A Review Study on Bio-Diesel Droplet Ignition

V. D. Sonara[1] and Dr. Pravin P. Rathod[2],
PG Student[1], Associate Professor[2]
Mechanical Engineering Department
Government Engineering College, BHUJ-37001

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Biodiesel is one of the part solutions in alleviating the world's dependence on fossil fuels due to the rapid depletion of non-renewable petroleum resources. Biodiesel is an alternative fuel produced from renewable resources with potential to substantially reduce emission associated with petroleum diesel usage.

Combustion and Ignition analysis of Biodiesel and its blends with diesel gives insight into it. Diesel droplet ignition reveals stages of combustion and droplet vaporization at given condition. Further, investigation has proved the effect of Reynolds number on vaporization of droplet at various conditions. Few of the researchers have studied the different parameter(such as Cetane number engine power, economy, engine torque, brake specific fuel consumption ,brake thermal efficiency, exhaust gas temperature) and also find reduction in emission(PM,CO,HC) and increased NO formation. All the fuel tested adheres to the relationship, more or less with droplet complicated size variation and with droplet surface area d^2 v/s time.

Combustion characteristics as well as engine performance are measured for different biodiesel – diesel blends. It has been shown that B50 (50% of biodiesel in a mixture of biodiesel and diesel fuel) gives the highest peak pressure at 1750 rpm, while B10 gives the highest peak pressure at low speed, 1000 rpm. B50 shows upper brake torque, while B0 shows the highest volumetric efficiency. B50 shows also, the highest BSFC by about (12.5–25%) compared with diesel fuel. B10 gives the highest brake thermal efficiency. B50 to B30 show nearly the lowest CO concentration, besides CO concentration is the highest at both idle and high running speeds. Exhaust temperature and NO are maximum for B50. Delay period is measured and correlated for different blends. The delay period is found to be decreased with the increase of cylinder pressure, temperature and equivalence ratio.

***Key words**: Ignition delay; Diesel engine; Bio-Diesel, Combustion*

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1.0 Introduction

The resources of petroleum as fuel are dwindling day by day and increasing demand of fuels, as well as increasingly stringent regulations, pose a challenge to science and technology. With the commercialization of bioenergy, it has provided an effective way to fight against the problem of petroleum scarce and the influence on environment. Bio-Diesel, as an alternative fuel of diesel, is described as fatty acid methyl or ethyl esters from vegetable oils or animal fats. It is renewable, biodegradable and oxygenated. Although many researches pointed out that it might help to reduce greenhouse gas emissions, promote sustainable rural development, and improve income distribution, there still exist some resistances for using it. The primary cause is a lack of new knowledge about the influence of Bio-Diesel on diesel engines. For example, the reduce of engine power for Bio-Diesel, as well as the increase of fuel consumption, is not as much as anticipated; the early research conclusions have been kept in many people's mind, that is, it is more prone to oxidation for Bio-Diesel which may result in insoluble gums and sediments that can plug fuel filter, and thus it will affect engine durability [13].

1.1 Bio-Diesel

This section provides a basic overview of Bio-Diesel. Technical details about many aspects of Bio-Diesel are provided in Sections.

1.1.1Bio-Diesel Basics

Bio-Diesel is a diesel replacement fuel for use in CI engines. Renewable energy source such as natural gas, biogas, vegetable (green) biofuels are recently gained much scientific efforts to be produced in economical, available, safe and environment friendly nature. Bio-Diesel as an alternative fuel derived from vegetable (green) oil or animal fats are oxygenated, biodegradable, on-toxic and environmentally safe. It consists of alkyl monoester of fatty acids from tri-acyglycerols. Bio-Diesel s are classified into two categories; namely edible and non-edible oils. Edible oils are such that sunflower, corn, rapeseed, palm, soybean and waste vegetable oils. The non-edible oils are such that Jatropha, Jojoba, Karanja, Polanga oils and likes [13].

Because plants produce oils from sunlight and air, and can do so year after year on cropland, these oils are renewable. Animal fats are produced when the animal consumes plants or animals, and these too are renewable. Used cooking oils are mostly plant based, but may also contain animal fats. Used cooking oils are both recycled and renewable. The Bio-Diesel manufacturing process converts oils and fats into chemicals called long-chain mono alkyl esters, or Bio-Diesel. These chemicals are also referred to as fatty acid methyl esters (FAME) and the process is referred to as trans esterification. Roughly speaking, 100 pounds of oil or fat are reacted with 10 pounds of a short-chain alcohol (usually methanol) in the presence of a catalyst (usually sodium hydroxide [NaOH] or potassium hydroxide [KOH]) to form 100 pounds of Bio-Diesel and 10 pounds of glycerin. Glycerin is a sugar, and is a co product of the Bio-Diesel process.

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2.0 Diesel Combustion

While diesel engines are well known, an in-depth understanding of how a diesel engine works is required to understand this topic. Some aspects are introduced here, but for a more detailed description see the long report. The diesel engine is a form of compression ignition, internal combustion engine. First built by Rudolph Diesel in 1894, the original version ran on peanut oil. Diesels quickly evolved to use petroleum based diesel, which burnt more completely with less soot than vegetable oils. Diesels use some of the heavier fractions from distillation of crude oil and the fuel is generally composed of blends of C 11 to C hydrocarbon chains.

2.1 Heat Release Rate

One of the most common measures used in analyzing diesel combustion and ignition delay is the heat release rate (HRR), due to the large amount of information gained from it and the simple pressure diagnostics required to determine it. An example of a typical HRR plot is shown in Fig.2.1, showing the three major zones commonly associated with DI diesel engines. After fuel injection begins and before combustion, the fuel takes a short time to ignite. During this ignition delay fuel vaporizes and mixes with air, after igniting this mixture burns rapidly causing what is known as the “pre–mixed burn spike”[17]. Once this prepared mixture has combusted, the burning rate is controlled by mixing of the fuel jet and fresh air. This period is called the diffusion flame, and lasts until the injector closes.

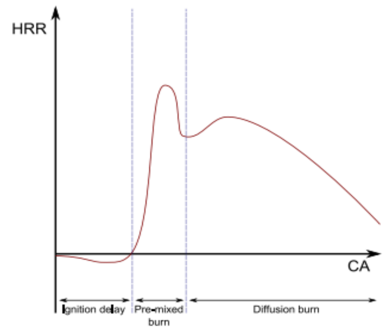

Fig.2.1 typical HRR plot [17]

2.2 Ignition delay

Ignition delay is commonly defined as the time between the start of injection (SOI) and the start of combustion (SOC). These two points in the engine cycle are rather arbitrarily defined. For example, experimental measurements for the start of injection often use Hall Effect transducers to measure needle lift, or monitor fuel rail pressure for a drop corresponding with injection.

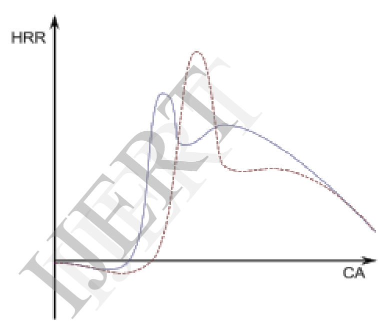

Fig. 2.2: Illustration of the effect of ignition delay on the HRR [17]

Start of combustion (SOC) is also rather arbitrary with many defining it as the first moment of positive heat release, while researchers with visual access usually use the start of luminous flame. Ignition delay is an important tuning parameter. If a fuel is injected and then undergoes a delay before ignition, the fuel evaporates and mixes with the air charge in the cylinder. After ignition, this pre–mixed charge burns very rapidly, producing high pressures. The effect of rapid burning can easily be seen in heat release rate diagrams, where the later the pre–mixed combustion peak occurs the larger it is, as illustrated in Fig.2.2 This rapid combustion produces regions of high temperature which cause large NOx emissions through the thermal NO mechanism and also produce large peak pressures. The rapid pressure rise causes noisy engine running and also means that the design of the engine has to cope with a higher peak pressure. To break down the ignition delay further, it is known that in a perfectly prepared mixture suddenly raised to auto ignition conditions (temperature, pressure, etc.), there will be a delay before ignition. This is referred to as the chemical portion of the ignition delay and is the time required to form the reactive species from unreactive sources. However, the fuel and oxidizer require preparation before these chemical processes can occur. The fuel must vaporize and form a mixture within certain limits of fuel–to–air equivalence ratio. In a diesel engine, the fuel is injected as a liquid spray into hot gas. It then breaks up and forms droplets that greatly enlarge the fuel's surface area, which in turn speeds the evaporation rate.

The time taken for this preparation is referred to as the physical delay. Obviously the physical delay depends on the fuel injection system, in cylinder conditions and fuel physical properties. The chemical delay is assumed to be dependent only on fuel properties, combustion chamber conditions and equivalence ratio.

The ignition delay of a compression ignition (CI) engine is defined as the time (or crank angle) interval between the start of injection and start of combustion [17]. This delay is due to physical and chemical processes that takes place before a significant fraction of the chemical energy of the injected liquid fuel is released. The physical processes are: atomization of liquid fuel jet, evaporation of fuel droplets and mixing of fuel vapour with air. The chemical processes are pre combustion reactions of fuel, air, residual gas mixture that leads to auto ignition. These processes are affected by engine design, operating variables and fuel characteristics. Ignition quality of CI engine fuels are rated by its Cetane number and the ignition delay of CI engine fuel is inversely proportional to its Cetane number. Ignition delay of CI engine plays a significant role in combustion and emission characteristics of the engine. As the delay period increases the maximum rate of pressure rise increases and also engine noise. This will lead to engine knocking which reduce the engine life. Longer delay period will retard the start of combustion closer to TDC and major portion of the fuel gets burned during expansion stroke of the piston which reduces the power developed in the engine. This also increases the BSFC and smoke emission of the engine. Shorter delay period increases the compression work against products of combustion which increase the combustion temperature and hence the NOx formation. As longer as well as shorter delay period leads to considerable side effects, the CI engine has to operate with optimum delay period for effective functioning of the engine. Ignition delay of CI engine was affected by both fuel characteristics and engine design & operating parameters. As the engine combustion and emission characteristics are influenced by ignition delay, its role is vital in diesel engine research. Research on reduction of diesel engine pollutants is progressed significantly to meet the stringent emission norms. Any methodology proposed for reducing the diesel engine pollutants has an effect on ignition delay of the engine. Research works have been carried out to reduce the diesel engine pollutants by modifying fuel injection timing. Effect of fuel injection timing on diesel engine pollutants fuelled with diesel and Bio-Diesel were investigated by many researchers.

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2.2.1. Ignition delay correlations

Arrhenus equation modified by EL-Bahnasy and El-Kotb [15] has been considered, with the help of Heywood [16] to calculate the delay period of Jatropha biodiesel blends [9] with diesel fuels as a function of cylinder pressure, cylinder temperature, and equivalence ratio as follows:

$$\tau_{id} = A\, P^{-n}\, \Phi_1^{-m}\, EXP(\, E_a / \bar{R}\, T)$$

One can get the coefficients A, n, m and the general empirical relation of each blend. Some equations were obtained for each blend as a function of each parameter (P, T, ϕ).

3.0 Literature Review

3.1 Review of Various Literatures:

The literature reviews in with this topic is in below table with chronological order.

Author	Year of paper published	Parameter under observation	Objective of the research paper	Result
C. K. LAW[7]	1982	RECENT ADVANCES IN DROPLET VAPORIZATION AND COMBUSTION " of multicomponent fuels including the miscible fuel blends, immiscible emulsions and coal-oil mixtures.	Fundamental mechanisms governing droplet vaporization and combustion were reviewed and it has given the classical d^2-Law. Its limitations; the major transient processes of droplet heating and fuel vapour accumulation.	Droplet vaporization and combustion was summarized 1.Unsteadiness during single droplet gasification has a variety of causes like unsteady diffusion, Droplet heating, Fuel vapour accumulation, Natural and forced convection, instantaneous droplet size 2. There were two major transient processes involved, namely droplet heating which mostly influences the initial droplet regression rate, and fuel vapor accumulation
C. H. WANG, X. Q. LIU, and C. K. LAW[12]	1984	Combustion and Micro explosion of Freely Falling Multicomponent Droplets " with droplet of n-hexadecane	Multicomponent droplets freely falling in a hot, oxidizing gas flow were studied.	1.Two-compone fuels substantiate a three-staged combustion behavior, with diffusion being the dominant liquid-phase transport mechanism 2.Microexplosion show that its occurrence depends sensitively on the mixture concentration as well as the stability of the droplet generation mode

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M. RENKSIZBUL and BUSSMANN[4]	1993	Multicomponent droplet evaporation at intermediate Reynolds numbers" with hydrocarbon droplet (decane-hexadecane)	The convective evaporation of a binary hydrocarbon droplet (decane-hexadecane) in air at 1000 K and at a pressure of 10 atmospheres has been studied using numerical methods.	1. At elevated pressures, the evaporation of relatively heavy hydrocarbon droplets is essentially controlled by liquid phase heating. 2. Reynolds number decreases largely due to the deceleration of the droplet, as droplet radius varies much more slowly.
S.C. Anthony Lam and Andrzej Sobiesiak[2]	2006	Investigated on Bio-Diesel , ultra-low sulphur diesel and, ethanol Bio-Diesel droplet, ethanol for the droplet combustion	▪ Burning rate and temperature histories were reported. ▪ Apparatus for determining droplet diameter & thermocouple arrangement to measure droplet temperature history ▪ Series of frames from a high-speed movie capturing the entire Bio-Diesel burning sequence ▪ Changes of droplet diameter^2 over time and temperature was observed ▪	Three stages in droplet combustion 1. Warm-up and combustion 2. Combustion of the droplet with the liquid phase boiling 3. Burn-off of vaporized fuel.

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Jiunn-Shyan Huang and Tsong-Sheng Lee[8]	2006	Comparison Of Single-Droplet Combustion Characteristics Between Bio-Diesel And Diesel	Combustion characteristics of Bio-Diesel and diesel was experimentally investigated at Reynolds numbers 93 to 192 Upper branch (93 to 192) Lower branch (192 to 93)	1.Multiple state phenomenon was observed for Bio-Diesel droplet at 119< Re <154 & Diesel droplet at 101<Re<145,multiple flame configuration and burning rate at same Re 2.Ratio of Bio-Diesel and Diesel droplet burning rate 1.4 to 1 in envelope 3.Burning rate decreased by factor 4.35 and 3.03 for Bio-Diesel and Diesel droplet respectively for upper branch when envelope flame transformed in to wake flame 3.Flame of Diesel droplet deeper yellow colour compare to Bio-Diesel
Hyun Kyu Suh,Hyun Gu Roh, Chang Sik Lee[6]	2008	Spray and Combustion Characteristics of Bio-Diesel Diesel Blended Fuel in a Direct Injection Common-Rail Diesel Engine	▪ Effect of the blending ratio and pilot injection on the spray and combustion characteristics of diesel & Bio-Diesel fuel in a direct injection common-rail diesel engine. ▪ Exhaust emissions and engine performance were	1. Single injection, fuel injection profiles for diesel and Bio-Diesel blended fuels are very similar compare to pilot injection; an increase of the blending ratio induced a decrease of the peak injection rate. 2. Effect of fuel blending and injection pressure on single spray tip penetration is slight, and the pilot spray development of Bio-Diesel is shorter compared with the pilot and main injection of diesel

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			conducted at various Bio-Diesel blending ratios and injection conditions for engine operating conditions.	fuel. 3. CO emissions of both fuels with single injection decreased with advanced injection timing. The NO emissions of Bio-Diesel were increased as the injection pressure increased due to the higher heat release rate from the higher injection pressure. It can be seen that No_x increases dramatically as the pilot injection timing approaches the main injection timing because of a high rate of heat release.
Jyotirmoy Barman, R.P. Gakkhar, Vineet Kumar, Vipin Kumar, Sunita Gakkhar[14]	2008	Experimental Investigation of Bio-Diesel Droplet Ignition	▪ Ignition delay of bio-diesel and its blends with diesel at different atmosphere condition has been measured with different droplet diameter.	1. Ignition Delay Bio-Diesel fuel has longer ignition delay than diesel fuel. 2. The ignition delay decreases for blends and depends on the amount of diesel in the blend of diesel and bio-diesel. 3. Activation Energy of diesel and bio-diesel calculated.
K. Anbumani and Ajit Pal Singh[3]	2010	Performance of Mustard & Neem oil blends	▪ Blending with pure diesel in the ratio of 10:90, 15:85, 20:80, and 25:75 by volume ▪ Engine (C.I.) was run at different loads (0, 4,	1. Blending vegetable oils with diesel a remarkable improvement in their physical and chemical properties was observed. Cetane number came to be very close to pure diesel. 2. However, mustard oil at 20% blend with diesel gave best performance as

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			8, 12, 16, and 20 kg) at a constant speed (1500 rpm) separately on each blend and also on pure diesel.	compared to neem oil blends in terms of low smoke intensity, emission of HC and $No_{x.}$
T. Balusamy and R. Marappan	2010	Effect Of Injection Time And Injection Pressure On CI Engine Fuelled With METPSO(Methyl Ester Of Thevetia Peruviana Seed Oil)	Study the effect of injection timing and injection pressure on diesel engine fuelled with methyl ester of thevetia peruviana seed oil on automated, single cylinder, constant speed, and direct injection diesel engine.	1. Initial phase of combustion, the premixed part. Advancing the injection timing by 40crank angle (from 230 to 270 bTDC) resulted in the following improvements at full load: ▪ Increase in the brake thermal efficiency from 31.22% to 33.41%. ▪ Reduction in CO emission to 25%. ▪ Reduction in the HC level from 9.5 to 7.7 ppm. ▪ Reduction in smoke level from 48% to 35%. 2. By optimizing the injection pressure (225 bar) and injection timing (27bTDC) the performance and emissions of the engine with METPSO can be improved significantly.

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Jinlin Xue, Tony E. Grift, Alan C.Hansen[13]	Nov 2010	Effect of Bio-Diesel on engine performances and emissions	For CI engines, Bio-Diesel instead of diesel has been increasingly fuelled to study its effects on engine performances and emissions in the recent. Studies have been reviewed for Bio-Diesel and performances and emissions, were cited preferentially. The effect of Bio-Diesel on engine power, economy, durability and emissions including regulated and non-regulated emissions, and the corresponding effect factors are surveyed and analyzed in detail.	The use of Bio-Diesel leads to the substantial reduction in PM, HC and CO emissions accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in NO emission on conventional diesel engines with no or fewer modification. And it favours to reduce carbon deposit and wear of the key engine parts. Therefore, the blends of Bio-Diesel with small content in place of petroleum diesel can help in controlling air pollution and easing the pressure on scarce resources without significantly sacrificing engine power and economy.
Mohammed EL-Kasaby & Medhat A. Nemit-allah[9]	2012	Researched on ignition delay period & performance test for Jatropha oil Bio-Diesel	Jatropha-curcas as a non-edible methyl ester Bio-Diesel fuel Combustion characteristics as well as engine performance are measured for different Bio-Diesel – diesel blends	1. It has been shown that B50 gives the highest peak pressure at 1750 rpm, while B10 at low speed, 1000 rpm. 2. Higher percentage of NO in case of Bio-Diesel compared with that of diesel was due to the higher combustion temperature of oxygenated Bio-Diesel resulted from

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				advanced injection.

4. Conclusion:

1. One of the above Bio-Diesel is most promising, Jatropha curcas as biodiesel renewable alternative fuel source for diesel engine is preferred to be planted over large desert areas with municipal waste water. Non-edible vegetable (green) oil derived from some plants as Jatropha that can be grown in an un-fertilized land must be widely cultivated to produce bi-diesel fuel instead of using the edible oil plants such as corn, sun-flower, and soybean.
2. Peak pressure of B50 is higher at low and high engine speed, while that of B10 and B20 are optimum at economic engine speed (medium speed).
3. Higher percentage of NO_x in case of biodiesel compared with that of diesel is attributed to the higher combustion temperature of oxygenated biodiesel resulted from advanced injection.
4. Mustard oil at 20% blend with diesel gave best performance in terms of low smoke intensity, emission of HC and NO_x. Cetane number, total fuel consumption, specific energy consumption, specific fuel consumption, brake thermal efficiency, and cylindrical peak pressure were almost equal when engine was run on pure diesel.
5. Experimentally investigated Single-droplet combustion characteristics have the effect at various Reynolds numbers, for Bio-Diesel and diesel.

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