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Increase of Performance and Smoke Emission by Increasing ERG Rate in IDI Diesel Engine using Jatropha Oil and Diesel Fuel Blends

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ABSTRACT

Recently, a study of biodiesel fuel use as a substitute of diesel fuel becomes an interesting topic due to critical fossil fuel availability. The use of biodiesel fuel directly into diesel engine without the change of fuel injector parameter causes the problems because of different properties of biodiesel fuel compared with that of diesel fuel. The aim of present study is to investigate experimentally the effect of exhaust gas recirculation (EGR) on the diesel engine performance and smoke emissions by using jatropha oil and diesel fuel blends as the fuel. EGR is one of methods to increase the fuel efficiency of diesel engine. The use of EGR method on diesel engine may also reduce NOx emissions. In this research, EGR temperature is varied to study its effect on the diesel engine consumption and smoke emissions. Jatropha oil blend is in the range of 10 to 30 %. It is found that the high EGR rate expressed the low fuel consumption compared with that of the low EGR rate by using diesel fuel or jatropha oil - diesel fuel blends. The present paper also shows that the high EGR rate results the high smoke emissions for both cases.

Keywords:EGR rate, EGR temperature, performance, smoke emissions, jatropha oil and diesel fuel blends

ABSTRAK

Akhir-akhir ini penelitian tentang penggunaan bahan bakar biodiesel sebagai bahan bakar substitusi dari bahan bakar diesel menjadi topik yang menarik oleh karena kritisnya ketersediaan bahan bakar fosil. Penggunaan bahan bakar biodiesel secara langsung ke dalam mesin diesel tanpa pengubahan parameter injektor bahan bakar menyebabkan beberaapa persoalan oleh karena sifat-sifat fisik bahan bakar biodiesel yang berbeda dengan bahan bakar diesel. Tujuan penelitian ini adalah untuk meneliti secara eksperimen pengaruh resirkulasi gas buang (EGR) terhadap performa dan emisi jelaga mesin diesel berbahan bakar campuran minyak jatropha dan solar. EGR adalah salah satu metode untuk meningkatkan efisiensi bahan bakar mesin diesel. Penggunaan metode EGR pada mesin diesel juga dapat menurunkan emisi NO_x*. Dalam penelitian ini, temperatur EGR diubah-ubah untuk mempelajari pengaruhnya terhadap consumsi bahan bakar mesin diesel dan emisi jelaga yang dihasilkannya. Campuran minyak jatropha pada penelitian ini diberikan pada rentang 10% sampai 30%. Dari penelitian ini diperoleh bahwa laju EGR yang tinggi memberikan konsumsi bahan bakar yang rendah dibandingkan pada laju EGR yang rendah dengan menggunakan bahan bakar diesel atau menggunakan bahan bakar campuran minyak jatropha dan bahan bakar diesel. Peper ini juga menunjukkan bahwa laju EGR yang tinggi menghasilkan emisi jelaga yang tinggi untuk kedua kasus.*

***Kata kunci**: Laju dan temperature EGR, emisi jelaga, campuran minyak jatropha dan bahan bakar diesel*

INTRODUCTION

Diesel engine has higher efficiency than that of gasoline engine. Therefore, the use of diesel engine as transportation vehicle increases. As a consequence, the diesel fuel demand also rises. In order to minimize the diesel fuel consumption, it is required some techniques to increase an efficiency of diesel engine. One of the techniques to increase the efficiency of diesel engine is an EGR (Exhaust Gas Recirculation) in which a part of exhaust gas is inducted into a combustion chamber. In the EGR system, the exhaust gas mixes with the fresh air and unburned fuel in the combustion chamber. The EGR technique can reduce the fuel consumption without any modification of diesel engine design.

Several investigations of EGR technique were carried out by the researchers. Husberget al. studied the effect of EGR on diesel engine combustion visually for a heavy-duty engine [1]. They found that the EGR had positive effects on the fuel consumption. They used an optical measurement to monitor the spray mixing and to identify the different combustion region. The influence of EGR on auto-ignition quality was investigated by Risberg etal [2]. However, their investigation was focused on a gasoline engine. They observed that there was no evidence of EGR effects on auto-ignition due to the changes in the thermo dynamic parameters caused by EGR. The effects of EGR on a direct injection of natural gas were studied by McTaggartetal [3]. In the present experiment, EGR rate was varied from 0 to 40%. They indicated that the fuel efficiency, NO_x and Co emissions depend on the EGR level. The effects of EGR on the soot formation in a HSDI diesel engine were investigated numerically by Tao et al [4]. They used KIVA-3V code software with an improved phenomenological soot model. The EGR rate was in the range of 0 to 68%.They predicted that the higher soot emissions were resulted at the higher EGR rates. This prediction also expressed that the soot emissions decreased as EGR rate exceeds the critical value (65%). The effects of EGR on particulate morphology for a light-duty diesel engine were studied by Zhu et al [5]. They found that the primary particle sizes increased with the increasing EGR rate. Their results revealed that the EGR rate affects sensitively to the particulate geometry. Modeling of the EGR effects on a heavy duty DI diesel engine by using new quasi-dimensional combustion model was carried out by Pariotisetal [6]. They concerned to the soot and NO emissions. The effects of EGR on the exhaust gas temperature and exhaust opacity in compression ignition engine were studied by Avinashet et al. [7]. They denoted that the exhaust gas temperature was decreased as the increase of EGR rate.

The use of EGR technique in the diesel engine application reduces only a few percent of fuel consumption. For concerning the long–term of conventional diesel fuel, the researchers studied to develop an alternative fuels. Several discussions of biodiesel as alternative diesel fuel have been carried out. Gogoiet al predict the performance of a diesel engine fuelled by the diesel and biodiesel blends using a cycle simulation model [8]. Biodiesel blended with the diesel fuel was in the range 20 to 60% with interval 20%. They found that the similar performance was obtained for biodiesel 20% and 40% blending. However, the brake power and thermal efficiency had better performance in 60% biodiesel blending. Biodiesel as an alternative diesel fuel is distinguished based on their source that is non-edible and edible oils. Both kinds of biodiesel have been studied and applied in the diesel engine. Amit et al. [9], investigated experimentally the influence of non-edible and edible biodiesel oils on the oxidation stability. They blended jatropha biodiesel, pongamia syinthesized (non-edible) and palm biodiesel (edible) to examine the effect on the oxidation stability. The use of waste plastic oil as biodiesel fuel studied by Mani et al [10], they blended the waste plastic oil and diesel fuel to observe their effect on the compression ignition engine.

Based on the study literatures above, the use of EGR in the diesel engine fuelled by jatropha oil and diesel fuel blends is studied experimentally in the present paper. The main goal of this research is to observe the effects of EGR rate on the performance and smoke emissions of diesel engine using jatropha oil and diesel fuel blends.

EXPERIMENTAL METHOD

The test engine specification used in this study is denoted in Table 1. Indirect injection four strokes diesel engine is used in this research. The fuels are injected at 10˚ crank angle. The properties of jatropha oil used in this experiment are shown in Table 2. Jatropha oil has kinematic viscosity of 4.84 cSt at temperature of 40˚C and caloric value of 37 to 38 Mj/kg. Cetane number of jatropha oil is 51with the sulfur content less than 50.

The setup of engine is expressed in Figure 1 which consists of 1. dynamometer, 2. EGR orifice, 3. heater, 4. cooler, 5. fresh air orifice, 6. diesel engine, 7. engine speed censor, 8. fuel control, 9. smoke meter and 10. gas analyzer. EGR (Exhaust Gas Recirculation) is one of the techniques in which a part of exhaust gas is inducted into combustion chamber. The rate of EGR is calculated by using Equation 1.

$$\%EGR = \frac{\dot{m}_{EGR}}{\dot{m}_i} x100\% \quad (1)$$

Where $\dot{m}_{EGR}$ is the EGR rate which is calculated by multiplication among density, velocity of exhaust gas and cross sectional area of EGR pipe. Velocity of exhaust gas in EGR pipe is measured by using an orifice meter.

Table 1. Engine Specification

Engine	4 cylinders 4 strokes indirect injection
Bore	88 mm
Stroke	92 mm
Displacement	2238 cc
Compression ratio	21:1
Injection timing	10˚

Table 2. Physical Properties of Jatropha Oil

Density	0.879 g/ml at 15˚C
Kinematic viscosity	4.84 cSt at 40˚C
Cloud point	5˚C
Ignition point	191˚C
Caloric value	37-38 Mj/kg
Sulfur content	<50 ppm
Cetane number	51
Acid number	198 mg KOH/g
Iod number	95-107

Figure 1. Experimental Setup

In this study, EGR rate is in the range of 0 to 12.6%. Variation of EGR rates is obtained by controlling the valve. $\dot{m}_i$is the inducted mass rate which is obtained from $\dot{m}_i = \dot{m}_{air} + \dot{m}_{EGR}$. Mass of fresh air, $\dot{m}_{air}$, is calculated by multiplying density of fresh air, velocity of fresh air and cross sectional area in which air pass through an intake manifold. Velocity of air inducted into combustion engine is measured by using an orifice manometer.

In this experiment, loads are varied from 25 to 100% with interval 25% which are measured by using a dynamometer. The dynamometer used in this experiment is an absorption dynamometer. The load is obtained by flowing water into dynamometer. Variations of load are acquired by controlling a valve located in the inlet side of dynamometer. In the outlet side of dynamometer, water becomes warm because they absorb heat from the rotor of dynamometer.

Some thermocouples are set in this system to monitor the temperatures of air, exhaust gas and EGR. In this study, EGR temperature is varied in the range of 37 to 100˚C. The temperature of exhaust gas in the outlet manifold of diesel engine is approximately 220 to 350˚C. In order to attain the desired temperature, a shell and tube heat exchanger and a heater are set in the EGR pipe as denoted in Figure 2.

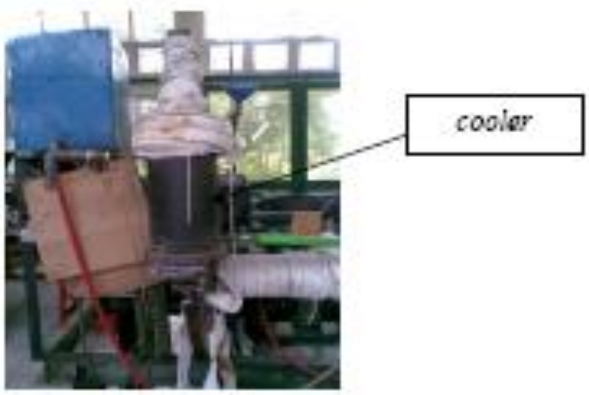

Figure 2. EGR Cooler (shell and tube type)

The heater is set in this experiment because the EGR temperature reduces under the acquire temperature due to heat loss when exhaust gas pass through the EGR pipe. Engine speed is varied in the range of 1300 to 2500 rpm with interval 400 rpm. Engine speed is monitored by using a tachometer. The error data of engine speeds are approximately ± 0.3%.

In this investigation, the fuel is varied with pure diesel fuel (D100), 10% jatropha oil and 90% diesel fuel (B10D90), 20% jatropha oil and 80% diesel fuel (B20D80), and 30% jatropha oil and 70% diesel fuel (B30D70). The fuel consumption is obtained by measuring the oil reduction level during 20 seconds in the measuring glass. The fuel consumption is measured for each variation of parameters.

RESULTS AND DISCUSSION

In this present paper, the performance of diesel engine as the results includes brake power, equivalence ratio and fuel consumption. As it is shown by Figure 3, the comparison of EGR temperature 37 and 100˚C for brake power at the variation of loads and EGR rates with diesel fuel is found. Different colors express the different EGR rates. The solid line denotes for the brake power at EGR temperature of 37˚C and dash line reveals for brake power at EGR temperature of 100˚C. The solid line with black color shows for the case without EGR. The results show that the increase of EGR rate increases the brake power for EGR temperature of 37˚C. However, the brake power reduces with the increase of EGR rate at EGR temperature of 100˚C. This is caused by the rise of heat loss at high EGR temperature. For the diesel engine fuelled with jatropha oil and diesel fuel blends, the high EGR rate at the EGR temperature of 37˚C has the high brake power. Conversely, the high EGR rate at the EGR temperature of 100˚C has low brake power as shown in Figure 4.

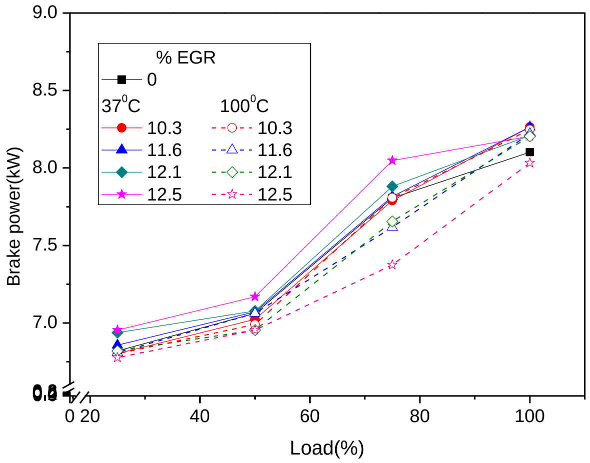

Figure 3. Comparison of EGR Temperatures of 37 and 100˚C for Brake Power in Variation of Loads and EGR Rates at Engine Speed of 2500 rpm with Diesel Fuel.

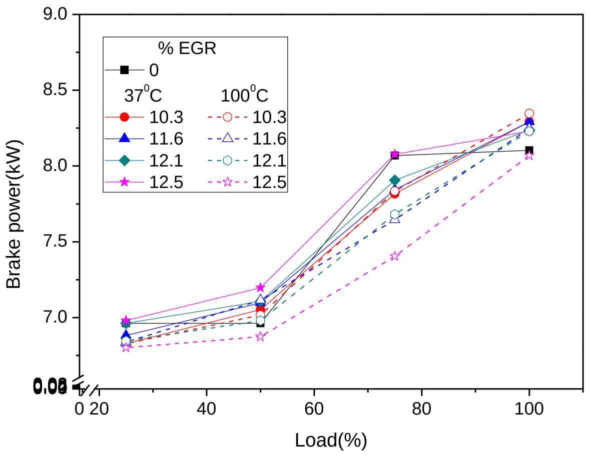

Figure 4. Comparison of EGR Temperatures of 37 and 100˚C for Brake Power in Variation of Loads and EGR Rates at Engine Speeed of 2500 rpm with Jatropha Oil and Diesel Fuel Blends.

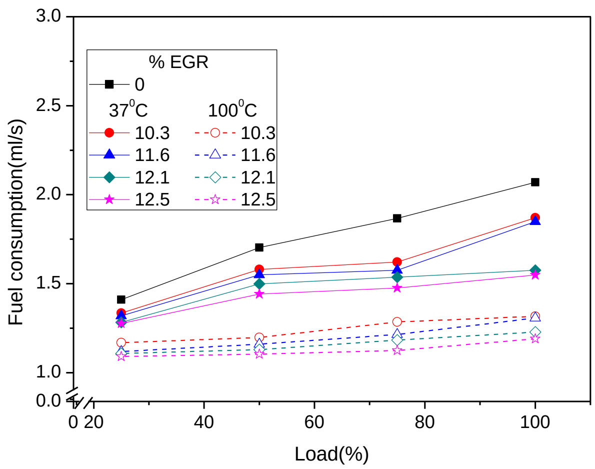

Figure 5. Comparison of EGR Temperatures of 37 and 100˚C for Fuel Consumption in Variation of Loads and EGR Rates at Engine Speed of 2500 rpm with Diesel Fuel.

Figure 5 expresses the comparison of EGR temperatures of 37 and 100˚C for fuel consumption at the variation of loads and EGR rates with the diesel engine fuelled by diesel fuel. The solid line with black color denotes the fuel consumption values in the case of diesel engine without EGR. The solid line with red, blue, dark cyan and magenta color expreses the fuel consumption values at the rise of EGR rate, respectively, in the case of diesel engine with EGR for the EGR temperature of 37˚C. At the EGR temperature of 100˚C, the values of fuel consumption are denoted by the dash line with the different symbols. It can be seen from this figure, the fuel consumption increases as the rise of load. The increase of the EGR rate decreases the fuel consumption. The value of fuel consumption at the EGR temperature of 100˚C is favorable comparing with that of the EGR temperature of 37˚C because the temperature inside the combustion chamber is more warm at the EGR temperature 100˚C than that at the EGR temperature of 37˚C. The use of EGR technique reduces the fuel consumption because it increases the ignition delay providing the fuel droplet to evaporate. By comparing between Figures 6 and 5, the similar tendencies are observed. However, the fuel consumption for the diesel engine fuelled by jatropha oil and diesel fuel blends has a little bit higher than that of diesel engine fuelled by the pure diesel fuel. It can be seen in Figure 6, the rise of EGR rate decreases the fuel consumption. The values of fuel consumption at the EGR temperature of 100˚C is lower than that at the EGR temperature of 37˚C. The intense reduction of fuel consumptiion is found at the high load for the EGR temperature of 37˚C when the EGR rate is increased.Figure 7 denotes the comparison of EGR temperatures of 37˚C and 100˚C for the equivalence ratio at the engine speed of 2500 rpm in the variation of loads and EGR rates with the diesel engine fuelled by diesel fuel.

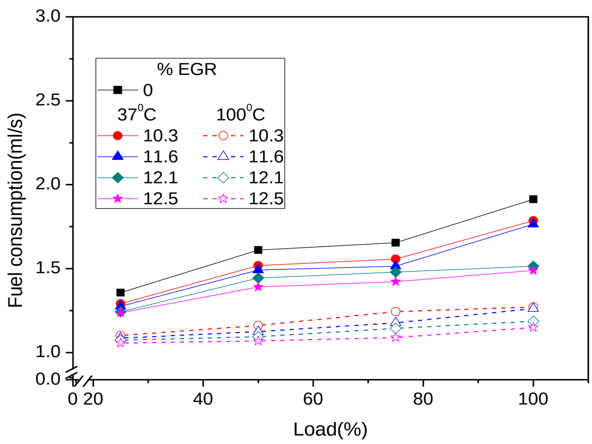

Figure 6. Comparison of EGR Temperatures of 37 and 100˚C for Fuel Consumption in Variation of Loads and EGR Rates at Engine Speed of 2500 rpm with Jatropha Oil and Diesel Fuel Blends.

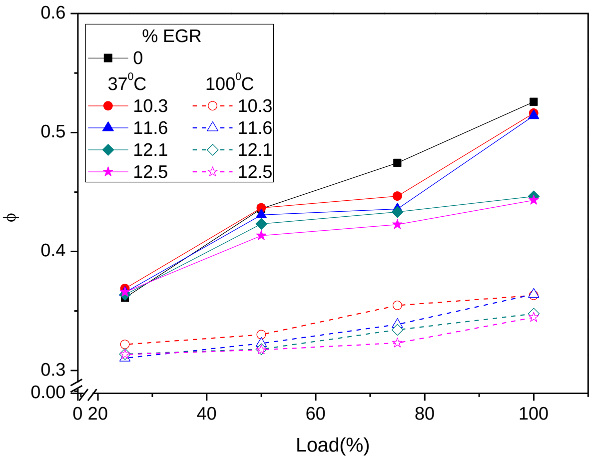

Figure 7. Comparison of EGR Temperatures of 37 and 100°C for Equivalence Ratio in Variation of Loads and EGR Rates at Engine Speed of 2500 rpm with Diesel Fuel.

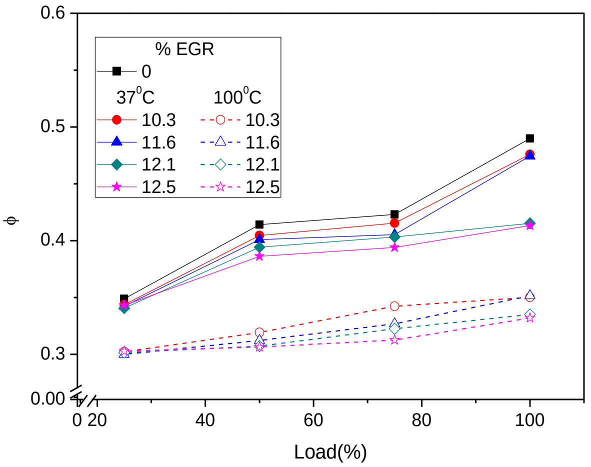

Figure 8. Comparison of EGR Temperatures of 37 and 100°C for Equivalence Ratio in Variation of Loads and EGR Rates at Engine Speed of 2500 rpm with Jatropha Oil and Diesel Fuel Blends.

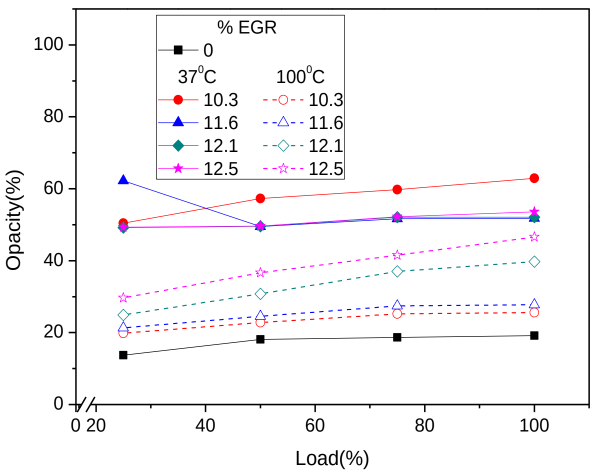

Figure 9. Comparison of EGR Temperatures of 37°C and 100°C for Opacity in Variation of Loads and EGR Rates at Engine Speed of 2500 rpm with Diesel Fuel.

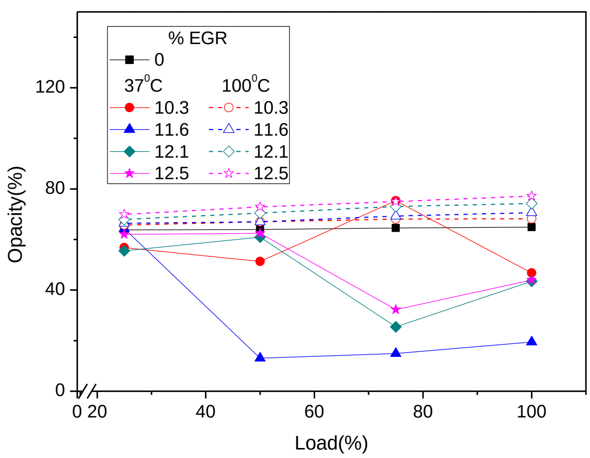

Figure 10. Comparison of EGR Temperatures of 37 and 100°C for Opacity in Variation of Loads And EGR Rates at Engine Speed of 2500 rpm with Jatropha oil and Diesel Fuel Blends.

The solid line with black color expresses the values of equivalence ratio for the diesel engine without EGR. The solid lines with different colors denote the values of equivalence ratio at the EGR temperature of 37°C. While the dash lines with different colors show the values of equivalence ratio at the EGR temperature of 100°C. The results show that the equivalence ratio increases as rising the load. Conversely, the equivalence ratio decreases as the increase of EGR rate. The equivalence ratio at the EGR temperature of 100°C is lower than that at the EGR temperature of 37°C. The intense rise of equivalence ratio is observed at the high load for EGR temperature of 37°C.

By comparing Figures 7 and 8, the similar tendencies are found. In the case of diesel engine fuelled by blending jatropha oil and diesel fuel, the values of equivalence ratio increases as the rise of load. On the contrary, the equivalence ratio decreases as the increase of EGR rate. The equivalence ratio at the EGR temperature of 100°C is lower than that at the EGR temperature of 37°C.

Figure 9 shows the comparison of EGR temperatures of 37 and 100°C for the opacity at the engine speed of 2500 rpm in the variation of loads and EGR rates with the diesel engine fuelled by the diesel fuel. As shown in Figure 9, the opacity increases as the rise of EGR rate. This is caused by decreasing the amount of oxygen from fresh air which is required as an oxidant for carbon atom. The opacity values at EGR temperature of 100°C are lower than that at the EGR temperature of 37°C because the carbon atom is much more oxidized at the high temperature than that at the low temperature. The results also show that the slight increase of opacity as the rise of load. The different results are expressed in the case of diesel engine fuelled by blending jatropha oil and diesel fuel as given in Figure 10. According to this figure, the average value of opacity at the EGR temperature of 37˚C is lower than that in the case of diesel engine without EGR. Conversely, the values of opacity at the EGR temperature of 100˚C are higher than that in the case of diesel engine without EGR. The results also show that the rise of EGR rate increases the opacity values at the EGR temperature of 100˚C, especially. The values of opacity at the EGR temperature of 37˚C fluctuate with the variation of loads.

CONCLUSIONS

The experiment was carried out. The brake power in the case of diesel engine fuelled by diesel fuel had different results for different EGR temperatures. The brake power decreased as the increase of EGR rates at the high EGR temperature. Conversely, the brake power increased as the rise of EGR rate at the low EGR temperature. The similar tendencies were found in the case of diesel engine fuelled by blending jatropha oil and diesel fuel.

Generally, the fuel consumption decreased as the rise of EGR rates in the case of diesel engine fuelled by diesel fuel and blending jatropha oil and diesel fuel. The fuel consumption at high EGR temperature was more favorable than that at low temperature.

As in the results of fuel consumption, the equivalence ratio decreased as the increase of EGR rates. The equivalence ratio at the high EGR temperature was lower than that at low EGR temperature. However, the equivalence ratio with EGR technique was lower than that without EGR.

The opacity increased as the rise of EGR rates in the case of diesel engine fuelled by diesel fuel. While the opacity value at the high EGR temperature was lower than that at low EGR temperature. On the contrary, the opacity values in the case of diesel engine fuelled by jatropha oil and diesel fuel blends were higher at the high EGR temperature than that at the low EGR temperature.

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