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EXPERIMENTAL STUDY OF THE EFFECT OF THE INJECTION PRESSURE CHANGE USING WASTE VEGETABLE OILS ON DIESEL ENGINE PERFORMANCE

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Abstract

The diesel engine is an internal combustion engine that converts the chemical energy in the fuel into kinetic energy. Waste vegetable oils can be used as an alternative fuel in conventional diesel engines. When waste vegetable oils are used directly as a fuel in a diesel engine; the injection pressure of diesel engines can be altered to help ensure that the viscosity of the vegetable oils is low enough to allow proper atomization of the fuel. Waste vegetable oils can also be blended with diesel fuel for use under a wide range of conditions. The injection pressure is one of the important variables affecting the performance of the engine. In this paper, the effect of changing the injection pressure from 170 to 200 bars on the performance of diesel engine was studied by using different types of blends of waste vegetable oils with diesel fuel. From the most important results of increasing in the injection pressure is improving the engine performance by increasing the brake thermal efficiency in a range of percentages from 3.8% to 19% compared to the 170 bar injection pressure at different loads and reducing the brake specific fuel consumption in a range of percentages from 3.5% to 13% compared to the 170 bar injection pressure at different loads thus increasing the air-fuel ratio in a range of percentages from 3.5% to 19% compared to the 170 bar injection pressure at different loads. The use of these oils in engines helps to reduce dependence on conventional fuels, which leads to preserving the climate, in addition to the fact that re-processing and reusing these oils is harmful to human health.

Keywords

Injection Pressure, Diesel Engine, Diesel Fuel, Waste Vegetable oil, Renewable Fuel and Engine Performance.

1. Introduction

Diesel engine is an internal combustion engine in which air is compressed to adequate temperature to ignite diesel fuel injected into the cylinder where, combustion and expansion actuate a piston. It transforms the chemical energy that stored in the fuel into mechanical energy. One of the important variables that affects the performance and emissions of the diesel engine is the injection pressure. Vegetable oils are viewed as an alternative fuel or sustainable fuel and are utilized straightforwardly in diesel engines since these oils are sustainable and ecological amicable.

Numerous specialists concentrated on the effect of injection pressure on performance of diesel engine using different fuels. The used different fuels are: Hone-Biodiesel with injection pressure 180 to 240 bars [1], Neem-oil-methyl-ester and castor-oil-methyl-ester [2], Diesel-fuel with injection pressure from 100 to 250 bars [3], Different fuel cetane numbers with injection pressure 100 to 250 bars [4], Ethanol-diesel-fuel with injection pressure 150 to 250 bars [5], Fresh-corn and palm-oils with injection pressure 120 to 210 bars [6], Lemon-grass-methyl-ester with injection pressure 210 to 240 bars [7], The light duty and heavy diesel engine with injection pressure 150 to 250 bars [8], Waste-cooking-oil at 160 bar injection pressure [9], Algae-oil-methyl-ester with injection pressure 240 to 260 bars [10], Polanga-oil and thyme-oil with injection pressure 180 to 220 bars [11], Honge-Rice-bran-bio diesel with injection pressure 180 to 220 bars [12], Syzygium-cumini-oil-biodiesel with injection pressure 200 to 260 bars [13], Pentanol and jatropha-oil with injection pressure 400 to 600 bars [14], Waste-cooking-oil-biodiesel with injection pressure 170 to 220 bars [15] and Fish-oil-biodiesel [16]. Other researchers have investigated the effect of biodiesel blended with diesel fuel on diesel engine performance with or without change of injection pressure, such as, biodiesel from sunflower-oil and soybean-oil [17, 18], Biodiesel from jatropha-oil [19], Biodiesel from algae [20], and Biodiesel from waste-cooking-oil and cyclohexane [21, 22]. Biodiesel is produced from many types of vegetable oils by transesterification—a process that transforms fats and oils into biodiesel and glycerin. Therefore, we will use wasted vegetable oils in this research because they are environmentally friendly

The aim of the research is to use other types of oils as fuel for the diesel engine which are: WPKO and WSFO. This study is to perform experiment on a diesel engine using different types of fuels and to study the effect of injection pressure and engine load on engine performance at constant engine speed. Differences in results were observed because of some reasons such as: using of different fuels and different injection pressures versus engine loads in each investigation. Also, the goals of the research is to improve engine performance by increasing injection pressure with the use of these oils, because reusing these oils after purification and chemical treatment is harmful to human health, in addition to preserving the environment by significantly reducing dependence on traditional fossil fuels.

2. Experimental Set-Up and Test Procedure

The plan designed for the experimental investigation of the performance of diesel engine using different types of fuels, DF, and three kinds of blends (by volume) of WPKO with DF i.e. blends of 20% WPKO with 80% DF (B20-WPKO), 30% WPKO with 70% DF (B30-WPKO) and 40% WPKO with 60% DF (B40-WPKO) and also three kinds of blends (by volume) of WSFO with DF i.e. blends of 20% WSFO with 80% DF (B20-WSFO), 30% WSFO with 70% DF (B30-WSFO) and 40% WSFO with 60% DF (B40-WSFO) were studied at change of injection pressure and engine load at constant engine speed. Injection pressures used are 170, 185 and 200 bar as well as the percentage of engine loads used 20%, 40% and 60% from maximum engine power.

Table No. 1 shows main properties of the fuel tested. The density and calorific value of the fuel used can be calculated from equations (1) and (2) respectively, BRV=0 or BRM=0 for pure diesel fuel and BRV=1 or BRM=1 for pure WVO.

$$\rho_{fuel\ used} = (1-BRV) * \rho_{DF} + BRV * \rho_{WVO} \quad (1)$$

$$C.V_{fuel\ used} = (1-BRM) * C.V_{DF} + BRM * C.V_{WVO} \quad (2)$$

We note that the density of the blend increases compared to diesel fuel by increasing the percentage of WVO in the blends and the calorific value of the blend decreases compared to diesel fuel with an increase in the percentage of WVO in the blends.

Table 1. Properties of Fuel

	DF	***Pure WPKO***	***Pure WSFO***
Calorific value (kJ/kg)	42700	37200	37000
Viscosity (mm2/s) at 35 ºC	5	69.6	67.7
Density (kg/m3)	780	835	845
Cetane No.	48	36.5	37
Chemical Formula	$C_{10.8}H_{18.7}$ [23]	-	$C_{57}H_{103}O_6$ [24]

The diesel engine used in the current experimental study its specifications are shown in table No. 2. Schematic diagram and a photographing plate of the experimental set-up are shown in Fig.1.

Table 2. Specification of the used diesel engine.

Model	Deutz-F1L511
Type	4 stroke, direct injection
No. of cylinder	1
Compression ratio	17
Bore	100 mm
Stroke	105 mm
Power	5.7 Kw
Type of cooling	Air cooling

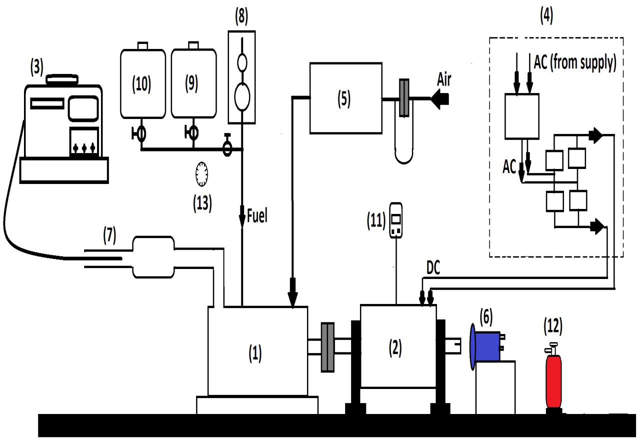

Figure 1(a) Schematic Diagram of the Experimental Setup

Figure 1 (b) A photographing Plate of the Experimental Set-up

(1) Diesel-Engine; (2) Electrical-Dynamometer;
(3) Exhaust-Gas-Analyzer; (4) Voltage-Regulator;(5) Air-Box;
(6) The-Optical-Tachometer; (7) Exhaust-Gases-Pipes;
(8) Fuel-Consumption-Rate-Device; (9) Biofuel-Tank;
(10) Diesel-Fuel-Tank;(11) The-Digital-Weight;
(12) Fire-Extinguisher and (13) Stop-Watch

Figure 1. Schematic Diagram and a photographing Plate of the Experimental Set-up

The diesel engine is directly connected to the electrical dynamometer with a maximum power of 15 hp. The engine output is controlled by adjusting the excitation field voltage (applied on the electrical dynamometer) and for this it is said that the engine operates at a certain load (percentage of the maximum torque). The values of the excitation field voltage vary with the change of load at constant engine speed of 1500 rpm during test. From the experimental results, the uncertainty and percentage error in the measured parameters are illustrated in table No.3.

Table 3. The uncertainty and percentage error in the measured parameters

The measured parameters	The uncertainty	%age error in measured parameter
Voiume Flow Rate	±0.5 cm³	$\Delta v = \frac{\text{The uncertainty}}{\text{the recorded volume}}$ $\Delta v = \pm\frac{0.5}{50} = \pm 1\%$
The Optical Tachometer	±5 rpm	$\Delta N = \frac{\text{The uncertainty}}{\text{the recorded speed}}$ $\Delta N = \pm\frac{5}{1500} = \pm 0.333\%$
Weight Scale	± 50 grams	$\Delta m = \frac{\text{The uncertainty}}{\text{the recorded weight}}$ $\Delta m = \pm\frac{50}{3000} = \pm 1.67\%$
Water Manometer	± 10 mm	$\Delta H = \frac{\text{The uncertainty}}{\text{the recorded hight}}$ $\Delta H = \pm\frac{10}{625} = \pm 1.6\%$

3. Experimental Results and Discussion

3.1. Air-fuel ratio for different Fuels

Figures 2-A , 2-B, 2-C, 2-D, 2-E, 2-F and 2-G show the measured AFR for DF, B20-WPKO, B30-WPKO, B40-WPKO, B20-WSFO, B30-WSFO and B40-WSFO respectively at different injection pressures versus engine loads at constant engine speed. From these figures: it can be observed that the AFR during combustion process by using WVO blends is less than that of DF. This may be due to the high viscosity, density and low CN of these blends or may be due to the decrease in mechanical efficiency while increasing the injection pressure increases the air-fuel ratios for the different blends of WVO. This may be due to the reduced viscosity of WVO blends which contributes to better atomization and combustion, because with increase in the injection pressure the viscosity of various WVO blends decreases. On the other hand, there is no noticeable increase in AFR for DF with increasing injection pressure from 185 to 200 bars [3].

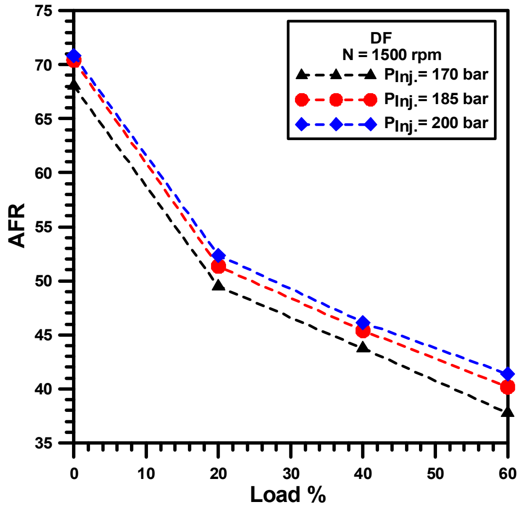

Figure (2-A) Effect of injection pressure on AFR for Diesel Fuel

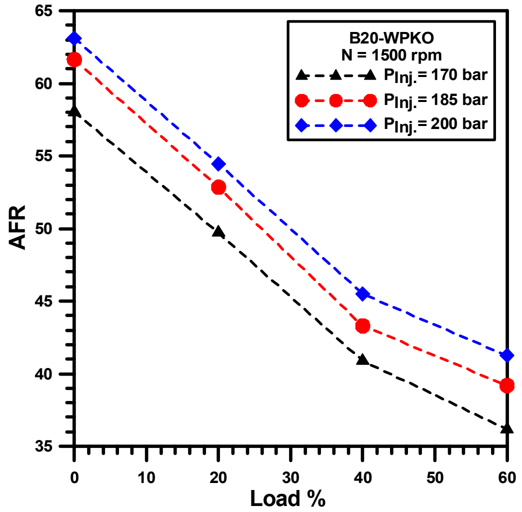

Figure (2-B) Effect of injection pressure on AFR for B20-WPKO

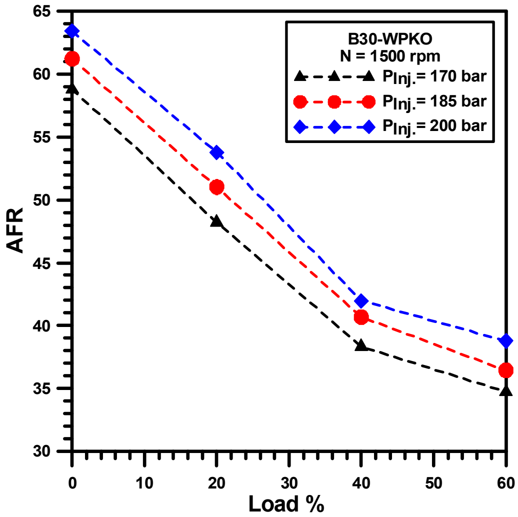

Figure (2-C) Effect of injection pressure on AFR for B30-WPKO

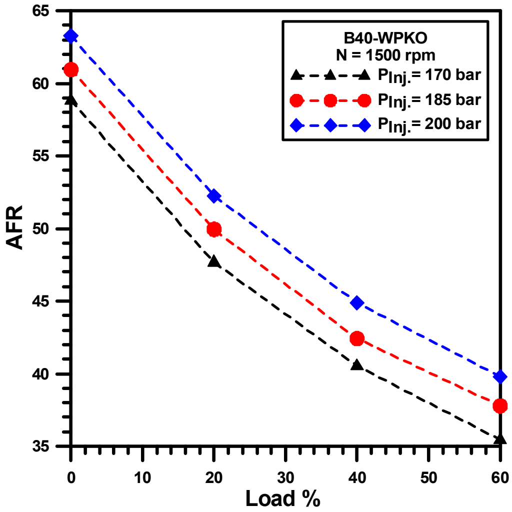

Figure (2-D) Effect of injection pressure on AFR for B40-WPKO

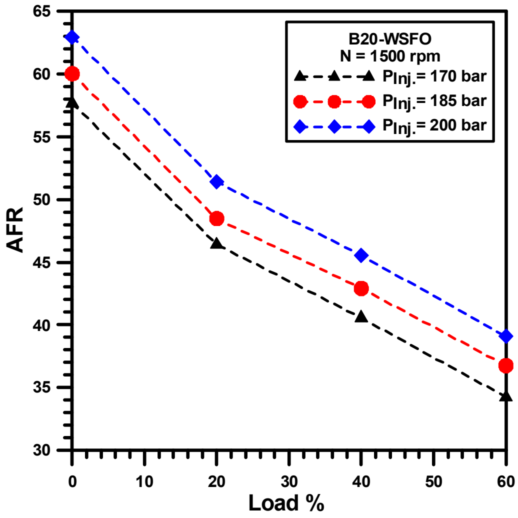

Figure (2-E) Effect of injection pressure on AFR for B20-WSFO

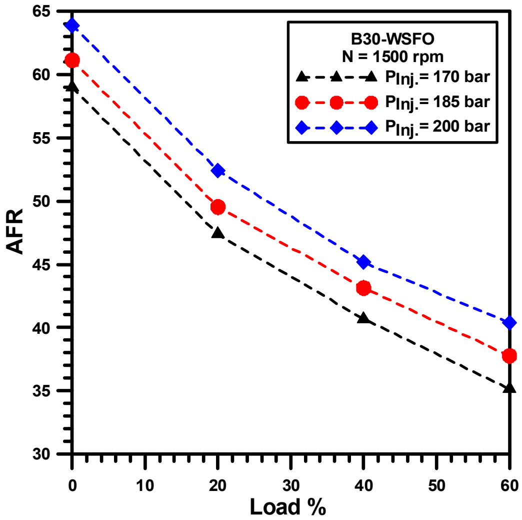

Figure (2-F) Effect of injection pressure on AFR for B30-WSFO

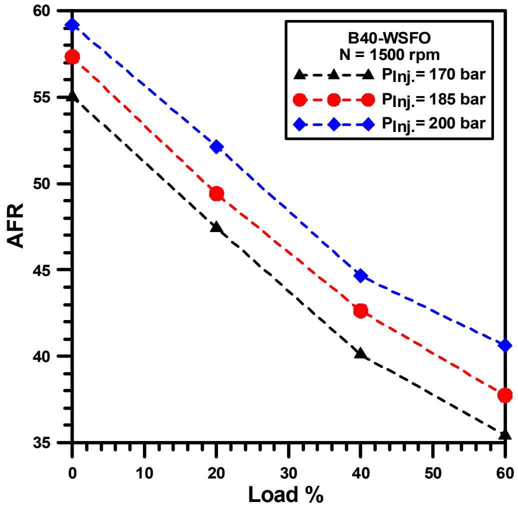

Figure (2.G) Effect of injection pressure on AFR for B40-WSFO

Figure 2. The injection pressure effect on AFR for different fuels

3.2. Brake specific fuel consumption for different fuels

The brake specific fuel consumption is the reciprocal measure of the brake thermal efficiency so, it is used to evaluate the effect of WVO blends on the engine performance. The brake specific fuel consumption is calculated as follows.

$$BSFC = \frac{m^{*}_{fuel}}{\mathrm{BP}} \qquad (3)$$

Figures 3-A , 3-B, 3-C, 3-D, 3-E, 3-F and 3-G illustrate a comparison the BSFC with engine load for DF, B20-WPKO, B30-WPKO, B40-WPKO, B20-WSFO, B30-WSFO and B40-WSFO, respectively at different injection pressures at constant engine speed. BSFC for a diesel engine depends on the flow rate of the fuel volume from the engine injection system, fuel viscosity, density and calorific value. It can be seen that BSFC decreases with increasing injection pressure due to the improvement of the combustion process of different blends of WVO. This may be due to the reduced viscosity of WVO blends which contributes to better atomization and combustion [3, 6, 9, 12 and 22].

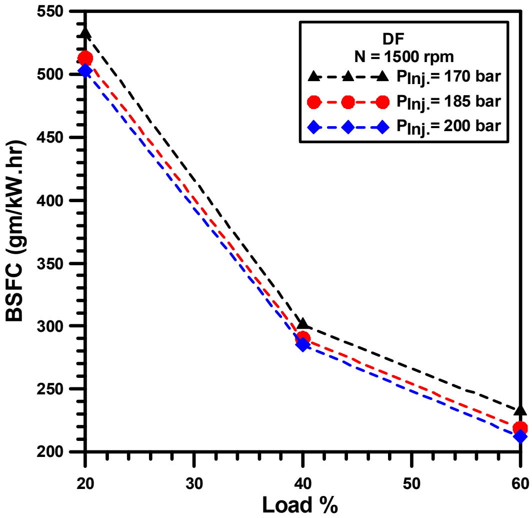

Figure (3-A) Effect of injection pressure on BSFC for DF

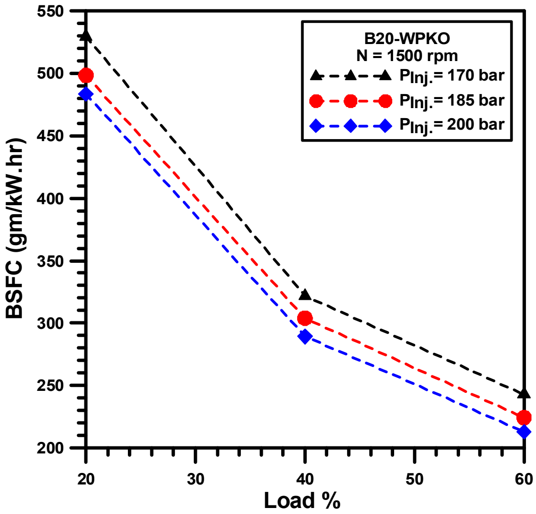

Figure (3-B) Effect of injection pressure on BSFC for B20-WPKO

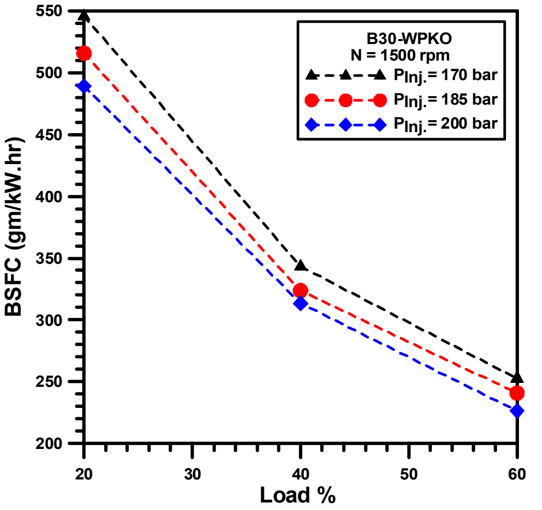

Figure (3-C) Effect of injection pressure on BSFC for B30-WPKO

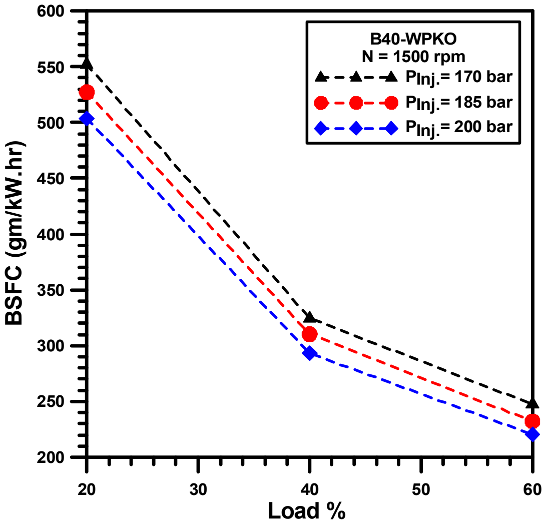

Figure (3-D) Effect of injection pressure on BSFC for B40-WPKO

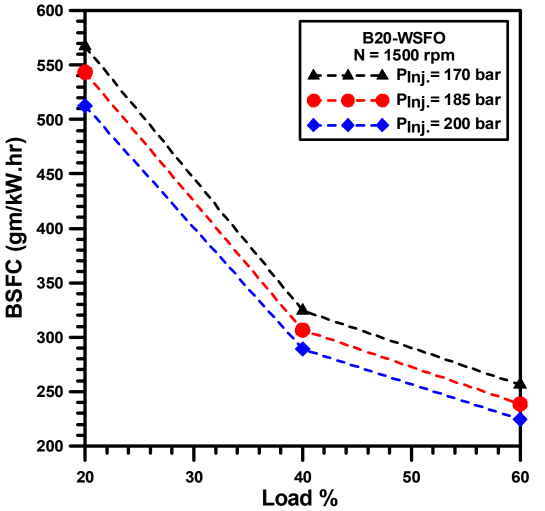

Figure (3-E) Effect of injection pressure on BSFC for B20-WSFO

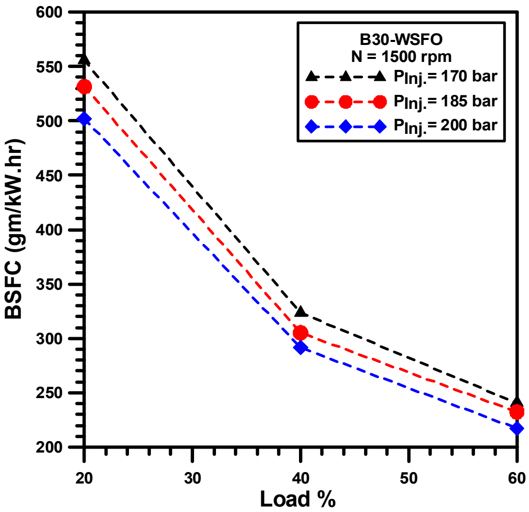

Figure (3-F) Effect of injection pressure on BSFC for B30-WSFO

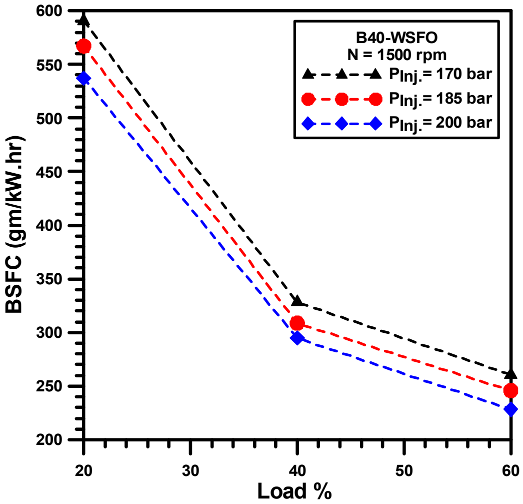

Figure (3-G) Effect of injection pressure on BSFC for B40-WSFO

Figure (3) The injection pressure effect on BSFC for different fuels

3.3 Brake thermal efficiency for different fuels

The brake thermal efficiency of an engine is inversely proportional to its BSFC and the calorific value of the fuel. The BTE is defined as:

$$BTE\ \% = \frac{3600}{\mathrm{BSFC} * \mathrm{CV}} * 100 \qquad (4)$$

Where: BSFC (kg/kW.hr)

Figures 4-A , 4-B, 4-C, 4-D, 4-E, 4-F and 4-G show the variation of BTE for the diesel engine using WVO blends and DF with engine loads at different injection pressures. The BTE of a diesel engine depends on the fuel volume flow rate from the engine injection system, fuel viscosity, density and calorific value. It can be seen that BTE increases with increasing injection pressure due to the improvement of the combustion process of different blends of WVO. This may be due to the increase in mechanical efficiency also; the observed increase in BTE for all blend ratios can be attributed to the relative of calorific value and higher viscosity and density of the blend [3, 4, 6, 9, 12, 15 and 22].

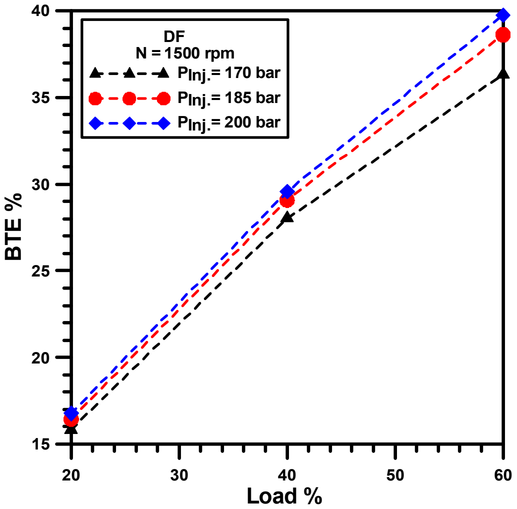

Figure (4-A) Effect of injection pressure on BTE for DF

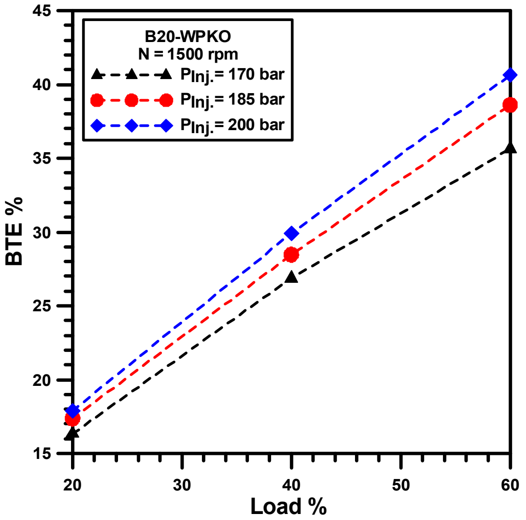

Figure (4-B) Effect of injection pressure on BTE for B20-WPKO

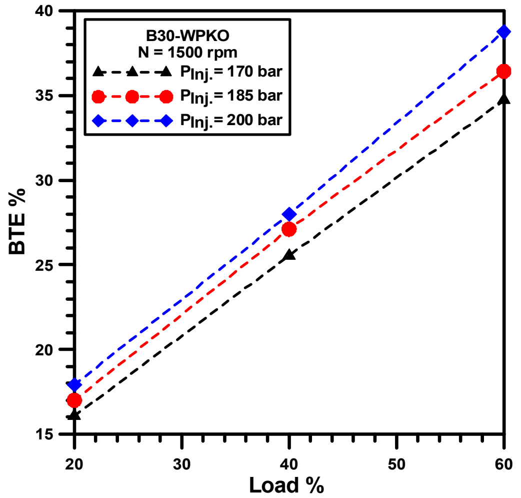

Figure (4-C) Effect of injection pressure on BTE for B30-WPKO

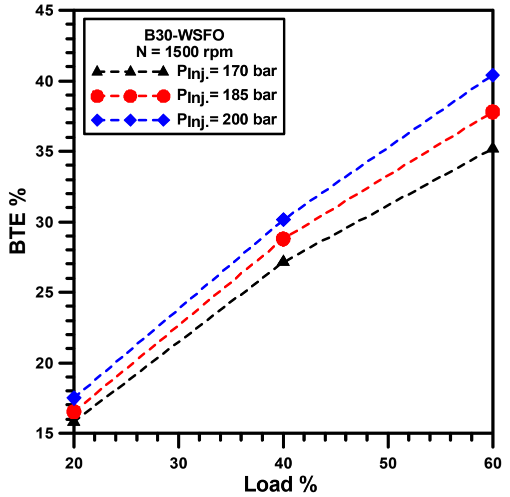

Figure (4-F) Effect of injection pressure on BTE for B30-WSFO

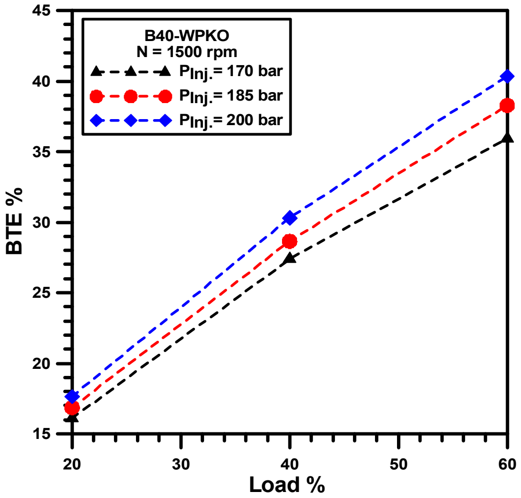

Figure (4-D) Effect of injection pressure on BTE for B40-WPKO

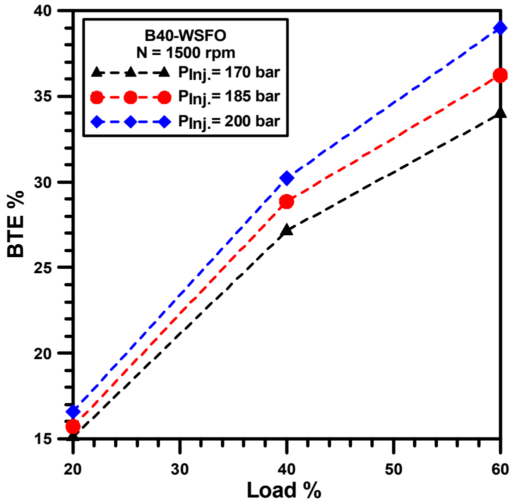

Figure (4-G) Effect of injection pressure on BTE for B40-WSFO

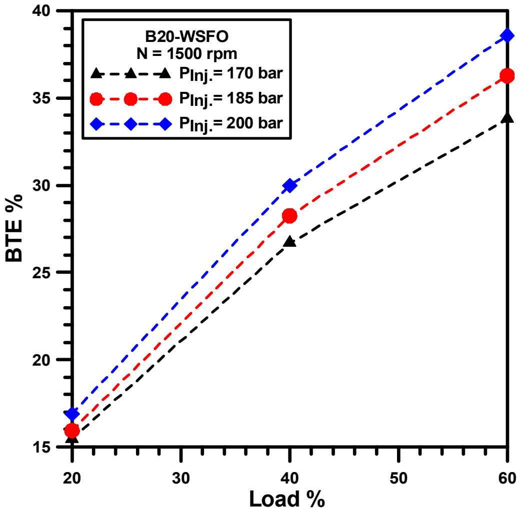

Figure (4-E) Effect of injection pressure on BTE for B20-WSFO

Figure (4) The injection pressure effect on BTE for different fuels

4. Conclusions

An experimental investigation of the performance of a diesel engine using different fuels at different injection pressures (170, 185 and 200 bar) was researched. The percentages of increase or decrease in AFR, BSFC and BTE that have been studied are determined compared to the results of these variables at an injection pressure of 170 bars. The following conclusions were obtained:

- The air fuel ratio increases with increasing of injection pressure at all different loads. The percentages of increase in AFR at 185 and 200 bars compared to that AFR at 170 bars and different loads in a range of percentages from 3.5% to 19% are illustrated the figures in Appendix (A) for each fuel used.
- The brake specific fuel consumption decreases with increasing of injection pressure at all different loads. The percentages of decrease in BSFC at 185 and 200 bars compared to that BSFC at 170 bars and different loads in a range of percentages from 3.5% to 13% are illustrated the figures in Appendix (B) for each fuel used.
- The brake thermal efficiency increases with increasing of injection pressure at all different loads. The percentages of increase in BTE at 185 and 200 bars compared to that BTE at 170 bars and different loads in a range of percentages from 3.8% to 19% are illustrated the figures in Appendix (A) for each fuel used.

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Nomenclatures and Symbols

AFR	Air Fuel Ratio	
BP	Brake Power	(Kw)
BRM	Blend Ratio by Mass	
BRV	Blend Ratio by Volume	
BSFC	Brake Specific Fuel Consumption	(gm/kW. hr)
BTE	Brake Thermal Efficiency	
C.N	Cetane Number	
C.V	Calorific value	kJ/kg
DF	Diesel Fuel	DF
P_{inj}	Injection Pressure	bar
WPKO	Waste Palm Kernel Oil	
WSFO	Waste Sunflower Oil	
WVO	Waste Vegetable Oils	
ρ	Density	Kg/m^3
ΔH	Percentage Error in Water Manometer	
Δm	Percentage Error in Weight Scale	
ΔN	Percentage Error in The Optical Tachometer	
Δv	Percentage Error in Volume Flow Rate	

Appendix (A)

$$\%\text{age. increase in AFR}_j = \frac{AFR_{i,j} - AFR_{170bar,j}}{AFR_{170bar,j}}$$

At the same load

Where, i=185 or 200 bar

j=DF, B20-WPKO, B30-WPKO, B40-WPKO, B20-WSFO, B30-WSFO and B40-WSFO

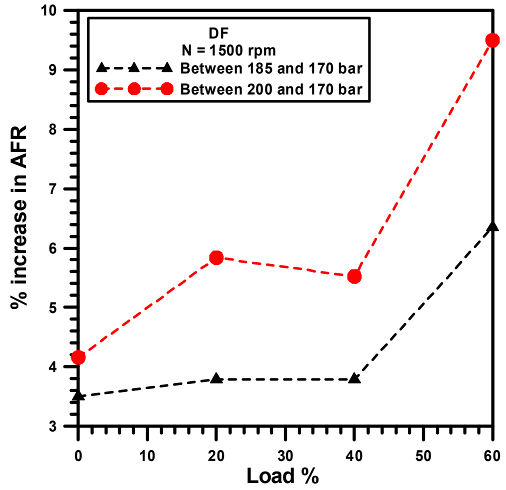


Figure (A.1) %age. increase in AFR for DF

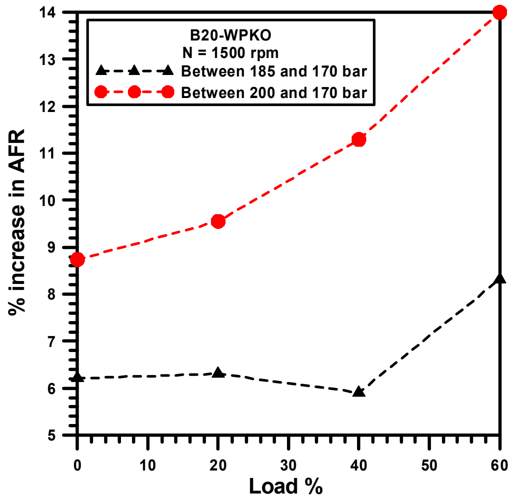


Figure (A.2) %age. increase in AFR for B20-WPKO

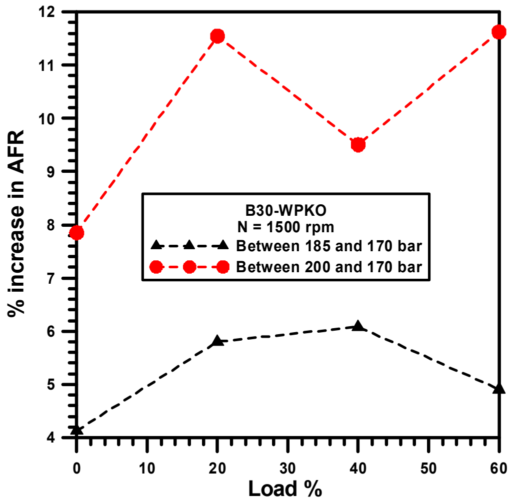
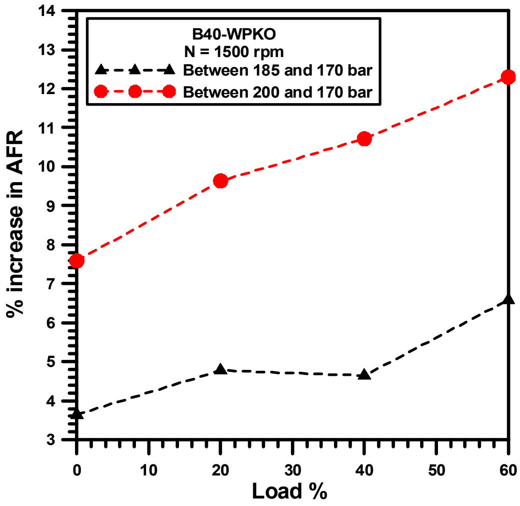


Figure (A.3) %age. increase in AFR for B30-WPKO



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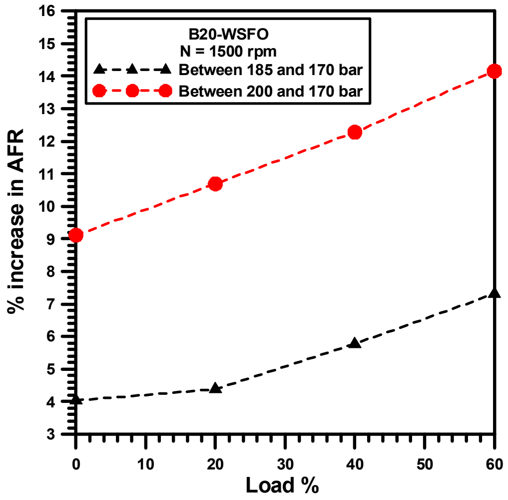

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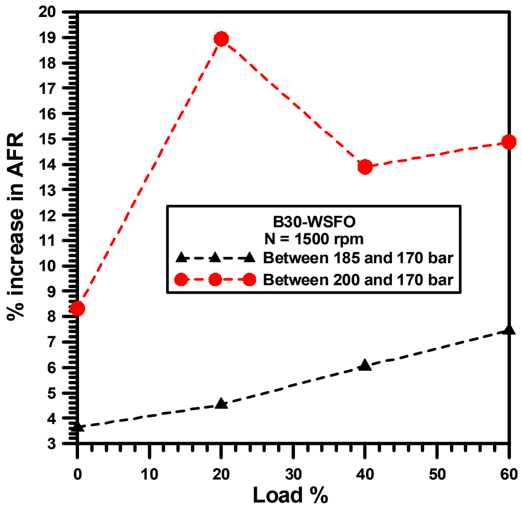


Figure (A.6) %age. increase in AFR for B30-WSFO

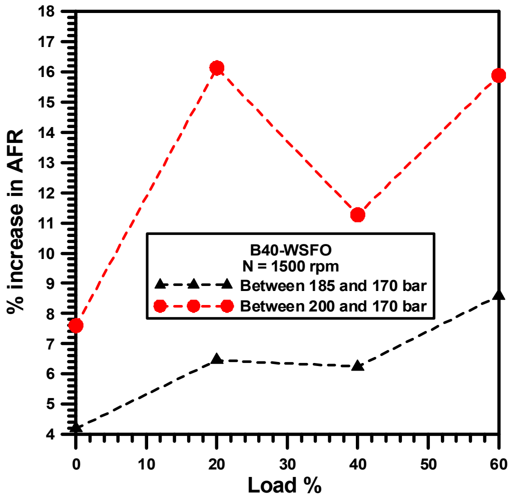


Figure (A.7) %age. increase in AFR for B40-WSFO

Fig. (A) %age. increase in AFR for different fuels

Appendix (B)

$$\%\text{age. decrease in BSFC}_j = \frac{BSFC_{i,j} - BSFC_{170bar,j}}{BSFC_{170bar,j}}$$

At the same load

Where, i=185 or 200 bar

j=DF, B20-WPKO, B30-WPKO, B40-WPKO, B20-WSFO, B30-WSFO and B40-WSFO

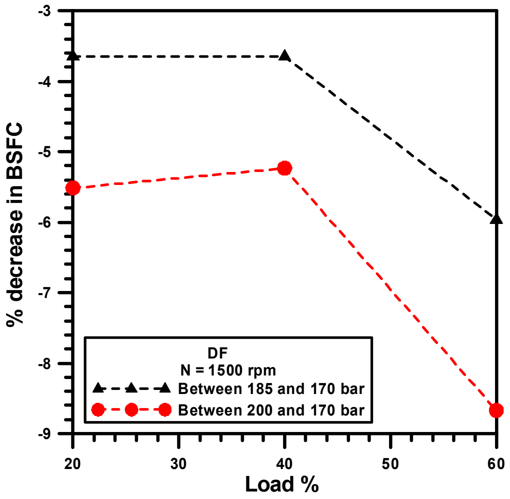


Figure (B.1) %age. decrease in BSFC for DF

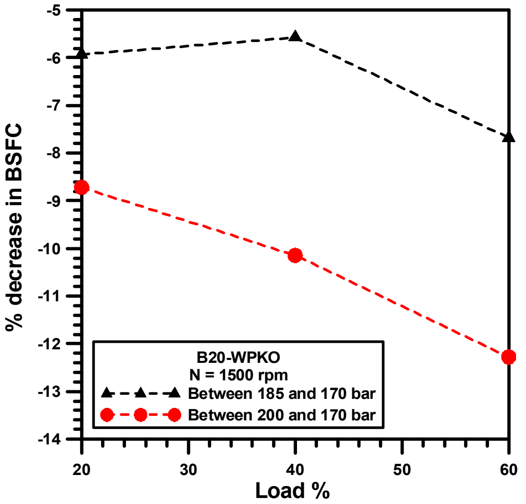


Figure (B.2) %age. decrease in BSFC for B20-WPKO

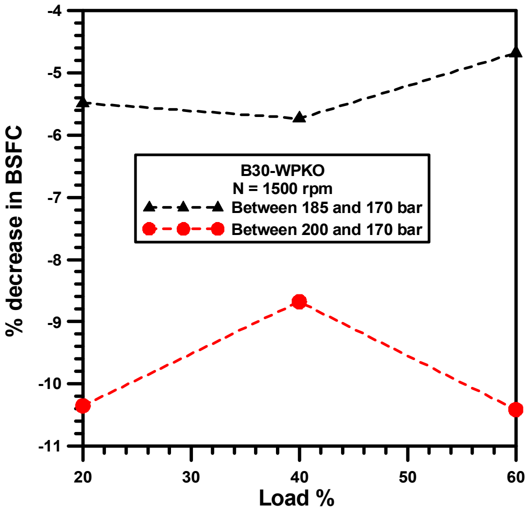
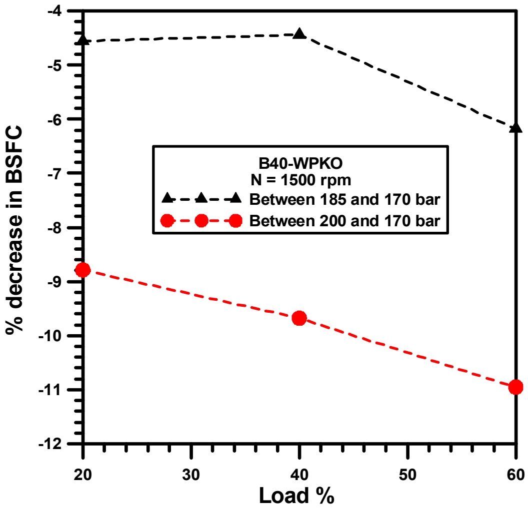


Figure (B.3) %age. decrease in BSFC for B30-WPKO



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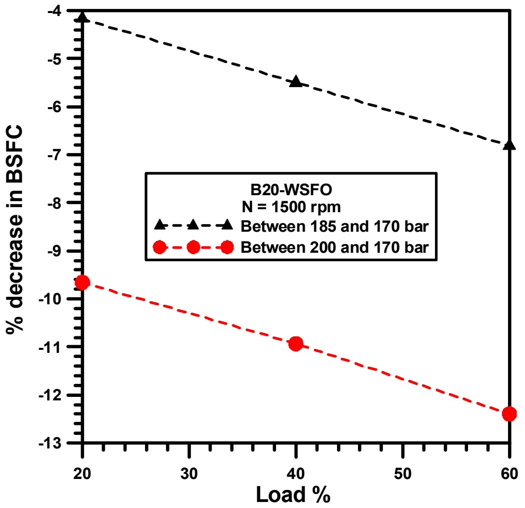

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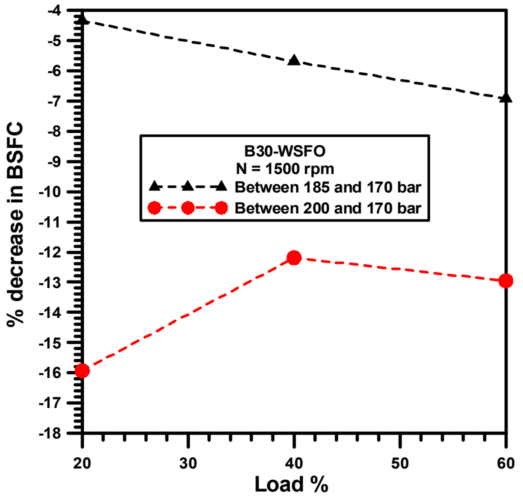


Figure (B.6) %age. decrease in BSFC for B30-WSFO

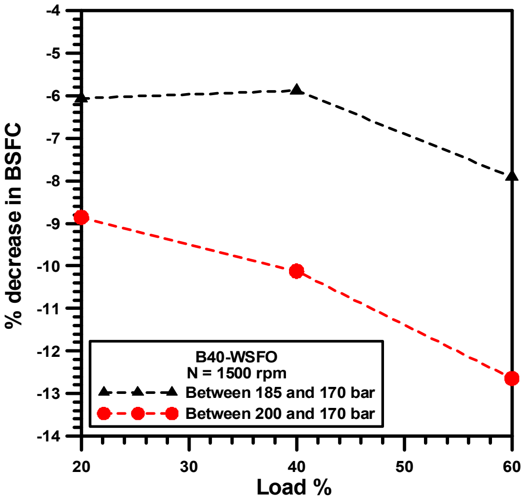


Figure (B.7) %age. decrease in BSFC for B40-WSFO

Figure (B) %age. decrease in BSFC for different fuels

Appendix (C)

$$\%\text{age. increase in } \mathrm{BTE}_j = \frac{\mathrm{BTE}_{i,j} - \mathrm{BTE}_{170\mathrm{bar},j}}{\mathrm{BTE}_{170\mathrm{bar},j}}$$

At the same load

Where, i=185 or 200 bar

j=DF, B20-WPKO, B30-WPKO, B40-WPKO, B20-WSFO, B30-WSFO and B40-WSFO

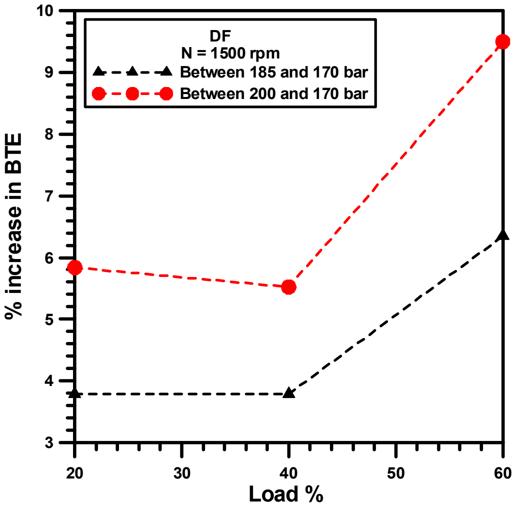


Fig. (C.1) %age. increase in BTE for DF

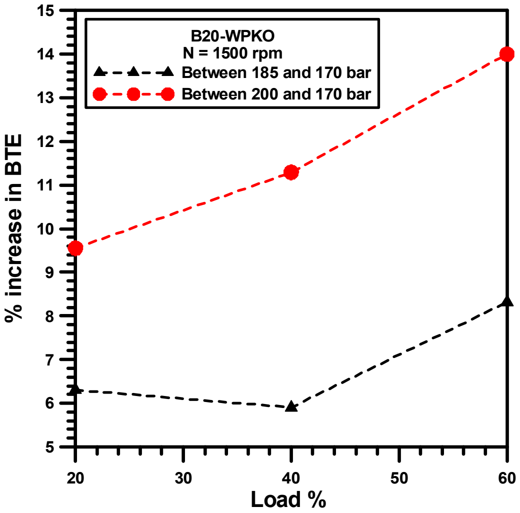
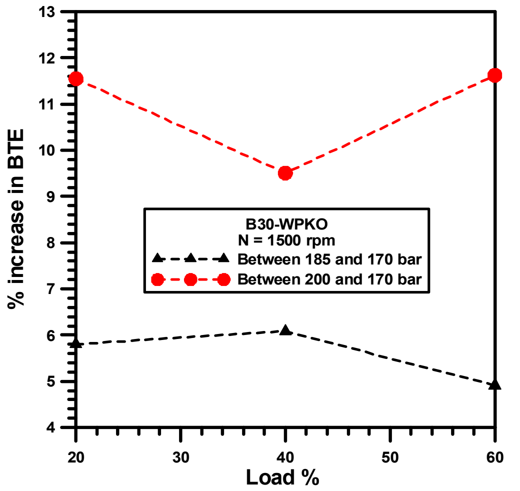


Figure (C.2) %age. increase in BTE for B20-WPKO



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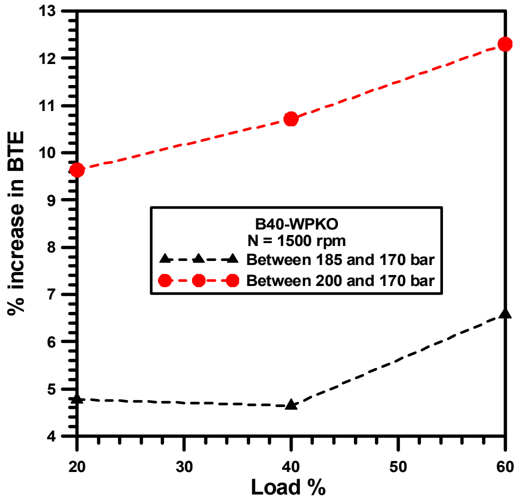

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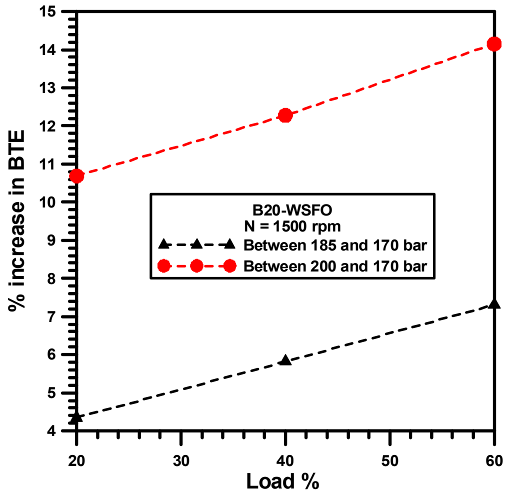

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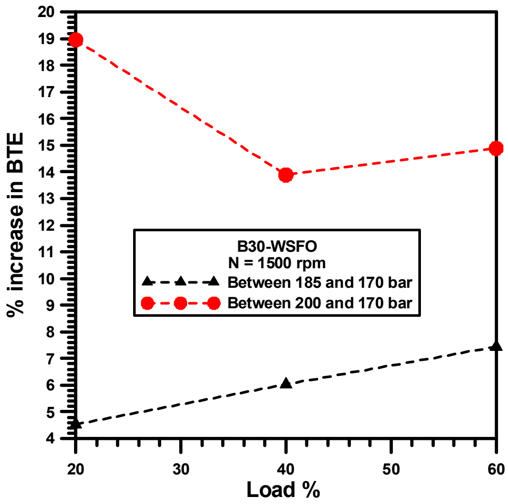

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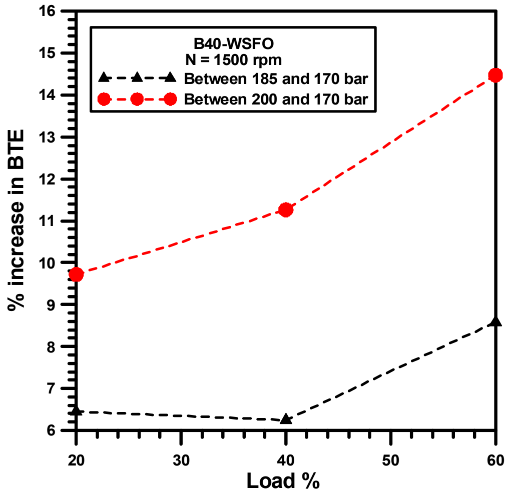

Figure (C.7) %age. increase in BTE for B40-WSFO

Figure (C) %age. increase in BTE for different fuels

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