An Experimental Investigation of Combustion Emissions and Diesel Engine Performance of Water in Diesel Nano Emulsion Fuel

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Abstract:

Water in Diesel Nano-Emulsions (WiDNE) fuel are an important environmental fuels for decreasing the combustion pollution of diesel engines. WiDNE fuel is a dispersion stable thermodynamic and kinetic system consisting of diesel oil, surfactant and water phase. WiDNE fuel due to their nano scale droplet size (20–200 nm) and large surface area burns more completely and hence a reduction in emissions than straight diesel.

The objective of this project is to evaluate the combustion characteristics of WiDNE fuel prepared by rotor-stator homogenizer using mixed surfactants based on nonionic emulsifiers Span™ 80, Tween™ 80. Direct injection (DI), Fiat engine was used and run at 1500 rpm, constant fuel pressure (400 bar) with varying the operation load.

Multi gas analyzer model 4880 was used to measure the concentration of the emission gases such as NO_x, unburned total hydrocarbon HC, CO_2 and CO. The AVL-415 meter was used for smoke emissions. The experimental results of WiDNE imposes the capability to improve fuel properties, the engine efficiency as well as reduction of gas emissions.

Keywords Water in Diesel Nanoemulsions, Diesel Fuel, Engine Performance, Combustion Emissions.

دراسة تجريبية لانبعاثات الاحتراق وأداء محرك الديزل لوقود ديزل مستحلب نانوي

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الخلاصة

يعتبر وقود الديزل المستحلب النانوي من انواع الوقود المهمة البديلة والصديقة للبيئة والتي يمكن استخدامها للحد من انبعاث غازات الاحتراق الداخلي لمحركات الديزل. ويتالف قود الديزل المستحلب النانوي من نظام مشتت مستقر ثرموديناميكيا وديناميكيا ويتكون من زيت الديزل، والماء ومواد خافظة للشد السطحي و بسبب حجم القطرات النانوية الحجم بقياس (20-200 نانومتر) وذات مساحة سطحية الواسعة فيكون احتراقها بالهواء ذات الانبعاثات الملوثة قليلة مقارنة بالديزل التقليدي.

ان الهدف من هذا البحث هو تحضير وقود ديزل المستحلب النانوي وتقييم سلوك و كفاءة الاحتراق وكمية الغازات المنبعثة الملوثة من محرك ديزل . لقد حضر وقود ديزل المستحلب النانوي مختبريا باستخدام homogenizer وبأضافة مزيج من مواد خافظة للشد السطحي يتكون من Span™ 80، Tween™ 80. لقد استخدام محرك الديزل فيات ذو حقن مباشر، وتبريد بالمياه لاسطواناته الاربعة، ويشتغل المحرك بسرعة دوران ثابتة (1500 دورة في الدقيقة) وضغط ثابت لحقن الوقود (400 بار). لقد تم تحليل الانبعاثات باستخدام جهاز مقياس انبعاثات متعدد الغازات النموذجي 4880 لقياس تركيز الغازات مثل أكاسيد النتروجين و الهيدروكربونات الكلية الغير المحترقة و غاز اول وثاني اوكسيد الكربون. تم قياس الدخان المنبعث من عوادم المحرك باستخدام مقياس الدخان نوع AVL - 415 لقد بينت النتائج التجريبية بأن وقود الديزل المستحلب النانوي يحسن قدرة خصائص الوقود، وتحسين كفاءة المحرك، فضلا عن خفظ تراكيز انبعاثات غازات العادم .

1. Introduction

Diesel engines offer better fuel to the modem industries and technology, and in another hand they assumed of the large pollution source, especially are particulate matters, smoke, nitrogen & sulfur oxides of, hydrocarbon, carbon oxides [1]. Increasing environmental regulation drives a major research in order to reduce the exhaust pollutants [2, 3].

Various works have been reported for improving fuel performance and reducing pollution. One such approach is the use of emulsions of water-diesel which have an effect on several emission constituents [4,5,6].

In this study an attempt was made to impart nanotechnology in the field of diesel fuels in order to make use of water droplets in nano size can be injected uniformly along with conventional diesel fuel in compression ignition engine and tested for its performance and emission characteristics.

The objective of this study is to prepare WiDNE fuel using based Span™ 80 & Tween™ 80 surfactants. Concentration of the emission gases such NOx, unburned total hydrocarbon HC, CO_2 and CO were also studied.

2. Materials And Methods

2.1. WiDNE Preparation and Properties:

Diesel fuel was used for WiDNE preparation as the continuous emulsion phase. The technical grade emulsifiers used throughout the investigation namely Tween™ 80 a hydrophilic surfactant with Hydrophile-Liophile Balance (HLB) = 15, and Span™ 80, a lipophilic surfactant with HLB = 4.3. WiDNE fuel was prepared at room temperature in a glass beaker initially by mixing surfactants based on nonionic emulsifiers Span™ 80, Tween™ 80 at 3.4% concentration according to HLB equal to 5.7 and then blended with diesel fuel by using rotor-stator homogenizer at 17000 rpm and stirring time 40 min and then a 12% of water are added to the mixture of surfactant and diesel fuel until constant pH = 9.8 were achieved. Finally as a result of it WiDNE was obtained in creamy white in color figure (1). Table (1) illustrates the comparison properties of diesel and WiDNE fuels.

Fig. (1) Physical Appearance of Diesel and WiDNE Fuel

Table (1) Comparison Between Diesel Fuel and Prepared WiDNE Fuel

Properties (measured)	Diesel fuel	WiDNE fuel
Calorific value(kJ/kg)	44800	38850
Flash point (^oC)	54	61
Viscosity at 40 ^oC (cSt)	3.268	4.56
Density (g/cm^3)	0.87	0.882

2.2. Engine setup and experimental method:

Fiat engine was used in this work to test the diesel fuel and its detailed specification is listed in Table (2).

The engine was coupled to a dynamometer and the load was supplied by the torque. Multi gas model 4880 analyzer was used to measure the concentration of emission gases. The smoke emissions were measured by AVL – 415 meter. The schematic of the experimental setup is shown in Figure (2). Initially diesel fuel was tested for its performance and emission characteristics and then followed by WiDNE fuel was tested in the same engine and their results were compared against the base diesel fuel.

Table (2) Engine Specifications

Four cylinder, four stroke type
TD 313 model
DI, water cooled, natural aspirated
Displacement volume 3.666 L
Two Valve /cylinder
Bore 100 mm
Stroke 110 mm
Compression ratio 17
Unit pump 26 mm diameter plunger
Nozzle hole diameter (0.48mm) , Spray angle= 160^o

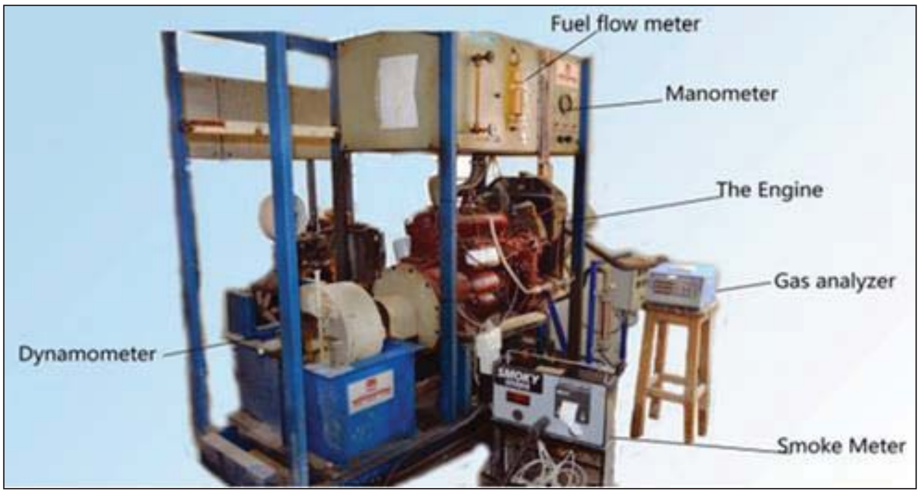

Fig. (2) Schematic of Test Rig

3. Results And Discussion

3.1 Engine Performance

3.1.1 Brake Specific Fuel Consumption (BSFC)

BSFC of an engine is defined as the amount of fuel used in kgs per Kwhr. Figure 3 shows the brake specific fuel consumption (BSFC) variation with load (brake mean effective pressure).

The results shows that the BSFC increases when used the WiDNE fuel. The water content increases the combustion efficiency by keeping the temperature in the suitable range. It can be seen that the BSFC values for WiDNE fuel was less than that of individual diesel fuel. The BSFC decreases at all conditions as shown in Figure (3). The effect may be due to the increase of the evaporation rates, which is led to reduction in the ignition delay with increasing surface area to volume ratio which improve combustion efficiency.

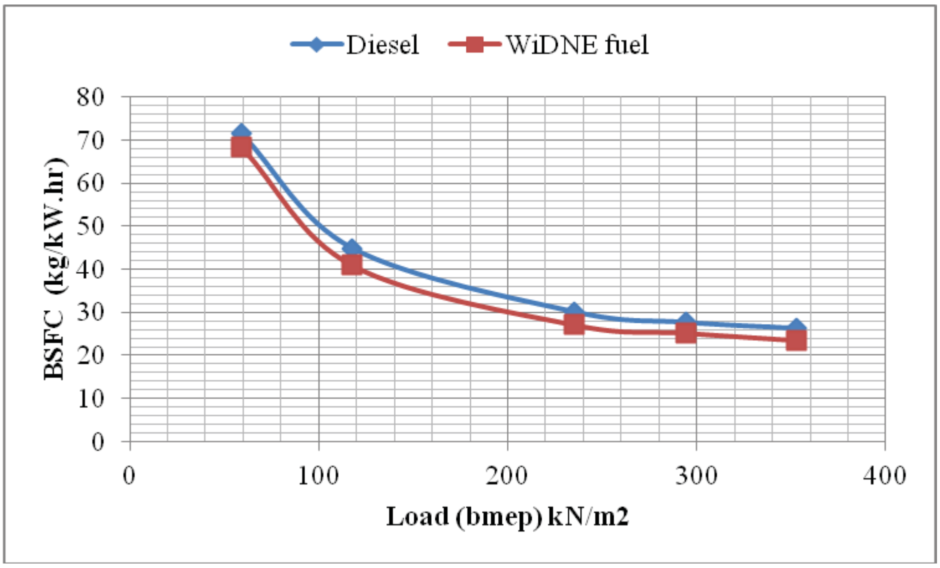

Fig. (3) Load vs Brake Specific Fuel Consumption (BSFC)

3.1.2. Brake Thermal Efficiency (BTE)

BTE is a very important performance parameter. It increases with increase in load, it can be shown in Figure (4) that it is increased linearly. It can be observed that BTE for WiDNE fuel are more than that of diesel. So. This characteristic is due to an increasing in expansion work and also decreasing in compression works as a result of evaporation of water .[7]

In the WiDNE fuel, the diesel quantity is replaced by water. So, any increase in net work happen with decreasing of fuel consumption lead to higher BTE and indicated efficiency.[8]

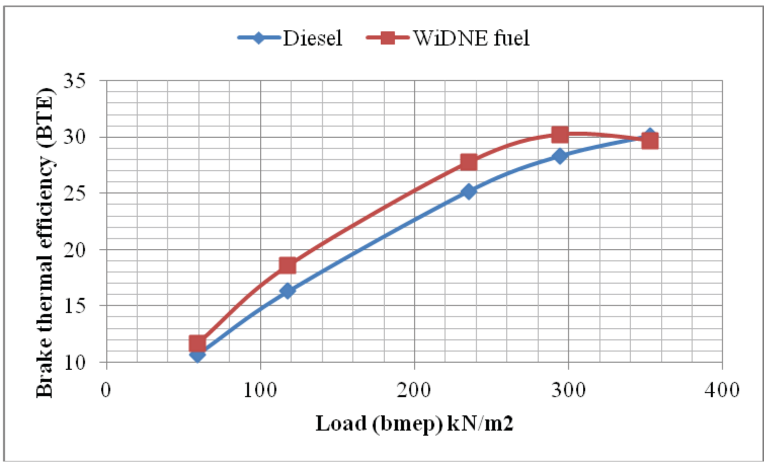

Fig. (4) Brake Power vs Thermal Efficiency

3.2. Emission Characteristics

When the WiDNE fuel is used, the exhaust gas temperature decreases. The smoke, Hydrocarbon HC, CO, NOx are decreases as shown in Figures (5, 6, 7 and 8).

3.2.1. Smoke Opacity

The relation of smoke opacity vs. load bmep was shown in Figure (5). The smoke opacity WiDNE fuels is lower due to uniform fuel mixture, thus combustion rate would increase and the gas phase oxidation and thermal cracking will decrease. Also, the water absorbs heat which would reduce the cylinder temperature. Thereby reducing the smoke formation could reduce [9, 10].

3.2.2. HC Emissions

gases leaving the combustion chamber contains up to 100 ppm of HC emissions due to cracking of fuel molecules. The relation of HC emissions vs. bmep is shown in Figure (6). The HC emission for Diesel is higher compared to WiDNE fuel due to its lower thermal efficiency resulting in incomplete combustion. This could be due to improved combustion characteristics of WiDNE fuel, which leads to improved combustion.

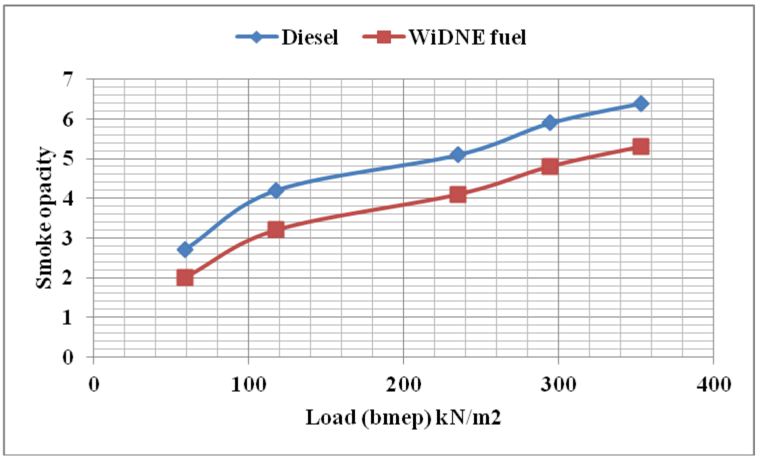

Fig. (5) Load vs Smoke Opacity

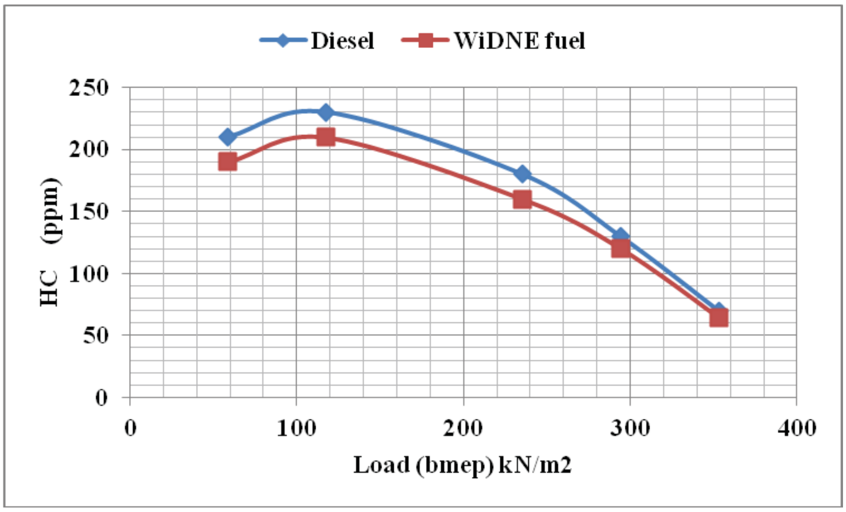

Fig. (6) Load vs HC ppm

3.2.3. CO Emissions

CO is emitted as a result of incomplete fuel combustion. This emission highly depends on the air to fuel ratio [11]. Figure (7) observed that there is a decrease in CO emissions, which possibly related to the short ignition delay and the enriched ignition characteristics of nano droplets in the WiDNE fuel due to improving fuel air mixing in the combustion chamber [12].

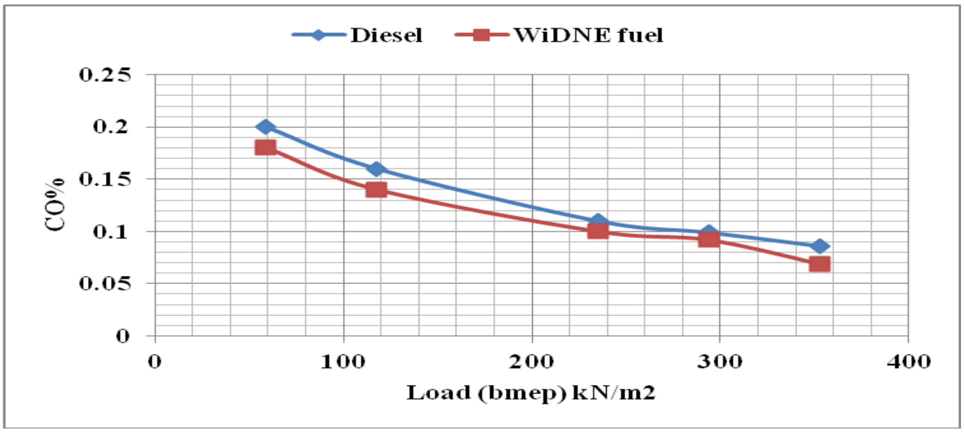

Fig. (7) Load vs CO%

3.2.4. NOx Emissions

It is observed from Figure (8) that using WiDNE fuel reduces the NOx emissions This because water droplet absorbed some heat and then directly vaporized at high temperature and pressure inside the combustion cylinder. As a result the decreases the chances of formation of NOx. In general, the WiDNE used will reduce the flame temperature and then resulting in measurable reductions in the NOx emissions. [13-17].

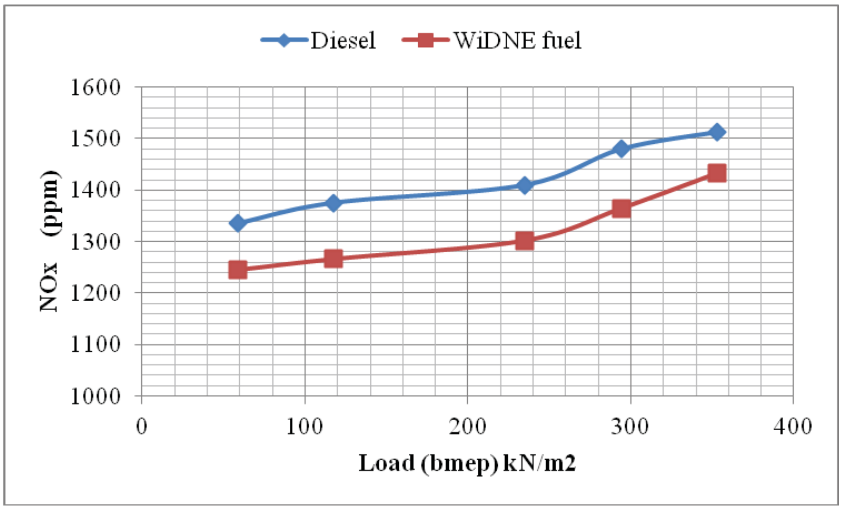

Fig. (8) Load vs NOx ppm

4. Conclusions

The use of WiDNE fuel increases the efficiency of the engine in certain modes of operation. This result confirms the need for a more complete study combining the characteristics of the emulsion with the tuning of the engine parameters. For the operating modes discussed here, a decrease in the measured pollutant was observed when using WiDNE. In general, the results are given here suggest that the WiDNE fuel improve the engine performance and reduce emissions NOx, CO, smoke and HC emissions.

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