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REVIEW PAPER ON PERFORMANCE OF CI ENGINE WITH DIFFERENT DIAMETER INJECTORS

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Abstract: *There are several types of fuels that are available in our environment but conventional fuels are depleting at a tremendous rate. It is however seen that we have limited amount of resources that are being used in the field of automobile. So it's time to focus on some natural resources such as bio fuel. A bio fuel is a solid, liquid or gas that is made from recently living material. It produces less CO2 when burnt. Ethanol, sugar corn, soya bean are some examples of bio fuels. Bio fuels can also be used in the field of Automobiles. Biodiesel is used in automobile sectors and is a specific type of bio fuel that can be used in diesel engines. An experimental study was carried out to find out the effect of fuel injector nozzle hole diameter on diesel engine performance using straight/crude Waste frying oil- diesel blends. For this experimental study, a 5.97 kW single cylinder, water-cooled, direct injection diesel engine with mechanical dynamometer was used for the experimental work. Engine performance parameters such as brake thermal efficiency (BTE), brake specific energy consumption (BSEC) ,brake power (BP), total fuel consumption(TFC) and exhaust gas temperature were determined. These performance parameters were measured using four different size nozzles. One nozzle with holes of 0.35 mm, second nozzle with all three holes of 0.45 5 mm size, third nozzle with all three holes of 0.55 5 5 mm size. The process of laser drilling was used to increase the diameter of the nozzle holes. Results indicated that brake thermal efficiency decreased with the increase in nozzle size. B20 was having the highest brake power at 20 kg load in case of nozzles with increased nozzle hole diameter*

Key Words: *Diesel, biodiesel, BSFC, BTE, BP.*

1. INTRODUCTION:

Day- to-day, fuel economy of engine is getting improved and will continue to improve. However, enormous increases in number of vehicles have started dictating the demand for fuel. Gasoline and diesel will become scarce and most costly in the near future. With increased use and the depletion of fossil fuels, alternative fuel technology will become more common in the coming decades. All these years there have always been some IC engines fuelled with non-gasoline or diesel oil fuels .However; their numbers have been relatively very small. Because of the high cost of petroleum products, some developing countries are trying to use alternative fuels for their vehicles. Another reason motivating the development of alternative fuels for the IC engines is the concern over emission problems of gasoline and diesel engines. Combined with other air polluting systems, large number of automobiles is the major contributor to the air quality problem of the world. Quite a lot of improvements have been made in reducing emissions from automobile engines. If a 35% improvement made over a period of years, it is to be noticed that during the same time the number of automobiles in the world increases by 40%, thereby nullifying the improvement. Lot of efforts has gone into for achieving the net improvement in cleaning up automobiles exhaust. However, more improvements are needed to bring down the ever-increasing air pollution due to automobile population.

ENGINE PERFORMANCE PARAMETER:

- Specific fuel consumption: Specific fuel consumption is defined as the amount of fuel consumed per unit of power developed per hour. It is clear indication of the efficiency with which the engine develops power from fuel. Brake specific fuel consumption (BSFC) is determined on the basis of brake output of the engine while indicated specific fuel consumption (ISFC) is determined on the basis of indicated output of the engine. (68)

- Brake power: The power developed by en engine at the output shaft is called the brake power (B.P). The measurement of power involves the measurement of force (or torque) as well as speed. The power is measured done with the help of a dynamometer.
- Brake specific fuel consumption (BSFC): It is the measure of fuel efficiency of IC engine that burns the fuel and produces rotational or shaft power. It is typically used for comparing the efficiency of IC engine with a shaft output.
- Brake thermal efficiency (BTE): It is defined as brake power of a heat engine as a function of the thermal input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy.
- Brake specific energy consumption (BSEC): It is defined as product of BSFC and calorific value of fuel.
- Brake mean effective pressure (BMEP): It is the average pressure which is applied uniformly on the piston from top to bottom. An experimental study was carried out to find out the effect of fuel injector nozzle hole diameter on the performance of the CI engine. Straight Waste frying oil oil- diesel blends were used as fuel. Diesel, B5, B10, B15, B20 fuels were used in the engine with nozzles of different diameters i.e. nozzle with holes of 0.35 mm, nozzle with all three holes of 0.45 mm, 0.55 5 5 mm and 0.6 mm. At different loads and different nozzle hole sizes, engine was tested with waste frying oil oil- diesel blends with zirconia (0.3mm) coating. The performance parameters such as brake specific fuel consumption, brake power, brake thermal efficiency, total fuel consumption, brake specific energy consumption and exhaust gas temperature were determined. The engine under study is coupled to a rope brake dynamometer. COIn the compression ignition engines, liquid fuel is injected in the cylinder close to the end of compression stroke in the hot compressed air. The fuel which is injected consists of one orseveral high velocity fuel jets injected at high pressure through small orifices in the injector nozzle, which penetrate far into combustion chamber. The fuel is injected either directly into combustion chamber contained into the bowl in the piston crown (direct injection or open chamber engines, DI) or in a small combustion chamber contained in the cylinder head which is attached to the main chamber in the cylinder (indirect injection engines, IDI) (38)

2. COMBUSTION IN C.I. ENGINE:

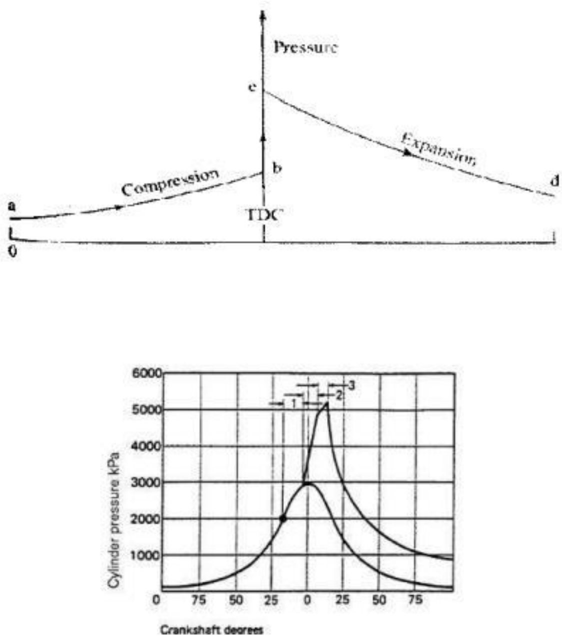
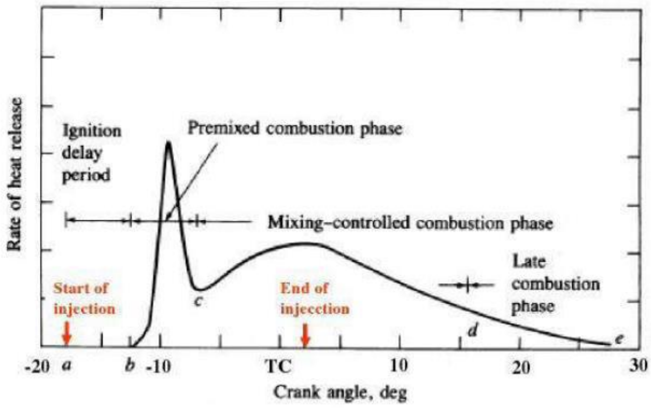


Figure 1. Theoretical diagrams pressure crank angle

The first Stage is referred to as the ignition lag or preparation in which growth and development of a self propagating nucleus of flame takes place. This is a chemical process depending upon both temperature and pressure, the nature of the fuel and the proportion of the exhaust residual gas. Further, it also depends upon the relationship between the temperature and the rate of reaction. (68) The second stage is a physical one and it is concerned with the spread of the flame throughout the combustion chamber. The starting point of the second stage is where the first measurable rise of pressure is seen on the indicator diagram i.e., the point where the line of combustion departs from the compression line.



This can be seen from the deviation from the motoring curve. Page 6 during the second stage the flame propagates practically at a constant velocity. Heat transfer to the cylinder wall is low, because only a small part of the burning mixture comes in contact with the cylinder wall during this period. The rate of heat release depends largely on the turbulence intensity and also on the reaction rate which is dependent on the mixture composition. The rate of pressure is proportional to the rate of heat-release because during this stage, the combustion chamber volume remains practically constant (since position is near the top dead centre) (19) The starting point of the third stage is usually taken as the instant at which the maximum pressure is reached on the indicator diagram. The flame velocity decreases during this stage. The rate of combustion becomes low due to lower flame velocity decrease and reduced flame front surface during this stage. Since the expansion stroke starts before this stage of combustion with the piston moving away from the top dead centre,

3. FACTORS AFFECTING THE COMBUSTION:

- Fuel-air ratio: The composition of the working mixture influence the rate of combustion and the amount of heat evolved. With hydrocarbon fuels the maximum flame velocities occur when mixture strength is 110% of stoichiometric (i.e. about 10% richer than stoichiometric). When the mixture is made or is enriched still more, the velocity of flame diminishes. Lean mixtures release less thermal energy resulting in lower flame temperature and flame speed. Very rich mixtures have incomplete combustion which results in production of less thermal energy and hence flame speed is again low.
- Compression ratio: A higher compression ratio increases the pressure and temperature of the working mixture and decrease the concentration of residual gases. These favorable conditions reduce the ignition lag of combustion and hence less ignition advance is needed. High Pressure and temperature of the compressed mixture also speed up the second phase of combustion.
- Intake temperature and pressure: Increase in intake temperature and pressure increase the flame speed.
- Engine load: With increase in engine load the cycle pressure increase. Hence the flame speed increases.
- Turbulence: Turbulence plays a very important role in combustion phenomenon. The flame speed is very low in non-turbulent mixtures. A turbulence motion of mixture intensifies the process of heat transfer and mixing of the burned and unburned portions in the flame front. These two factors cause the velocity of turbulent flame to increase particularly in proportion to the turbulence velocity. The effects of turbulence can be summarized as follows.
- Turbulence accelerates chemical action by intimate mixing of fuel and oxygen. Hence turbulence allows the ignition advance to be reduced and therefore weak mixtures can be burnt. The increase of flame speed due to turbulence reduces the combustion time and hence the tendency to detonate. no pressure rise during this stage (69).Requirement of diesel injection system: The fuel should be introduced into the combustion chamber within a precisely period of the cycle. The rate of injection should be such that it results in the desired heat release pattern. The quantities of the fuel metered should vary to meet changing speed and load requirements. The injected fuel must be broken into very fine droplets, i.e., good atomization should be obtained. The spray-pattern must be such that it results in rapid mixing of fuel and air. The beginning and the end of injection should be sharp, i.e., there should not be any dribbling or after injection. The injection timing, if desired, should be change to suit the engine speed and load requirements. In the case multi cylinder engines, the distribution of the metered fuel among various cylinders should be uniform. In addition to the above requirements, the weight and the size of the fuel injection system must be less.

4. LITERATURE REVIEW:

M. Vijay Kumar, A. Veeresh babu, P. Ravi Kumar & T. Manoj Kumar Dundi (2019) [1], Influence of different nozzle hole orifice diameter on performance, combustion and emissions in a diesel engine, In this article, the experimental tests were carried out to explore the performance, combustion and emissions by modifying the different nozzles hole size injectors such as (3 holes × Ø = 0.20 mm (modified)), (3 holes × Ø = 0.28 mm (Base)) and (3 holes × Ø = 0.20 mm (modified)). The experiments are performed on Kirloskar 4-stroke computerised solitary cylinder diesel engine fuelled with diesel at 1500 rpm, water-cooled direct injection diesel engine with eddy current dynamometer with the standard injection timing of 23° bTDC with an injection pressure of 210 bar was maintained constant throughout the experiment. From the results, it was pointed out that in all the three different nozzles (3 holes × Ø = 0.20 mm (modified)) improves the vaporisation, atomisation and air-fuel mixing are resulting in a shorter duration. The impressive results are seen in the performance, combustion and emissions. The only negative aspect is the NOx increasing with small orifice Nozzle Hole Diameter.

Semin and Abdul Rahim Ismail (2019) [2], Effect of injector nozzle holes on diesel engine performance, The four-stroke direct-injection diesel engine typical was measured and modeled by Bakar et al (2007) using GT-POWER computational model and has explored of diesel engine performance effect based on engine speeds. GT-POWER is the leading engine simulation tool used by engine and vehicle makers and suppliers and is suitable for analysis of a wide range of engine issues. The details of the diesel engine design vary significantly over the engine performance and size range. In particular, different combustion chamber geometries and fuel injection characteristics are required to deal effectively with major diesel engine design problem achieving sufficiently rapid fuel-air mixing rates to complete the fuel burning process in the time available.

O M I NWAFOR (2018) [3], Effect of advanced injection timing on the performance of natural gas in diesel engines, Concern over the environment and=or the increasing demand for conventional fossil fuel has promoted interest in the development of alternative sources of fuel energy for internal combustion (IC) engines. The effect of advanced injection timing on the performance of natural gas used as primary fuel in dual-fuel combustion has been examined. Satisfactory diesel engine combustion demands selfignition of the fuel as it is injected near the top dead centre (TDC) into the hot swirling compressed cylinder gas. Longer delays between injection and ignition lead to unacceptable rates of pressure rise (diesel knock) because too much fuel is ready to burn when combustion eventually occurs. Natural gas has been noted to exhibit longer ignition delays and slower burning rates especially at low load levels hence resulting in late combustion in the expansion stroke. Advanced injection timing is expected to compensate for these effects. The engine has standard injection timing of 30_ before TDC (BTDC). The injection was first advanced by 5:5_given injection timing of 35:5_ BTDC. The engine ran for about 5 minutes at this timing and stopped. The engine failed to start upon subsequent attempts. The injection was then advanced by 3:5_ (i.e. 33:5_ BTDC). The engine ran smoothly on this timing but seemed to incur penalty on fuel consumption especially at high load levels.

H K Suh, S W Park, and C S Lee (2018) [4], Effect of grouped-hole nozzle geometry on the improvement of biodiesel fuel atomization characteristics in a compression ignition engine. This paper describes the influence of grouped-hole nozzle geometry on the atomization characteristics of a biodiesel fuel. The effects of injection rate profile, spray evolution, droplet mean diameter, and mean velocity of the droplets are investigated in a highpressure injection system. It was revealed that the biodiesel injection rate profile from a single-hole nozzle with the same overall nozzle area shows a similar injection rate profile to that of the grouped-hole nozzle. The injection rate profiles for a split injection strategy are lower than for a single injection and the peak value of the second injection is lower than for the first injection. The Sauter mean diameterdistributions of biodiesel from the grouped-hole nozzle have a larger diameter because the small droplets injected through the grouped-hole nozzle collide and coalesce with each other, which leads to an increase in droplet diameter. From these results, it can be concluded that the use of a grouped-hole nozzle and split injection strategy does not improve on the fuel atomization performance for biodiesel fuel for a single-hole nozzle.

Sattar Jabbar Murad Algayyim , Andrew P. Wandel ID and Talal Yusaf (2017) [5],The Impact of Injector Hole Diameter on Spray Behavior for Butanol-Diesel Blends Optimizing the combustion process in compression ignition (CI) engines is of interest in current research as a potential means to reduce fuel consumption and emission levels. Combustion optimization can be achieved as a result of understanding the relationship between spraying technique and combustion characteristics. Understanding macroscopic characteristics of spray is an important step in predicting combustion behavior. This study investigates the impact of injector hole diameter on macroscopic spray characteristics (spray penetration, spray cone angle, and spray volume) of butanol-diesel blends. In the current study, a Bosch (0.18 mm diameter) and a Delphi (0.198 mm) injector were used. Spray tests were carried out in a constant volume vessel (CVV) under different injection conditions.

Xiangang Wang , Zuohua Huang , Wu Zhang , Olawole Abiola Kuti , Keiya Nishida (2017)[6], Effects of ultra-high injection pressure and micro-hole nozzle on flame structure and soot formation of impinging diesel spray, The effects of ultra-high injection pressure (Pinj = 300 MPa) and micro-hole nozzle (d = 0.08 mm) on flame structure and soot formation of impinging diesel spray were studied with a high speed video camera in a constant volume combustion vessel. Two-color pyrometry was used to measure the line-of-sight soot temperature and concentration with two wavelengths of 650 and 800 nm. A flat wall vertical to the injector axis is located 30 mm away from the injector nozzle tip to generate impinging spray flame. Three injection pressures of 100, 200 and 300 MPa and two injector nozzles with diameters of 0.16 and 0.08 mm were used. With the conventional injector nozzle (0.16 mm), ultra-high injection pressure generates appreciably lower soot formation.

KM Sajesh, Neelesh Soni and Siddhartha Kosti (2016) [6] They perform CFD analysis of a rectangular fin engine is carried out. A two wheeler bike engine is chosen (e.g. Unicorn bike engine) and geometry is designed in Design Modeller in Ansys 16.0.they used for is Al 6063 which has a thermal conductivity of 200 W/m K. a modification in design of engine is made by creating holes on fin. Transient and Steady state heat transfer simulation is carried out on the engine for a period of 400 seconds. An Extensive analysis has been carried out to study the variation of temperature on creation of various diameters 2mm, 6mm, & 10mm holes on fin.

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H.Sumithra & B. Sandhya Rani (2015) [10] After doing the three different coupled (thermal & structural) analysis with three different materials, we found that the maximum stresses for those three materials. Before Modification For Material Aluminum-92, Material Aluminum-96 and Material Aluminum- Silican Nitrate the maximum temperatures are 671.45,665.74 and 505.73. After Modification For Material Aluminum-92, Material Aluminum-96 and Material Aluminum Silican Nitrate the maximum temperatures are 459.68,449.91and 294.95.

M Syamala Devi1, E Venkateswara Rao & K Sunil Ratna Kumar (2014) [11], From this analysis they concluded that shape and thickness along with material plays an important role in defining the amount of heat transfer from the fins. Among the 3 shapes, elliptical shape fins are giving the best results than the rectangular and triangular fins. Also, thickness of the fins plays an important role in heat transfer. As they keep reducing the thickness, heat transfer rate is shooting up for a defined shape and material. But while

Poonia et al (2014) [12], converted a single cylinder 4-stroke diesel engine to operate in the dual fuel mode. They have reported that, brake thermal efficiency is found to be better with larger pilots at light loads. This is because larger pilots lead to stronger ignition source and hence a more complete and rapid combustion of the gaseous fuel. Also increasing the intake temperature at any pilot, leads to an improvement in thermal efficiency by about 1 %. In addition at low loads a small pilot fuel quantity will result in high HC emission levels and poor thermal efficiency due to incomplete and slow combustion. At higher loads, more volume of gaseous fuel admission results in uncontrolled reaction rates near the pilot fuel spray and leads to rapid combustion rates and hence very high rates of pressure rise leading to knock.

Ramesh et al (2013) [13], conducted an experimental work on LPG-Diesel dual fuel engine. They suggested that performance of a dual fuel engine at low loads could be improved by preheating the intake charge, advancing the injection timing, thermal insulation of the combustion chamber, use of hot EGR, and use of proper pilot injection quantity. In addition they reported that use of optimum flow rate of hot EGR with sufficient quantity of pilot fuel injection, the thermal efficiency could be improved by about 1.1 % at part loads.

Shuji Kimura et al (2013) [14], developed a new combustion concept, called modulated kinetics (MK) applied on HCCI mode operation, which simultaneously reduces NOx and smoke levels through low-temperature combustion and premixed combustion respectively without increasing the fuel consumption. Low-temperature combustion is accomplished in the MK combustion concept, by applying heavy exhaust gas recirculation (EGR) to reduce oxygen concentration. They concluded that with lower oxygen concentration, the smoke levels could be reduced to less than 1 BSU and NOx emissions were dramatically reduced by approximately 90 % by the method of MK combustion.

Hisashi Akagwa et al (2012) [15], on a single-cylinder, four strokes, DI diesel engine operated in HCCI mode. Tests were conducted for various inlet air temperatures in order to find its effect of heat release rate. From the experimental results they observed that inlet temperature at 35 °C, 60 °C, and 80 °C, the heat release rate increases and the larger peak as well as smaller peak advances before TDC. Finally they concluded that the most significant observation was that the smaller peak (cool flame) height was progressively decreased from lower temperature to higher temperature.

Zhili chen et al (2012) [16], have conducted experiments on DI diesel engine having compression ratio of 17.7 to investigate the applications of mixing DEE to LPG in various proportions. The results showed that LPG/DEE mixture can operate the engine quietly and smoothly over a wide load range and with excess air ratio between 2.1 to 5.2.

Jajoo et al (2012) [17], have studied about control of smoke emission by LPG-diesel dual fuel engine by using twin cylinder, water-cooled engine of capacity 7.46 kW. The maximum value of smoke density in neat diesel operation was 71 BSU at full load. In the case of dual fuel operation the maximum value was 29 BSU for 50 % pilot injection at full load

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