EFFECT OF INJECTION PRESSURE ON PERFORMANCE AND EMISSION CHARACTERISTICS OF SINGLE CYLINDER DIESEL ENGINE USING NEEM-NIGER BIODIESEL: A REVIEW

Mr. Kadam S. S.[1], Mr. Ghaysundar A. G.[2]

[1] *M.E. Heat and Power Engineering, DYPSOEA, Maharashtra, India*
[2] *Assistant Professor, Mechanical Department, DYPSOEA, Maharashtra, India*

ABSTRACT

Petroleum based fuels are likely to be unavailable in the future. Environmental warnings and limited extent of petroleum fuels have prompted the search for alternative fuels for internal combustion engines. Bio-diesels that meet the criteria have been used by a number of academic researchers who have stated that, biodiesel exhibits very similar engine performance characteristics attributed to diesel fuel and diminishes the exhaust emissions from diesel engines. The performance in terms of brake thermal efficiency of the engine running on bio-diesel blends is equivalent to that of diesel fuel. This is in agreement with the findings reported by numerous investigators while fueling diesel engines by bio-diesels attained from palm, sunflower, soybean, sunflower, canola, olive, karanja, jatropha, mahua, neem, niger and rubber seed oils. Among all these neem and niger seeds are abundantly available and are great potential source of energy. Again there are two ways to improve the performance and emission characteristics of internal combustion engine, one by varying the compression ratio and other one is by varying the injection pressure.

Keyword: - *Neem oil, Niger ol, Biodiesel, Injection pressure, etc.*

1. INTRODUCTION

The growing demand for fuel and increasing concern for the environment due to the use of fossil fuel have led to the increasing popularity of biofuel as a useful alternative and environmentally friendly energy resource. The increasing population of both the developing nations of the world, their steady increasing in the diesel consumption, the non-renewability of the fossil fuels as well as their environmental effects are some of the reasons that has made the biofuels as alternative and attractive. Diesel engines are the major source of power generation and transportation hence diesel is being used extensively ,but due to the gradual impact of environmental pollution there is an urgent need for suitable alternate fuels for use in diesel engine without any modification. There are different kinds of vegetable oils and biodiesel have been tested in diesel engines its reducing characteristic for greenhouse gas emissions.

Biodiesel (a mixture of fatty acid methyl esters) has become very attractive as a biofuel because of its environmental benefits as it has less air pollutants per net energy than diesel and is nontoxic and biodegradables because it is produced from renewable sources with high energetic efficiency, biodiesel yields from an estimated 90% to 40% more energy than the energy invested in producing it [6]. Biodiesel derived from a wide variety of sources can be

used as a direct substitute for petro-diesel fuels [1,2,3,4,5]. They are several non-edible oil seed such as Karanja (Pongomia Pinnate), Jatropha (Jatropha curca), Neem (Azadirachta Indica) etc. Among these, Azadirachta Indica is one of the largest producer neem oil and its seed contains 30% oil content. It is an untapped source in India [1,2,7]. Implementation of biodiesel in India will lead to many advantages like green cover to wasteland, support to agriculture and rural economy and reduction independence on imported crude oil and reduction in air pollution.
In existing diesel engine/internal combustion engine, Biodiesels are used with constant parameters of engine such as C.R. and I.P. So we can't get best output or results for particular use of that biodiesel[8,9,10,11,12,13,14,15,16]. So in this project we shall going to check at which injection pressure we get best results or output like performance and emission characteristics of internal combustion engine[8 to 16].

1.1 Biodiesel

Bio-diesel is fatty acid methyl or ethyl ester made from virgin or used vegetable oils (both edible & non-edible) band animal fats [6]. The main commodity sources for bio- diesel in India can be non-edible oils obtained from plant species such as Jatropha, Karanj, Neem, Mahua etc. Bio-diesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a bio-diesel blend or can be used in its pure form. Just like petroleum diesel, bio-diesel can operates in compression ignition engine; which essentially require very little or no engine modifications because biodiesel has properties similar to petroleum diesel fuels [1 to 5]. It can be stored just like the petroleum diesel fuel and hence does not require separate infrastructure [6]. The use of bio-diesel in conventional diesel engines results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particulate matters. Bio-diesel is considered clean fuel since it has almost no sulphur, no aromatics and has about 10% built-in oxygen, which helps it to burn fully. Its higher cetane number improves the ignition quality even when blended in the petroleum diesel. It provides significant lubricity improvement over petroleum diesel fuel. Lubricity results of biodiesel and petroleum diesel using industry test methods indicate that there is a marked improvement in lubricity when bio-diesel is added to conventional diesel fuel[4,5]. Even bio-diesel level as low as 1% can provide up to 65% increase in lubricity in distillate fuels. HC and CO emissions were also reported to be lower. Non-regulated emissions were also found to be lower [1 to 5].

1.2 Neem Biodiesel

A Neem tree can produce many thousands of flowers. In one flowering cycle, a mature tree may produce a large number of seeds. Neem trees start bearing harvestable seeds within 3-5 years, and full production may be started in 10 years, and this will continue up to 150-200 years of age. A mature Neem tree may produce 30-50 kg of fruit each year. By rough estimate India has nearly 20 million Neem trees. Indian Neem trees have a potentials to provide one million tonnes of fruits per year and 0.1 million tons of kernels per years (assuming 10% kernel yield). Neem seeds yield 40-60% oil. Neem is a golden tree that has gained world-wide importance owing to its multiple uses. Besides agro forestry, it is used in pest control, toiletries, cosmetics, pharmaceuticals, plant and animal nutrition and energy generation. Neem trees are considered to be a divine tree in India because of their numerous valuable uses. The commercial value of Neem has been known since Vedic times. Every part of Neem tree viz., leaf, flower, fruit, seed, kernel, seed oil, bark, wood, twig, root etc. has been in use and traded in various purpose. The fuel properties of neem biodiesel were within the limits and comparable with the conventional diesel. Except calorific value, all other fuel properties of neem biodiesel were found to be higher as compared to diesel [1,2,3,4].

1.3 Niger Oil

Native to Ethiopia and Malawi, niger seed is also grown in India.[2] Niger seed resembles sunflower seeds in shape, but is smaller in size and black. It bears a fairly thick, adherent seed coat and can be stored for up to a year without deterioration. Niger seed contains proteins, oil and soluble sugars. Niger seeds are used as bird feed worldwide. Commercial niger seed is grown in Africa, India and other areas of southeast Asia, and the seed is imported around the world as a popular type of birdseed. Before it is imported, however, niger seed is sterilized by intense heat to prevent germination of any additional seeds that may be part of the mix. Treated niger seed may germinate but would typically be stunted, limiting its spread and offering less of a threat to native plants.

2. LITERATURE REVIEW

Lovekush Prasad, Dr. AlkaAgrawal et al [1]: The depletion of oil resources as well as the environmental regulation has led to the development of alternate energy sources. In this present work the performance characteristics of a single cylinder diesel engine when fuelled with blends of Neem oil and diesel are evaluated. Experiments were conducted with different blends (B10&B20) of Neem oil and diesel as various loads. The results show that the brake thermal efficiency of diesel is slightly higher at all loads followed by blends of Neem oil and diesel, it has been established that 20% of Neem oil biodiesel can be used as a substitute for diesel without any engine modification thus Neem oil as non-edible oil can be a good renewable raw material for biodiesel production.

V. Kulkarni, S.D. Bhopale et al [2]: Good mixture formation and lower smoke emission are the key factors for good CI engine performance. These factors are highly influenced by viscosity, density, and volatility of the fuel. For bio-diesels, these factors are mainly decided by the effectiveness of the transesterification process. With properties close to diesel fuel, bio-diesel from Jatropha, pongamia pinnata and Neem seed oil can provide a useful substitute for diesel thereby promoting our economy. Biodiesel and diesel fuel blends may prove an alternative option as diesel fuel in the future because they are renewable resources and less polluting.

G. Sucharitha, A. Kumaraswamy et al [3]: Neem oil can be directly used in compression ignition engine. However, the performance is inferior to diesel. This is due to its high viscosity and carbon residue. The performance of the Neem oil fuelled engine can be improved by esterifying, preheating or using dual fuel mode with petrol carburetion. In this experimental work, performance and emission characteristics of a single cylinder, water cooled ,direct injection diesel engine operating on Neem oil, its ester, preheated Neem oil and Neem oil-petrol dual fuel mode were evaluated and compared with diesel operation. The brake thermal efficiency of the engine with Neem oil is 24.9%, Neem oil ester is 26.39%, preheated Neem oil at 160 deg Celsius (temperature at which Neem oil viscosity equals to diesel viscosity) is 29.1 % and that of diesel is 31.4% at full load. At knock limited point (60% full load,1500 rpm), brake thermal efficiency increases from 24% to 30.5% at 33.7% of energy share of petrol with Neem oil, and from 26.8% to 32.3% at 30.3% of energy share of petrol with Neem oil ester, Smoke, HC/CO decrease with esterification and preheating but increase with petrol carburetion.

Dharmendra Yadav, Nitin Shrivastava and Vipin Shrivastava et al [4]: Increasing oil prices, and global warming activates the research and development of substitute energy resources to maintain economic development. The methyl esters of vegetable oil, known as biodiesel are becoming popular because of their low ecological effect and potential as a green substitute for compression ignition engine. The main objective of this study is to investigate the performance of Neem oil methyl ester on a single cylinder, four stroke, direct injection, and 8 HP capacity diesel engine. The Experimental research has been performed to analyze the performance of different blends 20% (BD20), 50% (BD50), and 100% (BD100) of Neem oil biodiesel. Biodiesel, when compared to conventional diesel fuel, results showed that the brake specific fuel consumption and brake specific energy consumption are higher and brake thermal efficiency less during testing of engine. It is investigated that the neem oil biodiesel 20% blend showed very close performance when compared to plain diesel and hence can be used as an alternative fuel for conventional diesel in the future.

M. Kannahi and R. Arulmozhi et al [5]: Biodiesel fuel (BDF) produced by alcoholysis of vegetable oils or fats is viewed as a promising renewable fuel source. Diminishing petroleum reserves and increasing environmental regulations have made the search for renewable fuel. Biodiesel is non-toxic and biodegradable produced from renewable sources and contributes a minimal amount of net green-house gases, such as CO2, SO2 and NO emissions to the atmosphere. The main objective of the present study is to produce biodiesel from vegetable oils (edible and non-edible oil) and to use micro-emulsions with solvents ethanol and methanol following acid, alkali and fungal enzyme catalysis methods. The best suited method of biodiesel production was ethanolic and alkali mediated transesterification process rather than methanolic and acidic transesterification. The maximum yield of biodiesel was obtained from Rhizopusoryzae lipase enzyme, ethanolic and alkali mediated transesterification followed by Aspergillusniger.

Fangrui Maa, Milford A. Hannab el al [6]: Described the four primary ways to make biodiesel, direct use and blending, micro-emulsions, thermal cracking (pyrolysis) and transesterification. Of the several methods available for producing biodiesel, transesterification of natural oils and fats was the method of choice. The purpose of the process is to lower the viscosity of the oil or fat. Although blending of oils and other solvents and micro emulsions of vegetable oils lowers the viscosity, engine performance problems, such as carbon deposit and lubricating oil contamination, still exist. Pyrolysis produces more bio gasoline than biodiesel fuel. Transesterification is basically a sequential reaction. Triglycerides are first reduced to diglycerides. The diglycerides are subsequently reduced to monoglycerides. The monoglycerides are finally reduced to fatty acid esters. The order of the reaction changes with the reaction conditions. The main factors affecting transesterification are molar ratio of glycerides to alcohol, catalysts, reaction temperature and time and the contents of free fatty acids and water in oils and fats. The commonly accepted molar ratio of alcohol to glycerides is 6:1. Base catalysts are more effective than acid catalysts and enzymes. The reaction was slow at the beginning for a short time and proceeds quickly and then slowed down again. Base catalyzed transesterifications were basically finished within one hour.

Tejaswita Kajale, Abhay Pawar, Channapatana et al [7]:"Study of Engine Performance and Emission with Neem Oil (NOME) BasedBio-Diesel." The objective of this paper was to investigate the effect of the biodiesel produced from high free fatty acid feed stocks on engine performance & emissions. Biodiesel performance and testing is done in C.I. engine. Results shows that use of biodiesel involves reduction of some emitted pollutants. This is much helpful in reducing pollution caused due to diesel engine emission.

K. Kannan and M. Udayakumar et al [8]: The light duty diesel engine is normally employed for agricultural water pumping, electrical power generation etc. where the engine mostly operated above 75% load. At 5 kW load, the engine performance parameter brake thermal efficiency found increasing in the order 250-200-150 bar injection pressure and brake specific fuel consumption found decreasing in the order of 250-200-150 bar injection pressure. Though at 150 bar higher brake thermal efficiency and lower brake specific fuel consumption were obtained the percentage of improvement was at the maximum of 1%. So, increasing injection pressure gave insignificant effect on engine performance. At 5 kW load, CO2 and NOx emissions were found the lowest at 200 bar and HC emission and smoke level were found lowest at 150 bar. CO2 is 15% and 24% and NOx is 12% and 20% lower compared with 150 bar and 250 bar respectively. HC emission is 30% and 34% lower and smoke level is 7% and 1% lower compared with 200 bar and 250 bar, respectively. Fuel economy is important for engine. But environmental protection is more important than fuel economy. So, decreasing emission is the primary concern which demands moderate injection pressure for a light duty diesel engine.

L. Karikalan and M. Chandrasekaran et al [9]: The present work is to improvise the diesel engine performance by varying fuel injection pressure of J20 biodiesel from 180bar to 240bar through experimental investigation in a single cylinder CI engine. From this research work it is clear that J20 biodiesel blend at injection pressure of 240bar with a standard injection timing of 27º bTDC and with a standard compression ratio of 17.5:1 gives slightly improved performance and lesser emission when equated to diesel fuel.

Rosli Abu Bakar, Semin and Abdul Rahim Ismail et al [10]: The experiment results shows that, the fixed load variation speeds and fixed speed-variation loads have been given that the higher engine speed (rpm) given higher engine power. The increasing injection pressure is in line with increasing power. The fuel consumptions experiment result for fixed load-variation speeds and fixed speed-variation loads have been given that increasing injection pressure given increased of fuel consumption for the diesel engine.

V. S. Hariharan and K. Vijayakumar Reddy et al [11]: Increasing the injector opening pressure (IOP) from the rated value for the diesel i.e. 170 bar to 190 bar resulted in a significant improvement in performance and emissions with Sea lemon oil due to better spray formation. The changes noted at maximum engine output were: 1. Brake thermal efficiency increases from 27.3% to 29.1%, 2. HC reduced from 166 to 130ppm, 3. NOx level increases with increasing IOP due to faster combustion and higher temperatures reached in the cycle and 4. Smoke level reduced from 4.6BSU to 3.2 BSU. Smoke levels steadily fall with increase in the injector opening pressure due to improved mixture formation because of well-atomized spray. On the whole a significant improvement in the performance and emissions can be realized by properly optimizing the injector opening pressure when a diesel engine is to be operated with neat Sea lemon oil.

Vaibhav R. Wakode, A.B. Kanase-Patil et al [12]: The performance and emission testing of single cylinder diesel engine is carried out for different FIP and CR values. For a given engine, the simulation model was developed in Diesel-RK tool. This model gave 20.53% and 12.67% average error between experimental and simulation values for BSFC and torque respectively. This indicated satisfactory validation of simulation model with experimental data. The maximum engine performance (33.66% BTE and 0.27 kg/kWh BSFC) was obtained at FIP 220 bar and CR 17. In this case, BTE and BSFC values improved by 14% and 6.8% compared to FIP 200 bar. At higher FIP and load values, CO emissions decreased while HC emissions increased slightly. The lowest CO emissions (0.03%) and CO2 emissions (1.57%) are observed at FIP 220 bar and CR 18 case. Also, in this case, NO emissions decreased by 3.5

times and smoke emissions increased by 9.86 times compared to FIP 200 bar. In general, optimum engine performance and emissions are observed at FIP 220 bar and CR 18 combination.

Yie Hua Tan, Mohammad Omar Abdullah, Cirilo Nolasco-Hipolito, Nur Syuhada Ahmad Zauzi, Georgie Wong Abdullah et al [13]: The summary of the experimental results on the emulsification characteristics, performance and emissions in a diesel engine fueled with various volume fractions of diesel, biodiesel and bioethanol emulsion fuels are as follows:

- Increase the volume percentage of bioethanol (tested up to 15% in the present study) in diesel-biodiesel-bioethanol emulsion fuels increases the number of dispersed droplets and the mean droplet size. FTIR analysis shown that there is no significant difference between the emulsions and the standard diesel. The total heating value and density decrease with increasing of bioethanol content in the blend. The total heating value of the diesel-biodiesel-bioethanol fuels were averagely 21% higher than the total heating value of the pure biodiesel and slightly lower (2%) than diesel fuel.
- The diesel engines can run smoothly with all the prepared emulsion fuels and there was no engine modification required. The emulsion fuels show lower brake power and torque compared to diesel fuel. All tested blends (B, C, D and E) exhibited higher brake specific fuel consumption (BSFC) and lower exhaust gas temperature.
- The CO2 emissions of B, C, D and E were found to be lesser than diesel fuel for all speed conditions. A significant reduction in CO emissions of B, C, D and E blends were noticed at low and medium speeds than diesel. As the engine speed increases, the CO emissions of the emulsion fuels increase gradually while the CO emission of diesel decreased. The usage of emulsion fuels in the diesel engine decreased the NOx emissions at medium engine speeds, i.e. _30%. Higher NOx emissions for the emulsion fuels (B, C, D and E) were observed at lower and higher speed conditions.

K. Nanthagopal, B. Ashok, R. Thundil Karuppa Raj et al [14]: C. inophyllum methyl ester (CIME) could be considered as the most promising alternate source for biodiesel in India. The effect of CIME injection pressure is investigated on performance, emission and combustion characteristics of a direct injection compression ignition and the results are summarized as follows:

- The brake thermal efficiency of CIME at higher injection pressures is comparable with conventional diesel at full load operating condition.
- Higher BSFC was observed in case of CIME with respect to neat diesel at all loads for different injection pressures. The BSFC for CIME decreased with increasing injection pressure due to better atomization of fuel.
- Maximum in-cylinder gas pressure and peak heat release rate was observed with CIME at 220 bar injection pressure.
- Higher reductions in UBHC, carbon monoxide and smoke emissions were observed for CIME at 220 bar injection pressure than that of neat diesel at 200 bar and CIME at 200 and 240 bar injection pressures.
- NOx emissions of CIME are relatively higher than that of conventional diesel at all injection pressure. Moreover NOx for CIME increases with increases in injection pressure.
- CIME injected at 220 bar shows better performance and emissions results compared to other injection pressures.

Gang Li, Chunhua Zhang, Yangyang Li et al [15]: An experimental study was performed to investigate the effects of diesel injection parameters on the rapid combustion and emissions of a water-cooled, 6-cylinder, common-rail diesel engine fueled with diesel-methanol dual-fuel and some specific conclusions are drawn as follows:

- Both of a and roar-combustion level of the DMDF engine exhibit a large value at higher diesel injection pressure due to better fuel atomization. Additionally, COVIMEP decreases with the increase of diesel injection pressure, and it is always smaller than 2% under all test conditions.
- When the diesel injection timing is advanced, the roar combustion level of the DMDF engine increases, but a decreases. At the engine load of 60%, the combustion duration is slightly shortened and the minimized COVIMEP is obtained at 8 _CA BTDC.
- As the diesel injection quantity increases, the HRR of rapid combustion phase decreases while that of slow combustion phase increases, leading to a, roar-combustion level and COVIMEP are decreased obviously.
- The DMDF mode can effectively reduce NOx and smoke emissions, but CO and HC emissions may increase significantly. Further optimization for smoke emission can be achieved by coupling the high diesel injection pressure and the advanced diesel injection timing. However, NOx emission may increase in this case.

Ahmed Syed, Syed Azam Pasha Quadri, G. Amba Prasad Rao, Mohd Wajid et al [16]: A single cylinder compression ignition engine was operated successfully using B20 as pilot fuel and hydrogen as inducted fuel at different injection opening pressures. Tests carried out at 200, 225, 250 and 275 bar IOP indicated that 250 bar IOP is optimum pressure for better performance and least emissions. The following conclusions are summarized based on the experimental results obtained for hydrogen operated engine with B20 as pilot fuel injected with 250 bar injection opening pressure and compared to pure diesel operation at rated injection opening pressure of 200 bar at 75% load.

3. CONCLUSIONS

From all the research, we can say that Niger seed oil can be used as new source for biofuel i.e. biodiesel. And its oil can be blend with neem biodiesel and forms new blend of biodiesel (in proportion of 50% neem & 50% niger). Also by varying the injection pressure of fuel we can run the internal combustion engine fueled with different blends of biodiesel with different injection pressure. But up to certain limit of increase in injection pressure can shows better results than lower injection pressure in internal combustion engine.

4. REFERENCES

[1]. Lovekush Prasad, Dr. Alka Agrawal "Experimental Investigation of Performance of Diesel Engine Working On Diesel and Neem Oil Blends" IOSR Journal of Mechanical and Civil Engineering VOL. 1, Issue. 4, juy - aug 2012.

[2]. A. V. Kulkarni, S. D. Bhopale "Performance Analysis and Investigation ofEmissions of C.I. Diesel Engine Using Neem Oil as Blending Agent: Review" International Journal of Innovative Research in Science, Engineering and Technology Volume 3, Special Issue 4, April 2014.

[3]. G. Sucharitha, A. Kumaraswamy 'Experimental Analysis of Using Neem Oil as an Alternative Fuel" International Journal of Engineering Research and Applications (IJERA) Vol. 3, Issue 1, January -February 2013, pp.320-325.

[4]. Dharmendra Yadav, Nitin Shrivastava and Vipin Shrivastava "experimental investigation Of performance parameters of single Cylinder four stroke di diesel engineOperating on neem oil biodieselAnd its blends"IJMERR Vol. 1, No. 3, October 2012.

[5]. M. Kannahi and R. Arulmozhi "Production of biodiesel from edible and non-edible oils using Rhizopusoryzae and Aspergillusniger" Asian Journal of Plant Science and Research, 2013, 3(5):60-64.

[6]. Fangrui Ma, Milford A. Hanna "Biodiesel production: a review" Elsevier Science Bioresource Technology 70 (1999).

[7]. Tejaswita Kajale, Abhay Pawar, Channapatana "Study of Engine Performance and Emission with Neem Oil (NOME) Based Bio-Diesel" International Journal of Recent Trends in Science and Technology, Volume 11, Issue 1, 2014 pp 09-11.

[8]. K. Kannan and M. Udayakumar "Experimental study of the effect of fuel injection Pressure on diesel engine performance and emission" ARPN Journal of Engineering and Applied Sciences VOL. 5, NO. 5, MAY 2010.

[9]. L. Karikalan and M. Chandrasekaran "Effect of varying fuel injection pressure of Selective Vegetable oil biodiesel on C.I engine performance and Pollutants" International Journal of ChemTech Research CODEN (USA): IJCRGG Vol.8, No.12 pp 312-318, 2015.

[10]. Rosli Abu Bakar, Semin and Abdul Rahim Ismail "Fuel Injection Pressure Effect on Performance of Direct Injection Diesel Engines Based on Experiment" American Journal of Applied Sciences 5 (3): 197-202, 2008.

[11]. V.S. Hariharan and K. Vijayakumar Reddy "Effect of injection pressure on diesel engine performance with Sea lemon oil" Indian Journal of Science and Technology Vol. 4 No. 8 (Aug 2011)

[12]. Vaibhav R. Wakode, A.B. Kanase-Patil "Regression analysis and optimization of diesel engine performance for change in fuel injection pressure and compression ratio" PII: S1359-4311(16)32847-2, DOI: http://dx.doi.org/10.1016/j.applthermaleng.2016.10.178, Reference: ATE 9380

[13]. Yie Hua Tan, Mohammad Omar Abdullah, Cirilo Nolasco-Hipolito, Nur Syuhada Ahmad Zauzi, Georgie Wong Abdullah. "Engine performance and emissions characteristics of a diesel engine fueled with diesel-biodiesel-bioethanol emulsions." Energy Conversion and Management 132 (2017) 54–64

[14]. K. Nanthagopal, B. Ashok, R. Thundil Karuppa Raj "Influence of fuel injection pressures on Calophyllum inophyllum methyl ester fuelled direct injection diesel engine" Energy Conversion and Management 116 (2016) 165–173.

[15]. Gang Li, Chunhua Zhang, Yangyang Li "Effects of diesel injection parameters on the rapid combustion and emissions of an HD common-rail diesel engine fueled with diesel-methanol dual-fuel" Applied Thermal Engineering 108 (2016) 1214–1225.
[16]. Ahmed Syed, Syed Azam Pasha Quadri, G. Amba Prasad Rao, Mohd Wajid "Experimental investigations on DI (Direct injection) diesel engine operated on dual fuel mode with hydrogen and Mahua oil methyl ester (MOME) as injected fuels and effects of injection opening pressure" PII: S1359-4311(16)33521-9, DOI: http://dx.doi.org/10.1016/j.applthermaleng.2016.11.152 Reference: ATE 9563.

BIOGRAPHIES

	Mr. Kadam Swapnil S. M. E. Heat Power Engineering Student DYPSOEA, Pune