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EFFECTS OF INTAKE AIR PREHEAT AND FUEL BLEND RATIO ON A DIESEL ENGINE PERFORMANCE CHARACTERISTICS OPERATING ON BIO-DIESEL AND IT'S BLENDS

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ABSTRACT

In this study, performance and exhaust emission characteristics of Pongamia Pinnata oil blends (B10,B20,B30 and B50) with mineral diesel were investigated in preheated intake air conditions in a single cylinder 4-Stroke direct injection CI engine at 75 % maximum load and its rated engine speed 1500 rpm. Two types of heat exchanger designed to preheat the suction air and the heating is accomplished by both engine cooling water and exhaust gases. Two types of heat exchanger includes concentric tube counter flow heat exchanger (to recover heat from engine exhaust gases) and shell and tube heat exchanger (to recover heat from engine jacket cooling water) is mounted along intake manifold to preheat the suction air. Test is carried out at atmospheric air temperature (30^{o}C), preheated air temperature of 45^{o}C,60^{o}C and75^{o}C. Performance parameters such as Mechanical Efficiency, Combustion Efficiency, Brake Thermal Efficiency, Brake Specific Fuel Consumption (BSFC) and Volumetric Efficiency .Investigation revealed that except volumetric efficiency all other performance parameters improved with mineral diesel for all biodiesel blend ratio and it is superior for the blend ratio of B20 for all preheated air temperature .However the volumetric efficiency decreases with increase in biodiesel mixtures for all preheated air temperature.

Keywords: Biodiesel, Pongamia Pinnata, Diesel Engine ,Performance Characteristics, Preheating of Intake Air Temperature and Biodiesel blend ratio.

1. INTRODUCTION

In a normal Diesel engine, about thirty percent of the total energy is rejected to the coolant of the engine cooling system [1].Also Approximately 30% to 40% of heat generated in the process of fuel combustion is exchanged in to useful work in the compression Ignition engines. The remaining heat energy is emitted to the environment through exhaust gases [2].Therefore, even partial use of this waste heat would significantly improve the overall performance of engine [3-6].To improve overall performance of diesel engine, Waste heat energy from the both engine cooling system and exhaust gases is recovered only by the proper design of special and ordinary type of heat exchanger. Waste heat energy can be used to preheat either suction air or diesel fuel by equipping these heat exchangers at the proper location of either in the intake manifold or fuel supply system.

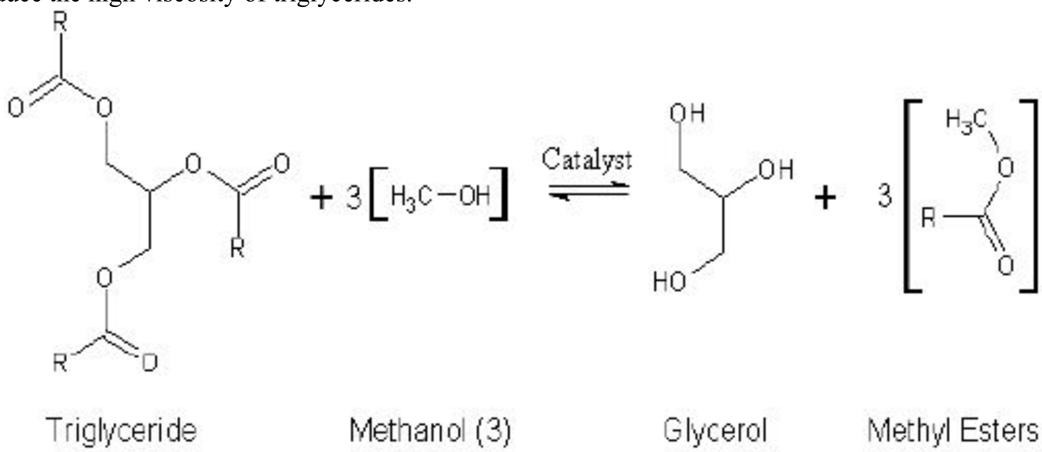
Diesel engine combustion is a complex phenomenon. Various processes affect the efficient combustion such as, atomization and evaporation of the fuel, mixing of the fuel with surrounding gases, self-ignition, oxidation, turbulence induced by air and fuel jet, the possible interaction of the fuel jet with the cylinder walls, heat transfer between the fuel and the surrounding gases, and between combustion gases and the cylinder walls, etc. [7-10]. The homogeneous air–fuel mixing in time is largely influenced by the combustion chamber geometry and the fuel injection characteristics [11-15]. Higher the injection pressures the faster the combustion rates resulting higher combustion chamber gas temperature. This is because of the increasing vaporization rate of spray fuel and reduction of its penetration into the combustion chamber

Biodiesel can produce by using different techniques such as ultrasonic cavitation, hydrodynamic cavitation, microwave irradiation, response surface technology, two-step reaction process etc. Experiments had been conducted for different types of combustion chambers. It was found that spherical combustion chamber gives better results than other type of combustion chambers. The scientists tested a number of different raw and processed vegetable oils like rapeseed oil, sunflower oil, palm oil, soybean oil. [16-18]

In this paper, the required amount of biodiesel is prepared from non-edible source of Pongamia pinnata kernel seed .Methyl ester of Pongamia Pinnata (PPME) is derived by chemical process of Transesterification, its properties are measured and detailed experimental investigation is carried out for different biodiesel (BD) mixtures like B10,B20,B30 and B50 and effects of both preheated intake air temperature and biodiesel blend ratio on performance characteristics are experimentally investigated at 75 % maximum load and at constant rated engine speed. Test is conducted three times and average value taken for calculation purpose. Performance Parameters such as Mechanical Efficiency, Brake Thermal Efficiency, Combustion Efficiency, Brake Specific Fuel Consumption and Volumetric Efficiency calculated and the results are discussed.

2. PRODUCTION OF BIO-DIESEL

The tranesterification process is the reaction of triglyceride (fat/oil) with an alcohol in the presence of acidic, alkaline or lipase as a catalyst to form mono alkyl ester that is biodiesel and glycerol. However the presence of strong acid or base accelerates the conversion. It is reported that alkaline catalyzed transesterification is fastest and require simple set up therefore, in current study the oil of Pongamia Pinnata were transesterified with methyl alcohol in presence of strong alkaline catalyst like sodium hydroxide or potassium hydroxide in a batch type transesterification reactor. The transesterification reaction is given below 22 this process has been widely used to reduce the high viscosity of triglycerides.



To prepare biodiesel from pongamia crude oil first sodium hydroxide was added in to the methyl alcohol to form sodiummethoxide; simultaneously oil was heated in a separate vessel of transesterification reactor and subjected to heating and stirring. When temperature of oil reached at 60°C then sodium methoxide was mixed in to the oil and reaction mixture was stirred for one and half hour. After reaction completion, the reaction mixture was transferred in separating funnel. The mixture of glycerol and methyl ester was allowed to settle for 8 hours. After settling for 8 hours glycerol and methyl esters was separated manually. The methyl ester was the washed with hot water to remove traces of sodium hydroxide impurity. The washed biodiesel then distilled to remove moisture and final good quality biodiesel was subjected for chemical analysis. The property of various biodiesel blends is given in **Table 1.**

Table 1 Properties of Various Biodiesel

Property	**Raw Oil**	**Pongamia Pinnata Methyl Ester (PPME)**	**B10**	**B20**	**B30**	**B50**	**DIESEL**
Density in kg/m^3	938.2	857.9	838.6	841.4	845.8	848.2	833.7
Kinematic viscosity at 40°C in Cst	35.98	21.45	14.32	16.21	17.31	17.45	2.72
Flash point (°C)	237	172	92	102	112	118	48
Fire Point (°C)	320	210	145	156	158	162	220
Calorific Value (MJ/KG)	37.87	41.66	40.34	40.84	41.45	41.78	43.06
Cetane Index	46	48	51	51	53	54	50

3. EXPERIMENTAL SETUP & PROCEDURE

The engine used in this experiment was a single cylinder water-cooled, 4-stroke, DI diesel engine and it was coupled with electric dynamometer. The specifications of the Test Engine are shown in **Table 2**. The dynamic fuel injection timing was set at 24^o BTDC (before top dead center). The engine exhaust emissions like Unburned hydrocarbon (HC) , Nitrogen Oxide (NOx), Carbon Monoxide(CO), and carbon dioxide (CO_2) were measured with AVL Five gas analyzer .AVL Five gas analyzer specification shown in **Table 3.** Fuel consumption was measured by a burette attached to the engine and a stop watch was used to measure fuel consumption time for every 10 cm^3 fuel. A mechanical fuel pump was used in the injection system. Nozzle with a hole diameter of 0.35 mm was used in the injection system. To preheat intake air, two heat exchangers are designed and is provided along with intake manifold as shown in figure 1.The atmospheric air is first heated by the Engine jacket cooling water in a shell and tube heat exchanger and then secondly heated by Engine's exhaust gases in a concentric tube counter flow heat exchanger. Thermocouples are provided at various location in the experimental setup to measures the temperature of preheated air, engine jacket cooling water (both inlet and outlet) and exhaust gas temperature (both inlet and outlet) of the heat exchanger. Separate Flow control valves are also provided to regulate flow of both jacket cooling water and exhaust gases and to maintain the required preheated air temperature. The experiment is conducted for each of Preheated intake air temperature i.e 30^{o}C,45^{o}C,60^{o}C and 75^{o}C for different blending of biodiesel B10,B20,B30,B50 and pure diesel when the engine loaded at 75% of the maximum load and running at its rated speed .The experimental data reading was taken three times and the mean of the three was taken.The experimental set up shown in **Figure 1**. Preheated Intake Air Temperature is noted and corresponding performance parameters like Mechanical Efficiency(η_{mech}),Combustion Efficiency, Brake Thermal Efficiency (η_{bth}), Brake Specific Fuel Consumption (BSFC) and Volumetric efficiency are calculated. The Exhaust emissions like Carbon-dioxide (CO_2), Carbon Monoxide (CO), HC emission, Nitrogen Oxide (NOx) and percentage of excess oxygen were measured and it is noted. The experiments conducted three times and average values are taken for results and discussion.

Table 2 Test Engine Specification

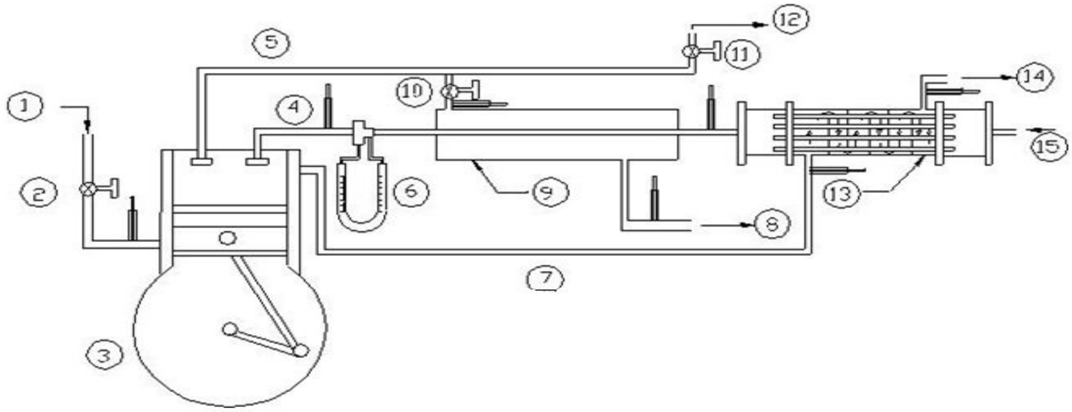
Engine Make	Kirloskar Engine
Engine Types	Single Cylinder Four stroke Diesel engine
Rated HP/KW	5 / 3.7
Engine rated Speed	1500 rpm
Bore Diameter	80 mm
Stroke	110 mm
Brake specific fuel consumption	245 gm/KW-hour
Compression Ratio	16.5:1
Types of fuel pump	High Pressure Mechanical type

Table 3 AVL Five Gas Analyzer Specification

Type	Digas 444
Power Supply	11 to 22 VDC/100-300 VAC @50 Hz
Power Consumption	25W maximum
Operating Temperature	5 to 45 ^{o}C
Storage temperature	0- 50 ^{o}C
Relative Humidity	≤95 % Non-Condensing

Inclination	0 to 90o
Normal Gas flow	1801/h
Maximum Over Pressures	450 KPa
Oxygen Sensor Type	Electro chemical
Oxygen sensor Model	O_2 SENS1

Figure 1.Experimental Set Up For Effects of Intake Suction Air Preheating and Biodiesel Blend Ratio



1.Cooling water Inlet(T 1°C)	**6.U tube Manometer**	**12.Exhaust gas To AVL Five gas Analyser**
2.Flow Control valve	**7Engine Cooling water Outlet**	**13.Shell and Tube Heat Exchanger-1**
3.Diesel Engine loaded with Eddy current Dynamometer	**8.Exhaust gas outlet from HE 2**	**14.Cooling water outlet from HE1**
4.Thermometer Intake Manifold	**9.Concetric Tube Counter Flow Heat Exchanger-2**	**15.Intake air**
5.Exhaust Gas	**10 &11.Flow Control Valve**	

4. RESULTS & DISCUSSION

4.1. Performance Characteristics

4.1.1. Mechanical Efficiency Vs Preheated Intake Air Temperature.

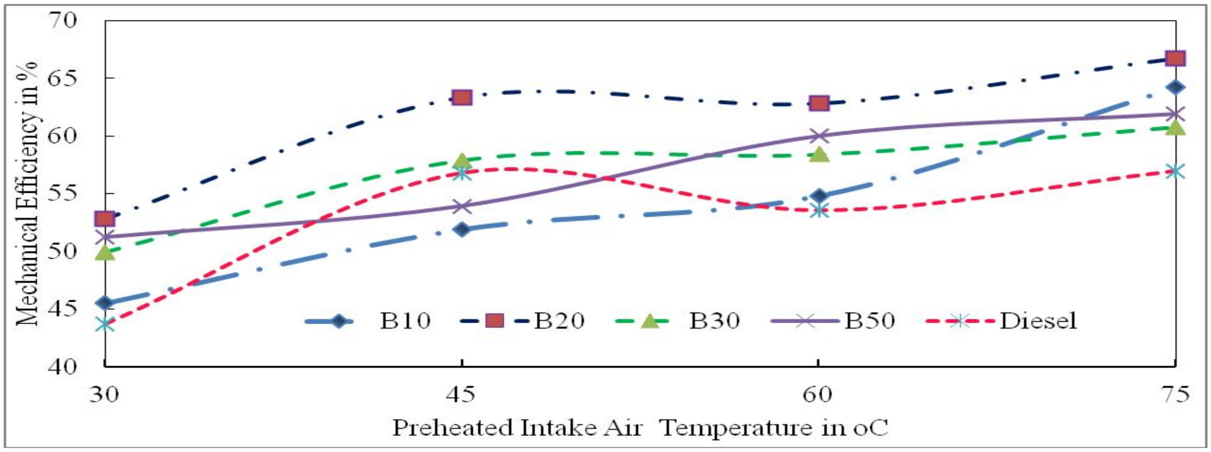


Figure 2 Mechanical Efficiency Vs Preheated Intake Air Temperature

Figure 2 shows the range of percentage change in performance parameters such as mechanical efficiency for different biodiesel blends and mineral diesel with the entire operating Preheated intake air temperature range of the engine. It is observed that, biodiesel mixture having increased mechanical efficiency compared with mineral diesel for all preheated intake air temperature. The mechanical efficiency for B20 biodiesel blend is higher than other biodiesel blend and it is slightly decreases for higher blend ratio . Biodiesel blend B20 produces 65% and 67% of mechanical efficiency at preheated intake air temperature 45^{o}Cand 75^{o}C respectively.

4.1.2 Brake Thermal Efficiency Vs Preheated Intake Air Temperature

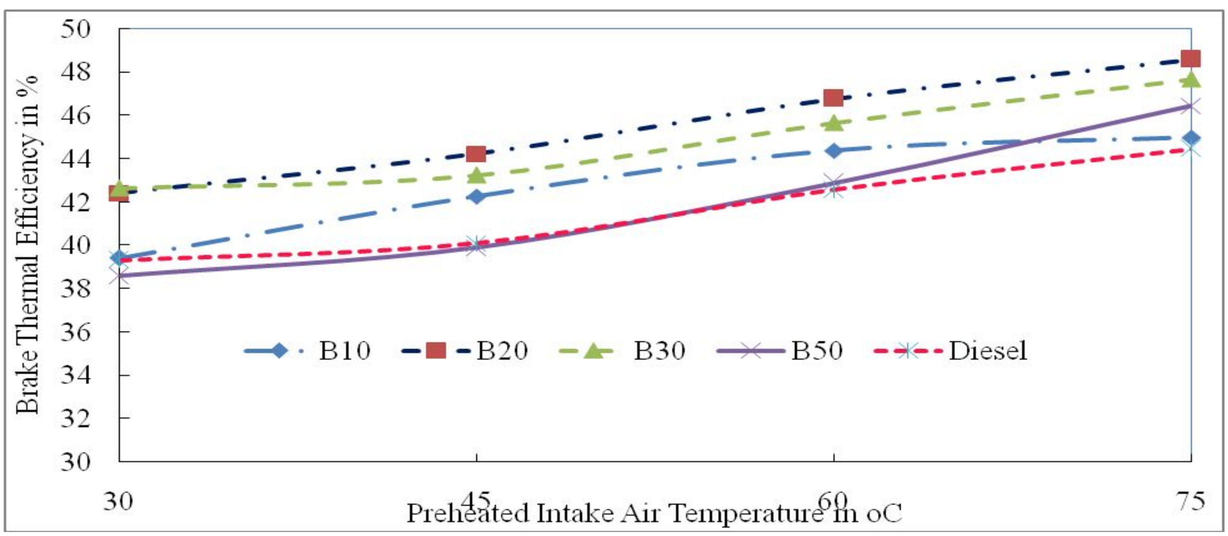


Figure. 3. Brake Thermal Efficiency Vs Preheated Intake Air Temperature

Figure 3 shows the variation of brake thermal efficiency for different biodiesel blends and mineral pure diesel with entire preheated intake air temperature. The brake thermal efficiency is the ratio of brake power output to heat input rate. The brake thermal efficiency is increases in proportion with biodiesel blend increases from B10 to

B20 and is decreases for others. The brake thermal efficiency of different biodiesel blends are higher than that of Mineral diesel and it is improved for lower blend ratio also comparable results are obtained for higher blend ratio with standard mineral diesel.This is due to the reason that improved combustion characteristics of preheated intake air temperature and the presence of oxygen in the biodiesel molecules improves the combustion efficiency of biodiesel hence its brake thermal efficiency increases with respect to mineral diesel at higher preheated intake air temperature. All blends and mineral diesel showed lower brake thermal efficiency at low operating preheated intake air temperature.

4.1.3 Combustion Efficiency Vs Preheated Intake Air Temperature

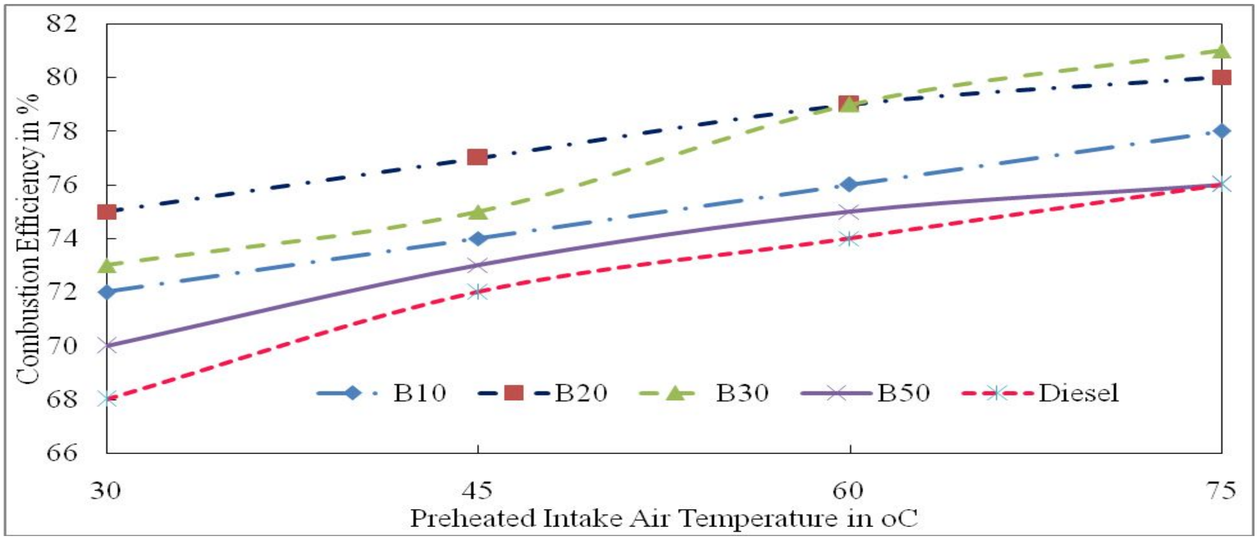


Figure.4.Combustion Efficiency Vs Preheated Intake Air Temperature

Figure 4 shows the variation of Combustion efficiency for different biodiesel blends and pure diesel with preheated intake air temperature It is experimentally observed that ,the combustion efficiency is generally increases for all biodiesel blends and it is higher for low blend ratio and it is lower for higher biodiesel ratio. The Combustion efficiency for the B20 blend is higher than that of other biodiesel blends and mineral diesel for all preheated intake air temperature. However, the combustion efficiency for higher blend ratio is comparable with mineral diesel for all preheated intake air temperature. The B30 biodiesel blend and mineral diesel produces 82% and 74% of combustion efficiency respectively at 75^{o}C preheated intake air temperature.

4.1.4. Brake Specific Fuel Consumption Vs Preheated Intake Air Temperature

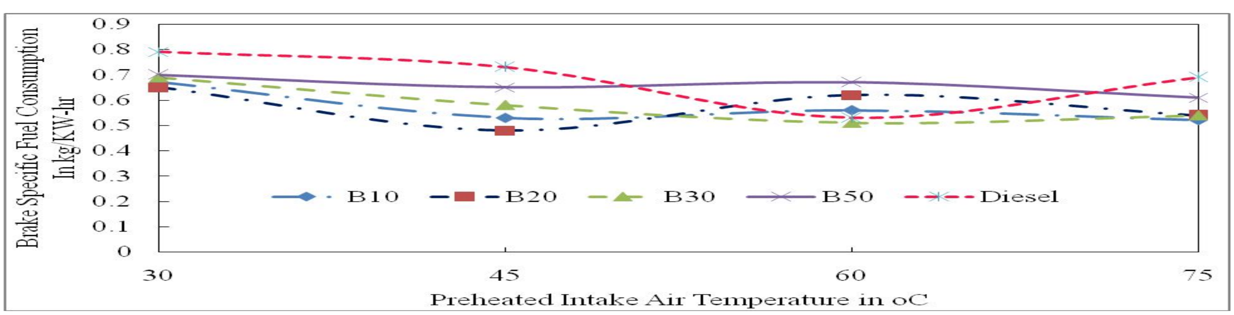


Figure. 5. Brake Specific Fuel Consumption Vs Preheated Intake Air Temperature

Figure 5 shows brake specific fuel consumptions of Standard diesel and various biodiesel blends at ambient temperature and preheated intake air temperature. Overall, all biodiesel blends show lower BSFC than mineral diesel except at 60^{o}C.This is main reason is that preheated suction air reduces fuel consumption considerably and biodiesel blend B20 shows low brake specific fuel consumption.

4.1.5. Volumetric Efficiency Vs Preheated Intake Air Temperature

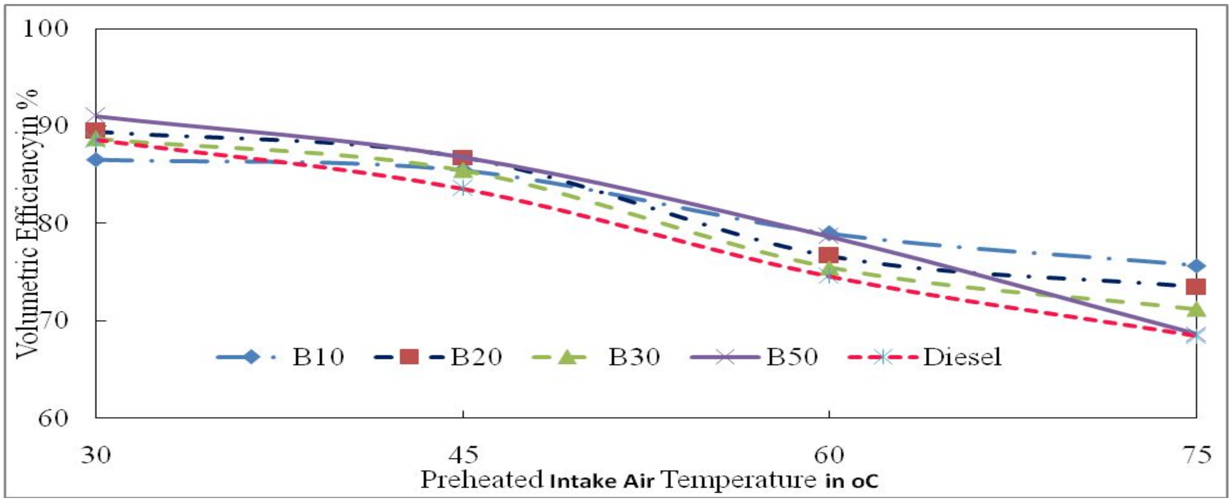


Figure .6. Volumetric Efficiency Vs Preheated Intake Air Temperature

Figure 6 Shows the range of percentage change in volumetric efficiency for different biodiesel blends and mineral diesel for all preheated Intake Air Temperature. It is observed that, the volumetric efficiency decreases for all biodiesel blends and mineral diesel with increase in preheated intake air temperature. This is due to the reason that, preheating decreases the density of air and therefore preheated air contains less densed molecules per unit volume of the cylinder. The volumetric efficiency for biodiesel blend B50 shows higher value about 92% at ambient temperature of 30^{o}C.Because more oxygen content present in higher percentage of biodiesel blends than other blend ratio.

5. CONCLUSIONS

Biodiesel prepared by Transesterifcation process from the non-edible seed of Pongamia Pinnata kernel. Biodiesel blends (B10, B20, B30 and B50) were run in single cylinder 4-stroke diesel engine and intake air preheated by Two heat exchangers (Designed to recover heat from both engine cooling water and engine's exhaust gases) Effects of intake air preheat and fuel blend ratio on performance and exhaust emission characteristics of the engine were investigated when engine operating at 75 % of maximum load and its rated speed for the first time in the literature. In general, The performance characteristics of diesel engine mainly depends on efficient combustion which intern depends on vaporization and atomization of the fuel ,intake air temperature, peak temperature at the end compression and biodiesel and its blend ratio with mineral diesel. It is concluded based on experimental investigation, Except volumetric efficiency other performance parameters increases with increase in both preheated suction air Temperature and blend ratio and among various blend ratio,the B20 blend ratio gives better results on performance compared with other blend ratio and mineral diesel therefore diesel engine is to be operated on the optimum blend ratio of B20.

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