Investigation of performance, feasibility and Combustion of Jatropha oil Blends in Diesel Engine

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I, AMANDEEP, Roll No. 2K19/THE/03, student of M. Tech (Thermal Engineering), hereby certify that the Project Dissertation titled **"BRIEF STUDY OF PERFORMANCE, FEASIBILITY AND EMISSIONS OF JATROPHA OIL BLENDS IN DIESEL ENGINE"** submitted by me to the Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirements for the award of the Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any degree, Diploma Associateship,

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Date: 22/11/2021

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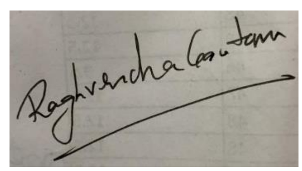
CERTIFICATE

I hereby certify that the Project Dissertation titled **"BRIEF STUDY OF PERFORMANCE, FEASIBILITY AND EMISSIONS OF JATROPHA OIL BLENDS IN DIESEL ENGINE"** submitted by AMANDEEP, Roll No. 2K19/THE/03, Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirements for the award of the Master of Technology, is a record of the project work has not been submitted in part or full or any Degree or Diploma to this University or Elsewhere.



Place: Delhi
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ABSTRACT

Nowadays, Pollution has become the biggest issue for the entire world. Along with the developing countries, the developed counties are also facing a problem to live in a polluted Environment. Air- pollution is at the top of the list among all types of pollutions. The Fuel emission is a major contributor in the increase of Air- quality index to a Dangerous value. This situation can be controlled by using different Alternative fuel blends to replace the fossil fuels which cause harmful emissions. The Jatropha Oil, which is obtained from the Jatropha curcas, which is a flowering plant that contains 27-40% oil in its seeds and can be processed to produce high- quality biodiesel. It is quite easy to process this plant for oil as Being a plant that generally grows in tropical conditions, it can be grown in any area depending upon the availability if it has low rainfall or high rainfall. As per the experimental analysis is has been observed that the emissions caused by the Jatropha oil fuel are comparatively less as compared to the conventional fossil fuel. Based on the research and the various experiments performed by the experts, it has been observed that Brake thermal efficiency (BTE) of Petroleum diesel was higher as compared to Jatropha Biodiesel blends unlike the Brake specific energy consumption (BSEC) which was comparatively low. Apart from this, the emission of unburned hydrocarbon (UBHC), carbon monoxide (CO) and carbon dioxide (CO_2) was lower, however the emission of Nitrogen oxide (NO_X) was higher of Jatropha methyl ester to diesel fuel. This results that the Jatropha oil can have major applications in the field of Alternative fuels in future as far as the production of a clean, renewable and very less harmful fuel is concerned unlike the conventional fossil fuels. With the further advancement of technology, it is clear that Jatropha oil and its blends can be a major breakthrough in the field alternative fuels and can be considered as the best replacement of the conventional diesel fuel with some minor modifications.

Keywords – Jatropha curcas, Fuel, Brake Thermal Efficiency, Brake Specific energy consumption, Carbon Monoxide, Technology, Alternative, Conventional, Modifications, Emissions.

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Chapter 1. Introduction

The energy consumption per person today has reached at an ultimate level that it costs a lot on one's budget to fulfill that need. Apart from this, the conventional sources of energy are also a major issue because of their scarcity. So, the research work in the field of renewable energy has become vital for the welfare of mankind. High efficiency of the diesel engine has been a key-factor to make its mark in the field of transportation and power sector [1]. They also have an application in the field of small-scale decentralized energy generation plants. Bio fuels which are extracted from the nature have proven as a better alternate for the conventional fuels which are derived from crude oil for the applications of transportation and energy generation [2]. The field of biofuels or alternative fuels is gaining of researchers worldwide for the development of various fields which include Agriculture, Rural Employment, Import, Energy security and Environmental degradation. The problems that are faced in these fields due to the use of conventional hydrocarbon fuels can also be solved by the research and production of Bio-fuels from Natural Sources [3]. Many types of changes and modifications are also required to use alternative fuels in the existing Diesel Engines. The Parameters which specifically require modifications are handling which mainly include transportation, ease of production, investment cost, price in the market etc.

In India the research is mainly focused on exploring various alternate for diesel engines. Apart from other alternates, vegetable oils are found to be most promising as they are renewable, Environmental-friendly and are easily found in the rural areas [4]. The characteristics of the vegetable oils are very much similar to the diesel fuel but the major issue with these oils is that they have high viscosity polarity is poor. To resolve this problem the most common method that is used is blending, trans-esterification, micro emulsion formation. Among all these, the blending method is preferred because of its simplicity and ease of processing. Other methods require engine modifications at a complicated level and skilled experts.

Fig. 1- Physical lookout of Jatropha plant with Jatropha seeds

It has also been observed that adding of high alcohols also decrease the kinematic viscosity. Ethane is used as a blending agent and even as an alternate in many countries. However, butane is also a promising agent in the blends of diesel to be used in CI engines.

Jatropha oil is also a type of edible oil extracted from Jatropha Curcas plant. Jatropha plant is a shrub that belongs to the *EUPHORBIAEASE* family [5]. It was first explored in south America and now it has extensively spread all over the globe starting from arid to semi-arid to tropical and sub- tropical regions. These types of climatic conditions help this plant to grow at a decent rate. This plant can also grow in approximately each and every type of soil, unaffecting the quality of seeds. The plant can produce average and good quality seeds in poor and even worst type of soil conditions. The best seeds are extracted from the light sandy oil. Another speciality of this plant is that it is drought resistant and the average period of fertility of this plant is said to be about 50 years [6]. Minimum 250mm of rainfall is required in a year to have a smooth and nourishing growth of this plant irrespective to the soil and it can withstand with maximum 3000mm of annual rainfall. These plants are found in plains as well as hilly regions in other words from the sea level to 1800mts altitude and even above sometimes. They can reach up-to 8m of maximum height and start yielding after 4 to 5 months after the time of incubation.

The Jatropha trees have round fruits which have a diameter of 1.5 to 3cm. soft to touch and a dark brown texture, weighing up-to 1.5 to 3gms [7]. The concentration of oil in the seeds is approximately 30 to 35%. The color variation is quite noticeable, as it goes from pale yellow to brown according to the ripening of the fruit. A toxic compound is also found in this oil named curcas which has a strong purging effect. The viscosity is the main disadvantage of Jatropha oil being used in diesel engine as it is measured very high in the Jatropha oil. Viscosity being very high it causes injection, atomization and mixing in diesel engines. Deep research has been done to dilute SVO by alcohols and its subsequent engine applications.

In the blending process, ethanol is mostly used. But apart from ethanol, methanol is also commonly used in this process [8]. Methanol is widely used for the purpose of trans-esterification process as the price is low and it also has some physical and chemical advantages in the blending process. The molecules of methanol have the shortest chain and are termed as most polar among all the alcohols as compared to other alcohols the catalyst dissolve in methanol faster or in other words the solubility is quite high and the reaction rate of methanol with triglycerides is faster which leads to fast conversion. Being non- renewable is a major problem with methanol while on the other hand, Ethanol which is renewable in nature is now being tested and observed for the trans-esterification

Process [9]. On the experimentation basis, the process of formation of ethyl ester is way more complicated than methyl ester reason behind this is the differing reactive properties to form alcohol-oxide.

Fig. 2 – Freshly prepared Jatropha oil inside a laboratory

In General, alcoholic reaction, the reaction proceeds with oil-alcohol emulsion formation but when it comes the case for Methanolysis, these emulsions are broken very quickly and the rapid formation of glycerol and methyl-ester takes place. Whereas, in etnalolysis these emulsions are seen to be much more stable. Other fact is that in ethanol the effect of mass transfer limitation is reduced and it has high solubility [10]. In the research field the main focus has been on methyl ester as methanolysis is concluded as easy method for the production of biodiesel. The cost of ethanol is very high as compared to methanol which is the main reason the product of fatty acid methyl ester has not been explored so far. Apart from this, the process of separating glycerol from the fuel at the end is also complicated which is a major problem in the trans-esterification process. Considering the performance parameters, ethanol is eco-friendlier and safer for use unlike methanol which has better performance in running conditions [11].

However, the efforts being made on this line is almost unsystematic and unplanned without foresight of the economic and eco-developmental use of bio-diesel and by products. On the other hand, identification of users' demand has not been worked out [12]. Since 2003 with the start of massive work on Jatropha, various private organizations have great worry of their seed and saplings raised in large quantity because as on today there is neither any high yielding seed and oil strain nor there is any integration among the organizations working in the field of various aspects like techniques of raising of saplings, seed and bio-diesel production, detoxification of cake, generation of bio gas, and production of bio fertilizer, feed and glycerol etc. [13].

In the last two decades, the demand of Diesel was raised up to 67MT from 52MT according to the study done by Planning Commission. 22% is the only total share of the domestic supply in the Diesel need of India which is quite low [14]. So, sustainable alternatives are being explored for the needs of oil to be met in future. Under bio-fuel mission, India has recently initiated R&D work on production of bio-diesel. A large number of government/ non-government organizations and industries are engaged in cultivation of tree borne oil species like Jatropha and Pongamia. A few are engaged in extraction of oil and transesterification process and testing & evaluation of bio- diesel. However, there is over publicity and euphoria about plantation and yield due to conspicuous lack of any authentic database [15]. As such there are no authenticated high yielding cultivars identified for different agro-climatic zones. However, ICAR, CSIR, DRDO, DBT, DST, TERI and different agricultural Universities have now been stepping up to come out with location/ region specific Jatropha cultivars through multi locational trials. Work regarding oil extraction, esterification and evaluation needs to be strengthened to up scaling the existing technology and establishing techno-economic viability [16]. The requirement of diesel by defence forces is huge which becomes an opportunity to work on bio-diesel with availability of resources i.e., land, human and funds.

In India, Government is planning to implement the European norms which are Euro 3 and Euro 4 norms [17]. A huge cost is being planned to be invested for this scheme which is almost 65000 crores. In this scheme better quality of oil will be produced and main focus will be on the high- grade refinery Process which will lead to less emission. Some part of this scheme will also be focused on the evaluation of the quality of Biodiesel which can improve the harmful emissions i.e., the unburnt hydrocarbons, Sulphur dioxide, smog forming potential and carbon monoxide concentration can be reduced to a significant level which is not very harmful for Environment by the concept of Blending [18]. NO_X emissions are observed to be quite high in biodiesel for solving this issue the engine modification is a smart Solution [19]. To overcome this problem DRDO has been taking this challenge in collaboration with CSIR and different Universities and lIT's to produce bio-diesel by planting Jatropha curcas on the land available with different DRDO laboratories and Military Farms along with the studies on the performance of different types of engines/vehicles available with Defence Forces at different altitudes so as to develop self-reliance and confidence in the field of indigenous production of bio-fuel, to reduce import of fossil fuel and further development of economy and eco sustenance [20].

Chapter 2. Literature Review

The source from where the raw materials has been extracted has a great significance in the production of biodiesel because it decides the properties that biodiesel will bear and also helps in determining the type of process to be used. Those raw materials which cost low, it has been observed that the contain a remarkable number of fatty acids (FFA), that leads to complicated and expensive final process [21]. The complication that come across are like accelerated catalyst depletion, increase in the purification cost, significant decrease in the yield of alkali catalyzed trans- esterification. Simple steps to reduce the processing cost are simplifying the refining process and eliminating waste streams. There are some biofuels present in some countries which are promising to overcome the above-mentioned situations. In this context, the example of some European countries can be taken, where some plants produce biodiesel by trans-esterification with the application of supercritical methanol without use of any kind of catalyst [22]. In the above-mentioned scenario, the reaction is rapid, the cost of downstream purification is decreased because of the absence of catalyst. However, the safety costs are increased because it requires a specific temperature and pressure [23]. The temperature required ranges from (350-400°C) and pressure ranges from (100-250 atm).

Another innovative way to produce biodiesel is to use the heterogenous catalysts which are easy to separate from the reaction products as compared to regular ones. The condition required for these reactants are quite less harsh as compared to supercritical methanol [24]. All the mentioned technologies are not so effective to produce low-cost biodiesel, even if some issues are resolved for conventional processes. For transforming the next generation biomass raw materials and the residual left behind still the technology is lacking. So, it is necessary to develop new technologies for the production of sustainable biodiesel [25].

2.1 PROGRESS MADE BY RESEARCHERS IN THE FIELD OF *JATROPHA* BIODIESEL

Kumar *et al*, this study shows the life cycle approach for production of 1 tonne Jatropha Biodiesel under controlled emissions. Displacement & Allocation approaches were applied for energy, life cycle inventory and GHG emission attribution to co-products. After the analysis of process energy & GHG emission the results revealed that both of them were strong function of co-product handling and irrigation. The value of NER is increased from 1.4 to 8.0 varying according to the Methodology. When co-products were used for the purpose to displace sugarcane lagasse as displacement for energy case the NER value was obtained maximum.

Kay *et al*, in this study low quality crude jatropha oil was treated under transesterification process using the modified natural zeolite as a solid catalyst to produce biodiesel. When 20:1 molar ratio of Methanol & oil, 70ºC reaction temperature and 5wt% catalyst was treated with low quality crude jatropha oil. It resettled in optimum yield and it was observed that biodiesel content exceeded 96.5% at 6h. This study revealed that this method has a great potential in producing a promising quality of biodiesel from low quality jatropha oil with low quality raw feed stock with high FFA.

Liang *et al*, in this study the change in the composition of Jatropha seed cake was observed when it was pretreated with line at 100ºC with various parameters. It was seen that 38.2±o.6% of lignin was removed when 0.2g of line dose was treated with 10ml per gram of Jatropha cake for 1 hour. This study has revealed that upon line pretreated & enzymatic hydrolysis the Jatropha seed cake could be used as a microalgal growth substrate. The fractionation of line has suggested study further regarding the removal of lignin and toxicity.

Lim *et al*, in this study the biodiesel production is done by the supercritical reactive extraction from jatropha curcas. This supercritical reactive extraction method can extract oil to fatty acid methyl esters in relatively short operating time. The reaction temperature & particle size of the seeds are the factors that are being tested in this investigation. The FAME yield efficiency can reach up to 105.3% v/v and 103.5%w/w for 2.5ml/g of n-hexane to seed ratio, 300ºC reaction temperature, 240MPa operating pressure and 10.0ml/g methanol to solid ratio which in result exceed the theoretical yield. This study proves that there is a huge potential for jatropha curcas L seeds for commercial production of biodiesel from oil seeds. This method can achieve 100% oil extraction and FAME yield in relatively short-time because the conventional oil extraction stage is skipped which takes up to 24 hours as no catalyst is involved it will greatly simplify downstream process.

Yaakobet *et al*, in this study the palm empty fruit bunch (EFB) generated from ASH was used for the transesterification process of Jatropha curcas oil with methanol. Impregnation technique was used to dope ash with KOH to achieve 20 wt% level Potassium. Biodiesel obtained in this study was higher in specification stipulated by European Biodiesel Quality standard because EFB catalyzed & KOH-EFB catalyzed reactions took place under controlled conditions. Efficient heterogeneous catalysts were obtained from waste material. This study provides a successful method to develop heterogeneous catalyst from naturally available material.

Boateng *et al*, in this study mainly three thermodynamics performance parameters are involved which are thermodynamic improvement potentials, exergy efficiency, exergy destruction. The Aspen Plus software used in this study concluded that only 36% & 56% energy is useful for work in microalgal methyl ester & Jatropha methyl ester for both MME & JME 38% & 39% of total exergy was destroyed in the oil extraction units and 5% & 2% was destroyed in transesterification respectively for 1 tonne of Biodiesel produced. All the results observed in this study indicate that only exergy analysis of transesterification cannot determine the thermodynamic feasibility of biodiesel production. This method is not very cost efficient so it can be improved by optimum working conditions. One method is by employing heat-integrated reactive distillation process. In this method sulphated zirconia is made to undergo catalytic reactive distillation solid acid catalyst for fatty acids esterification which can bring down energy consumption by 45%.

2.2 RESEARCH OBJECTIVES:

In this study we will find out the variation of different blends of *Jatropha* Biodiesel, they have while operating in a Diesel Engine. From preparation to experimentation everything will be observed and analyzed to keep the record of values and processes. This is going to be a study of Performance, Combustion and Emission testing and analysis of B20(20% Jatropha Biodiesel), B15(15% of Jatropha Biodiesel) and B10(10% of Jatropha Biodiesel) as compared to Pure Diesel (100% Diesel).

[1] Firstly, the preparation of Biodiesel from the transesterification process which includes the boiling of the raw oil and then threating it with Methanol and KOH mixture at fixed temperature for certain time period to extract the Biodiesel from the Jatropha Mixture.

[2] Testing the Biodiesel in the Experimental Setup and record and observe all the values under different loading conditions. Plot the graphs of all the parameters w.r.t. to the load they were tested and draw a conclusion based on those values that how can it made better for future applications.

2.3 NEED

Diesel engines play a vital role in the Indian economy as they have a high efficiency and ruggedness. So, they are widely used in the agriculture, transport and industrial sector. Esters in the modern day are gaining attention in the field of research for alternate fuels which can be used in the conventional engines with some modification [26]. The more use of biodiesel in the modern world decreases the dependency of a country on foreign oil and also helps in keeping the Environment clean. The problem with the diesel engine is the production of NO_x at a huge amount rapidly during combustion of fuel. The accumulation of CO_2 produced by the combustion of fossil fuels lead to various environment problems [27]. High viscosity is a major reason behind the non-usage of vegetable oils in the diesel engine so a chemical modification is required to produce the engine friendly biodiesel. Biodiesel is seen as a promising alternate for the regular petroleum diesel and it can also be used as a substitute with major engine modification to mineral diesel. When it comes for the largest carbon emitter countries in the world China and India hold a place among top 5 but indeed, they are also large importers of petroleum [28]. The dependency of these countries is on those energy sources which are external and are obtained from regions which are highly unstable and the chances are very high, that it may increase to uncomfortable levels. However, this fact cannot be ignored that the Energy security is a key issue in modern day for India. India produces about 22 % oil of its own requirement indigenously and imports 78 % of its total requirement [29]. The cost of Imports of India from other countries is around 100000 crores per year and if talk about the consumption so, India consumes approximately 2%of the world's oil. Further India and China will account for 43% increases in global oil consumption. Total crude oil imports in India accounts Rs.121500 crores in 2005. Total diesel consumption in India was 53 million MT (78%) which was imported and 11.50 MMT (22%) was indigenously produced [30].

Apart from being safer to the environment with low carbon dioxide emissions, biodiesel is easy to handle and renewable in nature. Biodiesel production in rest of the world is done mostly from the edible oils but here in India the scenario is a bit different. The production of edible oils in India is not that much to meet the requirement of biodiesel so heavy imports are done to fulfill the need of edible oils. However, non-edible oils are more promising to edible oils, if compared on different grounds. Because of the abundance of forest and plant cover which produce different seeds that can be extracted for the production of biodiesel [31].

The use of Jatropha oil with different blends in the diesel engine have given different results. Due to the limited availability of seeds, the government is giving a boost for the more production of oil seeds in the Nation. To successfully achieve this goal govt. of India launched the biodiesel programme which dates back in 2003 and focuses on increase of biodiesel production [32]. Trans-esterification is the process used to produce the ester from the various vegetable oils. It is a catalytic process. In this process the triglyceride reacts with alcohol in presence of a specified catalyst and the main products formed are glycerol and fatty acids. According to the reports of Planning Commission, it was estimated that, the requirement of diesel was around 52 million tonnes in 2006-07 and expected to be 67 million tonnes in 2011-2012 [33]. To overcome the demand situation, the domestic supply to the market was about 22%only which is not sufficient to fulfil the demand. Therefore, it is required that the dependency on imports is reduced and some better alternated are need to be found to overcome the basic demand. Under bio-fuel mission, India has recently initiated R&D work on production of bio-diesel. A large number of government/ non-government organizations and industries are engaged in cultivation of tree borne oil species like *Jatropha* and *Pongamia* [34]. In India, the possibility is not that much for the use of edible oils as well as edible oils are also not very much desirable for bio diesel and thus, non-edible oils are considered and also yield the required feedstock for the Bio-diesel. The Planning Commission has recognized this fact consciously and taken further steps. Higher cost of the edible oils, upgradation of wasteland for cultivation, huge employment opportunities in rural/tribal areas, and higher chances of survivability under the drought and extremely dry conditions are the other important factors that make the non-edible oils as the best alternate and appropriate feedstock for bio diesel in India.

2.4 Availability and Role of NBP (National Biofuel Policy) in India

NBL (National Biodiesel Fuel) has been launched by the government of India in 2008. The main objective of the policy was to achieve the production of E10 biodiesel in a huge amount of 10 million liters which could save the forex of worth Rs. 28 crores and the CO_2 emission could be reduced up-to 20,000 tonnnes [35]. The target of 20% fraction of ethanol in both Diesel and Petrol by the year 2017.

As per the reports from 2017, it was observed that with petrol only 2% blend was achieved and in Diesel it was about 0.1% which was way less than the target set to be achieved. So, in 2018 the NBP was revised again and new norms were set up to be achieved by 2030 which include 5% and 20% ethanol in diesel and petrol respectively. NBP's contribution to the biodiesel field play an important role in renewable energy sector as well as economy in India [36]. Constant improvement and implementation of fuels causing less emission can help in controlling the climate change situation in the country. It can also boost the employment sector specifically in the rural area by creating job opportunities in remote areas by encouraging the poor farmers to grow those crops which produce non-edible oils for the application [37]. Steps taken in this field in past have resulted in unsuccess because of the discouraging environment, poor pricing models and state govt. and agencies not taking interest in the development of such schemes which could built a positive environment for people to opt. this field as a career or money-making opportunity. Several countries in the world have active bio-diesel programme with legislative support and have national polices on bio-diesel development [38]. Soya is used for bio-diesel production in USA, Rape seed in France, USA and Germany, Sunflower in Italy and Southern France, Castor in Brazil, Coconut in Malaysia, Palm in Thailand and Philippines, Linseed and Olive in Spain, Cotton in Greece, Jatropha in Nigeria. Whereas, countries like Ireland, Austria, the Czech Republic, Denmark, Italy and Sweden have frying oil and animal fat for conversion to bio-diesel [39].

Bio-diesel production has registered a substantial leap during last 10 years, in EU (European Union) countries viz., Germany, France, Italy and Denmark. During this period, worldwide production has increased to over 3.5 MMT. European union enforced several legislative actions to double the renewable energy sources. The most important of these is to replace diesel and petrol up to 5.75% for transportation by 2010. EU has taken a lead in the production of bio-diesel across the world. The use of biodiesel is made mandatory in some EU countries and have strict regulations for following these norms [40]. The price of Petro diesel and Biodiesel is somewhat comparable and the main OEMs also accept this structure. Bio-diesel to be marketed internationally must meet the high standard set by the ASTM D6751 (US/Canada). The European specification EN14214 (Europe/Israel) is similar but slightly more stringent than ASTM D 6751 in a few areas. For B100 biodiesel stock, the ASTM D 6751 is the minimum specification that is acceptable in the market [41]. Different countries have different specifications for biodiesel for example – in China they use GBIT-20828, IRAM6515 in Argentina, Indonesia has SNI 04-7182 and for India it is IS 15607. Among world's top bio-diesel Producer countries, Germany ranks first producing 1310 million litres (56% of world share) by seed of sunflower, followed by France 440m million litres (19%) by rape seed and Italy 400 million litres (17%) by soybean (Ansari & Singh, 2019) [42]. United State produces 95 million litres (4%) by soybean and Denmark 88 million litres (4%) by rape seed.

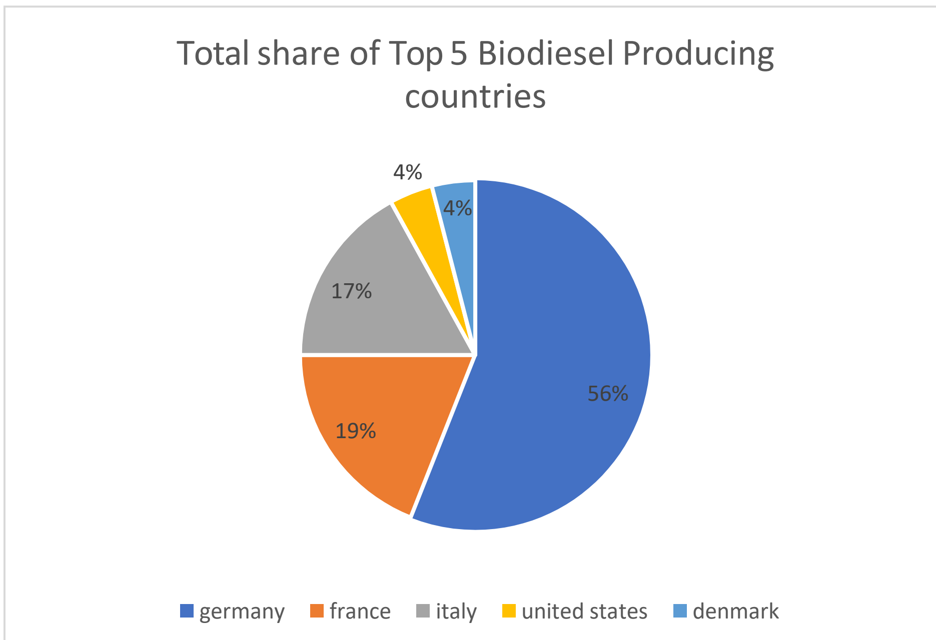

Fig. 3 – Major International Bio-Diesel Producers

European Union (EU) countries are world leaders in Bio- diesel production and have set target of market penetration 5.7% in 2010. Energy Crop Scheme under Common Agriculture Policy have been implemented. Investments are increasing in Bio diesel plants [43]. Nations emerging as the major biodiesel producers are Austria, Spain, France, Italy and Germany. Some other nations have also invested in this sector like Thailand, Australia, India, Canada, Philippines etc. The Europe has a great potential for the market of biodiesel due to the Dominance of diesel fuel vehicles in EU countries. Like India, the population density in EU is quite high so they are helpless to opt alternative option which are Eco-friendly in order to curb pollution [44]. Both consumption and production marks highest in the EU union. At retail outlets, the fuel dispensing units for B5, B10, B20 and B100 are available. The enforcement of law, that biodiesel is mandatory in vehicles has been already done in some EU countries even though use of biodiesel is getting in trend globally the pricing is quite comparable of biodiesel and petro-diesel and is also accepted by main OEMs.

BS6 norms has been implemented by the Indian govt. for the which the investment of about 65000 crores is required to be made which mainly focuses on the quality of the fuel that is produced in refineries by Upgradation of refinery facilities [45]. If a part of this amount is invested on bio-diesel, so it could be easy for us to achieve the norms as mentioned above as the evaluation of Biodiesel can improve the harmful emissions i.e., the unburnt hydrocarbons, Sulphur dioxide, smog forming potential and carbon monoxide concentration can be reduced to a significant level which is not very harmful for Environment by the concept of Blending. NO_X emissions are observed to be quite high in biodiesel for solving this issue the engine modification is a smart Solution [46]. To overcome this problem DRDO has been taking this challenge in collaboration with CSIR and different Universities and IIT's to produce bio-diesel by planting *Jatropha curcas* on the land available with different DRDO laboratories and Military Farms along with the studies on the performance of different types of engines/vehicles available with Defence Forces at different altitudes so as to develop self-reliance and confidence in the field of indigenous production of bio- fuel, to reduce import of fossil fuel and further development of economy and eco sustenance [47]. 30 thousand MT is the total production of biodiesel in our country. In our country huge tract of degraded and wasteland is available, the sunlight is more than enough and the man-power is available in abundance and other parameters which are required for production of biodiesel are also available in Plenty but still our country is yet to gain any ground or momentum in the field of biofuels. Tree born non-edible oils are concluded as the best suited raw material for production of Bio-diesel for our country unlike Western Countries which use edible oils like Rapseed Sunflower, soya bean etc. [48]

Non-edible oils may be a better choice for producing bio-diesel, As India is already deficit in edible oils. Vegetable oil production and demand scenario in India reveal that as against total production of vegetable oil i.e., 6463 tonnes, demand was 11747 tonnes in the year 2004 and 2005 and requirement was met by importing 5409 tonnes [49]. In this context, *Jatropha curcas*, because of its presence throughout the country, has been identified as most potential source by planning commission's task force. The plant of *Jatropha curcas* affects the water retention capacity of soil and make it suitable for upgradation process to take place. These properties allow the plant to grow and rehabilitate on dry and degradable lands.

In the past couple of years, the exploration of other oils which are mainly tree borne has taken a place in both private and public sector as it is being believed that Jatropha can also have other better alternatives which can be used to produce biodiesel [50]. The process of exploration cannot be successful till the sustainability of another alternative is validate. Govt. is implementing policies for the success of this programme and local organization and communities are also taking part to gain the pace [51]. Some private investors are also putting their time and money but to make the initiative absolutely eco-friendly the disposal of waste or waste management strategy needs to be upgraded. The current situation is to initiate a trend for the research in alternate option ignoring the fact what we have today we need to work on technology and generate new feedstocks. A boost needs to be given in the exploration and development of new age fuels in order to meet the future needs [52].

As per a report published by OCED-FAO agricultural outlook 2018-27, The countries which are still in developing phase are having a high demand of biofuels. These countries are also launching such policies which attract the investors in this field and that will help in the development of biofuels market. It has been forecasted that the demand of biofuels might decline in future in US and EU just like ethanol, which can affect the feedstock of vegetable oils and is expected to fall. Some developing countries may see a growth in the demand of biodiesel in future. The major names are Indonesia, Brazil, Argentina and other small developing countries. The Indian scenario of production of biodiesel in India, we need to take steps and launch suitable policies [53]. The OCMs in public sector need to opt the plan of smart cultivation to achieve higher feedstock yield. Partial variation needs to be done; short term plantation focused on some selected area needs to be established for the purpose to achieve supremacy. The crucial changes that are required in the policies are such, an attractive incentive mechanism, multi-feed feedstock method. Simultaneously conversion from feedstock to biodiesel, and most importantly the R&D is increasing the yield from feedstock.

Chapter 3: Overview of Blends of Biodiesel

The most commonly distributed biofuel in the market for use is the blend of biodiesel and conventional hydrocarbon diesel. The letter “B” is commonly used as the factor to classify the amount of biodiesel mixed in the neat diesel. When there is 100% biodiesel in it, it is called B100. When 20% biodiesel and 80% neat diesel is mixed it is termed as B20 [54]. If 5% biodiesel and 95% conventional diesel is used it is labelled as B5 and in B2, there is 2% biodiesel and 98% conventional diesel is used.

The diesel equipments in which the 20% biodiesel blend is recommended require NO or very less modification. Certain type of modification in the engine are required to use the (B100) type of biodiesel in the engine to avoid the performance and maintenance problems. ASTM D7 467 nomenclature covers the B6 and B20 blends by specification [55].

From 29 June 2017, the bureau of Indian standards has specified the standards and the blending limits for the vehicles using biodiesel. The government allowed the sale of biodiesel (B100) for blending with high-speed diesel directly to all consumers for the better usage of the biodiesel in the mainstream [56]. A joint venture was done between Indian oil corporation limited (IOCL) and Bharat petroleum corporation limited (BPCL) to carry out plantation of Jatropha in co-operation with the gram panchayats in Uttar-Pradesh. A joint venture company named “Bharat Renewable Energy limited (BREL)” was formed by the BPCL which has signed an agreement with the panchayats in their fallow lands. Due to the high operating costs and poor yields the joint venture company closed shortly. Under the Jeevan Jyoti yojana of Uttar-Pradesh govt., IOCL formed “Indian oil Ruchi Biofuels” a limited liability partnership for the purpose of Jatropha Plantation on the wastelands of panchayats with the help of gram panchayats. 1818 hectares of area for Jatropha Plantation was facilitated by this LLP. Due to the Un-availability of the Jatropha seeds, IOCL has to exit from LLP [57].

The use of biodiesel along with its blends, like B5 (95% petro diesel + 5% biodiesel), B10 (90% petro diesel + 10% biodiesel), B20 (80% petro diesel + 20% biodiesel), B50 (50% petro diesel + 50% biodiesel), and B100 (100% pure biodiesel) are some options which are seen as a solution to lower the greenhouse emission globally [58]. Nowadays, one of the most crucial environmental issues is the ozone formation by the use of biodiesel fuel it can be drastically decreased. If we compare the emission of both biodiesel and gasoline then we observe that the emissions which are produced by biodiesel are comparatively less reactive with sunlight. As a result, the potential of formation of harmful and damaging ozone is seen less. As the sun’s energy is converted into usable energy, that’s why Biodiesel is considered as a renewable energy resource. Pollutants that are emitted by the Biodiesel are quite less harmful being compared with the regular Diesel [59].

Bio-diesel blend performance has been tested by several important measures and found to give better results than petroleum diesel. The commercial application of biodiesel is not to that extent the major reason behind it is the high production cost and the availability of raw materials is limited [60]. Storage in cold climate and testing studies revealed that the bio-diesel should be kept at least 10 of above its cloud point to successfully blend with diesel. National Renewable Energy Laboratory (NREL) has sponsored research to find bio-diesel formulations that do not increase nitrogen oxide emissions by adding cetane enhancers- ditert-butyl peroxide at 1 percent or 2- ethylhexyl nitrate at 0.5 percent. The new alternative which is under investigation uses kerosene to reduce the emission of nitrogen oxide from the blend which contain 20% of Biodiesel [61].

Chapter 4: Lookout of Jatropha Plantation in India

Several MoUs have been signed by many private firms and Petroleum companies in order to enhance and promote the jatropha plantation by the method of contract farming with small and medium farmers or through plantation on the government owned wastelands. Projects based on Biodiesel become unreliable and uneconomic because of some significant factors which include wastelands availability, maintenance cost with high plantation [62]. Satisfactory results were not obtained in the test trials of high yielding varieties of Jatropha for the production of Biodiesel. According to the surveys, almost half a million hectares of poor graded wastelands in the entire country is under the plantation of Jatropha, among which 65-70 percent is new plantation which ages less than 3 years.

As per the current scenario in India, we need to establish research programmes with a joint venture of private as well as public sector in order to achieve high yield of feedstock. Planting jatropha crops in the Zaid season of crops plantation and assuring the plantation in a selected area to establish its viability [63].

In order to achieve the energy Independence, the Govt. of India is promoting the jatropha incentives. The plan to reach this goal is targeted in 2018. As we have discussed, the Jatropha biodiesel is produced from Jatropha oil which is extracted from the jatropha oil which is extracted from the jatropha curcas plant. It is determined as one of the best oils to derive biodiesel by chemical processes and moreover it can also grow on the waste and barren lands so it is also suitable from the Economic point of view [64]. India is looking forward to end its Dependence on coal and Petroleum for never Ending Demand of energy and to Promote the energy sector the jatropha cultivation is been promoted. For the upgradation of cultivation some selected areas have been kept Reserved. Jatropha Plantation is these areas will lead to increase in yield of raw oil. In the business sector the Jatropha plantation has a positive scope and it is also interesting investors [65]. 400,000 square kilometer (98 million acre) area has been selected by the Govt. of India to be kept in consideration for the plantation of Jatropha which will help in reducing the Diesel consumption 20% for overall oil needs. A study has revealed that jatropha based biodiesel production has shown favourable energy balance characteristics based on life cycle analysis.

The countries which are still in developing phase are having a high demand of biofuels. These countries are also launching such policies which attract the investors in this field and that will help in the development of biofuels market [66]. It has been forecasted that the demand of biofuels might decline in future in US and EU just like ethanol, which can affect the feedstock of vegetable oils and is expected to fall. Some developing countries may see a growth in the demand of biodiesel in future. The major names are Indonesia, Brazil, Argentina and other small developing countries. The Indian scenario of production of biodiesel in India, we need to take steps and launch suitable policies.

It would be possible to substitute petro-diesel with bio-diesel by 20% without any alterations/ modifications in existing Cl engines [67]. Thus, to have 20% blend of 67 million tonnes petro-diesel, 13.40 million tonnes of bio-diesel will be needed which in turn will require about 13 million ha of land. This can yield a revenue of approximately 20,000 crore rupees per annum besides employment opportunities to over 12 million people in cultivation and extraction/ Trans- esterification operations. Traditional plantation of Jatropha curcas is done in almost every state of country but the major issue is that it is not cultivated in a specific area but found in scattered manner and apart from it the oil content is quite low. Rural plantation has been productivity too [68]. Constant effort is being done in both public and private sector to explore superior varieties which possess high yield and oil content. Many agricultural Universities and institutions have been collecting seeds from various rural areas across the country which seem to be quite promising and constantly experimenting and evaluating to develop a model for modern plantation. Such plantation has been undertaken in more than 10,000 ha by 37 different Universities, Institutes, IIT's, SAU's and NGOs in 24 states. However, as per estimates of NOVOD about 31.17-lakh ha plantation would be completed by the end of 2008-09 to substitute about 5% diesel requirement of entire country [69]. The country has an estimated potential of more than 50 lakh tons of tree borne oil seeds with an annual potential of 2 million tonnes, however, only 8.10 lakh tonnes are being collected. At present 1.5 to 2.0 lakh tonnes of oil are being extracted out of 10 lakh tonnes of oil seed.

As per statistics on land availability, the total area of India in geographical terms is around 329 million hectares. Out of this, about 173 million hectares area is under cultivation. According to an estimation out of total geographical area of the country a large area is either wasteland or degraded which means it is not fit for the agriculture [70]. This area can be used for cultivation of bio- fuel plants. National Policy is being formulated to ensure sustainable production, conversion and application of bio-fuel to reduce the increasing and worry some on us of crude oil imports. The National Bio- fuel Development Board (NBDB) which will work under Prime Minister, comprises of Ministry of Agriculture, Ministry of Petroleum and Natural Gas, Ministry of Rural Development, Ministry of Non-Conventional Energy Sources, Department of Biotechnology, Science and Technology, and the Planning Commission. According to the report, the short-term target is to replace 5% petro diesel by 2012, 10% by 2017 and 20% by 2030. Few states like Uttaranchal, Chhattisgarh, Andhra Pradesh have constituted bio-fuel boards / Bio-fuel Development Authorities at state level [71].

Ministry of Petroleum and Natural Gas commission has also laid down a bio-diesel purchase policy which recognizes the vital role that Panchayati Raj Institutions can play in promotion of bio-diesel in consultation with NOVOD Board, National Botanical Research Institute and Department of Biotechnology are doing a joint venture and working on a network programme to produce quality biodiesel with innovative plantation [72]. The Petroleum Conservation Research Association (PCRA) has established a National Bio-fuel Centre at its HQ in New Delhi to provide information on bio- fuel development.

Chapter 5. Dependency on Crude Oil and Fossil Fuels

More than 80% of the demand of crude oil in India is fulfilled by the imports from different countries. Nearly, 102 billion US Dollars were spent in the financial year 2019-20 just for the import of the crude oil. The production of petroleum products from the indigenous crude oil is quite less as compared to the imports [73].

India ranks second in the terms of import of crude oil after China. Due to lack of reserves of petroleum, India mostly depends on the crude oil imports. To overcome the situation, India needs to work proactively and take necessary diplomatic steps to bring down the high prices of crude oil fixed by the OPEC+ and BIG OIL. The swing oil which is found in the Indian oil reserves should be used very wisely [74]. The basic steps regarding this objective are that, India must enhance the extraction rate to almost twice as compared to the presently used extraction rate and it should be made sure that the extraction is done on intermittent basis as in extraction at that time when the price exceed the present upper ceiling value. Continuous extraction should be avoided. Mutual co- relations between India and China are required as they both are largest importers of crude oil so that the price of crude oil in global market does not exceed much and the regular energy requirements could be met [75].

In 2006-2007, approximately 52 million MT of diesel fuels was burnt in combustion by vehicles in India and this is likely to exceed 67 million MTs in 2011-12. As per the estimation diesel fuel demand for the next 2 decades along with thee of crude oil in global market does not exceed much and the regular energy requirements could be met. Requirements of bio diesel for B5, BI0 and B20 blend levels is given in Table for 20% blending by 2030, 38 million ha of waste land is required if yield of Jatropha is estimated 5 tonnes/ha.

Specifications adopted by Bureau of Indian standards (BIS) for bio-diesel for use in India is ISI 5607(2005) [76]. The greatest advantage of bio diesel is that virtually it doesn't contain any sulphur. However, as per the report issued by the EPA in October 2002, almost 50% emissions of particulate matters (PM) and carbon mono oxide (CO) are reduced by burning BI00 and along with-it unburnt hydrocarbons is reduced by almost 70%. There is, however, a slight increase in NO_X emissions is seen, but after executing the blending process in biodiesel reduces NO_X emissions to a negligible amount.

S.No.	Year	Diesel Demand Million (MTs)	Bio-Diesel Demand (Million MTs)		
			B_5	B_{10}	B_{20}
1.	2006-07	52.33	2.62	5.24	10.48
2.	2007-08	55.26	2.76	5.52	11.04
3.	2008-09	58.35	2.92	5.84	11.68
4.	2009-10	61.62	3.08	6.16	12.32
5.	2010-11	65.07	3.25	6.50	13.00
6.	2011-12	66.90	3.35	6.69	13.08
7.	2020-21	111.92	5.60	11.20	22.38
8.	2030-31	202.84	10.14	20.28	40.56

Table 1. – Diesel and Biodiesel Demand in India

The Govt. has a vision to cut down oil import by 67% by the end of 2022 but the yield of local cultivation is not sufficient due to ageing fields and the domestic output has been decreasing from past couple of years. Suitable steps have been taken by the Govt. and some policies have also been introduced which are expected to attract capital and technology for the sector and as a result the output will increase [77]. Private sector firms have also invested their capital in this field but the overall production still continues to fall. Major oil Giants of our country like ONGC (oil and natural gas corporation) and OIL (oil India limited) have discovered some oil fields and took a step forward to bid them out but due to the economic unviability of these oil fields these were not monetized. 53 countries have already been bid out by the Govt. by conducting 2 bidding rounds and they are already in the implementation phase. By such kind of steps, it has been ensured that experienced personnel will come up with better solution for cultivation, innovative technology, superior management skills, more capital from the public sector for the production enhancement [78].

Finally, it is about increasing the acreage under exploration and production (E&P). "Without increasing the acreage, we cannot increase production, which has stagnated for the past many years," says Nath. A major step has been to bid out small discovered oil fields of the national oil companies like Oil and Natural Gas Corporation, Oil India Ltd etc., which have not been monetized because they were considered economically unviable by these companies [79]. Through two bidding rounds, the government has already awarded 53 contracts, which are in various stages of implementation. Such a step, say experts is likely to augment production by leveraging New technology, capital, and management practices through private sector participation.

On February 2019, Govt. introduced a new policy to ensure the equal and more participation of both International and Domestic investors in E&P, the main purpose of this policy is to Differentiate between different basins and different taxation structure [80]. For instance, in Category II and Category III basins, which has seen no commercial activity bids will be given out on the basis of the work programme promised by the contractor without any revenue or production sharing contract with the government. Bidding for six out the seven blocks bid out is already underway like those in Cambay, Mumbai offshore, Rajasthan, Krishna Godavari-Cauvery, etc. Bidding will end on October 31 [81].

Learning from the earlier experience of companies bidding too high to get a block and being unable to pay later, the government has set an upper ceiling on biddable revenue under the new PSCs [82]. Moreover, fiscal incentives have been announced for early field production and contractors have been given full marketing and pricing freedom to sell their crude oil and natural gas.

Chapter 6: Experimental Data and Analysis

6.1 Preparation of Biodiesel by Trans-Esterification Process

Lab testing of Different parameters is required to determine several results for the application of uses of Jatropha biodiesel in the Daily life. These testing include testing of viscosity, calorific value, Density etc. To check the compatibility with different types of Engines.

Preparation of biodiesel from trans-esterification process consist of different steps. Firstly, the oil is heated in a beaker by the application of a hot plate at 100°C and the temperature is kept in control by the use of a thermometer. Then the oil is kept to cool down until it reaches the temperature of 60°C. Then, a smaller beaker is taken with a specific amount of Ethanol in it which is approximately 40% the volume of the oil taken for the preparation of biodiesel. The Ethanol solution is then heated and KOH pellets are added to that heated solution while it is heating on the hot plate. The amount of KOH is about 1% the amount of oil taken in the terms of volume. After the pellets are added to Ethanol they are allowed to dissolve in the solution. When the pellets are dissolved, the ethanol solution is added slowly and in small amounts to the heated oil, if added rapidly it can form precipitates which can lead to failure of transesterification process.

After the addition of Ethanol solution, the oil is allowed to heat at a constant temperature of 60°C until the biodiesel is formed. It is a slow and process, so it takes a while for the impurities to settle down and the oil to come above the solution. But once the impurities settle down the oil film can be seen easily by the observer. After the impurities settle down the oil is the transferred to the separating funnel from the flask for the rest of the impurities to settle down. The oil remains in undisturbed state in the separating funnel for at least 24 hours and then the impurities are separated and the pure biodiesel is left in the separating funnel. It can be store for the further experimentation processes.

Fig. 4 – *Jatropha* Biodiesel prepared at Lab. for Testing

6.2 Fuel Properties

When tested in lab the different blends of the oil gave different readings the readings. Readings of J20 which contains 20% Jatropha biodiesel with 80% Diesel were taken. Similarly, J15 and J10 readings were also taken and an observation table was drawn.

Oil / Property	Pure Diesel (100% Diesel)	20% Jatropha Biodiesel (J20)	15% Jatropha Biodiesel (J15)	10% Jatropha Biodiesel (J10)
Dynamic viscosity (mPa.s)	5.4889	2.0583	2.0369	1.9403
Kinematic viscosity(mm^2/s)	6.2456	2.5261	2.5003	2.3900
Density(g/cm^3)	0.8788	0.8148	0.8147	0.8118

Table 2 – Fuel Observations taken in the Lab

Dynamic Viscosity (mPa.s) - Dynamic viscosity is the force needed by a fluid to overcome its own internal molecular friction so that the fluid will flow. In other words, dynamic viscosity is defined as the tangential force per unit area needed to move the fluid in one horizontal plane with respect to other plane with a unit velocity while the fluid's molecules maintain a unit distance apart.

Kinematic Viscosity(mm^2/s) - The kinematic viscosity of a fluid is the ratio of the viscosity of the fluid to the fluid's density. Mathematically, it is expressed as:

$$\nu = \mu / \rho$$

where ν is the kinematic viscosity, μ is the dynamic viscosity, and ρ is the density. By removing the factor of density, the viscosity of a fluid can be understood from the standpoint of the frictional forces between the molecules of a fluid rather than the gravitational effects. Kinematic viscosity is a temperature dependent property.

Density(g/cm^3) - The density (more precisely, the volumetric mass density; also known as specific mass), of a substance is its mass per unit volume. The symbol most often used for density is ρ (the lower-case Greek letter rho), although the Latin letter *D* can also be used. Mathematically, density is defined as mass divided by volume

6.3 EXPERIMENTAL SETUP AND APPARATUS USED

Fig. 5 – *Kirloskar* Diesel Engine Test Setup

All the testing procedure was done in the Automobile lab with VCR Deisel Engine test setup which included the performance as well as combustion testing. This engine test setup is loaded with single cylinder, four strokes, VCR (variable compression ratio) Diesel engine. For the loading process is uses the Eddy current type Dynamometer. The compression ratio can be varied during the test without altering the combustion chamber geometry or without stopping the engine. This comes possible by the specially designed tilting cylinder block arrangement. Setup has got all the instruments that can give a précised measurements of combustion pressure and crank angle. The engine indicator interfaces all the signals from the test to the computer for diagrams. There are also provisions for temperatures, fuel flow, interfacing air flow and load measurements. The setup has got a dedicated stand-alone panel-box consisting of air box, two fuel tanks for dual fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement.

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 and heat balance. Labview based Engine Performance Analysis software package "Engine soft is provided for on line performance evaluation. A computerized Diesel injection pressure measurement is optionally provided.

Features

- CR changing without stopping the engine
- No alteration in Combustion chamber geometry
- Arrangement for dual fuel test
- “-PV plots, performance plots and tabulated results
- Online measurements and performance analysis
- Data logging, editing, printing and export, Configurable graphs
- IP, IMEP, FP indication
- Combustion analysis

Technical Specifications

- Product: VCR Engine test setup 1 cylinder, 4 stroke, Diesel (Com.)
- Product code: 234, 234H*
- Engine: Make Kirloskar, Type 1 cylinder, 4 stroke Diesel, water cooled, power 3.5kW at 1500rpm, stroke 110mm, bore 87.5mm. 661cc, CR17.5, Modified to VCR engine CR 12 to 18
- Dynamometer: Product 234: Type eddy current, water cooled, Product 234H: Type Hydraulic
- Propeller shaft: With universal joints
- Air box: M S fabricated with orifice meter and manometer
- Fuel tank: Capacity 15 lit with glass fuel metering column
- Calorimeter: Type Pipe in pipe
- Piezo sensor: Range 5000 PSI, with low noise cable
- Crank angle sensor: Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
- Data acquisition device: NI USB-6210, 16-bit, 250kS/s.
- Piezo powering unit: Make-Cuadra, Model AX-409.
- Temperature transmitter: Type two wire, Input RTD PT100, Range 0-100 Deg C, Output 4-20 mA and Type two wire, Input Thermocouple,
- Load indicator: Digital, Range 0-50 Kg, Supply 230VAC
- Load sensor: Load cell, type strain gauge, range 0-50 Kg
- Fuel flow transmitter: DP transmitter, Range 0-500 mm WC
- Air flow transmitter: Pressure transmitter, Range (-) 250 mm WC
- Software: "EnginesoftLV" Engine performance analysis software
- Rotameter: Engine cooling 40-400 LPH; Calorimeter 25-250 LPH

- Pump: Type Monoblock
- Overall dimensions: W 2000 x D 2500 x H 1500 mm
- Optional: Computerized Diesel injection pressure measurement

6.3 PERFORMANCE CHARACTERISTICS

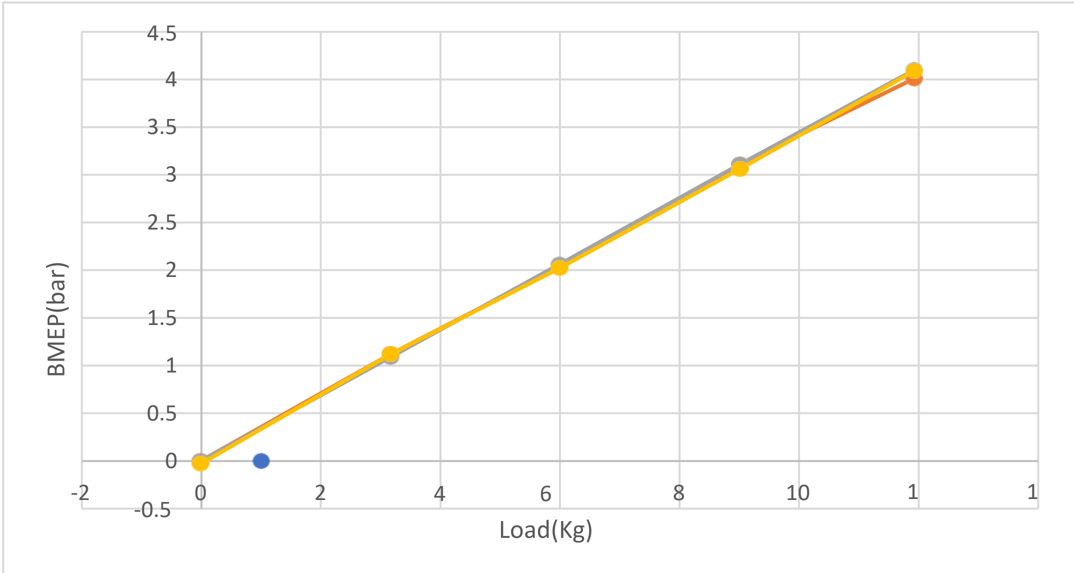

Fig. 6 – Brake Mean Effective Pressure *vs* Load -Characteristics

In this curve of BMEP *vs* Load, it is observed that the pressure keeps increasing along with the load. A linear curve is observed for the combined reading of all the blends. The initial value for No load condition, all the blends is approximately same which is around (0.00 bar) but in the full load condition (12kg) the highest value observed differs in a small range, (4.10 bar) for B20, (4.01bar) for B15, (4.11bar) for B10 and for pure Diesel it is (4.09 bar).

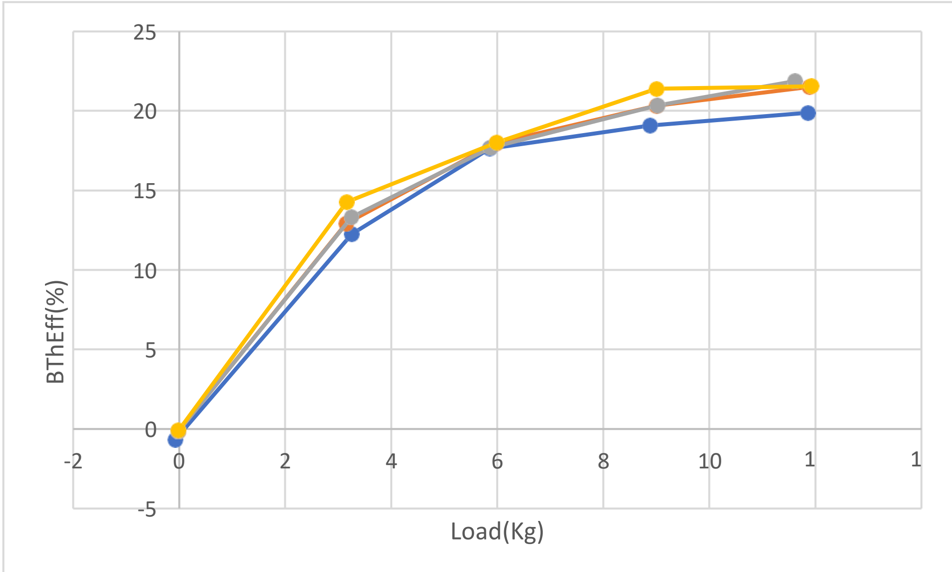

Fig. 7 – Brake Thermal Efficiency *vs* Load - Characteristics

In this curve of BThEff *vs* Load, it is observed that the Brake Thermal Efficiency keeps increasing along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. The initial value for No load condition, are lying in the range of (-0.09 to – 0.13) % but for pure diesel the value is quite low around -0.65. For the full load condition, the value ranges from (21.50 to 21.90) % and for Diesel this value is also quite low (19.89) % approximately.

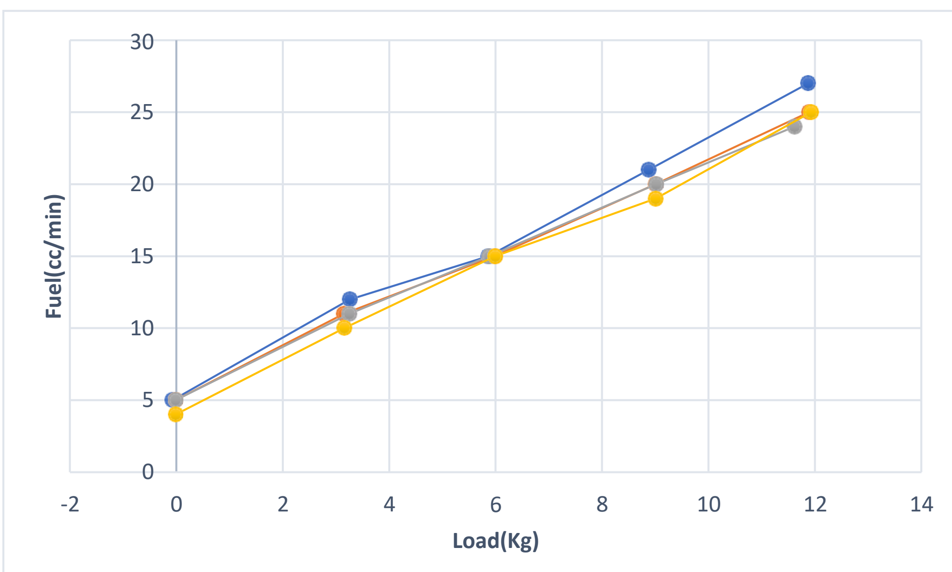

Fig. 8 – Fuel Flow *vs* Load-Characteristics

In this curve of Fuel flow *vs* Load, it is observed that the Fuel Flow keeps increasing along with the load. A curve is observed approximately linear for the combined reading of all the blends. The proportionality limit is followed by all the blends and one specification is that the initial reading is not starting from origin. The initial reading is approximately same for all the blends including pure Diesel but the final readings quite differ from each other. For full load condition the value of B20 is (25cc/min), B15 is (24cc/min), B10 is (25cc/min) and for pure diesel it is a bit more that is (27cc/min).

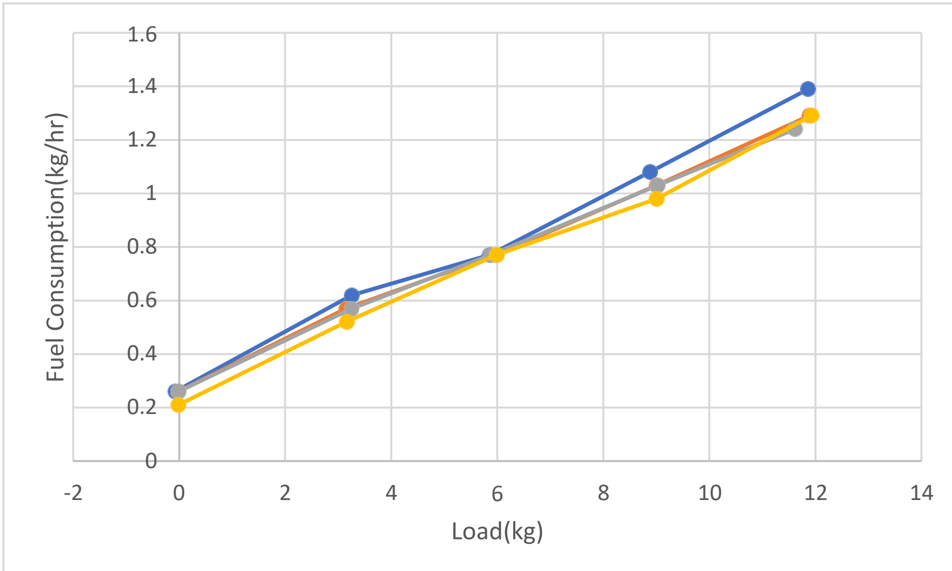

Fig. 9 – Fuel Consumption *vs* Load-Characteristics

In this curve of Fuel Consumption *vs* Load, it is observed that the Fuel Flow keeps increasing along with the load. A curve is observed approximately linear for the combined reading of all the blends. The proportionality limit is followed by all the blends and one specification is that the initial reading is not starting from origin. At no load condition the fuel flow is same for all the blends. For full load condition the all blends show a value of around 1.2(kg/hr) but for pure Diesel it is around 1.3(kg/hr).

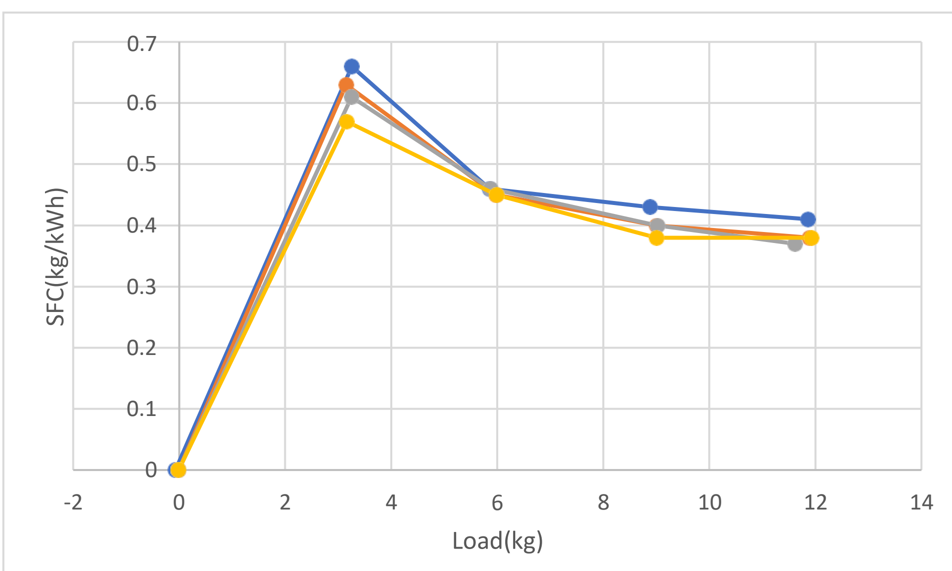

Fig. 10 – Specific Fuel Consumption *vs* Load-Characteristics

In this curve of Specific Fuel Consumption *vs* Load, it is observed that the SFC keeps increasing along with the load only up to a limit. In this graph a different kind of curve is observed, the curve is linear between No load condition to 3kg load condition and then falls down and for Full load condition it is observed to be constant approximately for values near Full load condition. The value is absolutely Zero for No load condition but for a variation is seen between 3kg loading and other loading conditions. The value for 3kg loading condition for B20, B15, B10 and pure diesel is 0.63, 0.61, 0.57 and 0.66 respectively and for full load condition it is 0.38, 0.37, 0.38 and 0.41 which are lower than 3kg loading.

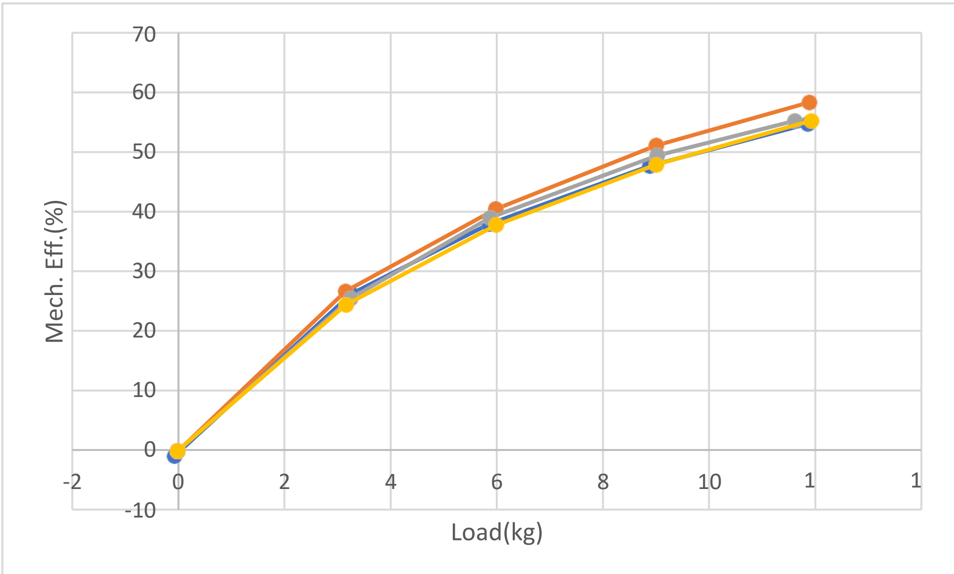

Fig. 11 – Mechanical Efficiency *vs* Load-Characteristics

In this curve of Mech.Eff *vs* Load, it is observed that the Mechanical Efficiency keeps increasing along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. For the No load condition, the range of Mechanical Efficiency is (-0.13 to -0.21) %. But as the load is increased the value for each blend differs from the other. For full load condition the value for B20 is (58.32) %, (55.23) % for B15, (55.25) % for B10 and (54.71) % for pure Diesel. From the data observed it is concluded that highest mechanical efficiency is for B20 blend.

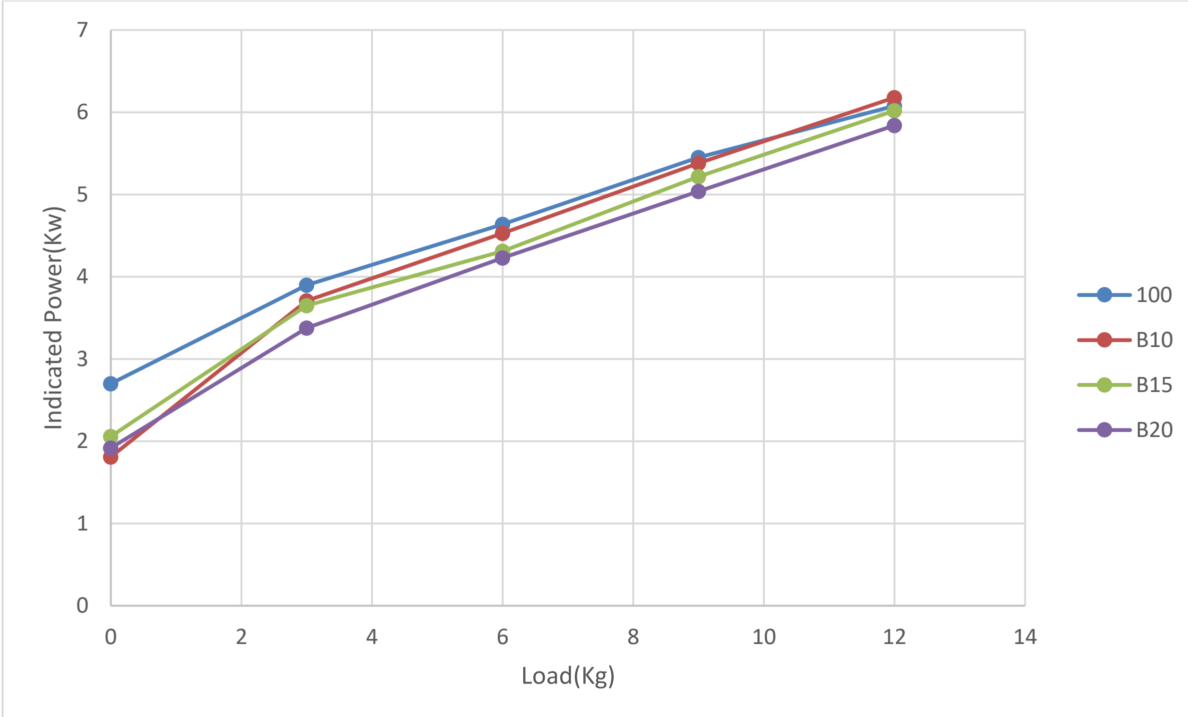

Fig. 12 – Indicated Power *vs* Load-Characteristics

In this curve of Indicated Power *vs* Load, it is observed that the Indicated Power keeps increasing along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. For the No load condition, the range of Indicated Power is (1.81 to – 2.06). But as the load is increased the value for each blend differs from the other. For full load condition the value for B20 is (5.84), (6.02) for B15, (5.38) for B10 and (6.22) for pure Diesel. From the data observed it is concluded that highest Indicated Power is for pure Diesel.

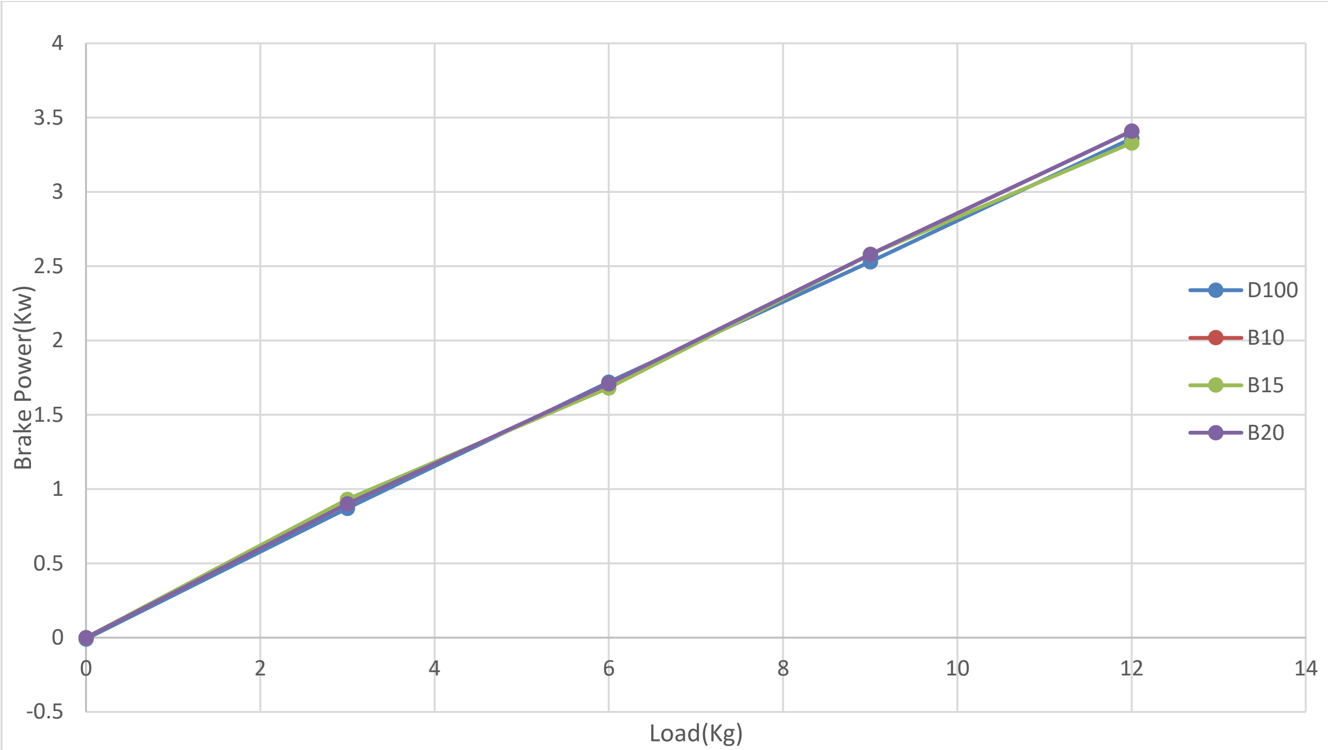

Fig. 13 – Brake Power *vs* load -Characteristics

In this curve of Brake Power *vs* Load, it is observed that the Brake Power keeps increasing along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. For the No load condition, the range of Brake Power is (3.33 to 3.41). But as the load is increased the value for each blend differs from the other. For full load condition the value for B20 is (3.41), (3.33) for B15, (3.41) for B10 and (3.40) for pure Diesel. From the data observed it is concluded that highest Brake Power is for pure Diesel and B20 blend.

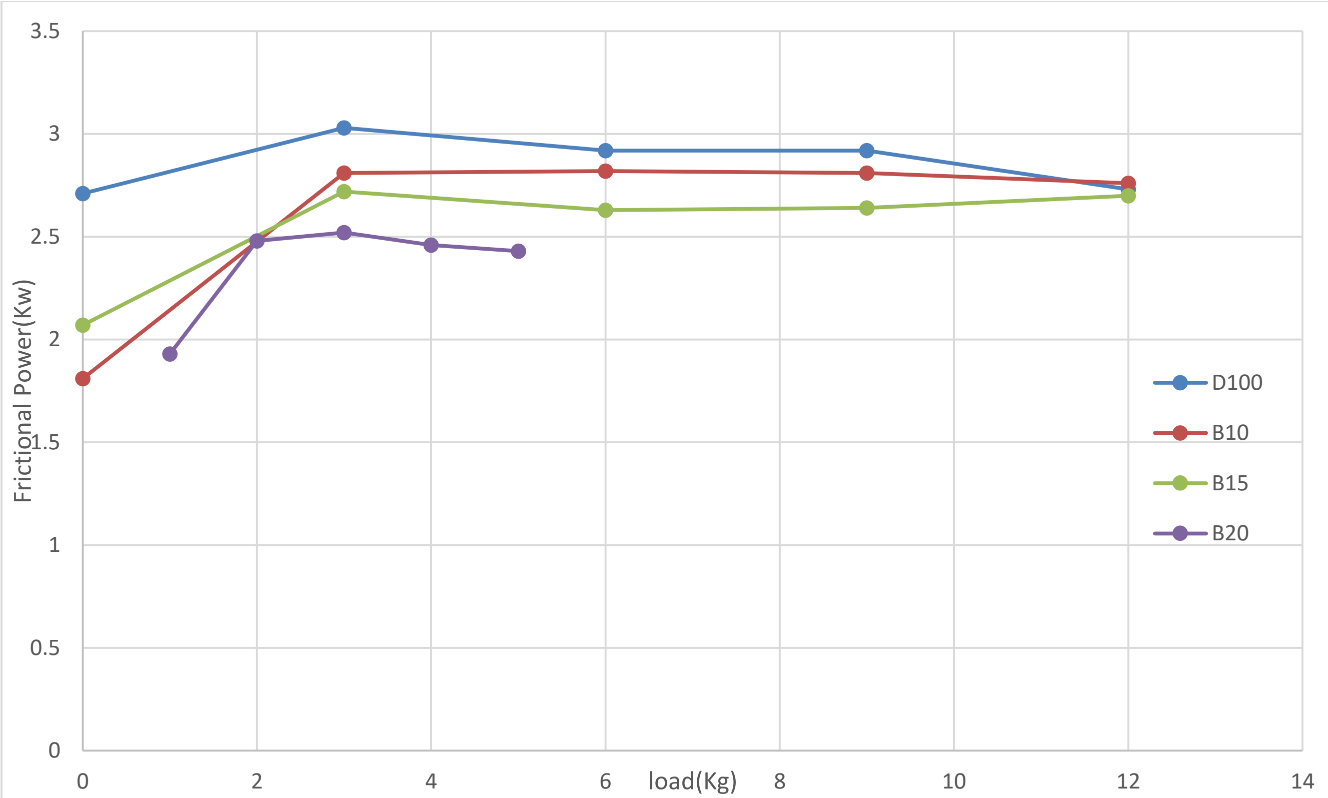

Fig. 14 - Friction Power *vs* load- Characteristics

In this curve of Friction Power *vs* Load, it is observed that the Friction Power keeps increasing along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. For the No load condition, the range of Brake Power is (3.33 to 3.41). But as the load is increased the value for each blend differs from the other. For full load condition the value for B20 is (3.41), (3.33) for B15, (3.41) for B10 and (3.40) for pure Diesel. From the data observed it is concluded that highest Friction Power is for pure Diesel.

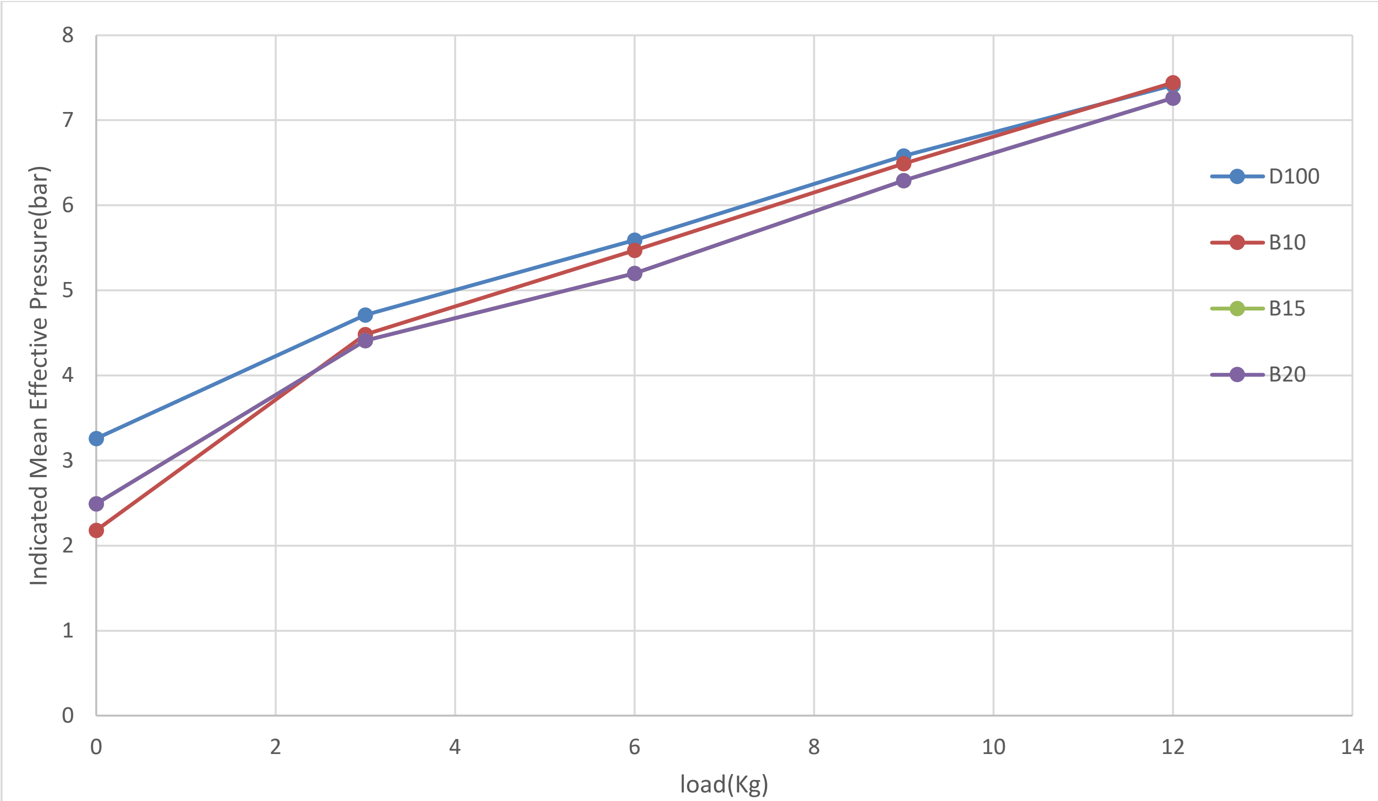

Fig. 15 – Indicated Mean Effective Pressure *vs* Load- Characteristics

In this curve of Indicated Mean Effective Pressure *vs* Load, it is observed that the Indicated Mean Effective Pressure keeps increasing along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. For the No load condition, the range of Indicated Mean Effective Pressure is (7.03 to 7.48). But as the load is increased the value for each blend differs from the other. For full load condition the value for B20 is (7.03), (7.26) for B15, (7.44) for B10 and (7.48) for pure Diesel. From the data observed it is concluded that highest Friction Power is for pure Diesel.

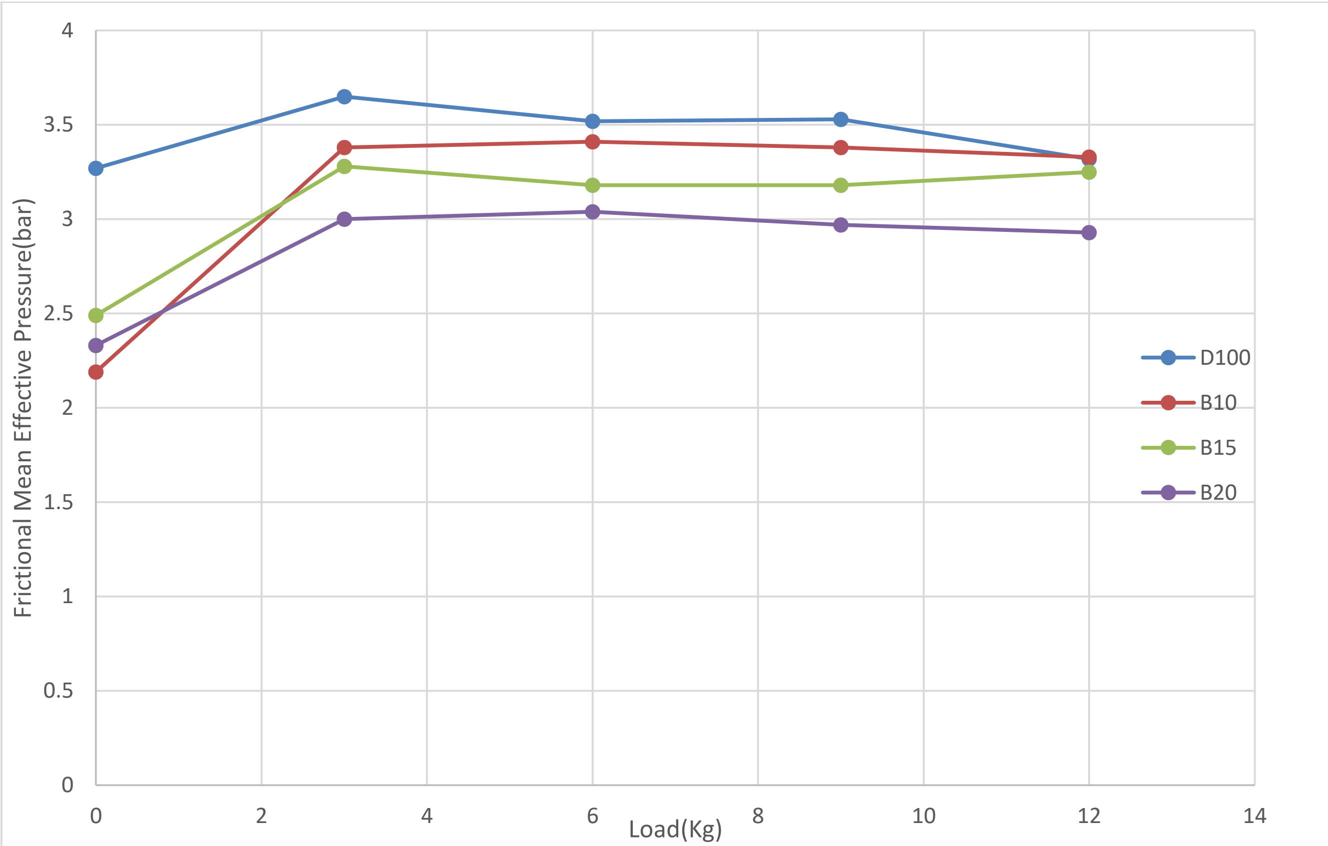

Fig. 16 – Frictional Mean Effective Pressure *vs* Load - Characteristics

In this curve of Frictional Mean Effective Pressure *vs* Load, it is observed that the Frictional Mean Effective Pressure keeps increasing along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. For the No load condition, the range of Frictional Mean Effective Pressure is (7.03 to 7.48). But as the load is increased the value for each blend differs from the other. For full load condition the value for B20 is (2.93), (3.25) for B15, (3.33) for B10 and (3.39) for pure Diesel. From the data observed it is concluded that highest Friction Power is for pure Diesel.

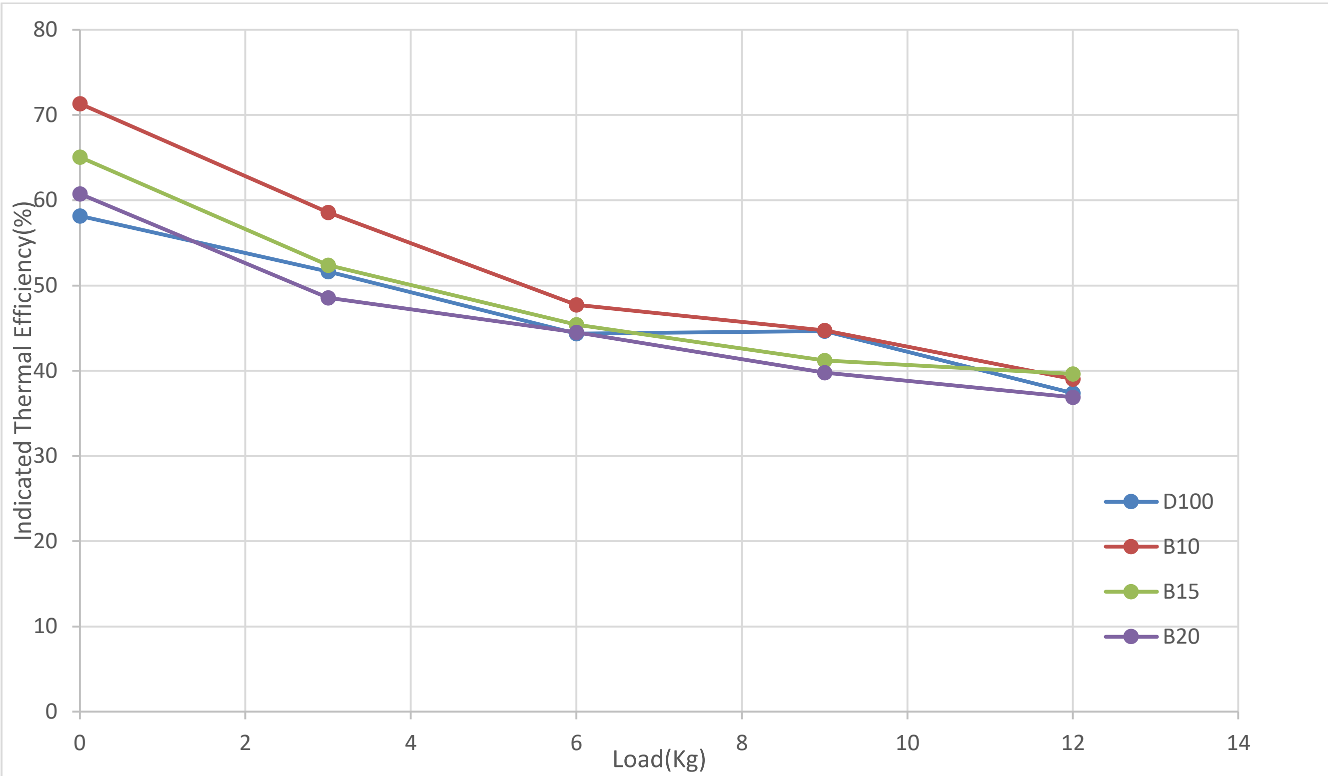

Fig. 17 – Indicated Thermal Efficiency *vs* Load – Characteristics

In this curve of Indicated Thermal Efficiency *vs* Load, it is observed that the Indicated Thermal Efficiency keeps increasing along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. For the No load condition, the range of Indicated Thermal Efficiency is (36.35% to 39.61%). But as the load is increased the value for each blend differs from the other. For full load condition the value for B20 is (36.88%), (39.61%) for B15, (39.01%) for B10 and (36.35%) for pure Diesel. From the data observed it is concluded that highest Friction Power is for B15.

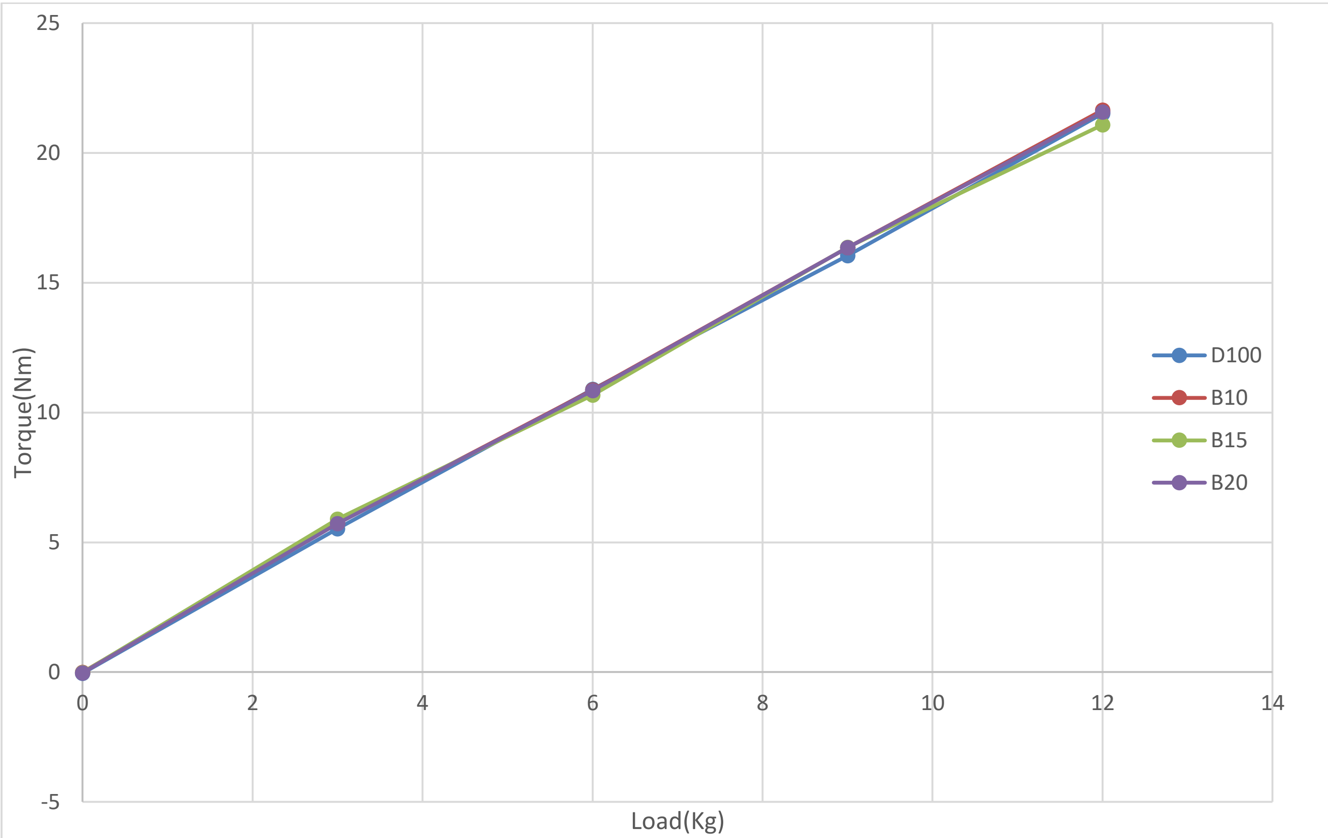

Fig.18 – Torque *vs* Load – Characteristics

In this curve of Torque *vs* Load, it is observed that the Torque keeps increasing along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. For the No load condition, the range of Torque is (21.09 to 21.65). But as the load is increased the value for each blend differs from the other. For full load condition the value for B20 is (21.58), (21.09) for B15, (21.65) for B10 and (21.54) for pure Diesel. From the data observed it is concluded that highest torque is for B15.

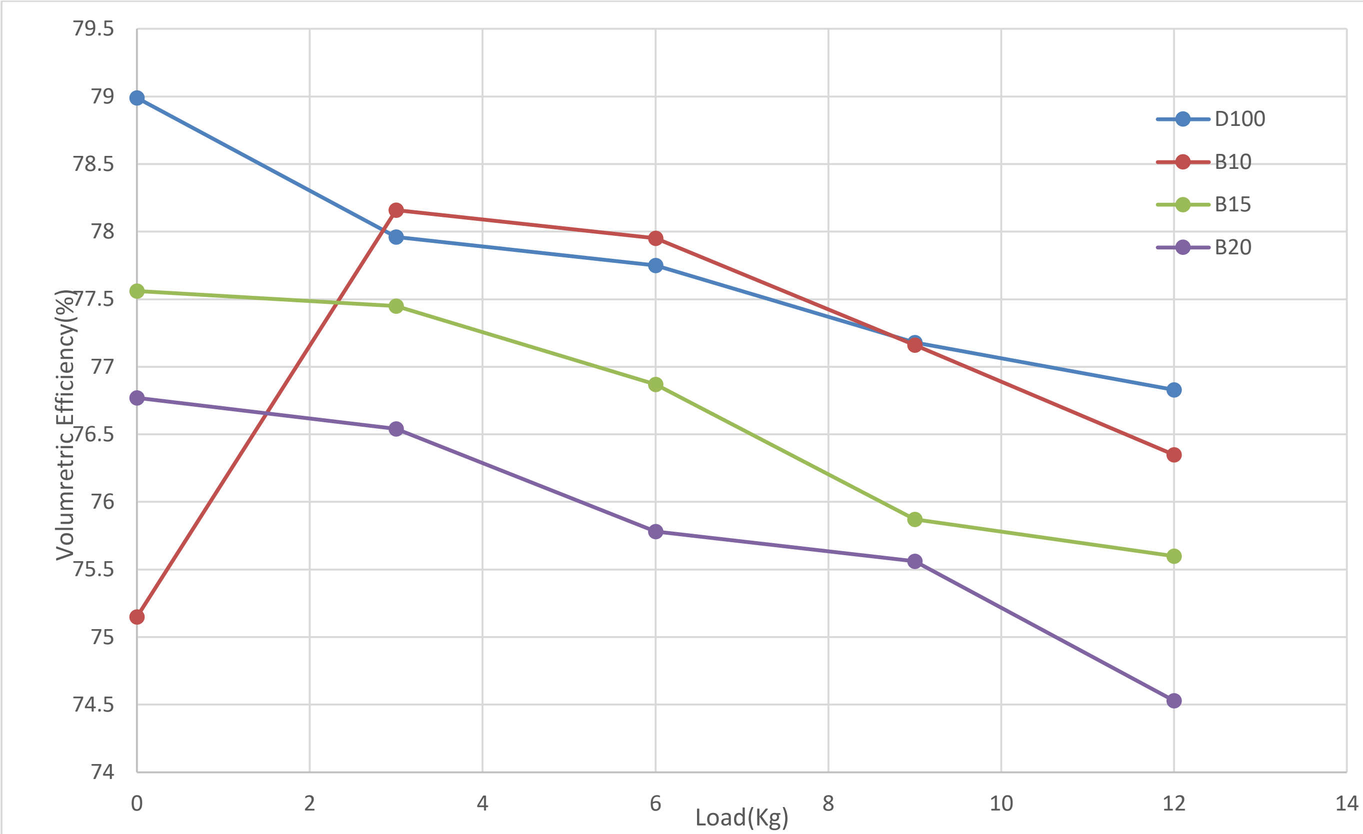

Fig. 19 – Volumetric Efficiency *vs* load – Characteristics

In this curve of Volumetric Efficiency *vs* Load, it is observed that the Volumetric Efficiency keeps increasing along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. For the No load condition, the range of Volumetric Efficiency is (74.21% to 76.35%). But as the load is increased the value for each blend differs from the other. For full load condition the value for B20 is (74.53%), (75.60%) for B15, (76.35%) for B10 and (74.21%) for pure Diesel. From the data observed it is concluded that highest Volumetric Efficiency is for B10.

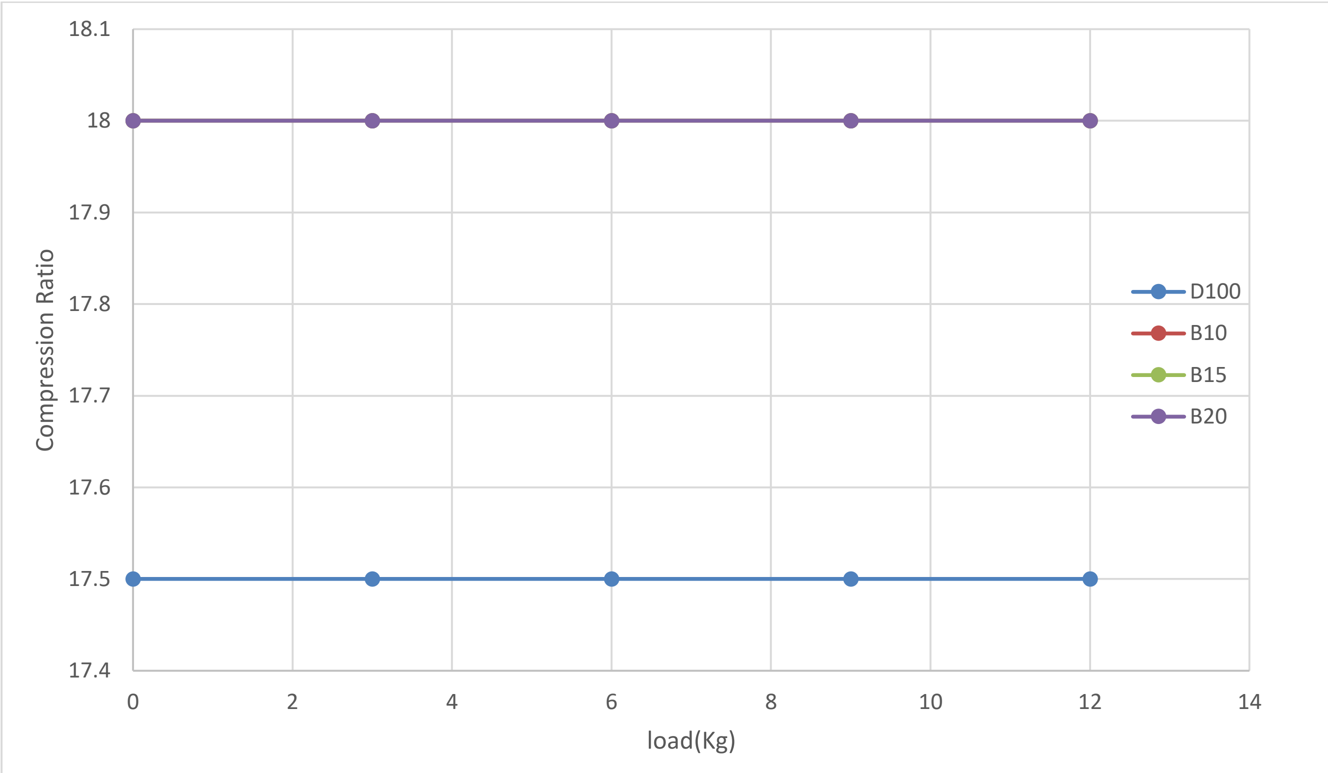

Fig. 20 – Compression Ratio *vs* load – Characteristics

In this curve of Compression Ratio *vs* Load, it is observed that the Compression Ratio is steady along with the load. A curve is observed linear initially then it tilts towards x-axis for the combined reading of all the blends. For the No load condition, the range of Compression Ratio is 18. But as the load is increased even then no change is observed in the compression ratio the value is almost the same. For full load condition the value for B20 is (18), (18) for B15, (18) for B10 and (18) for pure Diesel. From the data observed it is concluded that Compression ratio is same for all the blends.

6.4 COMBUSTION CHARACTERISTICS

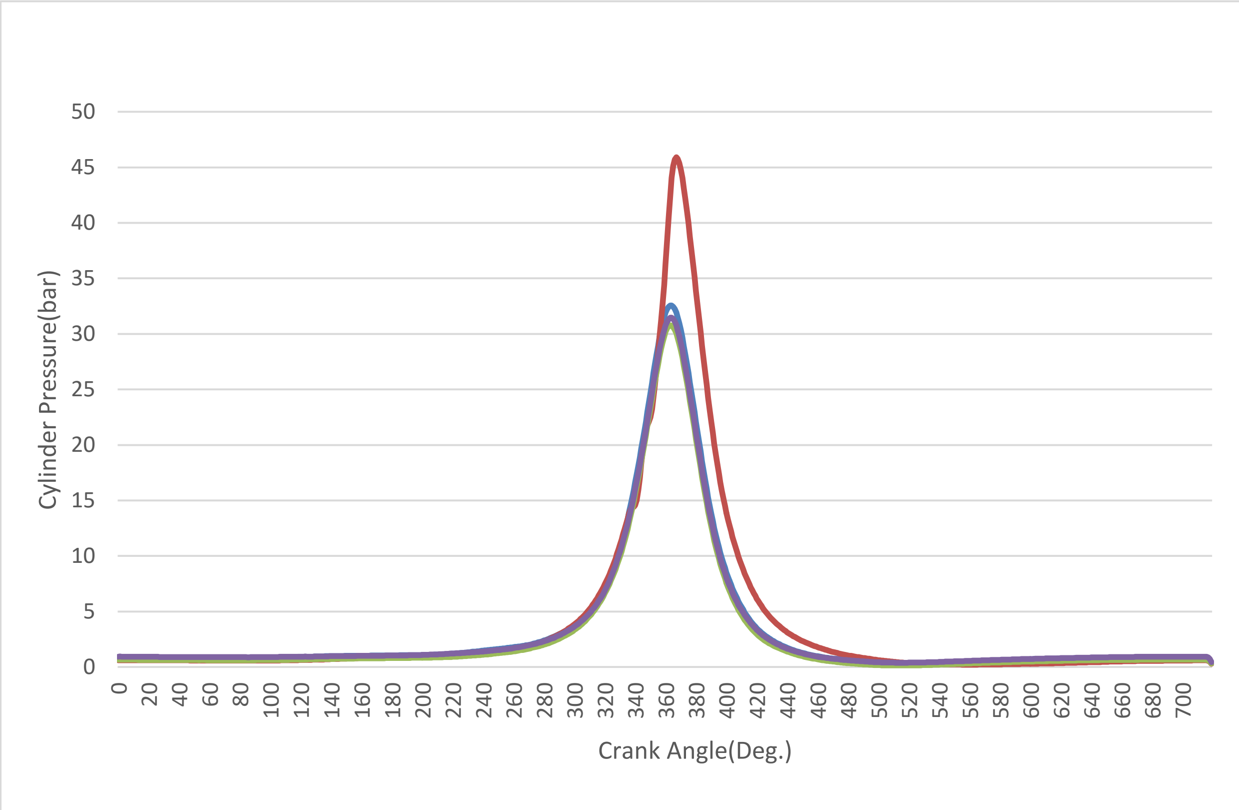

Fig. 21 – Cylinder pressure *vs* Crank angle - Characteristics

In this curve of Cylinder pressure *vs* Crank angle, a six-sigma kind of curve is observed which is linear at initial at final readings but a gradual rise and fall is seen after the maximum pressure is attained by the engine. This is due to the compression stroke as when the compression stroke ends the pressure is highest and then it falls till the end of compression stroke. The end of combustion stroke initiates the opening of the exhaust valve which further decreases the pressure of the cylinder, this is reason despite being going upwards the piston is not able to generate that much pressure which is observed in the compression stroke.

The maximum Cylinder Pressure observed for B20 is (31.46 bar) at 364°, B15 is (30.78 bar) at 363°, B10 is (32.55 bar) at 364° and for pure diesel it is (45.91 bar) at 367°.

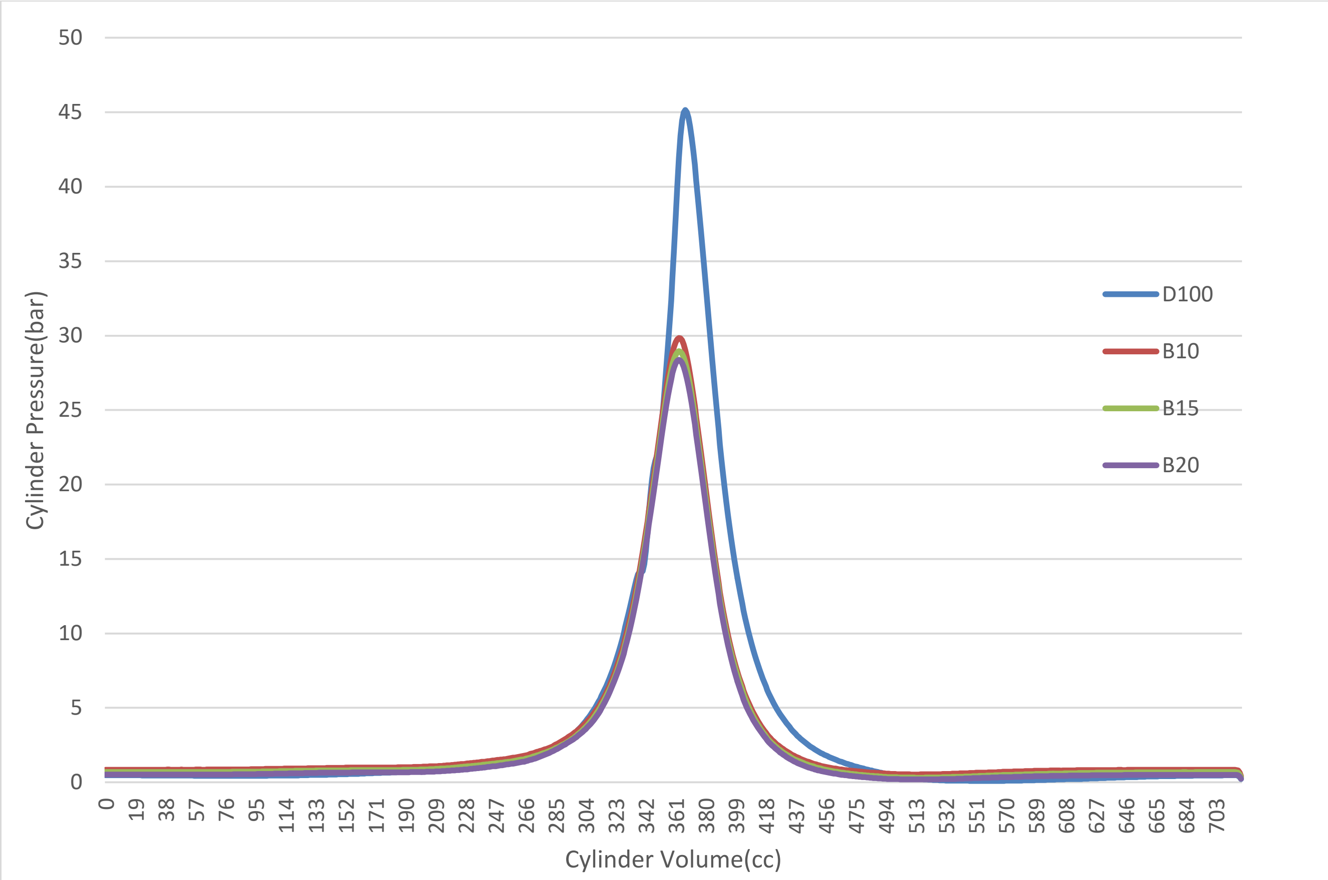

Fig. 22 – Cylinder volume *vs* Crank angle - Characteristics

In this curve of Cylinder volume *vs* Crank angle, a six-sigma kind of curve is observed which is linear at initial at final readings but a gradual rise and fall is seen after the maximum pressure is attained by the engine. In this graph the cylinder volume keeps increasing with increase of the pressure and when the maximum pressure is attained the volume is decreased, this clearly depicts that the highest volume is observed at the highest pressure. The pure diesel has the highest reading in terms of the cylinder volume.

The maximum Cylinder Volume observed for B20 is (28.37 bar) at 363°, B15 is (28.95 bar) at 363°, B10 is (29.85 bar) at 363° and for pure diesel it is (45.01 bar) at 368°.

Fig. 23 – Cumulative Heat Release *vs* Crank angle – Characteristics

In this curve of Cumulative Heat Release *vs* Crank angle, a random kind of curve is observed which is somewhat linear at initial at final readings, several cresta and troughs are observed before and after the highest readings. In this graph the cylinder volume keeps increasing with increase of the crank angle, rise and fall is seen at some points on the graph, this clearly depicts that the highest value of cumulative heat release is observed between the range of 350 to 400 degrees of crank angle. The pure diesel has the highest reading in terms of the Cumulative heat release.

The maximum Cumulative heat release observed for B20 is (0.20) at 450°, B15 is (0.25) at 410°, B10 is (0.27) at 582° and for pure diesel it is (0.56) at 417°.

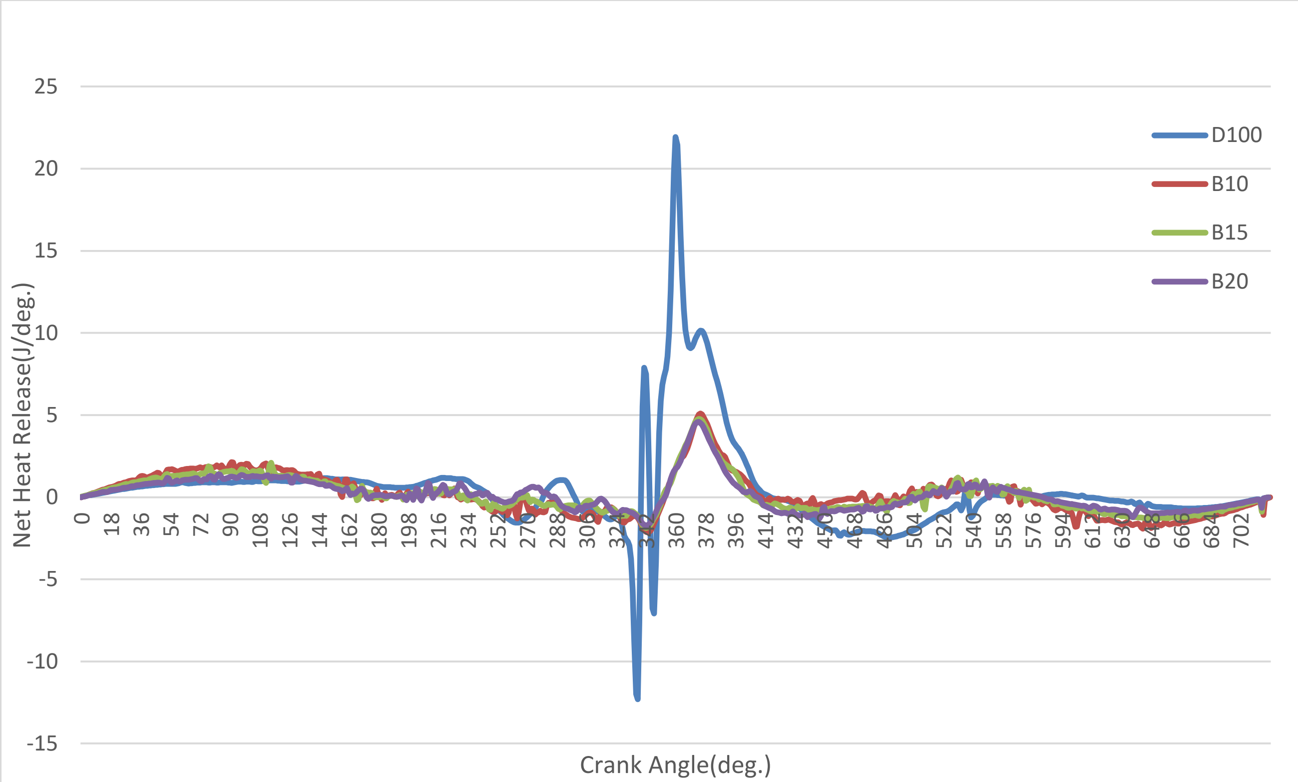

Fig. 24 – Net Heat Release *vs* Crank angle – Characteristics

In this curve of Net Heat Release *vs* Crank angle, a random kind of curve is observed which is somewhat linear at initial at final readings, a sharp reading of Net heat release is observed at the middle. In this graph the net heat release keeps increasing gradually with increase of the crank angle, rise and fall is seen at some points on the graph, this clearly depicts that the highest value of net heat release is observed between the range of 350 to 400 degrees of crank angle. The pure diesel has the highest reading in terms of the Net heat release.

The maximum Net heat release observed for B20 is (4.58) at 374°, B15 is (4.76) at 374°, B10 is (5.10) at 374° and for pure diesel it is (12.31) at 337°.

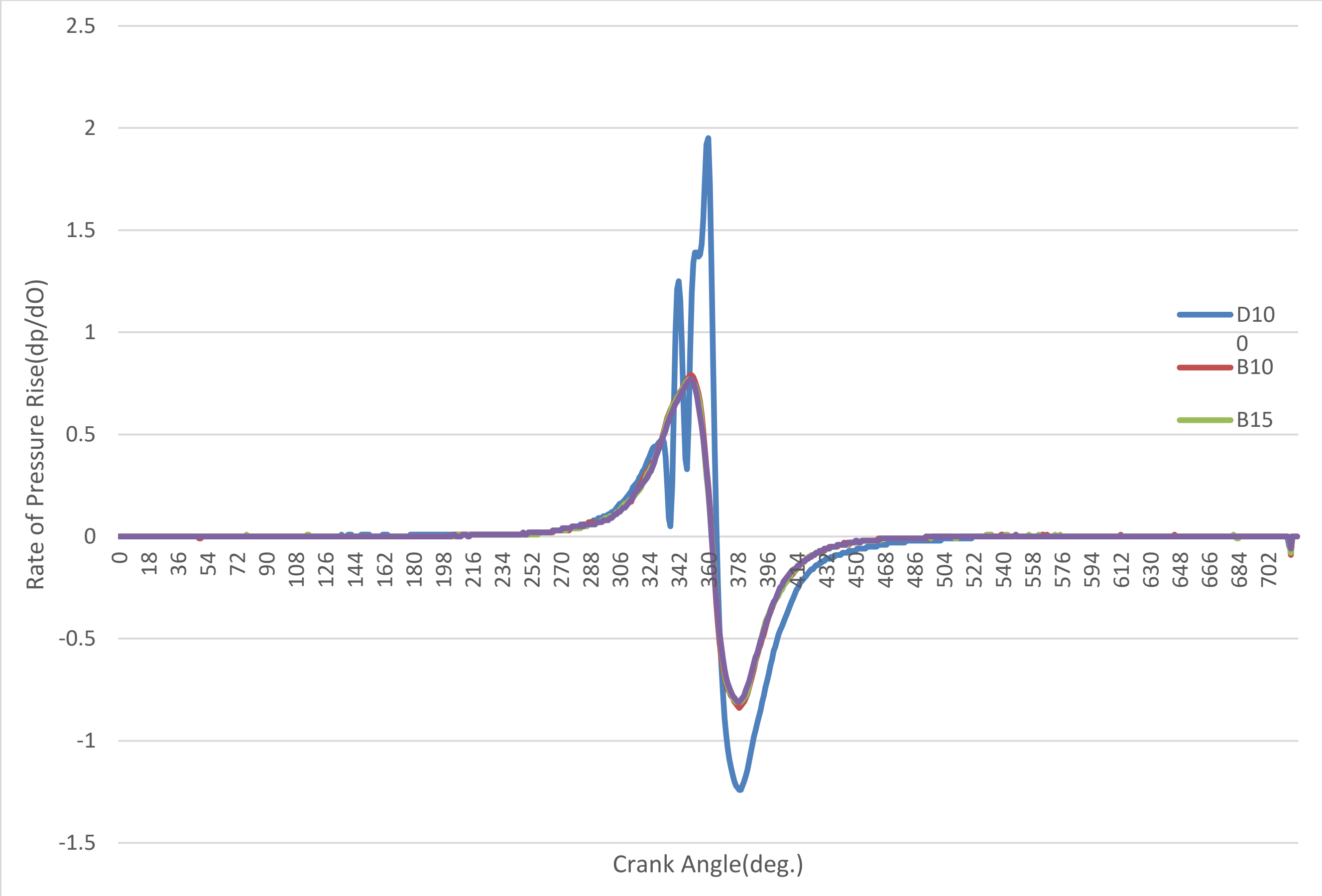

Fig. 25 – Rate of Pressure Rise *vs* Crank angle – Characteristics

In this curve of Rate of Pressure Rise *vs* Crank angle, a random kind of curve is observed which is somewhat linear at initial at final readings, a sharp reading of rate of Pressure rise is observed at the middle. In this graph the net heat release keeps increasing gradually with increase of the crank angle, rise and fall is seen at some points on the graph, this clearly depicts that the highest value of Rate of Pressure rise is observed between the range of 320 to 370 degrees of crank angle. The pure diesel has the highest reading in terms of rate of Pressure rise.

The maximum Rate of Pressure Rise observed for B20 is (0.77) at 349°, B15 is (0.77) at 348°, B10 is (0.79) at 349° and for pure diesel it is (1.95) at 360°.

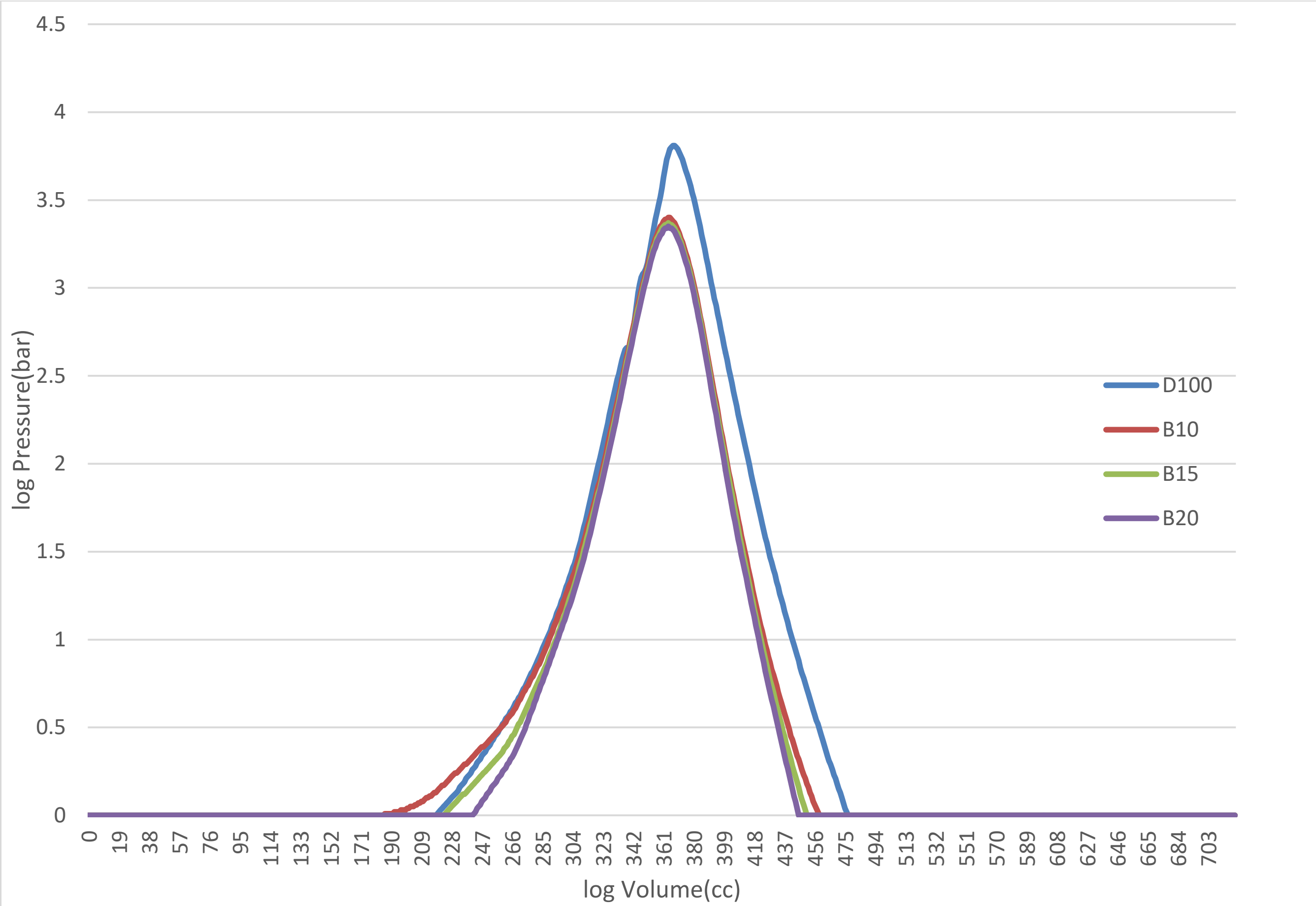

Fig. 26 – log pressure *vs* log volume – Characteristics

In this curve of log pressure *vs* Crank angle, a six-sigma kind of curve is observed which is linear at initial at final readings with readings starting from 0, but a gradual rise and fall is seen after the maximum log pressure is attained by the engine. Logarithmic scale results in a more intuitive approach for deriving the final form of the efficiency equation. In this graph the cylinder volume keeps increasing with increase of the pressure and when the maximum pressure is attained the volume is decreased, this clearly depicts that the highest volume is observed at the highest pressure. The pure diesel has the highest reading in terms of rate of Pressure rise.

The maximum Cylinder Pressure observed for B20 is (3.35 bar) at 363°, B15 is (3.37 bar) at 363°, B10 is (3.39 bar) at 365° and for pure diesel it is (3.81 bar) at 368°.

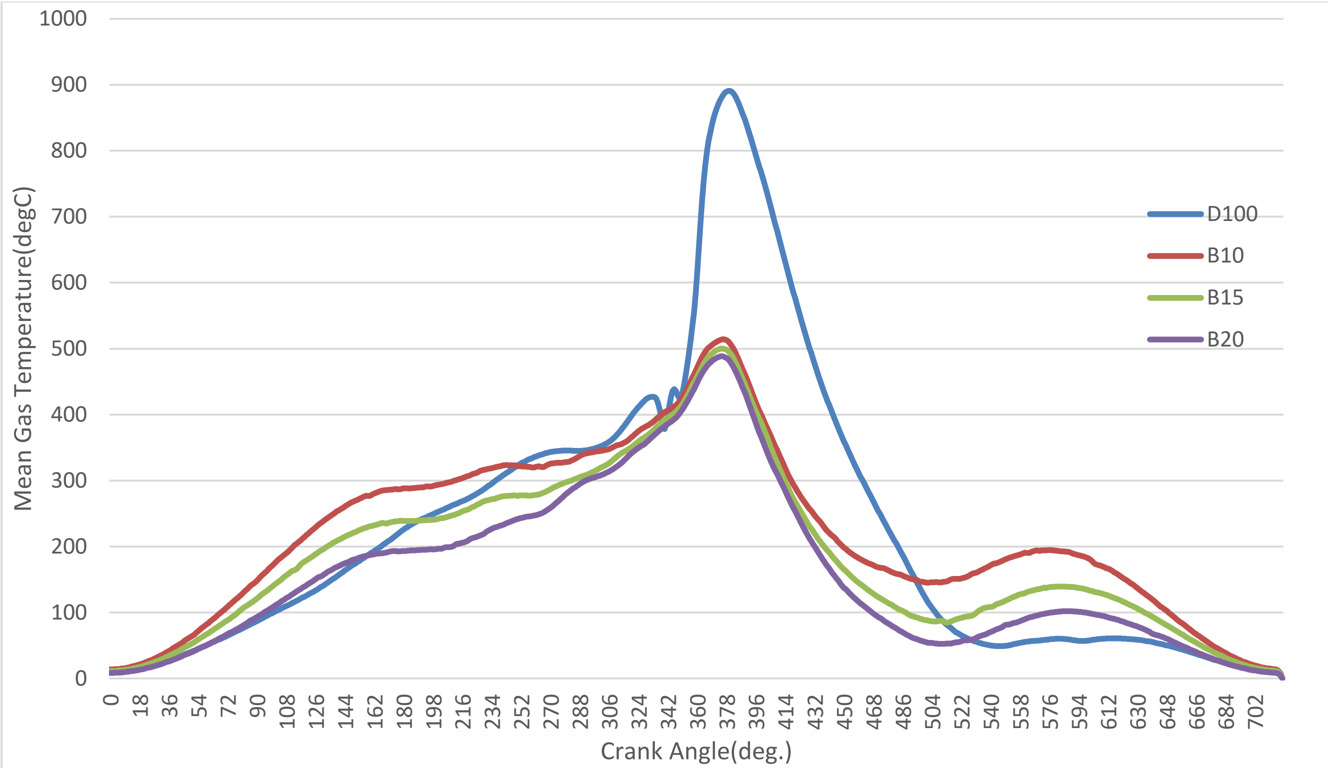

Fig. 27 – Mean gas temperature *vs* crank angle – Characteristics

In this curve of Mean gas Temperature *vs* Crank angle, a random kind of curve is observed which is somewhat linear at initial at final readings, a major crest is observed at the highest readings. In this graph the mean gas temperature keeps increasing with increase of the crank angle, rise and fall is seen at some points on the graph, this clearly depicts that the highest value of mean gas temperature is observed between the range of 350 to 400 degrees of crank angle. The pure diesel has the highest reading in terms of mean gas temperature.

The maximum mean gas temperature observed for B20 is (101.82) at 588°, B15 is (139.29) at 583°, B10 is (194.51) at 576° and for pure diesel it is (60.06) at 583°.

Conclusion

In this study of various blends of Jatropha oil, various experimental data was observed and studied based on the exhaustive engine trials. All these trials were done under controlled conditions and different loadings of engine. A single cylinder diesel engine was used in this study and was fueled with blends of jatropha oil containing methanol and petroleum diesel and comparative and independent analysis was done. A no. of performance and combustion characteristics of engine were tested and the results were noted down and comparative analysis was done based on the data given by the engine mechanism when it ran on Jatropha blends as well as Diesel fuel. Some of the major challenges faced by the biodiesel industry include readily available and affordable feedstocks, competition from a popular and cheaper energy source, technological advancements and acceptability.

Biodiesel has successfully remained an energy source to be reckoned with even after being relegated to the back- ground for so many years. Concerns over diminishing oil reserves, increasing crude oil prices and associated environmental impacts aided the reemergence of biodiesel; making it the fastest growing industry worldwide. Several technologies were developed while more advances are in the process of being established. Other successes associated with the biodiesel industry include reduction in environmental impacts, job creation, energy security and waste-utilization. Biodiesel is regarded as a viable alternative or additive to Petro diesel because of its good properties such as nontoxicity, clean-burning, renewability and acceptability. Consequently, the prospects of the biodiesel industry are numerous.

In developed and some developing countries more and more R & D activities are being sponsored by the private sector and their governments are assisting them and taking part in these activities by way of tax incentives and award schemes. It is recommended that policies should be designed and incentives be offered by government to develop biodiesel companies and industries in the country. production of biodiesel to final use by consumer, quality should be given priority. Number of strategies should be given importance such as collection of seeds, extractions, processing, handling, storage and marketing. Therefore, positive inspection system for all these sectors including agriculture, private sector and farming system. the economic importance of national plants resources used for biodiesel production, research, development and cultivation efforts should be focused on these plants and identified other resources. to further extend the project of bio-diesel. There is need to establish pilot projects to commercialize bio-diesel and set up its supply chain. The project may be extended step wise like conversion of vehicle fleets of designated departments on biodiesel.

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