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Working Features Evaluation of the Diesel Engine Lubricated with Blends of Renewable Corn Oil and Carbon Nanotubes

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ABSTRACT: Vegetable oils are one of the renewable resources that extracted from surplus or non-edible vegetables, instead of the conventional energy resources (fossil), because it's close to be free and renewable and used in many applications such as lubricant oils in recent years. In this work, the performance of the four stroke single cylinder diesel engine are examined and evaluated experimentally using the non-edible corn oil as lubricant in instead of the mineral oil. Furthermore, the effect of disappearing multi-wall carbon nanotube (MWCNT) in this lubricant oil is tested experimentally with different concentration ratios 0.1, 0.2 and 0.3%. The tests are done with different operation conditions applied on engine such as different load and different engine speeds. The experimental results shows that the using of non-edible corn oil, leads to reduction in cylinder surface temperature and brake specific fuel consumption of the used internal combustion engine about 5 and 7% respectively, comparative with the used mineral oil. While the increasing in the brake thermal efficiency was 8%. MWCNT additives at 0.1,0.2 and 0.3% concentration ratios to non-edible corn oil gives improvement in the engine performance about 9,13 and 17% in reduction of cylinder surface temperature, 10.5, 13.5 and, 17% in reduction of brake specific fuel consumption, and 11,15 and 21% in increasing of brake thermal efficiency, respectively, oil comparative with the used mineral oil.

KEYWORDS: Renewable lubricant; Corn oil; MWCNT; Nano-oil; Internal combustion engine

INTRODUCTION

The main causer in the reduction of the useful power is the friction between the automobile engine internal moving parts such as bearings, piston rings, and transmission parts. Lubricants are supplied to reducing these frictions and lead to reduce in the power losses also contribute to engines cooling [1]. The growth in engines technology leads to closer tolerances between engine parts, smaller capacity of oil sump (due to space limitations) and higher in engine operating temperatures and speeds. All of these are required for improving lubricant specifications for good engine performance [2]. For enhancing a lubricants specifications to reducing friction and wear of the engine, less resistance for moving parts and provide better in engine cooling by improving the thermal properties of lubricants, nanoparticulates additives in oils come as a new technology for these reasons.

The engines sliding parts wear and friction performance using boric acid and copper nanoparticles as additives in raw oil is studied by several researchers that give the reducing on these performances [3]. While the operating parameters such as temperature and sliding speed concentration were studied to influence the friction performance [4-6]. It is seen that, by scanning electron microscopy (SEM), atomic force microscopic (AFM), and X-ray energy dispersive spectroscopic analyses the addition of boron nitride nanoparticles to the lubricant oil with a small amount gives excellent tribological performance behavior [7]. While there are studies shows the reducing in wear and friction with good solubility and stability in the lubricant using titanium oxide (TiO_2) nanoparticles as additives into the multi-grade mineral engine oil, so the tribological behavior was investigated with variable load and varying concentrations of nanoparticles in lubricating oil using pin-on-disc under [8]. Because of the inherent high thermal conductivity of carbon nanotubes (CNT), the CNT particles are very important as a dispersible material in base working fluids (water, oil and etc) [9]. The most lubricants on the markets are the synthetics and mineral oils, but they are not friendly to the environment beside the effective of these oils in lubrication. The replacing of the mineral and synthetic lubricants by the renewable ones was investigated by the new researches to show the ability to use these oils. Vegetable oils are one of the renewable resource lubricants that are less harmful to the environment [10]. In addition, the importance of using vegetable oils are for developing new lubricants that which meet the current economic needs of the country and for protection of the environment and improved quality of life [11]. Many researchers was classified the ability of using vegetable oils of instead of the synthetic and mineral oils into four sites to evaluate these oils, pure vegetable oils tribological attributes [12,13], vegetable oil emulsion [14], additives to vegetable oils properties enhancement [15], and the vegetable oil tribological characteristics as an additive [16]. Characteristic (tribological) of the many samples of plant fluids were tested depending the (ASTM D4172) method like bunches of empty fruit (EFB) of palm fruit, castor oil and mustard fluid as a new alternative source of fluid [17-22]. Based on the literature above, this experimental work conducted to evaluate and examine the effect of using corn oil as a bio-lubricant instead of the mineral oil on the performance of engine, such as brake specific fuel consumption (bsfc), brake thermal efficiency, and engine temperature. Furthermore, the effect the using multi-wall carbon nanotube (MWCNT) with different concentration ratios as an additive in this lubricant on these performances.

RESEARCH METHODOLOGY

Governing Equations

Producing nano-oil using of MWCNT with corn oil lead to a change in the physical properties of used corn oil. The important enhancement in the physical properties of corn oil with using the MWCNT is in the thermal conductivity of this lubricant. The following correlations are used to calculate the thermo-physical properties of nano-oil [23-25]

Thermal conductivity of nano-oil (*k nano-oil*),

$$k_{n-oil} = [\frac{k_{np} + 2k_{oil} - 2(k_{oil} - k_{np})\phi}{k_{np} + 2k_{oil} - (k_{oil} - k_{np})\phi}]k_{oil} \quad (1)$$

The density of nano-oil (ρ_{n-oil}) can be calculated using

$$\rho_{n-oil} = (1-\phi)\rho_{oil} + \phi\rho_{np} \quad (2)$$

And the specific heat of nano-oil (Cp_{n-oil}) is

$$(\rho Cp)_{n-oil} = (1-\phi)(\rho Cp)_{oil} + \phi(\rho Cp)_{np} \quad (3)$$

Where, ϕ refers to the nanoparticles volumetric concentration ratio in the used base fluid, which is defined as follows:

$$\phi = \frac{V_{np}}{V_T} = \frac{\frac{m_{np}}{\rho_{np}}}{\frac{m_{np}}{\rho_{np}} + \frac{m_{oil}}{\rho_{oil}}} \qquad (4)$$

While, the performance of the IC Engine can be estimated with the fallowing equations [2,26].

The power generated from fuel is expressed as:

$$P.F = C_v * \dot{m_f} \qquad (5)$$

And the consumption of fuel:

$$\dot{m_f} = (V_f * \rho_f)/t_b \qquad (6)$$

The brake power of the IC engine can be calculated from:

$$b.p = \frac{2\pi * N * T}{60 * 1000} \qquad (7)$$

Then, the brake specific fuel consumption can be found using:

$$bsfc = \dot{m_f}/b.p \qquad (8)$$

And the brake thermal efficiency of IC engine:

$$\eta_{b.th} = \frac{b.P}{C_v * \dot{m_f}} \qquad (9)$$

Experimental Procedures

The experimental procedure aims to show the effect of using renewable corn oil as a lubricant instead of the mineral oil (SAE 20W-40) on the performance of the internal combustion engine. Furthermore; the effect the using multi-wall carbon nanotube (MWCNT) which specified (purity>95wt%, ash<1.5wt%, 8-15 in outer diameter and 10-50 nm in length), as additive into corn oil lubricant with 0.1, 0.2 and 0.3% concentration ratios on the engine performance. Therefore, the experimental procedure can be summarized to:

Preparing of MWCNT/Corn oil

The amount of the MWCNT that used to product 1 litters of nano-oil (MWCNT/Corn oil) at 0.1, 0.2 and 0.3% concentration ratios was 4.19, 8.264 and 12.325 gm. respectively. The HR-250AZ digital scale was used to the weight of used nanoparticles for the wanted concentration ratios which delimited by equation (4).

The JY92-IIN ultrasonic homogenizer used to prepare the MWCNT/Corn oil. While, the kinematic viscosity of the used lubricant oil samples (mineral oil, corn oil,and MWCNT/Corn oil) was measured experimentally by a Cole-Parmer rotary viscometer.

Apparatus

Four-stroke single-cylinder internal combustion engine was used to assess the mechanical performance under different speeds and loads, as shown in the figure 1. The maximum torque and power of the used engine are 16 N.m and 3.5kW respectively at 3600 revs/min. The applied variable loads on the used engine provided by dynamo motor. The applied loads with engine speeds are changes by a digital controller board.

The fuel type of engine is diesel with specifications 0.8304 SP. gravity, 37.1 API gravity, 72.8 oC flashpoint, 838.8 kg/m3density, and 10921 Kal/kg calorific value.

The first test was done using lubricant mineral oil, the second test was done using corn oil instead of the mineral oil, while the other tests were done using 0.1,0.2 and 0.3% of MWCNT/ Corn oil. the IC engine performance evaluated under different operating conditions with the previous five lubricant oils:

- Four tests were done at constant engine speed 2000 rev/min under different applied loads 2, 4, 6 and 8 N.m .
- Four tests were done at constant engine load 2N.m with different engine speed 1500, 2000, 2500 and 3000 rev/min.

The digital thermometer type TM-946 with two K-type thermocouples fixed on the engine cylinder body was used to measure the surface cylinder temperatures of the IC engine.

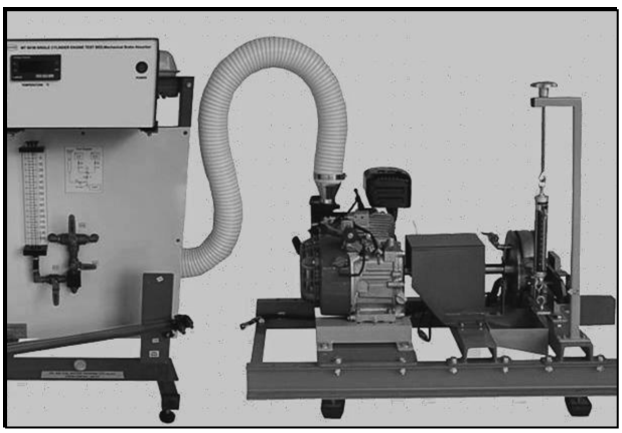
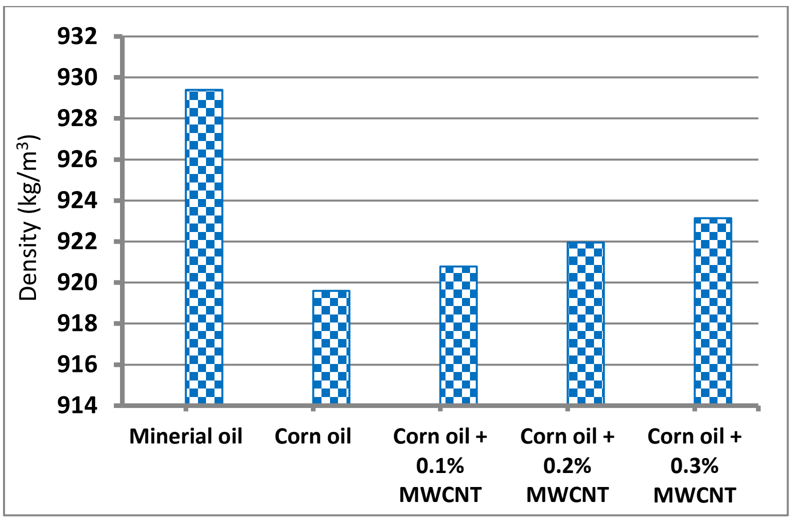


Figure 1. Photograph of the used engine

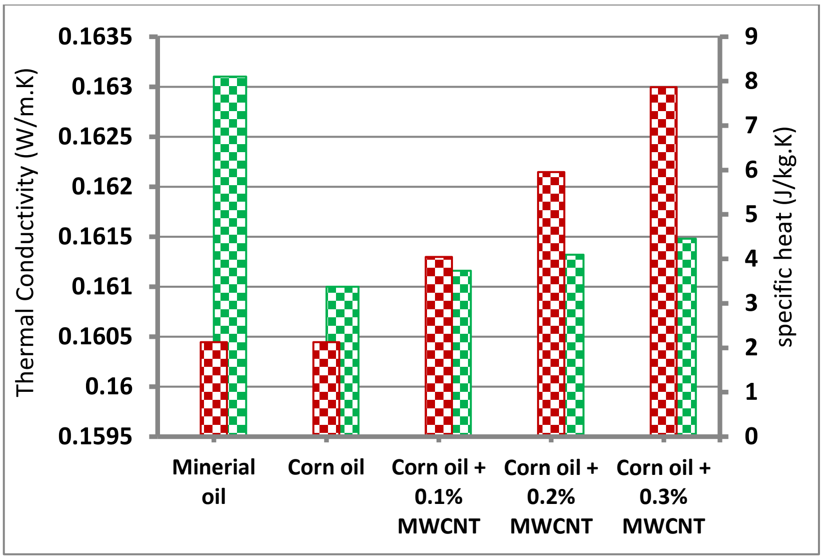
RESULTS AND DISCUSSIONS

Figure 2 shows the thermo-physical properties of the used material (mineral oil, corn oil, and MWCNT/corn oil with different concentration ratios) at room temperature.A rotary viscometer tests results give the kinematic viscosity of the used mineral and corn lubricants oil with rising in temperature before applied the used lubricants oil in the engine, as shown in figure 3. It is seen that at low temperatures test until 75ºC, the used corn oil has less viscosity than the mineral oil. But after 75ºC the used corn oil has a higher viscosity than mineral oil in small ranges. This result gives a good indicator for the ability to use the corn oil in engines lubricant instead of mineral oil because at starting a cold engine lubricated with high-viscosity oil is very difficult i.e.,(more work is required to pump it, and to shear it between moving parts). This gives greater friction work, reducing brake power and increasing in fuel consumption rate. But in higher operation temperature, increasing in viscosity of the lubricant is suitable ranges are important for enhancing engines performance and keeps its parts [1]. The engine's temperatures recorded data from starting to the end of tests time are gives in figure 4, for each type of lubricant oils that used in the engine at 2N.m and 2000 revs/min of applied load and engine speed. The corn oil is contributed to reducing engine temperature, also the used MWCNT additives at 0.1, 0.2 and 0.3% concentration ratios led to more drooping in engine temperatures. The results demonstrated that MWCNT particle additives can effectively improve the oil lubricating properties, because of these nanoparticles enters in the friction zone along with the flow of lubricant, and convert sliding friction into rolling friction [27]. This led to helping to cool the engine. In another way, the used lubricating oil in the engine also helps to cool the engine. Because of its location, a piston gets very little cooling from the coolant in the external finned surface of an air-cooled engine or the water jacket of a water-cooled engine [1].

Figures 5& 6 show the engine temperatures at the end of each test with the different operation conditions.Figure 7 shows that brake specific fuel consumption (bsfc) at constant load 2N.m applied on the engine with different engine speeds. The bsfc is decreased from the higher values at lower speeds of the engine, reaches to a minimum then increases as engine speed increases. Because, at low engine speed, gives longer time per cycle, and this allows more heat loss (fuel consumption goes up). While at high engine speeds, the greater friction losses gives higher in brake specific fuel consumption [1].The increase in the engine's applied load with constant engine speed 2000 rev/min lead to increases in the knock that heard from the engine, which contributes increases in brake power losses then brake specific fuel consumption gradually, as shown in figure 8.internal combustion engine brake thermal efficiency depends on brake power generated and fuel consumption rate of the engine i.e. (related on brake specific fuel consumption). The increases in friction losses due to high speeds led to decreases in brake thermal efficiency, using the corn oil lubricants led to enhancing in the brake thermal efficiency due to effect of its suitable viscosity comparatives with the used mineral lubricant oil. Furthermore, the used MWCNT as additives to corn oil with 0.1, 0.2, and 0.3% concentration ratios led to more enhancements in the brake thermal efficiency, as showed in figures 9&10.From the above-discussed figures, it can be conducted the percentage of engine performance enhancements using corn oil lubricants with MWCNT additives comparative with used mineral oil lubricant as shown in figures 11, 12 and 13.



(a)



(b)

Figure 2. Thermo-physical properties of the oil samples: (a) density,

(b) thermal conductivity with specific heat

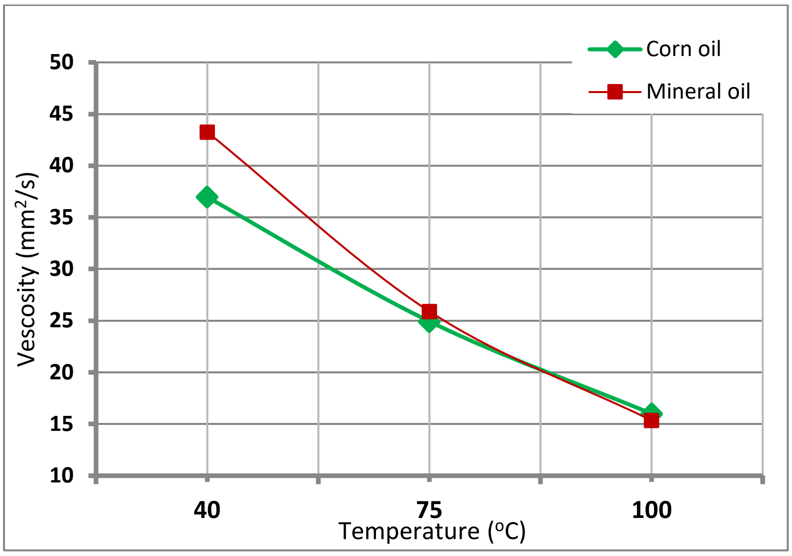


Figure 3. kinematic viscosity of the oil samples under different temperature

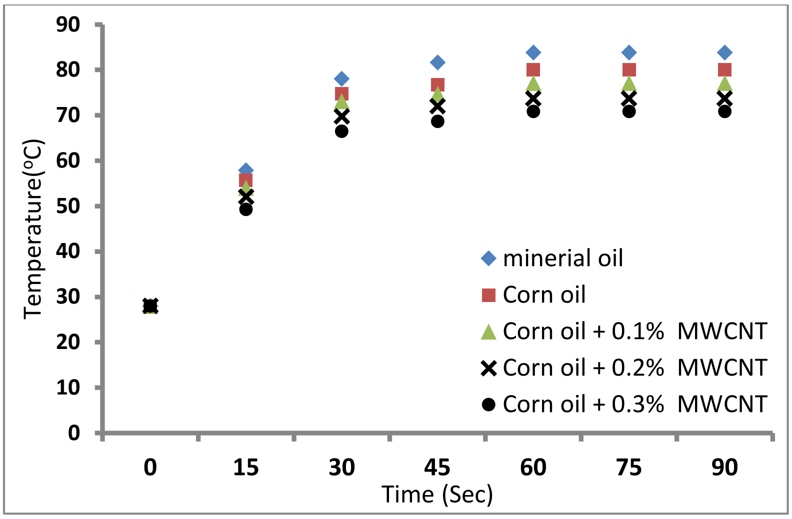


Figure 4. Engine temperatures at (2 N.m) and (2000 rev/min)

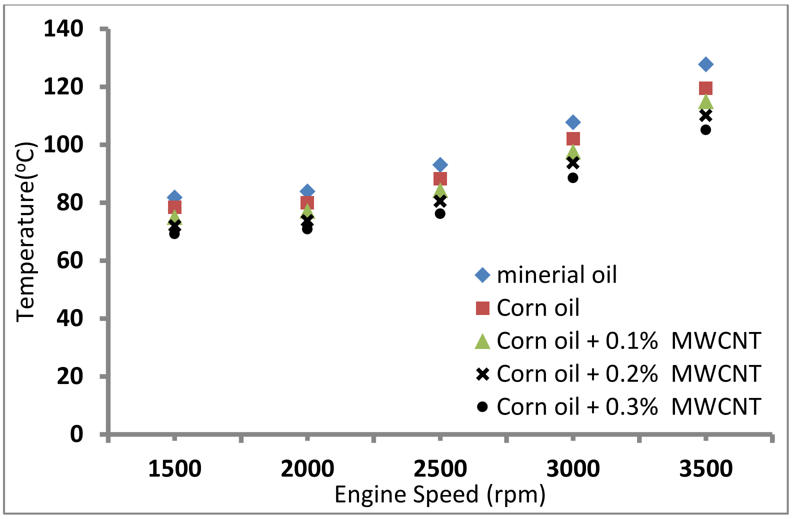


Figure 5. Engine temperatures at (2 N.m) with different engine speeds

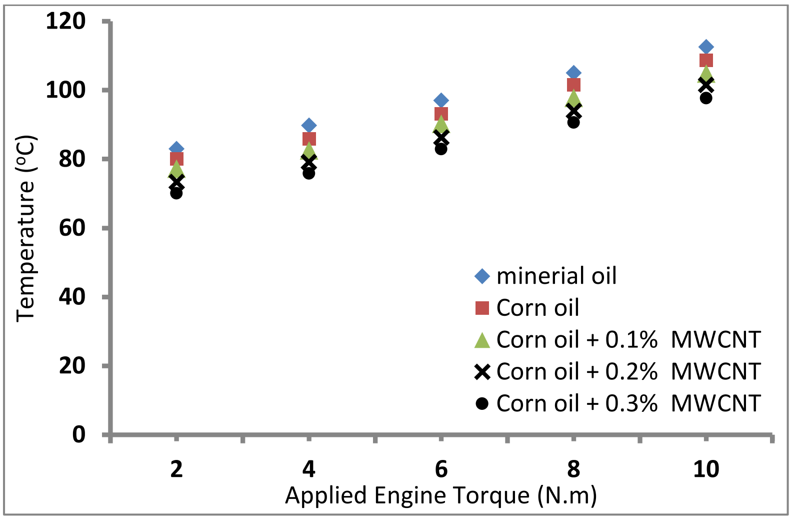


Figure 6. Engine temperatures at (2000 rev/min) with different applied loads

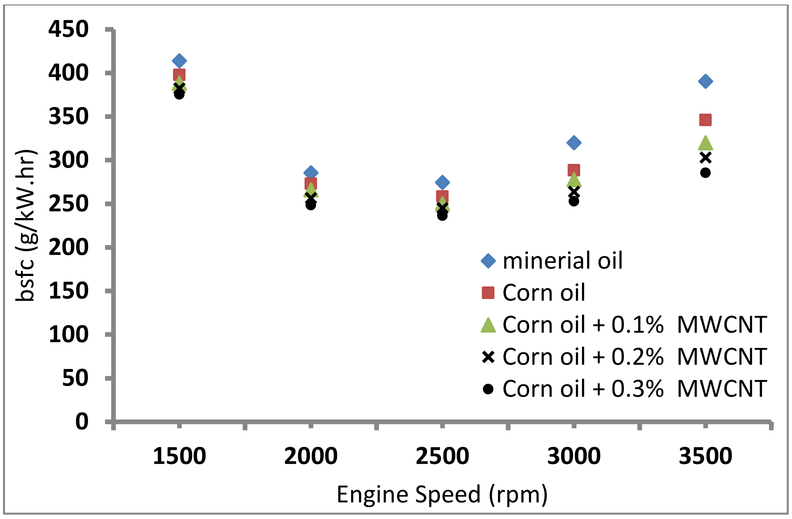


Figure 7. bsfc of the engine at (2N.m) with different engine speeds

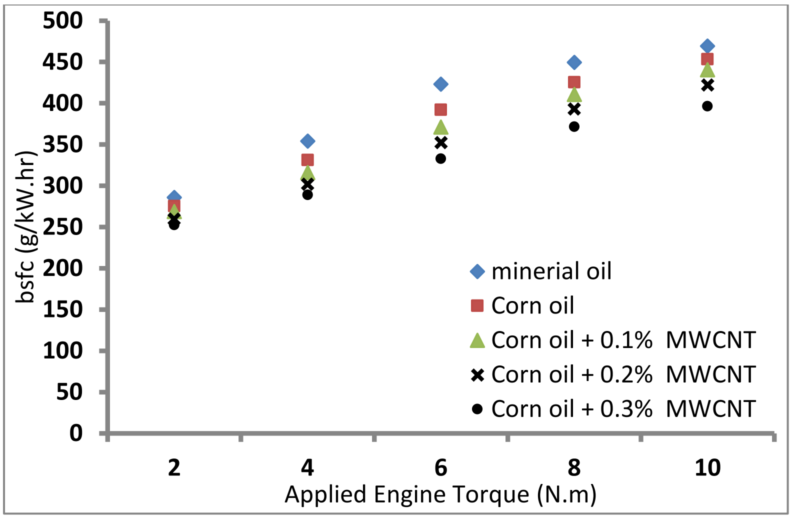


Figure 8. bsfc of the engine at (2000 rev/min) with different applied loads

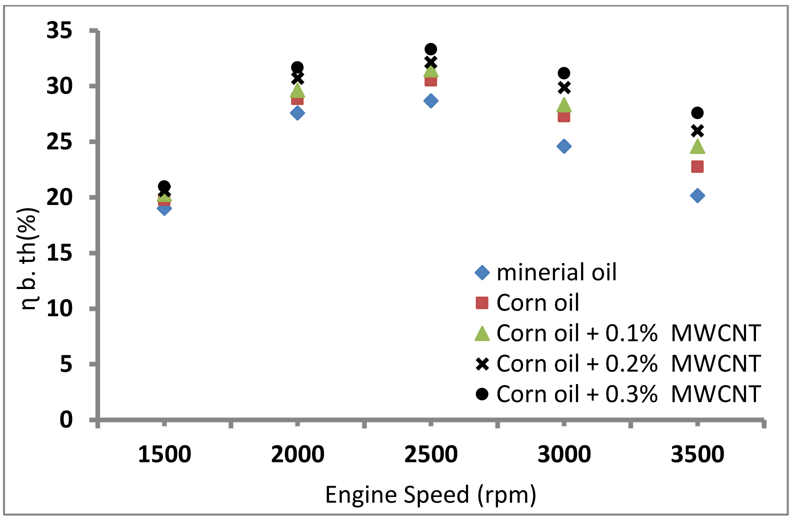


Figure 9. Brake thermal efficiency of the engine at (2N.m) under different engine speeds

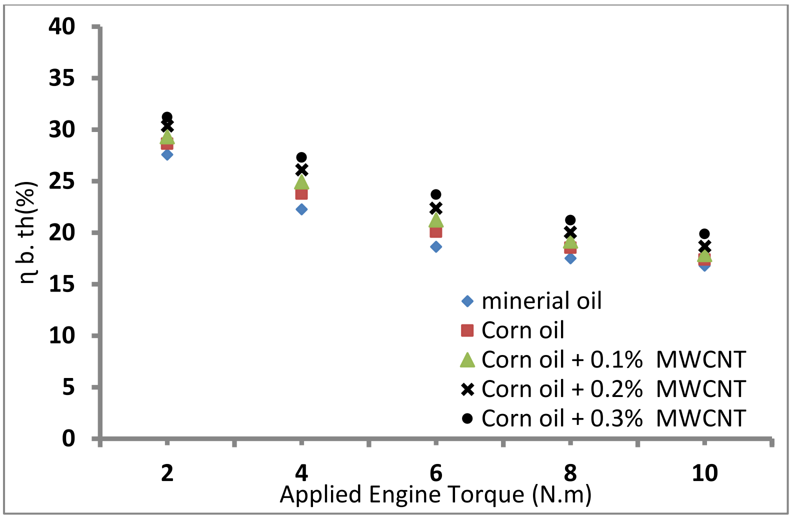


Figure 10. Brake thermal efficiency at (2000 rev/min) with different applied loads

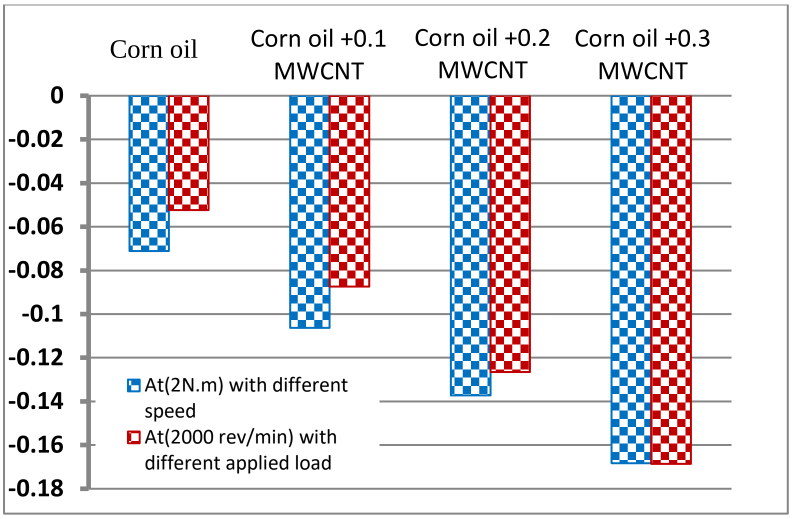


Figure 11. Percentage of the engine bsfc decreasing

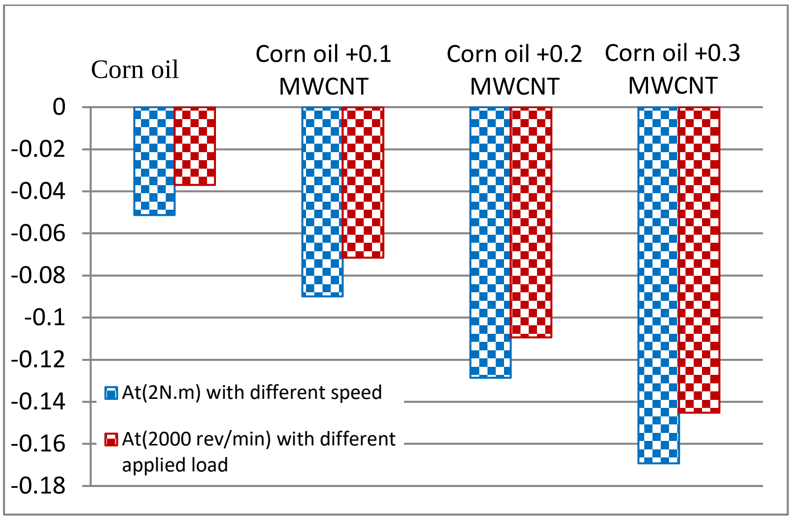


Figure 12. Percentage of the engine cylinder surface temperature

decreasing for the oil samples

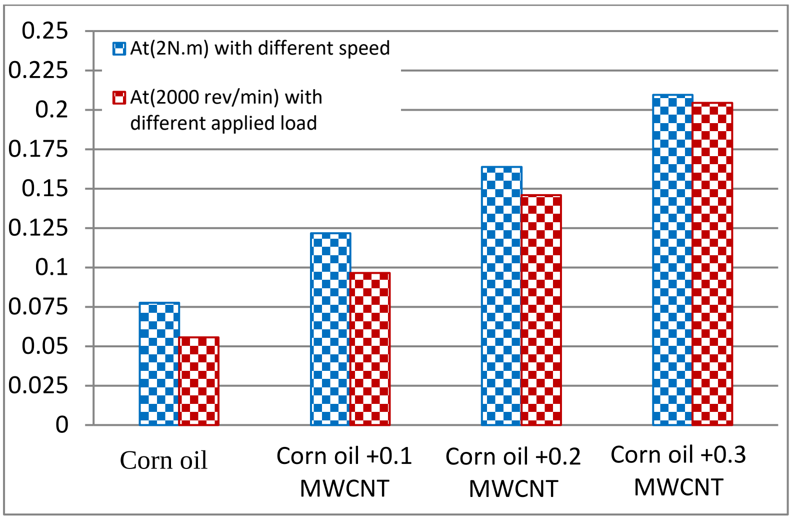


Figure 13. Percentage of engine brake thermal efficiency increasing

CONCLUSIONS

From the performance evaluation of the IC engine with used lubricants experimentally, it can conclude the following:

- Using the corn oil as engine lubricant instead of the mineral oil, contributes to engine cooling and reducing in the brake specific fuel consumption and increasing in brake power thermal efficiency of the IC engine, due to the best viscosity at low and high temperatures of the corn oil than the mineral comparative with the mineral oil.

- The effect of using the MWCNT as additives to corn oil at 0.1, 0.2 and 0.3% concentration ratios give decreasing in the brake specific fuel consumption and decrease in the engine's temperature with increasing in brake power thermal efficiency of the used IC engine.

NOMENCLATURES

b.p	*Engine brake power (kW).*
bsf	*Brake specific fuel consumption of the engine (g/kW.hr)*
C_v	*The used fuel higher calorific value (45693.46 kJ/ kg) or (10921kcal/kg).*
I.p	*Engine indicated power (kW).*
$\dot{m_f}$	*Consumption of fuel (g/s).*
N	*Engine speed (rpm).*
P	*Power generated from fuel (kW).*
T	*Engine toque (N.m).*
t_b	*Time needed to empty the fuel burette (s).*
V_f	*Used volume of fuel (8 ×10-6 m3).*
$\eta_{b.th}$	*Engine brake thermal efficiency (%).*
ρ_f	*Density of the fuel (kg/ m³).*

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