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 NOx, unburned total hydrocarbon HC, CO2 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 وآداء محرك الدیزل لوقود الدیزل مستحلب نانوی

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الخلاصة

يعتبر وقود الدیزل المستحلب النانوي من انواع الوقود المهمة البديلة والصديقة للبيئة والتي يمكن استخدامها للحد من انبعاث غازات الاحتراق الداخلي لمحركات الدیزل. ويتألف فود الدیزل المستحلب النانوي من نظام مشتت مستقر ترموديناميكياً وديناميكياً ويتكون من زيت الدیزل، والماء، ومواد خاتحة للند السطحي، وسبب حجم الفترات النانوية الحجم يقاس (20-200 نانومتر) ذات سهولة سطحية الواسعة فتكون احتراقها بالهواء ذات الانبعاثات الملوثة قليلة مقارنة بالدیزل التقليدي.

ان الهدف من هذا البحث هو تحضير وقود دیزل المستحلب النانوی وتثبيت سلوك و كفاءة الاحتراق وكمية الغازات المنبعثة الملوثة من محرك دیزل. لقد حضر وقود دیزل المستحلب النانوی مختبريًا باستخدام homogenizer والمخلل. لقد حضر وقود دیزل المستحلب النانوی ب슘 خاتمة باستخدام TweenTM 80، SpanTM 80، وضمت مزيج من مواد خاتمة للند السطحي يكوب من 80، 80، 80 فيات ذو خون مباشر، وتبيرة بالماء لاستفاذاته الإربعة، ويشغل المحرك بسرعة دوران ثابتة (1500 دورة في الدقيقة) وضعت ثابت لحظة الوقود (400 بار). لقد تم تحليل الانبعاثات باستخدام جهاز مقياس انبعاثات متعدد الغازات النموذجي 4880 لقياس تركيز الغازات مثل أكسيد النيتروجين والهيدروكربونات الكلية الغير المحترقة وغاز أول وثاني أوكسيد الكربون. تم قياس الدخان المنبعث من عادات المحرك باستخدام مقياس الدخان نوع AVL 415. لقد بنيت النتائج التجريبية بأن وقود الدیزل المستحلب النانوی يحسن قدرة خصاص الوقود، وتحسين كفاءة المحرك، فضلا عن خفض تركيز انبعاثات غازات العادم.

1. Introduction

Diesel engines offer better fuel to the modern 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, CO₂ 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 (°C)      | 54          | 61         |
| Viscosity at 40 °C (cSt) | 3.268      | 4.56       |
| Density (g/cm³)       | 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

| 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° |
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.
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]
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](image-url)
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].

3.2.4. NOx Emissions
It is observed from Figure (8) that using WiDNE fuel reduces the NOx emissions. This is 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].

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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