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EFFECT OF WINTER AND SUMMER SEASON, SPEEDS AND TYPES OF FUEL ON 4-STROKE DIESEL ENGINE PERFORMANCE PARAMETERS UNDER DIFFERENT LOADS IN THE LABORATORY CONDITIONS

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Keywords:
Engine parameters in winter and summer season, analysis of local fuel, Baiji, Daura, Basrah fuel.

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ABSTRACT

The experiment was conducted at Heat Laboratory - College of Engineering - University of Baghdad during 2013. Three local diesel fuel included Baiji, Daura, Basrah. Five levels of engine speeds included 2000, 2250, 2500, 2750, 3000 RPM and five levels of loads included 2, 4, 6, 8, 10 Nm were used in this study. This study repeated in winter season in January under 13°C and in summer season in July under 39°C. The tests of this research were carried out on four stroke diesel engines to evaluate the effect of winter and summer season on diesel engine performance parameters by using different types of local fuel under different speed and loads. The experiment was executed according to a split split plots design under Randomized Complete Design (RCD) with three replications. Least significant differences (L.S.D) were used to compare means of treatments at 0.05 level. Performance parameters of engine were studied in this experiment are specific fuel consumption, indicated power, exhaust temperature, volumetric efficiency.

The results obtained reveals lowest specific fuel consumption was in Daura fuel in summer. Better indicated power was in Daura fuel in summer. Lowest temperature was in Daura fuel in summer. Best volumetric efficiency was in Daura fuel in winter. Lowest specific fuel consumption was in Daura fuel at 2750 RPM in summer. Better indicated power was in Daura fuel at 3000 RPM in summer. Lowest temperature was in Daura fuel at 2000 RPM in summer. Best volumetric efficiency was in Daura fuel at 2000 RPM in winter. Lowest specific fuel consumption was in Daura fuel at 10 Nm in summer. Better indicated power was in Daura fuel at 10 Nm in summer. Lowest temperature was in Daura fuel at 2 Nm in summer. Best volumetric efficiency was in Daura fuel at 2 Nm in winter. Lowest rate of specific fuel consumption was in Daura fuels at 2750 RPM, at 10 Nm in summer. Highest rate of indicated power was in Daura fuel at 3000 RPM at 10 Nm in summer. Lowest ratio of temperature was in Daura fuels at 2000 RPM at 2 Nm in summer. Highest rate of volumetric efficiency was in Daura fuel at 2000 RPM at 2 Nm in winter.

تأثير فصل الشتاء والصيف والسرع ونوع الوقود على مؤشرات اداء محرك الديزل رباعي الضربات تحت احمال مختلفة في الظروف المختبرية

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الكلمات المفتاحية: اداء المحرك في موسم الصيف والشتاء، تحليل الوقود المحلي، وقود الدورة وبيجي والبصرة.

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الخلاصة

أجريت التجربة في المختبر الحراري– قسم الهندسة الميكانيكية – كلية الهندسة – جامعة بغداد في العام 2013. استعملت في هذه الدراسة ثلاثة مصادر لوقود الديزل بيجي ، دورة ، بصرة، وخمسة مستويات لسرعة المحرك 2000 ، 2250 ، 2500 ، 2750 ، 3000 RPM وخمسة مستويات من الأحمال 2 ، 4 ، 6 ، 8 ، 10 Nm. وأعيدت التجربة في شهر كانون الثاني في درجة حرارة 13°م وشهر تموز في درجة حرارة 39°م. نفذت التجربة على محرك ديزل رباعي الاشواط لدراسة تأثير موسم الشتاء والصيف على كفاءة اداء محرك الديزل باستعمال ثلاثة انواع من الوقود المحلي تحت تأثير خمسة سرع وخمسة احمال مختلفة. نفذت التجربة وفق تصميم التجربة المنشقة المنشقة تحت التصميم الكامل العشوائي (RCD) وبثلاثة مكررات واختبرت الفروق المعنوية بطريقة اقل فرق معنوي على مستوى احتمالية 0.05. وكانت الصفات المدروسة

استهلاك الوقود النوعي والقدرة البيانية ودرجة حرارة العادم والكفاءة الحجمية.

أظهرت النتائج ان اقل استهلاك نوعي للوقود كان عند استخدام وقود الدورة في الصيف. أفضل قدرة بيانية كانت عند استخدام وقود الدورة في الصيف، اقل درجة حرارة للعادم كانت عند استخدام وقود الدورة في الصيف. أفضل كفاءة حجمية كانت عند استخدام وقود الدورة في الشتاء. اقل استهلاك نوعي للوقود كان باستخدام وقود الدورة عند السرعة 2750 RPM في الصيف. أفضل قدرة بيانية كانت باستخدام وقود الدورة عند السرعة 3000 RPM في الصيف. اقل درجة حرارة للعادم كانت باستخدام وقود الدورة عند السرعة 2000 RPM في الصيف. أفضل كفاءة حجمية كانت باستخدام وقود الدورة عند السرعة 2000 RPM في الشتاء. اقل استهلاك نوعي للوقود كان باستخدام وقود الدورة عند العزم 10 Nm في الصيف. أفضل قدرة بيانية كانت باستخدام وقود الدورة عند العزم 10 Nm في الصيف. اقل درجة حرارة للعادم كانت باستخدام وقود الدورة عند العزم 2 Nm في الصيف. أفضل كفاءة حجمية كانت باستخدام وقود الدورة عند العزم 2 Nm في الشتاء. اقل استهلاك نوعي للوقود كان باستخدام وقود الدورة عند السرعة 2750 RPM عند العزم 10 Nm في الصيف. أعلى قدرة بيانية كانت باستخدام وقود الدورة عند السرعة 3000 RPM والعزم 10 Nm في الصيف. اقل درجة حرارة عادم كانت باستخدام وقود الدورة عند السرعة 2000 RPM والعزم 2 Nm في الصيف. أفضل كفاءة حجمية كانت باستخدام وقود الدورة عند السرعة 2000 RPM والعزم 2 Nm في الشتاء.

INTRODUCTION

It is probably safe to say that over 99 percent of the world's internal combustion engines use liquid fuels mostly derived from petroleum. Diesel fuel is a mixture of light distillate hydrocarbons with a higher point range than gasoline. Low speed industrial and marine diesels often use a heavy diesel fuels, (Jain and Rai, 2006). Diesel No.1-D is used for cold weather applications and No.2-D is most common fuel for diesel vehicles. Number 4-D is used for medium to low speed engines and for stationary applications. In terms of combustion considerations the major factors are viscosity and cetane number, (Stalip and Prabhu, 2007). The actual composition of diesel fuel can differ among refineries or over between batches produced at one refinery. Each component used tend to have somewhat different properties and interrelationships with properties of the fuel to which it is added, (Casey, et al., 2005). Vaughn, et al., (2006) said that the fuel with a high cetane number starts to burn shortly after it is injected into the cylinder, therefore, it has a short ignition delay period. A fuel with a low cetane number resists auto ignition and has a longer ignition delay period, so that starting of combustion is nearer to top dead center. This is similar to retarding of injection timing, although the cetane number of a fuel is assumed to predict its ignition delay in any engine. Meher, et al., (2004) shown that the increasing of the cetane number value above that required for a given engine may not improve engine performance. Rakopoulos and Kyritsis, (2006) mentioned that the minimum cetane number for diesel fuel (Grades No.1 and 2) is 40. Some manufacturers may recommend higher cetane number fuels, so the vehicle or equipment owner's manual should always be consulted. Satge, et al., (2001) found that if the liquid fuel supplied to engine in fully or partly vaporized condition, the volatility of the fuel may result in a mixture temperature below sometimes above that of atmosphere or of the supercharging air supplied to the engine and thus increase or decrease the effective heat value of mixture. Kidoguchi, et al., (2000) indicated that the density had been used as a primary indicator of liquid products, however the higher value products have lower densities, a diesel fuel with a low API gravity (increased density) contains more energy per gallon (heat value), such a fuel would tend to improve economy. Hansen, et al., (2005) illustrated that the viscosity indicates the ease at which it can be pumped and the ease of atomization. Tat and Van, (2003) said that the liquid fuel is injected into combustion space of the diesel cylinder by a high pressure pump and this pump must overcome the resistance of the liquid to flow and friction which resists the motion of the pump. Mohamad, et al., (2002) shown that the high viscosity also may cause filter damage and can impact injector spray patterns. Broge, (2002) found that the viscosity of liquids increases with decreasing temperature. Beatrice, et al., (2000) illustrated that the greater number of carbon atoms leads to greater viscosity of the fuel. If two hydrocarbons have the same number of carbon atoms, the one with the lower hydrogen content will have a higher viscosity. Rakopoulos, et al., (2004) indicated that the evaporation and mixing of diesel fuel with air is essential for ignition and burning, fuel with higher front - end volatility tends to improve starting and warm up performance and reduce smoke. Zhou, et al., (2003) shown that the ideal

fuel volatility requirement will vary based on engine size and design, speed and load conditions and atmospheric conditions. More volatility fuels may provide better performance for fluctuating loads and speeds such as those experienced by trucks and buses. Monyem and Van, (2001) mentioned that the pour point is the lowest temperature at which the fuel will flow and is used to predict the lowest temperature at which the fuel can be pumped. When this temperature is reached, the fuel can no longer be moved effectively with pumps. When the flow of the fuel stops, the engine will die. Sen, (1984) shown that the portion of the power developed inside the cylinder (indicated power) is lost in friction between the moving parts in the engine. The net power available at the crankshaft for doing useful work is known as shaft power or generally called brake power (B.P). Rente, (2004) shown that the Specific fuel consumption is a useful measure of engine performance because it relates directly to the economy of an engine. It enables the operator to calculate how much fuel is required to produce a certain power output for a certain length of time. Andersson, (2006) mentioned that the calorific values of most fuels are approximately the same, so specific fuel consumption can also be used for comparing the economy performance of different types of engine. Westerberg, (2003) said that when the mixture Ø (air/fuel ratio) increases (fuel quantity increases), the specific fuel consumption increases. With an increase in the fuel, the amount of heat generated increases, and simultaneously indicated power (IP) developed also increases. But the rate of increase in IP is less than the rate of increase in fuel, therefore, the specific fuel consumption continuously increases. Jain and Rai, (2006) mentioned that the heating values are defined as higher calorific value (HCV) or lower calorific value (LCV) depending on whether the water created in combustion is recovered as liquid or vapor respectively. Kalligeros, et al., (2004) indicated that the less than half (34%) of the fuel equivalent power is available for useful work at the flywheel of an engine. Khovakh, (1979) mentioned that the amount of air entering the cylinder due to the vacuum created by the downward motion of the piston is always less than the actual displacement of the piston. Eriksson, (2002) shown that the power obtained from an engine depend upon the mass of combustible mixture drawn into the cylinders and given a mixture with the correct air fuel ratio. So any reduction in volumetric efficiency will reduce the power output.
The objectives of this study can be summarized as follows :

1. To choose suitable fuel from the local sources (Baiji, Doura, Basrah) to get highest performance of the engine to use in winter and summer season.
2. To choose suitable speed and load of the engine for getting highest engine performance in winter and summer season.

MATERIALS AND METHODS

The experiment was conducted at Heat laboratory - College of engineering - University of Baghdad to evaluate the effect of winter and summer season on diesel engine performance parameters by using different types of local fuel under different speed and loads. Three local diesel fuel were used in the experiment Baiji, Daura, Basrah. Analyses of the samples of sources were conducted at Quality Control and Researches Department – AL-Daura – Midland Refineries Company. Table (2) shows the results of fuel analyses. The tests of this research were carried out on four stroke diesel engines. Table (1) shows the technical specifications of the engine. This engine is linked horizontally with a hydraulic device to measure the power with all its instrumentations. The instrumentation unit is designed to housing the instruments necessary for measuring the engine performance. It contains the fuel system, the air box/viscous flow meter, the torque meter, speed measurement device, exhaust temperature measurement device. Figure (1) shows the linking of the engine accessories. Three local diesel fuel included Baiji, Daura, Basrah. Five levels of engine speeds included 2000, 2250, 2500, 2750, 3000 RPM and five levels of loads included 2, 4, 6, 8, 10 Nm were used in this study. This study repeated in winter season in January under 13°C inside the laboratory and in summer season in July under 39°C inside the laboratory. The engine speed is measured electronically by a Tachometer, the torque is measured by hydraulic dynamometer connected with a rotary potentiometer (Willard, 1997), the output of the potentiometer is fed into the input of the torque meter. The experiment was executed according to a split split plots design under Randomized Complete Design (RCD) with three replications. Where the sources of fuel was treated as sub secondary, speed treated as secondary and load treated as main. Least significant differences (L.S.D) were used to compare means of treatments at 0.05 level.

Table. 1: The Technical Specifications of The Engine.

Engine Manufacturer	'Robin' - Fuji DY23D.
Piston Displacement	230 cm^3.
Stroke	60 mm.
Bore	70 mm.
Nominal Output	3.5 kW at 3600 rev/min.
Maximum Torque	10.5 Nm at 2200 rev/min.

Table. 2: The Analyses of The Fuel Samples.

Data	Baiji	Basra	Daura
SP. Gravity @ 40˚C	0.8333	0.8319	0.8309
API. Gr. @ 100˚C	38.6	38.8	38.3
Flash point ˚C	75.4	72.4	80.0
Colour (ASTM)	0.5	0.5	0.5
Pour Point ˚C	-15	-12	-9
Vis Cst @ 40 ˚C	2.83	2.74	3.3
Carbon Res. Wt %	0.09	0.097	0.15
Sulfur. Wt %	1.048	1.188	1.1
Diesel Index	60.1	59.4	62.2
Cetane No.	58.5	56.0	58.5
Calorific Value Kcal/Kg	10947	10950	10942
Distillation: I.B.P	193	188	183
10 %	226	224	213
20 %	241	240	228
30 %	254	254	245
40 %	264	260	255
50 %	274	277	265
60 %	283	288	275
70 %	293	300	286
80 %	303	318	298
90 %	320	343	320
E.P ˚C	348	376	345
T.D. %	99.5 ML	99.5 ML	99 ML
Res.	0.4 ML	0.4 ML	0.9 ML
Loss	0.1 ML	0.1 ML	0.1 ML
Rec. @ 350 %	--	--	94 ML

Performance parameters of engine were studied in this experiment are:

1. Measurement of Brake Specific Fuel Consumption: the fuel flows into the bottom of a pipette, graduated in volumes of 8, 16 and 32 ml. The fuel consumption is determined by measuring the time (t) taken for the engine to consume a given volume of fuel, say (8) ml. Thus, the fuel consumption can be determined by the following equation, (Chaven and Pathak, 2008):

$$m^{\circ}_{f} = \frac{sg_f \times 8 \times 0.001}{t} \times 3600 \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

Where:
m°_{f} = Fuel Consumption (kg/hr).
sg_f = Specific Gravity of the fuel (kg/L).
Thus, Brake Specific Fuel Consumption can be calculated from this equation, (Jain and Rai, 2006) :

BSFC = $\frac{m^{\circ}{}_{f}}{BP}$ ……………………………. (2)

Where:
BSFC = Brake Specific Fuel Consumption (kg/kW.hr).
$m^{\circ}{}_{f}$ = Fuel Consumption (kg/hr).
BP = Brake Power (kW).

2. Measurement of Indicated Power : The friction power measured by Willan`s Line method and the brake power can be calculated from this equation, (Willard, 1997):

BP = $\frac{2\pi NT}{60{,}000}$ ……………..…….………. (3)

Where :
BP = Brake Power (kW).
N = Engine Speed in Revolution Per Minute.
T = Torque Produced (Nm).
Thus, Indicated Power (IP) can be calculated from the following formula, (Mohanty, 2007) :
IP = BP + FP ………………………..…... (4)
Where :
IP = Indicated Power (kW).
BP = Brake Power (kW).
FP = Friction Power (kW).

3. Measurement of Volumetric Efficiency: The air consumption measured by an inclined tube manometer calibrated in millimeters of water connected with an air tight chamber fitted with a sharp edged orifice to reduce the pressure pulsations. Volumetric Efficiency can be calculated from this equation, (Maleev, 1985) :

ŋv = $\frac{2m^{\circ}{}_{a}}{60 \times N \times \rho_a \times Vs}$ …………………..… (5)

Where :
ŋv = Volumetric Efficiency (%).
$m^{\circ}{}_{a}$ = Air Consumption (kg/hr).
N = Speed in revolution per minute.
ρ_a = Air Density (kg/m^3).
Vs = Swept Volume of The Cylinder (m^3).

4. Measurement of Exhaust gas temperature: Exhaust gas temperature is measured by a Chrome/Alumel thermocouple connected with a direct reading meter scaled from 0 to 1000˚C.

The statistical analysis was carried out by using of SAS, (2000) program.

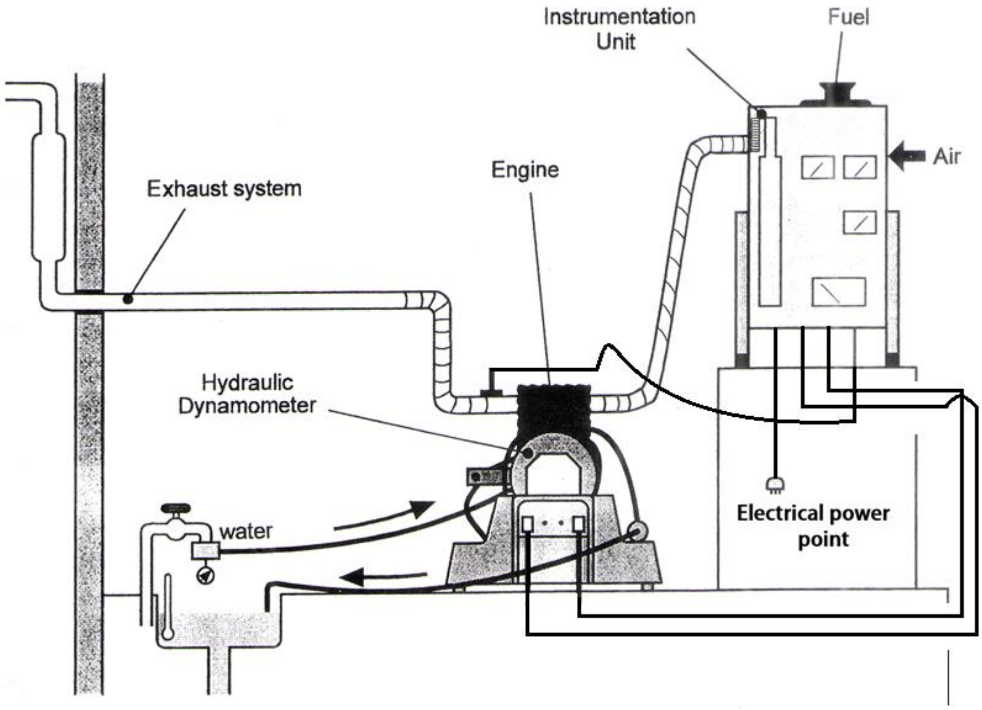

Fig. 1: The Linking of The Engine Accessories.

RESULTS AND DISCUSSION

Effect of parameters on Brake specific Fuel Consumption:

Figure (2) & (3) illustrates that the season have a clear impact on Brake Specific Fuel Consumption (BSFC) of fuel sources. The type of Baiji fuel registered the highest percentage of BSFC in winter followed it Basrah, and Daura. Daura fuel had the lowest ratio of BSFC for all velocities and torques in summer season. Which may be due to the conversion of chemical energy of fuel to thermal energy in Daura fuel in summer better than the rest, may be due to the high temperature of the air in summer leads to complete combustion of the fuel. Thereby reducing the amount of fuel needed to produce the power. This is in line with what happened to the indicated power for Daura fuel in summer, where was the largest from the remaining sources of fuel, which reduces fuel consumption. Higher BSFC was in Baiji fuel in winter at 2000 RPM and less ratio of BSFC was in Daura fuel at 2750 RPM in summer. The rising of Baiji fuel consumption at 2000 RPM in winter is attributable to the low temperature of air in winter leads to formation of quench zone within the combustion chamber, leads to extinguishment of the flame. Thereby increasing the amount of fuel needed to produce the power as well as decrease the speed decreasing the brake power of the engine. Since the relationship between the BSFC and the brake power is reverse, thus BSFC increasing for all types of fuel. While the BSFC varies by the difference of fuel composition and its ability to liberate thermal energy. This is in line with increasing the indicated power for Daura fuel in summer more than the rest of the types, where the fuel thermal energy increases the amount of fuel decreases which needed to generate the power compared with other types of fuel. Highest ratio of BSFC was in Baiji fuel at 2 Nm in winter and lowest ratio of BSFC was in Daura fuel at 10 Nm in summer, for all speeds. The reason is that the rise of temperature of air leads to increase the amount of converting of chemical energy of Daura fuel to useful work which leads to reduce the BSFC. As well as increase the torque will increase the brake power which reduce BSFC for all types of fuel. But the BSFC varies by the difference of fuel composition and its ability to release large amount of the thermal energy during combustion. This is in line with increasing the indicated power for Daura fuel in summer larger than the rest of the other fuels where the increase of indicated power converts the chemical energy of fuel to a useful work increasingly and thus the fuel consumption reduces comparing with other types of fuel. Generally, we realized that the highest rate of BSFC was in Baiji fuel at 2000 RPM at 2 Nm in winter and the lowest rate of BSFC was in Daura fuels at 2750 RPM, at 10 Nm in summer.

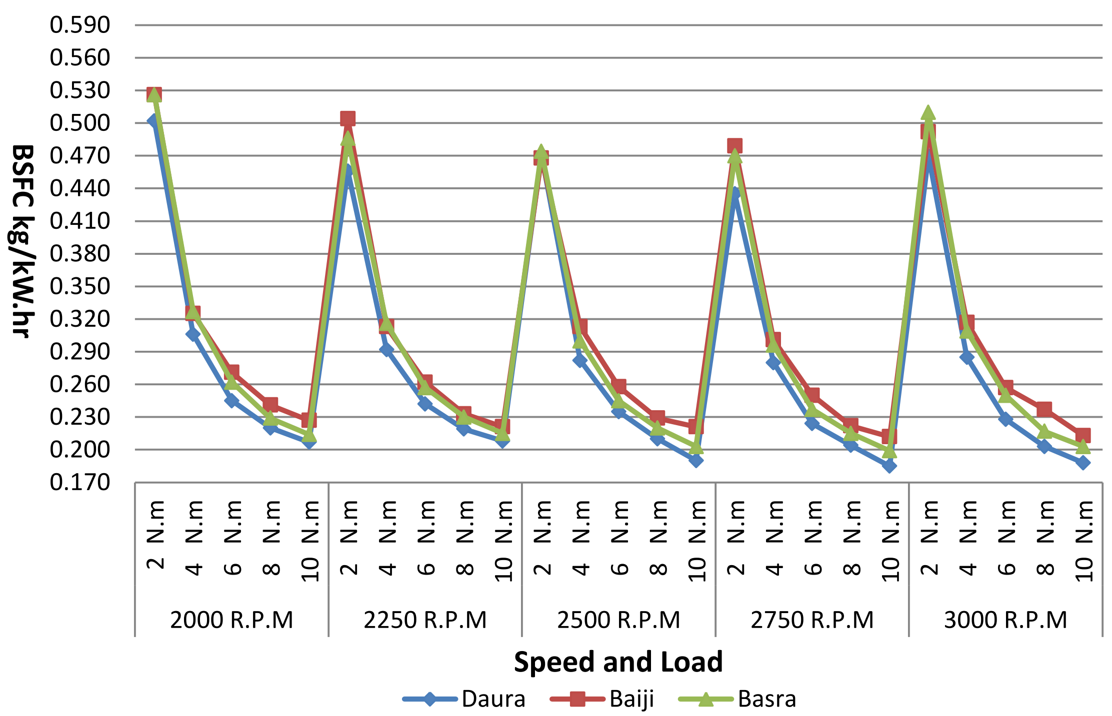

Fig. 2: Effect of summer season and fuel sources on BSFC

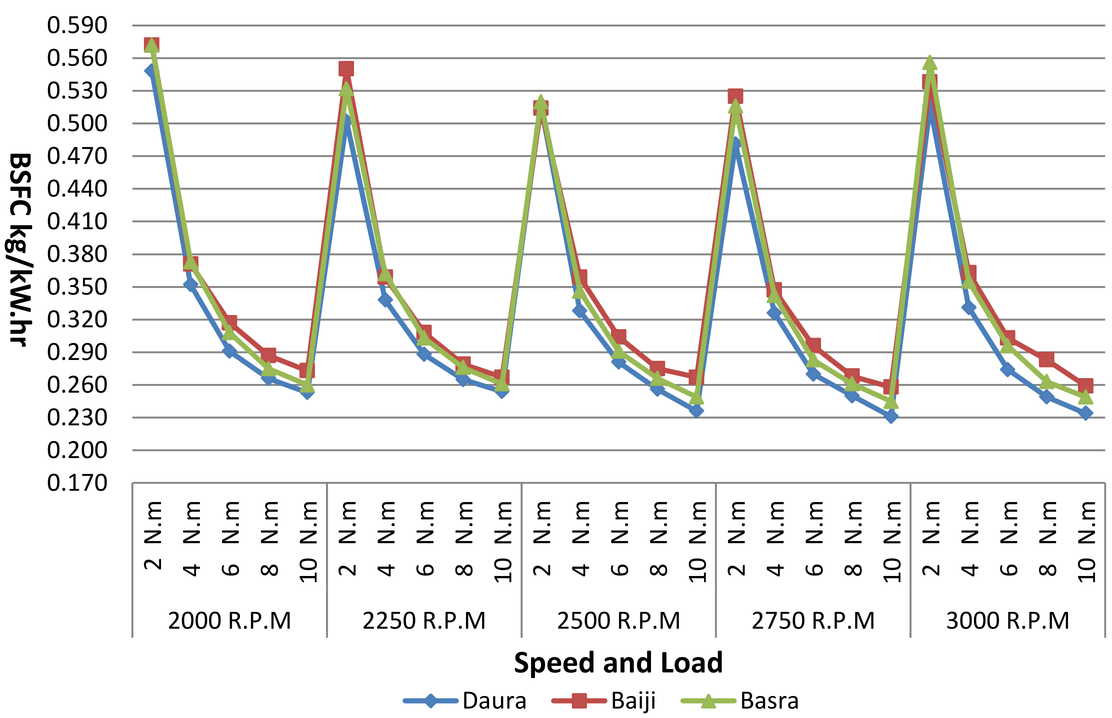

Fig. 3: Effect of winter season and fuel sources on BSFC

Effect of parameters on Indicated Power:

Figure (4) & (5) illustrates that the season have a clear impact on indicated power (IP) of fuel sources. The type of Daura fuel in summer registered the highest percentage of indicated power followed it Basrah and Baiji. Baiji fuel in winter had the lowest ratio of indicated power for all velocities and torques, which may be due to the chemical composition of fuel and its suitability for full combustion in winter at these conditions. Thereby the different chemical structure of the fuel leading to a disparity in the liberation of chemical energy of fuel to useful work. This explained the difference between the fuel power and the power on the piston (IP) for the same fuel comparing with other sources of fuels. We noticed that the fuel with highest power has a less indicated power in winter (IP always less than fuel power) because of the loses of energy during the combustion process in winter which maybe the cause to the chemical structure of the fuel where the fuel would not be able to complete combustion within the conditions of combustion chamber in winter like heat. This result agree with Hansen, et al., (2005). Highest ratio of indicated power was in Daura fuel at 3000 RPM in summer and lowest ratio of indicated power was in Baiji fuel at 2000 RPM in winter for all torques. The reason maybe that the increasing of speed leads to inject more fuel into the combustion chamber, in addition the generation of heat in summer more than winter and good distribution of air with the fuel within these speed which increases the combustion efficiency and the amount of energy transformed to a useful work and reduce the losses of fuel. Also we noticed that the variance between the fuel power and the indicated power for fuel sources and its ability to liberation of power at these speeds. Highest ratio of indicated power was in Daura fuel in summer at 10 Nm and lowest ratio of indicated power was in Baiji fuel in winter at 2 Nm for all speeds it may be due to the increase of torque which leads to injecting more fuel inside combustion chamber, and the rise of air temperature in summer leads to complete the combustion of fuel thereby increasing the amount of converting of thermal energy of Daura fuel to useful work during the combustion. Generally, we note that the highest rate of indicated power was in Daura fuel at 3000 RPM at 10 Nm in summer and the lowest ratio of indicated power was in Baiji fuels at 2000 RPM at 2 Nm in winter.

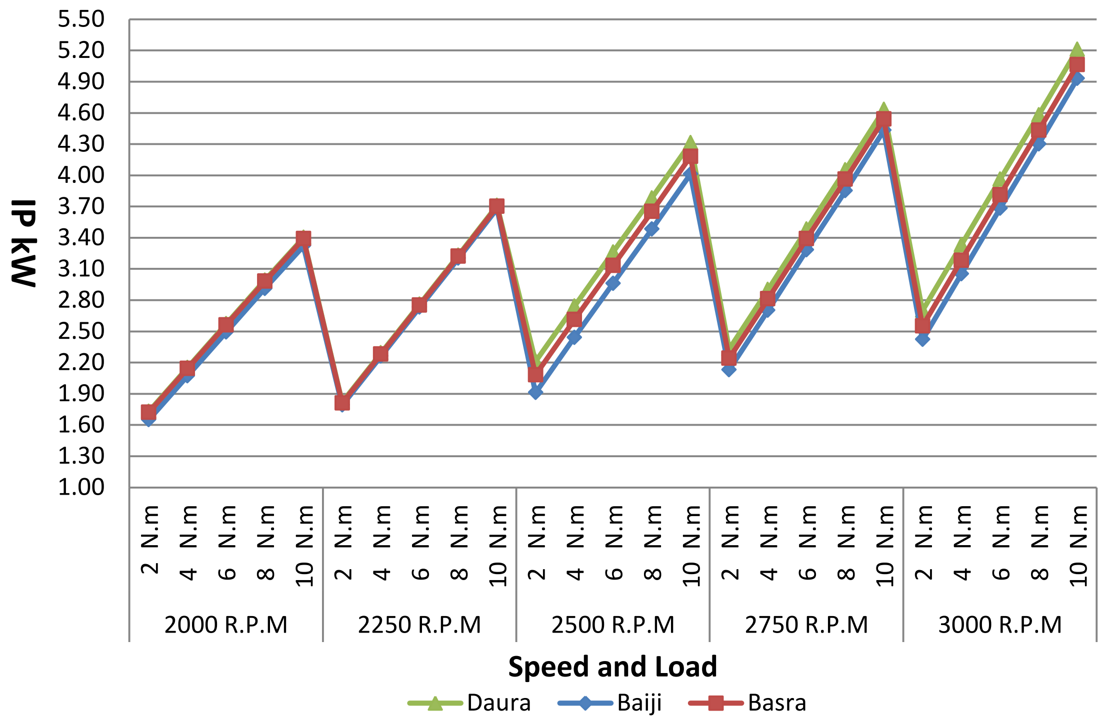

Fig. 4: Effect of summer season and fuel sources on IP

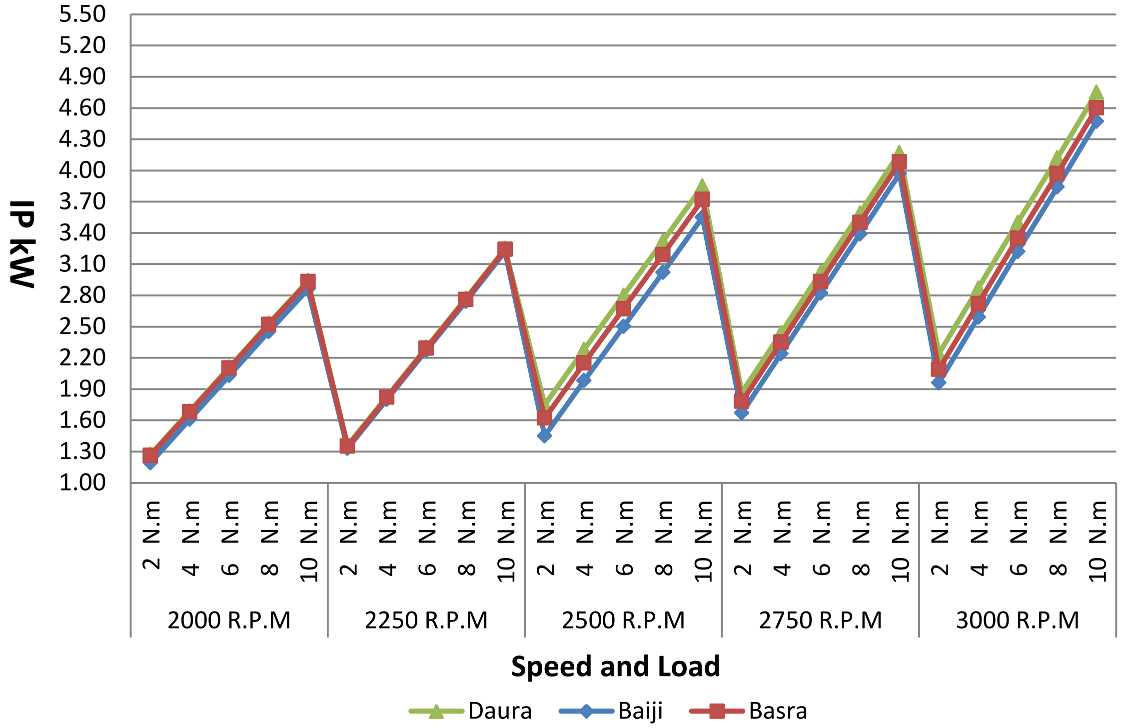

Fig. 5: Effect of winter season and fuel sources on IP

Effect of parameters on Exhaust Temperature:

Figure (6) & (7) illustrates that the season have a clear impact on the engine temperature. Daura fuel has a less impact on the rise of engine temperature in summer among the rest, Basrah and Baiji fuels have no significant effect on the temperature, where they have the same effect. May be due to the decreasing the Daura fuel consumption in summer comparing to other types leads to generate less heat during the combustion, due to the difference of chemical composition of the sources of fuel, leading to the difference in the quality of combustion of each type within the conditions of combustion chamber like heat, the oxygen availability and compression ratio, which generates different heat and different combustion products. This agree with Dasari, et al., (2003). There is no significant effect of both types of fuel and speed on the temperature among both season, where all types of fuel and speeds have the same effect on temperature almost, but highest temperature was in Baiji fuel at 3000 RPM in winter, and lower temperature was in Daura fuel at 2000 RPM in summer. It might be the reason for the rise of temperature in winter with increasing of the speed to inject largest quantity of fuel resulting in incomplete combustion to generate heat and power, in addition to the various exhaust products. Engine temperature reduces in summer with reducing the speed unlike the previous reasons. Highest ratio of temperature was in Baiji fuel at 10 Nm in winter and lowest ratio of temperature was in Daura fuel at 2 Nm in summer for all speeds, it might be the reason for the rise of temperature in winter with increasing of the torque to the increase of the amount of fuel at high load needed to produce the power in winter where the fuel would not be able to complete combustion properly which generate more heat, and vice versa at low load. Generally, we noticed that the highest rate of temperature was in Baiji fuel at 3000 RPM and 10 Nm in winter and the lowest ratio of temperature was in Daura fuels at 2000 RPM at 2 Nm in summer.

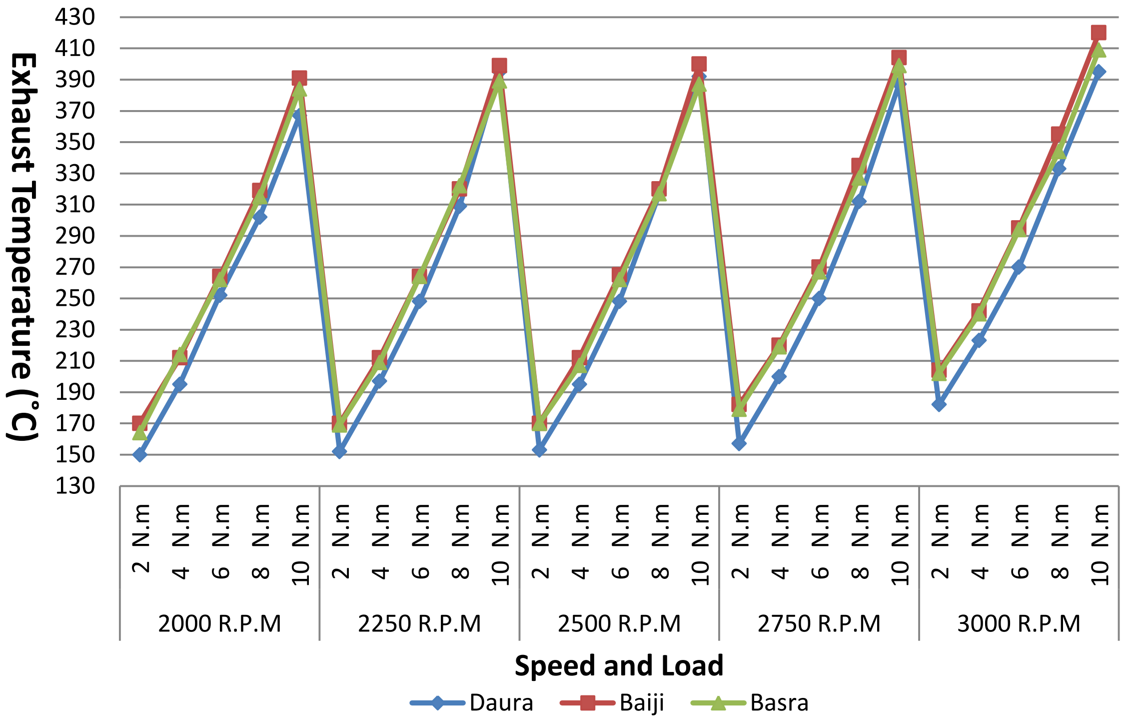

Fig. 6: Effect of summer season and fuel sources on Exhaust Temperature

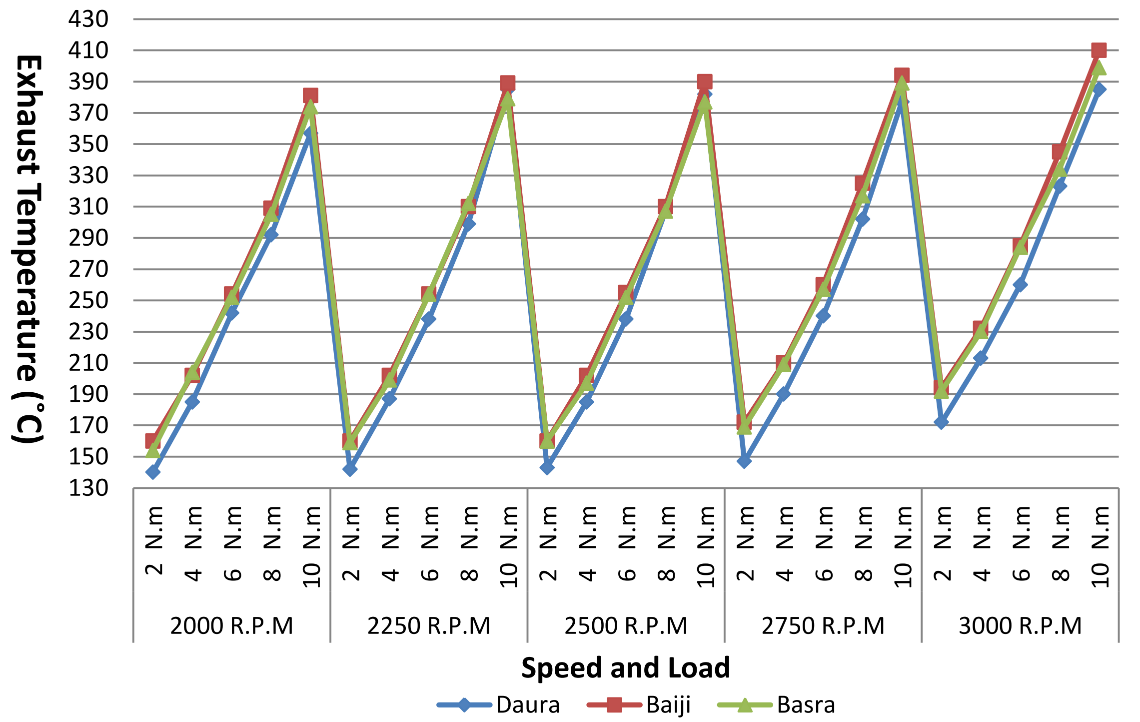

Fig. 7: Effect of winter season and fuel sources on Exhaust Temperature

Effect of parameters on Volumetric Efficiency:

Figure (8) & (9) illustrates that the season have a clear impact on the volumetric efficiency. The volumetric efficiency is not affected by the types of fuel. The types of fuel have the same effect on volumetric efficiency. The type of Baiji fuel in summer registered the lowest percentage of volumetric efficiency followed it Basrah and Daura. Daura fuel in winter had the highest ratio of volumetric efficiency for all velocities and torques, it may be caused by the high temperature of the engine in Baiji fuel in summer than the rest of the other species which lead to increase the air temperature and the air will expand to be less density, thereby reducing the amount of air inside the cylinder which leads to reduce the volumetric efficiency compared with winter season among other species of fuel. Highest ratio of volumetric efficiency was in Daura fuel at 2000 RPM in winter and lowest ratio of volumetric efficiency ratio was in Baiji fuel at 3000 RPM in summer for all torques. The reason is that the rise of air temperature in summer leads to expansion of air inside the cylinder to be less density, thereby the reduction of the amount of air inside the cylinder reduces the volumetric efficiency, thereby the fuel would not be able to complete combustion within the conditions of combustion chamber like oxygen availability. As well as the increasing the speed of the engine in summer leads to short duration of air to enter to the cylinder, thus does not enter large amount of air inside the cylinder. There is no significant effect of both types of fuel and torque on the volumetric efficiency among both season, where all types of fuel and torques have the same effect on volumetric efficiency almost, but highest volumetric efficiency was in Daura fuel at 2 Nm in in winter and lower volumetric efficiency was in Baiji fuel at 10 Nm in summer. The reason maybe that increasing the torque in Baiji fuel in summer leads to increase the temperature of the engine as a result of rising the air temperature and burning more fuel as a result of incomplete combustion, leads to expanding of the air to be less density and less volumetric efficiency which unsuitability for full combustion at these conditions. It may also be due to increase the amount of fuel burned inside the combustion chamber increasing the combustion products and cannot find enough time to get out in the exhaust stroke which leads to remaining of a part from it inside the cylinder, thereby reducing the amount of fresh air inside the cylinder and reducing the volumetric efficiency. In general, we found that the highest rate of volumetric efficiency was in Daura fuel at 2000 RPM at 2 Nm in winter and the lowest ratio of volumetric efficiency was in Baiji fuels at 3000 RPM at 10 Nm in summer.

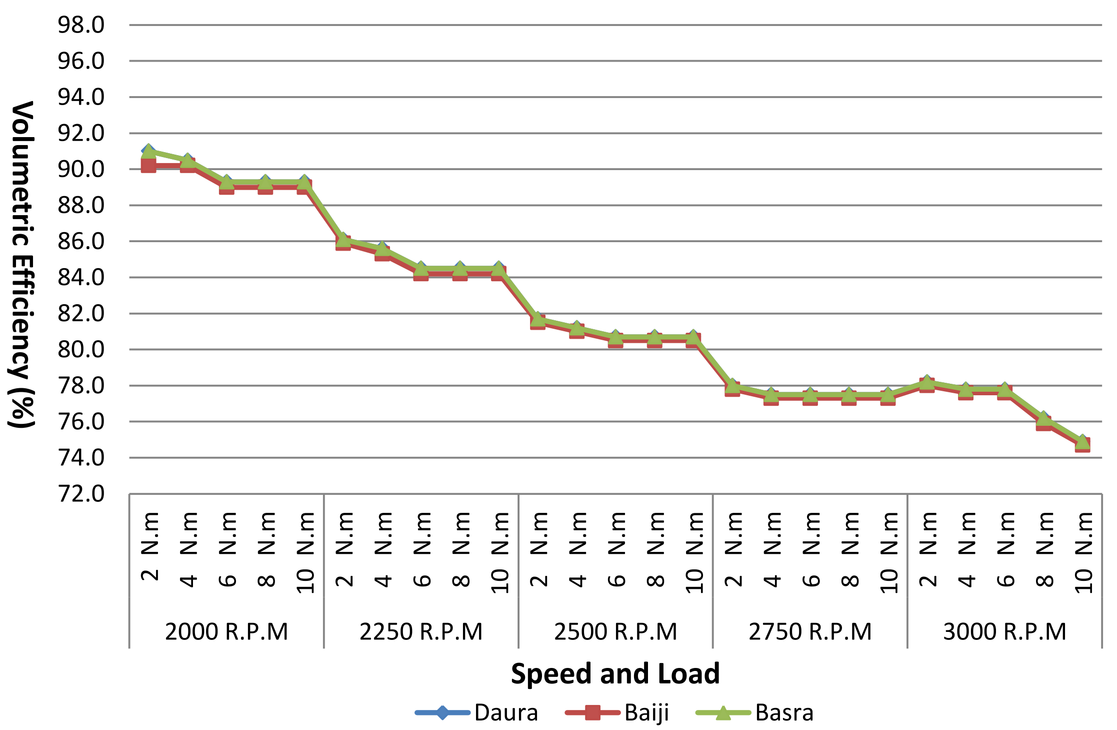

Fig. 8: Effect of summer season and fuel sources on Volumetric Efficiency

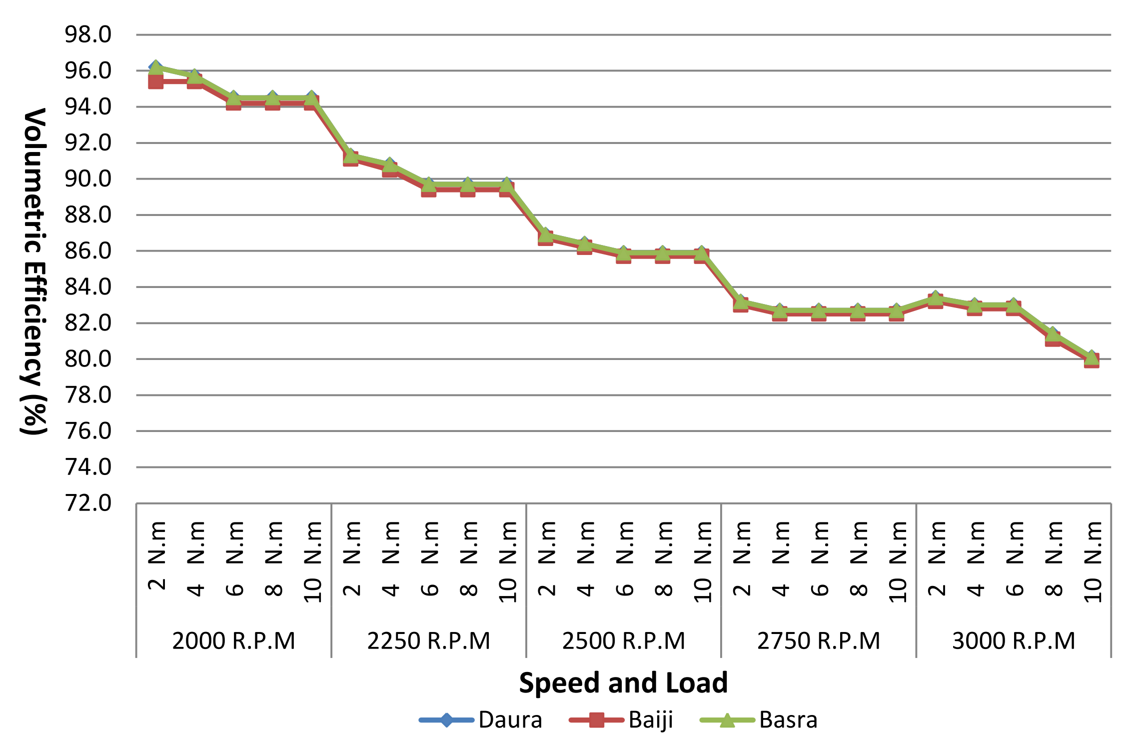

Fig. 9: Effect of winter season and fuel sources on Volumetric Efficiency

We conclude from above:

1. Lowest specific fuel consumption was in Daura fuel at 2750 RPM at 10 Nm in summer. Highest rate of indicated power was in Daura fuel at 3000 RPM at 10 Nm in summer. Lowest exhaust temperature was in Daura fuel at 2000 RPM at 2 Nm in summer. Best volumetric efficiency was in Daura fuel at 2000 RPM at 2 Nm in winter.
2. The different chemical structure of the fuel leading to a disparity in the liberation of chemical energy of fuel to useful work and the high temperature of the air in summer leads to complete combustion of Daura fuel and convert more chemical energy of fuel to thermal energy better than the rest species of fuel.
3. The low temperature of air in winter leads to formation of quench zone within the combustion chamber, leads to extinguishment of the flame and loses of energy. Thereby increasing the amount of fuel needed to produce the power to overcome the high load.
4. The high temperature of the engine in Baiji fuel in summer than the rest of the other species lead to increase the air temperature and the air will expand to be less density, thereby the fuel would not be able to complete combustion within the conditions of combustion chamber like oxygen availability and mixed it with fuel.

From the previous results we recommend to use Baiji and Basrah in addition to Daura fuel in summer season to get best performance from engine and compensation to Daura in winter season for high performance.

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