EFFECT OF SPEEDS AND SOURCE OF FUEL ON THE EMISSIONS OF 4-STROKE DIESEL ENGINE OF AGRICULTURAL TRACTORS BY DIFFERENT LOADS IN LABORATORY IN WINTER AND SUMMER SEASON.

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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 were used in this study. The tests were carried out to evaluate the effect of speeds and loads and winter and summer season on the diesel engine emissions of agricultural tractors with different types of local fuel.

Results were showed that the lowest rate of hydrocarbons (*HC*) was in Daura fuel in summer. Lowest rate of carbon monoxide (*CO*) was in Daura fuel in summer. Best rate of carbon dioxide ($CO_{2)}$ was in Daura fuel in summer. Lowest ratio of hydrocarbons was in Daura fuels at 2000 r.p.m at 2 N.m in summer. Lowest rate of carbon monoxide was in Daura fuel at 3000 r.p.m at 8 N.m in summer. Highest rate of carbon dioxide was in Daura fuel at 2000 r.p.m at 10 N.m in summer.

Keywords: Engine emissions in winter season, Engine emissions in summer season, Local fuel, Baiji fuel, Daura fuel, Basrah fuel.

INTRODUCTION

Low speed industrial and marine diesels often use a heavy diesel fuels. 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 used for stationary applications, (Jain and Rai, 2006). In terms of combustion considerations the major factors are viscosity and cetane number, (Brian, 1996). The actual composition of diesel fuel can differ among refineries or over between batches produced at one refinery, (Casey, *et al*., 2005). Gvidonas and Stasy, (2004) indicated that the increasing of cetane number level to improving fuel combustion also tends to reduce emissions of nitrogen oxides (*NOx*) and particulate matter (*PM*), and reduces the noise and hydrocarbon levels. Meher, *et al*., (2004) said that the fuels have high heat values require large volume of air for complete combustion, and the excessively low API gravity could result in increased engine deposits and smoke. Diesel fuel usually has an API gravity between

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30 minimum and 45 maximum. Tat and Van, (2003) 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. Xi and Zhong, (2006). 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) illustrated that the fuel with higher front - end volatility tends to improve starting and warm up performance and reduce smoke, and the carbon monoxide *(CO)* is formed when there is insufficient oxygen (O_2) to oxidize the fuel fully during the combustion of fuel (incomplete combustion). Anandram, *et al*., (2006) mentioned if temperatures are enough, the *CO* can further react with oxygen to form carbon dioxide (CO_2). Rakopoulos, *et al*., (2007) mentioned that the unburned hydrocarbon emission (*UBHC*) is the direct result of incomplete combustion, and the cylinder wall and crevice regions around the top of the piston edge and above the rings are much cooler than the combustion gases and tend to slow down, stop reaction and quench flames as they encroach. Thus fuel at the cylinder wall can contribute to hydrocarbon emissions *(HC)*. Boulouchos and Kirchen, (2008) found that during the normal operation of the engine, the cold wall quenches the fuel mixture and inhibits the combustion leaving a thick large of unburned fuel air mixture over the entire surface of the combustion chamber. This layer is called the quench zone, which exists next to the cooled combustion chamber walls. This unburned quenched mixture is forced out of the combustion chamber during the exhaust. Canakei and Van, (2003) illustrated that the thickness of this layer depended upon combustion pressure, temperature and mixture ratio (air/fuel), and turbulence and residual gases in the engine at the end of the exhaust stroke, and wall surface material and combustion deposits on the wall. Kaario, *et al*., (2005) said that the deposit on the wall may soak fuel vapor during suction and compression and evaporate during expansion and exhaust. Tao, *et al*., (2004) shown that the emission of *HC* in exhaust is decreased with an increase in compression ratio, this is because higher compression ratio has a higher exhaust temperature which may promote oxidation of hydrocarbons carried with the exhaust and reduced *HC* emission. Tao, *et al*., (2005) found that the temperature levels increase with speed due to reduced cooling and increased hot residuals. Hydrocarbons do not follow the expected decrease with temperature due to improved oxidation, because of the offsetting factor of less time to oxidize. Egnell, (2005) indicated that the primary effect of fuel volatility is to increase the rate of premixed burning and create more lean regions which do not burn, thus increasing *HC*.

The objectives of this study can be summarized as follows :

1. To choose suitable fuel gives lowest pollution of the engine during winter and summer season.
2. To choose suitable speed and load of the engine give lowest pollution of the engine during 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 emissions by using different types of local fuel under different speeds and loads. 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 dynamometer 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). Three local diesel fuel included *Baiji*, *Daura*, *Basrah*, five levels of engine speeds included 2000, 2250, 2500, 2750, 3000 r.p.m and five levels of loads included 2, 4, 6, 8, 10 N.m were used in this experiment. Analyses of the samples of fuels were carried out at Quality Control and Researches Department – AL-Daura – Midland Refineries Company (Table 2).

This study was carried out in winter season January under 13 $°C$ inside the laboratory and repeated in summer season 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 plot, speed treated as sub plot and load treated as main plot. Least significant differences (*L.S.D*) were used to compare means of treatments at 0.05 level. Analysis of the exhaust gases was done by the gas analyzer. The analyzer detects the carbon monoxide *(CO) %*, carbon dioxide (CO_2) *%* and hydrocarbon *(HC)* ppm content.

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

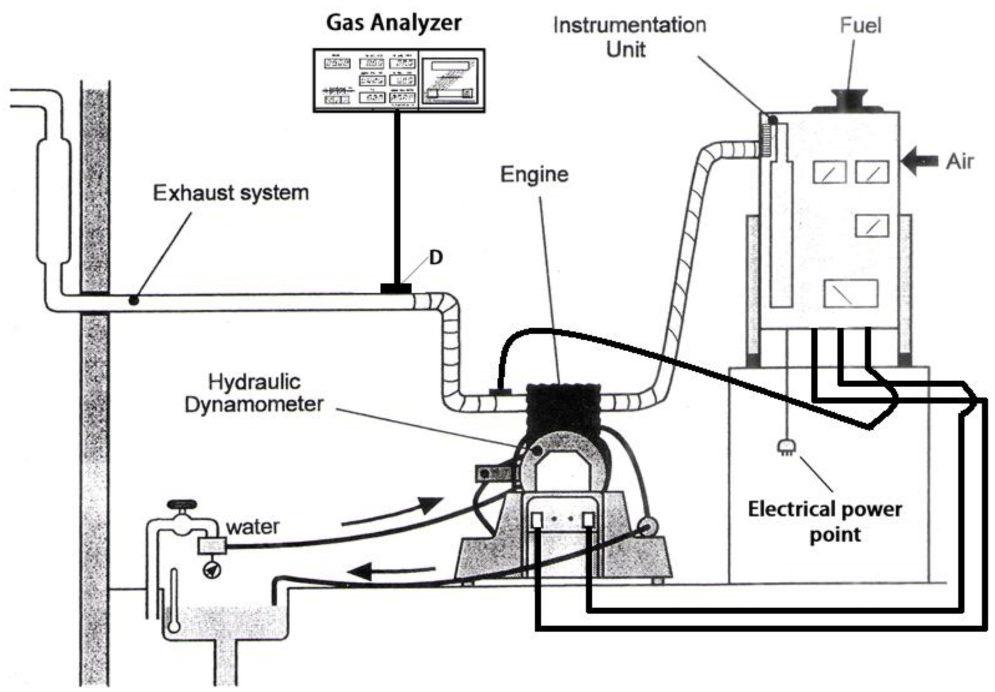

Figure 1: Linking of The Engine Accessories.

Table 1: 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 N.m at 2200 rev/min.

Table 2: Analyses of The Fuel Samples.

Data	*Baiji*	*Basra*	*Daura*
SP. Gravity @ 40˚C	0.8333	0.8319	0.8309
API. Gr. @ 100˚C	38.6000	38.8000	38.3000
Flash point ˚C	75.4000	72.4000	80.0000
Colour (ASTM)	0.5000	0.5000	0.5000
Pour Point ˚C	-15.0000	-12.0000	-9.0000
Vis Cst @ 40 ˚C	2.8300	2.7400	3.3000
Carbon Res. Wt %	0.0900	0.0970	0.1500
Sulfur. Wt %	1.0480	1.1880	1.1000
Diesel Index	60.1000	59.4000	62.2000
Cetane No.	58.5000	56.0000	58.5000
Calorific Value Kcal/Kg	10947.0000	10950.0000	10942.0000
Distillation: I.B.P	193.0000	188.0000	183.0000
10 %	226.0000	224.0000	213.0000
20 %	241.0000	240.0000	228.0000
30 %	254.0000	254.0000	245.0000
40 %	264.0000	260.0000	255.0000
50 %	274.0000	277.0000	265.0000
60 %	283.0000	288.0000	275.0000
70 %	293.0000	300.0000	286.0000
80 %	303.0000	318.0000	298.0000
90 %	320.0000	343.0000	320.0000
E.P ˚C	348.0000	376.0000	345.0000
T.D. %	99.5000 ML	99.5000 ML	99.0000 ML
Res.	0.4000 ML	0.4000 ML	0.9000 ML
Loss	0.1000 ML	0.1000 ML	0.1000 ML
Rec. @ 350 %	--	--	94.0000 ML

RESULTS AND DISCUSSION

Effect of parameters on Unburned Hydrocarbons:

Figure (2) & (3) illustrates that the season have a clear impact on the hydrocarbon. The type of *Baiji* fuel registered the highest percentage of hydrocarbons in winter followed it *Basrah* and *Daura*. *Daura* fuel was recorded the lowest ratios of hydrocarbons in summer for all velocities and torques. The reason that all of *Baiji* and *Basrah* fuel does not burn completely inside the combustion chamber in condition of winter season because of the chemical structure of fuel and the refining process of crude oil unlike *Daura* fuel which burns and generates a smaller percentage of hydrocarbons within the conditions of combustion chamber like temperature of air and compression ratio. Highest ratio of hydrocarbons was in *Baiji* fuel at 2750 r.p.m in winter and lowest hydrocarbon ratio was in *Daura* fuel at 2000 r.p.m in summer for all torques. The reason of increase hydrocarbons at high speed (2750 r.p.m) in *Baiji* fuel in winter to low temperature which leads to formation of quench zone within the combustion chamber and extinguishment of the flame and increase the formation of hydrocarbons.

As result of incomplete combustion as well as increasing the speed leads to increase the amount of fuel burned inside the combustion chamber. The decrease of hydrocarbons at low speed (2000 r.p.m) in *Daura* fuel in summer caused by high temperature of air in summer and oxygen availability at low speed leads to combustion of the full charge of fuel. In the case of average speeds where the oxygen content relatively adequate, the reason for the difference of hydrocarbons to the inadequate chemical structure of the fuel for combustion completely within the operating conditions of the engine at average speeds in terms of increased temperature in summer leads to burning of fuel completely and reduces the hydrocarbons. Highest ratio of hydrocarbons was in *Baiji* fuel at 10 N.m in winter and lowest ratio of hydrocarbons was in *Daura* fuel at 2 N.m in summer for all speeds. The reason that at high torque in winter season the engine needs to increase the amount of fuel to generate the power to overcome the high load, since the amount of air fixed in a diesel engine at different load, low temperature leads to formation of quench zone within the combustion chamber, leads to extinguishment of the flame where *Baiji* fuel would not be able to complete combustion within this conditions of combustion chamber and increase the formation of hydrocarbons.

We noticed the consumption of fuel rises in the same conditions which explain the rise of hydrocarbons. Generally, we found that the highest rate of hydrocarbons was in *Baiji* fuel at 2250 r.p.m at 10 N.m in winter and the lowest ratio of hydrocarbons was in *Daura* fuels at 2000 r.p.m at 2 N.m in summer.

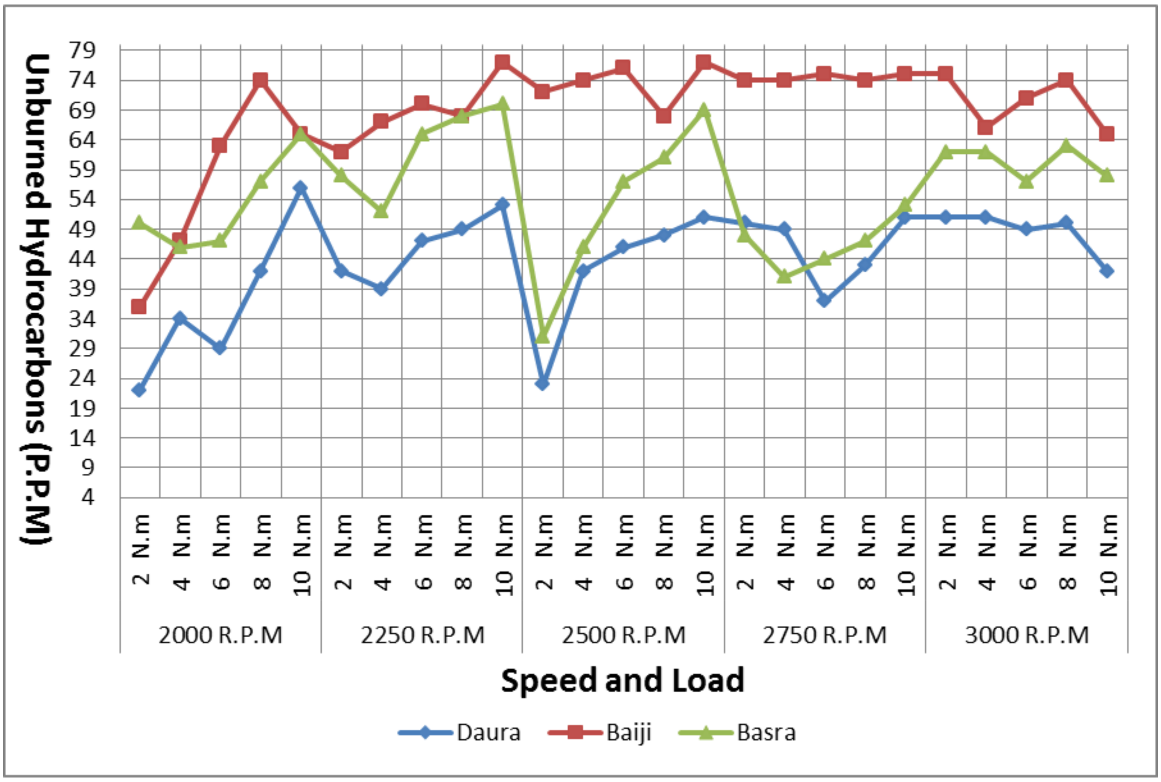

Fig. 2: Effect of fuel sources and speeds and loads on Unburned Hydrocarbons in winter season.

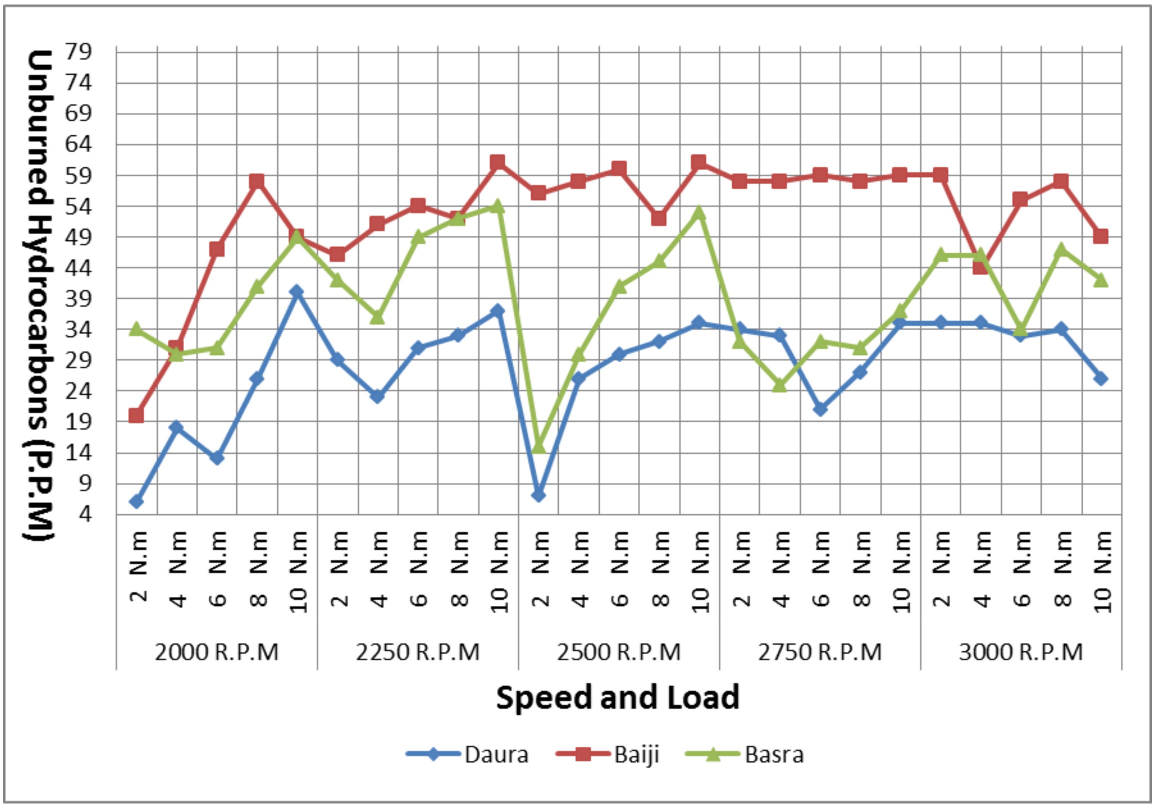

Fig. 3: Effect of fuel sources and speeds and loads on Unburned Hydrocarbons in summer season.

Effect of parameters on Carbon Monoxide:

Figure (4) & (5) illustrates that the season have a visible impact on the carbon monoxide *(CO*). The type of *Baiji* fuel recorded higher ratio of *CO* in winter followed it *Basrah* and *Daura*, where *Daura* fuel in summer was the lowest ratio of *CO* for all velocities and torques. 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 and compression ratio. We noticed the hydrocarbon rises in *Daura* and *Baiji* fuel in the same circumstances because of incomplete combustion. Highest proportion of *CO* was in *Baiji* fuel at 2250 r.p.m in winter and lowest ratio of *CO* was in *Daura* fuel at 3000 r.p.m in summer for all torques. It caused by inadequate chemical composition for *Baiji* fuel to full combustion due to the highest percentage of *BSFC* of *Baiji* fuel compared with other species of fuel resulting in incomplete combustion as a result of low air temperature in winter season, as well as non-air distribution is well within the combustion chamber at 2250 r.p.m leading to incomplete combustion of the fuel. The disparity of *CO* ratio vary by varying of the suitability of the chemical composition to combustion. Highest percentage of *CO* was in *Baiji* fuel at 10 N.m in winter and lowest percentage of *CO* was in *Daura* fuel at 8 N.m in summer for all speeds. It caused by inadequate chemical composition for *Baiji* fuel to full combustion due to low air temperature in winter season which leads to increase the *BSFC* of *Baiji* fuel compared with other species of fuel. Where the rise and decrease of hydrocarbons note at the same conditions because of uncomplete combustion. In general, we realized that the highest rate of *CO* was in *Baiji* fuel at 2000 r.p.m at 10 N.m in winter and the lowest rate of *CO* was in *Daura* fuel at 3000 r.p.m at 8 N.m in summer.

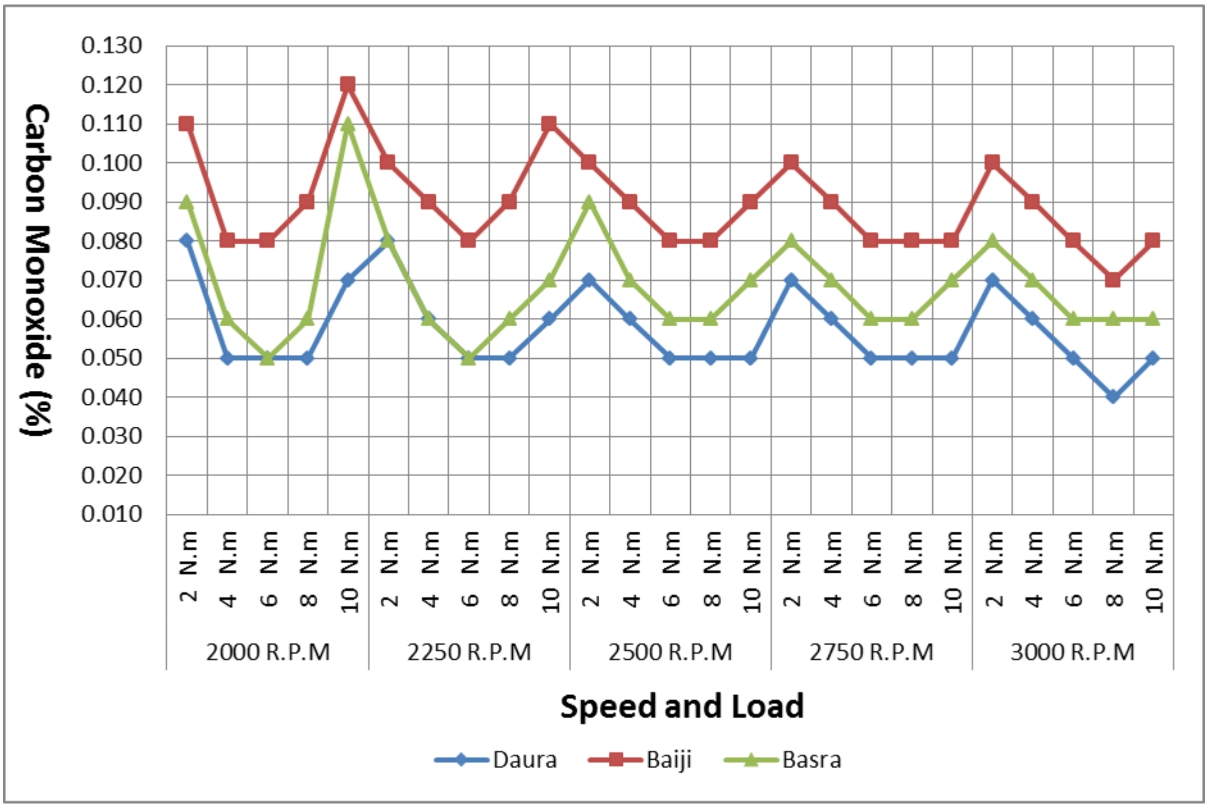

Fig. 4: Effect of fuel sources and speeds and loads on Carbon Monoxide in winter season.

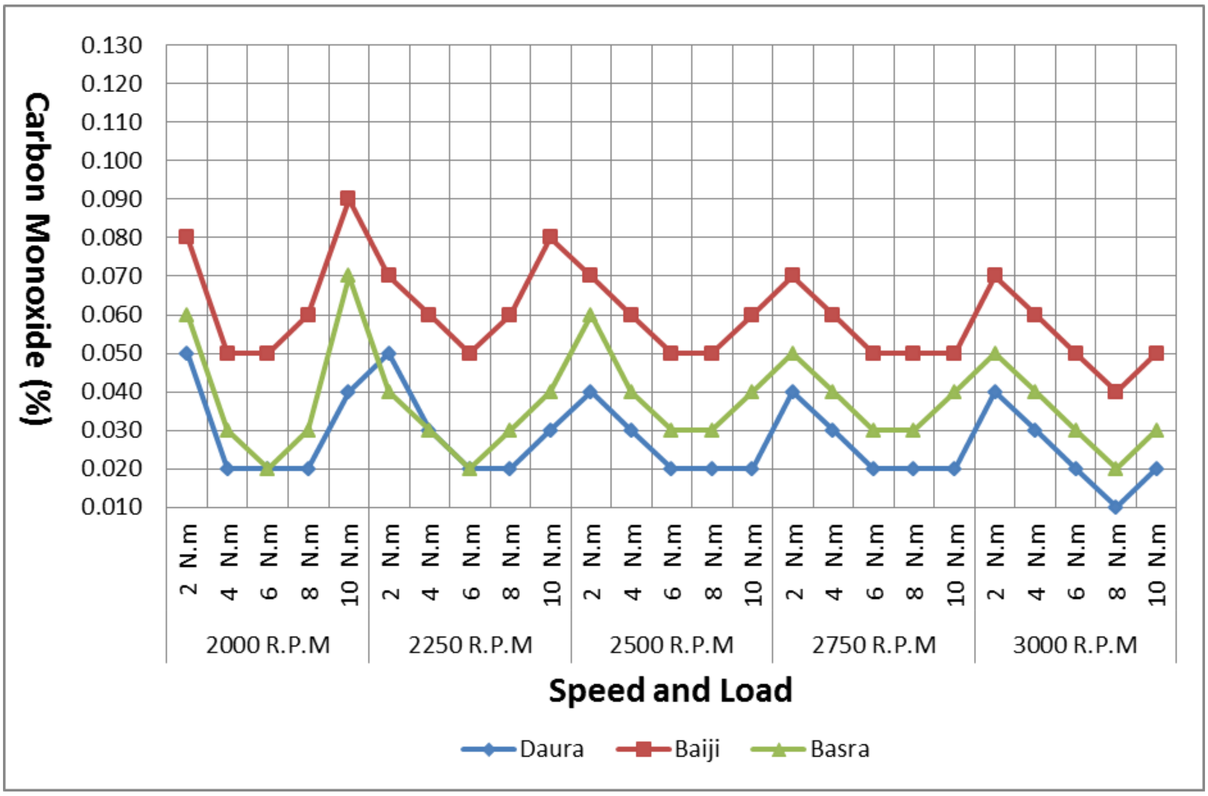

Fig. 5: Effect of fuel sources and speeds and loads on Carbon Monoxide in summer season.

Effect of parameters on Carbon Dioxide:

Figure (6) & (7) illustrates that the season have a visible impact on the carbon dioxide *(CO_2)* where the type of *Daura* fuel in summer recorded the highest rate of CO_2 followed it *Basrah* and *Baiji*, where *Baiji* fuel produced the less ratio of CO_2 in winter for all speeds and torques. Because the combustion in *Daura* fuel in summer was greater than other source of fuels. The reason to the differences in chemical composition of the sources of fuel, where the *Daura* fuel would be able to complete combustion in summer within the conditions of combustion chamber like heat, the oxygen availability and compression ratio. Highest ratio of CO_2 was in *Daura* fuel at 2000 r.p.m in summer and lowest ratio of CO_2 was in *Baiji* fuel at 2500 r.p.m in winter for all torques. It caused by appropriate chemical composition of *Daura* fuel for complete combustion at those conditions where high air temperature in summer as well as providing enough oxygen to complete the combustion of fuel at low speed which increase CO_2. In the case of decreasing CO_2 in the 2500 r.p.m in winter due to low air temperature as well as highest percentage of *BSFC* in *Baiji* fuel in winter, leading to incomplete combustion of the fuel and decreasing the ratio of CO_2. Highest ratio of CO_2 was in *Daura* fuel at 10 N.m in summer and lowest ratio of CO_2 was in *Baiji* fuel at 2 N.m in winter for all speeds which cause by the chemical structure of the fuel where the fuel would not be able to complete combustion within low air temperature in winter as well as low engine temperature at low torque resulting in incomplete combustion of carbon with oxygen thereby reducing CO_2. In general, we found that the highest rate of CO_2 was in *Daura* fuel at 2000 r.p.m at 10 N.m in summer and the lowest ratio of CO_2 was in *Baiji* fuels at 2500 r.p.m at 2 N.m in winter.

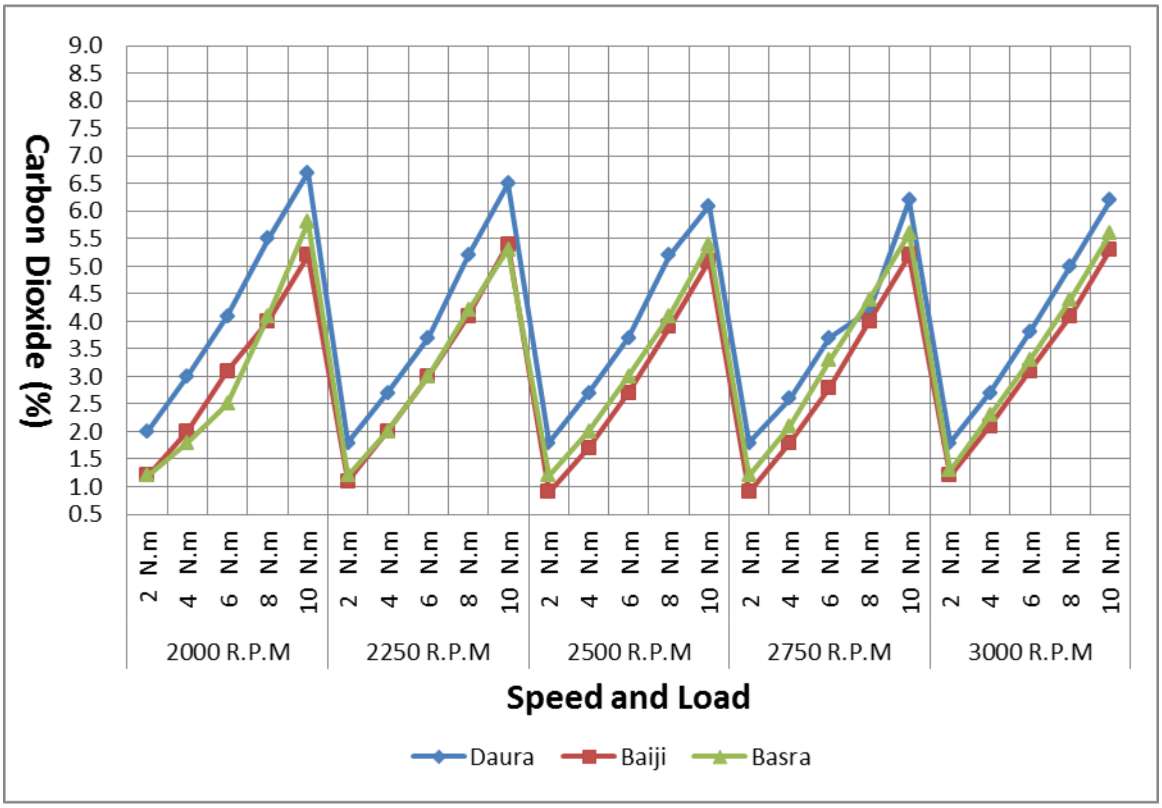

Fig. 6: Effect of fuel sources and speeds and loads on Carbon Dioxide in winter season.

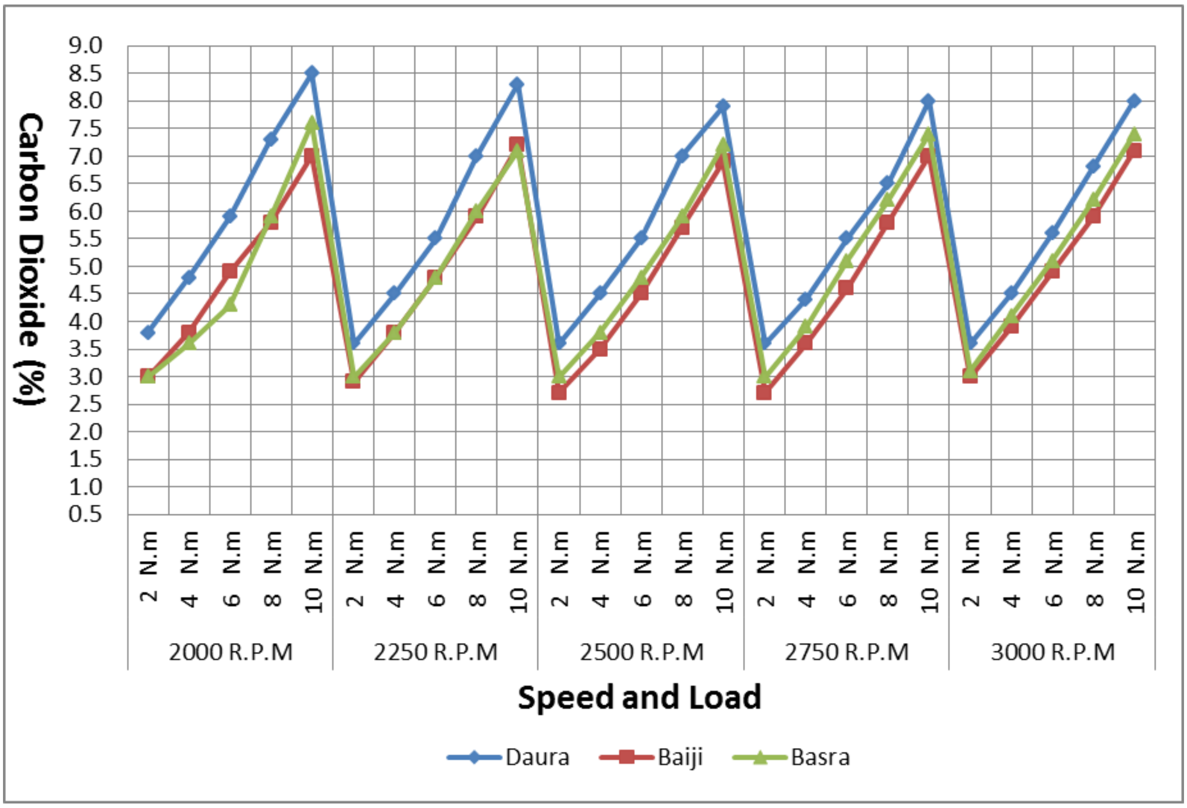

Fig. 7: Effect of fuel sources and speeds and loads on Carbon Dioxide in summer season.

From the above results, conclusions can be summarized as follows:

1. Lowest rate of hydrocarbons was in *Daura* fuel at 2000 r.p.m at 2 N.m in summer. Lowest rate of carbon monoxide was in *Daura* fuel at 3000 r.p.m at 8 N.m in summer. Highest rate of carbon dioxide was in *Daura* fuel at 2000 r.p.m at 10 N.m in summer.
2. The different chemical structure of the fuel leading to a disparity in the exhaust products of fuel and the high temperature of the air in summer leads to complete combustion of *Daura* fuel and convert more fuel to thermal energy and generates a smaller percentage of hydrocarbons and carbon monoxide 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. Thereby increasing the amount of fuel needed to produce the power to overcome the high load which lead to increase the formation of hydrocarbons and reduce carbon dioxide within the conditions of combustion chamber like heat and compression ratio.
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 which increase the conversion of a large part of fuel charge to exhaust products and heat instead of power.

From the previous results using *Baiji* and *Basrah* in addition to *Daura* fuel in summer season to get less pollution and compensation to *Daura* fuel in winter season for less pollution can be recommended.

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تأثير السرع ومصادر الوقود على انبعاثات غازات عادم المحركات الرباعيَة الاشواط للجرارات الزراعية بأحمال مختلفة في المختبر في موسمي الشتاء والصيف..

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المستخلص

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. نفذت التجربة في محرك ديزل رباعي الاشواط لدراسة تأثير خمس سرع وخمسة احمال مختلفة للمحرك في موسمي الشتاء والصيف في غازات عادم المحركات الرباعية الاشواط للجرارات الزراعية باستعمال ثلاثة انواع من الوقود المحلي.

اظهرت نتائج البحث ان اقل نسبة للهيدروكربونات كانت عند وقود الدورة في الصيف. أقل نسبة لأحادي اوكسيد الكاربون كانت عند وقود الدورة في الصيف. أفضل نسبة لثنائي أوكسيد الكاربون كانت عند وقود الدورة في الصيف. اقل نسبة للهيدروكربونات كانت باستخدام وقود الدورة عند السرعة 2000 دورة/دقيقة عند العزم 2 نيوتن.متر في الصيف. اقل نسبة لأحادي أوكسيد الكاربون كانت باستخدام وقود الدورة عند السرعة 3000 دورة/دقيقة عند العزم 8 نيوتن.متر في الصيف. أعلى نسبة لثنائي اوكسيد الكاربون كانت باستخدام وقود الدورة عند السرعة 2000 دورة/دقيقة عند العزم 10 نيوتن.متر في الصيف.

الكلمات المفتاحية: انبعاثات غازات عادم محرك الديزل في موسم الصيف، انبعاثات غازات عادم محرك الديزل في موسم الشتاء، الوقود المحلي، وقود الدورة، وقود بيجي، وقود البصرة.