Investigation of Performance and Combustion Characteristics of Linseed Biodiesel in Diesel Engine

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DECLARATION

I hereby declare that the project work entitled **"INVESTIGATION OF PERFORMANCE AND COMBUSTION CHARACTERISTICS OF LINSEED BIODIESEL IN DIESEL ENGINE"** submitted to the DELHI TECHNOLOGICAL UNIVERSITY is a record of an original work done by me under the guidance of Dr. Raghvendra Gautam & Dr. Naushad Ahmad Ansari Assistant Professor, Department of Mechanical Engineering, Delhi Technological University and this project work is submitted in the partial fulfillment of the requirement for the award of the degree of master of technology in Thermal engineering. The results embodied in this thesis have not been submitted to any other university or institute for the award of any degree or diploma.

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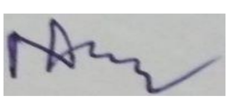
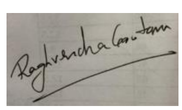
CERTIFICATE

I hereby certify that the Project Dissertation titled **"INVESTIGATION OF PERFORMANCE AND COMBUSTION CHARACTERISTICS OF LINSEED BIODIESEL IN DIESEL ENGINE"** which is submitted by ROHIT KUMAR, 2K19/THE/08, Department Of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of master of technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in the part or full for any degree or diploma to this university or elsewhere.





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ABSTRACT

In Current scenario Pollution become the most significant setback for whole world. It affects the human kind society. Many countries has been participated together to surmount this situation. Air pollution impacts soundly on Air quality index. When the fuel burn it emits the harmful emission. By raising the use of fossil fuel, Fossil fuel decreases rapidly. To keeping these factors in the mind biofuel has been selected as a renewable sustainable source of energy. By doing many experiments by experts on vegetable Oils. Various types of biofuel oil shows distinguish physiochemical Properties. Experimental investigation and analysis of performance and combustion characteristics of Linseed biofuel. Experimental investigation is performed on VCR diesel engine fuel by linseed biodiesel. By doing investigation Different performance and combustion characteristics performed. In performance analysis, Brake power is more for pure diesel D100 about (3.4kW) followed by B15, B20, and B10. Brake thermal efficiency is maximum for B20 at maximum power of (3.34kW). When compare between brake power and brake mean effective pressure, maximum power generation is for B10 and minimum for B20. Specific fuel consumption for 3kg load is maximum, and maximum generated specific fuel consumption is for B20 and minimum for D100. As shown in fuel flow B20 has the maximum fuel flow and minimum for B10. Conversion of neat diesel to linseed biodiesel is occur by the process of transesterification. The main objective of this investigation is to get better information regarding behavior of linseed biofuel and its blends.

Keywords – Linseed oil, Tranesterification process, fatty acid, alternate, conventional diesel, Brake Thermal Efficiency (BTE), Specific fuel consumption (SFCs).

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List of Abbreviation:

ABBREVIATION	FULL FORM
CI	Compression Ignition
SI	Self Ignition
NOx	Nitrogen Oxide
SOx	Sulphur Oxide
IP	Indicated power
BP	Brake power
FP	Frictional power
ITHE	Indicated Thermal Efficiency
BTHE	Brake Thermal Efficiency
IMEP	Indicated Mean Effective Pressure
BMEP	Brake Mean Effective Pressure
SFC	Specific Fuel Consumption
ME	Mechanical Efficiency
VE	Volumetric Efficiency

CHAPTER 1

1.1 Introduction

Energy consumption becomes the essential part of human life and industries all over the world. Energy Consumption per person has increasing day by day to an extreme level. So By the next century there is a drastic change in fossil fuels energy. That's why we need an Alternative Method to surmount this situation. Renewable Energy is plays a vital role to overcome up to limited extend because of its ecological benefits. Vegetable oils are used to decrease the pollution level. Many experiments are done on linseed oil by many researchers. Combustions, performance and emission characteristics in diesel engine investigated (2020) [1]. Mixing of biodiesel and alcohol in compression ignition system is used to optimize the engine exhaust emission and performance parameters (2020) [2]. Engine combustion analysis is done in (2021) [3].A largest part of energy used in petroleum and decreasing it day by day. Petroleum Fuel mainly used in automobiles. Combustion and emission parameters used biomass to liquid [BTL] is done in (2015) [4]. So Decrease change in reserved energy because of growing technological advancement and population. Diesel Engine has been widely used due to its higher thermal efficiency compare to spark ignition system especially for working under heavy duties. The Emissions coming Out from diesel engine is CO, NOx, soot. These emissions harm surrounding and human life deficiently. Current scenario of biofuel in india using its performance is investigated (2016) [5]. Moreover it causes pollution during production, transmission and usage of energy. For these reasons scientist had tried to surmount this situation to produce effective and economical methods to use vegetable oil as a renewable source of energy. It is possible to operate SI engine to simulate using gaseous fuel is done in(2020) [6]. Among all methods biodiesel is ecofriendly and economical methods to produce energy having efficiency similar to that of conventional diesel engine. Running engine with the help of biodiesel and its blends on heavy duty cycle diesel engine numerically and experimentally done (2014) [7].

Vegetable oil is Renewable Source and inexhaustible source of energy with efficiency similar to that of diesel. Using ethyl ester kusum oil and its blends performance and emission tested (2019) [8]. Compare of methanol and ethanol blending with gasoline in 1D engine (2015) [9]. Percentage effect of ethanol for performance using simulation tool is done (2015) [10]. The main problem associated with using direct vegetable oil its high viscosity in compression ignition which leads to fouling in injection and damages other parts. The main disadvantages associated using vegetable oil as a diesel is: a) low volatility b) high viscous in nature c) Unreacted hydrocarbon. Transesterification process is used to decrease the viscous nature of vegetable oil and to decrease its flash point.

Linseed is a tiny stem plant, and Flax is like a cultivation of *linum usitatissimum,* which mean in Latin is most useful. Linseed has been used for hundreds of years. Even though the main dissimilarity between them is Linseed, unlike Flax, puts all of its inherent energy into producing Linseed (seeds). Heat transfer using boiling to see effect on performance using medium speed diesel engine and rapeseed methyl ester done (2020) [11]. Biodiesel influence its combustion and performance can investigate (2011) [12]. Huang et al investigate production of biodiesel by micro algal biotechnology (2010) [13]. Production of biodiesel (1999) [14].

Linseed is used to produce oil but the seed is used to produce food products and is classed as super food due to its rich content of essential fats Omega 3, 6.But all the Vitamins and Minerals and the fact of High Fiber, Low Carbohydrate, Gluten Free, Low GI (glycemic index) and has the highest content of lignan than any other seed.

In India, the largest producer of linseed oil is Madhya Pradesh about (1.25 lakh HA) and Chhattisgarh came after Madhya Pradesh about (0.35 lakh HA) and lowest producer of linseed oil in India is Karnataka about (0.05 lakh HA). India ranked fourth for production of linseed oil about (8.45%) of the total world production and Canada is the largest producer of linseed oil about (42.65%). Performance characteristics, emission characteristics and injection characteristics are done in (2013) [15]. Comparison of fuel properties, emission and performance characteristics are done in (2014) [16].

The main purpose of transesterification process is to lower the viscosity of pure oil because if we use pure oil as a source of energy in diesel engine. There is very large compression ignition engine in pure oil and take extra power to compressing high viscosity fuel. That's why we use oil of low viscosity to lower the compressing power.

By compressing high viscosity fuel resulting fouling on injectors and many other problems associated with it. The main disadvantages associated with is high viscosity, high flash point, un reacted hydrocarbon chain.

Biodiesel production from different origin is investigated in (2013) [17]. One researched on use of ethyl and methyl ester for small capacity diesel engine (2016) [18]. Using three phase emulsions as a fuel to find combustion and performance characteristics are done in (2004) [19]. Using various source of biodiesel to find engine performance and emission in diesel engine done in (2013) [20]. One investigated carbonyl compounds characteristics using ethanol-diesel form diesel engine (2006) [21]. Injection characteristics using numerical analysis is done in (2006) [22].

Fig.1 linseed plant with seeds.

Linseed oil can be a good substitute of pure diesel because it provides high brake power and low emissions. It can be searched that blends shows different behavior at different loading condition. These blends can be used to check the performance of the engine and combustion of the fuel. Emission also checked by using blends at different loading condition.

By checking different properties, we can relate the properties with conventional diesel like Brake power, brake thermal efficiency, specific fuel consumption etc.

The main constituents of linseed seed is 35-45% oil. The oil is obtained the process of cold pressing. Cold pressing is a method of mechanical extraction with reduces heat, which is produced from rotational friction. It has yellowish in color. But In case of hot-pressed oil at 210C is yellowish brown. Fresh linseed oil has viscous in nature and bland in taste

CHAPTER 2

Literature Review:

Biodiesel Extraction from vegetable oil has become more important than use of conventional diesel. NOx emission is more in diesel when compare with biodiesel. Vegetable oil is main important as fossil fuels degrade day by day. The process by which vegetable oil is converted into biodiesel is Tranesterification process. Many researches are done on optimization of performance, combustion and emission characteristics of different vegetable oil which is further converted in biodiesel. We should reduce emission coming out from exhaust of compressed ignition diesel engine like NOx and SOx emission. Using different condition at different loading condition we should differentiate characteristics of perforamca, combustion and emission.

Vegetable oil is used because of its lower emissions NOx emission can be reduced using biodiesel is analyzed in 2020) [23]. Biodiesel is also made by vegetable oil ester such that one investigate blend of methyl and ethyl ester of jatropha in diesel CI engine which has highly efficient (2013) [24]. One experiment is also done on NOx emission by using reducing antioxidant additive on emission of multi cylinder CI engine using jatropha oil investigated in (2014) [25]. NOx emission become dangerous emission coming out from diesel like NOx in biodiesel fueled CI engine is done by (2006) [26]. Using soap nut biodiesel blend to optimize performance and emission in CI engine using different loading condition is done in (2019) [27].

Day by day increase of vegetable oil how to develop methyl ester and ethyl ester is plays an important role in biodiesel scenario. Ethyl ester development from jatropha using response surface methodology done in (2020) [28]. By increasing sources of vegetable oil investigate ethyl ester kusum oil and butanol blends to find performance abd combustion (2019) [29]. Many researcher researched on performance characteristics, emission characteristics one research is done on fludized bed combustion technology in india is done in (2017) [30]. Since we know pyrolysis reactor is used in biomass thermal cracking of karanja oil seed cake on pyrolysis reactor for producing bio-oil in diesel engine (2020) [31]. Many research is done on optimization one research is done on performance and exhaust emission using biodiesel- alcohol using taguchi method done in (2020) [32]. One investigate transesterification of citrus peel waste into biodiesel using supercritical technology (2014) [33].

After Tranesterification process yield of oil occurs this comes in the form of ester. Ethyl ester of jatropha oil and diesel blends in diesel engine in small capacities done in (2013) [34]. Many researches is done on injection timing and pressure to find suitable time to inject the fuel to get proper combustion. Using EGR technique effect of variation of injection pressure to see performance and emission characteristics in diesel engine done in (2021) [35]. Using biofueled diesel engine to find performance, combustion and emission by (2022) [36]. Using experimental and numerical analyze spay characteristics of biodiesel using pressure swirl atomizer [37]. By changing input parameter we change brake thermal efficiency and brake power, one research is done Optimize input parameters on common rail direct injection diesel engine using response surface methodology done in (2021) [38]. Decreasing fossil fuel we have to find alternative method Study the future of electric vehicle in current Indian scenario done by (2019) [39]. (1999) investigate drying and oxidative degradation of linseed oil [40]. Linseed oil is edibleand its characteristics in (2006) [41]. Using different vegetable oil by changing its parameter we differentiate its performance and combustion analyze the optimization of performance and exhaust emission using soapnut oil and its blends in CI engine (2019) [42].

Stability of vegetable oil biodiesel in diesel oil is more in compression ignition engine as compare neat diesel , Study of oxidative stability of linseed oil in (2001) [43]. Conversion of vegetable oil to biodiesel is done by Tranesterification process, Linseed oil alkali transesterification of linseed oil production in (2013) [44]. Performance and combustion analysis of jatropha ethyl ester and its alcohol by (2018) [45]. Using linseed oil and rubber oil to see combustion and performance characteristics with ternary blends done in (2021) [46]. Using tallow oil to find combustion and performance characteristics by (2020) [47]. Using different solvent we find the efficiency and power characteristics of different fuel, one research is on optimization of biodiesel production form linseed using co-solved done by (2018) [48]. Another research is done on optimization of linseed biodiesel and blends using CI engine done by (2012) [49]. Using alternative fuel to improve performance is done by (2021) [50].

OBJECTIVE OF RESEARCH:

The present investigation aims to improve engine performance, combustion and also reduce harmful emissions for n blended biodiesel engine. Following objectives has been identified for proposed research:-

- Identify and select linseed oil for new developed biodiesel blending.
- Select and proceed Tranesterification process to prepare biodiesel of selected feed stock.
- To conduct the chemical analysis to check the biodiesel physiochemical properties.
- To perform experimental analysis of brake thermal efficiency and brake specific fuel consumption on biofueled diesel engine (Variable compression diesel engine) at different parameter of engine.
- To perform experimental analysis of combustion characteristics on biofueled diesel engine (Variable compression diesel engine) at different parameter of engine.
- To perform comparative study of engine performance and combustion characteristics of biodiesel and neat diesel oil on Variable compression ratio diesel engine

RESEARCH GAP:

- On the through scrutiny of the published work on the biofuel blending used for engine performance and emission characteristics, the following observations have been made:

- Biofuel are available in wide variety due to which different biofuel has different physio-chemical properties. Physio-chemical properties of biofuel have soundly impact on engine performance and emission characteristics. Researchers are looking to search suitable physiochemical feedstock to meet optimal engine performance and emission characteristics.
- From the literature review it was investigated that biodiesel has higher viscosity comparatively due to which various problems may be occurred such as poor atomization, improper dispersion of air fuel mixture, longer ignition delay, higher fuel consumption and detonation in CI engine. It is need to search an appropriates production process to reduce viscosity of biofuel.
- It was observed that biofuel blending with diesel reduces the harmful emissions accept nitrogen oxide formation (NOx). Researchers are doing extended efforts to reduce the oxide of nitrogen through various technologies.

- It has been observed that the limited work has been done for suitable blended biofuel to achieve desired optimal engine performance and emission characteristics.
- It is investigated that that there is a limited study about oxidation stability of biofuels. Oxidation of biodiesel causes sediments to form in the fuel. These sediments can in turn clog fuel filters

.Biodiesel made from unsaturated fats (i.e., vegetable oils) tends to oxidize and thus degrade more rapidly than fuel made from saturated fats, such as animal fats. Storage conditions are important. For example, biodiesel should not be stored or transported in copper, brass, bronze, lead, tin, or zinc because these metals will hasten degradation.

- There is a lack of research evidence towards the improvement in free fatty composition of biofuel with suitable catalyst and nanoparticles additives. Biofuel free fatty acids composition directly related to biofuel properties.

- There is no more information available for injection pressure effect on penetration of fluid spray, dispersion of fuel, mass transfer, evaporation and heat transfer rate of molecule of fuel and air for various biofuel blend.

CHAPTER 3

3.1 Tranesterification Process

It is defined as the process of converting linseed biodiesel from vegetable oils. It is process of Separating out glycerol from its biodiesel.

The process used to produce biodiesel was discovered by G Chavanne in 1937 of university of Brussels in Belgium.

It is a reversible reaction carried out by the mixing the reactants like fatty acid, catalyst and alcohol. Catalyst is used to increase the rate of reaction. It is a process of exchange reaction from one ester transformed into another ester by interchanging of alkoxy moiety. Using methanol and ethanol in production of linseed oil in non- catalytic SFC condition is done (2009) [51].

The products which are coming out from transesterification process are raw biodiesel and raw glycerol. Using rice bran oil to produce biodiesel by Tranesterification process is covered by (2008) [52].

Firstly, we have to Heat the vegetable oil at 100C. Then we have to cool up to 60C and maintain vegetable oil at this temperature. Then we have to add Alcohol like Methanol 10% of vegetable oil and 1% of potassium hydroxide at 60C. Then we have to rotate this mixture regularly by a stirrer properly about 40 to 45 min at 300RPM. We have to check temperature of mixture regularly not to drop this temperature less than 60C. After 40 to 45 minutes, we have to stop stir machine then we have to wait until the glycerol separate out from its biodiesel and sit on the bottom due to its high density and biodiesel floats due to its lower density.

It is used to lower the viscosity of fuel and low volatility. Tranesterification process to manufacture of rape oil ethyl ester (1993) [53]. Using Neem oil in air cooled diesel engine to check performance done in (2012) [54]. Tranesterification of rape oil done in (1991) [55].

By using biodiesel, we have to make blends like B20 (20%biodiesel and 80%diesel), B10 (10%biodiesel and 90%diesel), B15 (15%biodiesel and 85%diesel).

These blends are used to check the performance, combustion, emission of diesel engine at different loading condition.

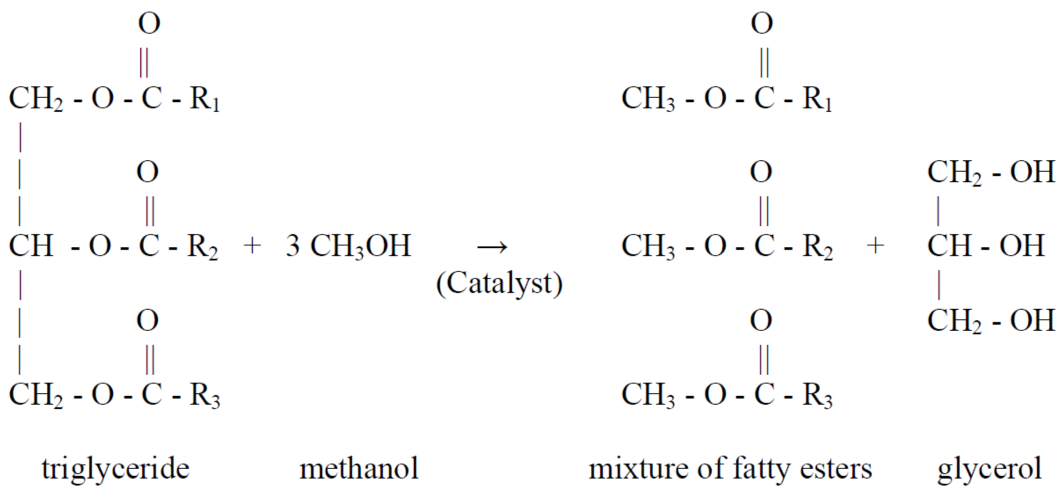

Fig.2 Transesterification Process reaction.

Fig. 3 Linseed Biodiesel prepared in lab.

3.2 Experimental Setup

A single Cylinder four stroke diesel engine is utilized in experiment. Engine Specification as shown in TABLE 1. The testing Engine is coupled with dynamometer which is used to increasing load in engine at 3.5KW at 1500RPM.

Fig.4 VCR Diesel Engine.

The Engine is run at constant speed of 1500RPM. We have Perform different blend like B10, B15, B20, and D100 at different load condition like 3.05kg, 6.01kg, 8.84kg, 11.84kg, and 14.68kg. And the fuel is kept at room temperature.

The engine is rotated at different loading condition. Different Blends shows different behavior of performance characteristics and combustion characteristics.

These are some specification of engine shows in table1.Stoke length is 110mm, connecting rod length is 87.5mm.Rated power is 3.5kW, Speed is 1500RPM, and Compression ratio is 18:1.

TABLE 3

SYSTEM CONSTANTS

Engine:	
No. of Cylinders	1
No. of Strokes	4
Cylinder Diameter	87.5mm
Stroke Length	110mm
Connecting Rod Length	**20mm**
Orifice Diameter	**185mm**
Dynamometer arm Length	
Fuel:	**Diesel**
Power	3.5KW
Speed	1500RPM
CR range	12:1 TO 18.:1

Combustion Parameters:

Specific Gas Const (kJ/kgK): 1.00, Air Density (kg/m^3) : 1.17, Adiabatic Index : 1.41, Polytrophic Index : 1.33, Number Of Cycles : 10, Cylinder Pressure Reference : 3, Smoothing 2, TDC Reference : 0

Performance Parameters:

Orifice Diameter (mm): 20 Orifice Coeff. Of Discharge: 0.60, Dynamometer Arm Length (mm): 185, Fuel Pipe dia (mm): 14.50, Ambient Temp. (Deg C): 27, Pulses Per revolution: 360, Fuel Type: Diesel, Fuel Density (Kg/m^3): 830, Calorific Value Of Fuel (kJ/kg): 42000.

STABINGER VISCOMETER:

This viscometer is used to find the fuel properties like kinematic viscosity and dynamic viscosity of the flowing fluid inside the tube. This is SVM3000 Stabinger viscometer. It works in the principle with peilter thermostat enables wide viscosity. It also finds density of flowing fluid with a single system.

DYNAMIC VISCOSITY: It is defined as the resistance of one layer of flowing fluid to another layer.

KINEMAIC VISCOSITY: It is defined as the ratio of dynamic viscosity to the density.

Fig.5 Stainbinger Viscometer

CHAPTER 4

4.1 Fuel Properties

OIL PROPERTIES	PURE DIESEL (100%)	20%LINSEED BIODIESE(B20)	15%LINSEED BIODIESEL(B15)	10%LINSEED BIODIESEL(B10)
Dynamic Viscosity (mPa s.)	4.6585	2.2272	2.0044	1.8988
Kinematic viscosity(mm^2/s)	5.2507	2.7142	2.4565	2.3398
Density(g/cm^3)	0.8862	0.8206	0.8159	0.8115
Heating Value (kJ/Kg)	44500	42000	41500	40900
Cetane Number	>53	42	44	48
Flash Point (deg.C)	45	65	60	55
Pour Point (deg.C)	<-6	<-6	<-6	<-6

Table 4 Fuel properties of different blends

- As shown in table dynamic viscosity is more for D100 pure diesel compare to linseed biodiesel blends.
- Kinematic viscosity is more for pure diesel D100 because kinematic viscosity is directly proportional to dynamic viscosity.
- Density is more for pure diesel compare to linseed biodiesel blends.
- Heat releases is more for pure diesel compare to its blends.
- Power generation and brake thermal efficiency is more for pure diesel compare to its blends.
- Emission is also more for pure diesel (NOx formation) which is harmful for environment.

Fuel properties take place important role on performance, combustion and emission of engine. Heat release is more in pure diesel because of its more density. Due to more density power generation is more in pure diesel due to its more density. Due to its more power generation brake thermal efficiency is more for pure diesel.

Emission releases from diesel is more for pure diesel because it creates (NOx) formation which is very harmful for our environment.

Fuel property takes place an important role in engine testing.

4.2 Blends of Biodiesel

By using transesterification process we make biodiesel. But we didn't use biodiesel completely in diesel engine. We use blends, Blends is the amount in percentage mixed with pure diesel to run the engine. This is used to decrease the harmful gases which are developed in diesel engine.

- B20: It means that we use 20% of biodiesel and 80% of diesel.
- B15: It means that we use 15% of biodiesel and 85% of diesel.
- B10: It means that we use 10% of biodiesel and 90% of diesel.
- D100: It means that we use 100% pure diesel.

These blends used in VCR Engine with variable loading condition. The load is varied using dynamometer. These blends used to check the fuel property, performance, combustion characteristics and emission testing. Tranesterification process of diesel is done in (1998) [56]. Biodiesel production using development of ultrasound assisted catalytic transesterification process (2019) [57]. Different blends show different behavior in performance, combustion and emission characteristics. We used to compare different blends with each other and compare with conventional diesel.

Indian standards have specified the standards and the limits of blending for vehicles using biodiesel. The government allowed the sale of biodiesel (B100) for blending with directly to all consumers for the better usage of the biodiesel in the main field.
Compare emission and performance of jatropha alkyl ester, butanol diesel blends in CI engine investigated by (2015) [58]. Biod.iesel production from microalgae via non catalytic Tranesterification process done by (2019) [59]. Optimization of base catalyst of Tranesterification of karanja oil for biodiesel production done in (2009) [60].

WHY INDIA IS STRUGGLING SO MUCH TO GET BIOFUEL PLAN:-
Most important thing in 21th century is energy and overcome the challenges of availing such energy without compromising the government progress toward climate change- India has launched NBP (National Biofuel policy).
Biofuel is product of blending fossil fuel with certain percentage of ethanol. This ethanol is generated by waste, oilseeds etc. We used to mix them properly. NBP targeted ethanol fraction of approx. 20% in both diesel and petrol by 2016.
However, India has reached only 2% blend with petrol and 0.1% with diesel. So target is revised and new targets are 20% ethanol in petrol and 5% ethanol in diesel by 2030.

4.3 Procedure on Engine Testing:

We take blends and put one by one in the Variable Compression Ratio (VCR) engine. And engine is turned on. While engine is turned on, load is varying by the help of dynamometer.

There is checkup the performance and characteristics curve while load is varying.

- We prepare blend B20, we have to check the performance and characteristics curve of blend B20, then we have to check the blend at no load condition, 3kg, 6kg, 9kg, 12kg by the help of dynamometer.
- Let us take a blend B15, we have check the performance and characteristics curve of bend B15, then we have to check the blend at no load condition ,3kg, 6kg, 9kg, 12kg by the help of dynamometer.
- Let us take a blend B10, we have to check the performance and characteristics curve of blend B10, then we have to check the blend at no load condition, 3kg, 6kg, 9kg, 12kg by the help of dynamometer.
- Let us take a blend D100, we have check the performance and characteristics curve of bend D100, then we have to check the blend at no load condition ,3kg, 6kg, 9kg, 12kg by the help of dynamometer.
- By doing this experiment, we have to check out the entire combustion graph at each degree of crank rotation, and we have got data on performance characteristics of each blend.
- By checking all the combustion graph and performance graph we used to compare all the blends with each other. This is used to check the difference between blends and behavior of blends at different loading condition.
- Then, we draw comparison graph of all blends used to compare the performance and combustion characteristics of blends.
- By checking all the necessary information, we can conclude the result.

CHAPTER 5

Result & Discussion:

This has been used to compare all the necessary information regarding different blends and compare with all the other different blends. This is used to compare performance and combustion characteristics. All the necessary information has been used in this comparison. Biodiesel production using heterogeneous catalyst to optimize form jatropha oil investigated in (2011) [61]. This comparison is used to check the blends emission compare to conventional diesel.

5.1 Combustion Characteristics:

Combustion characteristics are used to know all the necessary information in each cycle at each degree of crank rotation up to 720 Degree. These are some combustion parameters used to know the combustion performance of engine, like,

- Specific gas constant is used to measure heat per unit mass.
- Air density used to know density of air.
- Adiabatic index knows for process with no heat and work.
- Polytrophic process is used to check the process followed by the heat transfer and work transfer.

SGC Specific gas const.(kJ/kgK)	1.00
AD Air density(kg/m^3)	1.17
Adiabatically Index	1.41
Polytropically Index	1.33
NOC Number Of Cycles	10

Table 5

- The main advantage of combustion analysis is used to compare the (crank angle vs. pressure) and check the pressure distribution over each degree of crank angle.
- It is also used to compare the (pressure variation over the volume).
- It is also used to compare (cumulative heat released and net heat release vs. crank angle).

5.1.1 Combustion Performance of B20: -

5.1.1(A) Pressure Vs Crank Angle:

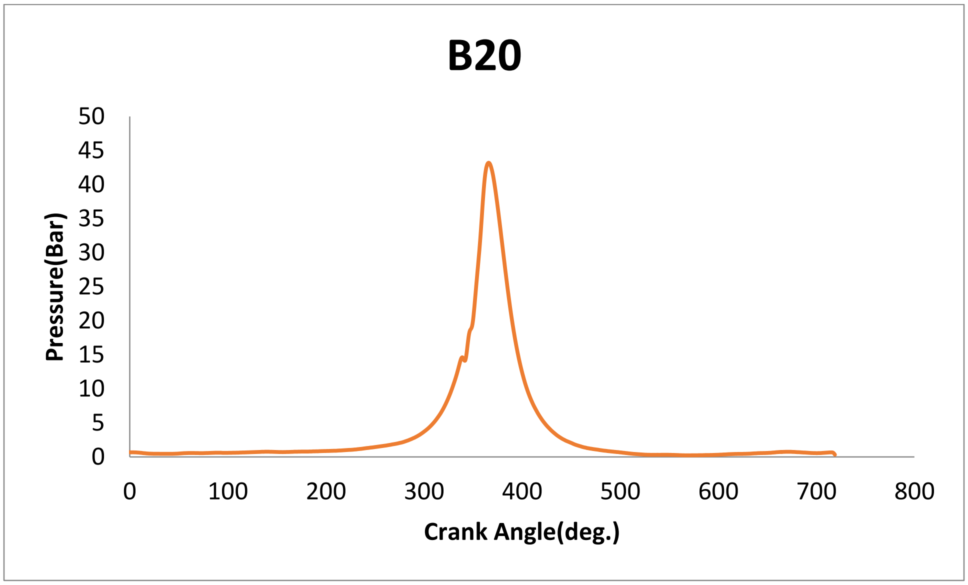

Fig.5 shows Pressure Vs Crank Angle in B20

- Different fuel shows different behavior of pressure at different crank angle.
- Maximum pressure rise is (43.21bar) at 366 deg.
- There is a slight constant graph near 347 to 350 degree at a pressure approx (18bar).
- After 367 degree pressure fall rapidly up to 460 degree.
- As shown in fig. combustion occurs after top dead centre nearly 360 degree then pressure rise rapidly and piston moves downward.
- By moving downward pressure reduces at a certain limit then pressure is remain nearly constant after 540 degree.
- After then removal of exhaust gases occurs when piston moves bottom dead centre (BDC) to top dead centre (TDC).
- There is slight increasing point after compression when pressure rise rapidly. It is the combustion point where combustion flame front start travelling in the fuel and fuel get excited.
- There is a phenomenon called detonation. It occurs when flame front excited early due to compression.

5.1.1(B) Pressure Vs Volume:-

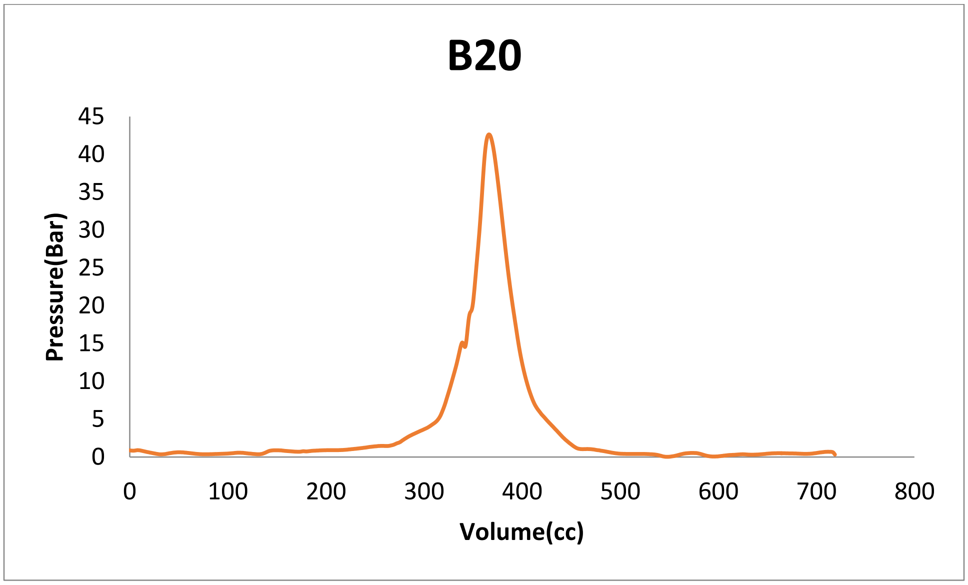

Fig.6 shows Pressure Vs Volume in B20.

- Different fuel shows different behavior of pressure at different crank angle.
- Maximum pressure rise is (43.21bar) at 367cc.
- There is a slight constant graph near 347 to 350 cc at a pressure approx (18bar).
- After 367 cc pressure fall rapidly up to 460 cc.
- As shown in fig. combustion occurs after top dead centre nearly 360 cc then pressure rise rapidly and piston moves downward.
- By moving downward pressure reduces at a certain limit then pressure is remain nearly constant after 540 cc.
- After then removal of exhaust gases occurs when piston moves bottom dead centre (BDC) to top dead centre (TDC).
- There is slight increasing point after compression when pressure rise rapidly. It is the combustion point where combustion flame front start travelling in the fuel and fuel get excited.

There is a phenomenon called detonation. It occurs when flame front excited early due to compression.

5.1.1(C) Cumulative Heat Release Vs Cranks Angle:

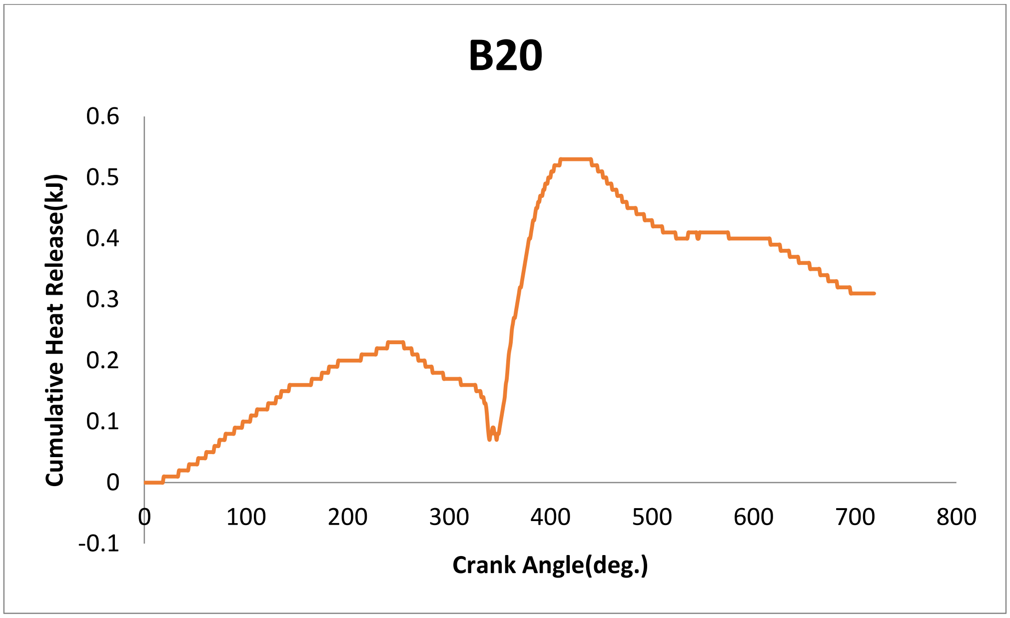

Fig.7 shows Cumulative heat release Vs Crank Angle in B20.

- Cumulative heat starts after 18degree of crank angle and increasing linearly up to 276degree when piston moves bottom dead centre to top dead centre during compression.
- After 276degree heat release decreases rapidly up to 378 degree (0.4kJ) and again start rising up to (0.5kJ) 455 degree then it remains constant up to 460 degree.
- After 460 degree again heat decreases rapidly up to 535 degree and remains constant up to 540 degree.
- After 540 degree again cumulative heat decreases but it in constant partition up to (0.3kJ).
- Cumulative heat release is important to find the efficiency of engine using different fuel. It means that cumulative means that together heat release.
- Maximum cumulative heat release is (0.53kJ) 410 degrees to 440 degree at a constant heat release rate.
- Minimum cumulative heat release is (0.8kJ) at 345 degree at constant heat release rate.
- This variation shows that heat release Vs crank angle at different particular cringle angle different heat release is present.

5.1.1(D) Net Heat Release Vs Crank Angle:

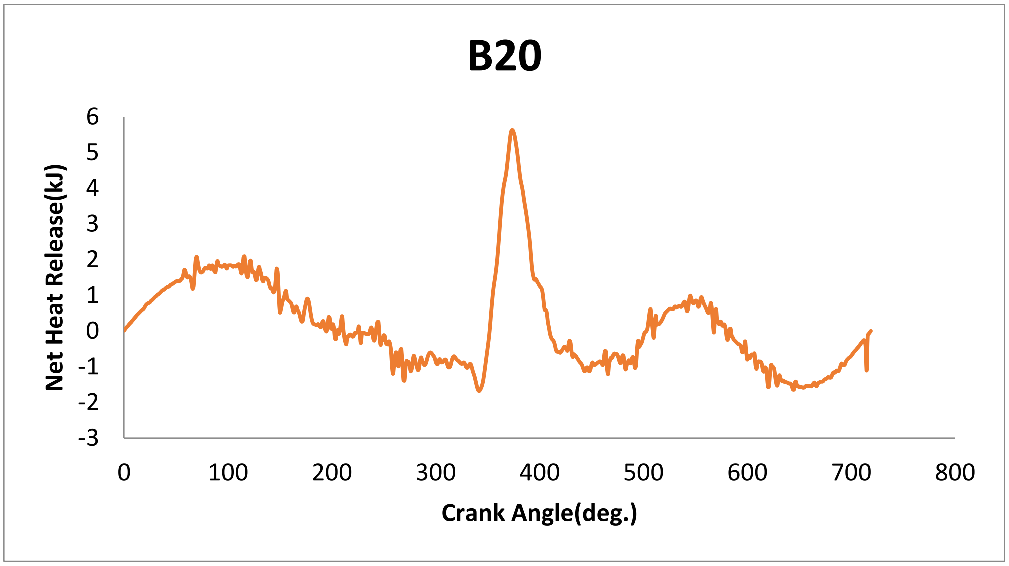

Fig.8 shows Net heat release Vs Crank Angle in B20.

- Different blends shows different variation of net heat release according to crank angle, we have to see B20 in this figure.
- After 120 degree net heat release decreases slowly but after 350 degree net heat release increases rapidly up to nearly (5.63kJ) at 367 degree.
- After 368 degree again net heat release decreases rapidly up to 500 degree then again net heat release increases at a certain amount up to 560 degree.
- Then again net heat release decreases up to 640 degree then again net heat release increases.
- Maximum heat releases is (5.63kJ) at 367 degree and minimum heat release is (-1.26kJ) at 640 degree.
- Net Heat release is defined as the heat release at top of the piston after heat dissipation from the surrounding of piston.
- This graph completes 720 degree in crank angle and four strokes like suction occurs for (0 to 180 degree), compression occurs from (180 to 360 degree) , expansion occurs (360 to 540 degree) then lastly exhaust occurs (540 to 720 degree).

5.1.1(E) Mass Fraction Burned Vs Crank Angle:

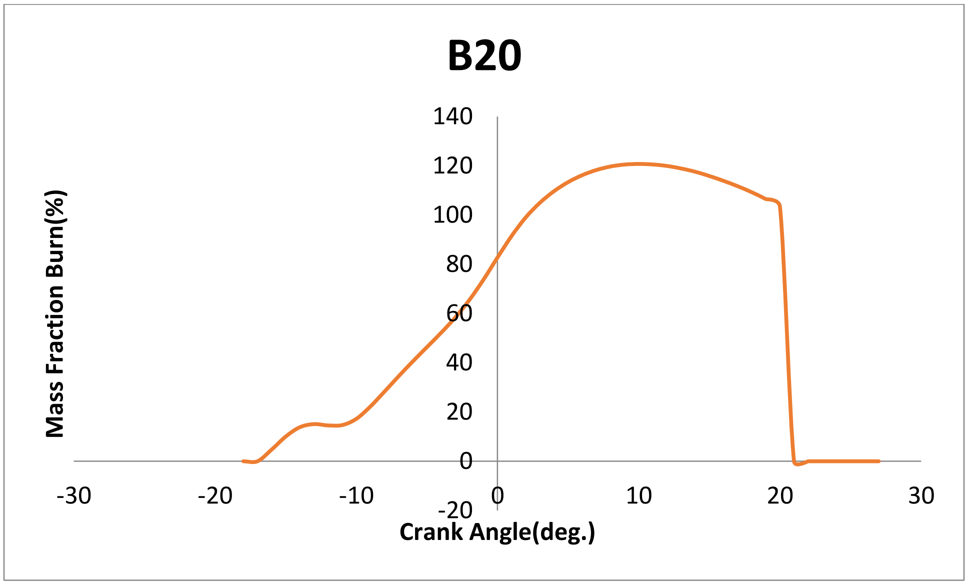

Fig.9 shows Mass Fraction Burned Vs Crank Angle in B20.

- Different blend shows different behavior of mass fraction burned with respect to crank angle. In this fig. we have to study B20.
- Mass fraction burned is defined as the ratio of mass burned to the total mass of fuel coming in the combustion chamber.
- As shown in fig. at a crank angle -16 degree mass fraction has a value of (4.47%).
- Maximum mass fraction burned is (119.73%) at an crank angle of (8degree).
- After 20 degree the mass fraction burned percentage decreases at an slope of (90 degree) at a very fast rate.
- At a crank angle 0 degree mass fraction burned has (82.77%) and slightly increases after that.
- This graph completes 720 degree in crank angle and four strokes like suction occurs for (0 to 180 degree), compression occurs from (180 to 360 degree) , expansion occurs (360 to 540 degree) then lastly exhaust occurs (540 to 720 degree).
- This fig. actually used to find the mass burned to the total mass of fuel entered in the combustion chamber.

5.1.2 Combustion Characteristics of B15:

5.1.2 (A) Pressure Vs Crank Angle:

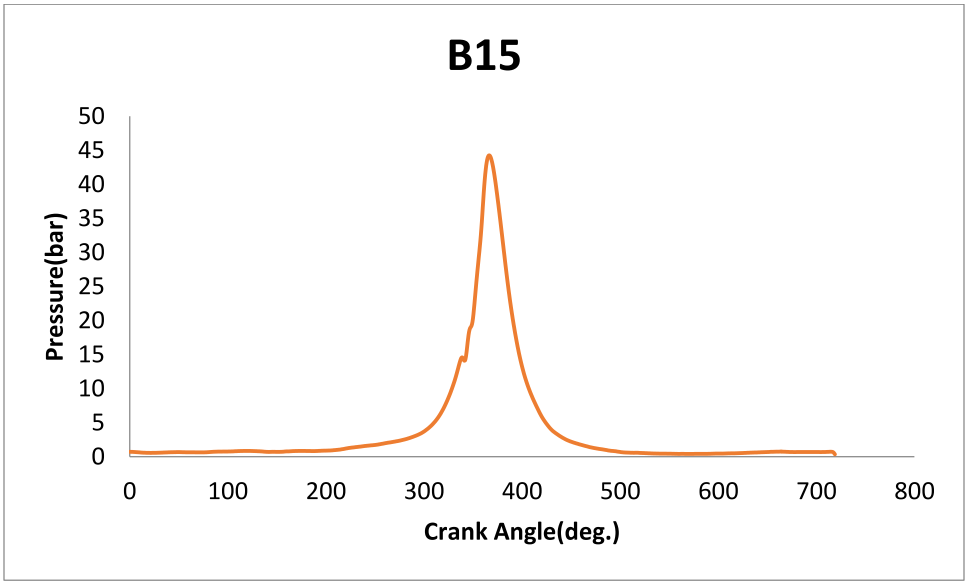

Fig.10 shows Pressure Vs Crank Angle in B15

- Different fuel shows different behavior of pressure at different crank angle.
- Maximum pressure rise is (44.24bar) at 367 deg.
- There is a slight constant graph near 346 to 351 degree at a pressure approx (19bar).
- After 368 degree pressure fall rapidly up to 458 degree.
- As shown in fig. combustion occurs after top dead centre nearly 360 degree then pressure rise rapidly and piston moves downward.
- By moving downward pressure reduces at a certain limit then pressure is remain nearly constant after 540 degree.
- After then removal of exhaust gases occurs when piston moves bottom dead centre (BDC) to top dead centre (TDC).
- There is slight increasing point after compression when pressure rise rapidly. It is the combustion point where combustion flame front start travelling in the fuel and fuel get excited.

There is a phenomenon called detonation. It occurs when flame front excited early due to compression.

5.1.2 (B) Pressure Vs Volume:-

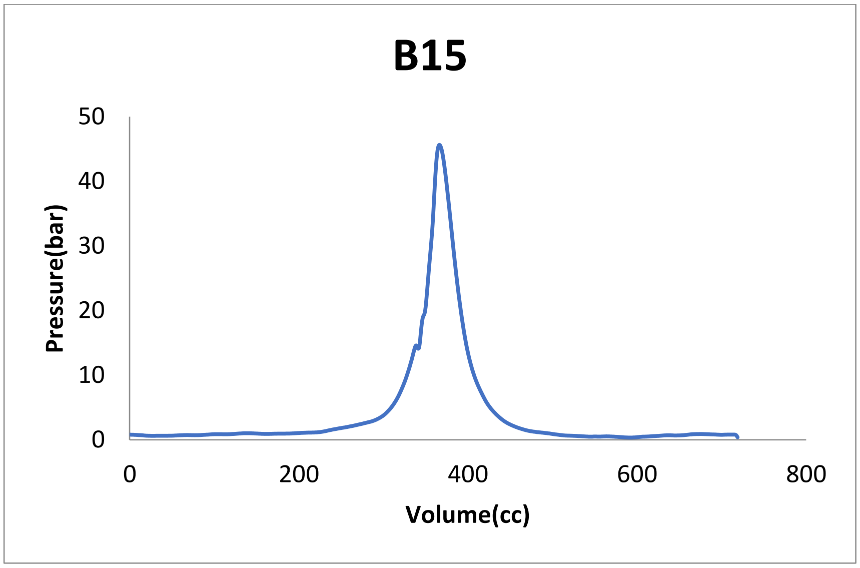

Fig.11 shows Pressure Vs Volume in B15.

- Different fuel shows different behavior of pressure at different crank angle.
- Maximum pressure rise is (44.24bar) at 367cc.
- There is a slight constant graph near 346 to 351 cc at a pressure approx (19bar).
- After 368 cc pressure fall rapidly up to 458 cc.
- As shown in fig. combustion occurs after top dead centre nearly 360 cc then pressure rise rapidly and piston moves downward.
- By moving downward pressure reduces at a certain limit then pressure is remain nearly constant after 540 cc.
- After then removal of exhaust gases occurs when piston moves bottom dead centre (BDC) to top dead centre (TDC).
- There is slight increasing point after compression when pressure rise rapidly. It is the combustion point where combustion flame front start travelling in the fuel and fuel get excited.

There is a phenomenon called detonation. It occurs when flame front excited early due to compression.

5.1.2 (C) Cumulative Heat Release Vs Crank Angle:

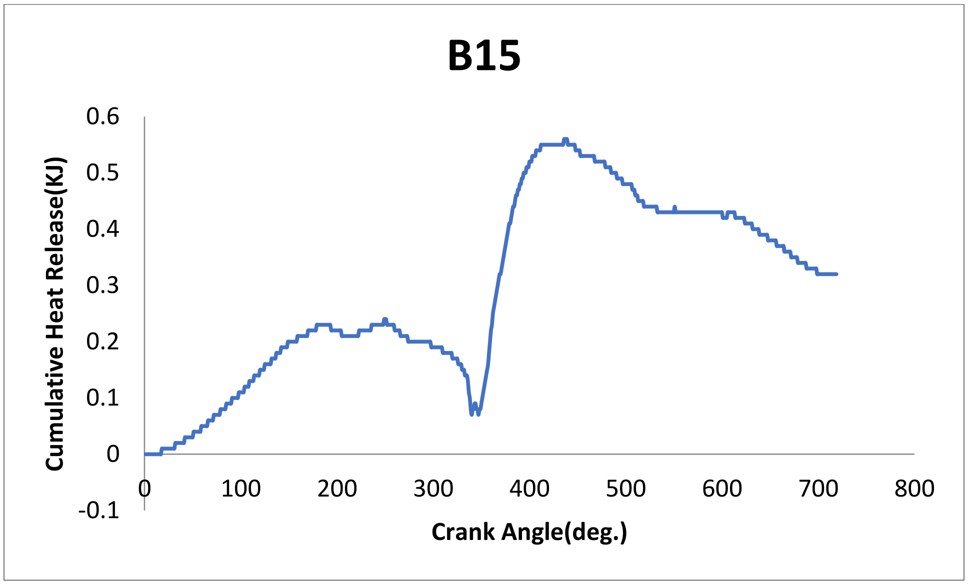

Fig.12 shows Cumulative heat release Vs Crank Angle in B15.

- Cumulative heat starts after 18degree of crank angle and increasing linearly up to 262degree when piston moves bottom dead centre to top dead centre during compression.
- After 263degree heat release decreases rapidly up to 351 degree (0.1kJ) and again start rising up to (0.53kJ) 454 degree then it remains constant up to 463 degree.
- After 467 degree again heat decreases rapidly up to 535 degree and remains constant up to 540 degree.
- After 540 degree again cumulative heat decreases but it in constant partition up to (0.32kJ).
- Cumulative heat release is important to find the efficiency of engine using different fuel. It means that cumulative means that together heat release.
- Maximum cumulative heat release is (0.54kJ) 410 degrees to 440 degree at a constant heat release rate.
- Minimum cumulative heat release is (0.1kJ) at 350 degree at constant heat release rate.
- This variation shows that heat release Vs crank angle at different particular cringle angle different heat release is present.

5.1.2 (D) Net Heat Release Vs Crank Angle:

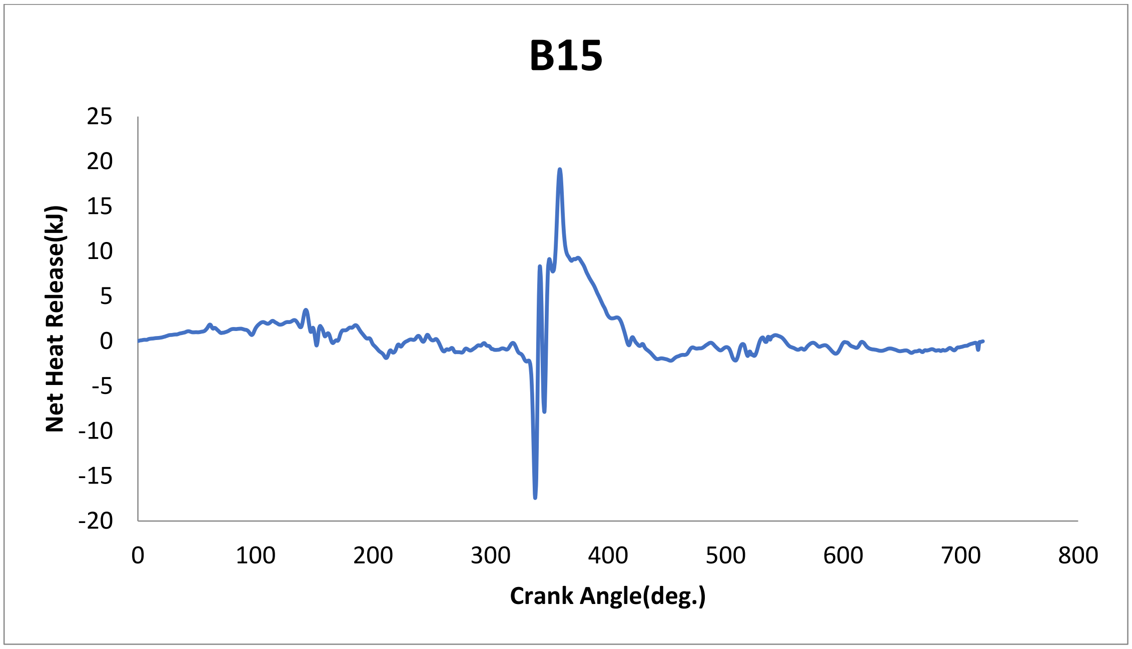

Fig.13 shows Net heat release Vs Crank Angle in B15.

- Different blends shows different variation of net heat release according to crank angle, we have to see B15 in this figure.
- Fig is increasing and decreasing up to 330 degree but after that net heat release decreases rapidly p to (-17.43kJ) at a crank angle of 338 degree.
- After 338 degree again net heat release rate increases up to (19.15kJ) at a crank angle of 359 degree.
- Then again net heat release decreases up to 362 degree then again net heat release increases.
- Maximum heat releases is (19.17kJ) at 361 degree and minimum heat release is (-17.52kJ) at 640 degree.
- Net Heat release is defined as the heat release at top of the piston after heat dissipation from the surrounding of piston.
- This graph completes 720 degree in crank angle and four strokes like suction occurs for (0 to 180 degree), compression occurs from (180 to 360 degree) , expansion occurs (360 to 540 degree) then lastly exhaust occurs (540 to 720 degree).

5.1.2 (E) Mass Fraction Burned Vs Crank Angle:

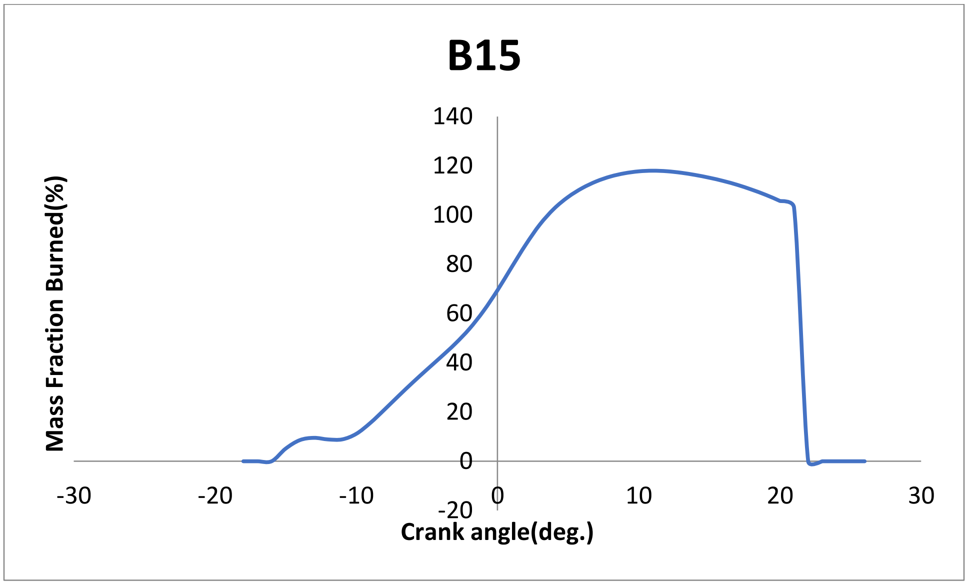

Fig.14 shows Mass Fraction Burned Vs Crank Angle in B15.

- Different blend shows different behavior of mass fraction burned with respect to crank angle. In this fig. we have to study B15.
- Mass fraction burned is defined as the ratio of mass burned to the total mass of fuel coming in the combustion chamber.
- As shown in fig. at a crank angle -15 degree mass fraction has a value of (5.15%).
- Maximum mass fraction burned is (118.02%) at a crank angle of (11degree).
- After 20 degree the mass fraction burned percentage decreases at a slope of (90 degree) at a very fast rate.
- At a crank angle 0 degree mass fraction burned has (69.47%) and slightly increases after that.
- This graph completes 720 degree in crank angle and four strokes like suction occurs for (0 to 180 degree), compression occurs from (180 to 360 degree) , expansion occurs (360 to 540 degree) then lastly exhaust occurs (540 to 720 degree).

This fig. actually used to find the mass burned to the total mass of fuel entered in the combustion chamber.

5.1.3 Combustion Characteristics of B10:

5.1.3 (A) Pressure Vs Crank Angle:

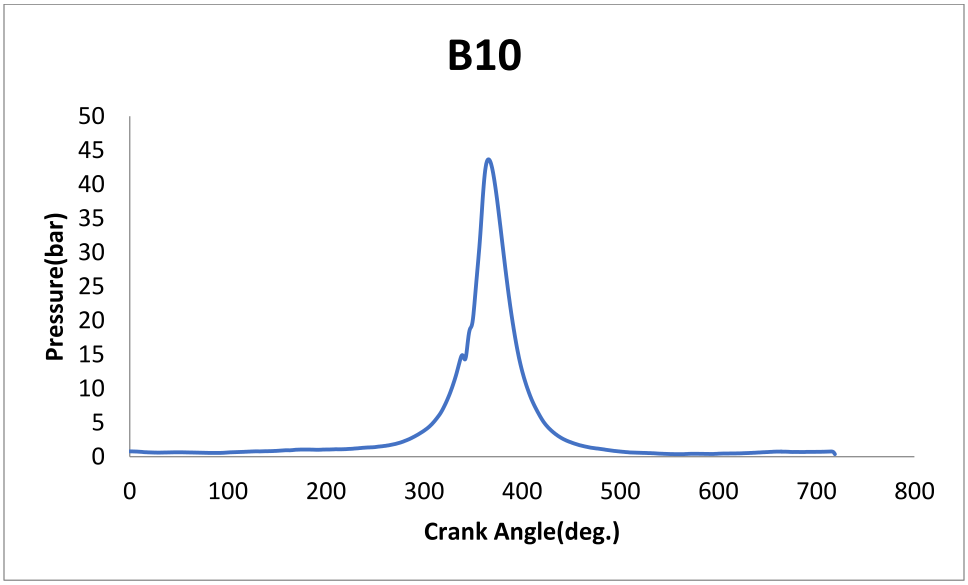

Fig.15 shows Pressure Vs Crank Angle in B10

- Different fuel shows different behavior of pressure at different crank angle.
- Maximum pressure rise is (43.68bar) at 366 deg.
- There is a slight constant graph near 344 to 349 degree at a pressure approx (18.76bar).
- After 368 degree pressure fall rapidly up to 445 degree.
- As shown in fig. combustion occurs after top dead centre nearly 360 degree then pressure rise rapidly and piston moves downward.
- By moving downward pressure reduces at a certain limit then pressure is remain nearly constant after 540 degree.
- After then removal of exhaust gases occurs when piston moves bottom dead centre (BDC) to top dead centre (TDC).
- There is slight increasing point after compression when pressure rise rapidly. It is the combustion point where combustion flame front start travelling in the fuel and fuel get excited.

There is a phenomenon called detonation. It occurs when flame front excited early due to compression.

5.1.3 (B) Pressure Vs Volume:-

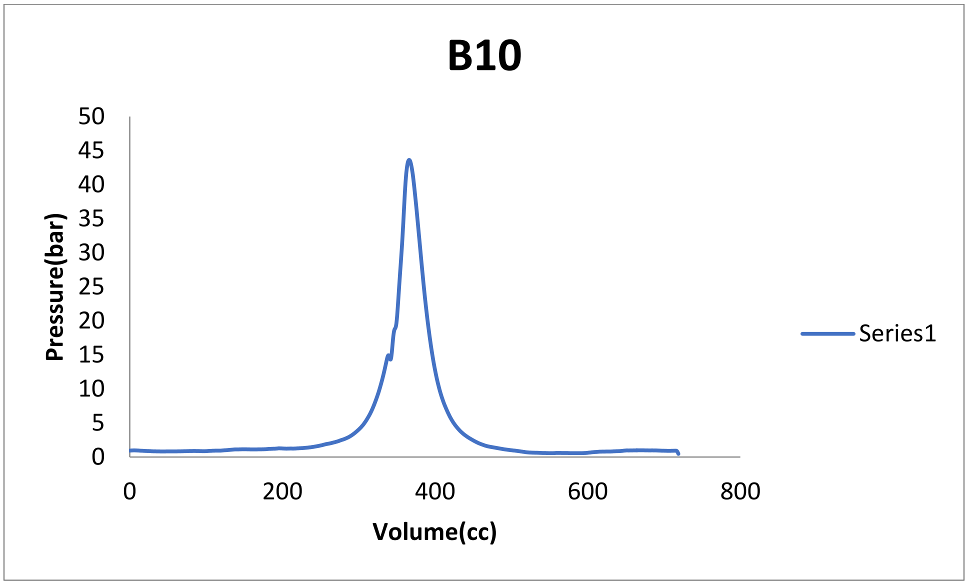

Fig.16 shows Pressure Vs Volume in B10.

- Different fuel shows different behavior of pressure at different crank angle.
- Maximum pressure rise is (43.68bar) at 366cc.
- There is a slight constant graph near 344 to 349 cc at a pressure approx (19bar).
- After 368 cc pressure fall rapidly up to 445 cc.
- As shown in fig. combustion occurs after top dead centre nearly 360 cc then pressure rise rapidly and piston moves downward.
- By moving downward pressure reduces at a certain limit then pressure is remain nearly constant after 540 cc.
- After then removal of exhaust gases occurs when piston moves bottom dead centre (BDC) to top dead centre (TDC).
- There is slight increasing point after compression when pressure rise rapidly. It is the combustion point where combustion flame front start travelling in the fuel and fuel get excited.

There is a phenomenon called detonation. It occurs when flame front excited early due to compression.

5.1.3 (C) Cumulative Heat Release Vs Cranks Angle:

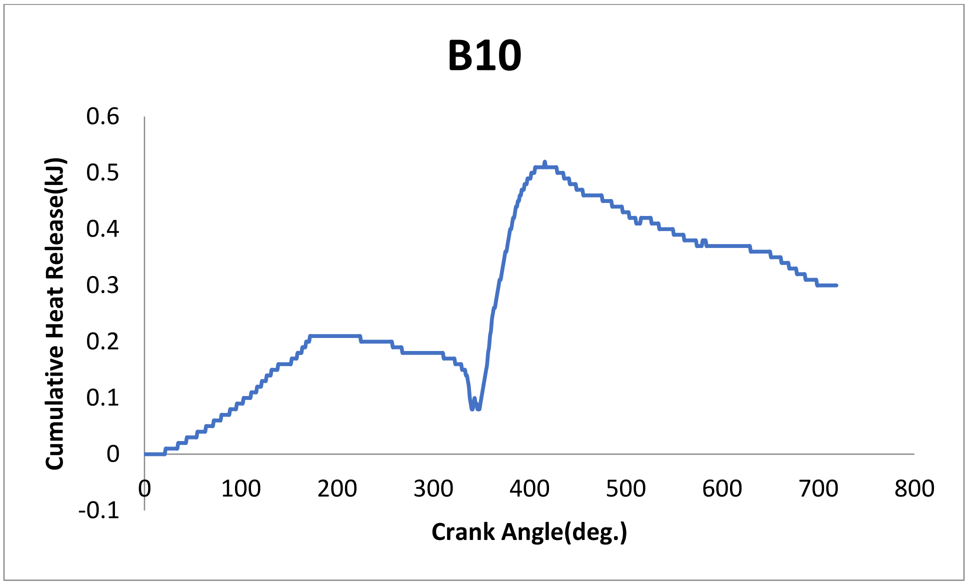

Fig.17 shows Cumulative heat release Vs Crank Angle in B10.

- Cumulative heat starts after 22degree of crank angle and increasing linearly up to 224degree when piston moves bottom dead centre to top dead centre during compression.
- After 225degree heat release decreases rapidly up to 356 degree (0.16kJ) and again start rising up to (0.52kJ) 416 degree.
- After 417 degree again heat decreases rapidly up to 535 degree and remains constant up to 540 degree.
- After 540 degree again cumulative heat decreases but it in constant partition up to (0.3kJ).
- Cumulative heat release is important to find the efficiency of engine using different fuel. It means that cumulative means that together heat release.
- Maximum cumulative heat release is (0.53kJ) 410 degrees to 440 degree at a constant heat release rate.
- Minimum cumulative heat release is (0.17kJ) at 357 degree at constant heat release rate.
- This variation shows that heat release Vs crank angle at different particular cringle angle different heat release is present.

5.1.3 (D) Net Heat Release Vs Crank Angle:

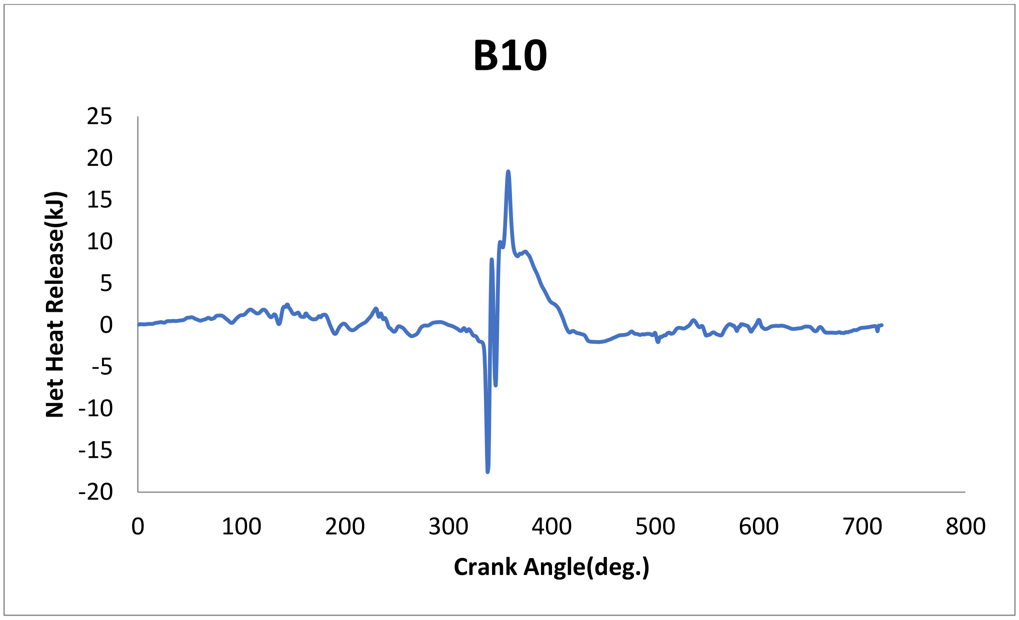

Fig.18 shows Net heat release Vs Crank Angle in B10.

- Different blends shows different variation of net heat release according to crank angle, we have to see B10 in this figure.
- Fig is increasing and decreasing up to 335 degree but after that net heat release decreases rapidly p to (-17.58kJ) at a crank angle of 338 degree.
- After 338 degree again net heat release rate increases up to (18.43kJ) at a crank angle of 358 degree.
- Then again net heat release decreases up to 362 degree then again net heat release increases.
- Maximum heat releases is (18.47kJ) at 360 degree and minimum heat release is (-17.58kJ) at 338 degree.
- Net Heat release is defined as the heat release at top of the piston after heat dissipation from the surrounding of piston.
- This graph completes 720 degree in crank angle and four strokes like suction occurs for (0 to 180 degree), compression occurs from (180 to 360 degree) , expansion occurs (360 to 540 degree) then lastly exhaust occurs (540 to 720 degree).

5.1.3 (E) Mass Fraction Burned Vs Crank Angle:

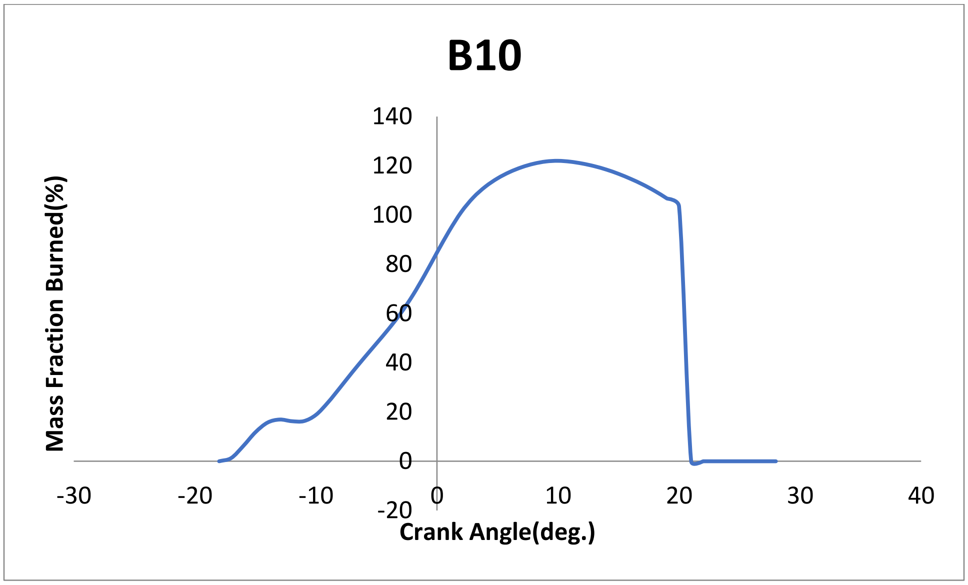

Fig.19 shows Mass Fraction Burned Vs Crank Angle in B10.

- Different blend shows different behavior of mass fraction burned with respect to crank angle. In this fig. we have to study B10.
- Mass fraction burned is defined as the ratio of mass burned to the total mass of fuel coming in the combustion chamber.
- As shown in fig. at a crank angle -17 degree mass fraction has a value of (1.32%).
- Maximum mass fraction burned is (122.04%) at a crank angle of (10degree).
- After 20 degree the mass fraction burned percentage decreases at a slope of (90 degree) at a very fast rate.
- At a crank angle 0 degree mass fraction burned has (84.78%) and slightly increases after that.
- This graph completes 720 degree in crank angle and four strokes like suction occurs for (0 to 180 degree), compression occurs from (180 to 360 degree) , expansion occurs (360 to 540 degree) then lastly exhaust occurs (540 to 720 degree).

This fig. actually used to find the mass burned to the total mass of fuel entered in the combustion chamber.

5.1.4 Combustion characteristics of D100:

5.1.4 (A) Pressure Vs Crank Angle:

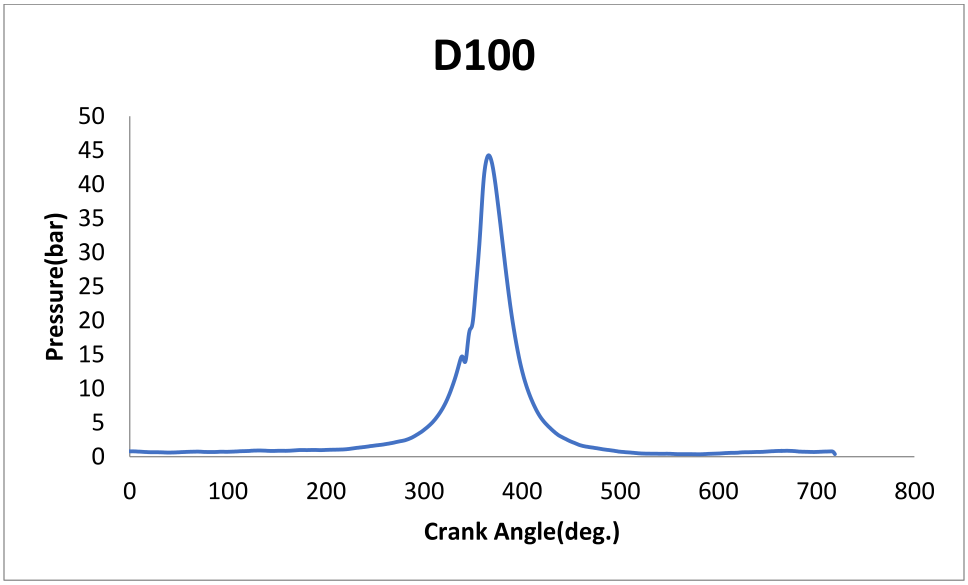

Fig.20 shows Pressure Vs Crank Angle in D100.

- Different fuel shows different behavior of pressure at different crank angle.
- Maximum pressure rise is (44.28bar) at 366 deg.
- There is a slight constant graph near 346 to 349 degree at a pressure approx (18.89bar).
- After 350 degree pressure fall rapidly up to 448 degree.
- As shown in fig. combustion occurs after top dead centre nearly 360 degree then pressure rise rapidly and piston moves downward.
- By moving downward pressure reduces at a certain limit then pressure is remain nearly constant after 540 degree.
- After then removal of exhaust gases occurs when piston moves bottom dead centre (BDC) to top dead centre (TDC).
- There is slight increasing point after compression when pressure rise rapidly. It is the combustion point where combustion flame front start travelling in the fuel and fuel get excited.

There is a phenomenon called detonation. It occurs when flame front excited early due to compression.

5.1.4 (B) Pressure Vs Volume:-

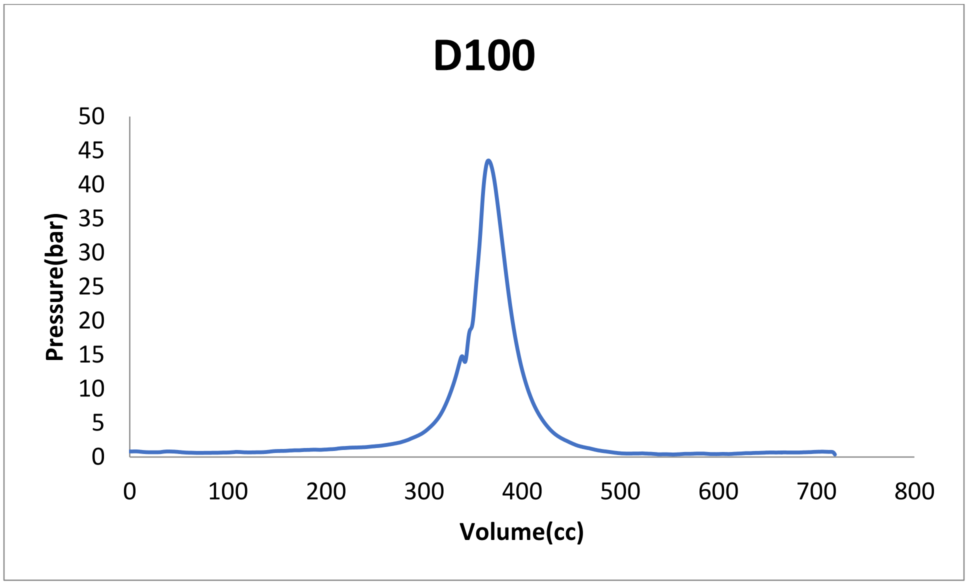

Fig.21 shows Pressure Vs Volume in D100.

- Different fuel shows different behavior of pressure at different crank angle.
- Maximum pressure rise is (44.28bar) at 366cc.
- There is a slight constant graph near 346 to 349 cc at a pressure approx (19bar).
- After 350 cc pressure fall rapidly up to 448 cc.
- As shown in fig. combustion occurs after top dead centre nearly 360 cc then pressure rise rapidly and piston moves downward.
- By moving downward pressure reduces at a certain limit then pressure is remain nearly constant after 540 cc.
- After then removal of exhaust gases occurs when piston moves bottom dead centre (BDC) to top dead centre (TDC).
- There is slight increasing point after compression when pressure rise rapidly. It is the combustion point where combustion flame front start travelling in the fuel and fuel get excited.

There is a phenomenon called detonation. It occurs when flame front excited early due to compression.

5.1.4 (C) Cumulative Heat Release Vs Crank Angle:

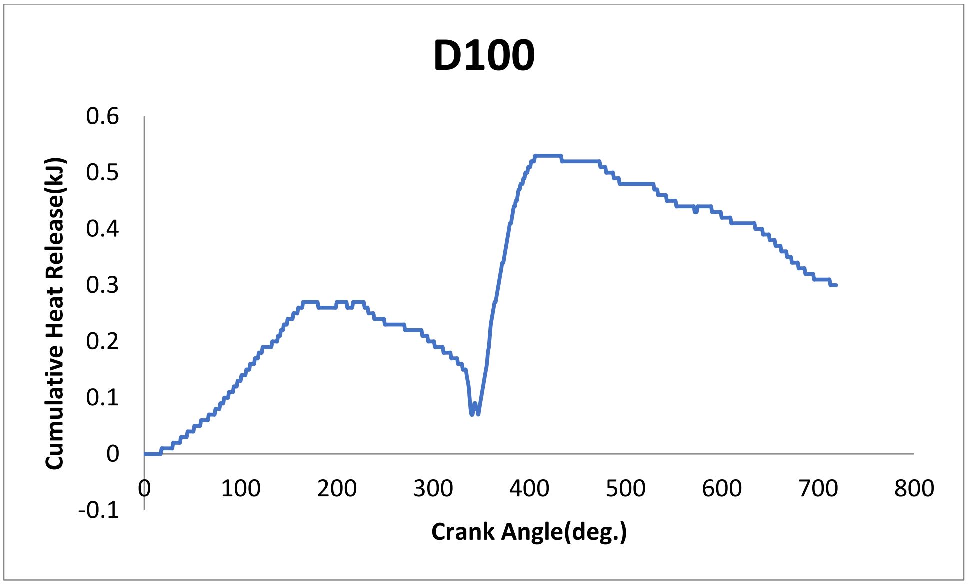

Fig.22 shows Cumulative heat release Vs Crank Angle in D100.

- Cumulative heat starts after 18degree of crank angle and increasing linearly up to 268degree when piston moves bottom dead centre to top dead centre during compression.
- After 269degree heat release decreases rapidly up to 349 degree (0.09kJ) and again start rising up to (0.53kJ) 431 degree.
- After 417 degree again heat decreases rapidly up to 535 degree and remains constant up to 540 degree.
- After 540 degree again cumulative heat decreases but it in constant partition up to (0.3kJ).
- Cumulative heat release is important to find the efficiency of engine using different fuel. It means that cumulative means that together heat release.
- Maximum cumulative heat release is (0.53kJ) 410 degrees to 440 degree at a constant heat release rate.
- Minimum cumulative heat release is (0.17kJ) at 357 degree at constant heat release rate.
- This variation shows that heat release Vs crank angle at different particular cringle angle different heat release is present.

5.1.4 (D) Net Heat Release Vs Crank Angle:

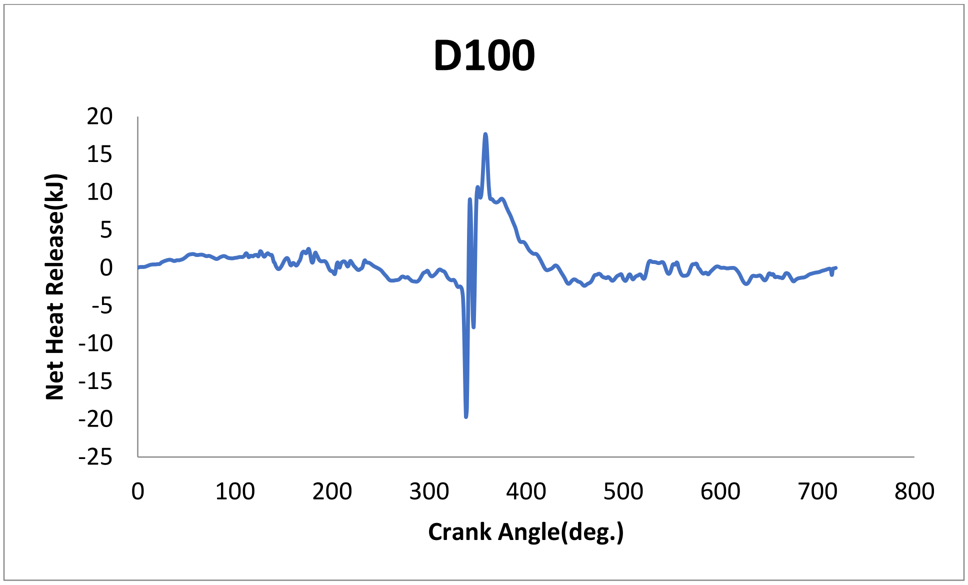

Fig.23 shows Net heat release Vs Crank Angle in D100.

- Different blends shows different variation of net heat release according to crank angle, we have to see D100 in this figure.
- Fig is increasing and decreasing up to 335 degree but after that net heat release decreases rapidly up to (-19.68kJ) at a crank angle of 338 degree.
- After 338 degree again net heat release rate increases up to (10.07kJ) at a crank angle of 362 degree.
- Then again net heat release decreases up to 365 degree then again net heat release increases.
- Maximum heat releases is (10.11kJ) at 364 degree and minimum heat release is (-19.68kJ) at 338 degree.
- Net Heat release is defined as the heat release at top of the piston after heat dissipation from the surrounding of piston.
- This graph completes 720 degree in crank angle and four strokes like suction occurs for (0 to 180 degree), compression occurs from (180 to 360 degree) , expansion occurs (360 to 540 degree) then lastly exhaust occurs (540 to 720 degree).

5.1.4 (E) Mass Fraction Burned Vs Crank Angle:

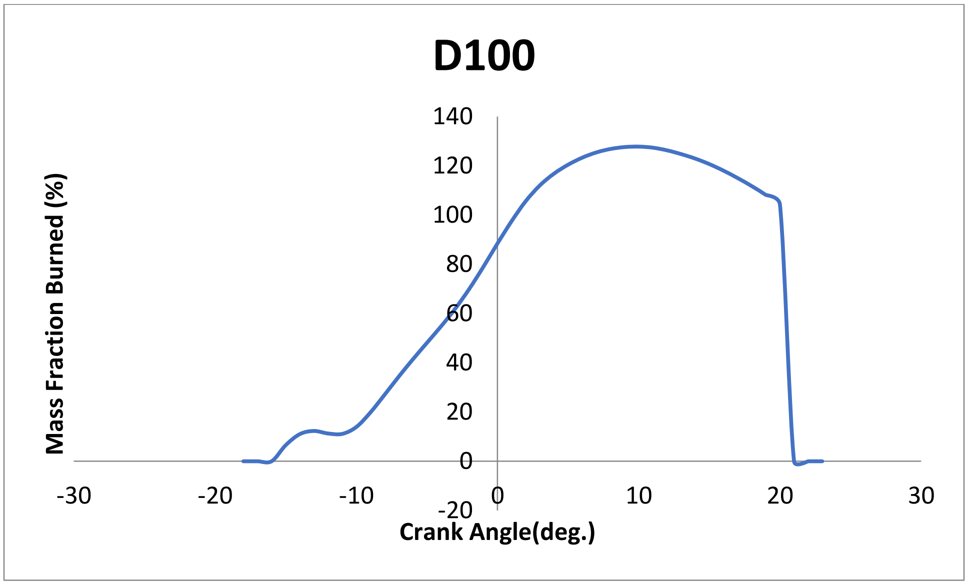

Fig.24 shows Mass Fraction Burned Vs Crank Angle in D100.

- Different blend shows different behavior of mass fraction burned with respect to crank angle. In this fig. we have to study D100.
- Mass fraction burned is defined as the ratio of mass burned to the total mass of fuel coming in the combustion chamber.
- As shown in fig. at a crank angle -15 degree mass fraction has a value of (6.53%).
- Maximum mass fraction burned is (127.81%) at a crank angle of (10degree).
- After 20 degree the mass fraction burned percentage decreases at a slope of (90 degree) at a very fast rate.
- At a crank angle 0 degree mass fraction burned has (88.48%) and slightly increases after that.
- This graph completes 720 degree in crank angle and four strokes like suction occurs for (0 to 180 degree), compression occurs from (180 to 360 degree) , expansion occurs (360 to 540 degree) then lastly exhaust occurs (540 to 720 degree).

This fig. actually used to find the mass burned to the total mass of fuel entered in the combustion chamber.

5.2 Performance Characteristics:

In Table 6 Performance characteristics are used to know all the necessary information regarding performance and analyze them used to compare all the blends and check the necessary condition like maximum power and thermal efficiency etc. Using cooling oil to optimization of base catalyzed done (2004) [63]. Optimization of biodiesel production from linseed oil using Tranesterification process using co-valent done (2018) [64]. All the researches is used to find the information regarding combustion, performance and emission.

OD Dia of orifice. (mm)	20.00
OCD Orifice Coeff. Of Discharge	0.60
Length of dynamometer (mm)	185
Dia. of fuel pipe(mm)	14.50
Surrounding temp. (Deg C)	27
Revolution of pulse	360
Density of Diesel (Kg/m^3)	830
CV calorific value of Fuel (kJ/kg)	42000

- It is used to check the pressure, powers (Brake, Indicated, friction).
- It is used to check specific fuel consumption.
- It is used to check efficiency (Brake thermal, indicated thermal).
- It is used to compare power and thermal efficiency of blends.
- Graph is drawn between all blends and check performance.
- Performance characteristics used to check power generation and efficiency of fuel.
- It is used to measure air and fuel flow.
- It is used to measure fuel consumption

One investigation biodiesel production from linseed oil using heterogenous based catalyst in bed reactor (2018) [65]. Using mixture of karanja oil and linseed oil to optimize process parameters done (2016) [66]. Optimization of jatropha biodiesel engine model using taguchi is done by (2009) [67]. Using high free fatty acid jatropha oil to optimize the process is analyzed in (2007)[68]. Using nano particls in biodiesel in diesel engiine to find performance, combustion and emission characteristics done by (2022) [69].

5.2.1 Brake Power Vs Torque:

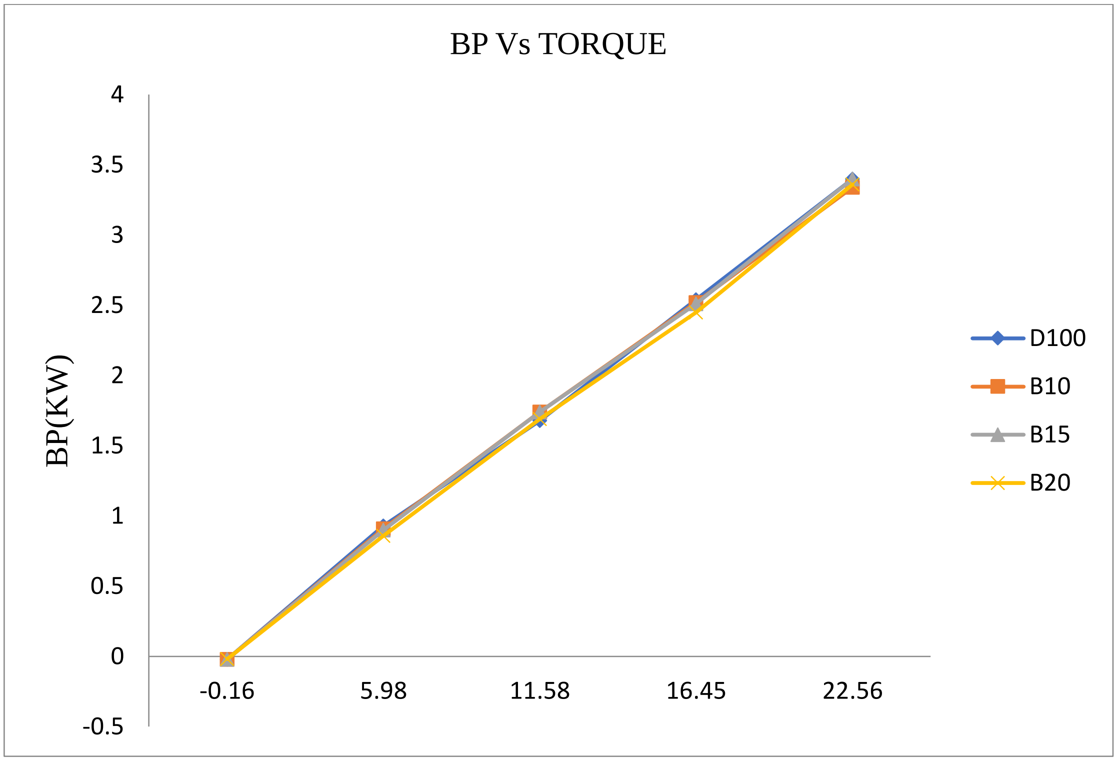

Fig.25 shows that BP Vs Torque for different blends.

1. Different blends show different behavior of brake power Vs torque.
2. Maximum power generation is for B10, B15 is (1.74kW). at torque of (11.05, 11.07Nm) at 6kg load.
3. Maximum power generation at 12kg is for D100 about (3.4kW) at torque of (21 .54Nm).
4. Maximum power generation is 3.4kW at torque of (22.56Nm) is for B20.

This graph shows that different behavior of blends in power generation and this curve shows that the maximum power generation is for Pure diesel. But we want to generate maximum power at different loading condition.

5.2.2 Brake Power Vs Brake Thermal Efficiency:

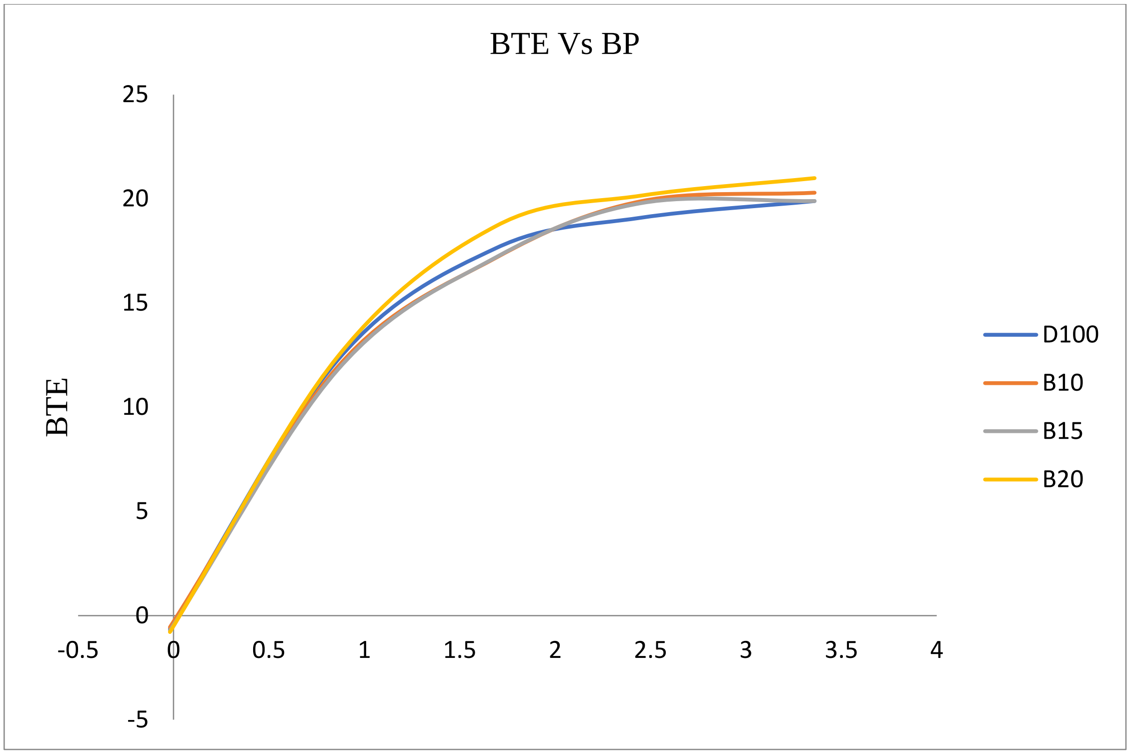

Fig.26 shows that BTE Vs BP in different blends

1. Different behavior shows different behavior in BTE Vs BP.
2. Maximum power generation is for B20 at (2.54kW) give (19.98%) Brake thermal efficiency.
3. Maximum Brake Thermal Efficiency is at (21.74%) at (3.34kW) Brake power.
4. As shown in fig. efficiency decrease at (2.45Kw) brake power of pure diesel.
5. At (1.69kW) efficiency is maximum for B20 and minimum foe B15.

The Fig. depict that different behavior of blends in power generation and this curve shows that the maximum power generation is for Blend 20. But we want to generate maximum power at different loading condition.

5.2.3 Brake Power Vs Brake Mean Effective Pressure:

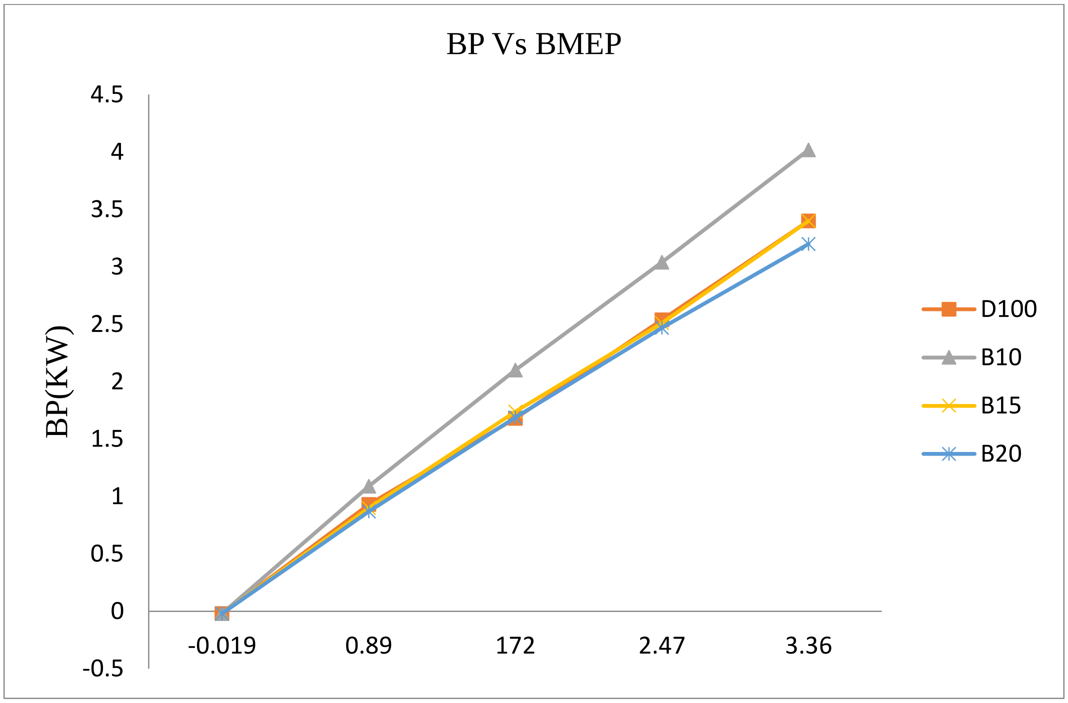

Fig.27 shows that BMEP Vs BP in different blends.

1. Different behavior shows different behavior in BTE Vs BP.
2. It can be shown in Fig. for the small mean effective pressure rise there is large power generation for B10.
3. It can be shown in fig. maximum brake power generation is (4.1kW) at maximum loading condition of 12kg.
4. It is clear in fig. that at all loading condition pressure is always drastically increases in B10.

The Fig. depict that all the blends and pure diesel, brake mean effective pressure is large for B10 at all loading condition, and brake mean effective pressure is nearly same of other blends and less than the B10. Lowest power generation compare to brake mean effective pressure is for blend B20.

5.2.4 Load Vs Indicated Power:

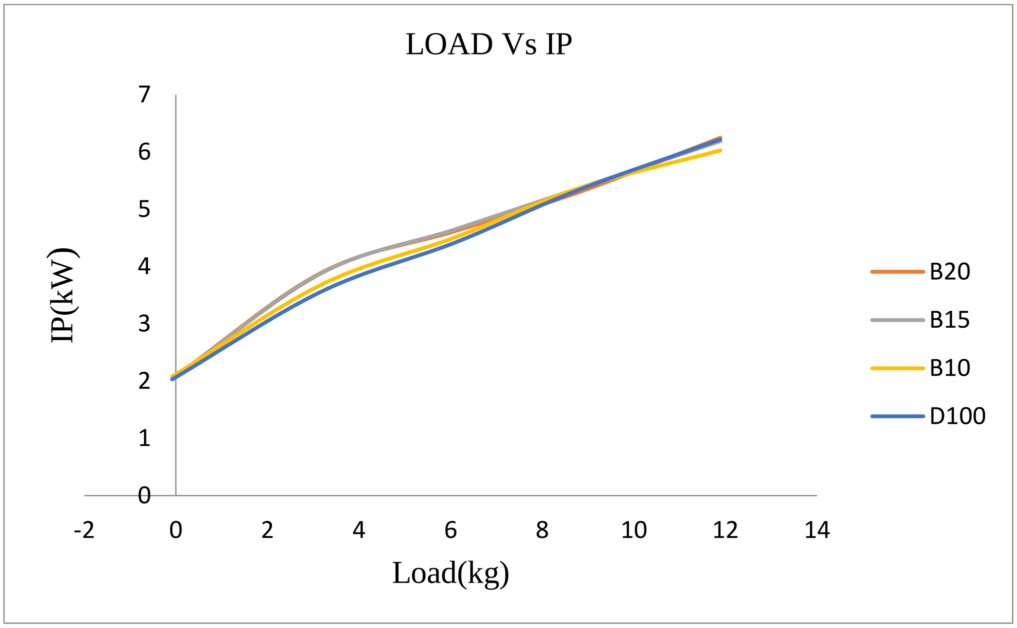

Fig.28 shows Behavior of Load Vs Indicated Power of different blends.

- Indicated Power is the power generated in the combustion chamber at the top of the piston face.
- Different Blend shows different behavior of Indicated power with respect to load.
- Maximum indicated power generated is (6.25kW) for B20 at maximum loading condition of 12kg.
- Minimum indicated power generated is (2.02kW) for B20 at no loading condition.
- At 3kg load maximum indicated power generated is for B15 and minimum for neat diesel.
- At 6kg load maximum indicated power generated is for B20 and minimum for B15.
- At 9kg load maximum indicated power generated is for B15 and minimum for neat diesel.
- As shown in fig. variation of B15 is more in between 3kg to 6kg followed by B20 which has lower variation compare to B15 and minimum variation is for neat diesel D100.
- Maximum indicated power generated for B20 is (6.25kW), for B15 is (6.19kW), for B10 is (6.03kW) and for D100 is (6.22kW).
- Minimum indicated power generated for B20 is (2.04kW), for B15 is (2.03kW), for B10 is (2.08kW) and for D100 is (2.03kW).

5.2.5 Load Vs Brake Power:

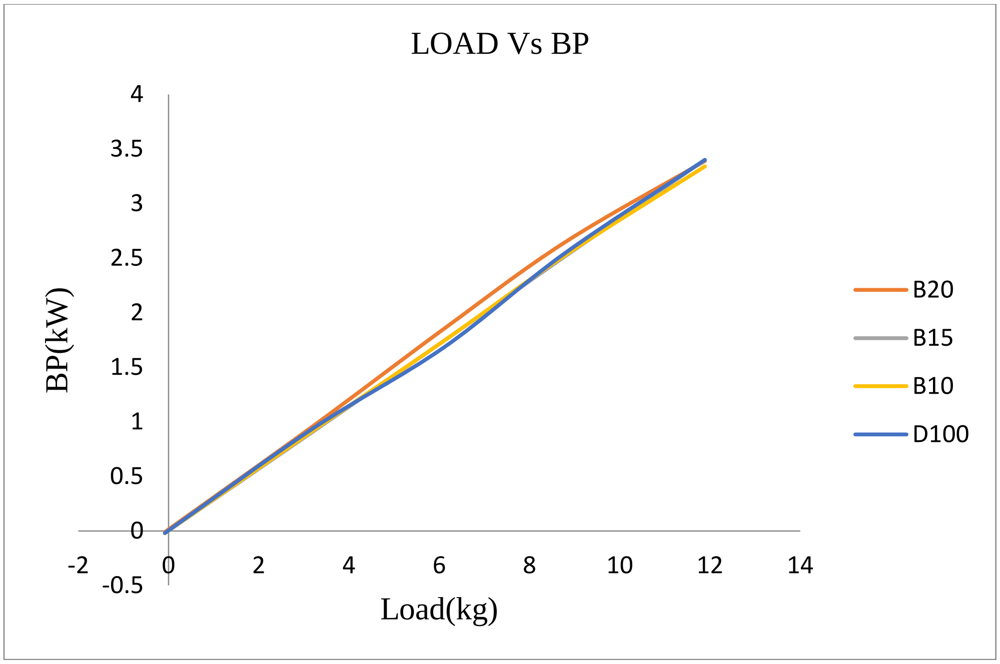

Fig.29 shows Behavior of Load Vs Brake Power of different blends.

- Brake Power is the power generated on the crank shaft when power is transferred through the connecting rod.
- Different Blend shows different behavior of Indicated power with respect to load.
- Maximum brake power generated is (3.4kW) for B15 at maximum loading condition of 12kg.
- Minimum brake power generated is (-0.01kW) for B20 at no loading condition.
- At 3kg load maximum brake power generated is for D100 and minimum for B15.
- At 6kg load maximum brake power generated is for B20 and minimum for D100.
- At 9kg load maximum brake power generated is for B20 and minimum for B15.
- As shown in fig. variation of B20 is more in between 5kg to 10kg followed by B15 which has lower variation compare to B20 and minimum variation is for neat diesel D100.
- Maximum brake power generated for B20 is (3.39kW), for B15 is (3.4kW), for B10 is (3.34kW) and for D100 is (3.4kW).
- Minimum brake power generated for B20 is (-0.01kW), for B15 is (-0.02kW), for B10 is (-0.02kW) and for D100 is (-0.02kW).

5.2.6 Load Vs Frictional Power:

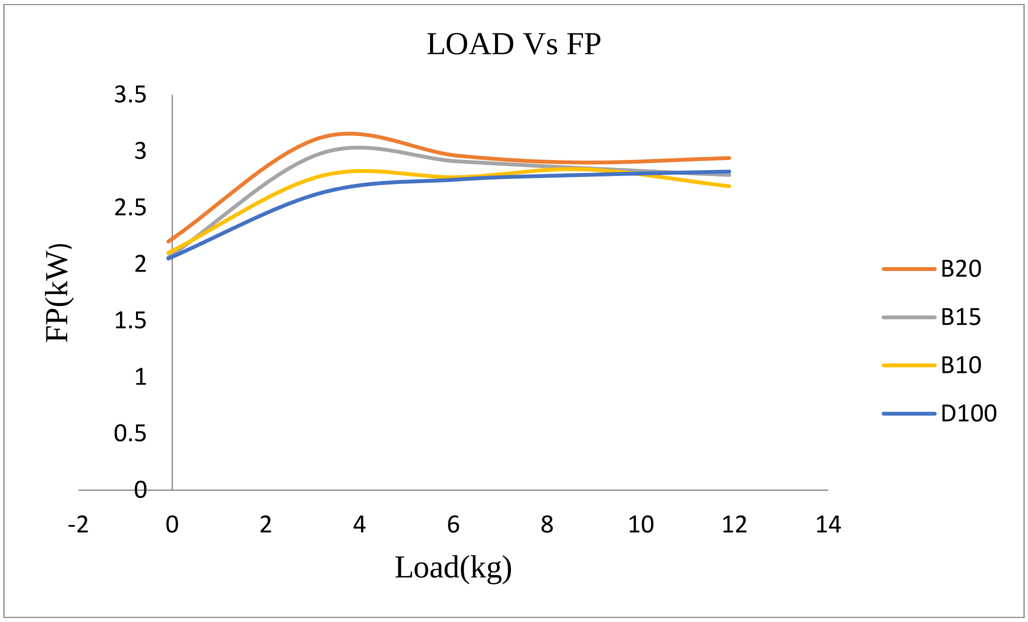

Fig.30 shows Behavior of Load Vs Frictional Power of different blends.

- Frictional Power is the difference between indicated power and brake power or it can defined as loss of power when power is transmitted through piston top to crank shaft.
- Different Blend shows different behavior of Indicated power with respect to load.
- Maximum frictional power generated is (2.94kW) for B20 at maximum loading condition of 12kg.
- Minimum frictional power generated is (2.05kW) for D100 at no loading condition.
- At 3kg load maximum frictional power generated is for B20 and minimum for D100.
- At 6kg load maximum frictional power generated is for B20 and minimum for D100.
- At 9kg load maximum frictional power generated is for B20 and minimum for B10.
- As shown in fig. variation of B20 is more in between 3kg to 6kg followed by B15 which has lower variation compare to B20 and minimum variation is for neat diesel D100.
- Maximum frictional power generated for B20 is (2.94kW), for B15 is (2.79kW), for B10 is (2.69kW) and for D100 is (2.82kW).
- Minimum frictional power generated for B20 is (2.2kW), for B15 is (2.06kW), for B10 is (2.1kW) and for D100 is (2.05kW).

5.2.7 Load Vs Indicated Mean Effective Pressure:

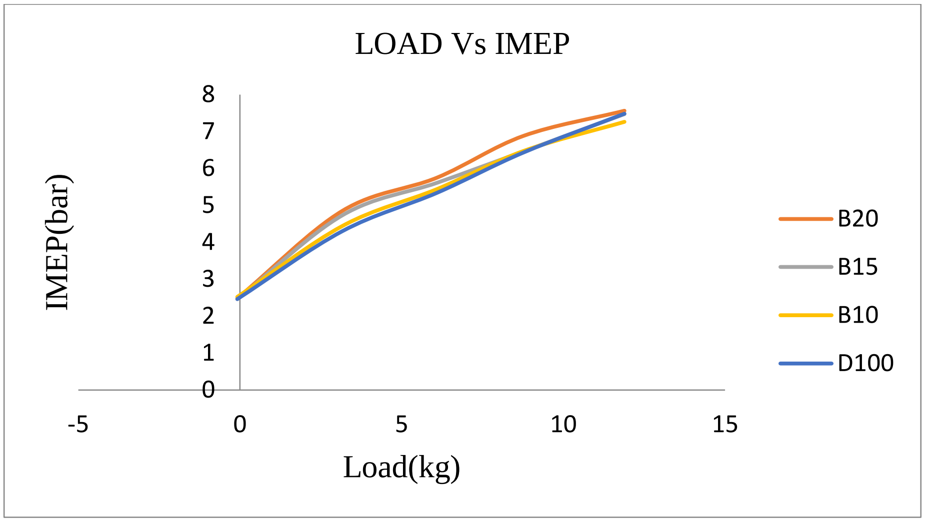

Fig.31 shows Behavior of Load Vs Indicated mean effective pressure of different blends.

- Indicated mean effective pressure is the pressure generated at the top of the piston when combustion occurs.
- Different Blend shows different behavior of Indicated mean effective pressure with respect to load.
- Maximum Indicated mean effective pressure generated is (7.56bar) for B20 at maximum loading condition of 12kg.
- Minimum indicated mean effective pressure generated is (2.46) for B15 at no loading condition.
- At 3kg load maximum indicated mean effective pressure generated is for B20 and minimum for D100.
- At 6kg load maximum indicated mean effective pressure generated is for B20 and minimum for D100.
- At 9kg load maximum indicated mean effective pressure generated is for B20 and minimum for B10.
- As shown in fig. variation of B20 is more in between 3kg to 6kg followed by B15 which has lower variation compare to B20 and minimum variation is for neat diesel D100.
- Maximum indicated mean effective generated pressure for B20 is (7.56bar), for B15 is (7.47ar), for B10 is (7.26bar) and for D100 is (7.48bar).
- Minimum indicated mean effective generated pressure for B20 is (2.48bar), for B15 is (2.46bar), for B10 is (2.52bar) and for D100 is (2.46bar).

5.2.8 Load Vs Brake Mean Effective Pressure:

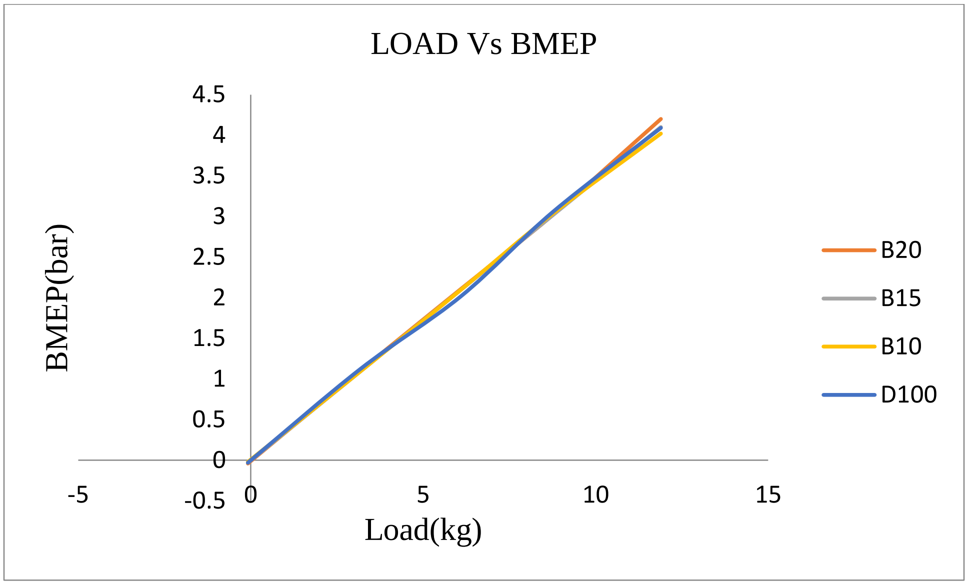

Fig.32 shows Behavior of Load Vs brake mean effective pressure of different blends.

- Brake mean effective pressure is the pressure generated at the crankshaft when it rotates with high speed.
- Different Blend shows different behavior of Brake mean effective pressure with respect to load.
- Maximum Brake mean effective pressure generated is (4.2bar) for B20 at maximum loading condition of 12kg.
- Minimum Brake mean effective pressure generated is (-0.04) for B20 at no loading condition.
- At 3kg load maximum Brake mean effective pressure generated is for D100 and minimum for B10.
- At 6kg load maximum Brake mean effective pressure generated is for D100 and minimum for B15.
- At 9kg load maximum Brake mean effective pressure generated is for D100 and minimum for B20.
- As shown in fig. variation of B20 is more in between 3kg to 6kg followed by B15 which has lower variation compare to B20 and minimum variation is for neat diesel D100.
- Maximum Brake mean effective pressure generated for B20 is (4.2bar), for B15 is (4.1bar), for B10 is (4.02bar) and for D100 is (4.09bar).

  Minimum Brake mean effective pressure generated for B20 is (-0.04bar), for B15 is (-0.03bar), for B10 is (-0.02bar) and for D100 is (-0.03bar).

5.2.9 Load Vs Frictional Mean Effective Pressure:

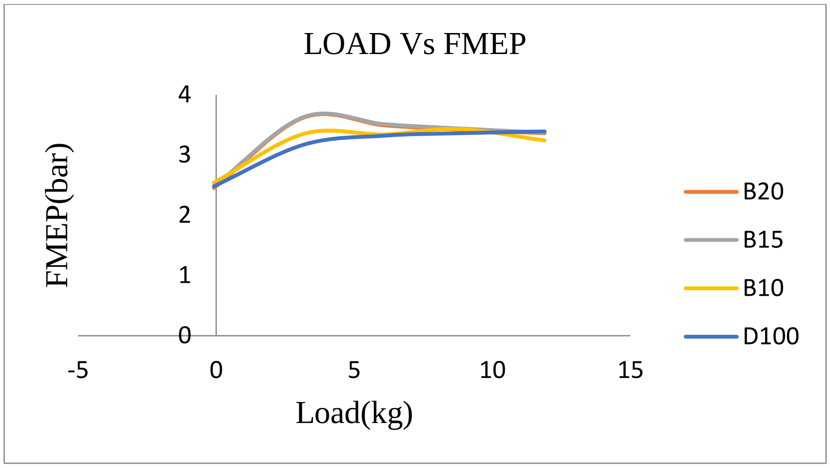

Fig.33 shows Behavior of Load Vs frictional mean effective pressure of different blends.

- Frictional mean effective pressure is the pressure generated at the top of the piston when combustion occurs.
- Different Blend shows different behavior of frictional mean effective pressure with respect to load.
- Maximum frictional mean effective pressure generated is (3.39bar) for D100 at maximum loading condition of 12kg.
- Minimum frictional mean effective pressure generated is (2.45bar) for B20 at no loading condition.
- At 3kg load maximum frictional mean effective pressure generated is for B15 and minimum for D100.
- At 6kg load maximum frictional mean effective pressure generated is for B15 and minimum for D100.
- At 9kg load maximum frictional mean effective pressure generated is for B15 and minimum for D100.
- As shown in fig. variation of B20 is more in between 3kg to 6kg followed by B15 which has lower variation compare to B20 and minimum variation is for neat diesel D100.
- Maximum frictional mean effective pressure generated for B20 is (3.36bar), for B15 is (3.37ar), for B10 is (3.24bar) and for D100 is (3.39bar).

  Minimum frictional mean effective pressure generated for B20 is (2.45bar), for B15 is (2.48bar), for B10 is (2.54bar) and for D100 is (2.48bar).

5.2.10 Load Vs Indicated Thermal Efficiency:

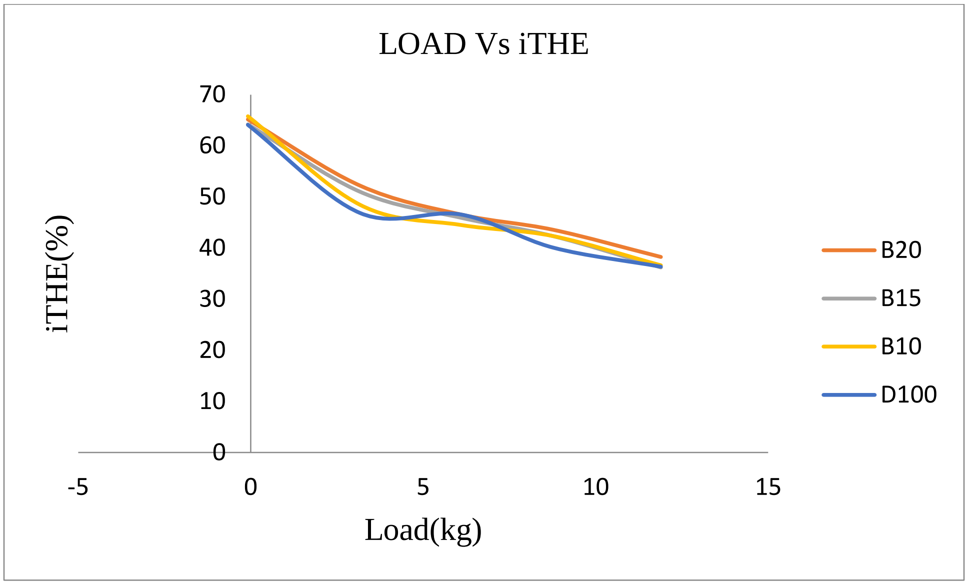

Fig.34 shows Behavior of Load Vs indicated thermal efficiency of different blends.

- Indicated thermal efficiency is the ratio of indicated power to the calorific value of fuel or heat ads per second.
- Different Blend shows different behavior of indicated thermal efficiency with respect to load.
- Maximum indicated thermal efficiency generated is (65.76%) for B10 at no loading condition.
- Minimum indicated thermal efficiency generated is (36.21%) for B10 at no loading condition.
- At 3kg load maximum indicated thermal efficiency generated is for B20 and minimum for D100.
- At 6kg load maximum indicated thermal efficiency generated is for D100 and minimum for B10.
- At 9kg load maximum indicated thermal efficiency generated is for B20 and minimum for D100.
- As shown in fig. variation of indicated thermal efficiency is more for B20 at increasing loading condition, but at maximum load B10 has max efficiency. Variation of indicated thermal efficiency is maximum for D100 at 3kg to 6kg load.
- Maximum indicated thermal efficiency generated for B20 is (65.14%), for B15 is (64.17%), for B10 is (65.76%) and for D100 is (64.08%).
- Minimum indicated thermal efficiency generated for B20 is (38.25%), for B15 is (36.21%), for B10 is (36.62%) and for D100 is (36.35%).

5.2.11 Load Vs Brake Thermal Efficiency:

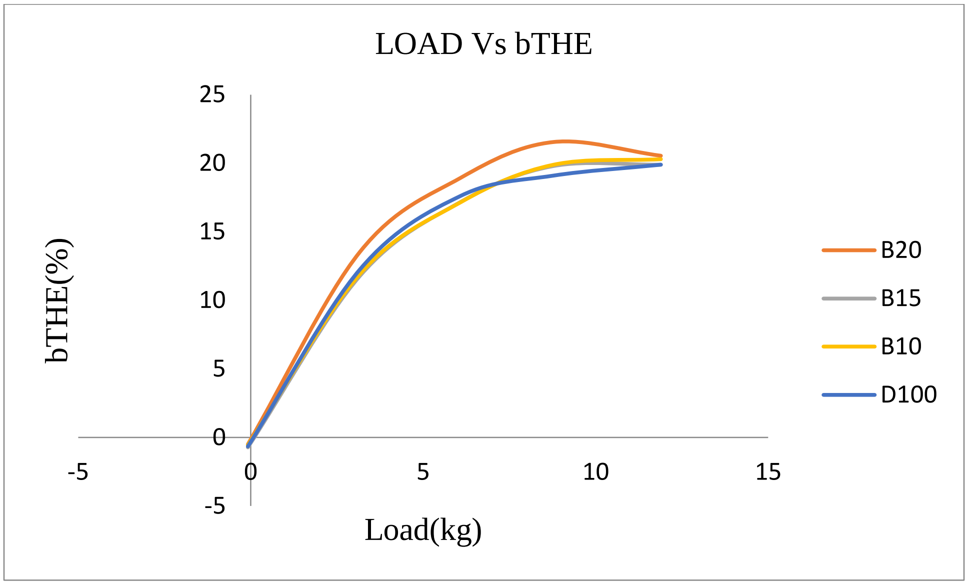

Fig.35 shows Behavior of Load Vs brake thermal efficiency of different blends.

- Brake thermal efficiency is the ratio of Brake power to the calorific value of fuel or heat ads per second.
- Different Blend shows different behavior of Brake thermal efficiency with respect to load.
- Maximum brake thermal efficiency generated is (20.54%) for B20 at maximum loading condition of 12kg.
- Minimum brake thermal efficiency generated is (-0.72%) for B15 at no loading condition.
- At 3kg load maximum brake thermal efficiency generated is for B20 and minimum for B15.
- At 6kg load maximum brake thermal efficiency generated is for B20 and minimum for B10.
- At 9kg load maximum brake thermal efficiency generated is for B20 and minimum for D100.
- As shown in fig. variation of Brake thermal efficiency is more for B20 at increasing loading condition, but at maximum load B10 has max efficiency. Variation of Brake thermal efficiency is maximum for B20 at 3kg to 6kg load.
- Maximum brake thermal efficiency generated for B20 is (20.54%), for B15 is (19.89%), for B10 is (20.29%) and for D100 is (19.89%).

  Minimum brake thermal efficiency generated for B20 is (-0.5%), for B15 is (-0.72%), for B10 is (-0.56%) and for D100 is (-0.65%).

5.2.12 Load Vs Torque:

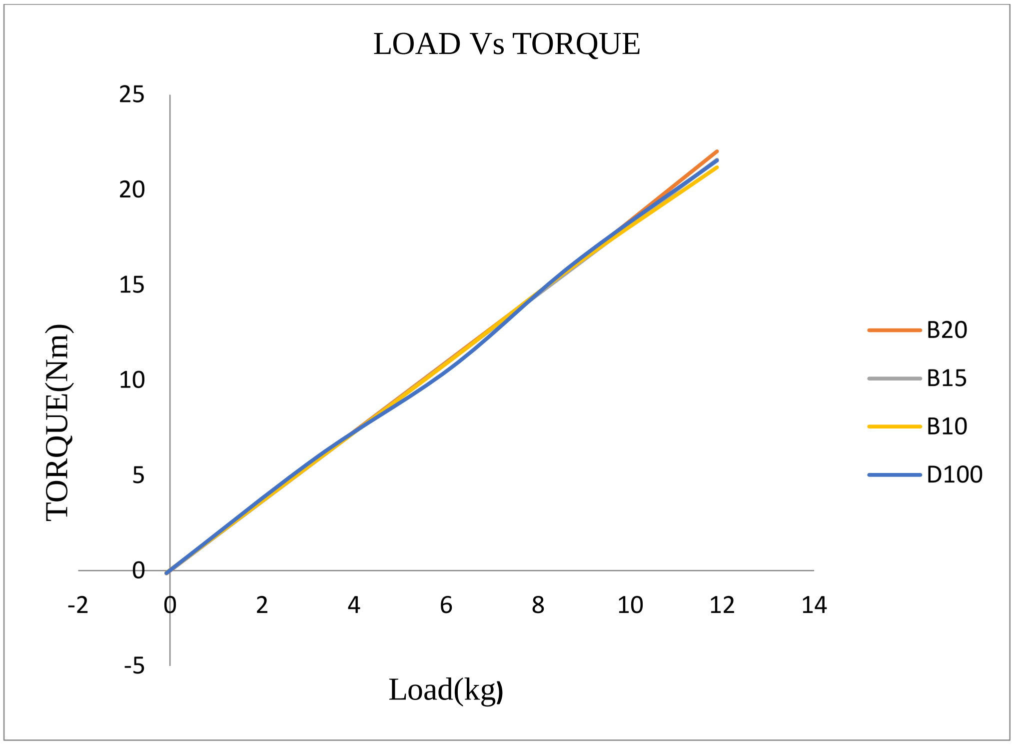

Fig.36 shows Behavior of Load Vs torque of different blends.

- Torque is define as the force exerted in perpendicular distance to that plane.
- Different Blend shows different behavior of torque with respect to load.
- Maximum torque generated is (22.02Nm) for B20 at maximum loading condition of 12kg.
- Minimum torque generated is (-0.15Nm) for B20 at no loading condition.
- At 3kg load maximum torque generated is for D100 and minimum for B15.
- At 6kg load maximum torque generated is for B20 and minimum for D100.
- At 9kg load maximum torque generated is for D100 and minimum for B15.
- As shown in fig. variation of torque is more for B20 at increasing loading condition, but at maximum load B10 has max. Variation of torque is maximum for B20 at 3kg to 6kg load.
- Maximum torque generated for B20 is (22.02Nm), for B15 is (21.58Nm), for B10 is (21.18Nm) and for D100 is (21.54Nm).

  Minimum torque generated for B20 is (-0.15Nm), for B15 is (-0.14Nm), for B10 is (-0.11Nm) and for D100 is (-0.13Nm).

5.2.13 Load Vs Mechanical Efficiency:

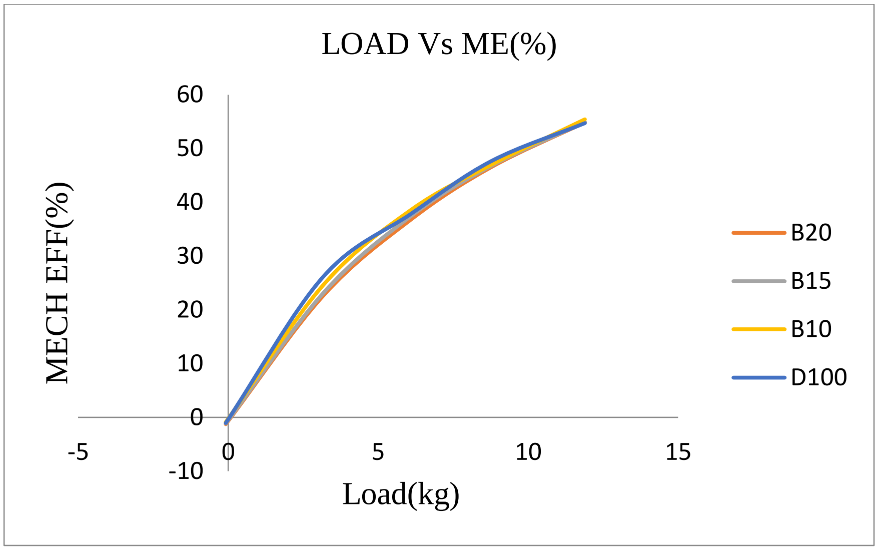

Fig.37 shows Behavior of Load Vs Mechanical efficiency of different blends.

- Mechanical efficiency is the ratio of Brake power to the indicated power.
- Different Blend shows different behavior of mechanical efficiency with respect to load.
- Maximum mechanical efficiency generated is (55.42%) for B20 at maximum loading condition of 12kg.
- Minimum mechanical efficiency generated is (-1.25%) for B20 at no loading condition.
- At 3kg load maximum mechanical efficiency generated is for D100 and minimum for B20.
- At 6kg load maximum mechanical efficiency generated is for B10 and minimum for B20.
- At 9kg load maximum mechanical efficiency generated is for D100 and minimum for B20.
- As shown in fig. variation of mechanical efficiency is more for B20 at increasing loading condition, but at maximum load B10 has max efficiency. Variation of mechanical efficiency is maximum for B20 at 3kg to 6kg load.
- Maximum mechanical efficiency generated for B20 is (54.85%), for B15 is (54.91%), for B10 is (55.42%) and for D100 is (54.71%).

  Minimum mechanical efficiency generated for B20 is (-1.25%), for B15 is (-1.12%), for B10 is (-0.86%) and for D100 is (-1.02%).

5.2.14 Load Vs Volumetric Efficiency:

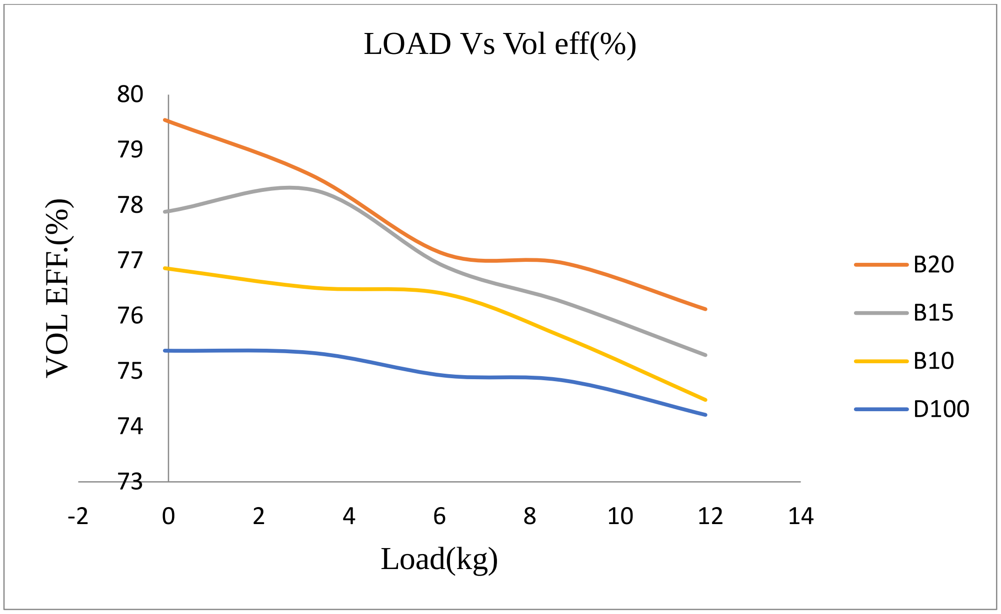

Fig.38 shows Behavior of Load Vs Mechanical efficiency of different blends.

- Volumetric efficiency is the ratio of vol. actual displaced to the maximum theoretical volume.
- Different Blend shows different behavior of volumetric efficiency with respect to load.
- Maximum volumetric efficiency generated is (79.54%) for B20 at no loading condition.
- Minimum volumetric efficiency generated is (74.21%) for D100 at maximum loading condition of 12kg.
- At 3kg load maximum volumetric efficiency generated is for B20 and minimum for D100.
- At 6kg load maximum volumetric efficiency generated is for B20 and minimum for D100.
- At 9kg load maximum volumetric efficiency generated is for B20 and minimum for D100.
- As shown in fig. variation of volumetric efficiency is more for B20 at decreasing loading condition, but at maximum load D100 has lowest efficiency. Variation of volumetric efficiency is maximum for B20 at 5kg to 8kg load.
- Maximum volumetric efficiency generated for B20 is (79.54%), for B15 is (77.88%), for B10 is (76.86%) and for D100 is (75.37%).

  Minimum volumetric efficiency generated for B20 is (76.12%), for B15 is (75.29%), for B10 is (74.48%) and for D100 is (74.21%).

5.2.15 Load Vs Specific Fuel Consumption:

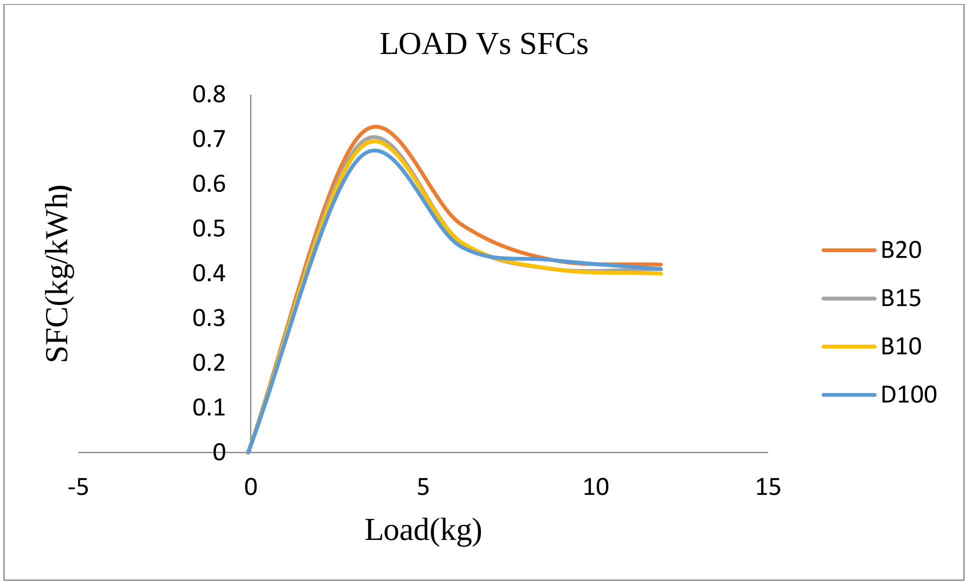

Fig.39 shows Behavior of Load Vs Specific fuel consumption of different blends.

- Specific fuel consumption is the ratio of mass to the power generated in the given specific time(in hour).
- Different Blend shows different behavior of specific fuel consumption with respect to load.
- Maximum specific fuel consumption generated is (0.71kg/kWh) for B20 at 3kg loading condition.
- Minimum specific fuel consumption generated is null for all the blends at no loading condition.
- At 3kg load maximum specific fuel consumption generated is for B20 and minimum for D100.
- At 6kg load maximum specific fuel consumption generated is for B20 and minimum for D100.
- At 9kg load maximum specific fuel consumption generated is for B20 and minimum for B10.
- As shown in fig. variation of specific fuel consumption is more for B20 at decreasing loading condition, but at maximum load D100 has lowest fuel Consumption. Variation of specific fuel consumption is maximum for B20 at 5kg to 8kg load.
- Maximum specific fuel consumption generated for B20 is (0.71kg/kWh), for B15 is (0.69kg/kWh), for B10 is (0.68kg/kWh) and for D100 is (0.66kg/kWh).

  Minimum specific fuel consumption generated for all blends is null at no loading condition.

5.2.16 Load Vs Fuel Consumption

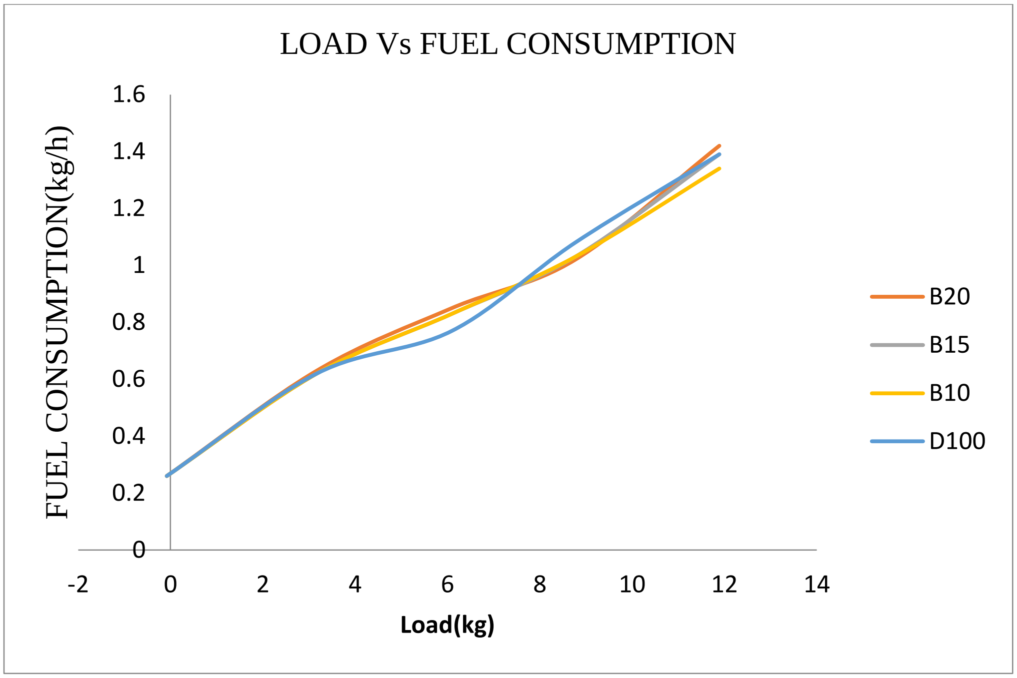

Fig.40 shows Behavior of Load Vs Fuel consumption of different blends.

- Fuel consumption is the ratio of mass flow of fuel per unit time.
- Maximum fuel consumption generated is (1.42kg/h) for B20 at maximum loading condition of 12kg.
- Minimum fuel consumption generated is (0.26kg/h) for all blends at no loading condition.
- At 3kg load maximum fuel consumption generated is for B20 and minimum for D100.
- At 6kg load maximum fuel consumption generated is for B20 and minimum for D100.
- At 9kg load maximum fuel consumption generated is for D100 and minimum for B20.
- As shown in fig. variation of fuel consumption is more for B20 at decreasing loading condition, but at maximum load D100 has lowest fuel Consumption. Variation of fuel consumption is maximum for B20 at 5kg to 8kg load.
- Maximum fuel consumption generated for B20 is (1.42kg/h), for B15 is (1.39kg/h), for B10 is (1.34kg/h) and for D100 is (1.39kg/h).

  Minimum fuel consumption generated for all the blends is (0.26kg/h) at no loading condition.

Conclusion:

In the present experimental study impact of linseed biodiesel on performance and combustion characteristics of a single cylinder VCR CRDI Diesel engine are investigated. The obtained conclusions relying on the experimental studies are summarized.

Various blends used to check the variation of all the parameters with variation of different loading condition at constant speed of 1500rpm. This is done on linseed oil which has low cetane number to check effect of linseed oil on diesel engine performance and emission.

- Maximum brake power generation is for B10 at load of 6kg using dynamometer and minimum brake power is for B20.
- Maximum Brake Thermal Efficiency is for B20 at maximum power of (2.54kW) and minimum brake thermal efficiency is for B15.
- Brake mean effective pressure is maximum for B10 at any loading condition. At maximum brake mean effective pressure, maximum power is generated and minimum brake mean effective pressure is for B20 and minimum power generation is also for B20.
- Maximum brake thermal efficiency is for neat diesel at maximum loading condition and minimum for B20 at 12kg load.
- Maximum specific fuel consumption is for B20 at any loading condition. It occurs highest at 3kg loading condition and minimum specific fuel consumption is for B10.
- Fuel flow is maximum for B20 at 3kg, 6kg load but after that neat diesel D100 has the maximum fuel flow and minimum for B10.
- Combustion characteristics of B20, Neat heat release is maximum up to (20.244kJ), and maximum pressure rise is 42.61bar at 366 degree.
- Combustion characteristics of B15, Neat heat release is maximum up to (18.23kJ), and maximum pressure rise is 44.24bar at 366 degree.
- Combustion characteristics of B10, Neat heat release is maximum up to (14.98kJ), and maximum pressure rise is 43.54bar at 367 degree.
- Combustion characteristics of D100, Neat heat release is maximum up to (21.93kJ), and maximum pressure rise is 45.39bar at 369 degree.

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