EXPERIMENTAL ANALYSIS USING TAGUCHI AND OPTIMIZATION OF DIFFERENT BLENDS OF BIODIESEL IN MULTIFUEL C.I ENGINE

By

Sanika Prabhu

15MMET24

DEPARTMENT OF MECHANICAL ENGINEERING

INSTITUTE OF TECHNOLOGY

NIRMA UNIVERSITY

AHMEDABAD-382481

MAY 2017

EXPERIMENTAL ANALYSIS USING TAGUCHI AND OPTIMIZATION USING DIFFERENT BLENDS OF BIODIESEL IN MULTIFUEL C.I ENGINE

Major Project Report

Submitted in partial fulfillment of the requirements

For the Degree of

Master of Technology in Mechanical Engineering (Thermal Engineering)

By

Sanika Prabhu

(15MMET24)

Guided By

Dr. A.M Lakdawala

Prof. N.K Shah

DEPARTMENT OF MECHANICAL ENGINEERING

INSTITUTE OF TECHNOLOGY

NIRMA UNIVERSITY

AHMEDABAD-382481

MAY 2017

Declaration

This is to certify that

1. The thesis comprises my original work towards the degree of Master of Technology in Thermal Engineering at Nirma University and has not been submitted elsewhere for a degree or diploma.

2. Due acknowledgement has been made in the text to all other material used.

Sanika Prabhu

15MMET24

Undertaking for Originality of the Work

I, **Sanika Prabhu**, Roll. No. **15MMET24**, give undertaking that the Major Project entitled "**EXPERIMENTAL ANALYSIS USING TAGUCHI AND OPTIMIZATION OF DIFFERENT BLENDS OF BIODIESEL IN MULITFUELED C.I ENGINE** " submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Mechanical Engineering (Thermal Engineering)** of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

Signature of Student

Date:

Place: Nirma University, Ahmedabad.

Endorsed by

(Signature of Guide)

Certificate

This is to certify that the Major Project Report entitled **"EXPERIMENTAL ANALYSIS USING TAGUCHI AND OPTIMIZATION FOR DIFFERENT BLENDS OF BIODIESEL IN MULITFUELED C.I ENGINE"** submitted by **Ms. Sanika Prabhu (15MMET24)**, towards the partial fulfillment of the requirements for the award of Degree of **Master of Technology in Mechanical Engineering (Thermal Engineering)** of Institute of Technology, Nirma University, Ahmadabad is the record of work carried out by him under our supervision and guidance. In our opinion, the submitted work has reached a level required for being accepted for examination.The result embodied in this major project, to the best of our knowledge, has not been submitted to any other University or Institution for award of any degree.

Prof N K Shah
Assistant Professor,
Department of Mechanical Engineering
Institute of Technology,
Nirma Univerisity,
Ahmedabad

Dr. A M Lakdawala
Associate Professor,
Department of Mechanical Engineering,
Institute of Technology,
Nirma University,
Ahmedabad.

Dr. R. N. Patel
Professor and Head,
Department of Mechanical Engineering,
Institute of Technology,
Nirma University,
Ahmedabad.

Dr. Alka Mahajan
Director,
Institute of Technology,
Nirma University,
Ahmedabad.

Acknowledgments

I take this opportunity to express deep sense of gratitude and sincere thanks for the invaluable assistance that I have received from my honorable and learned guide Prof A M Lakdawala (Associate Professor, Mechanical Engineering Department, IT, NU). He is the constant source of encouragement and momentum that any intricacy becomes simple. I gained a lot of invaluable guidance and prompt suggestions from him during my thesis work. I remain indebted of him forever and I take pride to work under him. My sincere thanks and due respect to my co-guide Mr. N.K Shah for his constant cooperation, valuable suggestions and guidance throughout this dissertation work and also Prof Shruti Mehta for her support in learning Minitab 17. I am very thankful to Dr. R N Patel (HOD, MED) and Dr. Alka Mahajan (Director, IT, NU) and all the faculty members of Mechanical Engineering Department who have directly or indirectly helped me during this dissertation work.My special thanks to my friends of M.Tech Thermal Engineering. At the end I am thankful to god, my family, and colleagues who have directly or indirectly helped me during this dissertation work and for their encouragement.

SANIKA PRABHU

Abstract

Energy being necessity for development of any country needs to be conserved and used judicially. World energy demand is continously increasing due to wide development in industrialization and rapid increase in population that our limited reservoirs of energy will soon be exhausted because of our current rate of consumption.Due to rapid depletion in world petroleum reserviours as well as harsh environmental concerns due to polution have stimulated the research for alternative renewable fuels that are capable of fulfilling our current increase in energy demand. In recent decades, the research concerning about the benefits of using renewable energy has intensified the efforts for sustainable energy sources. Both the energy needs as well as increased environmental destruction has stimulated the research for an alternative energy resourse.Biodiesel plays an important role in this area because of its properties as well as development activities to become a perfect candidate to replace fossil fuels.

Biodiesel fuel (fatty acid methyl ester (FAME)) which is derived from vegetable oil, primarily contains triglycerides (TGs) and free fatty acids (FFAs), is considered as the best option for substitution of diesel fuel in diesel engines which can be used as (100% biodiesel) or it can be blended with petroleum or diesel.It is a possible alternative (or extender) to petroleum or diesel fuel.

In this project we investigate the optimum blend of biodiesel with diesel in multifueled CI engine present in nirma university mechanical lab.Suitable blends like B10,B20,B30,B40,B50 and B70 are prepared and tested on 1 Cylinder, 4 Stroke, Multi-fueled,VCR(Computerized) present in Nirma University.Also a mathematical model using taguchi method in minitab17 is prepared using results of B10,B50,B70 and its interactions with Compression ratios 16,17,18 ansd Injection Pressure 180,200,220 are observed to find a scientific way of optimizating the result for different blends of biodiesel.

Contents

List of Figures

List of Tables

Abbriviations

kW	kilowatt
BSFC	Brake Specic Fuel Consumption
BMEP	Brake mean eective pressure
BTHE	Brake thermal efficiency
CV	Caloric value
CO	Carbon monoxide
CO2	Carbon dioxide
NOx	Nitrogen oxide
HC	Hydrocarbon
B0	Pure Diesel
B10	10% Bio-diesel mix with diesel
B20	20% Bio-diesel mix with diesel
B30	30% Bio-diesel mix with diesel
B40	40% Bio-diesel mix with diesel
B50	50% Bio-diesel mix with diesel
B70	70% Bio-diesel mix with diesel
CI	Compression Ignition
IP	Injection Pressure
S/N	Signal/Noise

Chapter 1

INTRODUCTION

Fossil fuels are derived from dead plants and animals buired under earth's crust over million of years ago .Fossil fuels are being used for fulfiling our energy requirments over a century. Almost 90% of our energy comes from fossil fuels currently as well.They are non-renewable sources of energy that take millions of years for their replenishment. Fossil fuels usually comes in form of coal, oil or natural gas. They are cheapest and easily available amoung all the fuels to acquire and use. The widespread use of these resources have immensely improved living conditions , the productive and meaningful lives that we are accustomed to today would be simply impossible without these. Consumption of fossil fuel has provided immense benefit to humankind.Fossil fuels are of precious importance as they are burned (oxidized to carbon dioxide and water) to producing significant amounts of energy per unit weight[17].

World energy consumption is total energy used by entire population of world. Typically measured per year, it involves all the energy harnessed from each and every energy source which is applied towards humanity's endeavors in every single industrial and technological sector, across each and every country in world. Being the power source metric of civilization, The World Energy Consumption has deep implications on humanity's social-economic-political sphere.

Fossil fuels is a non-renewable resource which take millions of years for its production. It is estimated fromour given current trends in consumption, and predictive discovery of new sources of fossil fuels, that the world is possible to run out of them within 100 to 200 years.Fossil fuels are also main cause of environmental issues like global warming, acid rain, air pollution, water pollution . Their production and consumption is one of the major reason for world polution.

1.1 Depletion of Fossil Fuel And Increase in Emmision Threats

Non-renewable resources are the energy sources that is consume faster than nature replenishes them. Fossil fuels such as coal, natural gas and crude oil take centuries for their formation naturally. These resources are not infinitely present and over a period of time, most experts believe that they will become extint .Perdiction based on the current worldwide consumption rates :The natural gas supply will run out within the next 35 years. and world oil reserves within next 70 years .Looking at the current rate of consumption for oil, the supply will run out in next 14 years.

Coal, oil, and gas mainly contains carbon and hydrogen. The process of burning is a chemical reaction with oxygen present in the air as a result of which carbon combines with oxygen to form carbon dioxide (CO2), and hydrogen combines with oxygen to form water vapor (H20). In these chemical reactions a substantial amount of energy is liberated as heat. Since heat is required to instigate these chemical reactions, we have a chain reaction: reactions cause heat, which causes reactions, which cause heat, and so on. Once the proces is started it continues until nearly all of the fuel has gone through the process (i.e., burned), or until something is done to stop it. The reason for arranging all this is to derive the heat**??**.

The carbon dioxide which is released during this process is the main cause of the greenhouse effect. A largescale coal-burning plant on an average annually burns around 3 million tons of coal which approximately produces 11 million tons of carbon dioxide. The water vapor released have no problems, since the amount of water vapour present in the atmosphere is determined by evaporation from the oceans — if more is produced by burning, that will result inmuch less evaporation from the seas.

Carbon dioxide levels are higher now than at any time in the past 750 000 years[18]. with beginning of the industrial revolution in the 18th century, the combustion of fossil fuels has raised CO2 levels from a approximately 280 parts per million (ppm) in the atmosphere in pre-industrial times to around 387 ppm today.Concentration of CO2 is increasing at a rate of about 2–3 ppm/year.

1.2 Renewable resources

Renewable energy is the form of energy that is produced or derived from natural processes which are replenished constantly. It is also derived directly from the sun, or from heat generated within the earth's crust.Renewable energy can also be defined as energy that is produced from resources which are naturally replenished in human lifetime, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable resources also includes goods or commodities such as wood, paper and leather, because these sources are renewable.Renewable resources are usually cleaner and plays an important role in reducing greenhouse gas emissions too. As renewable energy sources are used often, the dependence on fossil fuels is reduced. Unlike fossil fuels, except non-biomass renewable sources of energy (hydropower, geothermal, wind, and solar) does not directly emit greenhouse gases.

But renewable energy is more expensive to produce and to use than fossil fuel energy. Renewable resources which can be utilized are mostly located in remote areas, and it can be expensive to build power lines from the renewable energy sources to the cities that need the electricity.Despite this The consumption of biofuels and nonhydroelectric renewable energy sources has doubled from 2000 to 2015, mainly because of state and federal government mandates and incentives for renewable energy[20]1.1. The U.S. Energy Information Administration (EIA) predicts that the use of renewable energy in the United States will continue to grow through 2040.

Types of Renewable energy resources are:

- Solar Energy
- Wind Energy
- Hydropower
- Geothermal Energy
- Biomass

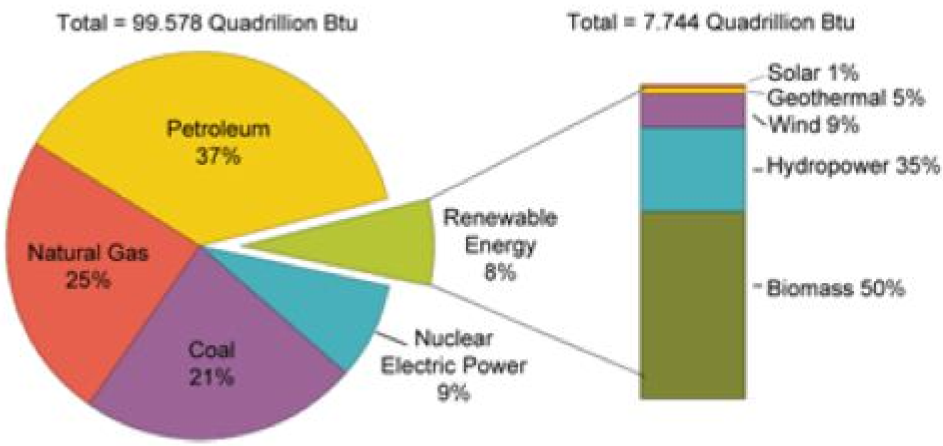

Figure 1.1: Renewable Energy Consumption

1.3 Biodiesel a Promising Alternative

Biodiesel is a renewable fuel which can be use of instead of the diesel and petroleum fuels. Biodiesel is most commonly produced by the transesterification of the vegetable oil or animal fat feedstock. There are several methods for carrying out this transesterification reaction including the common batch process, supercritical processes, ultrasonic methods, and even microwave methods. Rapeseed oil, sunflower oil, and palm oil are sources of the biodiesel that are consumed in many countries.Biodiesel is most commonly blended with petroleum or diesel in ratios of 2% (B2), 5% (B5), or 20% (B20). Biodiesel also can be used as pure biodiesel (B100) in regular diesel engines without making any changes in the engines. It also can be stored and transported using diesel fuel tanks and equipment.Before petroleum and diesel fuel became popular, Rudolf Diesel, the inventor of the diesel engine in 1897, experimented using vegetable oil (biodiesel) as fuel.Biodiesel is safe for the environment as it is made from renewable resources and has lower emission rate compared to petroleum and diesel. It's less toxic than salt and biodegrades as fast as sugar. It is produced domestically with natural resources. Its use decreases our dependence on imported fuel and contributes to our own economy.Global biodiesel production has reached 3.8 million tons in 2005. Approximately 85% of biodiesel production comes from the European Union.

1.3.1 Blends

Mostly everyone uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix:

- 100% biodiesel is referred as B100
- 20% biodiesel, 80% petrodiesel is referred asB20
- 5% biodiesel, 95% petrodiesel is referred as B5
- 2% biodiesel, 98% petrodiesel is referred as B2

Blends of 20% biodiesel and lower can be used in diesel equipment with no or minor modifications, although some manufacturers do not extend warranty coverage if equipment is damaged by these blends. The B6 to B20 blends are given by the ASTM D7467 specification.

1.3.2 Advantages of biodiesel

1. Produced from Renewable Resources: Biodiesel is a renewable energy source . Since it is made from animal and vegetable fat, it can be produced easily and also causes less pollution than petroleum diesel.

2. Diesel Engines: One of the main advantage of using biodiesel is that can be used in existing diesel engines with little modifications and can replace fossil fuels to become the most preferred primary transport energy source. Biodiesel can also be used in

100% (B100) or in blends with petroleum and diesel. For e.g.: B20 is called as 20% blend of biodiesel with 80% diesel fuel. It improves engine lubrication and increases engine life since it is sulphur free.

3. Less Greenhouse Gas Emissions (e.g., B20 reduces CO2 by 15%): Fossil fuels when ignited release greenhouse gases like carbon dioxide in the atmosphere that raises the temperature and causes global warming. To protect the environment from further damaging, many people have adopted the use of biofuels. It believe that using biodiesel instead of petroleum diesel can reduce greenhouse gases up to 78%.

4. Grown, Produced and Distributed Locally: Fossil fuels are limited and may not be able to fulfill our demand for coal, oil and natural gas after some years. Biodiesel can work as an alternative form of fuel and can reduce our dependence on foreign suppliers of oil as it is made from domestic energy crops.

5. Cleaner Biofuel Refineries: When oil is extracted from underground, it has to be refined . It can't be used straight away in the crude form. When it is refined, it releases many chemical compounds including benzene and butadiene which are harmful for animals, plants and human life. Biofuel refineries, which mainly uses vegetable and animal fat into biofuel releases less toxic chemicals.

6. Biodegradable and Non-Toxic: When Biofuels are ignited, they produce significantly less carbon output and few pollutants. As compared to petroleum and diesel fuel, biodiesel produces less soot (particulate matter), carbon monoxide, unburned hydrocarbons, and sulfur dioxide. Flashpoint for biodiesel is higher than 150°C whereas it is 52°C for petroleum diesel, which makes it less combustible[10]. Therefore it is safe to handle, store and transport.

7. Better Fuel Economy: Vehicles that run on biodiesel achieve 30% fuel economy than petroleum or diesel engines which means it makes fewer trips to gas stations and run more miles per gallon.

8. Positive Economic Impact : Biofuels are manufactured locally and thousands of people are employed in biofuel production plant. Since biodiesel is produced from crops , an increase in demand for biodiesel leads to increase in demand for biofuel crops. Moreover, it also creates less emission by reducing the amount of suspended particles in the air and reduces the cost of healthcare products.

9. Reduced Foreign Oil Dependance: As the biofuels are produced locally, many countries have reduced their dependance on fossil fuels. It may not solve all problems in one blow but a nation can save billions by reducing their usage on foreign oil.

10. More Health Benefits: Pollutants from gasoline engines when released in the air, form smog and make thousands of people ill every year. Biodiesel produce less toxic pollutants than fossil fuels.

1.3.3 Disadvantages of biodiesel

1. Variation in Quality of Biodiesel: Biodiesel is made from a variety of biofuel crops. When the oil is extracted and converted into fuel using chemical process, the result can vary in ability to produce power. In short, not all biofuel crops have same amount of vegetable oil .

2. Not Suitable for use in Low Temperatures: Biodiesel gels up in cold weather but the temperature that it will gel depends on the oil or fat that was used to make it. The best possible way to use biodiesel during the colder months is to blend it with winterized diesel fuel.

3. Food Shortage: Since biofuels are made from animal and vegetable fat, more demands for these products may lead to rise in prices for these products and create food crisis in some countries.

4. Increased use of Fertilizers: As more crops are grown to produce biofuels, more fertilizer is being used which can have devastating effect on environment. The excess use of fertilizers can result in soil erosion and can lead to land pollution as well.

5. Clogging in Engine: Biodiesel clears dirt from the engine thus preventing from clogging.

6. Regional Suitability: Some regions are not fit for oil producing crops. The most productive crops can't be produced anywhere and they need to be transported to the plants which leads to increase cost and amount of emission associated with the production and transportation.

7. Water Shortage: The use of water is required to produce more crops can put pressure on local water resources. The areas where there is water scarcity, production of these crops is not a wise idea.

8. Monoculture: Monoculture is to the practice of producing same crop over and over again rather than producing different crops. While this results in fetching best price for the farmers but it has some serious environmental demerits. When the same crop is grown over large acres, the pest population may grow and it may also go beyond control. Without crop rotation, the nutrients of soil are not regained back which may result in soil erosion.

9. Fuel Distribution: Biodiesel is not well distributed as petroleum and diesel. The infrastructure still requires many modifications so that it is adopted as most preferred way to run engines.

10. Use of Petroleum Diesel to Produce Biodiesel: It requires more amount of energy to produce biodiesel fuel from soy crops as energy is needed for sowing, fertilizing and harvesting crops[10]. Apart from that, raw material are needed to be transported through trucks which may consume some additional fuel. Some scientists believe that production of one gallon of biofuel needs energy equivalent to several gallons of petroleum fuel.

11. Slight Increase in Nitrogen Oxide Emissions: Biodiesel is believed to have about 10% higher Nitrogen Oxide than other petroleum products. Nitrogen Oxide is one of the major gas that is used in the formation of smog and Ozone. Once it is dissolved in atmospheric moisture, can cause acid rain.

1.4 Optimization is needed

Over the years scientists and researchers have carried out several experiments on CI engine using different blends of biodiesel and comparing the results with fossil fuels[13].Following are the common conclusion that has been obeserved:

There is a small difference observed in break specific fuel consumption for different blends at various engine loads.

There is a steady increase of temperature with increase in engine load.

It is found that the NOx emission increases directly with increased temperature(as the engine load increases).

The biodiesel contribution increases the power output and the amount of heat release is observed to be higher for increased proportion of biodiesel.

The efficiency of electrical output increases with increase in engine load due to which NOx emission also increases.

The net utilisation factor is observed significantly higher than the efficiency of the system under single generation mode.

Adding the heat exchanger to the system to extract additional heat from the exhaust gases is observed to increase the overall efficiency of the system between 15% and 25%.

Hence due to following observations optimization is needed to make biodiesel as an alternative to fossil fuel.

1.5 Taguchi Method

Taguchi method is a simplest method used for optimization,it optimises experimental parameters using less number of trials. The number of parameters that are involved in the experiment determines the number of trials which required for the experimentation. More the number of parameters more will be the number of trials as a result it will consume more time to complete the experiment[12]. Hence, it optimise the levels of the parameter involved in the experiment. This method uses an orthogonal array to study the entire parameter space with just a small number of experiments .For selecting an appropriate orthogonal array for the experiments, the total degrees of freedom is computed. The degrees of freedom are defined as the number of comparisons between design parameters that need to be made1.2.

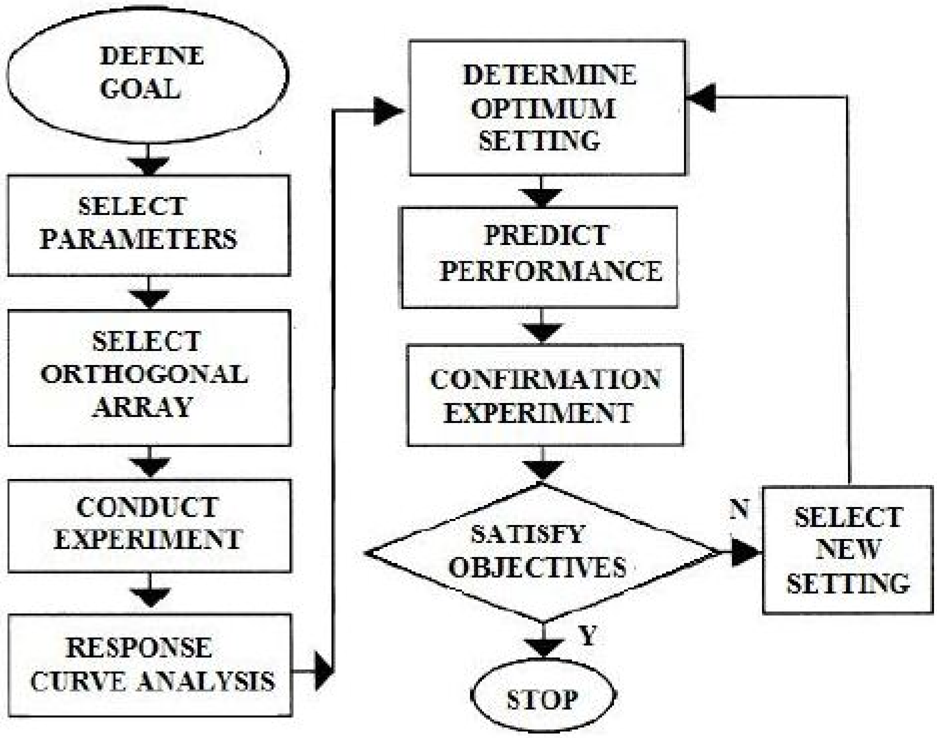

Figure 1.2: Flow chart of taguchi method

The optimum condition is identified by studying the main effects of each of the parameters. The main effects indicate the general trend of influence of each parameter. The steps involved in DOE method are:

- Identifying the response functions and control parameters to be evaluated.
- Determining the number of levels of the control parameters.
- Selecting the appropriate orthogonal array, assigning the parameters to the array and conducting the experiments.

- Analyzing the experimental results and selecting the optimum level of control parameters.

- Validating the optimal control parameters through a confirmation experiment.

In the present investigation, the S/N data analysis has been performed. The effect of the selected control parameters on the response functions has been investigated. The optimal conditions are established and verified through a confirmation experiment.

Chapter 2

LITERATURE REVIEW

Based on problem definition, before carrying out a project, it is required to know the work carried out by different researchers nationally and internationally. Number of journals and conference papers were reviewed, out of which papers with concern topic are briey summarized as under.

R. Maceiras, A. Cancela, M. Rodríguez, A. Sánchez1, S. Urréjola Chemical Engineering Department. University of Vigo. Campus Lagoas-Marcosende. 2Materials Department. University of Vigo.(2010): In this, paper Biodiesel production from oil extracted from marine algae is feasible by transesterification. Moreover, this study indicates that the oil extraction can be carried out simultaneously with the transesterification[21]. Finally, the authors of this work consider that algae biodiesel stocks may become in the future a very attractive investment due to the technique positive points related to the technology.

S. Oberweis, T.T Al-Shemmeri Faculty of Computing, Engineering and Technology Staffordshire University (2010): In this paper, there is a small difference in break specific fuel consumption for different blends at various engine loads. There is a steady increase of temperature with engine load, as expected it is observed that all the CO2 emission of diesel fuels is higher than that of the blended fuels. It is observed that the NOx emission increases directly with increased temperature[14]. Increasing the amount of biodiesel has proportional effect on the rate of NOx production going up from 4 g/kWh (at no load) for petro diesel, up to 14 g/kWh for 100% biodiesel. The biodiesel contribution increases the powe output and the amount of heat release is higher for increased proportion of biodiesel. The efficiency of electrical output increases with increased engine load. The net utilisation factor is significantly higher than the efficiency of the system under single generation mode. Adding the heat exchanger to the system to extract additional heat from the exhaust gases increases the overall efficiency of the system between 15% and 25%.

Journal of Biobased Materials and Bioenergy 2007: In this paper,biodiesel properties are strongly influenced by the properties of the individual fatty esters.It therefore appears reasonable to enrich the fuel with certain fatty esters with desirable properties in the fuel in order to improve the properties of the whole fuel[10].It may be possible in the future to improve the properties of biodiesel by means of genetic engineering of the parent oils, which could eventually lead to a fuel enriched with certain fatty acids, possibly oleic acid, that exhibit a combination of improved fuelproperties.

Dipak Patil , Dr. Rachayya.R. Arakerimath Dr. Babasaheb Ambedkar Technological University, Lonere, Maharashtra, India Department of Mechanical Engineering, G H Raisoni College of Engineering and Management, Wagholi, Pune, Maharashtra, India (2009): In this paper, It is observed that the biodiesel has good lubricity when used in diesel engines. The biodiesel with 20%, 30% and 40% blends are used in the conventional diesel engine without any modification in engine design or fuel system the biodiesel performance evaluation is done[13]. No other trouble was found during entire running period of the engine. It was observed that the brake power (B.P), brake thermal efficiency, mechanical efficiency, and time for fuel consumption is higher at constant speed and also at variable speed and load condition for 20% and 40% biodiesel blends with diesel fuel.

Gaurav Dwivedi, Siddharth Jain, M.P. Sharma Alternate Hydro Energy Systems, AHEC, Indian Institute of Technology Roorkee Roorkee, India : In this paper,the engine performance evaluation has found that brake specific fuel consumption for B100 was 14.8% higher than diesel for biodiesel from Jatropha oil, thereby indicating the use of 100% biodiesel can produce same output of energy using higher amount of biodiesel and therefore both deserve to become the “On Farmer Fuel” where farmer can grow his own resource, convert to biodiesel and use in agricultural sets itself without the need of any diesel for blending[19].The brake specific fuel consumption for B10 blend was 4% higher than diesel for biodiesel from jatropha oil at full load while B20 gave the BSFC similar to diesel showing that energy contents of both the blends and diesel are almost same. The brake thermal efficiency is found higher upto B30 in comparison to diesel while BTE of B100 (24%) was almost equals to diesel (24.5%) for JOME.

K.Satyanarayana, Vinodh Kumar Padala, T.V.Hanumantha Rao, S.V.Umamaheswararao Department of Mechanical Engineering, Anil Neerukonda Institute of Technology And Sciences, Sangivalasa, Visakhapatnam, Andhra Pradesh, India (2015): In this paper, the experimentations carried out on the C.I engine with diesel at various compression ratios. The optimum compression ratio is 19 as operation for the given engine. Better fuel economy is obtained at the compression ratio 19.Fuel consumption is higher at compression ratio 16.5.Smoke density is less at compression ratio 19.0.Exhaust gas temperatures are moderate at compression ratio 16.5[20]. For more power at high loads the engine should operate at compression ratio 19 due to less specific fuel consumption. For lower power output at light loads the engine should operate at compression ratio 16.5 due to less fuel consumption.

Biju Cherian Abraham Chindhu Prasad (2015): In this paper, For biodiesel mixture it can be see that SFC is much higher than that of diesel at lower BP and closer to diesel at higher brake power due to increased fuel efficiency. Volumetric efficiency is low for the biodiesel as compared to the diesel.[17] The biodiesels are oxygen rich fuels, so the requirement of air reduces even under low volumetric efficiency. The mechanical efficiency is higher for the biodiesel fuel. As compared to diesel, fuel blends have improved quality of spray, high reaction activity in the fuel rich zone and heat loss due to lower flame temperature may be the reason for increase in efficiency.

Rupesh L. Raut, Babaso N. Naik, Shekhar D. Thakare, Amol A. Gawali : In this paper, From the large number of experimental data for emission constituents obtained for various input parameters such as load, CR and blend, picking up an optimum combination of the input parameters manually is not possible[24]. The effect of blend proportion, load and CR create multi-objective scenario. Therefore, there is a need to find optimum conditions considering emission constituents. Genetic Algorithm (GA) is one optimization technique that can help to tackle the multi-objective scenario.

Gayatri Kushwah (2013): In this paper, biodiesel in diesel engine reduces the percentage of emitted pollutants, hence with increasing quantity of biodiesel Emission of HC and CO decreases. In this experiment castor oil is taken as vegetable oil and mixed with methanol makes biodiesel, and this biodiesel used in diesel engine instead of diesel to get the results about emission of HC (hydrocarbons) & CO (carbon monooxide). So we finds quantity of HC & CO reduced with increasing quantity of biodiesel. But this quantity of pollutants increases with load increasing.

Paresh D. Patel , Absar Lakdawala , Sajan Chourasia , Rajesh N. Patel. Nirma University Ahmedabad(2016): In this paper, it has found that the significant physical and chemical properties for CI engine use are mostly within the corresponding values for standard diesel fuel. The main exception is viscosity, calorific values and oxygen content. Regarding the performance and emissions of engines running on biofuels, a review of 32 sources has shown that, compared to fossil fuel wide range of fluctuation In BP, BSFC and brake thermal efficiency[25]. Bio fuels are promising can tender to replace environmental emissions. After reviewing 36 sources, it is suggested to improve engine performance when fuelled with biofuels by changing engine operating parameters (injection timing, injection pressure & compression ratio). Although, literature on short run test suggest that biofuels can replace convention diesel fuel, a long run analysis is essential for assessment of engine life. Review of 22 sources on long run analysis it was reported that engine suffered problems such as carbon deposition, lubricating oil dilution, piston ring sticking and injector nozzle chocking running on pure plant oils. Without any change to oil or engine, short run test use if likely to be successful. To minimized these durability problems this review has highlighted that, the biofuels (estified oil / blend with diesel/ blend with diesel in presence of additives) is an attractive option.

A. Murugesan etal worked on suitability of biodiesel as a fuel in diesel engine. They presented a very promising scenario of functioning a biodiesel as an alternative fuel. The properties of these biodiesel can be compared favorably with the characteristics required for internal combustion engine fuels.[18] Fuel-related properties are reviewed and compared with those of conventional diesel fuel. Peak pressure devel- opment, heat release rate analysis, and vibration analysis of the engine are discussed in relation with the use of bio-diesel and conventional diesel fuel. Optimization of alkali-catalyzed transesterication of pungamia pinnata oil for the production of bio-diesel is discussed. Use of bio-diesel in a conventional diesel engine results in substantial reduction in unburned hydrocarbon (UBHC), carbon monoxide (CO), particulate matters (PM) emission and oxide of nitrogen (NOx).

Ekrem Buyukkaya used biodiesel as a renewable fuel in numerous studies eval- uating its potential use in diesel engines. These studies were investigated to evaluate the performance, emission and combustion of a diesel engine using neat rapeseedoil and its blends of 5%, 20% and 70%, and standard diesel fuel separately. The results indicate that the use of biodiesel produces lower smoke opacity (up to 60%), and higher brake specic fuel consumption (BSFC) (up to 11%) compared to diesel fuel. [10]The measured CO emissions of B5 and B100 fuels were found to be 9% and 32% lower than that of the diesel fuel, respectively. The BSFC of biodiesel at the maximum torque and rated power conditions were found to be 8.5% and 8% higher than that of the diesel fuel, respectively. From the combustion analysis, it was found that ignition delay was shorter for neat rapeseed oil and its blends tested compared to that of standard diesel. The combustion characteristics of rapeseed oil and its diesel blends closely followed those of standard diesel.

N. Stalin and H. J. Prabhu carried out an experimental work in this .They presents a review of the alternative technological methods that could be used to produce this fuel. Performance of IC engine using karanja biodiesel blending with diesel and with various blending ratios has been evaluated.[15] The engine performance studies were conducted with a prony brake-diesel engine set up. Parameters like speed of engine, fuel consumption and torque were measured at dierent loads for pure diesel and various combinations of dual fuel. Brake power, brake specic fuel consumption and brake thermal eciency were calculated. The test results indicate that the dual fuel combination of B40 can be used in the diesel engines without making any engine modications. Also the cost of dual fuel (B40) can be considerably reduced than pure diesel.

H. Raheman , S.V. Ghadge reviwed the eect of different compression ratio on engine performance using biodiesel as a fuel. The brake specic fuel consumption (BSFC) and exhaust gas temperature (EGT) increased, whereas brake thermal efficiency (BTE) decreased with increase in the proportion of biodiesel in the blends at all compression ratios (18:120:1) and injection timings (35 45 before TDC) tested. However, a reverse trend for these parameters was observed with increase in the compression ratio (CR) and advancement of injection timing (IT). The BSFC of B100 and its blends with high speed diesel reduced, whereas BTE and EGT increased with the increase in load for the range of CR and IT tested[20]. The differences of BTEs between HSD and B100 were also not statistically signicant at engine settings of 'CR20IT40' and 'CR20IT45'. Thus, even B100 could be used on the Ricardo engine at these settings without affecting the performance obtained using high speed diesel (HSD).

S. Jindal worked on diesel engine using biofuel. This study targets on the effects of the engine design parameters viz. compression ratio (CR) and fuel injection pressure (IP) jointly on the performance with regard to fuel consumption (BSFC), brake thermal eciency (BTHE) and emissions of CO, CO2, HC, NOx and Smoke opacity with jatropha methyl ester (JME) as fuel. Comparison of per- formance and emission was done for dierent values of compression ratio along with injection pressure to nd best possible combination for operating engine with JME. [11]It is found that the combined increase of compression ratio and injection pressure increases the BTHE and reduces BSFC while having lower emissions. For small sized direct injection constant speed engines used for agricultural applications (3.5 kW), the optimum combination was found as CR of 18 with IP of 250 bar.

M. Mani, G. Nagarajan worked on diesel engine using waste plastic oil. As an alternative, non-biodegradable, and renewable fuel, waste plastic oil is receiving increasing attention. The waste plastic oil was compared with the petroleum products and found that it can also be used as fuel in compression ignition engines. In the present work, the inuence of injection timing on the performance, emission and combustion characteristics of a single cylinder, four stroke, direct injection diesel engine has been experimentally investigated using waste plastic oil as a fuel.[25] Tests were performed at four injection timings (23 , 20 , 17 and 14 bTDC). When com- pared to the standard injection timing of 23 bTDC the retarded injection timing of 14 bTDC resulted in decreased oxides of nitrogen, carbon monoxide and unburned hydrocarbon while the brake thermal effciency, carbon dioxide and smoke increased under all the test conditions.

Kanokon Rodjanakid show the performance of engine using biodiesel made from rened palm oil stearin and crude coconut oil. Neat vegetable oil poses some problems when subjected to prolong use in CI engines. The problems are attributed to its high viscosity and low volatility. These problems can be minimized by the process of transesterication.[23] In this study thetransesterication reaction of rened palm oil stearin and crude coconut oil were carried out with methanol and ethanol using potassium hydroxide as a catalyst to yield biodiesels, methyl ester from rened palm oil stearin and ethyl ester from crude coconut oil. The products were evaluated by comparing physical characteristics of biodiesels to conventional diesel oil. These characteristics included specic gravity, density, viscosity, pour point, ash point, re point, heating value, copper strip corrosion etc. The biodiesels were then tested in a diesel engine to observe their actual performance and emissions. The fuel spray of biodiesels was also compared with the conventional diesel oil.

Magn Lapuerta worked on emission analysis using biodiesel in diesel engine. Experiments were carried out on diesel engine using biodiesel fuels as opposed to conventional diesel fuels. Since the basis for comparison is to maintain engine performance, the rest section is dedicated to the eect of biodiesel fuel on engine power, fuel consumption and thermal efficiency. The highest consensus lies in an increase in fuel consumption in approximate proportion to the loss of heating value. In the subsequent sections, the engine emissions from biodiesel and diesel fuels are compared, paying special attention to the most concerning emissions: nitric oxides and particulate matter, the latter not only in mass and composition but also in size distributions[21]. They analyzed sharp reduction in particulate emissions.

M. Gumus, S. Kasifoglu used biodiesel made from apricot seed kernel oil methyl ester. Apricot (Prunus armeniaca) seed kernel oil was transesteried with methanol using potassium hydroxide as catalyst to obtain apricot seed kernel oil methyl ester. Neat apricot seed kernel oil methyl ester and its blends with diesel fuel were tested in a compression ignition diesel engine to evaluate performance and emissions. Apricot seed kernel oil methyl ester and its blends can be successfully used in diesel engines without any modication.[20] Lower concentration of apricot seed kernel oil methyl ester in blends gives a better improvement in the engine performance and exhaust emissions. Therefore lower percent of apricot seed kernel oil methyl ester can be used as additive.

G. H. Kawade, S. T. Satpute worked on Biodiesel produced from vegetable oil (edible and non edible oil) renewable sources, it is a more sustainable source of energy and it will be play an increasingly significant role in providing the energy requirements for transportation. The Properties of biodiesel closely related to diesel fuel. The use of biodiesel will lead to loss in engine power mainly due to the reduction in heating value of biodiesel compared to diesel fuel. Increase in biodiesel fuel consumption, due to low heating value and high density and viscosity of biodiesel, has been found. PM emissions HC, CO emissions for biodiesel are significantly reduced, compared with diesel fuel. But NOx emissions may increases when using the biodiesel, this increase is mainly due to higher oxygen content for biodiesel. From the literature survey it can be concluded that the blends of biodiesel with small content by volume could replace diesel in order to help in controlling air pollution and improving engine performance of power and economy of engine when using biodiesel blending with diesel fuel. From the literature it may concluded that the optimization of C.I. engine performance and operating parameters through different software is most suitable technique. [16]Also it is more accurate technique and less time consuming as compaired to experimental method. Use of artificial neural networks for optimizing the C.I Engine parameters is most suitable technique. Therefore ANN will be a very good tool to optimize engines parameters in the future. Also the taguchi method can be effectively used for the investigation of multiple performance characteristics of a diesel engine.

Maulik A Modi, Tushar M Patel , Gaurav P Rathod studies that taguchi method was found to be an efficient technique for quantifying the effect of control parameters. The highest performance at set 16 compression ratio, engine load 10kg, and injection pressure 180 bar, which are optimum parameter setting for highest brake thermal efficiency. Engine performance is mostly influenced by engine load and is least influenced by bland ratio. Performance results obtained from the confirmation experiment using an optimum combination showed excellent agreement with the predicted result[18].

K. Sivaramakrishnan and P. Ravikumar worked on taguchi's approach analysis has been carried out for optimizing the performance of karanja biodiesels engine. The various input parameters have been optimized using SNR. Based on this study, it can be concluded that BTHE, BSFC and emissions of diesel engine depend upon biodiesel blend, compression ratio, nozzle pressure and injection timing. The results of this study revealed that almost identical combinations of engine parameters give optimum multiple performances for engine. [23]It was found that a diesel engine operating at a high compression ratio - 17.9, high pressure 230 bar, Injection timing of 27° BTDC, Biodiesel -diesel blend B30. And Brake power-3.64 kW achieves the optimum engine performance. The results are well supported by the findings of our confirmatory test.

Emel Kuram , Babur Ozcelik studied,the effects ofspindle speed,feed per tooth and depth ofcut ontool wear,force components (Fxand Fy) and surface roughness during microm illing of alumi- num were investigated using Taguchi experimental design method. All data gathered inthe experimental studies were used to formulate first-ordermodels with interaction. Responses were used alone inoptimization study as an objective function.Taguchi's signal tonoise ratio was utilized to minimize all responses.The effect offactors on responses was determined by ANOVA[11].Responses were optimized simultaneously using grey relational analysis. Cutting tools and workpiece surfaces were also examined via scanning electron microscope (SEM) sothat understand micro-milling process. Adhesion and abrasion wear mechanisms were observed in micro-milling of aluminum material. Accumulations of plastically deformed workpiece material were observed on the workpiece surfaces owing to the high ductility of aluminum material.First-order models with interaction were developed and it was found that these models could be used to predict tool wear,force and surface roughness with aminor error.From mono objective results it was concluded that the optimal values for minimizing tool wear were spindle speed of 10,000 rpm, feed per tooth of 0.5 lm/tooth and depth of cut of 50 lm. Tool wear increased with spindle speed and depth of cut.Initially an increment of tool wear with increasing of feed per tooth was observed;however as feed per tooth was further increased, tool wear eventual ly decreased. The optimum combination for Fxwas spindle speed of 10,000 rpm,feed per tooth of 0.5 lm/tooth and depth of cut of 100 lm. Fxincreased with an increment of spindle speed and feed per tooth but decreased with depth of cut.The optimum combinati on for Fywas spindle speed of 10,000 rpm,feed per tooth of 0.5 lm/tooth and depth of cut of 75 lm. Fy increased with an increment of spindle speed and feed per tooth.The increment of the depth of cut initially increased Fy however,as this parameter was further increased,Fy eventual ly decreased.For Ra, optimum parameters were found to be as spindle speed of 12,000 rpm, feed per tooth of 0.5 lm/tooth and depth of cut of 50 lm. Ra decreased with spindle speed and increased with feed per tooth and depth ofcut.From ANOVA results, it was concluded that spindle speed was more significant factor for all responses except for Ra.For Ra,feed per tooth was more significant factor.From multiobjective optimization results it was found that the best combination values for minimizing the tool wear,Fx,Fy and surface roughness were spindle speed of 10,000 rpm,feed per tooth of 0.5 lm/tooth and depth ofcut of 50 lm. The approach used in this study can be utilized in simultaneously optimizing the micro-milling of other materials and responses.

Avinash, Kailash B Anwar & Goweesh studied the response parameter i.e., brake thermal efficiency is optimized using taguchi's methodology to analyse the experimental data. [17]The main effects plot for signal to noise ratio the optimized combination is found to be no. of nozzle hole=3, Blends B80, I.O.P =240 and C.R=17. In this particular combination it is predicted from the experimental data that the engine performance is comparable to that of diesel. That means from the used blends of biodiesel and diesel, the B80 blend is found to be most suitable blend for use in the diesel engine without any engine modification. The corresponding compression ratio is 18 and the load applied on the engine is 100% load, i.e.12kW load. The confirmation test is also carried out to verify it and there we see improvements of signal to noise ratio. And finally it can be concluded that the biodiesel can be used in a diesel engine without any engine modifications. And from our experimental view, the best blend is the B80 blend where the engine performance is comparable to that of diesel.

Görkem Kökkülünk, Adnan Parlak, Eyup Bağci, Zafer Aydin observed from the results, that effective power, SFC, CO and CO2 are determined at least 99%, NOx at least 98.5% and torque, HC at least 96.5% confidence levels. The optimum design parameter combinations have been found as A4B4C1 (2400 rpm, 30% steam, 0% EGR), A1B4C1 (1200 rpm, 30% steam, 0% EGR) for CO and CO2, respectively and A4B3C1 (2400 rpm, 20% steam, 0% EGR) and A4B2C4 (2400 rpm, 10% steam, 30% EGR) for HC and NOx emissions, respectively.For the performance parameters, the optimum design parameter combinations have been found as A2B3C1 (1600 rpm, 20% steam, 0% EGR) for SFC, A4B3C1 (2400 rpm, 20% steam, 0% EGR) for effective power and A2B3C1 (1600 rpm, 20% steam, 0% EGR) for torque[22]. The optimum steam ratio is 10% for NOx and 20% for SFC. On the contrary, with regards to SFC, the minimum fuel consumption has been found with a 0% EGR ratio. For effective power and torque values, there is not considerable change in effective power and torque with an increase in EGR ratios. The reason of a limited reduction in effective power with the increase of EGR ratios could be explained due to steam injection.

2.1 Problem Denition

Environmental concern and availability of petroleum fuels have caused interests in the search for alternate fuels for internal combustion engines. In our country the usage ratio of diesel to gasoline fuel is 7:1[2], depicting a highly skewed situation. Thus, it is necessary to replace fossil diesel fuel by alternative fuels. Vegetable oils present a very promising scenario of functioning as alternative fuels to fossil diesel fuel. The properties of these oils can be compared favorably with the characteristics required for internal combustion engine fuels. Biodiesel has a high cetane number than diesel fuel, no aromatics, no sulfur and contains 10-12 % oxygen by weight. These characteristics of biodiesel reduce the harmful emissions of unburned hydrocarbon (HC), CO, and particulates than the diesel fuel. Several researchers found increased NOx emission as compare to petrol- diesel and many worked on analyzing the performance of engine using dierent blends of diesel-biodiesel.

2.2 Motivation

The motivation behind this project was to meetthe renewable energy utilization for internal combustion engines.The shortage of fossil fuels in entire world leads to exploring new forms of renewable resourses various energy source available in our country leads to decrease in burden of foreign exchange.Easily available sources of energy like vegetable oils(edible/non-edible) are an option which require more research. Hence the project was undertaken to analyze the selected fuels in CI engine.

2.3 Objective of Project

1. Performance and Emission analysis of CI Engine using different blends of biodiesel.
2. Analysis of operating parameters of CI Engine under influence of different blends of biodiesel.
3. Preparing L9 Orthogonal Array with Levels set as Blends,IP and CR.
4. Prepare a mathematical model to find a scientific way of finding optimum blend of biodiesel using Taguchi method.

Chapter 3

EXPERIMETATION AND EXPERIMENTAL SETUP

The main aim of the experimentation is to check the fesibility of biofuel in C.I engine fueled with diesel boi-diesel blends(B0,B10,B20,B30,B40,B50,B70).The experimentation is carried out for comparsion for different blends of biodiesel.Optimizing work for finding out optimum diesel-biodiesel blend.Firstly the properties(flash point,density,calorific value and viscosity) of biodiesel and diesel is determined using the following apparatus

Cleveland apparatus(flash point and fire point)

Redwood viscometer(viscometer)

Bomb Calorimeter(calorific value)

Finally experimentaion work on 1 cylinder 4 stoke Multifueled VCR(Computeristed) system is carried out.Readings for varies engine parameters is determined and compared with different biodiesel blends(B0,B10,B20,B30,B40,B50,B70).

3.1 Flash point using Cleveland apparatus

The sample is contained in an open cup which is heated and, at intervals, a flame is brought over the surface. The measured flash point will actually vary with the height of the flame above the liquid surface and, at sufficient height, the measured flash point temperature will coincide with the fire point. **Flash point** of fuel is defined as the temperature at which it will iginite when exposed toa flame or spark.**Fire point** is the temperature at which enough vapours will rise to produce a continous flame above the liquide level.

For biodiesel Flash point – 170 °C.

For diesel flash point 152^0C

3.2 Viscosity using Redwood Viscometer

Redwood Viscometer determines the viscosity in terms of seconds, a time taken by oil to pass through a standard orifice and collection of the same oil in 50cc flask.

Viscosity of bio-diesel @ 40^0C : 2.70 cSt.

Viscosity of diesel @ 40^0C : 2.20 cSt

3.3 Bomb Calorimeter

A bomb calorimeter is a type of constant-volume calorimeter used in measuring the heat of combustion of a particular reaction. Bomb calorimeters have to withstand the large pressure within the calorimeter as the reaction is being measured. Electrical energy is used to ignite the fuel; as the fuel is burning, it will heat up the surrounding air, which expands and escapes through a tube that leads the air out of the calorimeter. When the air is escaping through the copper tube it will also heat up the water outside the tube. The change in temperature of the water allows for calculating calorie content of the fuel.

Calorific value of diesel =43200 kJ/kg.

Calorific value of biodiesel=38100 kJ/kg.

3.4 1 Cylinder, 4 Stroke, Multi-fueled,VCR(Computerized)

The setup consists of single cylinder, four stroke, multifuel, research engine connected to eddy current type dynamometer for loading. The operation mode of the engine can be changed from diesel to petrol or from petrol to diesel with some necessary changes. In both modes the compression ratio can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The injection point and spark point can be changed for research tests.Setup is provided with necessary instruments for combustion pressure, diesel line pressure and crank-angle measurements. These signals are interfaced with computer for pressure crank-angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. The set up has stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and hardware interface. Rotameters are provided for cooling water and calorimeter water flow measurement. A battery, starter and battery charger is provided for engine electric start arrangement. The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, heat balance and combustion analysis[15]. Labview based Engine Performance Analysis software package "Enginesoft" is provided for on line performance evaluation3.1.

1.Eddy current dynamometer

2. Kirlosker single cylinder engine

3. Load indicator

4. Injection fuel pressure sensor

5. Load adjusting knob

6. Rotameter

7. Cylinder pressure sensor

8. Fuel indicator

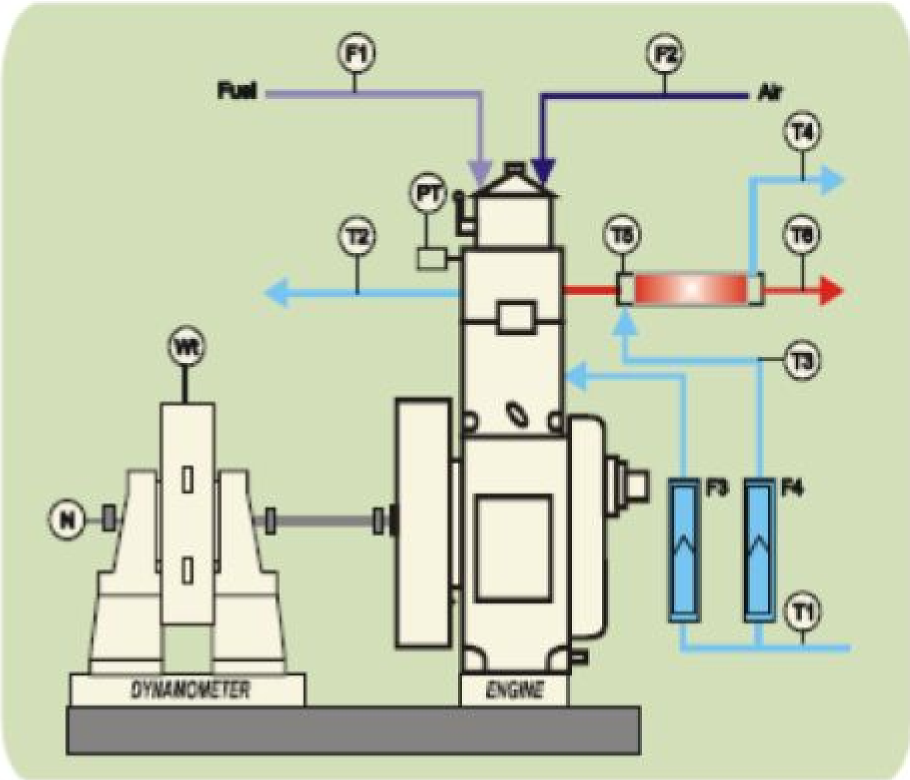

Figure 3.1: Schematic Arrangement

In the above Figure3.1 Sensors bag and fit 5 temp sensors are located at respective places

T1/T3 at the inlet water at pump outlet.

T2 at the Engine outlet water on the engine head.

T4 at the calorimeter water outlet.

Thermocouple T5 at the Exhaust inlet of calorimeter

Thermocouple T6 at the exhaust outlet of calorimeter.

Engine	1 CYL, 4 STROKE, water cooled, STROKE 110mm, bore 87.5mm
Diesel mode	Power 3.5 kW C.R. range 12.1-18.1 Speed 1500 rpm Injection Variation 0-250 BTDC
Dynamometer	Eddy current type, water cooled, with loading unit
Calorimeter	Type Pipe in Pipe
Rotameter	Engine cooling 40-400 LPH , Calorimeter 25-250 LPH
Piezo sensor	Combustion Range 5000 PSI, with low noise cable
Crank Angle Sensor	Resolution 1 deg, speed 5500 rpm with TDC pulse
Temperature Sensor	Type RTD,PT100 and Thermocouple,
Load Sensor	TYPE K Load cell, type strain gauge, range 0-50 Kg
Fuel Tank	Capacity 15 LIT
Software	ENGINESOFT, engine performance analysis software

Table 3.1: Engine set up specifications

Chapter 4

RESULTS AND DISSCUSION

In this chapter the results are presented in the form of comparision between the different blends of Bio-diesel with diesel on , BSFC, BTHE%,Fuel consumption,Mech Efficiency,BMEP which were evaluated in the test rig on CI engine.

4.1 Properties

The following properties of the fuels were measured as they are required as the input parameters for the Engine-soft software of the computerised engine test rig4.1.

Blends	Calorific Value(kJ/kg)	Density(kg/m^3)
B0	43200	822
B10	42690	825.8
B50	40650	841.3
B70	39630	849
B100	38100	860

Table 4.1: Property Table

4.2 Engine Test Parameter

The test engine was run with the base fuel as diesel, biodiesel-diesel blend after that the performance of the engine was recorded .

4.2.1 Effect of Brake Specific Fuel Consumption (BSFC) on different blends of bio-diesel

In general, the BSFC value of the blend were slightly higher than that of the base fuel i.e diesel at full load condition.Brake specic fuel consumption of the engine operating on the test fuels decreased with increasing load..The reason behind that may be, at high load, the cylinder wall temperature get increased, which reduces the ignition delay, thus, shortening of ignition delay improves combustion and reduces fuel consumption. Higher mechanical efficiency at high load explained such trends in the BSFC.BSFC of B20 is highest at load 0 whereas BSFC of B50 its lowest at 0 load.At highest load BSFC of B30 is highest4.1.

4.2.2 Effect of Efficiency on different blends of bio-diesel

Air standard efficiency of diesel cycle decreases as the load is increased. The simple reason is that with increase of load, cut off ratio also increases. With increase of load more fuel will be injected in combustion chamber.Hence ratio of volume before combustion to volume after combustion will also increase.Efficiency of B40 is observed to be maximum at 12kg load4.1.

4.2.3 Effect of fuel consumption on different blends of biodiesel

The mass of fuel consumption (mf) variation for the diesel, diesel-biodiesel is shown graph below.In general, the mf value of the some blend were slightly lower than those of the base fuel i.e diesel and biodiesel at part load condition.Mass of fuel consumption of the engine operating on the test fuels increases with increasing load.However, for B10 the mass of fuel consumption was nearly 8% lower at 75% loads as compared to base fuels4.1.

4.2.4 Effect of Brake Thermal Efficiency on different blends of biodiesel

The thermal efficiency distribution for diesel, diesel- biodiesel is shown below.With diesel-biodiesel blends, the addition of biodiesel shows almost same thermal efficiency at rated load but at part load its thermal efficiency increases compare to diesel. The reason behind that is the decrease in brake power with blends.BTHE% for B0 is highest at 12 load4.1.The variation in brake thermal efficiency for various blends was less than at part load than at higher load due to the raised temperatures inside the cylinder.This is due to high viscosity and low volatility of biodiesel.

4.2.5 Effect of Brake Mean Effective Pressure on different blends of bio-diesel

Brake Mean Effective Pressure Plot is shown below. BMEP increases with increase in load.There is not much of a difference observed with diffrent blends of bio-diesel as there is only slight difference in density of different blends4.1.

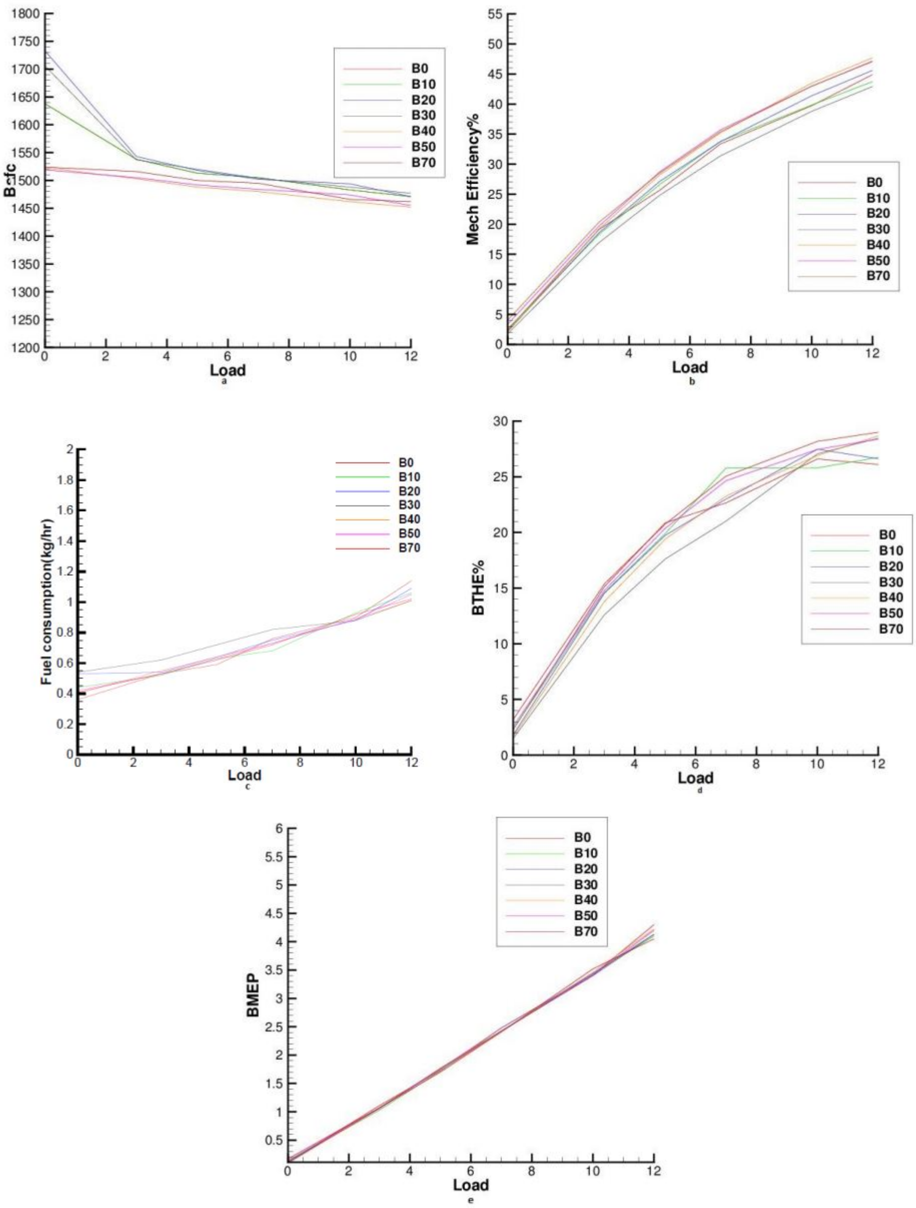

Figure 4.1: a)Effect of bsfc on different blends of biodiesel. b)Effects of efficiency on differennt blends of biodiesel. c)Effect of fuel consumption on different blends f biodiesel. d)Effect of BTHE on different blends of biodiesel. e)Effect of BMEP on differnnt blends of biodiesel

4.3 Selection of Level Factor and Orthognal Array

An orthogonal array presents the possible combinations of different levels of engine operating parameters which are to be varied to investigate their effect on engine responses with smaller number of experimental trials. Selection of orthogonal array depends on total degree of freedom of all engine operating parameters4.2. For every engine parameter the degree of freedom is calculated by using following relation Degree of freedom for each engine operating parameter = (L-1) Where, L is the number of levels of each engine operating parameter Total degree of freedom of all engine operating parameters, N = (L-1)*P where. P= number of engine operating parameters The OA must be selected such that, the number of trails in the selected orthogonal array (OA) must be equal to the N+1 As minimum number of trials to be conducted as per above relation is 7.In the present experiment blends, CR and IP has been selecetd as control parameter and (B10,B50,B50), (16,17,18) and (180,200,220) has been selected as levels respectively.An orthogonal array L9 containing 9 trials has been selected in present investigation 4.3.

Code	Control Parameters	Level 1	Level 2	Level 3
A	Blends	B10	B50	B100
B	CR	16	17	18
C	IP	180	200	220

Table 4.2: Selection of factor level

Blends	CR	IP
B10	16	180
B10	17	200
B10	18	220
B50	16	200
B50	17	220
B50	18	180
B70	16	220
B70	17	180
B70	18	200

Table 4.3: Orthogonal Array

The next step is determining optimal conditions of the control parameters to give the optimum responses. In this work the response variables to be optimized were BP and efficiency has to be maximized and B.S.F.C. to be reduced as much as possible. Hence the optimum parameter settings will be those that give maximum values of the BP and efficiency and minimum values of B.S.F.C,NOx,CO,CO_2HC and Smoke density4.4.

Sr No.	B.P(KW)	Bsfc(g/KWh)	Efficiency	NOx	CO	CO_2	HC	Smoke density
1	3.29716	0.301150	33.9092	2	0.025	2.66	5	1.295
2	3.29716	0.311519	32.7806	1	0.005	0.4	9	0.713
3	3.29490	0.289628	35.2583	1	0.010	0.4	16	0.600
4	3.30849	0.314296	33.4928	6	0.006	0.4	3	2.420
5	3.27677	0.299007	35.2054	4	0.008	0.4	4	2.010
6	3.29716	0.295014	35.6819	3	0.010	3.01	12	1.326
7	3.28583	0.312074	34.2857	9.1	0.012	0.40	2	2.800
8	3.29943	0.304921	35.0900	6	0.021	2.70	2	2.400
9	3.31303	0.307667	34.7767	5.4	0.005	0.40	9	2.100

Table 4.4: Result Table

4.4 Analysis for Response Curve

Response curve analysis is aimed at determining influential parameters and their optimum levels. It is graphical representations of change in performance characteristics with the variation in process parameter. The curve gives a pictorial view of variation of each factor and describe what the effect on the system performance would be when a parameter shifts from one level to another.

4.4.1 S/N ratio

The S/N ratio for the performance curve is calculated at each factor level and average effects are determined by taking the total of each factor level and dividing by the number of data points in the total. The greater difference between levels, the parametric level having the highest S/N ratio corresponds to the parameters setting indicates highest performance.S/N ratio is used as measurable value instead of standard deviattion due the fact that,as the mean decrease, the standard deviation also decreases and vice verse. In other words, the standard deviation cannot be minimized first na d brought to the target.In practice, the target mean value may change duringthe process development.Two of the application s in which the concept S/N ratio is useful are the improvement of quality through variabilty reduction and the improvement of measurement .The S/N ratio characteristics can be divided into three categories given by4.5.This technique is used to indentify the controllable factors taht reduce the effect of thr uncontrollable(nosie) factors on the response.The chosen factors with the highest S/N ratio would give the optimum quality with the least variance.Ranking of parameters using signal to noise ratios was obtained and the load was the dominant parameter followed by injection pressure and fuel blend.

Signal to noise ratio	Goal of experiment	Data characteristics	Signal to noise ratio formulas
Larger is better	Maximize the response	Positive	S/N=-10*log($\sum(1/Y^2)/n$
Smaller is better	Minimize the response	Non-negative with a target value of zero	S/N=-10*log($\sum(Y^2)/n$
Nominal is best	Nominalize the response	Positive, zero or negative	S/N=-10*log()

Table 4.5: S/N ratios

4.4.1.1 Main Effect Plot for S/N ratios on BP

To calculate S/N ratio for BP Larger is better is to be used as we have to maximize the results for BP so as to obtain an optimum combination of blend,CRand IP.In the graph we can observe that for blend B70, for CR 18 and for IP 200 we can get maximum BP. Hence the best combination is B70,CR18 and IP2004.2.

4.4.1.2 Main Effect Plot for S/N ratios on Efficiency

To calculate S/N ratio for Efficiency Larger is better is to be used as we have to maximize the results for Efficiency so as to obtain an optimum combination of blend,CRand IP.In the graph we can observe that for blend B50, for CR 18 and for IP 180 we can get maximum BP. Hence the best combination is B50,CR18 and IP1804.2.

4.4.1.3 Main Effect Plot for S/N ratios on Bsfc

To calculate S/N ratio for Bsfc smaller is better is to be used as we have to minimise the results for Bsfc so as to obtain an optimum combination of blend,CRand IP.In the graph we can observe that for blend B10, for CR 18 and for IP 220 we can get maximum BP. Hence the best combination is B10,CR18 and IP2204.2.

4.4.1.4 Main Effect Plot for S/N ratios on CO

To calculate S/N ratio for CO smaller is better is to be used as we have to minimise the results for CO so as to obtain an optimum combination of blend,CRand IP.In the graph we can observe that for blend B70, for CR 18 and for IP 200 we can get maximum BP. Hence the best combination is B70,CR18 and IP2004.2.

4.4.1.5 Main Effect Plot for S/N ratios on CO_2

To calculate S/N ratio for CO_2 smaller is better is to be used as we have to minimise the results for CO_2 so as to obtain an optimum combination of blend,CRand IP.In the graph we can observe that for blend B10, for CR 16 and for IP 180 we can get maximum BP. Hence the best combination is B10,CR16 and IP1804.2.

4.4.1.6 Main Effect Plot for S/N ratios on HC

To calculate S/N ratio for HC smaller is better is to be used as we have to minimise the results for HC so as to obtain an optimum combination of blend,CRand IP.In the graph we can observe that for blend B70, for CR 16 and for IP 220 we can get maximum BP. Hence the best combination is B70,CR16 and IP2204.2.

4.4.1.7 Main Effect Plot for S/N ratios on NOx

To calculate S/N ratio for NOx smaller is better is to be used as we have to minimise the results for NOx so as to obtain an optimum combination of blend,CRand IP.In the graph we can observe that for blend B10, for CR 16 and for IP 1800 we can get maximum BP. Hence the best combination is B10,CR16 and IP1804.2.

4.4.1.8 Main Effect Plot for S/N ratios on Smoke Density

To calculate S/N ratio for Smoke Density smaller is better is to be used as we have to minimise the results for Smoke Density so as to obtain an optimum combination of blend,CRand IP.In the graph we can observe that for blend B10, for CR 18 and for IP 220 we can get maximum BP. Hence the best combination is B10,CR18 and IP2204.2.

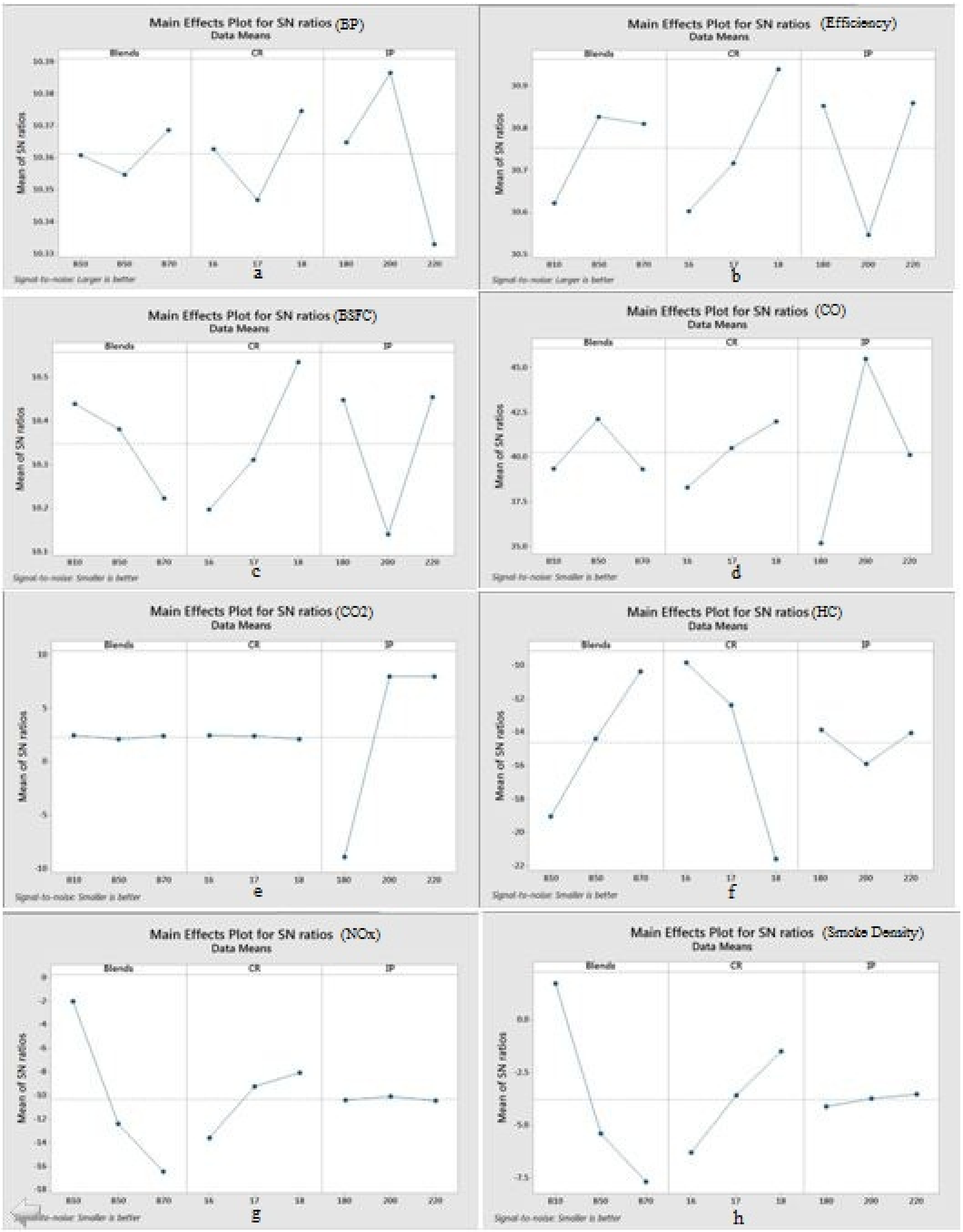

Figure 4.2: a) Main Plot for S/N Ratio Graph BP b)Main Plot for S/N Ratio Graph Efficiency c)Main Plot for S/N Ratio Graph Bsfc d)Main Plot for S/N Ratio Graph CO e)Main Plot for S/N Ratio Graph Main Plot for S/N Ratio Graph CO_2,f)Main Plot for S/N Ratio Graph HC, g)Main Plot for S/N Ratio Graph NOx h)Main Plot for S/N Ratio Graph Smoke Density

4.4.2 Interaction curve

When the effect of one factor depends on the level of the other factor.You can use an interaction plot to visualize possible interactions.Parellel lines in an interaction plot indicate no interaction. The greater the differce between the lines,the higher the degree of interaction.However, the interaction plot doesn't alert you if the interaction is statistically significant4.34.6.The following observations were made from the interaction curve.

4.4.2.1 Interaction Curve for Efficiency

The first graph depicts blends versus CR for efficiency.In this for Blend B50 and CR 18 we get maximum efficiency.This is due the fact that as the compression ratio increases efficiency increases as higher compression ratio results in higher in-cylinder pressure and higher heat release rate as well as lower ignition delay hence the fuel mixture is sufficiently compressed thereby increasing the thermal efficiency, so that less fuel is required to produce the same amount of energy.The reason for higher efficiency up to B50 is because of better combustion due to inherent oxygen and higher Cetane number. Beyond B50, the lower calorific value and higher viscosity is responsible for poor atomization of fuel in the engine cylinder.The second graph depicts Blends versus Injection pressure for efficiency.In this for blend B50 and IP 180 we get maximum efficiency.Due to high viscosity low IP is found to be benificial.The third graph depicts CR versus IP.In this for CR 18 and IP 180 we get maximum efficiency.Hence we can conclude that the best combination to maximize efficiency is B50,CR18 and IP1804.3.

4.4.2.2 Interaction Curve for Bsfc

The first graph depicts blends versus CR for Bsfc.In this for Blend 10 and CR 18 we get minimum Bfsc.This is due the fact that bsfc decreases as CR increases due to better combustion of fuel.The Bsfc increases with increase in biodiesel blend due to its lower heating value, greater density,lower calorific value and hence higher bulk modulus. The higher bulk modulus results in more discharge of fuel for same injection pressure, there by resulting increase in BSFC.The second graph depicts blends versus IP.In this for blend B10 and IP 220 we get minimum Bsfc.Increase in IP results in rapid buring of fuel due to incease in degree of atomization as a result of which Bsfc decreases.The third graph depicts CR versus IP.In this for CR 18 and IP 220 we get minimum Bsfc.Hence we can conclude that the best combination to minimize Bsfc is B10,CR18 and IP2204.3.

4.4.2.3 Interaction Curve for CO

The first graph depicts blend versus CR for CO.In this for blend B70 and CR 18 we get minimum CO.The lower CO emission of biodiesel decreases with increase in the percentage of biodiesel blends because oxygen content inherently present in the biodiesel helps in the more complete oxidation of fuel this extra oxygen results in oxidation of CO into CO2 which reduces CO emission..As CR increases combustion becomes proper as a result of which CO emission decreases which in turn is due to high air temperature inside the cylinder.The second graph depicts blends versus IP.In this for blend 70 and IP 200 we get minimum CO.This is due to the fact that as IP increases degree of atomization increases as a result combustion becomes better.The third graph depicts CR versus IP.In this for CR 18 and IP 200 we get minimum CO.Hence we can conclude that the best combination to minimise CO is B70,CR18 and IP2004.3.

4.4.2.4 Interaction Curve for BP

The first graph depicts blend versus CR for BP.In this graph for blend B70 and CR 18 we get maximum BP.This is due the fact that biodiesel contains oxygen that can be used in combustion thereby increasing torque and power therefore BP increases with increase in biodiesel blend.At higher CR due to proper burning or combustion of fuel as a result of which BP also increases.The second graph depicts blends versus IP.In this for blend B70 and IP 200 we get maximum BP.The values of B.P. increases from 180-200 bar I.P. and then decreases from 200-220 bar this is caused because of better atomization of fuel with increase in injection pressure from 180-200 bar and then at 220 bar with further increase in atomization momentum of very fine fuel droplets drops. For bio fuel blends B.P. value slightly less decreases with decrease in biodiesel blends because of less energy content and high viscosity of biofuels.The third graph depicts CR versus IP.In this graph for CR 18 and IP 200 we get maximum BP.Hence we can conclude that the best combination to maximize BP is B70,CR18 and IP2004.3.

4.4.2.5 Interaction Curve for NOx

The first graph depicts blend versus CR for NOx.In this graph for blend B10 and CR 16 we get minimum NOx.NOx formation increases with increase in biodiesel blends because due to high contain of oxygen in biodiesel as compared to diesel ,at high temperture leads to the formation of NOx.As CR increases fuel is properly burned at high temperature in engine cylinder as a result of which NOx formation alos increases.The second graph depicts Blend versus IP.In this graph for blend B10 and IP 180 we get minimum NOx.This is because of higher temperature at high injection pressure and high oxygen content of biodiesel. The oxygen content present in the biodiesel reacts with nitrogen present in the intake atmospheric air at high temperatures and results in higher values of NOx emissions.The third graph depicts CR versus IP.In this graph for CR 16 and IP 180 we get minimum NOx.Hence we can conclude that the best combination to minimise NOx is B10,CR16 and IP1804.3.

4.4.2.6 Interaction Curve for CO_2

The first graph depicts blends versus CR for CO_2.In this graph for blend B10 and CR 16 we get minimum CO_2.CO_2 formation increases with in crease in biodiesel contain because of high oxygen content in the biodiesel due to which more of the carbon gets oxygenated during combustion inside the cylinder which results in higher CO2 emission and partly CO.As CR increases combation rate also increases thus increasing CO_2formation.The second graph depicts blend versus IP.In this graph for blend B10 and IP 180 we get minimum CO_2.As IP increases,fue atomization take s place efficiently as a result of which more CO_2 is produced.The third graph depicts CR versus IP.In this graph for CR 16 and IP 180 we get minimum CO_2.Hence we can conclude that the best combination to minimise $CO_2$is B10,CR16 and IP1804.3.

4.4.2.7 Interaction Curve for HC

The first graph depicts blend versus CR for HC.In this graph for blend B70 and CR 16 we get minimum HC.The emissions of unburnt hydrocarbon for biodiesel blends is low dueto increased gas temperature and higher cetane number of biodiesel . Higher temperature of burnt gases in biodiesel fuel helps in preventing condensation of higher hydrocarbon reducing unburnt HC. The higher cetane number of biodiesel results decrease in HC emission due to shorter ignition delay.The second graph depicts blends versus IP.In this graph for blend B70 and IP 220 we get minimum HC.This is because of better atomization and higher temperature of gases at higher injection pressures results in increase in combustion efficiency.Hence we can conclude that the best combination to minimise HC is B70,CR16 and IP2204.3.

4.4.2.8 Interaction Curve for Smoke density

The first graph depicts blend verus CR.In this for B10 and CR 18 we get minimum smoke density.this is due to the fact that the viscosity of biodiesel is high as compared to diesel which is the dominating factor for poor atomization of fuel.As CR increases degree of fuel atomization increases as a result of which smoke density decreasesThe second graph depicts blend versus IP.In this graph for B10 and IP 220 we get minimum smoke density.This is due the fact that at high IP better atomization takes place hence smoke density decreases.The third graph depicts CR versus IP.In this graph for CR18 and IP 220 we get minimum smoke density.Hence we can conclude that the best combination for minimising smoke density is B10,CR18 and IP2204.3.

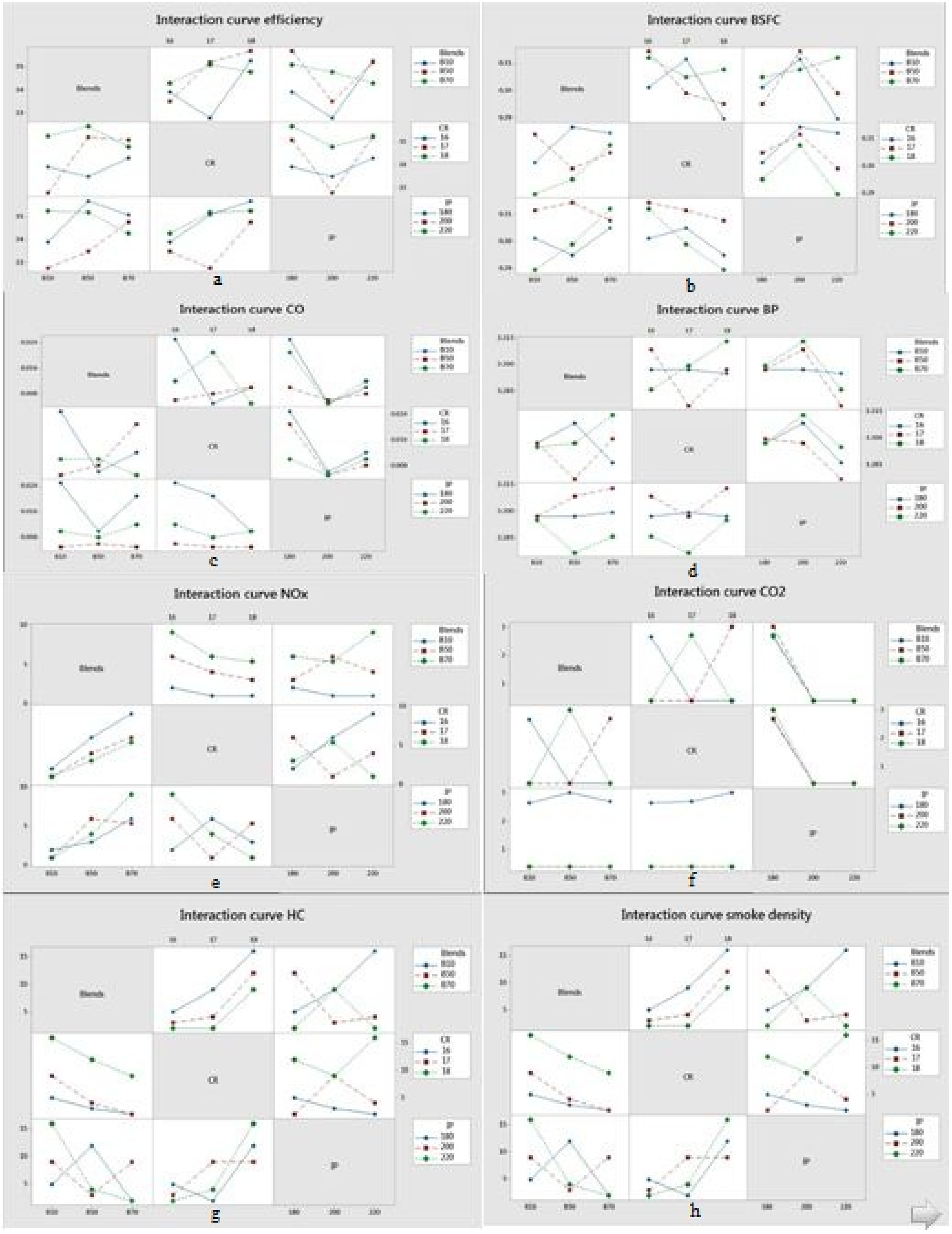

Figure 4.3: a)Interaction curve efficiency b)Interaction curve Bsfc c)Interaction curve CO d)Interaction curve BP e)Interaction curve NOx f)Interaction curve CO2 g)Interaction curve HC h)Interaction curve smoke density

The following table shows the optimum combination of Blends,CR and IP for the parameters or responses Efficiency,Bsfc,CO,BP,NOx,CO_2,HC and Smoke density.

Parameter	Blends	CR	IP
Efficiency	B50	18	180
Bsfc	B10	18	220
CO	B70	18	200
BP	B70	18	200
NOx	B10	16	180
CO_2	B10	16	180
HC	B70	16	220
Smoke Density	B10	18	220

Table 4.6: Best optimum combination responding to Interaction curve

From the baove table we can take Efficiency,Bsfc,NOx,CO and HC as parameters for finding an optimum combination.Hence the optimum blend lies between B10 to B50,CR 17 to 18 amd IP 180 to 2004.6.

4.4.3 Regression Analysis

The empirically developed mathematical model links a quantitative dependent variable BP, BSFC, Efficency, NOx,CO,CO_2,HCand smoke density to the selected independent variables or the design and control parameters(A, B, C) selected4.7. Regression is one of the popular statistical tools. The minitab regression tool is used for this. Regression analysis provides a method of linking the performance variable with the design parameters through a mathematical model if more than one design parameter affecting the response.parameters are there still linear regression can be used to mathematically link the dependent variable to the independent ones. This is termed as multiple regressions. When there are five design parameters involved the regression model becomes,

This model is natural extension of the simple linear regression model.Regression model is predication model within the influence space for the response variable BP, BSFC, Efficiency, CO, NOx,CO_2, HC, smoke density regression model is given by.

Code	Control Parameter
A	Blends
B	CR
C	IP

Table 4.7: Control Parameter

BP= 3.3170+0.000035A+0.00227B-0.000302C

BSFC=0.3994+0.000114A+0.00587B+0.000003C

Efficiency=22.39+0.0134A+0.672B+0.0006C

CO=0.1069-0.000029A-0.00300B-0.000217C

NOx=16.95+0.08929A-1.283B+0.0258C

CO_2=12.13+0.0006A+0.058B-0.0597C

HC=-70.5-0.0940A+4.500B+0.0250C

Smoke Density=7.01+0.02609A-0.04148B+0.00324C

Chapter 5

CONCLUSION

The experimentation work was carried out on computerised test rig with diesel and different blends biodiesel (B0,B10,B20,B30,B40,B50,B70).Density of biodiesel and diesel was determined with the help of digital weighting scale. Calorific value of diesel and biodiesel was determined with the help of bomb calorimeter.Also the flash point and fire point of diesel and biodiesel was determined with the help of cleveland apparatus.Various results were compared with varies parameters.Following Obersvations were made:

- Brake specic fuel consumption of the engine operating on the test fuels decreased with increasing load.It was obsevered that bsfc of B0 was lowest at highest load.where as the bsfc of B30 was found to be maximum at highest load.
- Efficiency decreases as the load is increased.Efficiency of B40,B50,B70 was found to be almost same where as efficiency of B20 was maximum at highest load.
- Mass of fuel consumption of the engine operating increases with increasing load.Fuel consumption was found to be maximum for B0 whereas for B30 it was found that the fuel consumption was higher at no load and 7 load condition amoung the other blends.
- BTHE% for B40,B50,B70 was found to be almost same. BTHE% for B30 is maximum at 12(110%) load, where as the BTHE% for B10 was found to be maximum at 7 load condition amoungs the other blends.
- BMEP increases with increase in load.No major deviation has been indicated as the density of blends tends to be almost same.

In the second part of Project Minitab17 software was used to find an optimum combination.An Orthogonal Array was generated L9 using levels as biodiesel blends,IP and CR and their values were (B10,B50,B70),(16,17,18) and (180,200,220) repectively.Experimentation was carried out with the given combination(L9).Efficiency,BP,Bsfc,NOx,CO_2,CO,HC and smoke density were selected as response and readings were taken. The results were optimized using taguchi method.S/N Ratio,interaction curves and regression equations were generated.Here BP and efficiency was maximized where as Bsfc,NOx,CO_2,CO,HC and smoke density were minimized.

Possible best combination were obtain so as to have an optimum combination

- For Efficiency Blend:B50 , CR:18 and IP:180.
- For Bsfc Blend:B10 , CR:18 and IP:220.
- For CO Blend:B70 , CR:18 and IP:200.
- For BP Blend:B70 , CR:18 and IP:200.
- For NOx Blend:B10 , CR:16 and IP:180.
- For CO_2 Blend:B10 , CR:16 and IP:180.
- For HC Blend:B70 , CR:16 and IP:220.
- For Smoke Density Blend:B10 , CR:18 and IP:220.

Hence from the above results we can conclude that for the best combination the optimum blend lies between B10 to B50,CR lies between 17 to 18 and IP lies between 180 to 200.

Bibliography

[1] K. Narasimharao, Adam Lee, and Karen WilsonDepartment of Chemistry, University of York, York YO10 5DD, UK Catalysts in Production of Biodiesel: A Review Journal of Biobased Materials and Bioenergy Vol.1, 1–12, 2007

[2] R. Maceiras, A. Cancela, M. Rodríguez, A. Sánchez, S. UrréjolaChemical Engineering Department. University of Vigo. Campus Lagoas-Marcosende.Materials Department. University of Vigo. Campus Lagoas-Marcosende An Innovative Biodiesel Production 36310 Vigo (Spain)

[3] Sri HarshaTirumala, A.V.Rohit, SivaKrishna.M Sudipta Saha SYNTHESIS OF NEEM BIODIESEL E-ISSN 0976-3945

[4] M. Thirumarimurugan, V. M. Sivakumar, A. Merly Xavier, D. Prabhakaran, and T. Kannadasan Preparation of Biodiesel from Sunflower Oil by Transesterification International Journal of Bioscience, Biochemistry and Bioinformatics, Vol. 2, No. 6, November 2012

[5] S. Oberweis, T.T Al-Shemmeri Effect of Biodiesel blending on emissions and efficiency in a stationary diesel engine European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

[6] Hossain A. B. M. S., Nasrulhaq Boyce A., Salleh A. and Chandran S. Biodiesel production from waste soybean oil biomass as renewable energy and environmental recycled process African Journal of Biotechnology Vol. 9(27), pp. 4233-4240, 5 July, 2010

[7] Dipak Patil, Dr. Rachayya.R. Arakerimath Performance Analysis of Multi-cylinder C.I. Engine by using Karanja Bio-diesel ISSN: 2248-9622

[8] Gaurav Dwivedi, Siddharth Jain, M.P. Sharma Impact of Biodiesel and its Blends with Diesel and Methanol on Engine Performance IJES

[9] K.Satyanarayana, Vinodh Kumar Padala, T.V.Hanumantha Rao, S.V.Umamaheswararao Variable Compression Ratio Diesel Engine Performance

Analysis International Journal of Engineering Trends and Technology (IJETT) – Volume 28 Number 1 - October 2015

[10] Biju Cherian Abraham Chindhu Prasad PERFORMANCE CHARACTERISTICS OF BIODIESEL MIXTURES IN A VARIABLE COMPRESSION RATIO ENGINE WITH CR 17 International Journal of Mechanical Engineering and Technology (IJMET) Volume 6, Issue 8, Aug 2015

[11] Rupesh L. Raut, Babaso N. Naik, Shekhar D. Thakare, Amol A. Gawali EMISSION ANALYSIS OF BIO-DIESEL BLENDS ON VARIABLE COMPRESSION RATIO ENGINE eISSN: 2319-1163 | pISSN: 2321-7308

[12] Gayatri Kushwah Analysis of smoke of diesel engine by using biodiesel as fuel International Journal of Scientific and ResearchPublications, Volume 3, Issue 4, April 2013 1 ISSN 2250-3153

[13] H. M. DHARMADHIKARI, PULI RAVI KUMAR, S. SRINIVASA RAO PERFORMANCE AND EMISSIONS OF C.I. ENGINE USING BLEND OF BIODIESEL AND DIESEL AT DIFFERENT INJECTION PRESSURES International Journal of Applied Research in Mechanical Engineering (IJARME) ISSN: 2231 –5950, Vol-2, Iss-2, 2012

[14] N. S Senthur, T. S Ravikumar, Cijil. B. John Eucalyptus Biodiesel; an Environmental friendly fuel for Compression Ignition Engines American Journal of Engineering Research (AJER) e-ISSN : 2320-0847 p-ISSN : 2320-0936 Volume-03, Issue-03, pp-144-149

[15] RESEARCH ENGINE TEST SET UP 1 CYLINDER, 4 STROKE, MULTI-FUEL,VCR(Computerized)Instruction manual

[16] Paresh D. Patel , Absar Lakdawala , Sajan Chourasia , Rajesh N. Patel Bio fuels for compression ignition engine: A review on engine performance, emission and life cycle analysis Renewable and Sustainable Energy Reviews 65 (2016) 23 April 2016 Accepted 15 June 2016

[17] J. B. Heywood, Internal combustion engine fundamentals. New York: McGraw Hill, 5 ed., 1988.

[18] A. Murugesan , C. Umarani , R. Subramanian , N. Nedunchezhian Bio-diesel as an alternative fuel for diesel enginesA review Renewable and Sustainable Energy Reviews 13, pp. 653662, 2009.

[19] Ekrem Buyukkaya Eect of biodiesel on a DI diesel engine performance, emis- sion and combustion characteristics, Fuel 89, pp. 3099-310, 2010.

[20] N. Stalin and H. J. Prabhu Performance test of ic engine using karanja biodiesel blending with diesel, Arpn Journal of Engineering and Applied Sciences, pp. 32-34, 2007.

[21] H. Raheman Performance of diesel engine with biodiesel at varying compression ratio and ignition timing, Fuel 87, pp. 26592666,2008.

[22] S. Jindal, B.P. Nandwana, N.S. Rathore, V.Vashistha Experimental investiga- tion of the eect of compression ratio and injection pressure in a direct injection diesel engine running on Jatropha methyl ester, Applied Thermal Engineering 30, pp. 442448, 2010.

[23] M. Mani , G. Nagarajan Inuence of injection timing on performance, emission and combustion characteristics of a DI diesel engine running on waste plastic oil, Energy 34, pp. 16171623, 2009.

[24] Kanok-on Rodjanakid1 and Chinda Charoenphonphanich Performance of an Engine Using Biodiesel from Rened Palm Oil Stearin and Biodiesel from Crude Coconut Oil, The Joint International Conference on Sustainable Energy and Environment (SEE) 1-3 December 2004, Hua Hin, Thailand.

[25] Magn Lapuerta, Octavio Armas, Jose Rodrguez-Fernandez Eect of biodiesel fuels on diesel engine emissions, Progress in Energy and Combustion Science 34, pp. 198223,2008.