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EXPLORING DIESEL ENGINE EFFICIENCY AND POLLUTANTS IN BLENDING DIESEL FUEL WITH WASTE TIRE OIL PYROLYSIS WITH PREHEATING PROCESS

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Abstract

Because so much tire waste is produced globally, there is a substantial waste disposal problem. Tires can be processed using pyrolysis to produce fuel, char, and gas as they do not disintegrate completely in the environment. This study focused on tire pyrolysis TP as an additional source of fuel as oxygenate blends, and conducted on a four-stroke diesel engine operating at 1500 rpm to test and compare pure diesel from Basra refinements DA 100% with other fuel categories. The di-fuel and tri-fuel mixture have been perpetrated by employing the magnetic stirrer devices, DA75%+TP25%, DB75% (high density diesel) from Dourah refinements75%+TP25%, and DA50%+DB25%+TP 25% this samples has been tested with and without pre-heating in diesel engine. Then all samples are placed in an Ultrasonic device to ensure a perfect mixture. It was found that the addition the TP decrease the engine power in all situation, and the maximum BTE% recorded for DA100%, and decreased for other samples by 7.7 and 11.9% when using DA75+TP25%, DB75%+TP25% respectively. The volumetric efficiency decreased by 7%, and all engine emissions recorded increased by 42.8%,10.71%,5.62%,78.125%, and 44.83% for CO, CO_2, UNH, NOx, and smoke opacity for DB75%+TP25% compared with Basra pure diesel. Moreover, heated fuel to 60 °C, DA50%+DB25%+TP25% appears to behave like DA100% in both engine performance and emissions.

Keywords: pyrolysis, pure diesel, combustion, heat release rate, pollutants

Nomenclature
A – area of piston (mm^2)
B –bore of piston (mm)
BP–The Brake Power(kW)
BSFC–Brake specific fuel consumption (kg/kW.hr)
BTE– Brake thermal efficiency (%)
C.N– Cetane number
CP–Cylinder Pressure(bar)
C.I.E. –Compression Ignition Engine;
L.C.V– Low fuel heating value (MJ/kg)
CR–Compression ratio
D100%–Pure Diesel
DA–Pure Diesel (Basra Refinement)
DB–Denser Diesel (Dourah Refinement)
D.I.E–Direct Injection Engine
DTOP–Distillate Tire Oil Pyrolysis
F.P– Flash Point Closed Cup-◦C
HR–Heat release (J/deg.°C)
do–orifice diameter(mm)
ho–height of the manometer (mm H_2O)
ID–ignition delay
imep–indicated mean effective pressure (KN/m^2)
LCV–lower calorific value (KJ/kg)
$\dot{m}f$ –fuel consumption rate(kg/sec)
$\dot{m}a$–air consumption rate(kg/sec)
N–speed(rpm)
P–pressure(bar)
V–volumetric flow rate(m^3/sec)
S–stroke length(mm)
Tb –brake torque (N. m)
Tex–Exhaust gas temperature(°C)
TP–Tire pyrolysis
t–Time (sec)
ρ – Density 15 ◦C(kg/m^3)
μ – Kinematic Viscosity at 38°C(cSt)
σ –Surface Tension (mmN/m)

1. INTRODUCTION

Because of their durability and efficiency, diesel engines have long been considered crucial to the automobile industry [1]. Highlights the importance of diesel engines' ability to properly convert diesel fuel into mechanical power [2]. Diesel engine efficiency directed dependent on a wide range of aspects, counting the quality of the diesel fuel used and the combustion process [3]. Recently, there has been a upward attention in examining potential fuel

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resources to improve performance and reduce pollutants released by diesel engines. 5.26*10^6tons of waste tire pyrolysis fuel can be produced from one billion waste tires [4]. It is distinguished by its black colour and viscose fuel comparing to diesel ≈ 16.39cSt measured at 40∘C [5]. And involves carbon by (81.18-86.47%wt), hydrogen by (10.92-11.73%wt), oxygen about (4.62%wt) and sulfur (0.8-0.83% wt) and nitrogen about (1.10-1.85%wt). Aromatics were found to be about 34.7 % to 75.6 %. Additionally, the use of waste tire oil allows reduce the dependency on traditional fossil fuels, contributing to environmental sustainability. Based on current research, the purpose of combining oxygenate blends with diesel as fuel for diesel engines is to enhance engine output while lowering pollutants. TP desulfurization and distillation result in qualities similar to diesel fuel, suitable for use in passenger automobiles and vans [6]. Diesel engines operate on a wide range of fuels with different molecular weights $170 \leq M_w \leq 200$ [7]. The cheapest fuel with a viscosity of up to 0.9 cSt is extracted from raw oil and can be used in C.I.E when blended with pure diesel or TP fuel. However, there is some limitations on this idea, by reducing the viscosity mixture became synthetic fuel appropriate for use in power plants and industrial operations, for which lowering viscosity usually requires preheating [8-10]. To investigate the impacts of incorporating diesel fuel with waste tire oil pyrolysis, investigators employed a single-cylinder, four-stroke engine arrangement. Precise control and monitoring of many parameters during the combustion process are made possible by this experimental setup. Researchers can examine the impact of the blended fuel's performance and emissions on diesel engine efficiency and pollutants [11-12]. TP produced from vacuum pyrolysis oil has been employed as a fuel in a diesel engine with the addition of an ignition improve by [13]. They also used TP the main fuel and tested in single-cylinder, four-stroke D.I.E. The performance, emissions, and combustion the characteristics of the DI diesel engine have been investigated and compared to D100%. At three flow rates(i.e.,) 65 g/h, 130 g/h, and 170 g/h, diethyl ether (DEE) was added in the engine air section. The observations showed that engine performed more effectively, when DEE added at a rate of 170 g/h with TP, and reduced emission rates. Nox emissions were found to be 5% lower in TP-DEE operations than in D100% operations. TP-DEE running increased HC, CO, and smoke pollutants by 2%, 4.5%, and 38% compared to diesel setting, respectively. [14] Studied the impact of TP on combustion characteristics, including CP, HR rate, (ID), combustion duration, and engine performance. TP10 led to higher in-CP and HR rates as engine load elevated. ID shorter with higher engine load for test fuels, but raised with TP. Also, They observed the LCV of TP fuels, operation leads to lower imep values. At 11.25 Nm engine load, D100%and TP10 achieved maximum thermal efficiency of 28.27% and 25.12%, respectively. Test results indicate that TP significantly impacts combustion characteristics, performance, and emissions. [15] enhanced by desulfurizing and distilling the raw tire pyrolysis oil. The study examined the efficiency of DTOP by CIE for several fuel mixtures, including D100%, D25-DTOP75%, D50-DTOP50%, and D25-DTOP75%, and engine speeds ranging from 880 to 1380 rpm. It was found that the DTPO has approximately 7% higher heating value compared to raw TP. The BTE for DTPO 25% is slightly lower than D100%. However, with DTPO 50 and DTPO 75, it is significantly lower than D100%. The BSFC of the DTPO 25 blend is quite similar to the specific fuel consumption of diesel. However, with DTOP 50 and DTPO 75, it is slightly higher. The hybrid fuels DTPO, TP, and D100% were tested in C.I.E by [16]. The mixtures were prepared using the following ratios: D70% + DTOP0%, D70% + TP30%. They compared the DTPO/D100% and TP/D100% mixtures in terms of engine overall combustion characteristics. A diesel engine powered by 5% TP is examined for both reliability and pollution aspects by[17]. Experiments revealed that adding 5% TP increased combustion duration and boosted Nox emissions. In an associated investigation, BSFC and BTE seemed practically equally effective with or without TP content fuelsThe investigation mainly contained an unique TP fuel at a 5% rate, so incorporating more TP content to D100% may yield better results. Based on current research, the purpose of present work study the impact of TP oxygenate blends with two types of diesel which produced from two different refinement in Iraqi country (Basra and Dourah). Four samples with varying diesel doses were examined, and the fuel sample DA50%+DB25%+TP25% also studied with pre-heating prosses to 60 degrees Celsius and without pre-heating. The article is distributed as follows: The first part of the introduction provides an overview on the problem and serves as motivation for carrying out the current piece of research work. Section 2 describes the problem fuel prepared methodology rig test specifications. Mathematical parameter formulation listed in section 3. The fourth section presents an explained investigation of the outcomes obtained. The conclusion section 5 summarizes the most interesting findings from the present study. The final section of references includes a list of all cited references.

2. ENGINE SETUP AND METHODOLOGY

The present section describes the experimental equipment and measuring devices used to measure the influence of two types of Iraqi diesel fuel mixing with TP with and without heating effect on diesel engine performance and pollutant concentrations. A Kirloskar single-cylinder compression ignition engine with a CR (17.5:1) and a swept volume of 661 cc has been employed to get results. The engine cooling system by air, and bore diameter 110mm, and stroke 110mm. The experimental rig is made up of the engine test unit, the diesel fueling unit, and the gas analysis unit. Fig 1 depict the experimental rig diagrammatically. The exhaust gas constituents (CO, CO2, UHC, NOx, and smoke) were determined in this study using a GC apparatus, emissions gas analysis. All of the experimental engine's details are shown in the Table 1.

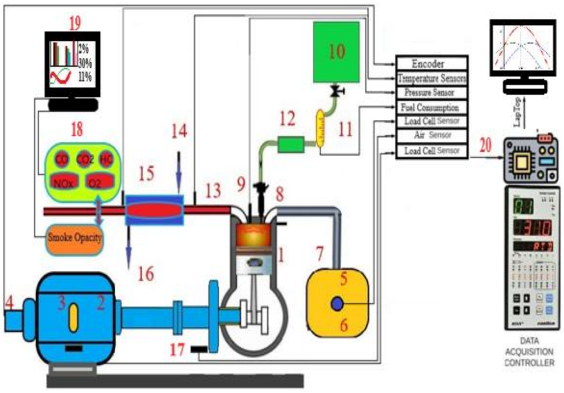

Fig. 1. Schematic diagram of the experimental setup (1) Diesel Engine; (2) Electrical Dynamometer; (3) Load Cell; (4) Encoder; (5) Orifice Plate; (6) Air Box; (7) Air Inlet Section; (8) Fuel Nozzle; (9) Cylinder Pressure ;(10) Fuel Tank thermocouple type K; (11) Burette; (12) Fuel Heater; (13) Exhaust Gas Pipe;(14) Water Inlet; (15) Colorimeter;(16) Water Outlet;(17) Photoelectric/Inductive proximity sensor;(18) Gas Analyzer;(19) Smoke Meter;(20) Data Acquisition Controller

Table 1. Specifications of the test engine

Model	Kirloskar -with natural aspirated
No. of cylinders	1 cylinder
Swept volume	661(cc)
No. of valves	Two vales
Bore	110 mm
Stroke	110 mm
CR	17.5:1
Injection system	Mechanical type
Fuel pump	Unit pump (BOSCH)
Injection pressure	350 [bar]
No. of nozzle holes	Three
Injection variation	0-25 Deg BTDC
Cooling system	air
Load	Electrical Dynamometer

2.1. Fuels

In order to address the issue of how to dispose of discarded tires and produce alternative liquid fuels, diesel fuel mixtures with tire fuel pyrolysis are emerging as a viable solution. Nevertheless, there hasn't been much of an easy use for the items made from pyrolyzing scrap tires. One goal of the preliminary work was to enhance understanding about some important qualities of the diesel mix liquid produced in an Iraqi local location. Kinematic viscosity, density heating value, flash point, PH value have been examined. DA is used in a variety of doses Fig 2, including DA75%+TP25%, DB75%-TP25%, and DA50%+DB25%+TP25%. with two possibilities for heating.

Magnetic stirrers and ultrasonic equipment are used to ensure that everything is mixed correctly prior to testing. The experimental work is carried out in the Faculty's laboratories Materials Engineering – University of Babylon. Table (2) shows the physical properties of the fuels under investigation.

2.2. Prepared fuel FTIR test

The identified peaks in the spectra are listed in Table 3. Fig. 3 depicts the transmittance (%) FTIR spectra (wave number cm^{-1}) of Basra and Dourha at DA75% + TP25%, DB75% + TP25%, DA50+DB25%+TP25%, and TP100%. Stretching caused by O-H is responsible for the weak absorption at approximately 3500 and 3200 cm^{-1}indicating the presence of hydroxyl groups like alcohols, phenols, and carboxylic acids, consistent with previous findings [18-20]. While 3100cm^{-1}indicates C-H stretching, indicating aromatic groups [18-20]. 3100-3005cm^{-1}C=H stretching alkenes groups. The C=H stretched alkane compounds are denoted by the band 3000-2700 cm^{-1}peaks at 1750-1675 cm^{-1}indicate C = O stretching caused by TP additives, primarily aldehydes or ketones. From the overall. The peaks range with 1670-1570 cm^{-1}refer carbon-carbon with double bonds, in the range 1566-1049 cm^{-1},the in FTIR test refer to appears C-H bending functional groups. While 1041-852 cm^{-1},and 802-686 $cm^{-1}$for alkenes groups C=C stretching, and aromatic groups C-H stretching respectively from additives waste tire oil pyrolysis in used as fuel source. The study discovered that TP contains an extremely aromatic content. This is consistent with other researchers' findings [21-22].

Table 2. Physical properties of the fuels

Fuel Property	ρ	μ	PH value	σ	C.N	LC.V
Units	kg/m3	38oCc St	-	mmN/m	-	MJ/kg
Diesel A	794	2.81	6.68	23.1	44	42.5
Diesel B	898	4.2	7.80	23.9	42.2	41.8
TP 100%	910	5.23	5.42	25.1	39.8	39.6
A80% +TP20 %	823	3.26	6.34	23.5	42.76	41.2
B80% + TP20 %	849	4.56	6.41	24.7	41.22	40.08
A50% +B20 %+ TP20 %	854	3.95	5.93	24.1	41.2	41.2

Fig. 2. fuel preparation 1-Fuel added 2- Mixing magnetic steers 3- Ultrasonic device 4-Samples ready to test 5- Surface tension test device

Table 3. FT-IR functional groups line (6) WT100%

Wave No.(cm^{-1})	Groups	compound
3500-3200	O-H stretching	Carboxylic acid, Alcohol compounds
3100	C-H stretching	Aromatic compound
3100-3005	C=H stretching	Alkenes compound
3000-2700	C-H stretching	Alkanes compound
1750-1675	C = O stretching	Ketones compound
1670-1570	C=C stretching	Alkenes compound
1566-1049	C-H bending	Aromatic compound
1041-852	C=C stretching	Alkenes compound
802-686	C-H stretching	Aromatic compound

3. THE FOLLOWING MATHEMATICAL EQUATIONS HAS BEEN USED TO CALCITE COMBUSTION PARAMETERS

3.1. Brake power (kW)

$$BP = \frac{2\pi\ N\ Tb}{60 * 10^3} \qquad (1)$$

3.2. To calculate the value of the thermal efficiency BTE(%)

$$BTE = \frac{BP}{\dot{m}_f * LCV} * 100\% \qquad (2)$$

3.3. (BSFC kg/kW.hr), by applying following equation:

$$BSFC = \frac{3600}{\dot{m}_f * BP} \qquad (3)$$

3.4. The volumetric efficiency (ηv):

$$\dot{m}_a = 0.001232 d_o * \sqrt{h_o * \frac{p_a}{Ta}} \qquad (4)$$

$$\eta v = \frac{\mathrm{Vair}}{\mathrm{Vdis}}$$

$$\eta v = \frac{\frac{\dot{m}a}{\rho a}}{A * S * \frac{N}{2} * \frac{1}{60}} \qquad (5)$$

3.5. Uncertainties measurements of Gas Analyzer

The error of instrument was listed in Table(4): It originated with the manufacturer as well[37].

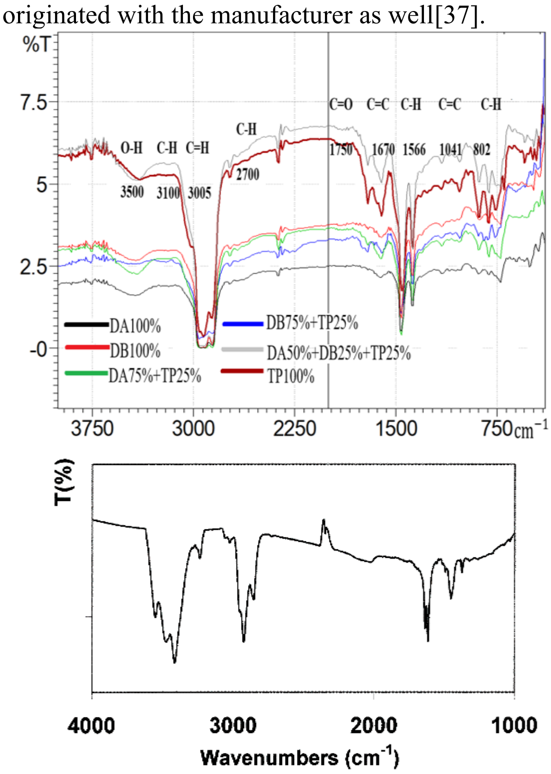

Fig 3. FTIR of present work test for pure and different fuel blended ration on upper and lower result [21]

Table 4. Error of instrument

	ID	Percent Error(%)
1	Carbon monoxide (CO)	± 0.01
2	Oxygen (O2)	± 0.01
3	Carbon dioxide (CO2)	± 0.1
4	UnburntHydrocarbon (UHC)	1 ppm
5	Nitrogen oxide (NOx)	1 ppm

4. RESULTS AND DISCUSSION

4.1. Engine durability and exhaust gas temperature

Four times, using the same setup, the experimental results are repeated, with a different sample DA100% each time. An average value from repeated exams was used in the analysis. The repeatability of exhaust temperature tests is shown in Fig. 4a. For the same conditions, different tests yield different results. This is caused by a number of things, such as effective errors, changes in the environment, human error, and error analysis. The variance of errors varies between 2% and 3%. The effect of TP fuel added to various fuels was displayed in Fig. 4b, which demonstrated that DA100% had a high cetane index and high LCV, causing combustion to occur precisely on time. While the low LCV mixed fuels had the highest levels of Tex. When the engine loaded to BP<1.6kW, this difference approached the optimum rang. When the BP is low, both the temperature and the pressure in the combustion chamber are relatively low. Consequently, all fuel types will exhibit the same behaviour due to the same amount of fuel is injected. When the engine's BP exceeds 1.6, additional fuel must be injected to the combustion chamber. By reason of the prolonged ignition delay period lower cetane index for other fuel types (high viscosity and density), a portion of the mixture will be burned later causing Tex to be maximized.

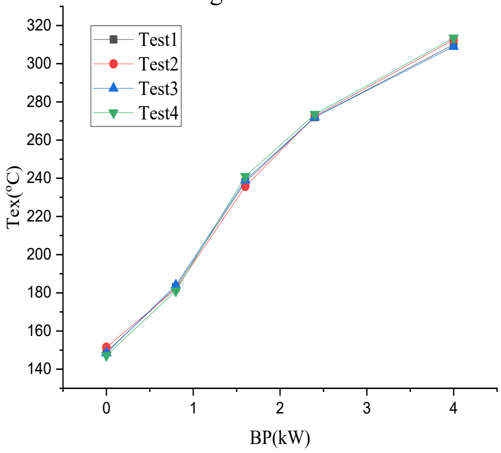

Fig.4 a. Variation of Tex with BP (engine durability test)

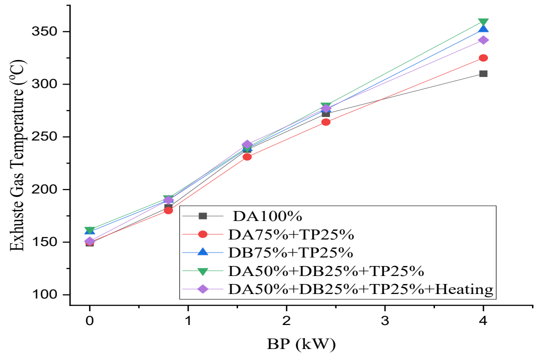

Fig 4b. Effect of TP addition with different fuel

4.2. Engine cylinders pressure

The proposed all prepared fuels' pressure history is shown in Fig 5. When TP and heating are present, CP is higher than with regular diesel. At 100% engine load the CP for the DB75%+25% observed by 56 bar related to 51.45, 52.3 and 52.5 bars for DA75%+TP25%, DA50%+DB25%+TP25% with heating and DA50%+DB25%+TP25% without heating respectively. Because more charge mixture was introduced into the cylinder, it was observed that in-cylinder pressure rose as engine power increased. As the engine loading raised gradually, more fuel energy is delivered to the cylinder; in other words, Because the quantity of air provided to the cylinder is fixed, the (A/F) decreases.

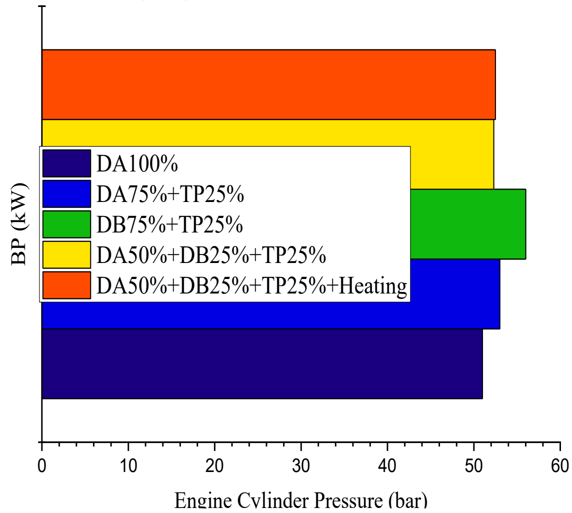

Fig. 5. Variation of cylinder pressure with BP

Increased oxygen concentration and viscosity in used TP enhanced combustion processes, leading to abrupt and swift combustion. Conversely, excessive or uneven additional cylinder pressure damage an engine. Thus, information regarding the detrimental impacts of the fuels utilized in the engine can be obtained by analysing the post-combustion pressures in the cylinder [23].

4.3. Brake thermal efficiency

Brake thermal efficiency BTE and brake specific fuel consumption (BSFC) were chosen as engine performance metrics for this study. Figs 6 and 7 represent the BTE and BSFC, respectively. The heating properties of test fuels have a major effect on BTE and BSFC. Thermal efficiency is the process of converting fuel energy into useful power. Fig. 6 shows the engine brake thermal efficiency more sensitively for both the mixture of diesel fuel with waste tire oil and heating. The lower calorific quantity in the tested blended fuel contributed to lower levels of BTE. It was discovered that the maximum BTE with diesel DA100% at 50% and 100%engine load were 18 and 24.4%, respectively, demonstrating superior performance across all loads compared to other options. The fuel enters a more heated environment as the load develops because the combustion chamber's temperature goes up. It was found that engine power lowered when the DA75%+TP25% blend was implemented in the engine. But at the same engine load, BTE decreased by about 7.7and 11.9%, respectively for viscose and denser DB75%+TP25% due to an increase in heat losses, This has been explained by TP's impurity, or higher aromatic concentration. This might be because diesel fuel has a higher heating energy than others blended fuels. The brake thermal efficiency for DA50%+DB25%+TP 25% with and without heating is 23.9, and 22.3 respectively. This could be due to improved mixing of air and fuel, resulting in increased heat release. In general, when the engine is run with a blend of fuel and heating, the brake thermal efficiencies are marginally higher than when not heated [24]. It was generally observed that waste tire pyrolysis oil, in the absence of mixes and additives, is unsuitable for use in diesel engines. A measurement of the mass needed to produce one unit of brake power is called brake specific fuel consumption, or BSFC (kg/kW.hr). It was possible to generate the same amount of power as diesel by using TP. However, additional fuel will be needed because TP has a low energy content. This will result in the low brake thermal efficiency. In the same line, excessive fuel consumption that has been documented. Furthermore, as the engine load increased, the test engine's power output increased as well. For the actual reason, the BSFC value dropped as engine loads increased. In every test fuel, the same situation was noted. The engine brake thermal efficiency improved as BSFC reduced refer to Fig. 6 and 7, as it was calculated depending on tested fuels heating values. DA had the highest BTE because of its low BSFC, higher calorific value, and reduced viscosity when contrasted with the remainder of the examined fuels. Then, DA50%+DB25%+TP25% with heating, DA75%+ TP25%, DA50%+DB25%+TP25% without heating DB75%+TP25% with heating was followed by pure diesel DA100%. Practical measurements showed increases in BSFC of, compared to DA100%. Previous studies reported similar findings [24-26]. Heating the test fuel could improve spraying the atomization process and reduce viscosity, leading to improved BSFC.

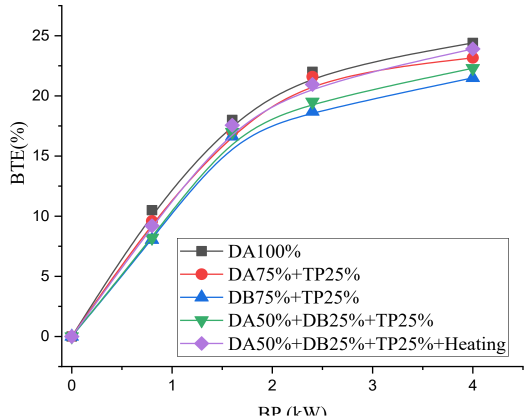

Fig. 6. Variation of BTE with

4.4. Volumetric Efficiency (η_v)

The ratio of actual flow to predicted theoretical flow is known as volumetric efficiency Fig. 8. Engine volumetric efficiency reduces as engine load increases because rising combustion chamber temperatures cause the specific volume of coming air to rise hence, cylinder volumetric efficiency dropping. Because the combustion chamber's walls are hotter, the volumetric efficiency recorded mitigation dissipation when tested at DB75%+WP20%. Due to the addition of fuels will be injected, and more energy will be released caused the combustion chamber to warm up. Further, increasing the specific volume of the incoming air. corresponding to leakage in air as compared to diesel fuel, the volumetric efficiency dropped by 0.97% and 2.63% for DB75%+TP25% and DA50+DB25%+TP25%, respectively.

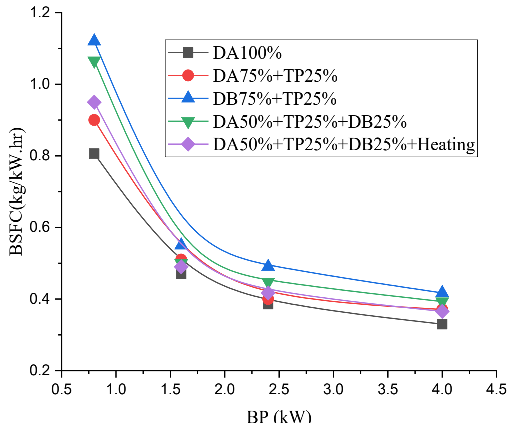

Fig. 7. Variation of BSF with BP

4.5. Analysis of emissions

4.5.1. Carbone monoxide (CO VOL%)

Fig. 9 shows the variations of CO with engine BP. Started with DA100%, DA75%+TP25%, DB75%+TP25%, DA50%+DB25%+TP25% with and without heating. In general increase CO concentrations by an average of 12.5%, 28.5%, 25%, 42.8%, 37.5%, 42.8%, 3.75%, 3% corresponding to engine load 50,100% respectively, over DA100%, it is evident that the heating of the mixture produces the desired effect because the viscosity reduces.

Although gasoline engines operated closer to stoichiometric mixtures, the engine that operated with diesel fuel and its blends ran at lean mixes, which resulted in lower CO emissions [27]. The existence of lower molecular weight compounds in prepared fuel influences fuel atomization inside the combustion chamber, resulting in locally rich mixes and enhanced emissions of carbon dioxide.

However, heating fuel improves combustion, but due to DB and TP extremely high molecular weight, the ignition delay period increases and a portion of the fuel burns near or after the top dead center, leading to a boost in CO pollutants.

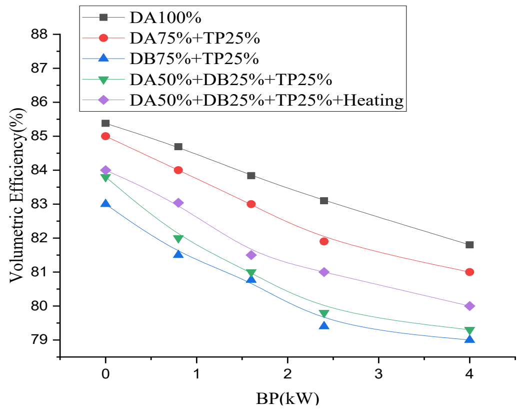

Fig. 8. Variation of volumetric efficiency with

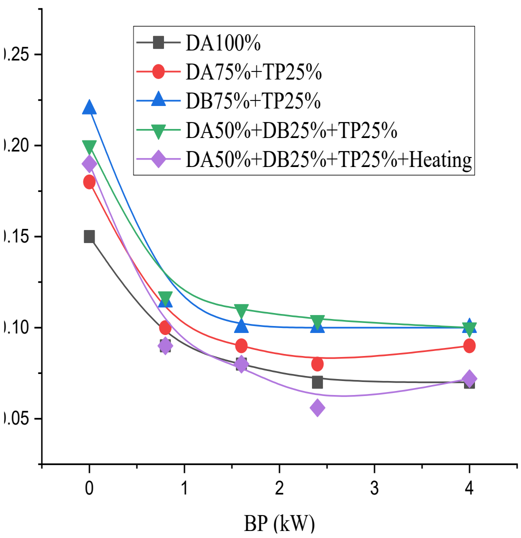

Fig. 9. Variation of CO with BP

4.5.2. Carbone dioxide (CO2 VOL%)

The relationship between CO2 and brake power at an engine speed of 1500 rpm is shown in Fig. 10. It was found that the value of CO2 rose more with torque. As expected, DA100% had emitted high levels of CO2 2.3, 4.4, 5.9, 7, and 8.4 (VOL%) for engine brake power 0≤BP (kW)≤4. Furthermore, the CO2 result decreased by 1.88, 3.79, 4.61, 6.82, and 7.71 (VOL%); also, 1.76, 3.39, 4.78, 6.05, and 7.66 (VOL%) blended DA50%+DB25%+TP25% for both preheating and unheated fuel, respectively. Impurities in TP fuel result in fuel with increased density, a high aromatic content, a lower cetane number, and a and a longer ignition delay when added to Dourah diesel DB75%+TP25% [28-29], which causes more deterioration in CO2levels by 39.13, 25, 23.73, 7.14, and 10.72%.

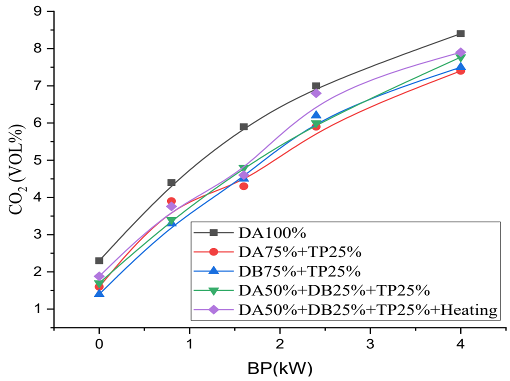

Fig. 10. Variation of CO_2 with BP

4.5.3. Unburned hydrocarbons UHC (ppm)

Fig. 11 depicts the range in hydrocarbon (HC) pollutants for investigated fuels under varied loads. TPO-DF produces higher HC emissions than DF at full load. The HC emissions for DF range from 22 to 25 ppm. HC emissions vary from 27 to 26 ppm for TPO 10, 24 to 29 ppm for TP 30, and 27 to 30 ppm for TP 50. Higher HC emissions are likely due to increased viscosity, density, low volatility, and rich fuel mixtures at higher loads. TP emits more unburned hydrocarbons due to its aromatic properties. But DA75%+TP25% in partial load situation these values are marginally closer to DA100%. However, its clearly at low loads (i.e.,) 0 ≤ BP(kW) ≤ 0.8, the longer ignition delay period creates locally over-lean mixtures, resulting in incomplete combustion and higher HC emissions.

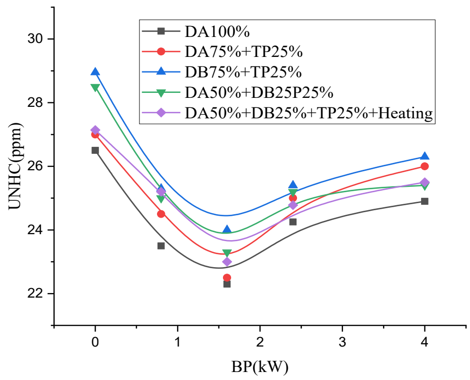

Fig. 11. Variation of UNHC with BP

4.5.4. Nitroxide NOx(ppm)

Since roughly 78% of the air's content is nitrogen, it cannot react under normal circumstances. Nitrogen may react with oxygen molecules in the combustion chamber due to the greater temperature, and during the combustion process, nitrogen oxides (NOx) may develop. Accordingly, a greater quantity of NO and a lesser amount of NO2 combine to produce the NOx emissions. Conversely, it has been stated that Zeldovich and Fenimore mechanisms are suitable for diesel fuel combustion processes. The operating at higher levels of temperature of the process of combustion frequently corresponds to levels of NOx emissions, oxygen molecule concentration, and length of time that nitrogen is exposed to high temperatures [30]. The graph that shows the NOx emission versus engine load is shown in Fig.12.The primary factor influencing the NOx emission level is, in fact, the temperature inside the cylinder. It is anticipated that the NOx emission will rise in line with the in-cylinder temperature. According to [14] The blending fuel created by mixing pure diesel with TPO emitted higher NOx because the oil's containing a high level of oxygen caused a reaction with nitrogen, raising the temperature inside the engine. At engine BP 0.8 to 1.6Kw, it was found that the engine emitted 104-220, 190-290, 205-420, 200-400, 195-290 ppm for DA100%, DA75%+TP25%, DB75%+TP25%, DA50 + DB25% + TP25%, and DA50 + DB25% + TP25% with heating. It's clearly that the pre-heating contributed to decreases the fuel NOx levels, due to more deterioration in fuel viscosity, and enhanced fuel atomization. As engine BP goes up the engine combustion wall temperature increases and the high chance of NOx production, at this point the instruments recorder increases 37.93%, 96.56,93.10, 65.17% for above mentioned fuel respectively. Again at full load condition the heated sample showed high level of NOx, this due to the heated fuel causes to adding more energy to combustion chamber.

4.5.5. Smoke Opacity (%)

Diesel fuel possesses a lower density when contrasted with TPO, but after distillation, it becomes comparable to diesel **[31]**. Fuel density is a significant factor to consider. Fig. 12 and 13 displays distribution of smoke with wide range of engine load. Smoke levels blends fuels were higher than those of diesel. The explanations offered were that poor atomization may have resulted from the high density and large TP molecules. With heating, smoke opacity declined for DA50% + DB25% + TP25%; if compared without heating fuel; a low flash point for Tp indicates strong volatility. This observation was ascribed to the low viscosity and low flash point of heated fuel.

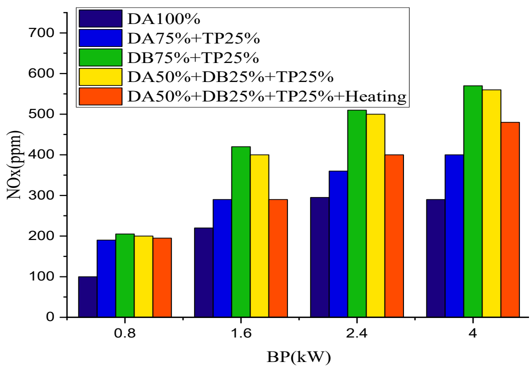

Fig. 12. Variation of NOx with BP

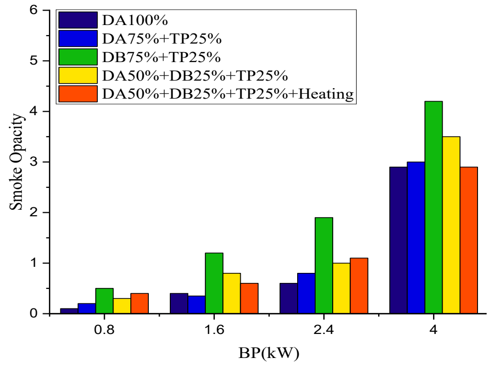

Fig. 13. Variation of smoke opacity with BP

5. CONCLUSIONS

Exploring the blending of diesel fuel with TP presents promising opportunities to enhance diesel engine efficiency and reduce pollutants **[32-33].** By understanding the combustion characteristics of pyrolysis oil and optimizing the blending process, researchers aim to achieve a more sustainable and environmentally friendly approach to fueling diesel engines [34-35]. However, below the following conclusions.

1- For economic considerations, high viscosity and density diesel fuel can be utilized as an alternative fuel after decreasing its viscosity, which can be achieved by fuel preheating methodology.

2- In all situations adding TP to DA and DB leads to decreases in BTE by 7.7 and 11.9%, respectively.

3-Both engine exhaust gases temperature and engine cylinder pressure recorded increases by 16.13%,4%, respectively for blends fuel DB75%+TP25%.

4- The FTIR diagram proved that the TP fuel containing high levels of aromatics and carboxylic acid, alcohol compounds.

5- All engine emissions recorded increased by 42.8%,10.71%,5.62%,78.125%, and 44.83% for CO, CO_2, UNH, NOx, and smoke opacity for DB75%+TP25% compared with Basra pure diesel.

6- Sample with DA50%+DB25%+TP25% with heating, the engine performance nearly behave like pure diesel DA100%.

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