PERFORMANCE ANALYSIS OF CI ENGINE BY USING TWO OILS (JATROPHA OIL & METHANOL) BLENDED WITH DIESEL AS ALTERNATIVE FUEL: A REVIEW

Mr. Ranavare V. R.[1], Mr. Kale S. S.[2]

[1]PG student, Mechanical Engineering Department, NK Orchid CET, Solapur, India
[2]Assistant Professor, Mechanical Engineering Department, NK Orchid CET, Solapur, India

***

Abstract - *The world is facing a huge problem of high fuel prices, air pollution and a lot of climatic changes. Alternate Fuels play an essential role in the present scenario in Internal Combustion Engines as the mineral fuels are depleting. Alternative fuels generally have lower vehicle emissions that contribute to smog, air pollution and global warming.*

Most alternative fuels don't come from finite fossil-fuel resources and are sustainable. To reduce reliance on petroleum-based fuels, Alternate fuels are best solution for the tomorrow IC engines. "Alternative fuel'' is used in motor vehicles to deliver direct propulsion, less damaging to the environment than conventional fuels.

Bio-diesel can be used as an alternate and non-conventional fuel to run all type of C.I. engine. Fast depletion of the fossil fuels and sometimes shortage during crisis period directs us to search for some alternative fuel which can reduce our dependence on fossil fuels. Thus, further increase requirement of this depleting fuel source. Many alternative fuels like biogas, methanol, ethanol and vegetable oils have been evaluated as a partial or complete substitute to diesel fuel.

The vegetable oil can be used directly in diesel engine as a fuel, because their calorific value is almost 90-95 percent of the diesel. The oil is extracted from the seeds and converted into methyl esters by the trans-esterification process. The methyl ester obtained from this process is known as bio diesel. Bio diesel is renewable source of energy which can be produced locally by our farmers by growing oil seed producing plants on their waste lands, barren land which is eco-friendly also. In order to propagate and promote the use of bio-diesel as an alternate source of energy in rural sector, the bio-diesel is produced from non-edible oils by using bio-diesel processor and the diesel engine performance for water lifting are tested on bio-diesel and bio-diesel blended with diesel. In addition, biodiesel is better than diesel fuel in terms of very low sulfur content and it is also having higher flash and fire point temperatures than in diesel fuel. Biodiesel and its blends with diesel were employed as a fuel for diesel engine without any modifications in the existing engine. We are mixing two oils blended with diesel & measure the Performance analysis of CI engine.

Key Words: **blended 1, flash and fire point 2, trans-esterification process 3, etc**

1. INTRODUCTION

The blends of varying proportions of jatropha oil and methanol blended with diesel were prepared, analyzed and compared with diesel fuel. The effect of temperature on the viscosity of biodiesel and jatropha oil was also studied. The performance of the engine using blends and jatropha oil was evaluated in a single cylinder C.I. engine and compared with the performance obtained with diesel. The use of biodiesel has slightly reduced the engine performances while notably increased Specific Fuel Consumption (SFC). The performance of the engine using blends and jatropha oil was evaluated in a single cylinder C.I. engine and compared with the performance obtained with diesel. Significant improvement in engine performance was observed compared to vegetable oil alone. The specific fuel consumption and the exhaust gas temperature were reduced due to decrease in viscosity of the vegetable oil. Acceptable thermal efficiencies of the engine were obtained with blends containing up to 50% volume of jatropha oil. From the properties and engine test results it has been established that 40–50% of jatropha oil can be substituted for diesel without any engine modification and preheating of the blends

Many papers have been published in the area of biodiesel performance. In this chapter, the results and conclusions of such papers are discussed. Biodiesel by definition is a compound of methyl ester derived from the esterification/ trans-esterification process of various types of vegetable oils or animal fats. The quality of biodiesel oscillates in a wide range mainly as a function of the quality of the feedstock, the fatty acid composition of the parent vegetable oil or animal fat, the production process and post-production parameters.

II. LITERATURE REVIEW:

The literature available on the current topic is as mentioned below:

Ambarish Datta & Bijan Kumar Mandal (2014) [1]: 'Use of Jatropha Biodiesel as a Future Sustainable Fuel' This article briefly discusses the present status and future scope for use of jatropha biodiesel as an alternative to diesel (fossil derived) in India. It is obligatory on the part of India to go in for some alternative, renewable, and eco-friendly fuels that can be cultivated in the otherwise barren land available in the country. In this respect, it may be mentioned that the government of India has identified jatropha as a possible and promising alternative to diesel. However, the bio-fuel policy adopted by the government through its bio-fuel mission launched in 2003 and 2007 in two phases did not evoke much success because of various challenges faced by the commercial production of jatropha, in spite of its many advantages. Therefore, in this era of energy crisis and fast degradation of the environment, the government must devise an appropriate plan of action to overcome these challenges and to implement the bio-fuel policy to promote the use of jatropha biodiesel as a partial substitute to mineral diesel fuel.

Y. V. Hanumantha Rao, Ram Sudheer Voleti, V. S. Hariharan, A. V. Sitarama Raju, P. Nageswara Reddy (2009) [2]: 'Use of Jatropha Oil Methyl Ester and Its Blends as an Alternative Fuel in Diesel Engine' Biomass derived vegetable oils are quite promising alternative fuels for agricultural diesel engines. Use of vegetable oils in diesel engines leads to slightly inferior performance and higher smoke emissions due to their high viscosity. The performance of vegetable oils can be improved by modifying them through the transesterification process. In the present work, the performance of single cylinder water-cooled diesel engine using methyl-ester of Jatropha oil as fuel was evaluated for its performance and exhaust emissions. The fuel properties of biodiesel such as kinematic viscosity, calorific value, flash point, carbon residue and specific gravity were found. Results indicated that B25 has closer performance to diesel and B100 has lower brake thermal efficiency, mainly due to its high viscosity compared to diesel. The brake thermal efficiency for biodiesel and its blends was found to be slightly higher than that of diesel fuel at tested load conditions and there was no difference between the biodiesel and its blended fuels efficiencies. For Jatropha biodiesel and its blended fuels, the exhaust gas temperature increased with increase in power and amount of biodiesel. But, diesel blends showed reasonable efficiency, lower smoke, CO2, CO and HC.

B. Deepanraj, C. Dhanesh, R. Senthil, 1M. Kannan, A. Santhoshkumar and P. Lawrence (2011) [3]: 'Use of Palm oil Biodiesel Blends as a Fuel for Compression Ignition Engine' Problem statement: The increasing awareness of the environmental hazards and the alarming levels of air pollution have led to more restrictive regulations on engines emission control in recent years. Approach: The dwindling resources and rising cost of crude oil had resulted in an intensified search for alternate fuels. In the present study biodiesel (palm oil methyl ester) blends with diesel was investigated in a direct injection stationary diesel engine. The stationary engine test bed used consists of a single-cylinder four stroke diesel engine, eddy current dynamometer with computer control data acquisition system and exhaust emissions analyzer. Results: Engine tests were conducted at constant speed using neat diesel fuel and various proportions of biodiesel blends. The exhaust emissions such as CO, HC and NOx were measured using exhaust gas analyzer. Performance characteristics like brake thermal efficiency and specific fuel consumption were recorded. The differences in the measured emissions and performance of the biodiesel-diesel fuel blends from the baseline operation of the engine, i.e., when working with neat diesel fuel were determined and compared. Conclusion: It is concluded that the lower blends of biodiesel increased the brake thermal efficiency and reduced the fuel consumption. Biodiesel blends produces lower engine emissions than diesel. From the result, it has been established that 20-40% of palm oil biodiesel can be use as a substitute for diesel without any engine modifications.

Surendra R. Kalbande and Subhash D. Vikhe (2008) [4]: 'Jatropha and Karanj bio-fuel: an alternate fuel for diesel engine' The bio-diesel was produced from non-edible oils by using bio-diesel processor and the diesel engine performance for water lifting was tested on bio-diesel and bio-diesel blended with diesel. The newly developed bio-diesel processor was capable of preparing the oil esters sufficient in quantity for running the commonly used farm engines. The fuel properties of bio-diesel such as kinematic viscosity and specific gravity were found within limited of BIS standard. Operational efficiency of diesel pump set for various blends of bio-diesel were found nearer to the expected efficiency of 20 percent. Bio-diesel can be used as an alternate and non-conventional fuel to run all type of C.I. engine.

Scott L. Springer () [5]: 'Experimental Evaluation of Alternative Fuels for Internal Combustion Engines' Due to global climate change fears, increasing levels of carbon dioxide in the atmosphere, and economic considerations, there is an interest in developing biological renewable alternatives for fossil fuels. Of particular interest in the United States, due to domestic production limits, is the development of technologies that can displace fossil fuels for internal combustion engine applications. Some promising research studying these options has been initiated in the University of Wisconsin Stout Integrated Technology Laboratory. The research program calls for undergraduate student discovery and design activities, utilizing a project based learning approach. In this paper several projects that connect undergraduate research and faculty scholarship are presented.

In recent years there has been increased focus on research that develops and evaluates fossil fuel alternatives for internal combustion (IC) engines. This is due in part to the belief that burning once inexpensive and plentiful fossil fuels, releases carbon dioxide (CO2) stored by plants many years ago into the atmosphere. Evidence suggests that the release of CO2 contributes to global climate change or global warming. The concerns of global warming include melting of glacial ice caps near the north and south poles which may lead to increased sea levels and significant human peril, especially in costal settlements. In the Integrated Technology

Laboratory at the University of Wisconsin Stout, we have developed an undergraduate student based research program to develop and report performance of various biomass based alternatives to fossil fuels for use in IC engines.

K. Srithar, K. Arun Balasubramanian, V. Pavendan, B. Ashok Kumar (2014) [6]: 'Experimental investigations on mixing of two biodiesels blended with diesel as alternative fuelfor diesel engines' The world faces the crises of energy demand, rising petroleum prices and depletion of fossil fuel resources. Biodiesel has obtained from vegetable oils that have been considered as a promising alternate fuel. The researches regarding blend of diesel and single biodiesel have been done already. Very few works have been done with the combination of two different biodiesel blends with diesel and left a lot of scope in this area. The present study brings out an experiment of two biodiesels from pongamia pinnata oil and mustard oil and they are blended with diesel at various mixing ratios. The effects of dual biodiesel works in engine and exhaust emissions were examined in a single cylinder, direct injection, air cooled and high speed diesel engine at various engine loads with constant engine speed of 3000 rpm. The influences of blends on CO, CO2, HC, NOx and smoke opacity were investigated by emission tests. The brake thermal efficiency of blend A was found higher than diesel. The emissions of smoke, hydro carbon and nitrogen oxides of dual biodiesel blends were higher than that of diesel. But the exhaust gas temperature for dual biodiesel blends was lower than diesel.

Hifjur Raheman, Prakash C Jena and Snehal S Jadav (2013) [7]: 'Performance of a diesel engine with blends of biodiesel (from a mixture of oils) and high-speed diesel'. A 10.3-kW single-cylinder water-cooled direct-injection diesel engine was evaluated using blends of biodiesel (B10 and B20) obtained from a mixture of mahua and simarouba oils (50:50) with high-speed diesel (HSD) in terms of brake specific fuel consumption, brake thermal efficiency, and exhaust gas temperature and emissions such as CO, HC, and NOx. Based on performance and emissions, blend B10 was selected for long-term use. Experiments were also conducted to assess soot deposits on engine components, such as cylinder head, piston crown, and fuel injector tip, and addition of wear metal in the lubricating oil of diesel engine when operated with the biodiesel blend (B10) for 100 h. The amount of soot deposits on the engine components was found to be, on average, 21% lesser for B10-fueled engine as compared with HSD-fueled engine due to better combustion. The addition of wear metals such as copper, zinc, iron, nickel, lead, magnesium, and aluminum, except for manganese, in the lubricating oil of B10-fueled engine after 100 h of engine operation was found to be 11% to 50% lesser than those of the HSD-fueled engine due to additional lubricity.

R.Thirunavukarasu, B.Suresh kumar (2015) [8]: 'Performance analysis of Two Biodiesel Blended with Various Diesel Ratio'. The world faces the energy demand, increased petroleum rates and decrease of fossil fuel resources. Biodiesel has extracted from vegetable oils that have been considered as an alternate fuel. The researches regarding blend of diesel and single biodiesel have been carried out already. A few works have been attempted with the combination of two different biodiesel blends with diesel and left with a lot of scope in this thrust area. The present study takes out an experiment of two biodiesels from pongamia pinnata oil and Neem oil. They are blended with diesel at various mixing ratios. The effects of two biodiesel works in engine were checked in a single cylinder, direct injection for pongamia pinnata oil and Neem oil, air cooled and high speed diesel engine at various engine loads with constant engine speed of 2500 rpm. The influences of blends on CO, CO2, HC, NOx and smoke opacity were investigated by emission tests. The brake thermal efficiency of blend was found higher than diesel. The emissions of smoke, hydro carbon and nitrogen oxides of two biodiesel blends were higher than that of diesel. But the exhaust gas temperature for dual biodiesel blends was lower than diesel.

S.Prasanth, Dr.M.Chandrasekar, Dr.T.Senthil kumar (2016) [9]: 'Experimental Investigations on Mixing of Two Biodiesels Blended with Diesel as Alternative Fuel for Diesel Engines' The world faces the crises of energy demand, rising petroleum prices and depletion of fossil fuel resources. Diesel engines are the most efficient prime movers. The rapid depletion of petroleum reserves and rising oil prices has led to the search for alternative fuels. Biodiesel is an alternative diesel fuel derived from vegetable oils and animal fats holds good promises as an eco-friendly alternative to diesel fuel. Transesterification process is the most widely used technology for producing biodiesel from vegetable oil. The researches regarding blend of diesel and single biodiesel have been done already. Very little works have been carried with the combination of two different biodiesel blends with diesel. This study brings out an experiment of two biodiesels Pongamia pinnata oil and Neem oil and they are blended with diesel at various mixing ratios (10%, 20%, 30%) to evaluate its fuel properties. Experimental investigations were conducted on unmodified single cylinder diesel engine using different blends of mixed biodiesel at variable loads. The result indicates that fuel properties and engine performance are good up to biodiesel blend B20.

Farouk K. El-Baz, M.S.Gad, Sayeda M. Abdo, K.A. Abed, Ibrahim A. Matter (2016) [10]: 'Performance and Exhaust Emissions of a Diesel Engine Burning Algal Biodiesel Blends' The production of biodiesel from algae is one of the promising alternative fuels for diesel engines. Algae oil was extracted from microalgae Scenedesmus obliquus. The biodiesel was produced from algal oil by transesterification. Biodiesel blends of 10 and 20% were prepared. Fatty acid analysis showed that fuel properties of S. obliquus were highly affected by fatty acids composition. Chemical and physical properties of biodiesel blends B10 and B20 were close to diesel oil. The performance parameters and exhaust emissions of a diesel engine burning biodiesel blends and diesel fuels were studied. Biodiesel blend B20 showed decrease in specific fuel consumption, exhaust gas temperature and increase in thermal efficiency compared to B10 and diesel fuels. There were reductions in the emissions gas for B20 compared to B10 and diesel fuels. It could be concluded that a high quality of biodiesel could be produced from microalgae S. obliquus and used efficiently and environmentally safe in conventional diesel engine.

Jacek Caban, Agata Gniecka, Lukáš Holeša (2013) [11]: 'Alternative fuels for diesel engines' This paper presents the development and genesis of the use of alternative fuels in internal combustion ignition engines. Based on the analysis of the literature, this article shows various alternative fuels used in Poland and all over the world. Furthermore, this article describes the research directions for alternative fuels use in road transport powered by diesel engines.

Pranil Singh, Jagjit Khurma and Anirudh Singh (2010) [12]: 'Coconut Oil Based Hybrid Fuels as Alternative Fuel for Diesel Engines' The use of vegetable oils as a fuel in diesel engines causes some problems due to their high viscosity compared with diesel. Various techniques and methods are used to solve the problems resulting from high viscosity. Approach: One of the techniques is the preparation of a microemulsion fuel, called a hybrid fuel. In this study, hybrid fuels consisting of coconut oil, ethanol and octan-1-ol were prepared with an aim to test their suitability as a fuel for diesel engines. Density, viscosity and gross calorific values of these fuels were determined and the fuels were used to run a direct injection diesel engine. The engine performance and exhaust emissions were investigated and compared with that of diesel and coconut oil. **Results:** The experimental results show that the engine efficiency of the hybrid fuels is comparable to that of diesel. As the percentage of ethanol and/or octan-1-ol increased, the viscosity of the hybrid fuels decreased and the engine efficiency increased. The exhaust emissions were lower than those for diesel, except carbon monoxide, which increased. Conclusion/Recommendations: Hence, it is concluded that these hybrid fuels can be used successfully as an alternative fuel in diesel engines without any modifications. Their completely renewable nature ensures that they are environmentally friendly.

Conclusion of literature review:

Relevant literatures are based on performance and emissions of various gases from diesel engine fuelled with different combinations of fuels at varying conditions such as varying load and compression ratio conditions .Most of the investigators suggested that biodiesel blends can be used in diesel engines without any engine modifications. The effect of the fuel on engine performance durability & emissions were considered. Fuelled by the blends, it is found that the smoke emissions from the engine were all lower than that fuelled by diesel. All emissions such as CO, CO_2, PM, HC, etc. are extensively decreased but NO_X emissions increase.

PRODUCTION PROCESS OF BIODIESEL

1) Heating of Oil: 1 litre of Vegetable Oil is heated up to a temperature of 55-60°C and maintained at this temperature.
2) Mixing of catalyst and methanol: 4 grams NaOH is mixed with 250 ml of methanol and stirred properly for 20 min. Sodium Methoxide is formed. This mixture of catalyst and methanol is poured into the oil.
3) Transesterification: The reaction process is called transesterification. The solution is stirred for 1 hour.
4) Settling: After shaking the solution is kept for 16 hours to settle the biodiesel and sediment layers clearly. Two distinct layers of glycerin and biodiesel are formed.
5) Separation of biodiesel: The biodiesel is separated from sedimentation by flask separator carefully.
6) Washing: Biodiesel is washed and rewashed by water until the water appears clean. This is necessary to remove the methanol and NaOH traces from the biodiesel. Avoid agitating the biodiesel while adding water as this agitation may cause emulsification of water and methyl ester. Each time the mixture takes 12-16 hours to settle properly.
7) Drying: Biodiesel is dried by keeping it under a running fan for 12 hours.

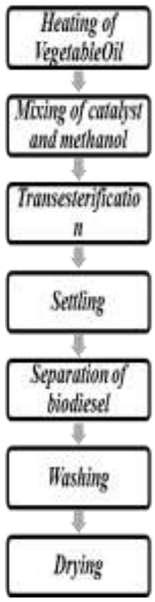

Fig 1. Production of biodiesel

III. PROPERTIES OF BIODIESEL USED IN THIS PROJECT:

Table1: Shows Properties of Jatropha oil & Methanol used in this paper

Property	Diesel	Jatropha oil	METHANOL
Calorific value (kJ/kgK)	42000	39340	22700
Kinematic Viscosity at 40^{0}C (cSt)	2.87	3.57	0.58
Specific Density (kg/m^3)	840	881	792
Flash Point (^{0}C)	75 to 78	174	11 to 12
Cetane Number	40 to 50	58.4	5
Calorific value (kJ/kgK)	42000	39340	22700

IV. PERFORMANCE OF I.C. ENGINES

A. Performance parameters of C.I. Engines

1) **Indicated thermal efficiency (η_t):** Indicated thermal efficiency is the ratio of energy in the indicated power to the fuel energy.
2) **Brake thermal efficiency (η_{bth}):** A measure of overall efficiency of the engine is given by the brake thermal efficiency. Brake thermal efficiency is the ratio of energy in the brake power to the fuel energy.
3) **Mechanical efficiency (η_m):** Mechanical efficiency is the ratio of brake horse power (delivered power) to the indicated horsepower (power provided to the piston). η =Brake Power / Indicated Power
4) **Specific fuel consumption (SFC):** Brake specific fuel consumption and indicated specific fuel consumption, abbreviated BSFC and ISFC, are the fuel consumptions on the basis of Brake power and Indicated power respectively.
5) **Fuel-air (F/A) or air-fuel (A/F) ratio:** The relative proportions of the fuel and air in the engine are very important for combustion and efficiency of the engine. This is expressed either as the ratio of the mass of the fuel to that of the air or vice versa
6) **Calorific value or Heating value or Heat of combustion:** It is the energy released per unit quantity of the fuel, when the combustible is burned and the products of combustion are cooled back to the initial temperature of combustible mixture. The heating value so obtained is called the higher or gross calorific value of the fuel. The lower or net calorific value is the heat released when water in the products of combustion is not condensed and remains in the vapour form.
7) **Power and Mechanical efficiency:** Power is defined as rate of doing work and equal to the product of force and linear velocity or the product of torque and angular velocity. Thus, the measurement of power involves the measurement of force (or torque) as well as speed.
8) **Mean effective pressure and torque:** Mean effective pressure is defined as a hypothetical pressure, which is thought to be acting on the piston throughout the power stroke.
Power in kW = (Pm LAN/n 100)/60 in bar
n = 2 (for four stroke engine)

Thus we can see that for a given engine the power output can be measured in terms of mean effective pressure. If the mean effective pressure is based on brake power it is called brake mean effective pressure (BMEP) and if based on indicated power it is called indicated mean effective pressure (IMEP)

9) **Volumetric efficiency (η_v):** The engine output is limited by the maximum amount of air that can be taken in during the suction stroke, because only a certain amount of fuel can be burned effectively with a given quantity of air.
Volumetric efficiency is an indication of the 'breathing' ability of the engine and is defined as the ratio of the air actually induced at ambient conditions to the swept volume of the engine.

V. BASIC MEASUREMENT PARAMETERS IN CI ENGINE:

The basic measurements, which usually should be undertaken to evaluate the performance of an engine in the test, are the following:

1) **Measurement of speed**
Following different speed measuring devices are used for speed measurement.
   i) Photoelectric/Inductive proximity pickup with speed indicator
   ii) Rotary encoder
2) **Measurement of fuel consumption**
   i) Volumetric method: The fuel consumed by an engine is measured by determining the volume flow of the fuel in a given time interval and multiplying it by the specific gravity of fuel. Generally a glass burette having graduations in mm is used for volume flow measurement. Time taken by the engine to consume this volume is measured by stopwatch.
   ii) Gravimetric method: In this method the time to consume a given weight of the fuel is measured. Differential pressure transmitters working on hydrostatic head principles can be used for fuel consumption measurement.
3) **Measurement of brake power**

Measurement of BP involves determination of the torque and angular speed of the engine output shaft. This torque-measuring device is called a dynamometer.

4) **Measurement of indicated power**
Indicator diagram: A dynamic pressure sensor (piezo sensor) is fitted in the cylinder head to sense combustion pressure. A rotary encoder is fitted on the engine shaft for crank angle signal. Both signals are simultaneously scanned by an engine indicator (electronic unit) and communicated to computer. The software in the computer draws pressure crank-angle and pressure volume plots and computes indicated power of the engine.

VI. CONCLUSION

In this review study we have seen different methods to improve the performance of Jatropha oil & methanol fuelled compression ignition (C.I.) engine. Many researchers used different techniques for investigation and results were compared with the diesel fuel. Many experiments were conducted with Jatropha oil & methanol by various Injection pressures, Compression ratios, additives, load etc. Almost all the experiments were conducted at a constant speed of 1500 rpm. It can be seen that all experiments showed improved performance. Injection pressure of 200 bar and 17.5:1 compression ratio can be used as optimum values and CI engines can be run with mixture of jatropha & methanol blend biodiesel. Hence it can be concluded that the blends of jatropha & methanol with diesel up to 20% by volume could replace diesel for running the diesel engine for getting less emissions without sacrificing the power output and will thus help in controlling air pollution to a great extent. In this paper we study the properties of jatropha & methanol, Biodiesel production process, properties and result of jatropha & methanol Biodiesel as an alternative fuel for CI engine. Based on this study on jatropha & methanol biodiesel, we can conclude that the jatropha & methanol oil can be used as an alternative fuel for diesel engine without any modification.

It can be concluded that:

1) The brake power, BSFC and mechanical efficiency for biodiesel at varying loads can be almost similar to that of diesel. Hence, there is no significant loss in power.
2) The brake thermal efficiency can be observed to be more for biodiesel compared to diesel.
3) Thus, it suggests that there is no degradation in performance of the C.I. engines running on biodiesel.

VII. ACKNOWLEDGEMENT

It is a matter of great me pleasure for me to present my project work on “Performance Analysis of CI Engine by using Two Oils (Jatropha oil & Methanol) blended with Diesel as Alternative Fuel: A Review”. First and foremost, I am highly thankful to my project guide Prof. S. S. Kale, Department of Mechanical Engg., NKOCET, Solapur for his expert guidance and continuous encouragement during all stages of dissertation. His help in the form of valuable information and research thoughts at proper time has brought life in this paper. I feel lucky to get an opportunity to work with him.

REFERENCES

[1] **Ambarish Datta & Bijan Kumar Mandal (2014) [1]:** ‘Use of Jatropha Biodiesel as a Future Sustainable Fuel’ Energy Technology & Policy, 1:1, 8-14, DOI:10.1080/23317000.2014.930723

[2] **Y. V. Hanumantha Rao, Ram Sudheer Voleti, V. S. Hariharan, A. V. Sitarama Raju, P. Nageswara Reddy (2009) [2]:** ‘Use of Jatropha Oil Methyl Ester and Its Blends as an Alternative Fuel in Diesel Engine’ July-September 2009, Vol. XXXI, No. 3 / **253**

[3] **B. Deepanraj, C. Dhanesh, R. Senthil, 1M. Kannan, A. Santhoshkumar and P. Lawrence (2011) [3]:** ‘Use of Palm oil Biodiesel Blends as a Fuel for Compression Ignition Engine’ American Journal of Applied Sciences 8 (11): 1154-1158, 2011 ISSN 1546-9239© 2011 Science Publications

[4] **Surendra R. Kalbande and Subhash D. Vikhe (2008) [4]:** ‘Jatropha and Karanj bio-fuel: an alternate fuel for diesel engine’ARPN Journal of Engineering and Applied Sciences ©2006-2008 Asian Research Publishing Network (ARPN). VOL. 3, NO. 1, FEBRUARY 2008

[5] **Scott L. Springer () [5]:** ‘Experimental Evaluation of Alternative Fuels for Internal Combustion Engines’ Proceedings of the 2013 Conference for Industry and Education Collaboration Copyright ©2013 American Society for Engineering Education

[6] **K. Srithar, K. Arun Balasubramanian, V. Pavendan, B. Ashok Kumar (2014) [6]:** ‘Experimental investigations on mixing of two biodiesels blended with diesel as alternative fuelfor diesel engines’ Received 5 December 2013; accepted 22 April 2014, Available online 30 April 2014. King Saud University-Journal of King Saud University – Engineering Sciences

[7] **Hifjur Raheman, Prakash C Jena and Snehal S Jadav (2013) [7]:** ‘Performance of a diesel engine with blends of biodiesel (from a mixture of oils) and high-speed diesel’. Raheman et al. International Journal of Energy and Environmental Engineering 2013, 4:6

[8] **R.Thirunavukarasu, B.Suresh kumar (2015) [8]:** ‘Performance analysis of Two Biodiesel Blended with Various Diesel Ratio’. international journal of innovative research in science, engineering and technology (an iso 3297: 2007 certified organization) vol. 4, special issue 6, may 2015

[9] **S.Prasanth, Dr.M.Chandrasekar, Dr.T.Senthil kumar (2016) [9]:** ‘Experimental Investigations on Mixing of Two Biodiesels Blended with Diesel as Alternative Fuel

for Diesel Engines' Volume 6 Issue No. 6 DOI 10.4010/2016.1577 ISSN 2321 3361 © 2016 IJESC

[10] **Farouk K. El-Baz, M.S.Gad, Sayeda M. Abdo, K.A. Abed, Ibrahim A. Matter (2016) [10]:** 'Performance and Exhaust Emissions of a Diesel Engine Burning Algal Biodiesel Blends'

[11] **Jacek Caban, Agata Gniecka, Lukáš Holeša (2013) [11]:** 'Alternative fuels for diesel engines' **Advances in Science and Technology Research Journal** Volume 7, No. 20, Dec. 2013, pp. 70-74, DOI: 10.5604/20804075.1073063

[12] **Pranil Singh, Jagjit Khurma and Anirudh Singh (2010) [12]:** 'Coconut Oil Based Hybrid Fuels as Alternative Fuel for Diesel Engines'American Journal of Environmental Sciences 6 (1): 71-77, 2010, ISSN 1553-345X© 2010 Science Publications