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Impact of Utilizing a Diesel/Ammonia Hydroxide Dual Fuel on Diesel Engines Performance and Emissions Characteristics

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Abstract: ***The problem of global warming and environmentally polluting emissions has become the call of the times. To solve this problem the trend to change or share new types of fuel has become a new way to solve this problem. One of the most promising future fuel types is ammonia, as it is a carbon-free fuel, unlike traditional fossil fuels. Because of the danger of using ammonia as a gas, it was safer to use ammonia as a liquid. This study used ammonia hydroxide as a proportion of diesel fuel in a PCCI diesel engine. The diesel engine is a single-cylinder, four-stroke engine. Ammonia hydroxide fuel with a 33% ammonia water ratio by volume is used with diesel fuel. The experiment was carried out with ammonia hydroxide ratios of 2.5%, 5%, 7.5%, and 10%, respectively. The emissions, thermal efficiency (BTE), fuel consumption (BSFC) and exhaust temperatures were compared. It was concluded that using ammonia hydroxide ratios to diesel led to an increase in thermal efficiency by 23.5% compared to diesel-only by 20.5% and fuel consumption was reduced. 391.083g/Kw.h compared to diesel is only 455.56 g/Kw.h. Because of ammonia hydroxide, exhaust temperatures are lower than when using diesel only. Therefore, this study discusses with practical experience the effect of using ammonia hydroxide with diesel on the performance and efficiency of the engine and fuel emissions characteristics.***

Keywords: ***PCCI engine, NOx emissions, Ammonia Hydroxide, Diesel engine***

I. INTRODUCTION

The topic of global warming, its detrimental impacts on the environment, the significance of lowering it, and the emissions that cause it have attracted a great deal of attention in recent decades [1-7]. In terms of our field, research has recently been focused on reducing emissions caused by fuel burning in internal combustion engines, and one approach to achieve this was to utilize carbon-free fuel; thus the optimum choice was to use ammonia [8-12]. Due to their lack of dependence on carbon and the absence of carbon dioxide (CO2) and hydrocarbons (HC) in their emissions, hydrogen and ammonia (NH3) are regarded as laboratory-successful alternatives to diesel at this time[13-16]. Fast combustion, a high calorific value, and a low minimum ignition energy are all benefits of hydrogen. Its sole combustion byproduct is water, making it the ideal fuel for IC engines that require carbon-free combustion [17-19]. Ammonia, hydrogen, natural gas, and others are considered alternative fuels with high reactivity compared to diesel [20-23]. The function of such alternatives is to improve combustion rates and reduce ignition delay in diesel engines. The combustion of ammonia alone is currently challenging to implement because it requires specialized injection methods and modifications to the internal engine designs. Therefore, the trend was to inject ammonia with diesel. In the gaseous case, such as mixing ammonia with air in the intake manifold. That is a flammable mixture, or mixing liquid ammonia with diesel and injecting it directly into the accumulator. After that, the fuel is injected before entering the combustion chamber. This double injection method has achieved impressive results in reducing carbon emissions [28-24].

Dual injection of ammonia and diesel has been proven to impact internal combustion engines in recent tests, and this was the preferred approach of several researchers. Unburned ammonia and nitrous oxide were the subject of experimental research by Nikki et al.[29-31]. In a 1.083 L four-stroke engine. Unburned ammonia and nitrous oxide emissions have been observed to rise with increased RAE and fall with higher torque levels. Experimental research on (ammonia-diesel) combustion on a four-cylinder light-duty diesel engine with a displacement of 4.5 litres was carried out by Reiter et al. [32-34]. He pointed out that raising the ammonia replacement ratio would slow overall combustion rates and lengthen the ignition delay. This outcome is in line with those from Rio.[35, 36]. Additionally, it was shown that NOx emissions increased compared to those in diesel-only mode when the RAE was above 40%, primarily because of fuel-dependent NOx production [37-40]. New investigated how diesel injection time and RAE affected combustion and emissions in a four-stroke engine with a 16.25 compression ratio. They discovered that, in comparison to diesel-only mode, increasing diesel injection timing could lower NOx emissions and produce a 12% decrease in greenhouse gas emissions. This has become clear in new research about the future outlook for diesel engines and convection ovens that use diesel fuel and other types of fuel, such as biodiesel, to work on reducing fuel emissions and working to raise the thermal efficiency of the engine and reduce specific fuel consumption[41-43]. The research has made clear how to use new injection systems that did not exist previously. Before such as PCCI, HCCI, RCCI and their effects in raising thermal efficiency and reducing emissions [27, 39, 44, 45]. Most research has also turned to the use of other types of fuel and additives improving the fuel combustion process, which in turn has confirmed an increase in the thermal efficiency of diesel engines and convection ovens and a reduction in emissions and soot[38, 46-49].

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As a result, the aforementioned studies have demonstrated that current research into engines that use both ammonia and diesel as dual injection concentrates mainly on parametric evaluations under particular operating conditions and lacks a systematic examination of performance and emissions characteristics across the board. The combustion properties, engine performance efficiency, and emissions for a diesel engine at a constant speed of 1500 rpm under typical weather circumstances with varying loads are discussed in this study work using a realistic experimental approach[50-53]. Diesel alone and the results of incremental volumetric additions of ammonia to diesel are contrasted. By integrating dual injection technology and ammonia fuel with diesel, the study showed that internal combustion engines can run steadily and efficiently.

II. EXPERIMENTAL METHODOLOGY AND PROCEDURE:

A. *TEST RIG SETUP*:

To study the combustion characteristics of a diesel engine, this is fueled by a binary system (diesel-liquid ammonia hydroxide). Laboratory experiments were carried out using a single-cylinder, four-stroke, air-cooled diesel engine, "DEUTZ FL 511/W"[10]. Modifications were made to it to operate in PCCI combustion mode, as shown in Figures 2 and 3, which are an illustration and an actual drawing of the engine with its contents, respectively[54-56]. This engine operates at a constant speed of about 1500 rpm, with an oil temperature of 90 °C, a direct pressure of 220 bar at 32 degrees below the top dead centre of the cylinder, and a compression ratio of about 17. The technical characteristics of the engine are shown in Table 1[57]. To maintain the engine at a constant speed of 1500 rpm. With the change in the amount of fuel injected, an electronic control unit was added to control the rate [58]. The engine contains a system for measuring fuel consumption, which includes a tank in which the diesel is placed in the operating state and a graduated tester in which the mixture or any other fuel used is placed, which will be injected into the engine according to The volumetric ratio used. The motor is loaded using an eddy current dynamometer [59, 60]. The dynamometer has a 5 kW synchronous generator connected to the crankshaft,. The generator is associated to 6 lamps (each block has 1 kW power) and a variable voltage device to control the output power, as shown in Figure 1[61].

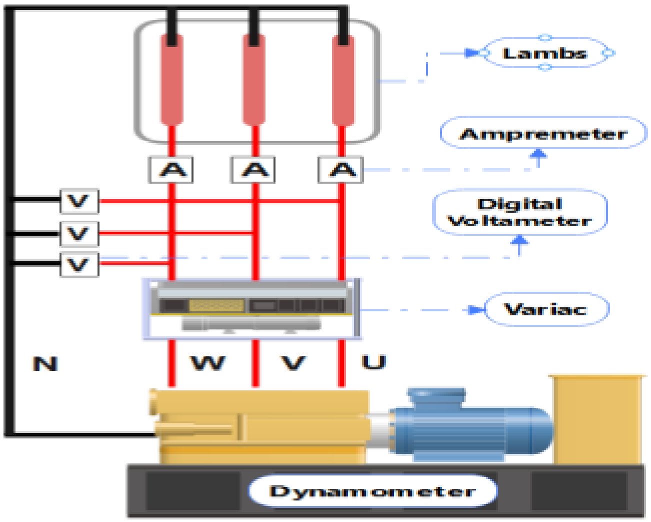

Figure 1 :Load and dynamometer circuit schematic diagram

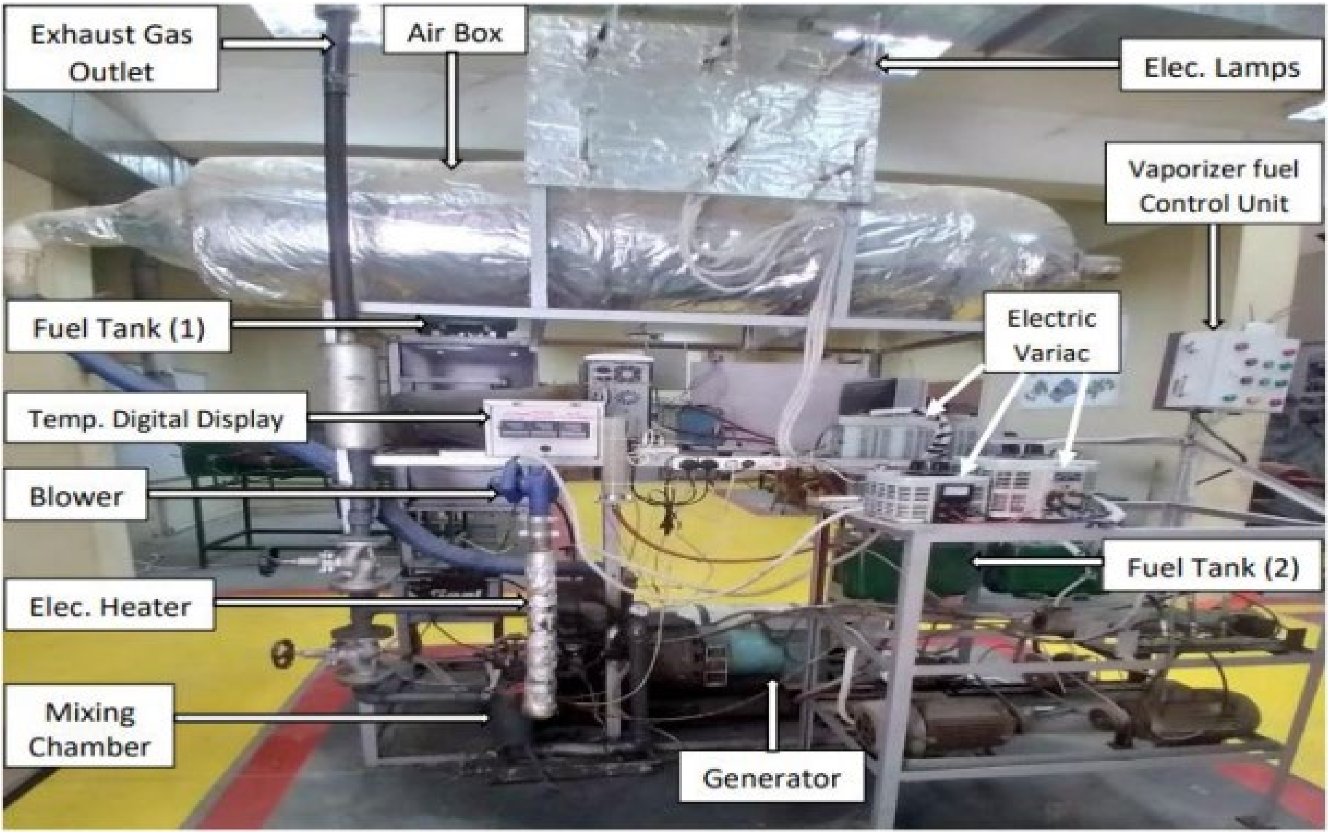

Figure 2 :Actual image of the experimental setup of the engine with fuel vaporizer

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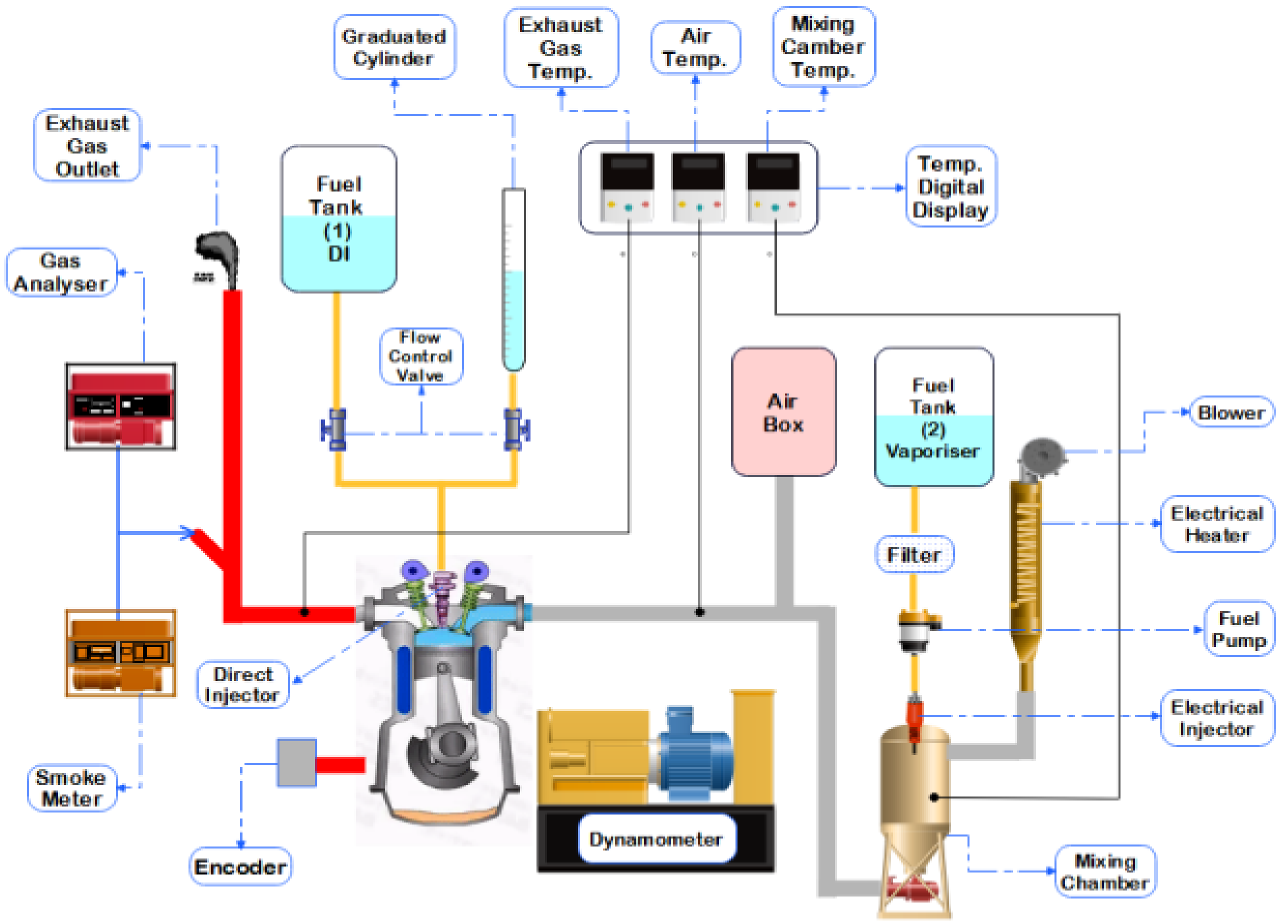

Figure 3 :Schematic diagram of the PCCI engine setup with fuel vaporizer

Table 1: technical characteristics of the engine

Parameters	Dimensions	Parameters	Dimensions
No.of cylinder	Single	**Engine version**	DEUTZ FL500/W
Displacement	825 cm^3	**Bore**	10cm
Cooling system	Air-cooled	**Stroke**	10.5cm
Power cycle	Four strokes	**Injection system**	Direct in injection
Rated Power	5KW at 1500rpm	**Compression ratio**	17
Inlet valve opening	32 CA BTDC	**Inlet valve closing**	59 CA ABDC
Exhaust valve opening	71 CA BBDC	**Exhaust valve closing**	32 CA BTDC

B. FUEL PREPARATION:

In this research, five fuel experiments will be conducted, includ ingD100, D97.5N2.5, D95N5, D92.5N7.5, and D90N10. D100 is a mineral diesel used in internal combustion engines. D97.5N2.5 is a mixture of diesel and ammonia hydroxide with a volume ratio of 97.5% and 2.5%, respectively, and so on, with the other volumetric percentages mentioned [41, 62-65]. To prepare the mixture, ammonia hydroxide with a concentration of 33% (NH3 - HOH) with a volume ratio of 2.5% is mixed with diesel with a volume ratio of 97.5% in a bowl placed under a mixer for one hour to ensure that it does not separate at a speed of about 550rpm.

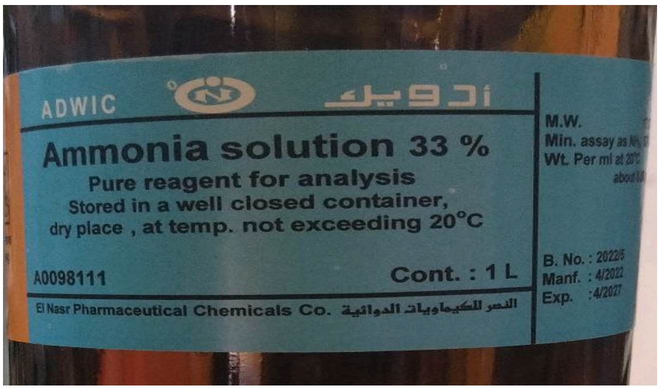

Figure 4: hydroxide ammonia solution

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C. MEASUREMENTS AND THE SYSTEM ACCURACY ANALYSIS:

The uncertainties of the used devices of the emission analyzer and sensors used are listed in Table 2[66, 67].

Table 2: devices and sensors utilization

Device/sensor	Utilization
Speed sensor	Attach to the engine's crankshaft to measure engine speed
1st thermocouple	At the inlet of the air to measure air temp.
2nd thermocouple	At the outlet of the exhaust to measure exhaust temp.
Orifice system	Measure the volume of air flowing into the engine
GASBOARD-5020 emission gas analyzer	Measure the values of [HC, NOx] in (ppm) and [CO, O_2 and CO_2] in (% vol).
GASBOARD-6010 opacity meter	Used to measure soot

Figure 5: emission gas and opacity analyzers

There are many tools and devices used to measure different variables. The difference in tools used and the difference in surrounding conditions may affect the accuracy of measurement and thus affect the accuracy of the research results of this study[68, 69]. Therefore, the error rate can be estimated using the following equations: 1 and 2 for the equipment and devices used. The calculated percentages for each device are listed in Table 4[70 ,44].

$$COV = \frac{\alpha}{\beta} * 100\% ------------- eq.1$$

$$\sigma = \sqrt{\frac{\sum_{1}^{n} (Xi - \beta)^2}{n-1}} ------------- eq.2$$

Where σ is the standard deviation, β is the average of the variable (x), n is the number of samples cycle.

Table 3: Device characteristics and accuracy

Instrument	Parameters	range	Accuracy
Shaft encoder	Speed	0-720^{0}CA	+0.2%, -0.2%
K-thermocouple	Exhaust gas temperature.	0-800 ^{0}C	+1%, -1%
Graduated cylinder/stopwatch	Fuel flow meter	1-30 cm^3	+1%, -1%
GASBOARD-5020 emission gas analyzer	NO	0-5000ppm	+5%, -5%
	O2	0-25%	+3%, -3%
	CO	0-20%	+1%, -1%
	HC	0-9999ppm	+5%, -5%
	CO2	0-20%	+4%, -4%
GASBOARD-6010 opacity meter	Soot opacity	0-100%	+0.01%, -0.01%

D. EXPERIMENTAL METHODOLOGY:

Parametric experiments in this study are conducted on a single-cylinder, four-stroke diesel engine operating at a constant speed of 1500 rpm under different load conditions, where the experiments begin at no load and partial load and reach full load[48, 71-73]. The following experiments were conducted in direct injection mode, and the effect of the combustion of the mixture on the combustion characteristics and performance of the engine and the resulting emissions value was studied[49, 74-76]. This mixture includes different volumetric ratios of ammonia hydroxide and diesel and is compared to their values for pure diesel in direct injection mode to study the effect of adding ammonia to diesel and choose the best ratio. Available for use[77].

III. RESULTS AND DISCUSSION:

According to our findings, the use of a mixture (ammonia hydroxide - diesel) improves combustion characteristics and reduces emissions resulting from combustion .

A. BRAKE THERMAL EFFICIENCY-BTE:

The amount of chemical energy from fuel that is transformed into practical work is known as brake thermal efficiency, and it is regarded as one of the most important engine factors. The amount of chemical energy generated by the fuel that is converted into useful work is known as brake thermal efficiency and is considered one of the most important factors of the engine.

Figure 6 shows the difference in BTE for pure diesel and the mixtures used: D97.5 N2.5, D95 N5, D92.5 N7.5, D90 N10. It is clear from the statement shown in the figure that the thermal efficiency increases with increasing load in all operating conditions due to the decrease in heat loss. The resulting energy increases due to the quality of combustion, and with the increase in the percentage of ammonia in the mixture, the thermal efficiency of the brakes increases.

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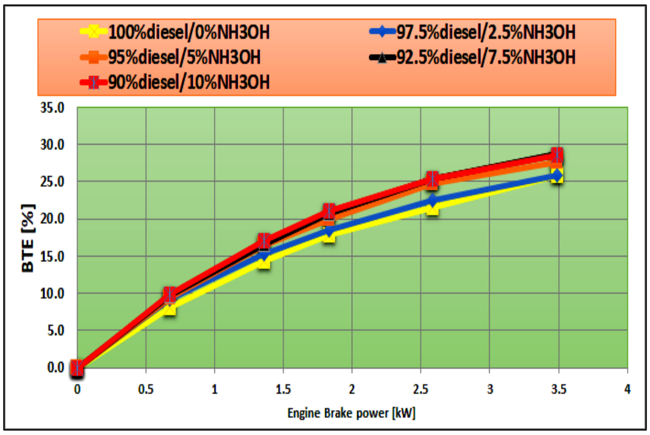

Figure 6: Brake Thermal Efficiency- BTE Under Various Loads Conditions.

B. Brake Specific Fuel Consumption- BSFC:

The quantity of fuel needed to create one unit of braking power is known as brake specific fuel consumption, or BSFC, and it depends on the fuel's calorific value. The calorific value of diesel and ammonia hydroxide mixes varies; hence it is not a useful measure to represent engine performance. When employing a variety of fuels with various calorific values, brake-specific energy consumption (BSEC) should be used as the standard. The BSEC is calculated by dividing the total energy used by the braking force generated. Equation 3 is used to obtain the BSEC value in MJ/kWh.

$$BSEC = \frac{[(m^{\circ} * LHV)_{diesel} + (m^{\circ} * LHV)_{NH4OH}] * 3600}{power} --- eq.3$$

Where BSEC in (MJ/kW.hr), m˚ in (kg/sec), LHV in (MJ/kg), and Power in (kW).

It was shown in Figure 7 that in the case of pure diesel, the fuel consumption rate was 455.5 [g/kw.h]. By adding ammonia hydroxide to the diesel at a rate of 2.5% by volume, the consumption rate was reduced to 434.29 [g/kw.h], reaching a percentage of 10 % ammonia hydroxide, the consumption rate reached the lowest value, which is 391.08 [g/kw.h]. The figure, it shows that at the same loads, the consumption rates in the presence of ammonia hydroxide are lower than in pure diesel.

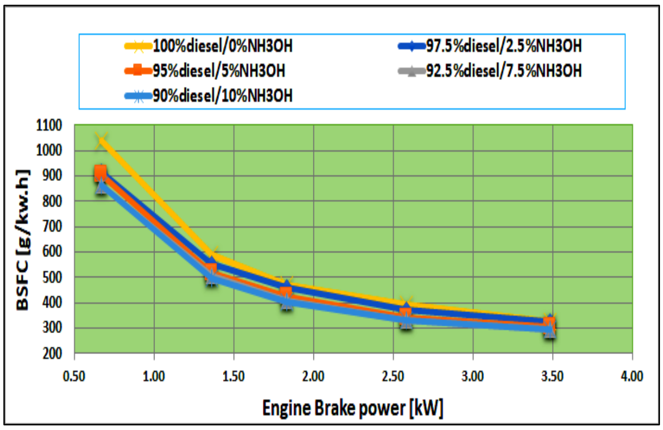

Figure 7:Brake Specific Fuel Consumption Under Variation of Loads Conditions

C. Exhaust Gas Temperature-EGT:

Exhaust gas temperature is an essential measurement since it is a gauge for combustion temperature and heat loss from the exhaust gases, corresponding to the engine's thermal stresses. Figure 8 illustrates the variation of exhaust temperatures with different loads. As the load increases, the exhaust temperature rises, which may cause increased fuel consumption, releasing more energy. However, this conclusion differs with adding ammonia hydroxide to diesel, as the presence of a percentage of water in the mixture may be the reason.

The exhaust temperature decreases, and thus, the engine temperature decreases, increasing the engine's thermal efficiency. Therefore, adding ammonia hydroxide at a higher percentage reduces the exhaust temperature when compared to the clear results with pure diesel. As is clear in the results, the temperature in the case of pure diesel reaches 204 ºC, while with the addition of ammonia hydroxide, it was reduced to reach a percentage of 2.5%. To be 200 ºC, while in the case of 10% ammonia hydroxide, we find it reaching 196 ºC.

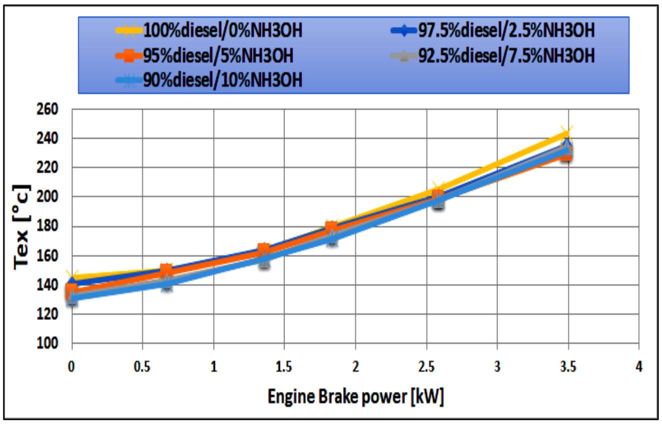

Figure 8: exhaust gas temperature under variation of load conditions

D. Oxides of Nitrogen – NO_X:

The availability of oxygen, the duration of combustion, and the temperature of the combustion chamber are basic factors on which the emission of nitrogen oxides depends. Figure 9 shows the variation of the nitrogen oxide emission values with the braking force for pure diesel and a mixture of ammonia hydroxide and diesel in the previously mentioned volumetric proportions.

From the figure, it is clear that the emission of nitrogen oxides increases with increasing load. This is due to the increase in the temperature of the combustion chamber, but in the case of the mixture, and because of the presence of water and nitrogen in the mixture, which works to reduce the temperature of the combustion chamber, the emission of nitrogen oxides in the mix is less than their diesel counterparts.

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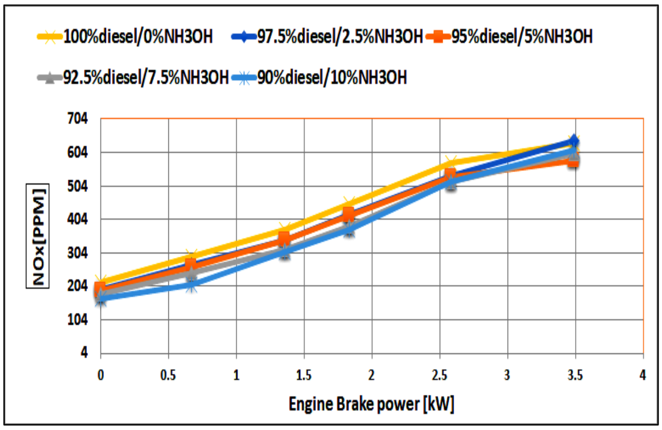

Figure 9: Oxides of Nitrogen Under Variation of Loads Conditions

E. Unburned Hydrocarbons-HC:

Unburned hydrocarbons are formed due to incomplete combustion of the fuel trapped in crevice volumes, an excessively lean or excessively rich mixture, and wetting of the liquid wall. In Figure 10, the variation in the engine HC emission results is clear. It is clear that in the case of pure diesel and with increasing loads, the hydrocarbon emissions values increase due to higher temperatures and the effect of complete combustion inside the engine. In the case of adding ammonia hydroxide the effect of the presence of the percentage of evaporated water, causes a decrease in engine temperatures and thus, Hydrocarbons increase. For example, at maximum load, diesel shows a value. At the same time, at a concentration of 5% ammonia hydroxide we find it 22, and at a concentration of 10% ammonia hydroxide we find it reaches 26, and so on, as shown in the graph in the figure.

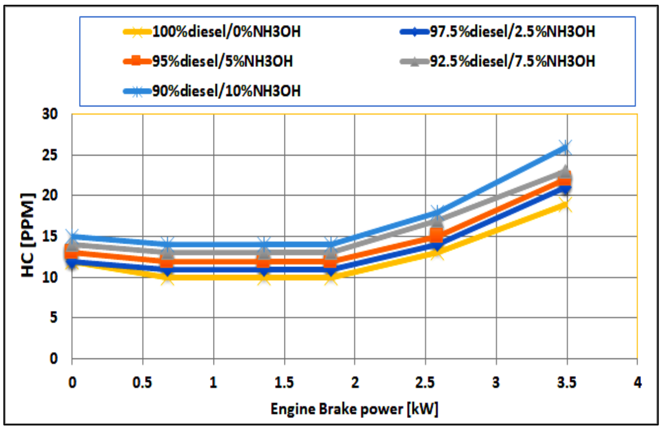

Figure 10 : The variation of the Hydrocarbon under various loads conditions

F. Carbon Monoxide-CO:

Carbon monoxide is considered one of the important emissions of the engine, as it is considered a toxic gas and has a high flammability. It is considered a product of incomplete combustion of carbon dioxide, and due to the low temperature of combustion and the decrease in the oxygen content, partial oxidation of carbon is generated, forming carbon monoxide. In Figure 11, the variation in the results for carbon monoxide for pure diesel fuel and the mixture of diesel and hydroxide is shown. It has been shown that with increasing loads in the experiment and as a result of an increase in the combustion temperature, the emission of carbon monoxide decreases. In the case of adding ammonia hydroxide in different proportions as explained previously and as is clear in The graph shows that as the exhaust temperature decreases and partial oxidation of carbon dioxide occurs, generating carbon monoxide, we will find that by adding ammonia hydroxide, the emission of carbon monoxide increases compared to diesel.

G. Smoke Opacity – Soot:

Figure 12 shows the variation in the results of the appearance of soot in the engine with increasing engine load in all operating conditions and based on the richness of the fuel-air ratio. When comparing pure diesel and a mixture of diesel and ammonia hydroxide with the previously mentioned volumetric ratios, you will find that in the case of diesel, the opacity of the smoke increases due to the richness of the air-fuel mixture. The results shown in the case of the mixture show that at a rate of 2.5% ammonia hydroxide, the value of soot decreases at the same load changes, and even a further decrease appears until we reach a rate of 10% ammonia hydroxide. The average values of smoke opacity were calculated at the studied values and it was found that in the case of pure diesel the value was 51.15%, the value of 2.5% ammonia hydroxide was 49.08%, and in the case of 10% ammonia hydroxide the value of smoke opacity was 44.71%.

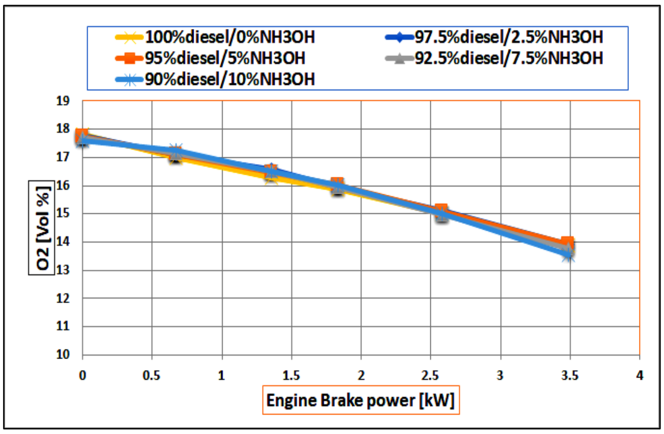

Figure 11: The variation of the Carbon monoxide under various loads conditions

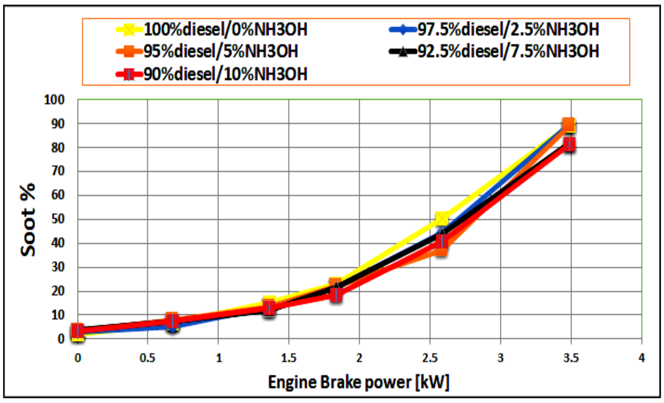

Figure 12: The variation of smoke opacity (SOOT) under various loads conditions

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H. AVERAGE WEIGHTED:

Below, the average results will be clarified and a comparison will be made between the results of diesel combustion and their counterparts from mixtures of ammonia hydroxide and diesel in order to reach the best mixture ratio that we can later work with and include in future studies.
Using Equation 4, average values for the results of our experiment will be deduced and included in the following illustrations.

$$W = \frac{\sum_{i=1}^{n} \omega_i * X_i}{\sum_{i=1}^{n} \omega_i} --------- eq.4$$

Where; W Is Weighted Average, n is no. of terms to be averaged, ω_i weights applied to x values, X_i data values to be averaged.

1. WEIGHTED AVERAGE -BTE:

Figure 13 shows the average values of the engine's thermal efficiency in the case of using pure diesel and the four mixtures of ammonia hydroxide and diesel. It has become clear that in the case of the mixture containing 7.5% and 10% ammonia hydroxide, they are the two highest percentages of the engine's thermal efficiency, and because the values are close between them, it will be preferable to use a mixture of 7.5% hydroxide. Ammonia achieves an average thermal efficiency of 23.4%, while diesel achieves 20.47%.

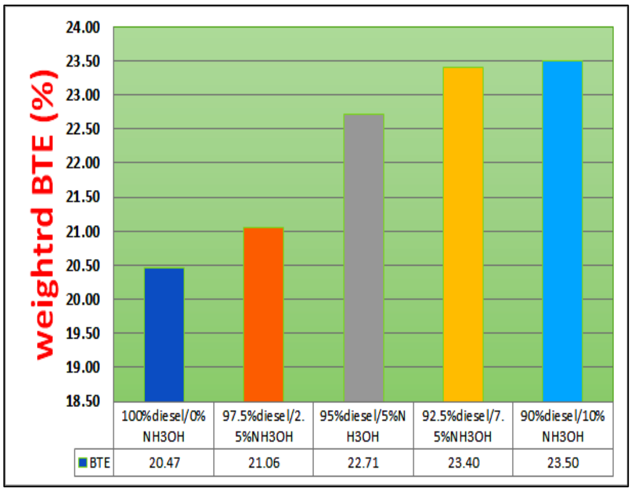

Figure 13: Weighted Average of BTE of the hydroxide ammonia variation

2. WEIGHTED AVERAGE – BSFC:

Figure 14 shows the average values of the fuel consumption rate injected into the engine in the case of using pure diesel and the four mixtures of ammonia hydroxide and diesel. It has become clear that in the case of the mixture containing 7.5% and 10% ammonia hydroxide that was considered as the two highest percentages of the fuel consumption of the injected fuel into the engine. In addition, because the values between them are close, it would be preferable to using a mixture of 7.5% ammonia hydroxide achieves an average fuel consumption rate of 393.84 g/kw.h, while in diesel it is 455.57 g/kw.h.

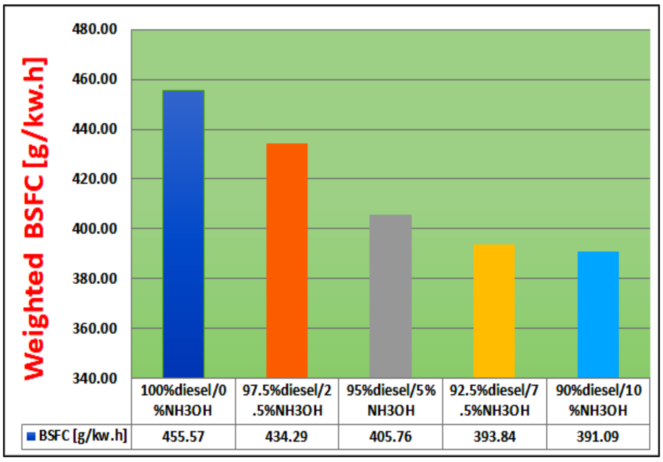

Figure 14: Weighted Average of BSFC Of the Hydroxide Ammonia Variation

3. WEIGHTED AVERAGE – EGT:

Figure 15 shows the average values of the exhaust temperatures leaving the engine in the case of using pure diesel and the four mixtures of ammonia hydroxide and diesel. It has become clear that in the case of the mixture containing 7.5% and 10% ammonia hydroxide, they are the lowest temperatures of the exhaust leaving the engine, and the values between them are close. It is preferable to use a mixture of 7.5 % ammonia hydroxide, as it achieves an average temperature of 196.9 ºc, while in diesel it is 204.3 ºc.

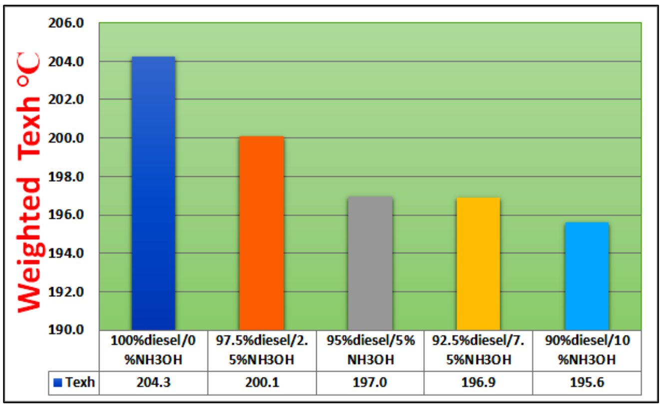

Figure 15: Weighted Average of EGT of the hydroxide ammonia variation

IV. CONCLUSIONS:

In this study, the effect of using pure diesel and mixtures (ammonium hydroxide and diesel) in volume ratios D97.5N2.5, D95N5, D92.5N7.5, D90N10, respectively, was studied on thermal efficiency, fuel consumption rate, and exhaust temperature leaving the engine, in addition to studying the combustion characteristics. In addition, the resulting emissions. The results showed that the use of ammonia hydroxide to diesel was effective, but its only

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penalty appeared in the emission of hydrocarbons. The following results from the experiments will be summarized:

- In the case of B90N10 mixture, the average value of BTE increases by about 15%, the fuel consumption rate (BSFC) decreases by about 13.55% compared to diesel.
- The value of the exhaust temperature - EGT is reduced by using the B90N10 mixture by 3.62% as a result of the presence of a percentage of H2O in the mixture that works to increase the engine efficiency.
- NOX emissions values decrease due to the lower exhaust temperature when using D90N10.
- The smoke opacity value decreases if a mixture of (ammonia hydroxide and diesel) is used. The average smoke opacity values were calculated at the studied values and it was found that in the case of pure diesel the value was 51.15%, the value of 2.5% ammonia hydroxide was 49.08%, and in the case of 10% ammonia hydroxide the value of Smoke opacity was 44.71%.
- The HC values increase if the mixture is used as a result of lower exhaust temperatures and incomplete combustion, and they increase by an average rate of about 22.2% in the case of using the D92.5N7.5 mixture.
- CO emission values increase as a result of the decrease in combustion temperature and thus partial oxidation of carbon dioxide occurs, forming carbon monoxide.

Finally, ammonia-diesel hydroxide can be used in traditional diesel engines, and because the values are similar in higher percentages, it is preferable to use ammonia hydroxide at a rate of 5.7% and diesel at a rate of 92.5%.

V. FUTURE RESEARCH DIRECTION

It is recommended to conduct future research on some exciting topics because of discussing the effect of adding ammonia and diesel hydroxide mixture on engine emissions characteristics, performance, and combustion characteristics, which were mentioned previously. Among the most important recommended topics are:

- The use of new technology for injection systems, such as PCCI. Many research and studies recommend the use of the aforementioned technology because of its benefit in the characteristics of combustion, emissions, and engine performance.
- Searching for other types of fuel that can be mixed with diesel and ammonia hydroxide so that the mixture is homogeneous and measuring the effect of these additives on engine performance, combustion characteristics, and fuel emissions.
- Using an electric injector is a good way compared to its mechanical counterpart with fuel injection pressure to achieve good control, reliability, and the possibility of working in combustion, as it enables it to control the amount of fuel that is sent directly to the injection in the cylinder to avoid knocking accidents in the engine.

VI. REFERENCES:

[1] M. Shen, W. Huang, M. Chen, B. Song, G. Zeng, and Y. Zhang, "(Micro) plastic crisis: un-ignorable contribution to global greenhouse gas emissions and climate change," *Journal of Cleaner Production,* vol. 254, p. 120138, 2020.

[2] M. Elkelawy, H. Alm-Eldin Bastawissi, K. K. Esmaeil, A. M. Radwan, H. Panchal, K. K. Sadasivuni, *et al.*, "Experimental studies on the biodiesel production parameters optimization of sunflower and soybean oil mixture and DI engine combustion, performance, and emission analysis fueled with diesel/biodiesel blends," *fuel,* vol. 255, p. 115791, 2019/11/01/ 2019.

[3] M. Elkelawy, H. A.-E. Bastawissi, K. K. Esmaeil, A. M. Radwan, H. Panchal, K. K. Sadasivuni, *et al.*, "Maximization of biodiesel production from sunflower and soybean oils and prediction of diesel engine performance and emission characteristics through response surface methodology," *fuel,* vol. 266, p. 117072, 2020/04/15/ 2020.

[4] S. Chandra Sekhar, K. Karuppasamy, N. Vedaraman, A. E. Kabeel, R. Sathyamurthy, M. Elkelawy, *et al.*, "Biodiesel production process optimization from Pithecellobium dulce seed oil: Performance, combustion, and emission analysis on compression ignition engine fuelled with diesel/biodiesel blends," *Energy Conversion and Management,* vol. 161, pp. 141-154, 2018/04/01/ 2018.

[5] A. Singh, S. Sinha, A. K. Choudhary, H. Panchal, M. Elkelawy, and K. K. Sadasivuni, "Optimization of performance and emission characteristics of CI engine fueled with Jatropha biodiesel produced using a heterogeneous catalyst (CaO)," *Fuel,* vol. 280, p. 118611, 2020/11/15/ 2020.

[6] M. Elkelawy, H. Alm-Eldin Bastawissi, E. A. El Shenawy, M. Taha, H. Panchal, and K. K. Sadasivuni, "Study of performance, combustion, and emissions parameters of DI-diesel engine fueled with algae biodiesel/diesel/n-pentane blends," *Energy Conversion and Management: X,* vol. 10, p. 100058, 2021/06/01/ 2021.

[7] E. A. El Shenawy, M. Elkelawy, H. A.-E. Bastawissi, H. Panchal, and M. M. Shams, "Comparative study of the combustion, performance, and emission characteristics of a direct injection diesel engine with a partially premixed lean charge compression ignition diesel engines," *fuel,* vol. 249, pp. 277-285, 2019/08/01/ 2019.

[8] C. Kurien and M. Mittal, "Review on the production and utilization of green ammonia as an alternate fuel in dual-fuel compression ignition engines," *Energy Conversion and Management,* vol. 251, p. 114990, 2022.

[9] E. A. El Shenawy, M. Elkelawy, H. A.-E. Bastawissi, M. M. Shams, H. Panchal, K. Sadasivuni, *et al.*, "Investigation and performance analysis of water-diesel emulsion for improvement of performance and emission characteristics of partially premixed charge compression ignition (PPCCI) diesel engines," *Sustainable Energy Technologies and Assessments,* vol. 36, p. 100546, 2019/12/01/ 2019.

[10] M. Elkelawy, A. E. Kabeel, E. A. El Shenawy, H. Panchal, A. Elbanna, H. A.-E. Bastawissi, *et al.*, "Experimental investigation on the influences of acetone organic compound additives into the diesel/biodiesel mixture in CI engine," *Sustainable Energy Technologies and Assessments,* vol. 37, p. 100614, 2020/02/01/ 2020.

[11] H. A. E. Bastawissi, M. Elkelawy, H. Panchal, and K. Kumar Sadasivuni, "Optimization of the multi-carburant

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©Tanta University, Faculty of Engineering
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e ISSN: 2735-4873

dose as an energy source for the application of the HCCI engine," *fuel,* vol. 253, pp. 15-24, 2019/10/01/ 2019.

[12] M. Elkelawy, E. A. El Shenawy, H. Alm-Eldin Bastawissi, M. M. Shams, and H. Panchal, "A comprehensive review on the effects of diesel/biofuel blends with nanofluid additives on compression ignition engine by response surface methodology," *Energy Conversion and Management: X,* vol. 14, p. 100177, 2022/05/01/ 2022.

[13] J. S. Cardoso, V. Silva, R. C. Rocha, M. J. Hall, M. Costa, and D. Eusébio, "Ammonia as an energy vector: Current and future prospects for low-carbon fuel applications in internal combustion engines," *Journal of Cleaner Production,* vol. 296, p. 126562, 2021.

[14] M. Elkelawy, S. E.-d. H. Etaiw, H. Alm-Eldin Bastawissi, M. I. Ayad, A. M. Radwan, and M. M. Dawood, "Diesel/ biodiesel /silver thiocyanate nanoparticles/hydrogen peroxide blends as new fuel for enhancement of performance, combustion, and Emission characteristics of a diesel engine," *energy,* vol. 216, p. 119284, 2021/02/01/ 2021.

[15] M. Elkelawy, S. E.-d. H. Etaiw, H. A.-E. Bastawissi, H. Marie, A. Elbanna, H. Panchal*, et al.*, "Study of diesel-biodiesel blends combustion and emission characteristics in a CI engine by adding nanoparticles of Mn (II) supramolecular complex," *Atmospheric Pollution Research,* vol. 11, pp. 117-128, 2020/01/01/ 2020.

[16] M. Elkelawy, S. E.-d. H. Etaiw, M. I. Ayad, H. Marie, M. Dawood, H. Panchal*, et al.*, "An enhancement in the diesel engine performance, combustion, and emission attributes fueled by diesel-biodiesel and 3D silver thiocyanate nanoparticles additive fuel blends," *Journal of the Taiwan Institute of Chemical Engineers,* vol. 124, pp. 369-380, 2021/07/01/ 2021.

[17] Y. Qi, W. Liu, S. Liu, W. Wang, Y. Peng, and Z. Wang, "A review on ammonia-hydrogen fueled internal combustion engines," *eTransportation,* p. 100288, 2023.

[18] S. C. Sekhar, K. Karuppasamy, R. Sathyamurthy, M. Elkelawy, H. A. E. D. Bastawissi, P. Paramasivan*, et al.*, "Emission analysis on compression ignition engine fueled with lower concentrations of Pithecellobium dulce biodiesel-diesel blends," *Heat Transfer—Asian Research,* vol. 48, pp. 254-269, 2019.

[19] A. M. Elzahaby, M. Elkelawy, H. A.-E. Bastawissi, S. M. El_Malla, and A. M. M. Naceb, "Kinetic modeling and experimental study on the combustion, performance and emission characteristics of a PCCI engine fueled with ethanol-diesel blends," *Egyptian Journal of Petroleum,* vol. 27, pp. 927-937, 2018/12/01/ 2018.

[20] A. Gholami, S. A. Jazayeri, and Q. Esmaili, "A detail performance and CO2 emission analysis of a very large crude carrier propulsion system with the main engine running on dual fuel mode using hydrogen/diesel versus natural gas/diesel and conventional diesel engines," *Process Safety and Environmental Protection,* vol. 163, pp. 621-635, 2022.

[21] D. Mevada, H. Panchal, H. A. ElDinBastawissi, M. Elkelawy, K. Sadashivuni, D. Ponnamma*, et al.*, "Applications of evacuated tubes collector to harness the solar energy: a review," *International Journal of Ambient Energy,* vol. 43, pp. 344-361, 2022/12/31 2022.

[22] E. A. El Shenawy, M. Elkelawy, H. A.-E. Bastawissi, M. Taha, H. Panchal, K. k. Sadasivuni*, et al.*, "Effect of cultivation parameters and heat management on the algae species growth conditions and biomass production in a continuous feedstock photobioreactor," *Renewable Energy,* vol. 148, pp. 807-815, 2020/04/01/ 2020.

[23] H. Panchal, K. Patel, M. Elkelawy, and H. A.-E. Bastawissi, "A use of various phase change materials on the performance of solar still: a review," *International Journal of Ambient Energy,* vol. 42, pp. 1575-1580, 2021/10/03 2021.

[24] P. Dimitriou and R. Javaid, "A review of ammonia as a compression ignition engine fuel," *International Journal of Hydrogen Energy,* vol. 45, pp. 7098-7118, 2020.

[25] M. Elkelawy, Z. Yu-Sheng, H. A. El-Din, and Y. Jing-zhou, "A comprehensive modeling study of natural gas (HCCI) engine combustion enhancement by using hydrogen addition," SAE Technical Paper 0148-7191, 2008.

[26] M. Elkelawy, Z. Yu-Sheng, A. E.-D. Hagar, and J.-z. Yu, "Challenging and Future of Homogeneous Charge Compression Ignition Engines; an Advanced and Novel Concepts Review," *Journal of Power and Energy Systems,* vol. 2, pp. 1108-1119, 2008.

[27] M. Elkelawy, E. A. El Shenawy, S. A. Mohamed, M. M. Elarabi, and H. Alm-Eldin Bastawissi, "Impacts of EGR on RCCI engines management: A comprehensive review," *Energy Conversion and Management: X,* vol. 14, p. 100216, 2022/05/01/ 2022.

[28] M. Elkelawy, E. A. El Shenawy, S. k. A. Almonem, M. H. Nasef, H. Panchal, H. A.-E. Bastawissi*, et al.*, "Experimental study on combustion, performance, and emission behaviours of diesel /WCO biodiesel/Cyclohexane blends in DI-CI engine," *Process Safety and Environmental Protection,* vol. 149, pp. 684-697, 2021/05/01/ 2021.

[29] Y. Niki, Y. Nitta, H. Sekiguchi, and K. Hirata, "Diesel fuel multiple injection effects on emission characteristics of diesel engine mixed ammonia gas into intake air," *Journal of Engineering for Gas Turbines and Power,* vol. 141, p. 061020, 2019.

[30] M. Elkelawy, H. Bastawissi, S. C. Sekar, K. Karuppasamy, N. Vedaraman, K. Sathiyamoorthy*, et al.*, "Numerical and experimental investigation of ethyl alcohol as oxygenator on the combustion, performance, and emission characteristics of diesel/cotton seed oil blends in homogenous charge compression ignition engine," SAE Technical Paper 0148-7191, 2018.

[31] M. Elkelawy, S. E.-d. H. Etaiw, H. A.-E. Bastawissi, H. Marie, A. M. Radwan, M. M. Dawood*, et al.*, "WCO biodiesel production by heterogeneous catalyst and using cadmium (II)-based supramolecular coordination polymer additives to improve diesel/biodiesel fueled engine performance and emissions," *Journal of Thermal Analysis and Calorimetry,* vol. 147, pp. 6375-6391, 2022/06/01 2022.

[32] V. Scharl, T. Lackovic, and T. Sattelmayer, "Characterization of ammonia spray combustion and mixture formation under high-pressure, direct injection conditions," *Fuel,* vol. 333, p. 126454, 2023.

[33] A. Mohammed Elbanna, C. Xiaobei, Y. Can, M. Elkelawy, H. Alm-Eldin Bastawissi, and H. Panchal, "Fuel reactivity controlled compression ignition engine and potential strategies to extend the engine operating range: A comprehensive review," *Energy Conversion and Management: X,* vol. 13, p. 100133, 2022/01/01/ 2022.

Doi: 10.21608/ERJENG.2023.234219.1229

[34] J.-z. Yu, Z. Yu-Sheng, M. Elkelawy, and Q. Kui, "Spray and combustion characteristics of HCCI engine using DME/diesel blended fuel by port-injection," SAE Technical Paper 0148-7191, 2010.

[35] K. Ryu, G. E. Zacharakis-Jutz, and S.-C. Kong, "Performance characteristics of compression-ignition engine using high concentration of ammonia mixed with dimethyl ether," *Applied Energy,* vol. 113, pp. 488-499, 2014.

[36] M. Elkelawy, "Experimental Investigation of Intake Diesel Aerosol Fuel Homogeneous Charge Compression Ignition (HCCI) Engine Combustion and Emissions," *Energy and Power Engineering,* vol. Vol.06No.14, p. 14, 2014.

[37] A. Yousefi, H. Guo, S. Dev, B. Liko, and S. Lafrance, "Effects of ammonia energy fraction and diesel injection timing on combustion and emissions of an ammonia/diesel dual-fuel engine," *Fuel,* vol. 314, p. 122723, 2022.

[38] H. A. El-Din, M. Elkelawy, and Z. Yu-Sheng, "HCCI engines combustion of CNG fuel with DME and H 2 additives," SAE Technical Paper 0148-7191, 2010.

[39] M. Elkelawy, E. A. El Shenawy, S. A. Mohamed, M. M. Elarabi, and H. A.-E. Bastawissi, "Impacts of using EGR and different DI-fuels on RCCI engine emissions, performance, and combustion characteristics," *Energy Conversion and Management: X,* vol. 15, p. 100236, 2022/08/01/ 2022.

[40] M. M. El-Sheekh, M. Y. Bedaiwy, A. A. El-Nagar, M. ElKelawy, and H. Alm-Eldin Bastawissi, "Ethanol biofuel production and characteristics optimization from wheat straw hydrolysate: Performance and emission study of DI-diesel engine fueled with diesel/biodiesel/ethanol blends," *Renewable Energy,* vol. 191, pp. 591-607, 2022/05/01/ 2022.

[41] A. M. Elbanna, C. Xiaobei, Y. Can, M. Elkelawy, and H. A.-E. Bastawissi, "A comparative study for the effect of different premixed charge ratios with conventional diesel engines on the performance, emissions, and vibrations of the engine block," *Environmental Science and Pollution Research,* 2022/09/17 2022.

[42] A. M. Elbanna, X. Cheng, C. Yang, M. Elkelawy, and H. Alm-Eldin Bastawissi, "Investigative research of diesel/ethanol advanced combustion strategies: A comparison of Premixed Charge Compression Ignition (PCCI) and Direct Dual Fuel Stratification (DDFS)," *Fuel,* vol. 345, p. 128143, 2023/08/01/ 2023.

[43] E. A. El-Shenawy, M. ElKelawy, H. A.-E. Bastawissi, and M. Al-Hofy, "Investigation of Combustion and Emission Characteristics of Diesel/Bioï¿ ¾Diesel Blends under Oxygenated Fuel Burner," *ERJ. Engineering Research Journal,* vol. 41, pp. 109-118, 2018.

[44] M. Elkelawy, H. Alm ElDin Mohamad, E. Abd elhamid, and M. A. M. El-Gamal, "A Critical Review of the Performance, Combustion, and Emissions Characteristics of PCCI Engine Controlled by Injection Strategy and Fuel Properties," *Journal of Engineering Research,* vol. 6, pp. 96-110, 2022.

[45] A. M. Elzahaby, M. Elkelawy, H. A.-E. Bastawissi, S. M. El-Malla, and A. M. M. Naceb, "Effect of Ethanol–Diesel Fuel Blends on Autoignition and Combustion Characteristics in HCCI Engines," pp. 1-15.

[46] E. A. El Shenawy, M. Elkelawy, H. A.-E. Bastawissi, and M. Shams, "EXPERIMENTAL STUDY ON THE PERFORMANCE AND EMISSION CHARACTERISTICS OF PPCCI ENGINE FUELED WITH BIODIESEL/DIESEL BLENDS," *ERJ. Engineering Research Journal,* vol. 41, pp. 119-132, 2018.

[47] M. Elkelawy, E. A. El Shenawy, H. A. E. Bastawissi, and I. A. El Shennawy, "The effect of using the WCO biodiesel as an alternative fuel in compression ignition diesel engine on performance and emissions characteristics," p. 012023.

[48] M. Elkelawy, H. Alm ElDin Mohamad, A. K. Abdel-Rahman, A. Abou Elyazied, and S. Mostafa El Malla, "Biodiesel as an Alternative Fuel in Terms of Production, Emission, Combustion Characteristics for Industrial Burners: a Review," *Journal of Engineering Research,* vol. 6, pp. 45-52, 2022.

[49] M. M. El-Sheekh, A. A. El-Nagar, M. ElKelawy, and H. A.-E. Bastawissi, "Maximization of bioethanol productivity from wheat straw, performance and emission analysis of diesel engine running with a triple fuel blend through response surface methodology," *Renewable energy,* vol. 211, pp. 706-722, 2023/07/01/ 2023.

[50] B. Işcan, "ANN modeling for justification of thermodynamic analysis of experimental applications on combustion parameters of a diesel engine using diesel and safflower biodiesel fuels," *fuel,* vol. 279, p. 118391, 2020.

[51] M. Elkelawy, H. A.-E. Bastawissi, A. M. Radwan, M. T. Ismail, and M. El-Sheekh, "Chapter 15 - Biojet fuels production from algae: conversion technologies, characteristics, performance, and process simulation," in *Handbook of Algal Biofuels*, M. El-Sheekh and A. E.-F. Abomohra, Eds., ed: Elsevier, 2022, pp. 331-361.

[52] A. E. Kabeel, M. Elkelawy, H. A. E. Bastawissi, and A. M. Elbanna, "An experimental and theoretical study on particles-in-air behavior characterization at different particles loading and turbulence modulation," *Alexandria Engineering Journal,* vol. 58, pp. 451-465, 2019/06/01/ 2019.

[53] H. Thakkar, K. k. Sadasivuni, P. V. Ramana, H. Panchal, M. Suresh, M. Israr, *et al.*, "Comparative analysis of the use of flash evaporator and solar still with a solar desalination system," *International Journal of Ambient Energy,* vol. 43, pp. 1561-1568, 2022/12/31 2022.

[54] M. Elkelawy, E. A. El Shenawy, H. A. E. Bastawissi, and I. A. El Shennawy, "The effect of using the WCO biodiesel as an alternative fuel in compression ignition diesel engine on performance and emissions characteristics," *Journal of Physics: Conference Series,* vol. 2299, p. 012023, 2022/07/01 2022.

[55] J. G. Vaghasia, J. K. Ratnadhariya, H. Panchal, K. K. Sadasivuni, D. Ponnamma, M. Elkelawy, *et al.*, "Experimental performance investigations on various orientations of evacuated double absorber tube for solar parabolic trough concentrator," *International Journal of Ambient Energy,* vol. 43, pp. 492-499, 2022/12/31 2022.

[56] M. ElKelawy, H. A.-E. Bastawissi, E.-S. A. El-Shenawy, H. Panchal, K. Sadashivuni, D. Ponnamma, *et al.*, "Experimental investigations on spray flames and emissions analysis of diesel and diesel/biodiesel blends for combustion in oxy-fuel burner," *Asia-Pacific Journal of Chemical Engineering,* vol. 14, p. e2375, 2019.

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Vol. 7 – No. 3, 2023
©Tanta University, Faculty of Engineering
ISSN: 2356-9441 https://erjeng.journals.ekb.eg/ e ISSN: 2735-4873

[57] M. Elkelawy, H. Alm ElDin Mohamad, and M. A. M. El-Gamal, "Experimental Investigation of the Biodiesel Direct Injection and Diesel Fuel as Premixed Charge on CI-Engine Emissions, Performance, and Combustion Characteristics," *Journal of Engineering Research,* vol. 7, pp. 177-187, 2023.

[58] J. Ramachander, S. K. Gugulothu, G. R. K. Sastry, J. K. Panda, and M. S. Surya, "Performance and emission predictions of a CRDI engine powered with diesel fuel: A combined study of injection parameters variation and Box-Behnken response surface methodology based optimization," *Fuel,* vol. 290, p. 120069, 2021.

[59] M. Elkelawy, H. Alm ElDin Mohamad, M. Samadony, A. M. Elbanna, and A. M. S. M. Safwat, "A Comparative Study on Developing the Hybrid-Electric Vehicle Systems and its Future Expectation over the Conventional Engines Cars," *Journal of Engineering Research,* vol. 6, pp. 21-34, 2022.

[60] A. E. Kabeel, M. Elkelawy, H. A.-E. Mohamad, A. M. Elbanna, H. Panchal, M. Suresh*, et al.*, "The influences of loading ratios and conveying velocity on gas-solid two phase flow characteristics: a comprehensive experimental CFD-DEM study," *International Journal of Ambient Energy,* vol. 43, pp. 2714-2726, 2022/12/31 2022.

[61] H. Alm ElDin Mohamad, E. Abd Elhamid, M. Elkelawy, and O. Hendawi, "Experimental Investigation on the Effect of using Oxy- Hydrogen Gas on Spark Ignition Engines Performances, and Emissions Characteristic," *Journal of Engineering Research,* vol. 7, pp. 32-41, 2023.

[62] S. F. Abd El Fattah, M. F. Ezzat, M. A. Mourad, M. Elkelawy, and I. M. Youssef, "Experimental Investigation of the Performance and Exhaust Emissions of a Spark-Ignition Engine Operating with Different Proportional Blends of Gasoline and Water Ammonia Solution," *Journal of Engineering Research,* vol. 5, pp. 38-45, 2022.

[63] S. El-din H. Etaiw, M. Elkelawy, I. Elziny, M. Taha, I. Veza, and H. Alm-Eldin Bastawissi, "Effect of nanocomposite SCP1 additive to waste cooking oil biodiesel as fuel enhancer on diesel engine performance and emission characteristics," *Sustainable Energy Technologies and Assessments,* vol. 52, p. 102291, 2022/08/01/ 2022.

[64] "A Computational Study of Cavitation Model Validity Using a New Quantitative Criterion," *Chinese Physics Letters,* vol. 29, p. 064703, 2012/06/01 2012.

[65] H. A. E.-D. Bastawissi and M. Elkelawy, "Computational Evaluation of Nozzle Flow and Cavitation Characteristics in a Diesel Injector," *SAE International Journal of Engines,* vol. 5, pp. 1605-1616, 2012.

[66] H. Alm El-Din, M. Elkelawy, and A. E. Kabeel, "Study of combustion behaviors for dimethyl ether asan alternative fuel using CFD with detailed chemical kinetics," *Alexandria Engineering Journal,* vol. 56, pp. 709-719, 2017/12/01/ 2017.

[67] H. A.-E. Bastawissi and M. Elkelawy, "Investigation of the Flow Pattern inside a Diesel Engine Injection Nozzle to Determine the Relationship between Various Flow Parameters and the Occurrence of Cavitation," *Engineering,* vol. Vol.06No.13, p. 13, 2014.

[68] A. M. Elbanna, X. Cheng, C. Yang, M. Elkelawy, and H. A. Elden, "Knock Recognition System in a PCCI Engine Powered by Diesel," *Highlights in Science, Engineering and Technology,* vol. 15, pp. 94-101, 2022.

[69] M. ElKelawy, A. El-Shenawy, H. A. E. Mohamad, and S. Abd Al Monem, "Experimental Investigation on Spray Characteristics of Waste Cooking Oil Biodiesel/Diesel Blends at Different Injection Parameters," *Journal of Engineering Research,* vol. 3, pp. 29-34, 2019.

[70] M. Elkelawy, A. Kamel, A. Abou-Elyazied, and S. M. El-malla, "Experimental investigation of the effects of using biofuel blends with conventional diesel on the performance, combustion, and emission characteristics of an industrial burner," *Egyptian Sugar Journal,* vol. 19, 2022.

[71] K. Shrivastava, S. S. Thipse, and I. D. Patil, "Optimization of diesel engine performance and emission parameters of Karanja biodiesel-ethanol-diesel blends at optimized operating conditions," *Fuel,* vol. 293, p. 120451, 2021.

[72] M. Elkelawy and H. A.-E. Bastawissi, "Numerical study on the hydrogen fueled SI engine combustion optimization through a combined operation of DI and PFI strategies," *Energy and Power Engineering,* vol. 5, p. 513, 2013.

[73] E. A. El-Shenawy, M. Elkelawy, H. A. Bastawissi, and M. Taha, "GROWTH CONDITIONS OF THE ALGAE SPECIES BIOMASS IN A CONTINUOUS FEEDSTOCK PHOTO BIOREACTOR BY CONTROLLING THE SOLAR THERMAL RADIATION AND CLIMATE TEMPERATURE," *The International Conference on Applied Mechanics and Mechanical Engineering,* vol. 18, pp. 1-19, 2018.

[74] M. Nibin, J. B. Raj, and V. E. Geo, "Experimental studies to improve the performance, emission and combustion characteristics of wheat germ oil fuelled CI engine using bioethanol injection in PCCI mode," *Fuel,* vol. 285, p. 119196, 2021.

[75] M. Elkelawy, H. Alm ElDin Mohamad, E. Abd elhamid, and M. A. M. El-Gamal, "Experimental Investigation of the Biodiesel Direct Injection and Diesel Fuel as Premixed Charge on CI-Engine Emissions, Performance, and Combustion Characteristics," *Journal of Engineering Research,* vol. 7, pp. 177-187, 2023.

[76] M. Elkelawy, E. Abd elhamid, H. Alm ElDin Mohamad, S. Abo-Samra, and I. Abd-Elhay Elshennawy, "Nanoparticles Additives for Diesel/Biodiesel Fuel Blends as a Performance and Emissions Enhancer in the Applications of Direct Injection Diesel Engines: A comparative Review," *Journal of Engineering Research,* vol. 7, pp. 112-121, 2023.

[77] M. F. Al-Dawody, W. Al-Obaidi, E. D. Aboud, M. A. Abdulwahid, K. Al-Farhany, W. Jamshed*, et al.*, "Mechanical engineering advantages of a dual fuel diesel engine powered by diesel and aqueous ammonia blends," *fuel,* vol. 346, p. 128398, 2023.

Doi: 10.21608/ERJENG.2023.234219.1229