“Performance and emission analysis of an agriculture CI engine using biogas and biodiesel-diesel blend”

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This is to certify that report entitled "**PERFORMANCE AND EMISSION ANALYSIS OF AN AGRICULTURE CI ENGINE USING BIOGAS AND BIODIESEL-DIESEL BLEND**" by KOUSHIK MAJI in the requirement of the partial fulfilment for the award of degree of **Master Of Technology (M.Tech)** in **Renewable Energy Technology** at **Delhi Technological University**. This work was completed under my supervision and guidance. He has completed the work with utmost sincerity and diligence. The work embodied in this project has not been submitted for the award of any other degree to the best of my knowledge.

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DECLARATION

I declare that the work presented in this thesis titled “performance and emission analysis of an agriculture CI engine using biogas and biodiesel-diesel blends”, submitted to Department of mechanical engineering, is an authentic record of my own work carried out under the supervision of Dr. Amit Pal, Associate Professor, Department of Mechanical Engineering, Delhi Technological University, Delhi.

This report does not contain part of my work which has been submitted for the award of any other degree either of this university or any other university without proper citation, to the best of my knowledge.

Date: Signature of the candidate

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ABSTARCT

The cost of petroleum products is continuously rising due to the restrictions of store; supply and demand of fossil fuel is also rises because of industrialization. The controls of exhaust gases from diesel engine have additionally been regulated, particularly for particulate matter (PM) and oxides of nitrogen (NO_X). There is subsequently need to search optional fuel which will diminish harmful emissions gases while keeping high thermal efficiency. Biogas is one such fuel, which can be adjusted for use in internal combustion (IC) engine. In this exploration, Compression Ignition (CI) engine was modified into a dual fuel engine which utilizes biogas and diesel or biogas and biodiesel-diesel blend with the emphasis on lowering of harmful emissions gases while keeping up high thermal efficiency.

The performance and emission characteristics of the modified engine were compared with those of the conventional diesel engine. The effect of ethanol (alcohol) on engine performance and emission was also studied. The air intake system of the engine was modified to allow mixing of air and biogas before supplying the mixture to the combustion chamber of the engine while the exhaust system was modified to allow measurement of the exhaust emissions. Canola biodiesel is blended with diesel in the ratio of 20:80 (biodiesel: diesel). Using canola blend (B20), amount of hydrocarbon is lowered. But amount of NO_X is getting higher. At 20% load, the amounts NO_X are 403 ppm, 115 ppm, 551 ppm, 108 ppm for diesel mode, diesel-biogas mode, canola (B20) mode, canola (B20)-biogas mode respectively. However the amount of unburnt hydrocarbon is decreased when added ethanol to the canola biodiesel blend. The brake thermal efficiency is also increased when added ethanol to canola biodiesel. At 100% load, the brake thermal efficiency is increased from 32% to 35%.

The performance characteristics of the modified engine showed that diesel can be substituted partly with biogas and engine used for a range of applications. The most appropriate areas of use are stationary applications such as driving of electric power generators, hoisting in construction sites and driving of machines such as water pumps and concrete mixers. This is due to the challenge of compact storage of the gas.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Many advanced and growing nations on the planet including India are presently confronting three vital issues; (i) taking care of the power demand, (ii) ecological degradation and (iii) unused by-product management. Because of the expansion in population, innovation advancement, industrialization and change in the way of life, the interest for power dependably increments. The supply and utilization of reasonable and clean energies are the real assignment of all nations. Subsequently, there is always a pressure on established researchers to put more subsidizes in the field of innovative work for presenting cleaner and greener energizes, which can either be get from sustainable power sources or natural waste substances. A typical element of sustainable power sources is that they are for the most part accessible through a decentralized, occasionally even individual approach. This produces a possibility of having power at one's own particular transfer yet makes an issue of administration and system when expansive power amounts are required. There has been a critical improvement in using sustainable power sources, for example, solar, wind, hydro and biomass for power production and transportation. Notwithstanding, still there is much opportunity for collecting power from an assortment of sources. This part examines the supply of power generation of natural contamination, and the possibly cleaner and greener fills that are accessible right now and the requirement for the present research work.

At present, electrical power production on the planet is essentially accomplished through thermal power plants, trailed by hydroelectric, atomic, and sustainable power sources, for example, solar, wind, biomass, tidal, and geothermal. In 2012, the world essential power supply was around 155,505 terawatt-hours (TWh) [1], while the world power utilization was 104,426 TWh, which was around 32% not as much as the aggregate supply.

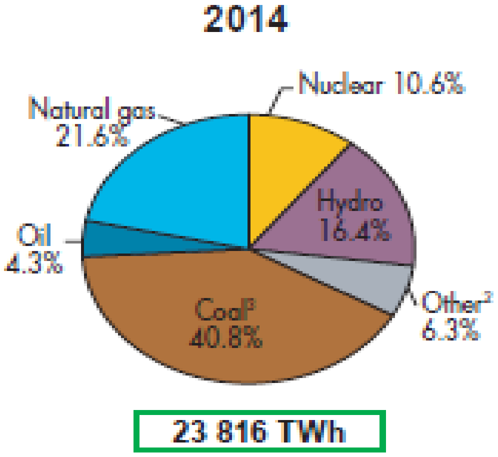

Figure 1: Global power production using different fossil fuel and renewable fuel in 2014. [2]

As of late, there has been an extensive increment in global understandings and national Energy Action Plans, for example, the EU 2009 Renewable Energy Directive, to expand the utilization of sustainable power sources because of the increasing worries about the contamination from the utilization of petroleum derivatives [3]. One such activity was the United Nations Development Program's World Energy Assessment in 2000, which highlighted that many difficulties would need to be overcome keeping in mind the end goal to move from non-renewable energy sources to sustainable power sources [4]. From 2000 - 2012 sustainable power sources developed at a rate higher than whatever other point ever, with a utilization increment of 176.5 million tons of oil. During this time period the oil, coal, and petroleum gas utilization additionally developed and had expanded significantly higher than the sustainable power sources. Figure 2, delineates the development in utilization of petroleum products, for example, oil, coal, and flammable gas and in addition inexhaustible supplies of power [5].

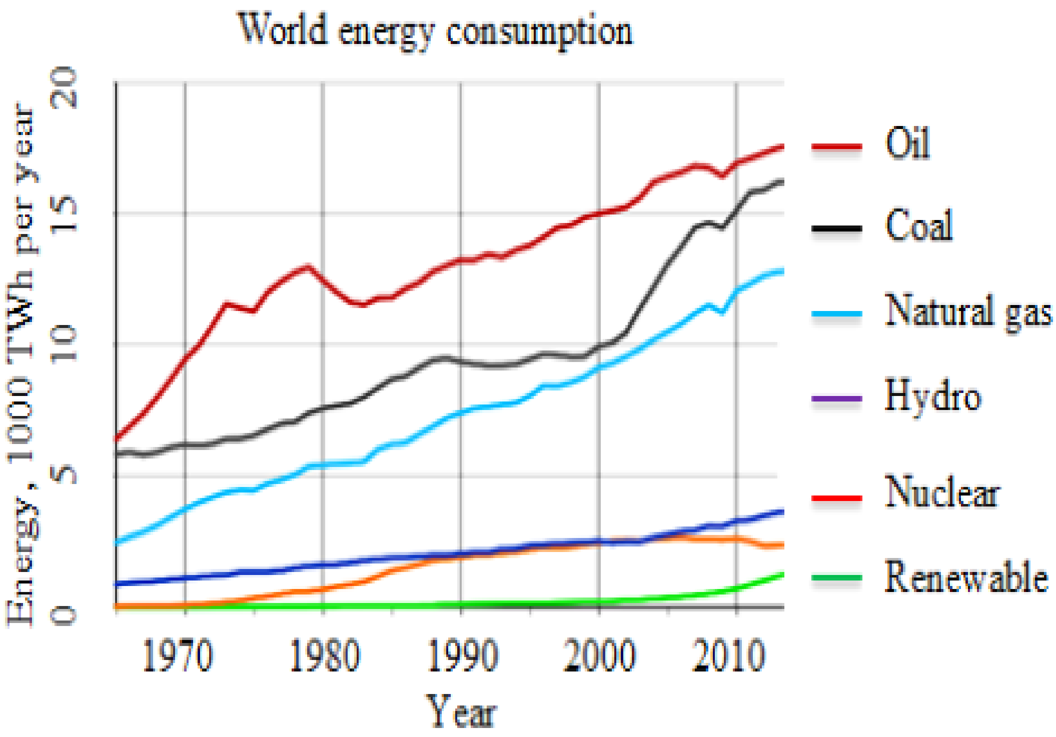

Figure 2: Development in utilization of oil, coal, and gaseous petrol and additionally inexhaustible sources [5].

Some developing countries end up under noteworthy power necessities. While the creating enthusiasm for family control lessens the fuelwood spares and fabricates desertification, their outside exchange pay doesn't consider adequate importation of energy. Their potential for other feasible power sources may be huge yet is not adequately abused for reasons like absence of capital and ability. Industrialized countries, however still in a position to import control, are feeling the heaviness of continually growing force cost while their maintainable power source potential is not tapped for, among others, political reasons.

Feasible power advancement procedures commonly include three noteworthy inventive difficulties: (a) power investment funds on the request side, (b) proficiency changes in power generation and (c) substitution of non-renewable energy sources by different supplies of sustainable power source.

1.2 PROBLEMS

Now a days Compression ignition (CI) engines are broadly utilized as power source for vehicles over worldwide. It is because of simple mechanical structure also because of improved thermal efficiency due to higher compression ratio. CI engines emit low carbon monoxide (CO), less unburnt hydrocarbon and carbon dioxide (CO_2) contrasted with those of spark ignition (SI) engines. From a natural perspective, be that as it may, diesel engine for the most part emits a bigger measure of particulate matter (PM) and nitrogen oxide (NO_X) toxin discharges than those of gasoline engines [6].

Air contamination by exhaust gases from IC engines has turned into a noteworthy worry in the majority of the nations of the world since it is responsible of causing respiratory illnesses and malignancies. Poor surrounding air quality is a noteworthy concern, generally in urban zones where there are more outflows because of the high number of vehicles. Air contamination is additionally responsible of genuine marvels, for example, acid rain and global warming. It is thus of these unfriendly impacts of the exhausts on human life and the earth, that the controls for outflows from IC engines have been fortified. This has prompted look into option powers for the IC engines, which would diminish destructive exhausts while keeping up high thermal efficiency [7].

Notwithstanding difficulties of exhaust from IC (Internal Combustion) engines due to utilization of non-renewable energy sources, the price of the petroleum derivatives is becoming expensive because of increment demand. All nations are at present vigorously reliant on oil energizes for transportation and agricultural machine. The way that a couple of countries deliver the majority of oil has prompted high price change and instabilities in supply for the expending countries. This thus has driven them to search for option powers that they themselves can deliver. Among the choices being considered are methanol, ethanol, biodiesel and biogas [8].

Air poisons are substances that have a uniform impact on the earth by snooping with the atmosphere, the physiology of plants, and creature of various kinds of species, whole biological communities, and also human property such as harvests or man-made structures. The worldwide environmental change has been perceived as a standout amongst the most imperative natural difficulties to be confronted by humankind in the 21st century.

Air pollutants can come from regular or anthropogenic (man-made) sources, or both. Cases of regular supplies of contamination incorporate volcanic ejections or wind disintegration. A few supplies of contamination, for example, forest fire, can be identified with both natural disaster and human exercises. Exhausts from heat engines are a commendable supply of anthropogenic contamination. In this specific situation, the world's most vital air pollutants and atmosphere changing operators, for example, oxides of nitrogen (NOx), carbon dioxide (CO_2), and oxides of Sulphur (SOx) are considered, and their particular sources, and natural impacts are talked about. Many research has demonstrated that biogas yield from organic wastes is a decent contrasting option to oil energizes and can be utilized as a part of compression ignition (CI) engines, in light of its better blending capacity with air and clean consuming nature. Biogas is delivered by anaerobic digestion of different organic substances, for example, kitchen wastes, agricultural wastes, municipal strong wastes and dairy animals waste.

The utilization of diesel fuel in CI engine discharges pollutants, for example, particulate matter, oxides of nitrogen, carbon monoxide, unburned hydrocarbon and carbon dioxide. A number of pollutants discharged are exceedingly subject to the oxygen level, combustion temperature and kind of fuel. These pollutants effectively affect human wellbeing and nature. Submission to these discharges may prompt wellbeing illnesses that diminish work productivity, along these lines prompting an ascent in neediness level. Likewise, toxin gathering results to ascend in outflow of nursery gasses causing an unnatural weather change. These effects combined with the difficulties of heightening fuel prices because of increment popular make a need to deliver and use elective energizes, for example, biogas.

The utilization of biogas in CI engines requires a method for conceding the gas into the engine ignition chamber and a method for controlling the pilot fuel, inferring that biogas can't be utilized as a part of the diesel engine without modification. These difficulties exhibit that there is a need to build up a dual fuel engine that would use biogas as an option fuel for direct ignition compression ignition engines.

Despite the fact that there are examines on the combustion and outflow characteristics of renewable fuels such as biodiesel and ethanol; and oil fuels with the dual fuel idea, it is important to research moreover in more detail, the performance characteristics of the biogas-diesel dual fuel engine. Moreover, dual fuel engines are not promptly accessible locally thus the need to create them for the neighbourhood advertise since a generous measure of biogas is right now being delivered the nation over.

The issue "biofuel" tends to start unfriendly responses, running from visually impaired eagerness and conviction by means of critical liberality or sensitivity to aggregate dismissal. Critical sensitivity has all the earmarks of being a decent precondition for dealing with biogas issues and for an effective advancement of biofuel related ventures.

1.3 BIOGAS: AN ALTERNATIVE FUEL FOR IC ENGINE

Oil and diesel are normal fluid fuels for internal ignition engines, while methanol, ethanol and biodiesel are elective fluid fuels. Utilization of Liquefied Petroleum Gas (LPG) in IC engines is likewise normal, particularly in sustenance preparing and fabricating businesses while elective gaseous fuels for IC engines incorporate hydrogen, syngas and biogas.

Biogas is a gaseous fuel delivered by anaerobic digestion of organic material that can be removed from fluctuated sources like creature wastes, vegetable wastes, and wastes from family units, wastes from the nourishment and feed industry and waste from profitable domesticated animals' cultivation [9]. It is viewed as an option clean power asset for CI engines in perspective of its ecological well-disposed nature.

Sustainable power source and its change to heat and power are key components for manageable improvement in nations with low or no oil fuel holds. A standout amongst the most imperative sustainable fuels is biogas, which is made mainly out of methane (30-70%, by vol.) furthermore, carbon dioxide (20-40%, by vol.) and is a promising option fuel for inward ignition engines since it is inexhaustible and suitable for surroundings [10].

Methane displays more noteworthy imperviousness to the knocking property because of its higher octane rating and auto-ignition temperature, making it suitable for engines with high compression ratio [11]. Furthermore, the carbon substance of methane is likewise moderately low contrasted with that of traditional diesel fuel, bringing about a significant diminish in contamination debilitate outflows.

Biomass contains high substance of cellulose, proteins, hemicellulose, lignin and extractives, subsequently shaping a characteristic, inexhaustible asset for an environment friendly, modest and practical material. These materials of biomass are promptly accessible as municipal strong waste (MSW), food waste (FW), crop residue (CR), agricultural waste (AW), and wood deposits. In biomass, the cellulose $(C_6H_{10}O_5)_X$ part is around 40 to half of the aggregate biomass by weight, though hemicellulose $(C_5H_8O_4)$□ is more often than not in the scope of 20 to 40% by weight and lignin $(C_9H_{10}O_3(OCH_3)_{0.9-1.7})_n$ is in the scope of 5 to 30% by weight, contingent upon the way of the plant, regardless of whether it is herbaceous or woody [12]. By and large, the greater part of bioenergy delivered from biomass is from agricultural or plant based waste, having a most extreme offer of around 64%, followed by MSW 24%, landfill gasses 5%, and the remaining are alternate biomass wastes.

Using biogas in engines, when contrasted with non-renewable energy sources stays away from any extra greenhouse gas outflow. Because of the organic way of the segments of biogas, consuming it in a gas engine for power generation produces a similar measure of CO_2 into the atmospheric circle as was initially invested during the time spent photosynthesis in the regular CO_2 cycle.

1.4 PRESENT SCENARIO

Biomass has the best potential as a sustainable power source, in both creating and created nations. 35% of essential power from biomass is expended in creating nations, raising the world's aggregate essential power utilization from biomass to 14%. To the extent nature is concerned, biofuel gives environment friendly exhausts. Plant based biomass assimilates CO_2

amid development and radiates it amid ignition, shaping an atmospheric reusing of CO_2 that prompts the decrease of the nursery impact. Likewise, biomass is a CO_2 -neutral fuel as it lessens the general CO_2 emission [13].

The fuels gotten from biomass sources offer particular points of interest; they are; (i) sustainable in nature, (ii) plentifully accessible, (iii) logical from regular sources, (iv) Environmental friendly, and (v) less expensive in price. As of late, biofuels were sorted into four generation gatherings. There are no strict technical definitions for these terms. The fundamental refinement between them is the feedstock utilized.

Agricultural, mechanical, and urban wastes are modest supplies of biomass. Power harvests can likewise be developed and utilized as a power plant fuel, yet this regularly rivals the land utilized for nourishment creation, and can be dubious. Different techniques for utilizing it incorporate co-firing biomass with coal in a coal-fired thermal station, control generation in IC engines with the assistance of running the IC engines on biodiesel, liquor and biogas. Some creature wastes can be transformed into an ignitable gas utilizing anaerobic absorption. A biomass control plant can give control when required, not at all like irregular inexhaustible sources, for example, the wind and the sun.

1.5 NECESSITY OF THE STUDY

These days, biodiesel generation from nonedible seeds, for example, Jatropha curcas (Jatropha), and edible seed like rapeseed, Rice bran is accepting more consideration overall [14]. The de-oiled cakes of non-consumable nature cannot be used, and arranged in the open, in light of the fact that these cannot be utilized as steers bolster nor straightforwardly in agricultural cultivating, because of their toxic nature. In this way, if these cakes are kept in an open situation, they would make ecological issues, by creating different gasses, for example, CH_4 (methane), N_2O (nitrous oxide), H_2S (hydrogen sulfide), NH_3 (ammonia), CO_2 (carbon dioxide) and volatile organic mixes, by the activity of different microorganisms. The use of such de-oiled cakes is a test today. As of late, anaerobic processing innovation has picked up significance, particularly for biomass wastes [15]. The creation of biogas from de-oiled cakes might be a superior answer for its successful use. Biogas is a carbon impartial gaseous fuel since it can be gotten from nature's photosynthetic items, without giving any expansion of greenhouse gasses (GHGs) to the earth.

As the biogas is a gaseous fuel and has a low cetane number, it can be utilized as a part of compression-ignition (CI) engines in the dual fuel mode for power, heat and electricity generation. Biogas innovation likewise gives the advantage of bio manure; the social and ecological advantages incorporate sanitation, lessening of deforestation and decrease in the utilization of non-renewable energy sources. In creating nations with agriculture-based economies, this innovation can diminish the utilization of wood-based fuels and can enhance the electricity framework through internal combustion (IC) engines.

The present examination is basically focused on the extraction of power from food, vegetable waste to create biogas by the anaerobic absorption prepare. Likewise an endeavour has been made towards the suitable application of the final result (i.e. biogas) as a gaseous fuel, in a diesel engine for power generation. A drifting arch biogas digester was composed and fabricated to complete the processing. The created biogas was utilized to run a diesel engine in the dual fuel mode, offering an answer of somewhat substituting diesel fuel, biodiesel and blending of diesel and biodiesel.

1.6 OBJECTIVE

The primary target of this examination was to change a diesel engine to keep running on biogas, diesel fuels as a dual fuel engine with diesel as the pilot fuel and biogas as the essential fuel and to accomplish ideal thermal efficiency with diminished gaseous exhausts. To accomplish these targets, the accompanying specific destinations were to be expert.

- To plan and fabricate an efficient blending device for biogas and air for the dual fuel engine.
- To assess the performance of the modified dual fuel engine and contrast and that of the diesel engine.

- To research the effect of blending alcohol and biodiesel with diesel on engine emission.

1.7 ORGANISATION OF THE REPORT

The proposal is partitioned into five sections. The present section highlights the current issue identified with the increment in price of oil fuels combined with large amounts of unsafe exhausts from CI engine and identifies the need to find elective fuels for the CI engine. Chapter 2 is a survey of existing documents on research that has been embraced towards utilization of option fuels in IC engines. It exhibits a critical survey on utilization of biofuels, for example, biogas and biodiesel in IC engines. The holes that have been identified in this survey have been laid out.

Chapter 3 diagrams the trial set-up and the system required in modification of the diesel engine into a dual fuel engine that utilizations biogas and diesel fuels. It likewise shows the parameters measured to set up performance of the modified CI engine. The parameters incorporate torque, engine speed and fuel utilization. In chapter 4, the outcomes acquired from engine performance tests and exhausts investigation from the modified dual fuel engine are exhibited and talked about. Chapter 5 contains the conclusions reasoned from the decided parameters of the dual fuel engine and the proposals for further work on utilization of biogas in CI engines.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW

Gaseous fuels are better than strong and fluid fuels as they have better blending quality, less viscosity, and are effectively ignitable and transportable. Along these lines, moving from the utilization of strong and fluid fuels to the gaseous fuels is more alluring these days. Liquefied petroleum gas (LPG), and compressed natural gas (CNG) are utilized for transportation and power generation in numerous nations, biogas is additionally thought to be a potential option fuel in many growing nations, on account of the extensively accessible feedstock for its generation. This part displays the compression ignition (CI) engine ideas as for engine operation, combustion and emission. Further, it shows the exploration works that were done identified with the generation and use of biogas gotten from different organic feedstocks, utilizing the anaerobic absorption method. This section likewise incorporates the audit of the biogas use in DI diesel engines worked on the dual fuel mode with biodiesel or diesel as a pilot fuel and biogas as the essential fuel. The difficulties related with the biogas dual fuel operation for the combustion, performance and discharge issues are additionally checked on and displayed in this section.

2.2 DUEL FUEL ENGINE

Garnier et al. [16] defined a dual fuel engine as a perfect multi-fuel engine that works adequately on an extensive variety of fuels including the adaptability of working as a conventional diesel engine. Amid dual fuel operation, a carburetted blend of air and high octane record gaseous fuel is sucked and compressed a similar way air is sucked in a conventional CI engine. The compressed blend of air and fuel-gas does not auto-touch off because of poor ignition nature of the gaseous fuel. Thus, it is ignited by a little fluid fuel injection, known as a pilot fuel, which lights suddenly toward the finish of the compression phase. A dual fuel engine subsequently utilizes an essential and auxiliary fuel. The essential fuel is the pilot fuel, for example, diesel and the optional fuel might be flammable natural gas, liquefied oil gas (LPG), hydrogen or biogas.

In 2006, J. Stewart et al. [17] modified an immediate injection CI engine into a dual fuel engine and fuelled it with three distinctive gaseous fuels: Methane, propane, and butane to examine performance at different gaseous fixations. They contemplated that a basic essential issue blending framework is the most modest and straight forward technique for conceding a gaseous fuel to the dual fuel engine. A straightforward Venturi type gas blender was in this way introduced at a separation of ten times the gas pipe distance across; upstream of the channel complex to guarantee finish blending of air and the fuel was accomplished. Engine performance information were acquired under enduring state working conditions at three burdens comparing to quarter, half and seventy five percent stack (with respect to 100 percent stacking being 18.7 kW). They presumed that propane demonstrated the most encouraging characteristic as a dual fuel engine fuel, with a decrease of up to 20 percent power utilization being recorded. This was ascribed to the upgraded reactivity of the fuel. Methane which has been the fuel of choice was found to build the brake specific power utilization for all cases considered. The review additionally expressed that the engine unmistakably demonstrated the benefits of decreased CO_2 exhaust which must be considered if proposed worldwide diminishments are to be accomplished inside the vehicle division. Discharge of CO_2 was decreased by up to 20 percent. This demonstrated dual fuel engines can be utilized to help accomplish decrease in exhaust outflows. The review likewise prescribed that better engine performance and further diminishment in CO_2 discharge could be accomplished with the work of present day fuel injection hardware, for example, high weight basic rail and various injection systems.

Explore has demonstrated that dual fuel engines as of now work under the NO_X and SO_X limits set out by the International Maritime Operations Tier 3 control, speaking to a fascinating contrasting option to diesel engines furnished with EGR or exhaust gas after treatment. As indicated by an extensive reproduction think about by C. Christen et al. [18], a homogeneous blend of fuel gas and air is essential with a specific end goal to accomplish low NO_X exhaust and additionally lessening the danger of knocking ignition. Consistent confirmation of fuel gas was found to accomplish best blending outcomes. A lot of gas affirmation prompted expanded collection of rich fuel gas in barrel crevices which was a principle supply of unburned hydrocarbons. The beginning stage of the re-enactment based review was an engine display adjusted with measured information acquired from a solitary chamber turbocharged dual fuel engine with Miller cycle and fixed camshaft including a standard fundamental diesel injection framework, a typical rail framework for pilot fuel injection and a port injection framework for gas confirmation. This reproduction model was augmented and modified with two-organize turbocharging framework and expanded compression proportion. The outcomes additionally demonstrated that efficiency and power yield of dual fuel engines can be generously enhanced by presenting two-arrange turbocharging and variable valve timing, pilot fuel injection framework prepared to do adaptable begin of injection setting, improved but settled compression proportion and a mechanical structure for a gas engine with brake mean compelling weight of 26 bar and chamber ring weight up to 220 bar. This technical data is helpful in building up a dual fuel engine from a diesel engine.

2.3 BIOGAS USAGE IN DUAL FUEL ENGINE

Dual fuel engines have been a subject of high enthusiasm because of their capability to decrease smoke outflow with enhanced exhibitions [19]. They display great thermal efficiency and low smoke level at high power yield. The downside is that this diminishment is frequently joined by an expansion in exhausts of carbon monoxide (CO) and unburned hydrocarbons. Over the most recent ten years, many reviews on the IC engines gone for expanding engine performance and lessening of exhaust exhausts have been completed by changing working parameters, for example, valve timing, injection timing, what's more, atomization rate among others.

Tentatively, I.D. Bedoya et al. [20] discovered that gasoline pilot port injection with high identicalness proportions over 0.4 in a Homogeneous

Charge Compression Ignition (HCCI) engine brought down CO and HC outflows while NO_X exhaust was expanded. A typical biogas synthesis of 60% CH_4 and 40% CO_2 in a volumetric premise was re-enacted by controlling the CH_4 and CO_2 stream rates. It was inferred that HCCI ignition of biogas empowers high general efficiency, and the techniques investigated in the exploration permitted higher power yield, and more balanced out combustion. In spite of the fact that the findings of this exploration merit acknowledging, it is noticed that the examination utilized mimicked biogas by blending methane and carbon dioxide in specific proportions. This won't give exact outcomes since real biogas has different parts, for example, hydrogen sulfide, nitrogen, hydrogen and oxygen. The utilization of genuine biogas would have given more solid outcomes for engine performance and outflow characteristics.

A trial examination was performed by S.H. Yun et al. [21] to concentrate the impact of dual fuel combustion characteristics on the exhaust discharges and ignition performance in a diesel engine fuelled with biogas and biodiesel. Biogas was infused amid the admission procedure by two electronically controlled gas injectors introduced in the admission pipe of the engine. The aftereffects of this review demonstrated that significantly bring down NO_X discharges were radiated under dual fuel operation for both instances of pilot fuels contrasted with single-fuel mode at all engine stack conditions. Additionally, biogas-biodiesel gave predominant performance in decreases of sediment discharges because of the nonattendance of aromatics, the low sulfur, and oxygen substance for biodiesel. The aftereffects of this work obviously demonstrate that the utilization of bio-fuels in IC engines is a certain method for decreasing exhaust outflows while keeping up high thermal efficiency. Be that as it may, the exploration did exclude a blending device to guarantee a homogeneous biogas-air blend for better ignition. Better engine performance and lower exhausts would be normal if an efficient blending device was embodied and EGR was utilized.

A performance assessment of a steady speed IC engine on compressed petroleum gas (CNG), methane enriched biogas and biogas was finished by R. Chandra et al. [22]. A Venturi sort air admission and fuel gas supply framework were utilized to supply the gaseous fuel into the engine. The watched misfortune in brake influence because of change of diesel engine into start ignition engine were 31.8%, 35.6% and 46.3% for packed petroleum gas, methane enriched biogas and crude biogas, individually. The outcomes indicate that the power misfortunes were very high, with the most elevated misfortune recorded for crude biogas. An arrangement of a blending chamber in the setup rather than a Venturi sort air admission could give a more homogenous air-fuel blend bringing about better combustion and enhanced engine performance. This is on the grounds that a blending load gives a more drawn out maintenance time of air and fuel inside it prompting a homogenous blend with better ignition capacity.

In a review by S. Siripornakarachai et al. [23], a transport diesel engine was modified to utilize biogas as fuel for electricity creation in a ranch. Modifications included expansion of biogas carburettor for air-fuel blending, supplanting the fuel injection framework with start ignition framework and lessening of compression proportion from the first 16:1 to 8:1 utilizing a chamber head spacer. The outcomes demonstrated that there was high discharge of CO, however the engine control yield was 134.20 kW which is attractive. Writing proposes that the compression proportion ought to be in the vicinity of 10:1 and 12:1 for biogas operation. Since the compression proportion was brought down to 8:1, this could have prompted deficient ignition henceforth increment in CO outflow.

In another review by H.S. Sorathia et al. [24], the first and second laws of thermodynamics were utilized to examine the amount and nature of power in a solitary chamber, coordinate injection diesel engine utilizing oil diesel oil and biogas as fuel. Parities of power and exergy rates for the engine were resolved and after those different performance parameters, power and exergy efficiencies were computed for diesel oil and diesel-biogas dual fuel. The most extreme brake thermal efficiency for biogas was 27.50% as thought about to 28.25% for diesel oil. For the diesel and diesel-biogas dual fuels, computation comes about demonstrated that 7.31% and 6.48% of the fuel exergy information was lost in heat exchange from the engine, individually. The review presumed that diesel-biogas dual fuel mode created brings down power change efficiency; which was balanced by vast substitution of diesel and acceptance air by biogas. The review closed likewise, that biogas premixed charge dual fuelling for the engine created no performance crumbling at all test speeds. The consequences of this theoretical thermodynamic examination are amazing and are worth approving through trial strategies.

N.S. Ray et al. [25] modified a CI engine into a dual fuel engine and utilized biogas for fractional substitution of diesel to concentrate the effect on performance of the engine. The consider indicated great performance of the modified engine as far as power yield as well as lessening of exhaust exhausts. There was a diminishment in both CO and HC outflows; however the brake engine control diminished marginally with increment in rate of biogas. This was because of lower power substance of biogas contrasted with diesel. It was reasoned that half substitution of diesel with biogas was the ideal proportion for dual fuel operation. The most elevated proportion tried was Biogas:Diesel in the proportion 50:50. There is in this way need to research performance of the engine at higher substitution proportions for example, Biogas:Diesel in the proportion 90:10.

2.3 USE OF HYDROGEN

Hydrogen can be utilized as a part of internal combustion (IC) engines with insignificant outflows of poison gasses. A hydrogen-worked engine produces water as its fundamental combustion item. It doesn't deliver significant measures of carbon monoxide (CO), hydrocarbon (HC) and carbon dioxide (CO_2). The main undesirable outflow is nitric oxide (NO) and nitrogen dioxide (NO_2), which are oxides of nitrogen (NO_X).

Gopal et al. [26] researched the performance in a conventional single barrel four-stroke diesel engine with hydrogen as enlisted fuel under an extensive variety of the engine operation. The outcomes demonstrated that the thermal efficiency got was tantamount with unadulterated diesel operation and up to a large portion of the engine's power necessity could be gotten from hydrogen. Be that as it may, the onset of knocking was a long time before stoichiometric combustion. The exploration demonstrated a smooth and smokeless engine operation from the utilization of hydrogen. Along these lines, the test that should be tended to is the early onset of knocking and the high cost of hydrogen.

From T. Korakianitis et al. [27], expanded NO_X discharges and pre-ignition inclinations amid hydrogen and emulsified biodiesel dual fuel operation contrasted and typical CI engine operation are significant limitations on engine control yield. One technique that has been utilized to effectively diminish NO_X exhausts is exhaust gas distribution (EGR). While EGR is extremely effective in diminishing NO_X outflows (decreases of the request of half with a 20% EGR volumetric admission substitution), past work appeared that hydrogen dual fuelling with EGR produces bring down thermal efficiencies than hydrogen dual fuelling without EGR. This is fundamentally because of the weakening effect of EGR, where the oxygen grouping of the admission charge is diminished. It is in this manner imperative to set up an exchange off between engine performances and exhausts when EGR is connected.

As indicated by an audit by L. P. Goswami et al. [28], a dual fuel engine has a high efficiency furthermore; it stays unaltered utilizing auxiliary fuel, for example, hydrogen, natural gas (NG) and liquefied petroleum gas (LPG). A diesel-hydrogen dual fuel engine can be worked with less fuel than perfect diesel operations, bringing about lower smoke level and higher brake thermal efficiency. NO_X discharge is however high because of the high ignition temperatures for hydrogen. The study likewise proposed that NO_X exhaust can be diminished through exhaust gas distribution.

2.4 USE OF SYNGAS IN IC ENGINE

Syngas is a gaseous fuel made significantly out of hydrogen and carbon monoxide. B.B Sahoo et al. [29] modified a diesel engine to keep running on diesel and syngas as a dual fuel engine. Segments, for example, gas blender, non-return valve, weight controller and gas carburettor were joined in the modification. At light loads (20 - 40% of full load) dual fuel operation with gaseous fuel acceptance demonstrated a mediocre engine performance. This is because of the lower ignition rate caused by CO content in the syngas fuel. Once more, at these heaps, a little pilot amount prompted poor ignition and combustion of lean air-gas blend. At higher loads past 40%, the engine performance moved forward with increment in load. Discharge of NO_X was observed to be high because of speedier ignition rate of H_2 present in syngas. The review however did not consider adjusting the engine for EGR as a method for lessening NO_X outflows.

B.B Sahoo et al. did an exploratory assessment on the effect of H_2:CO proportion in syngas on the performance of a dual fuel diesel engine operation. The CO substance of syngas brought about significant increments of the CO exhausts when contrasted with 100% H_2 mode because of deficient combustion of CO in the fuel-gas. Again for syngas that contains CO in its synthesis, the CO discharge levels appeared to be touchy to the engine stack. At low engine stacks, the CO outflows were expanded significantly. What's more, at high engine loads (past 60%), the more articulated premixed and progressed combustion of syngas fuels brought about expanded barrel weight and temperature and consequently, tended to expand the NO_X focus. This is because of the expansion of the combustion temperature at higher loads thus of speedier ignition rate of H_2 and CO. From this test, it was uncovered that utilization of syngas in IC engines requires a method for decreasing discharge of NO_X.

In the year 2012, C.T. Spaeth [30] did an exploration on performance characteristics of a diesel fuel guided syngas compression ignition engine. He changed over a solitary chamber diesel engine to work in dual fuel mode through the disposal of the senator framework and expansion of an in-chamber weight transducer and custom admission framework to encourage the blending of the gaseous fuel and ignition air. He at that point tried the engine on dual fuel operation utilizing methane and syngas independently, with diesel as the pilot fuel. At the point when worked on methane, the engine achieved higher crest in-barrel weights alongside higher torque, power, and thermal efficiency esteems for equivalent equality proportions. The outcomes demonstrate that more prominent measures of syngas must be utilized to achieve tantamount outcomes with methane because of the lower power substance of syngas. The ignition postponement was more prominent for syngas, and the onset of knock happened before with syngas in contrast with methane. The specialist inferred that it is important to utilize more prominent measures of syngas to make comparative performance esteems to that of methane due to the low power substance of syngas in contrast with methane. This was expected to the certainty that at a similar comparability proportion, the brake torque and brake control created by syngas were not exactly those for methane, and the power information was less for methane than for syngas. Also, syngas operation delivered brings down thermal efficiencies and higher BSFC esteems for relating equality proportions in contrast with methane operation. The essential benefit of utilizing syngas was that it is an inexhaustible fuel source that is carbon unbiased. These outcomes infer that since the real part of biogas is methane, its utilization in a diesel engine could give comes about similar to those of methane.

2.5 USE OF LIQUID BIO-FUELS IN IC (DUAL FUEL) ENGINES

2.5.1 ETHANOL

C. Sayin et al. [31] tentatively explored the influence of injection timing on the debilitate exhaust of a solitary chamber, four stroke, coordinate injection, normally suctioned diesel engine utilizing ethanol mixed diesel fuel from 0% to 15% with an addition of 5%. The trial test comes about demonstrated that NO_X and CO_2 exhausts expanded as CO and HC outflows diminished with expanding measure of ethanol in the fuel blend. Notwithstanding, with cutting edge injection timings (30° and 33° CA BTDC), HC and CO outflows decreased; while NO_X and CO_2 exhausts were helped for all test conditions. These outcomes demonstrated that there is have to find methods for diminishing the NO_X outflow for engine operation on ethanol.

In 2009, Zhiyou Wen et al. did an examination on creation of ethanol and its utilization in start ignition engines [32]. They revealed that Brazil, U.S.A and China are the main three ethanol makers on the planet. The ethanol creation from these three nations represents 78 percent of overall ethanol generation. The examination additionally indicated that ethanol has a higher octane number (ON 113) than general unleaded gasoline (ON 87) and premium unleaded gasoline (ON 93) and the higher octane number lessens the inclination for an engine to pre-touch off and knock, making it run all the more easily. The findings of this exploration demonstrated that a few engines (vehicle engines) can work on any mix of up to 85 percent ethanol. As of now, all significant automakers (General Motors, Ford Motor, Daimler Chrysler, Acura/Honda, Audi, BMW, Hyundai, Infinti/Nissan, Isuzu, Jaguar, Kia, Land Rover, Lexus/Toyota, Mercedes-Benz, Mazda, Mitsubishi, Porsche, Rolls Royce/Bentley, Saab, Saturn, Subaru, Suzuki, Volkswagen, and Volvo) affirm the utilization of gasohol (a blend of gasoline and ethanol.) up to 10 percent ethanol, under guarantee for the vehicles they create. Ethanol was uncovered to be an appropriate option fuel for SI engines. Be that as it may, it has a higher instability than consistent gasoline; along these lines, its outflows increment marginally in thermal climate because of dissipation.

2.5.2 BIODIESEL

Biodiesel is created when vegetable oil is responded with liquor within the sight of an impetus through a procedure of transesterification. The liquor replaces the glycerine in the vegetable oil particle to deliver an ester and glycerine. The glycerine is at that point permitted to settle out. Frequently the biodiesel is water-washed to extricate any remaining glycerine or different debasements. Biodiesel creation gives by-results of waste water also, glycerine. The favoured liquor, methanol, is conceivably unsafe and mind needs to be brought with its utilization. There are various varieties of biodiesel generation and each has its own natural focal points and burdens.

Daming H. et al. [33] ordered sustain stocks for biodiesel into yields; including soybean also, rapeseed among others. Oil trees, for example, palm oil were likewise incorporated into their findings. They noticed that these sorts of oils originated from vegetables or creature fat, making them biodegradable and nontoxic. Given the way that feedstock of biodiesel depends incredibly on atmosphere and neighbourhood soil conditions, biodiesel may not be an extremely solid fuel considering climatic change and soil corruption. A portion of the plants which shape the feedstock for biodiesel likewise set aside a long opportunity to develop, leaving biogas as a more dependable bio-fuel contrasted with biodiesel.

From the previous studies, utilization of both fluid and gaseous bio-fuels in the IC engine has been the concentration of analysts trying to find answers for the difficulties of ecological concerns and exhaustion of oil assets. Scientists have likewise probed the utilization of different gaseous fuels, for example, hydrogen, acetylene and packed flammable gas (CNG) in the IC engine as a contrasting option to the conventional diesel and petroleum fuels. Be that as it may, the high fuel costs and an expansion in the NO_X discharges related with these fuels still remains a test. What's more, a portion of the gasses such as acetylene, in spite of their amazing combustion properties require unique taking care of because of high combustibility. Biogas, which is delivered by anaerobic maturation of organic material, has been identified as an option clean power asset for the CI engine in perspective of its ecological well-disposed nature.

Dual fuel engines have been a subject of high enthusiasm because of their capability to diminish smoke outflow with enhanced exhibitions. This can be accomplished through the best possible outline of the blending device for air and the gaseous fuel prompting enhanced thermal efficiency also. The difficulties required in the modification of a diesel engine into a dual fuel engine results to; exhaust of particulates and carbon monoxide and loss of engine control because of inefficient blending of air and the fuel gas for finish combustion.

GAP IN THE LITERATURE REVIEW

From this study, it is apparent that sufficient examine has not yet been done to decide the ideal performance of a CI engine when keep running on biogas while keeping the exhaust discharges as low as could be expected under the circumstances. Utilization of biogas as an option fuel for autos still remains a test due to the issue of minimal stockpiling. Be that as it may, as scientists try to address this test, application can be made to stationary IC engines, for example, in power generation, lifting in development destinations and for pumps where biogas can be delivered and utilized at the purpose of generation.

CHAPTER 3

EXPERIMENTAL SET UP

3.1 INTRODUCTION

In this part, the modification of a Compression Ignition (CI) engine into a dual fuel engine for diesel and biogas is exhibited. The engine was modified to utilize biogas, with the concentration of keeping up high thermal efficiency while diminishing unsafe exhaust pollutants. The methodology utilized as a part of the outline and manufacture of different segments and additionally the setup of the analysis demonstrating the engine and its associate parts are appeared. From that point, the setup to measure the parameters important to assess the brake specific fuel consumption of tested fuel, brake thermal efficiency and emission property is displayed.

3.2 SET UP

The experimental setup comprised of the engine, the dynamometer, fuel supply and metering systems, engine and dynamometer water systems and measuring devices. Some of the components were designed and fabricated while others were modified to suit various applications. The test setup comprises of a single cylinder, four strokes, direct injection, water-cooled 3.5 kW diesel engine (Kirloskar made, India). The whole modified set up is shown below in figure 1. The set-up is connected to eddy current type dynamometer for loading. It is also connected to a dynamometer for loading on crankshaft. Dynamometer is cooled by water. To alter the compression ratio of the engine a cylindrical block has been incorporate with the engine. It can be done when engine is running without varying the geometry of combustion chamber.

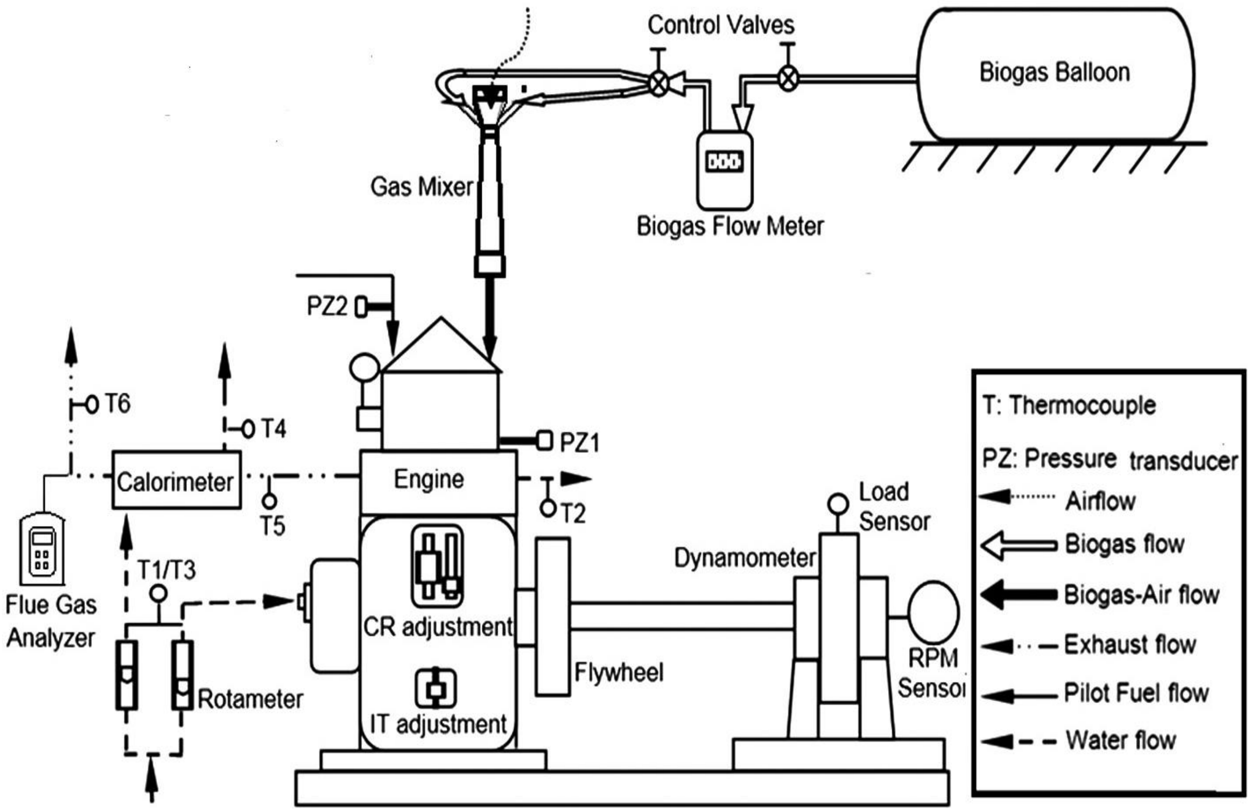

Figure 3: schematic diagram of experimental set up

To control the supply of power for load variation, controller is used and it is fitted with the panel box. A load sensor is also used to sense the load of the engine and it displays load (kg), applied on the engine, in digital form. From fuel tank the liquid fuel (diesel/ biodiesel or biodiesel–diesel blend) reaches fuel pump of diesel engine due to gravity. Total two Rotameters are fixed one is for the measuring of water flow to the engine and another one is for the measuring of water flow to the calorie meter. Engine specifications are given below in Table 1.

Table 1: Specification of engine

Parameter	Specification
Product	Engine test setup 1 cylinder, 4 stroke, Diesel
Code	234
Type of Engine	Kirloskar, Type 1 cylinder, 4 stroke Diesel
Power	3.5 kW at 1500 rpm.
Cooling type	Water cooled

CompressionRatio range	12 - 18
Dynamometer	Eddy current type and water cooled with loading unit
Air box	M S fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit with glass fuel metering column
Rotameter	Engine cooling 40-400 LPH, Calorimeter 25-250 LPH
Bore & stroke dimension	87.5 mm & 110 mm respectively
Capacity	661 cc
Load sensor	Load cell; type strain gauge; range 0 to 50 Kg
Digital milivoltmeter	Range 0-200mV; panel mounted

There are total two numbers of piezo sensors is used for measuring the pressure of fuel line and combustion pressure. Piezo sensors are fitted on the cylinder head. Every signal, which is getting from crank angle sensor, is then interfaced to computer through engine indicator to measure rotation of the diesel engine in rpm. There are total numbers of six thermocouples, which are fitted at different locations of the whole setup to measure the temperature of water and exhaust gas. The whole setup has a stand-alone panel box comprising of a manometer, fuel tank, air box, fuel measuring burette. Two Rotameters are fixed one is for the measuring of water flow to the engine and another one is for the measuring of water flow to the calorie meter. The existing diesel engine is modified by using a Venturi gas mixer at the inlet manifold for the dual fuel operation. Due to the design of the gas mixer a pressure difference is created, due to which it intake and mixes air & biogas in proper way. The liquid fuel supply is controlled by utilizing adjusted control lever system. The fuel control system is associated with fuel stopping valve. A biogas flow meter is used to measure the flow rate of biogas. The biogas, used in the experiment, is collected from a biogas digester of floating dome type. Kitchen waste, vegetable waste, food waste is used as raw material for biomass gasification.

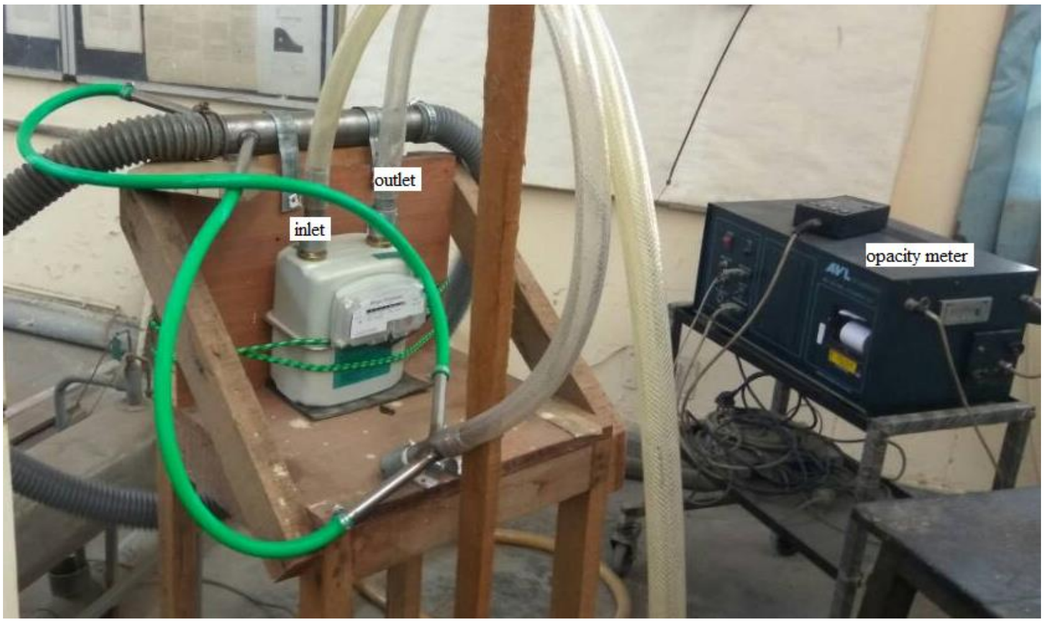

Figure 4: biogas flowmeter

3.3 BIOGAS SUPPLY SYSTEM AND FLOWMETER

A pictorial perspective of the biogas supply and metering framework is appeared in fig. below. Biogas was utilized to run the modified diesel engine in dual fuel mode and was provided to the engine from a flexible gas bag, through a biogas flowmeter to measure the flow of gas consumed by the engine.

Figure 5: biogas supply system

The framework comprised of a flexible gas bag (1000 lit), biogas flowmeter, biogas flow regulating valve. The gas was created from existing biogas digester, which is installed at Delhi Technological University (DTU). After biogas getting from the installed digester, the biogas filled balloon was transported to the engine laboratory, where experiments were done. PVC shut off valve is connected at both of opening of the biogas sack (bag). One end is fully closed and another end is connected to the flowmeter through a flow regulating valve (made of brass material). Shut of valve is used to either fully open or fully closed. Biogas flow is regulated by the flow regulating valve.

Figure 6: biogas plant installed in DTU

The biogas used in the tests was composition of 42.2% methane (CH_4) and 18.4 % carbon-di-oxide (CO_2). The composition shows the average amount of carbon dioxide in raw biogas produced in anaerobic digesters.

3.4 FLUE GAS ANALYSER

An AVL flue gas analyser (AVL digas 444) is used to analyse the emission parameter. The working method of the gas analyser is as per the following. At first, the analyser intakes fresh air and washes the entry. During the steady operation of the engine, the pipe gas is allowed to surge through a test and dried out by a condensation trap. From that point, each of the CO, HC, NO_X and CO2 pollutants focuses in the pipe gas is analysed by respective sensors and readings are at that point shown on the digital display of the control unit.

Figure 7: A view of AVL DIGAS 444, a gas analyser

Table 2: specification

Maker	AVL (AVL DIGAS 444)
Warm up time	7 min
Response time	T≤15 sec
Operating temperature	5-45℃

3.5 VENTURI GAS MIXTURE

A Venturi gas blender or gas mixer is introduced to convert diesel into dual fuel engine. The gas mixer is attached to the engine inlet manifold. It is introduced so that it can give a flammable blend of air and biogas in proper proportion. The fuel flow rate can be altered according to the required performance. At maximum load and speed of the engine gas mixer helps to supply an adequate measure of air. To design a gas mixer some parameter such as gas speed, specific fuel consumption, clearance volume, volumetric efficiency are considered. For this experiment, it uses the principle of Venturi meter. It consists of three sections according to the inlet and outlet, i) one air inlet, ii) two biogas inlet, iii) one outlet for blending of air and biogas. Again pipe section can be divided according to the shape of the pipe, i) Converge section ii) throat area, iii) diverge section. Converge section was made to increase the velocity of the fluid and it also help in decreasing static pressure. Due to the low pressure, this area will draw more gas and enhances the mixing of air and gas by creating turbulence. As a result a pressure difference is created between inlet and pipe throat.

Pressure difference is correlated with flow rate by using Bernoulli's equation:

$$P_1 - P_2 = \frac{V_2^2 - V_1^2}{2}\rho \qquad (1)$$

Using continuity equation:

$$A_1 V_1 = A_2 V_2 = Q \qquad (2)$$

$$\Delta P = \frac{A_1^2 - A_2^2}{A_1^2 \times A_2^2}\rho Q \qquad (3)$$

From the equations (3), it can be understood if density (ρ) and discharge (Q) are keep constant, pressure difference will be inversely proportional to the difference of square of the areas. Due to the reason, pressure is maximum at the throat of the pipe and it also minimise velocity at the throat region.

Figure 8: Venturi gas mixer

Four primary parameters are considered to design the Venturi gas mixer. These parameters are converging angle, nozzle angle, diverging angle and ratio between the diameters of throat and inlet manifold (β). The values of converging angle, diverging angle, nozzle angle and β are considered as 20°, 5°, 35° and 0.5 respectively as shown in (Fig .9). Diameter of throat of the mixer, inlet manifold diameter and biogas inlet pipe diameter are 20 mm, 40 mm and 10 mm respectively. However, if we consider the diverging angle of the gas mixer; i.e. 5° the length of the pipe is calculated to be 250 mm with respect to the manifold diameter of 40 mm. All of the above parameters, which are considered to design the gas mixer, are depend on the rated power (3.5 kW) of the diesel engine.

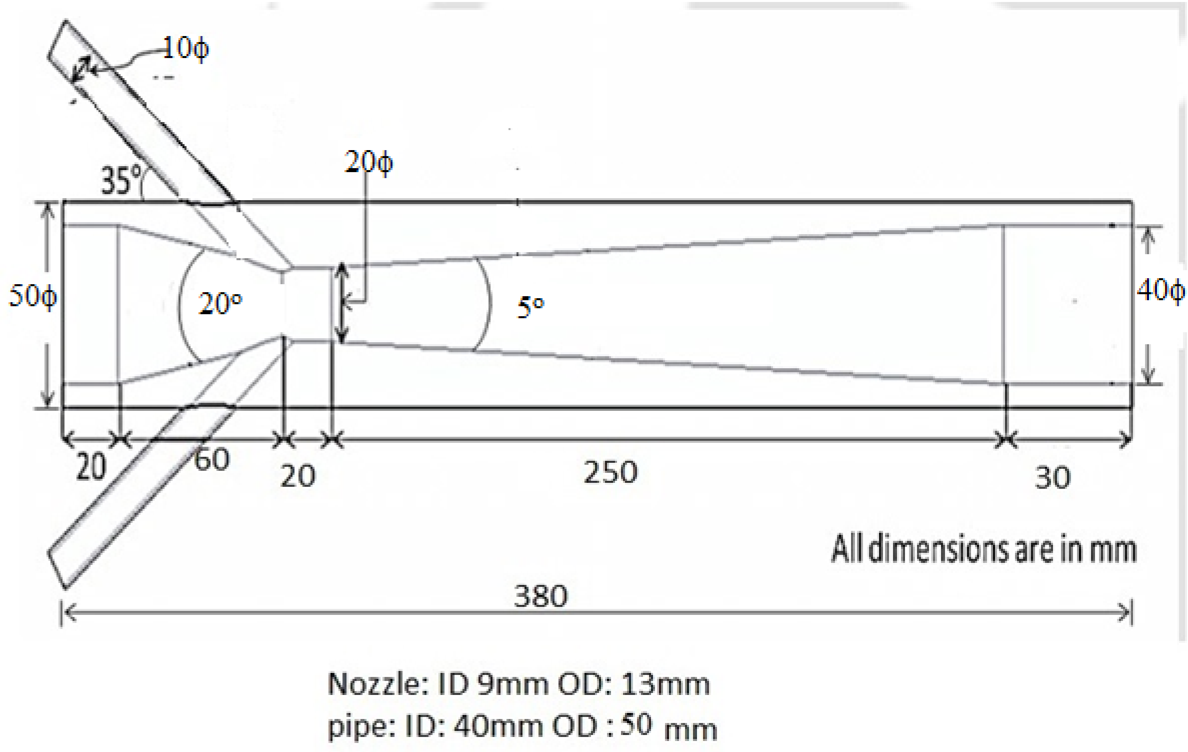

Figure 9: A schematic diagram of a Venturi gas mixer

We consider the volumetric efficiency as 90% and speed of the engine is considered as 1500 rpm. Maximum 80% diesel can be substituted by biogas in the engine.

3.6 EXPERIMENTAL PROCEDURE

At first, the test engine is kept running with diesel at a compression ratio of 18. To warm up ideally for pure combustion, the engine is at first kept running at zero load condition for quite a while. During the tests, the diesel engine is run with the increasing load from 20% to 100% load. The engine RPM decreases with the increase in load. Keeping in mind to keep up a consistent Brake Power (BP), the engine consumes more fuel. It results a higher heat output, and subsequently, a higher temperature inside the cylinder.

This increased temperature of the cooling water outlet and also the temperature of exhaust gas. At a specific indicated load, the DI engine is kept running for a couple of minutes and the cooling water outlet temperature and exhaust gas temperature are checked manually when it achieves a steady state condition. This demonstrates the ignition inside the chamber turns out to be steady. All the parameter readings such as air flow rate, fuel flow, temperature at all the inlet and outlet are recorded manually. At a specific load, at first, the rotation of the engine under diesel mode is noted. Then Biogas supply valve is opened gradually. As biogas flows into the engine, the DI engine speed increases. The speed increases because of extra energy that the engine gets because of combustion of biogas. The flow rate of biogas is gradually increased till the rotation (rpm) does not rise any further. Now, the pilot fuel that is diesel for this situation is gradually lessened by the modified fuel control valve.

The supply of pilot fuel is then decreased till original rpm run on diesel mode is accomplished for that specific load. The engine is allowed to keep running for a couple of minutes and afterward readings are recorded. Biogas flow rate is at that point noted from the biogas flowmeter. A similar method is taken after for readings at various loads.

CHAPTER 4

RESULT & DISCUSSION

4.1 INTRODUCTION

In this section, the test comes about on performance and exhaust gas or emission qualities of the dual fuel engine, modified from the compression ignition engine are displayed. The decided parameters are displayed and talked about to think about a variety of performance and emission characteristics of the dual fuel engine with an agriculture CI engine. The effect of blending ethanol with blended canola biodiesel is additionally introduced.

4.2 PERFORMANCE ANALYSIS ON DIESEL FUEL AND DUAL FUEL MODE.

BRAKE THERMAL EFFICIENCY

The brake thermal efficiency of the engine is more in the case of diesel mode only than dual fuel mode. This is due to the lower heating value of biogas.

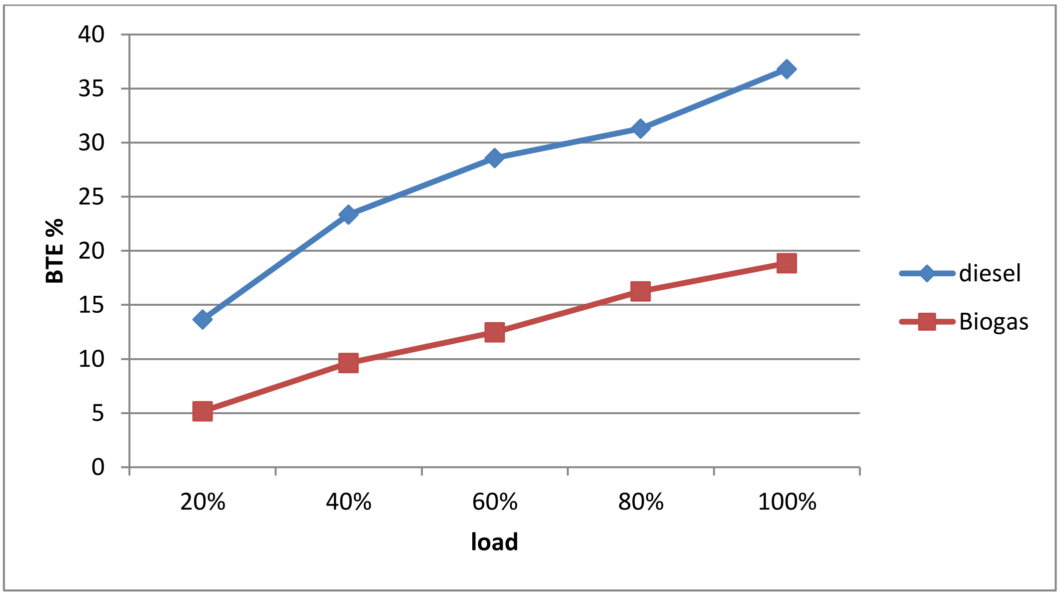

Figure 10: brake thermal efficiency vs load

Likewise, alternate variables like biogas residual, combusted residual gasses, low combustion temperature and low flame propagation speed, higher fuel flow rate during combustion is adding to the low thermal efficiency in dual fuel mode. In the above figure it can be seen that the percentage of brake thermal efficiency is increasing with the increase in the load of the CI engine.

VOLUMETRIC EFFICIENCY

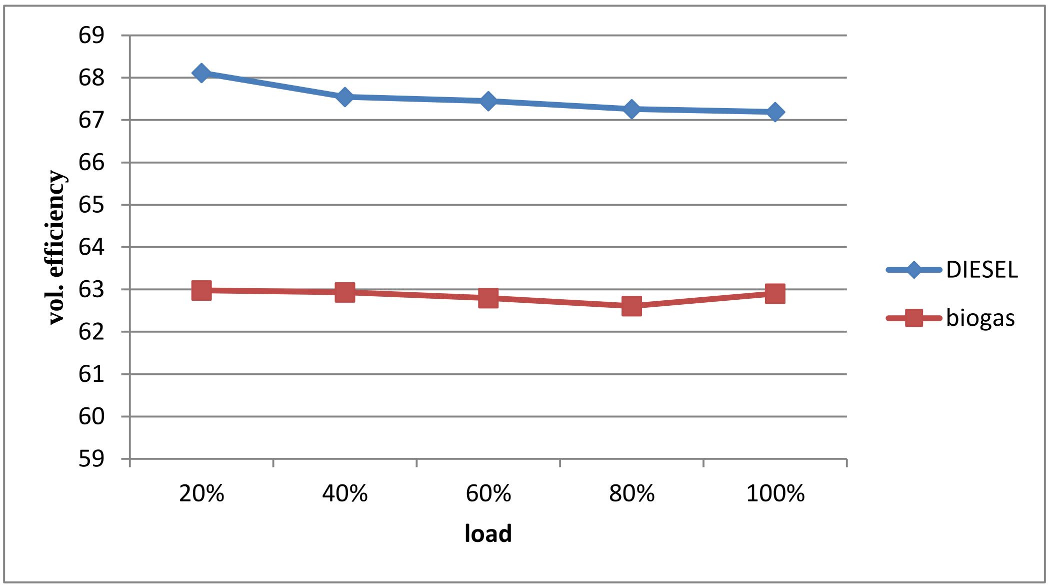

Figure 11: vol. efficiency vs load

From the above Figure.11 it is observed the volumetric efficiency ($\eta_{vol.}$) decreases with the increase in load for both diesel mode only and dual fuel modes. The exhaust gas temperature increases with the increase in load due to which it preheats the incoming air and thereby, it lowers the vol. efficiency. In the case of dual fuel mode, the biogas substitution displaces a greater portion of air with the increase of load. Hence, the vol. efficiency in dual fuel mode is lesser than the only diesel mode.

BRAKE SPECIFIC ENERGY CONSUMPTION

The brake specific energy consumption in case of diesel mode is less than that of dual fuel mode. At lower loads, the difference of Brake specific energy consumption between dual fuel mode and diesel mode is quite high. It is because of the low conversion of gaseous fuel to work.

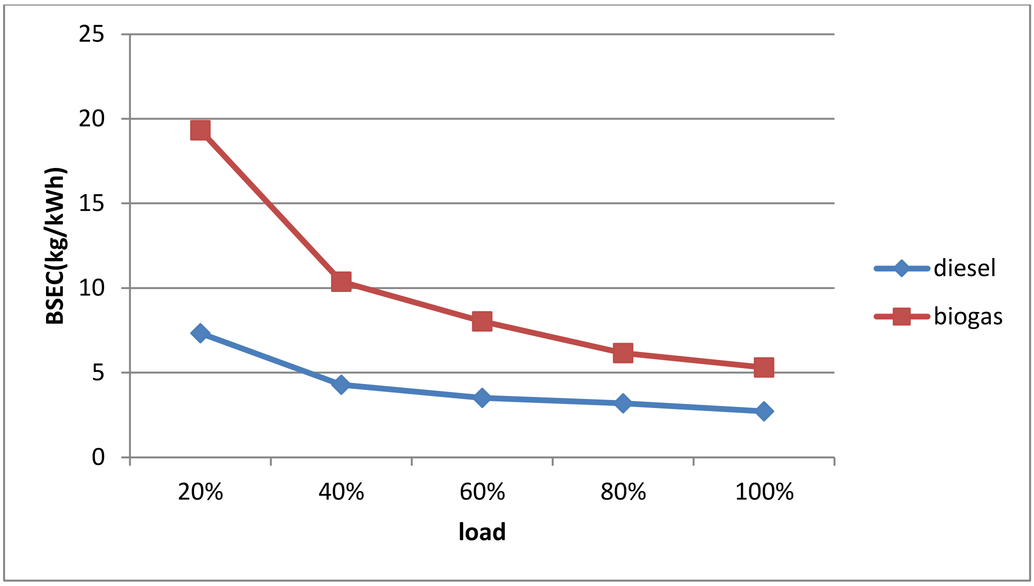

Figure 12: brake specific energy consumption vs load

However, at higher load, there is a considerable improvement in brake specific energy consumption of dual fuel mode. It is because of the high thermal load applied to the engine. This advances the high conversion of biogas into work.

4.3 EMISSION ANALYSIS ON DIESEL MODE AND DUAL FUEL MODE

VARIATION OF AMOUNT OF CO WITH LOAD

In this experiment carbon monoxide emission is higher in the case of dual fuel mode than that of diesel mode only. This is due to the stoichiometric flame speed of biogas is lesser than that of diesel. Hence, the flame front cannot propagate fast enough to consume the biogas-air mixture. At initial phase i.e. at low loads, the percentages of CO emissions are high. It then decreases at medium load, and again increases at high load, as seen in the graph. This is due to the low temperature of the cylinder at initial phase i.e. at low load, and hence the proper combustion of fuel does not happen. At higher load, a higher amount of fuel is needed. So, after a specific load, the fuel-air mixture becomes so rich that it cannot undergo complete combustion.

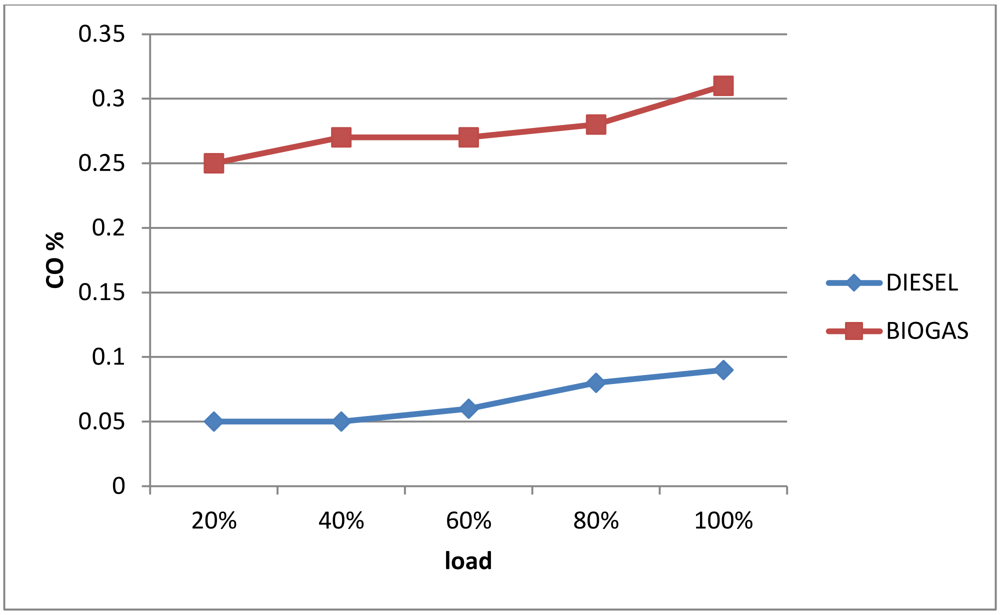

Figure 13: carbon monoxide vs load

VARIATION OF CO_2 WITH LOAD

Generally, due to the combustion of any type of hydrocarbon fuel carbon dioxide and water is produced.

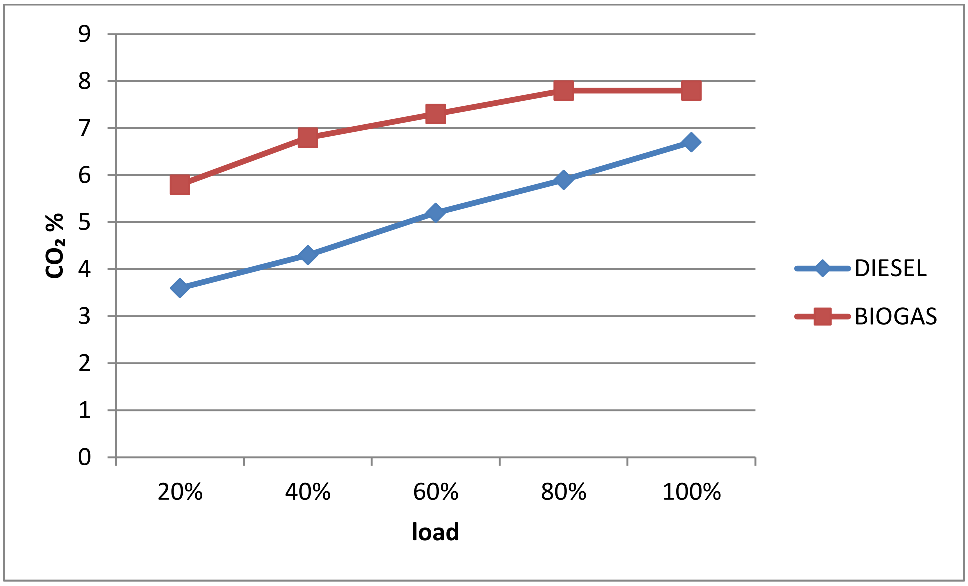

Figure 14: variation of carbon-di oxide with load

From the above figure it is seen that, the CO_2 emission is higher in the case of dual fuel mode than the diesel mode only. As CO_2 percentage in the biogas is high that's why CO_2 emission is also high in case of dual fuel mode. As seen from the above figure, in both the cases, CO_2 emission increases with the increase in loads.

VARIATION OF HYDROCARBON WITH LOADS

Due to the incomplete combustion unburnt hydrocarbon is produced. In this experiment, the amount of hydrocarbon is more in dual fuel mode than the diesel mode. This is because of the lower flame velocity of the biogas .The graph of emission of hydrocarbon particle is decreasing order in case of dual fuel mode.

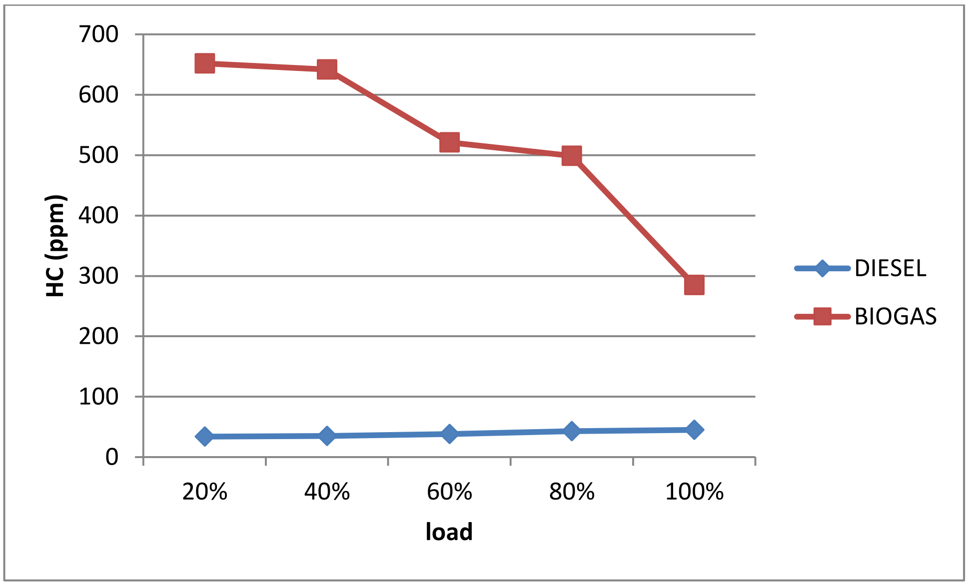

Figure 15: hydrocarbon vs load

The amount of HC particle is 34 ppm, 36 ppm, 39 ppm, 44 ppm, 45 ppm at 20%, 40%, 60%, 80%, 100% load respectively.

VARIATION OF NO_X

Due to the high temperature of combustion gases inside the engine the cylinder NO_X is formed. It is formed mainly by oxidation of nitrogen present in the intake air. Main constituents of NO_X are NO and a small amount of NO_2. In this experiment, the NO_X emission in the diesel mode is much higher than the dual fuel mode as observed in Fig 16. The reason is that NO_X formation depends upon the temperature of the combustion chamber. As diesel has high lower heating value, the temperature of the combustion chamber in case of diesel mode is higher than the dual fuel mode. Furthermore, the components of CO_2 in biogas decrease the temperature of the combustion chamber. From the graph it can be seen that the NO_X emission increases with the load as the fuel supply is increased with the increase of load. As a result temperature of the combustion chamber is increased.

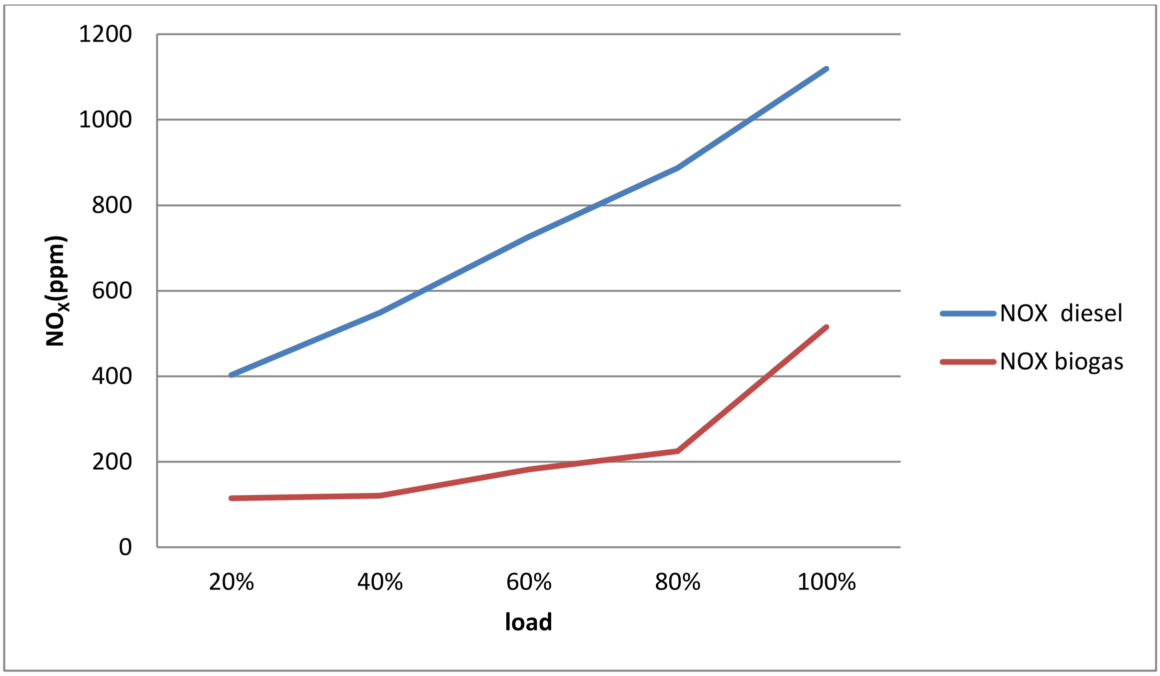

Figure 16: variation of NO_X with load

4.4 PERFORMANCE ANALYSIS OF CANOLA BLEND (B20) WITH AND WITHOUT BIOGAS

VARIATION OF BRAKE THERMAL EFFICIENCY

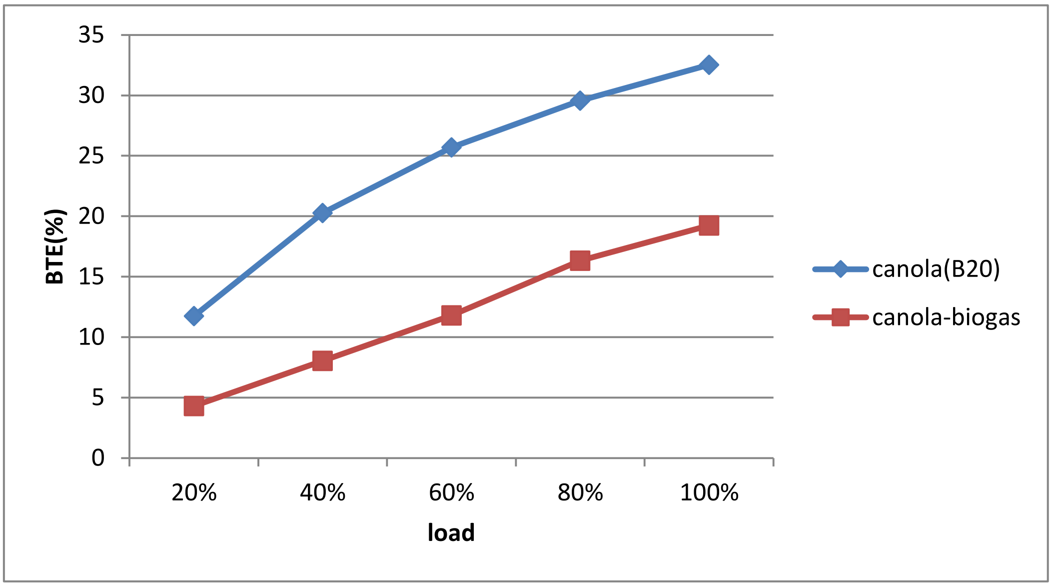

Figure 17: brake thermal efficiency vs load

In this experiment, we use canola bio-diesel in blending form as the fuel of compression ignition engine. 20% canola bio diesel is blended with diesel. As we can see in the graph, the brake thermal efficiency of only canola (B20) biodiesel is much more than that of canola (B20) with biogas. But comparing with pure diesel oil, the brake thermal efficiency of canola (B20) is 14% less than that of pure diesel. The brake thermal efficiency of canola (B20) at 20%, 40%, 60%, 80%, 100% are 11.7%, 20.3%, 25.7%, 29.5%, 32.5% respectively. The Brake thermal efficiency of both of the fuel is in increasing order with the increasing load, as depicted in the above figure.

VARIATION OF VOLUMETRIC EFFICIENCY

From the figure it is obvious that volumetric efficiency is decreasing in both the cases (i.e. canola (B20) with biogas and without biogas). From the data of the experiment, it can be seen that in the case of pure diesel trend of vol. efficiency is also decreasing but it is a little more than that of canola (B20) at lower loads.

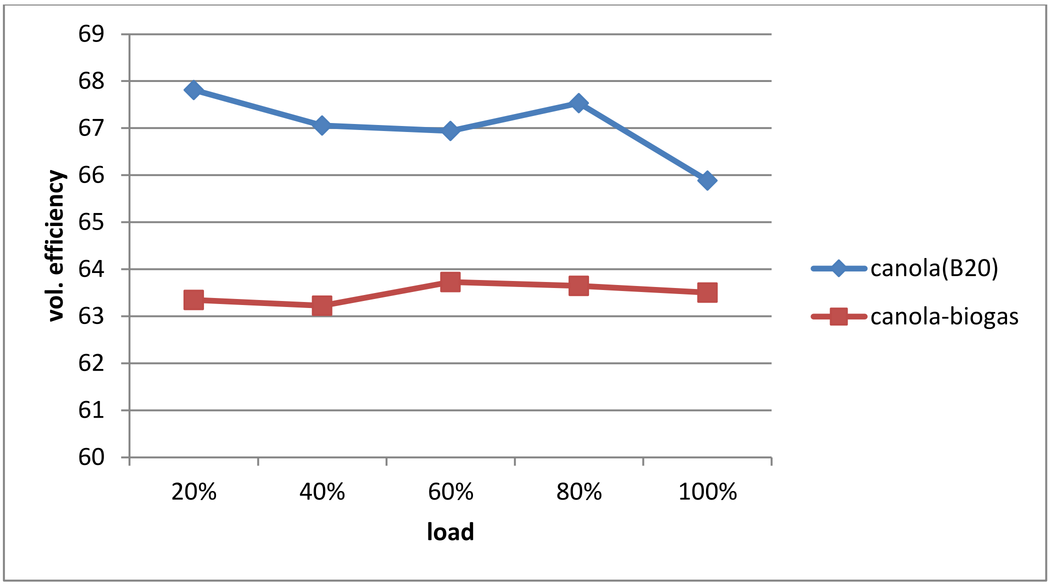

Figure 18: vol. efficiency vs load

At 20%, 40%, 60%, 80%, 100% volumetric efficiency of canola (B20) is 67.8%, 67.05%, 66.9%, 67.5%, 65.8%. At full loads, vol. efficiency of pure diesel is 2% more than that of canola (B20).

VARIATION OF BRAKE SPECIFIC ENERGY CONSUMPTION

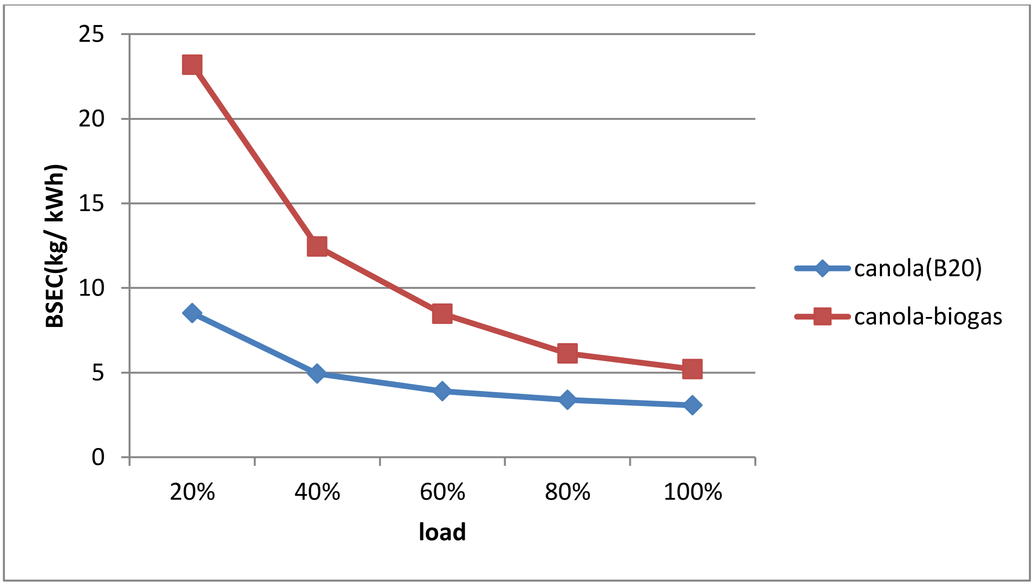

Figure 19: variation of brake specific energy consumption

The brake specific energy consumption in case of diesel mode is less than that of canola (B20)-biogas mode. At lower loads, the difference of Brake specific energy consumption between canola (B20)-biogas mode and canola (B20) mode is quite high. It is because of the low conversion of gaseous fuel to work. As the load is increased, the difference is also getting lowered. The difference between brake specific energy consumption of canola (B20) mode and canola (B20)-biogas mode is decreased 85.5%.

4.5 EMISSION ANALYSIS OF CANOLA (B20) MODE AND CANOLA (B20)-BIOGAS MODE

VARIATION OF CO EMISSION

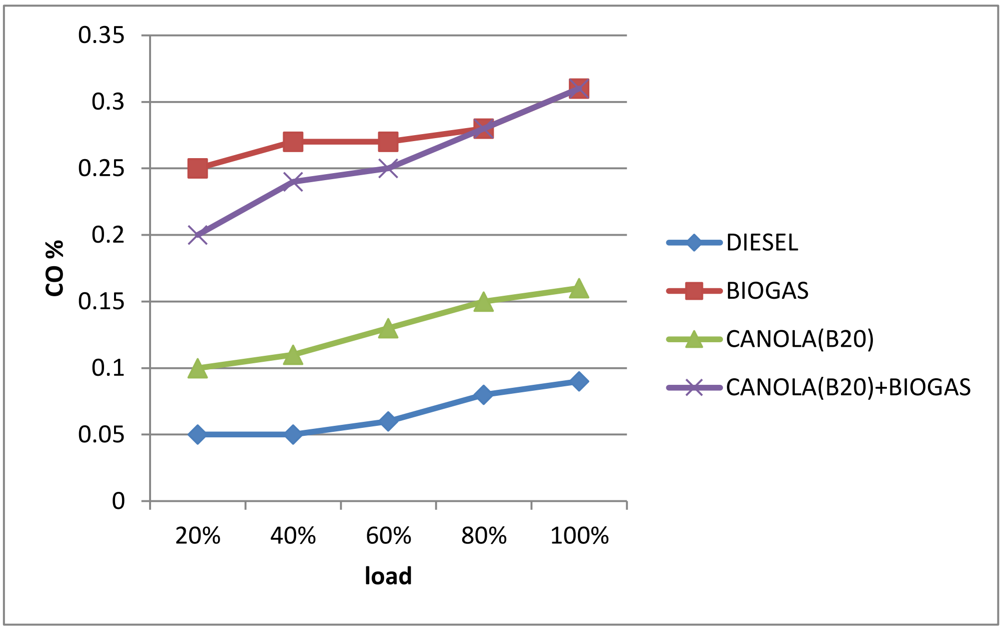

Figure 20: variation of CO emission with load

In this experiment carbon monoxide emission is higher in the case of canola-biogas mode than that of canola (B20) mode. This is due to the stoichiometric flame speed of biogas is lesser than that of diesel. Hence, the flame front cannot propagate fast enough to consume the biogas & air mixture. At initial phase i.e. at low loads, the percentages of CO emissions are high in canola (B20)-biogas mode. It then decreases at medium load, and again increases at high load, as seen in the graph. This is due to the low temperature of the cylinder at initial phase i.e. at low load, and hence the proper combustion of fuel does not happen. At higher load, a higher amount of fuel is needed. So, after a specific load, the fuel-air mixture becomes so rich that it cannot undergo complete combustion. As a result CO emission is again decreased.

VARIATION OF HC EMISSION

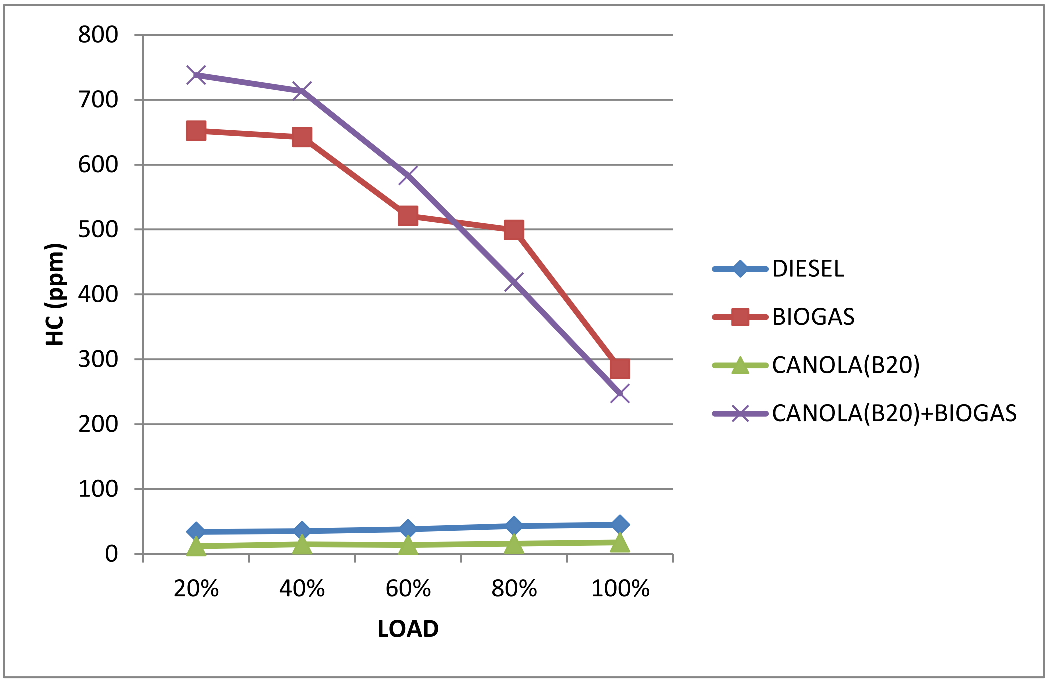

Figure 21: variation of HC emission with load

If we compare diesel mode with only canola (B20) mode, HC emission in diesel mode is higher than that of canola (B20) mode. It produces 60-65 % less hydrocarbon than the diesel mode. The HC emissions in canola (B20) mode are 12 ppm, 15 ppm, 14 ppm, 16 ppm, 18 ppm at 20%, 40%, 60%, 80%, 100% load respectively. But from the above chart, it can be seen that HC emission in diesel-biogas mode is lower than the canola (B20)-biogas mode. The trend of HC chart is in increasing order in case of both the single fuel mode and it is in decreasing order in both the dual fuel mode.

VARIATION OF CO_2 EMISSION

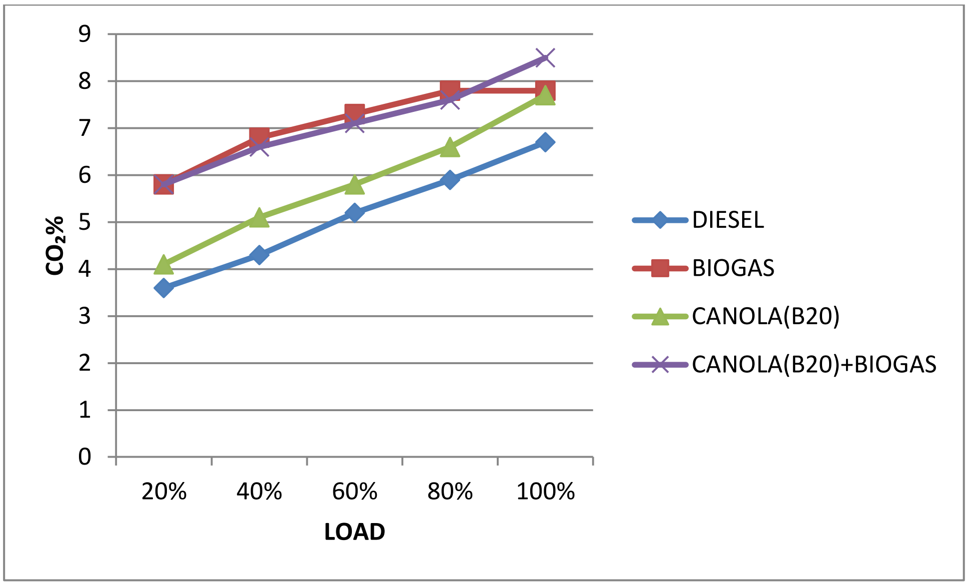

Figure 22: variation of CO_2 with load

Generally, due to the combustion of any type of hydrocarbon fuel carbon dioxide and water is produced. From the above figure it is seen that, the CO_2 emission is higher in the case of canola (B20)-biogas mode than the canola (B20) mode. As CO_2 percentage in the biogas is high that's why CO_2 emission is also high in case of canola (B20)-biogas mode. As seen from the above figure, in both the cases, CO_2 emission increases with the increase in loads. The amounts of CO_2 emissions at 20%, 40%, 60%, 80%, 100% loads are 4.1%, 5.1%, 5.8%, 6.6%, 7.7% of volume respectively.

VARIATION OF NO_X EMISSION

Due to the high temperature of combustion gases inside the engine the cylinder NO_X is formed. It is formed mainly by oxidation of nitrogen present in the intake air. Main constituents of NO_X are NO and a small amount of NO_2. In this experiment, the NO_X emission in the diesel mode is much higher than the dual fuel mode as observed in Fig 23. The reason is that NO_X formation depends upon the temperature of the combustion chamber. As diesel has high lower heating value, the temperature of the combustion chamber in case of diesel mode is higher than the dual fuel mode. Furthermore, the components of CO_2 in biogas decrease the temperature of the combustion chamber. From the graph it can be seen that the NO_X

emission increases with the load as the fuel supply is increased with the increase of load. As a result temperature of the combustion chamber is increased. But it is also seen in the graph that NO_X emission in canola (B20) mode is almost 37% higher than the diesel mode.

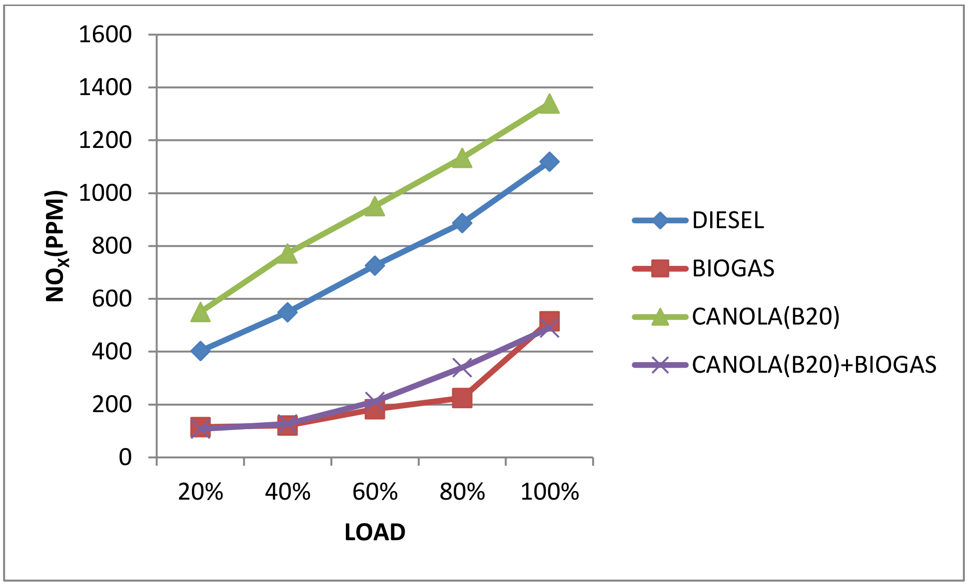

Figure 23: variation of NO_X with load

But when we use canola (B20) with biogas NO_X emission is reduced drastically. It is almost 80% less than the canola (B20) mode.

4.6 EFFECT OF ETHANOL ON THE PERFORMANCE OF CANOLA BIODIESEL IN CI ENGINE

This research studies the effect of the canola biodiesel blends with ethanol and diesel fuel on engine performance and exhaust emissions. The biodiesel was tested as BE20 (canola (B10)-ethanol (E10)-diesel) fuel mixture forms. Our main motive behind the blending of ethanol with canola biodiesel and diesel is whether we can blend ethanol with canola biodiesel to use in the diesel engine.

VARIATION IN BRAKE THERMAL EFFICIENCY (BTE)

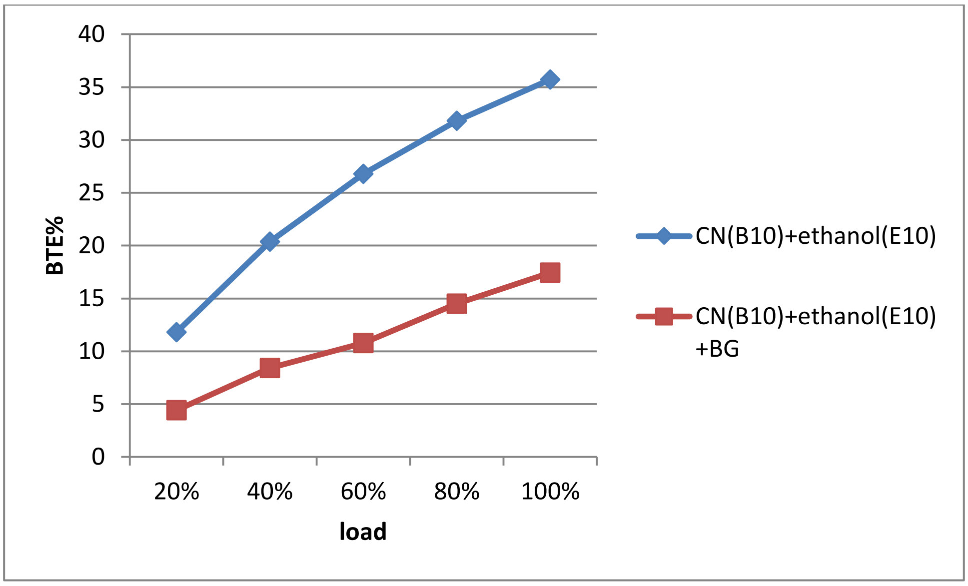

Figure 24: variation in BTE with load

Figure 23 shows the trend of brake thermal efficiency of the tested fuel. It is seen from the graph that brake thermal efficiency of the tested fuel (ethanol (E10) blended canola (B10)) with biogas is lower than that of the tested fuel without biogas. It can be observed from the graph at 20% load, the BTE is 11.82% for BE20 without biogas and 4.42% for BE20 with biogas. Brake thermal efficiency for both the fuel sample is increasing with the increase in load. Brake thermal efficiency is improved when ethanol is added to the canola biodiesel. This may be due to the more complete combustion and additional lubricity.

VARIATION IN VOLUMETRIC EFFICIENCY

Volumetric efficiency is much lower for BE20 with biogas than that of BE20 without biogas, as depicted in the Figure 25. The graph for both the tested fuel is in decreasing order with the increasing load. At 20% load the vol. efficiency for BE20 with biogas is 63.3% and for BE20 without biogas is 67.3%.

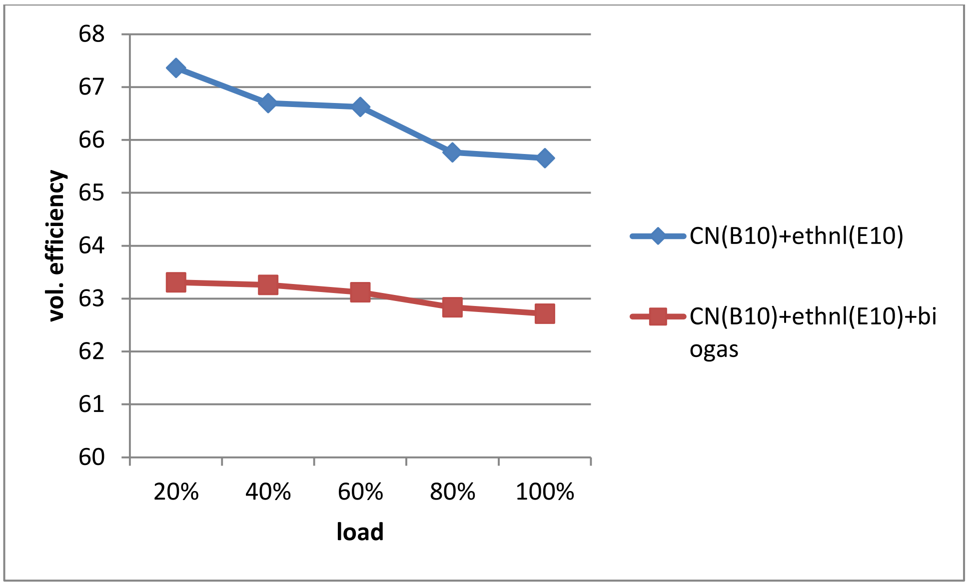

Figure 25: variation of vol. efficiency with load

But for only canola (B20) fuel vol. efficiency is little more improved than that of BE20.

VARIATION IN BRAKE SPECIFIC ENERGY CONSUMPTION

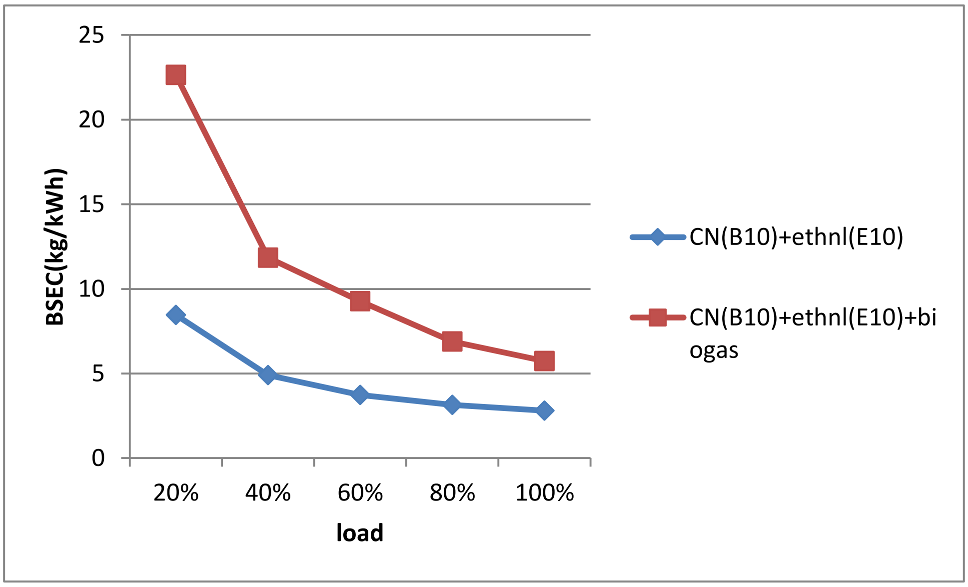

Figure 26: variation of BSEC with load

The brake specific energy consumption in case of diesel mode is less than the BSEC for BE20. At lower loads, the difference of Brake specific energy consumption between BE20 with biogas and BE20 without biogas is quite high. It is because of the low conversion of gaseous fuel to work. As the load is increased, the difference is also getting lowered. The difference between brake specific energy consumption (BSEC) of BE20 and BE20 with biogas is decreased 78%.

4.7 EFFECT OF ETHANOL ON THE EXHAUST EMISSION OF THE CANOLA BIODIESEL IN CI ENGINE

VARIATION IN CO EMISSION

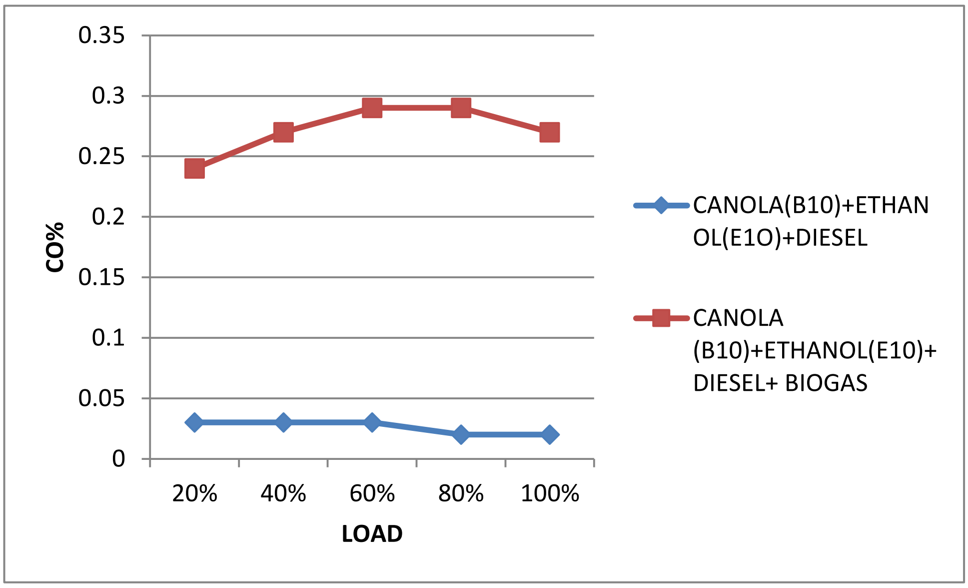

Figure 27: variation of CO emission with load

We can see from Figure. 27, that the CO emission by canola (B20) and BE20 biodiesel blends is less than the same for the corresponding diesel fuel. The reason may be the excess content of oxygen due to the addition of ethanol and canola biodiesel. Due to the excess oxygen it will increase the oxidation of CO during the entire emission process. This is done by combustion of excess O_2 in the combustion chamber by increasing the turbulence by increasing the piston speed. One can also observe from this figure that the BE20 blend fuel tends to produce lower exhaust CO values than the corresponding ones for the B20 case.

VARIATION IN HC EMISSION

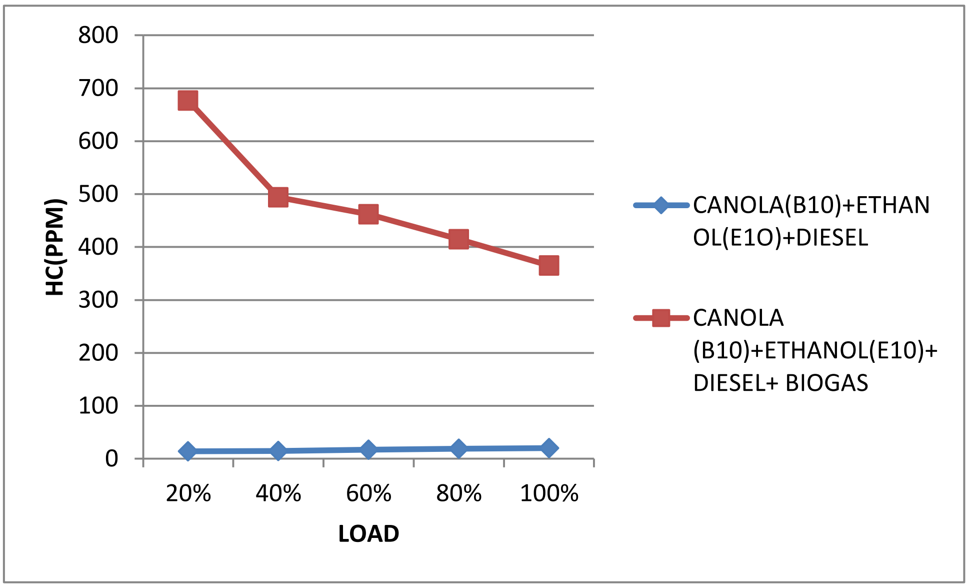

Figure 28: variation in hydrocarbon with load

If we compare diesel mode with BE20 fuel, HC emission in diesel mode is higher than that of canola (B20) mode. It produces 55-60 % less hydrocarbon than the diesel mode. The HC emissions in BE20 fuel are 14 ppm, 15 ppm, 17 ppm, 19 ppm, 20 ppm at 20%, 40%, 60%, 80%, 100% load respectively. But from the above chart, it can be seen that HC emission in BE20 fuel is lower than the BE20-biogas mode. The trend of HC chart is in increasing order in case of BE20 fuel and it is in decreasing order in BE20-biogas fuel.

VARIATION IN CO_2 EMISSION

The CO_2 emissions characteristics curve of the BE20 fuel and BE20-biogas fuel are shown in the figure 28. CO_2 emission of BE20-biogas fuel is much higher than the BE20 fuel. In case of diesel mode it is even much lower than that of BE20 fuel. As a result, it is also increase in thermal efficiency.
The CO_2 curve is in increasing order both the BE20 fuel and BE20-biogas fuel.

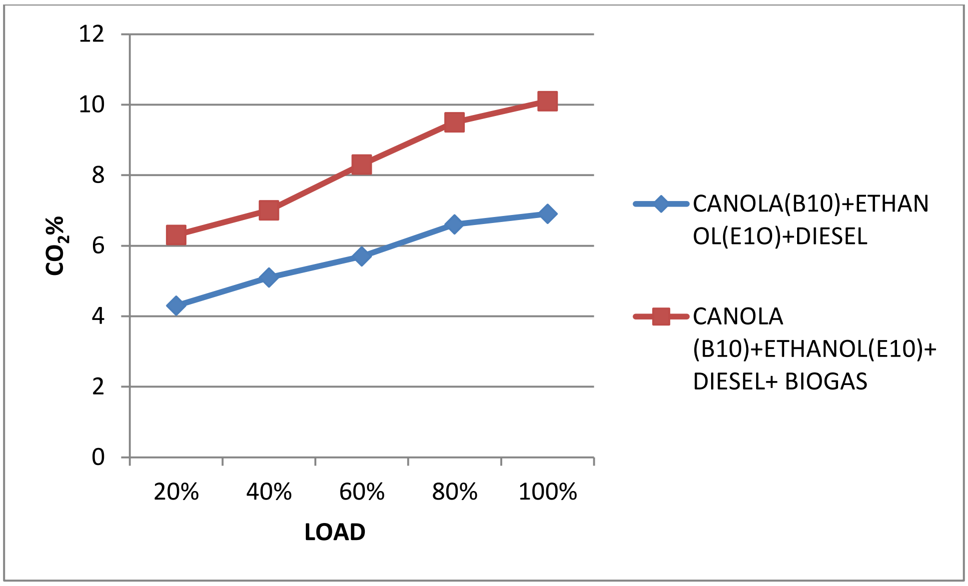

Figure 29: variation in CO_2 with the load

VARIATION IN NO_X EMISSION

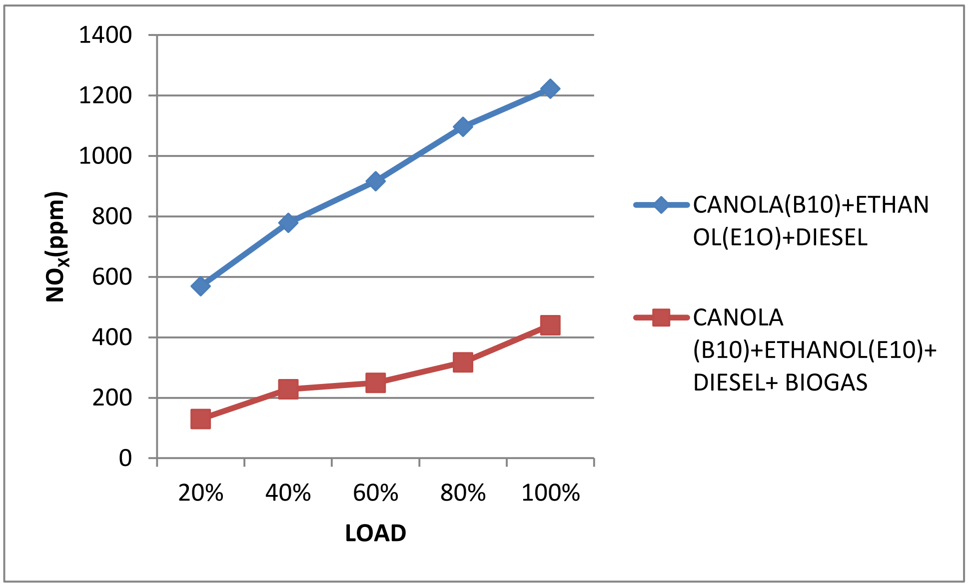

Figure 30: variation in NO_X with loads

The NO_X behaviour for both the fuel i.e. BE20 and BE20-biogas is in increasing order. But comparing BE20 fuel with canola (B20) and pure diesel it can be observed that at 20% and 40% load NO_X formation is higher in BE20 fuel but after intermediate load it is higher in case of canola (B20) fuel. When it tested with biogas NO_X formation is reduced drastically.

4.8 SMOKE OPACITY TEST

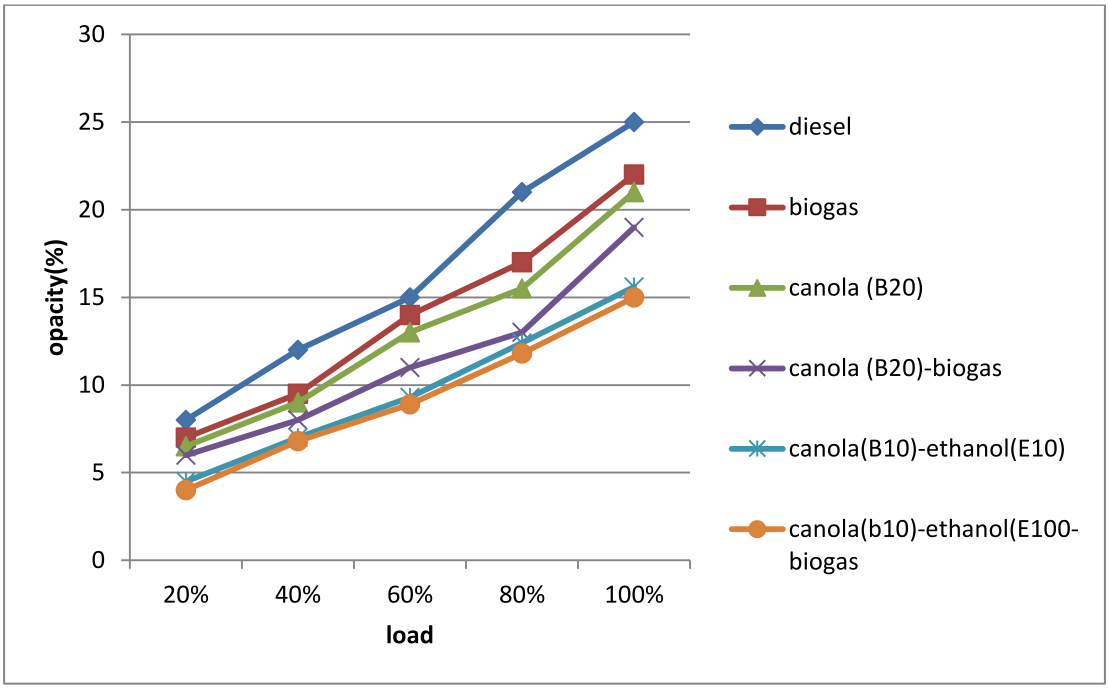

Figure 31: opacity test (%) vs load

Smoke is generally consists of particulate matter and soot. For more smoke opacity, the main reason is soot formation. Lower the smoke opacity lowers the soot formation. Smoke opacity is very low in case of dual fuel operation than that of pure diesel operation because of the biogas. As biogas have methane (CH_4) as main constituent, it has very low tendency to produce smoke. At full load, smoke opacity is decreased by 12 % in dual fuel operation. In case only canola (B20) blend as fuel in the engine, it gives much lower smoke opacity because it requires low air and as there is availability of oxygen, smoke opacity is decreased. Smoke opacity is decreased by 16 % in case of canola (B20) mode than the diesel mode. In all the case, smoke opacity increases with the increase in load.

CHAPTER 5

CONCLUSIONS

At first the diesel engine is converted into dual fuel mode to use biogas and diesel or biogas and biodiesel blend. The performance of the diesel engine is analysed by evaluating performance characteristics such as brake thermal efficiency, volumetric efficiency, brake specific energy consumption and exhaust emission is also analysed. The emission characteristics are depending on CO, HC, CO_2 and NO_X. This study is also focused on the performance of canola blend fuel. This experiment also researches the effect of ethanol on the performance and emission characteristics of canola blend diesel fuel.

- The operation of the engine is not possible by biogas alone. Diesel is substituted by the biogas for using in the dual fuel mode. Due to lower heating value of the biogas brake thermal efficiency of diesel mode is greater than that of the dual fuel mode. At full load brake thermal efficiency of diesel mode and dual mode are 36.8% and 18.8% respectively. At full load HC emission and NO_X emission of the diesel mode is 45 ppm and 1119 ppm. But in case of dual fuel mode HC content is increased to 285 ppm and NO_X content is decreased to 515 ppm.
- Volumetric efficiency of canola blend (B20) is lowered than the pure diesel. At 100% load volumetric efficiency of pure diesel and canola blend (B20) is 67.19% and 65.88% respectively. In case of canola (B20) blend amount CO and CO_2 is higher than that of pure diesel but the amount of hydrocarbon is less than the pure diesel. In case of NO_X, at lower load it is less for diesel and at higher load it is higher for canola (B20) blend.
- NO_X formation is always being lowered in case of biogas. But whenever diesel is partially substituted by biogas other contents like unburnt hydrocarbon is increased.

- Adding ethanol with canola (B20) blend as additive, BTE is increased. At full load, BTE for canola (B20) is 32.53% and BTE for canola-ethanol (BE20) blend is 35.7%.
- Advantage of the adding ethanol as additive is that unburnt hydrocarbon particle and carbon mono oxide particle is lowered due to more combustion. As adding ethanol to the fuel means increasing oxygen content in the fuel.
- Smoke opacity is very low in case of dual fuel operation than that of pure diesel operation. In case only canola (B20) blend as fuel in the engine, it gives much lower smoke opacity because it requires low air and as there is availability of oxygen, smoke opacity is decreased. Smoke opacity is decreased by 43 % in case of canola (B20) mode than the diesel mode.

CHAPTER 6

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