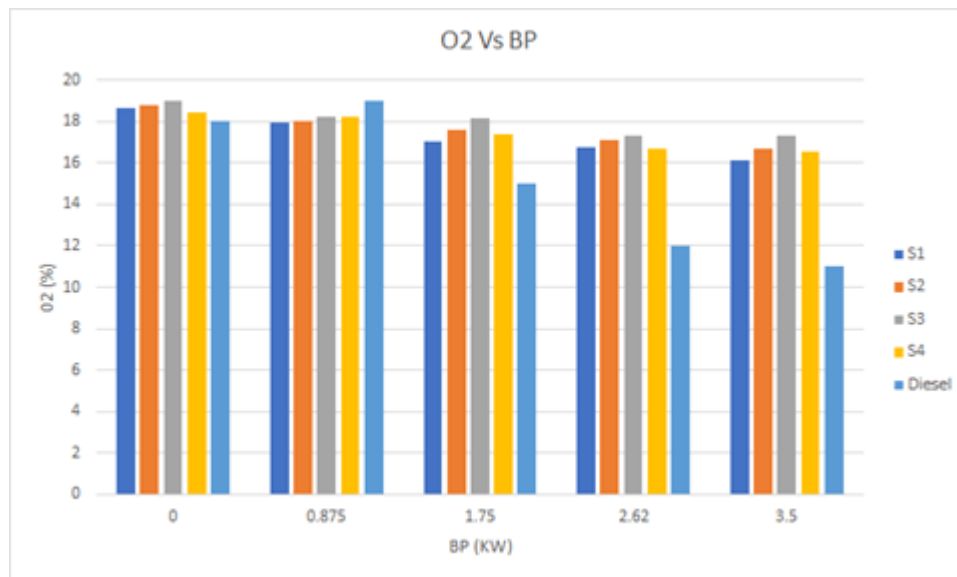


Fig.5.3: O₂ Vs BP.

Table 5.3: O₂ Emissions of S1, S2, S3, S4, Diesel with loads.

BP(KW)	0	0.875	1.75	2.62	3.5
S1	18.68	17.96	17.02	16.78	16.16
S2	18.77	18.02	17.62	17.11	16.69
S3	18.99	18.2	18.15	17.33	17.33
S4	18.41	18.2	17.38	16.71	16.56
Diesel	18	19	15	12	11

Figure 5.3 displays the change in O₂ emissions with the BP (KW) for S1, S2, S3, S4, Diesel. O₂ emissions for S1, S2, S3, S4 has higher content than diesel in every load conditions. There is increasing pattern of O₂ with the increasing load. S3 has highest content at every load condition than other samples and diesel.

5.5 CO2 EMISSIONS.

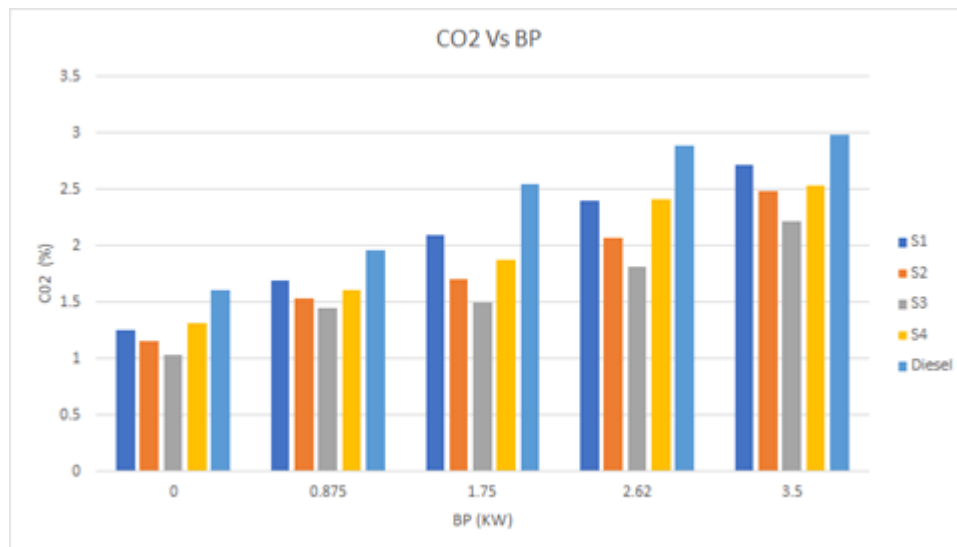


Fig.5.4: CO2 Vs BP.

Table 5.4: CO2 Emissions of S1, S2, S3, S4, Diesel with loads.

BP(KW)	0	0.875	1.75	2.62	3.5
S1	1.25	1.69	2.09	2.4	2.72
S2	1.15	1.53	1.7	2.07	2.48
S3	1.03	1.45	1.5	1.81	2.21
S4	1.31	1.6	1.87	2.41	2.53
Diesel	1.6	1.96	2.54	2.89	2.98

Figure 5.4 depicts the variation of CO2 emissions versus BP (KW) for different test fuels. It was recorded with increasing BP (KW) there is a slight increase of seawater emissions as expected. With increasing the blend percentage decreases the CO2 emissions up to 30 percentage. S3 second as the lowest of all CO2 emissions at every load conditions. Using more concentration then 30 percentage of biodiesel blends as fuel, CO2 emissions is found to increase. But its emission level is lower than that of diesel.

5.6 HC EMISSIONS.

Hydrocarbon emissions are composed of unburned fuels as a result of short temperature that happens close to the cylinder wall. At now, the air–fuel mixture temperature is considerably but the middle of the cylinder. Hydrocarbons encompass thousands of species, like alkanes, alkenes, and aromatics. they're usually declared in terms of equivalent CH₄ content.

Diesel engines usually emit low levels of hydrocarbons. Diesel hydrocarbon emissions occur in the main at lightweight loads. the most important supply of light-load organic compound emissions is lean air–fuel admixture. In lean mixtures, flame speeds could also be too low for combustion to be completed throughout the ability stroke, or combustion might not occur, and these conditions cause high hydrocarbon emissions.

In Diesel engines, the fuel kind, engine adjustment, and style have an effect on the content of hydrocarbons. Besides, HC emissions within the exhaust gas depend upon irregular in operation conditions. High levels of instant modification in engine speed, untidy injection, excessive nozzle cavity volumes, and appliance needle bounce will cause vital quantities of unburned fuel to pass into the exhaust.

Unburned hydrocarbons still react within the exhaust if the temperature is on top of 600 °C and present, thus organic compound emissions from the piping could also be considerably below the hydrocarbons going the cylinder.

Hydrocarbon emissions occur not solely within the vehicle exhaust, however additionally within the engine housing, the equipment, and from region emission of vapors throughout fuel distribution and dispensing. housing hydrocarbon emissions and phase transition losses of hydrocarbon emissions have, severally, 20–35 and 15–25 take some time piping organic compound emissions have 50–60 you look after total hydrocarbon emissions.

Hydrocarbons have harmful effects on atmosphere and human health. With alternative waste matter emissions, they play a big role within the formation of ground-level gas. Vehicles are to blame for regarding fifty you look after the emissions that kind gas. Hydrocarbons are cyanogenic with the potential to tract irritation and cause cancer.

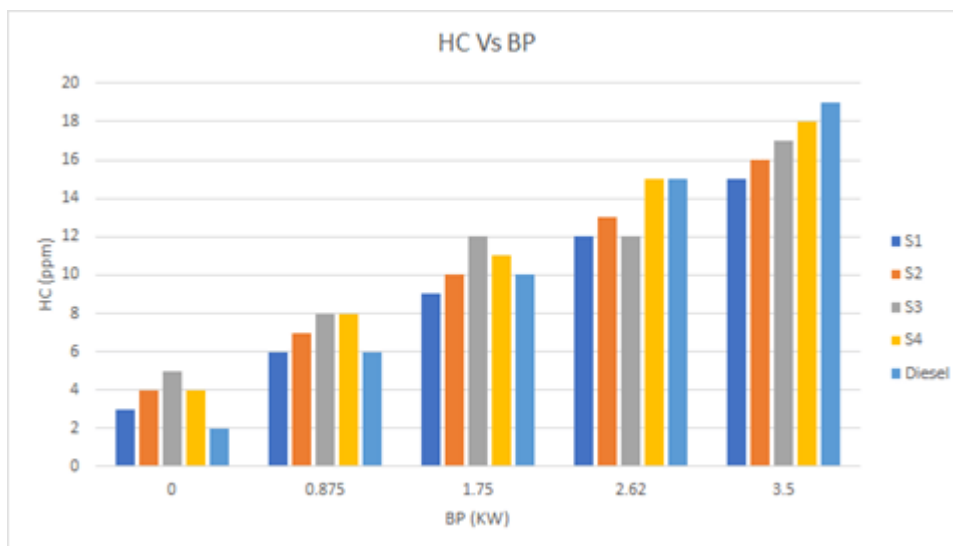


Fig.5.5: HC Vs BP.

Table 5.5: HC Emissions of S1, S2, S3, S4, Diesel with loads.

BP(KW)	0	0.875	1.75	2.62	3.5
S1	3	6	9	12	15
S2	4	7	10	13	16
S3	5	8	12	12	17
S4	4	8	11	15	18
Diesel	2	6	10	15	19

Figure 5.5 shows variation of HC emissions with Load (KW) of different biodiesel blends. It is shown that with increasing blend ratio there is increase in HC emissions. HC emissions increase with increase in load due to insufficient oxygen. S1 has less HC emissions than diesel and the other samples at almost all loads.

5.7 PERFORMANCE ANALYSIS.

5.7.1 BRAKE SPECIFIC FUEL CONSUMPTION (BSFC).

The fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft, power is typically measured with the help of a parameter called Brake Specific Fuel Consumption. It is typically used for comparing the efficiency of internal combustion engines with a shaft output. BSFC may be a live of the fuel potency of any engine that burns fuel and produces movement power output. The BSFC price indicates however with efficiency the engine converts fuel equipped into helpful work. one in every of the most parameters accustomed verify the characteristics of biodiesel on BSFC is hot price. the upper the hot price, the lower the BSFC as a result of a discount within the hot price of a fuel leads to an increase within the fuel consumption for attaining the corresponding power output. though biodiesel has higher hot price however still it's lesser than diesel which ends in higher BSFC than the diesel oil in any respect hundreds. Another parameter that decides the performance characteristics of biodiesel is that the Oxygen content gift within the fuel. this is often as a result of a higher the next oxygen content of biodiesel helps to facilitate better combustion. variable the engine load additionally plays a vital role in learning the performance characteristics of biodiesel. Studies have shown that increasing the engine load from zero to full load shows a decreasing trend within the BSFC and therefore the brake specific energy consumption decreases.

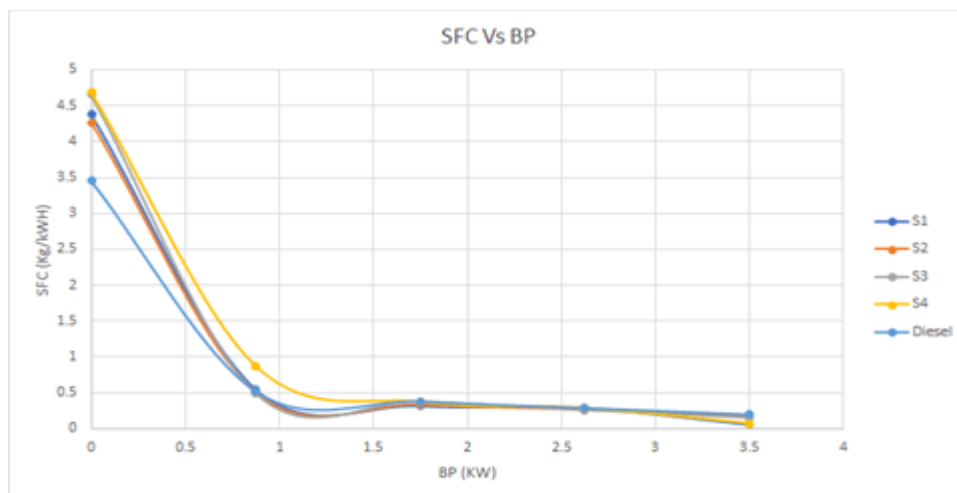


Fig.5.6: SFC Vs BP.

Table 5.6: SFC Values of S1, S2, S3, S4, Diesel with loads.

BP(KW)	0	0.875	1.75	2.62	3.5
S1	4.38	0.55	0.32	0.29	0.06
S2	4.27	0.51	0.34	0.27	0.18
S3	4.65	0.49	0.38	0.26	0.15
S4	4.69	0.87	0.37	0.29	0.07
Diesel	3.45	0.52	0.38	0.29	0.2

In this Figure. 5.6 Brake Power (KW) is plotted along X axis and SFC is plotted along Y axis. The variation of SFC for all tested biodiesel blends with varying engine loads is illustrated in the graph. It was found that with increasing BP (KW) there is decreasing in SFC. At lower loads of 0.875 kW, S4 has higher SFC than Petro diesel and other samples. At the peak load of 3.5 kW diesel has higher SFC and S4 has the least. At 2.62 kW of brake power (KW) SFC off every sample and diesel fuel and has been recorded the same.

5.7.2 BRAKE THERMAL EFFICIENCY (BTHE).

The variation of BTHE with loads for different fuels shows that BTHE increases with increase in % load due to the reduction in heat losses and increase in power with increasing load. Brake thermal efficiency can be determined as Brake Thermal Efficiency = (Brake Power *100%)/ (Fuel Equivalent of Power).

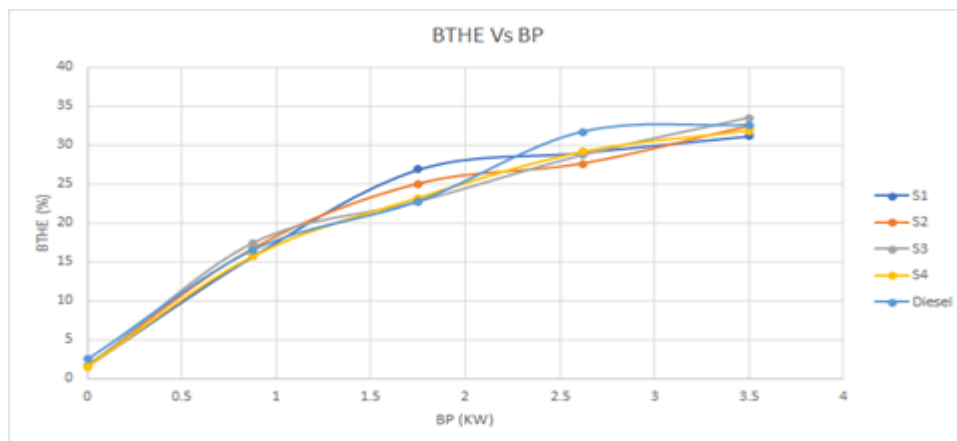


Fig.5.7: BTHE Vs BP.

Table 5.7: BTHE Values of S1, S2, S3, S3, S4, Diesel with Loads.

BP(KW)	0	0.875	1.75	2.62	3.5
S1	1.59	15.7	26.89	29.07	31.19
S2	1.63	16.68	25.03	27.62	32.45
S3	1.52	17.39	22.72	28.73	33.52
S4	1.51	15.7	23.2	29.15	31.87
Diesel	2.45	16.49	22.75	31.71	32.59

Fig 5.7 shows Brake thermal Efficiency is increasing with the increasing Brake Power (KW) , however sample 3 of 30% off AOME has highest BTHE more than diesel fuel at higher Load that is 3.5 KW. At 1.7 5 KW sample one has the highest BTHE while S3 coincides diesel. Increasing AOME blends percentage increases the BTE, but only up to 30%. S4 of 40% didn't perform well at every load.

CHAPTER - 6

SUMMARY AND CONCLUSION

6.1 SUMMARY.

Use of algae oil as a biofuel after transesterification is very attractive energy conservation in a country like India. To reduce the cost of algae biodiesel the catalyst used should allow re usability in transesterification. Sulfonated activated charcoal as Heterogenous acid catalyst has been used. TBHQ has been added to all test samples to improvise performance and emissions. An experiment has been done to find the performance and emission of biodiesel and its blend in a single cylinder, constant speed, direct injection engine. The emission trends determined in this experiment showed a difference between varying mixtures of diesel and biodiesel. Differences were also found in the amount of useful heat obtained from the fuels, which could be indicative of the differences in the fuels energy contents.

6.2 CONCLUSION.

- The maximum brake thermal efficiency obtained is about 33.52% for S3, which is quite higher than that of baseline diesel 32.59 percentage at full load.
- The SFC values of all samples are Lower in comparison of diesel fuel.
- HC emissions of S1 is lower than the diesel fuel and other samples.
- CO₂ EMISSIONS of S3 is lower than diesel fuel at every load conditions
- NO_x emission of S3 is lower than the diesel fuel at every load conditions.
- CO at every load in every sample there is slight increment than diesel emissions.
- O₂ emissions of S3 is higher than diesel fuel and other samples at all load conditions.

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