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Ultrasound Assisted Fuel Atomization To Enhance Performance Of A Microgas Turbine Engine

Abdullah E. Alrashidi[a]
[a]PuplicAthority of Applied Education and Training(PAAET),Vocational Training Institute, department of Automotive.

ABSTRACT
Jet engines are used in transportation such as civil aircraft, aircraft fighters and helicopters, Jet engines also used in the energy Production sector as gas turbine engines. Gas turbines, with both aircraft jet engines and stationary gas turbine engines, require a big amount of fuel. A pilot platform was developed using a small jet engine work with ultrasound technology merging with biodiesel system to dismantle the fuel as an auxiliary fuel source. A set of four ultrasonic fuel atomizers was used through the air intake area of the jet engine, each atomizers provide 5 liters / hourof fuel. Airflow was measured using mfs air flow mass sensor.a two separate fuel system (biodiesel fuel system ,fossil diesel system) load scale was installed to measure the actual power of the engine in kgf units. A exhaust gas analyzer was used to measure the proportion of oxygen, carbon monoxide, carbon dioxide, unburned hydrocarbons (uHC), nitrogen monoxide and nitrogen dioxide in the exhaust gas. Engine performance was tested under three levels of load (high, medium and low) ranging from 10 psi in a stable operation condition as a minimum value.

KEY WORDS:Micro gas turbine,Biodiesel,Emission,Experments, ultrasonic atomization, Diesel, Kerosene,

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SUBSCRIPTS
NO: Nitrogen monoxide.
NO_2: Nitrogen dioxide
CO: Carbon monoxide.
CO_2: Carbon dioxide.
B20: 20%v Biodiesel +80%v Kerosene.
B50: 50%v Biodiesel + 50%v Kerodene.
B75: 75%v Biodiesel + 25%v Kerosene.
B100: pure Biodiesle.

I. INTRODUCTION

A gas turbine is one of most efficient engine that used to generate power sector. main component of gas turbine is the compressor coupled to the turbine and a combustion chamber[1]. gas turbines generatethrust by providing achange in voluom by the expantion burned gasesand momentum to the air that enters and leaves the gas turbine [2] [3].

Gas turbine requires a combustor to occur combustion, the. The combustor is a vital component of the gas turbine, Unlike reciprocating engine, gas turbines have a continuous flame inside the combustor, which is lit for as long as the engine is running[4]. Once ignited, the flame by constantly injecting fuel to the high pressure compressed air from the compressor, using a fuel nozzle inside combuster can insure continuance operation . The main purposed of every fuel nozzle is to insure a good fuel atomization, to improve the mixing process of fuel and air [5]. The differences between various fuel injectors technologies lie in how exactly the droplets are produced. Thus, the size d ≥ 15 μm of the droplets can determine the effectiveness of atomization on the combustion process of gas turbine[6][7].Atomization is the breakup fuel liquid into fine droplets using an injection system [8]. ther are several kind of Atomizers classified into pressure injector, vorticinjector, air-blast atomizer, air-assist atomizers, twin-fluid atomizer, and rotary atomizer, ultrasonic atomizers, whistle atomizers and electrostatic atomizer [9] [10].

the atomization in a gas turbine is continuous without any kind of strok. However, in order to achieve clean combustion during the continuous process, the fuel must be injected in the combustion chamber mixid with compressed air coming from compressor.

Biodiesel fuel is normaly made fromwaste cooking oil, Vegetable oilsand animal fat, main components of which are fatty acid methyl esters .Biodiesel fuel is one of the important biofuels owing to the advantage of its large potential of CO2 emission reduction compared to the fossil oil.

average lower heating value of biodiesl fuel is near 38 MJ/kg, that's mean 10 % lower than that of fossil diesel fuel[11]. Moreover, biodiesl fuel can be refined from animal fat through a simple chemical reaction, such as transesterification, this processcan produces less amount of CO2 through refinery reaction. Merging between biodiesel and ultrasonic technologe can enhance the thermal efficiency and the Environmental pollution.

II. METHODOLOGY

an a laboratory has been established to support this study. the laboratory has been equipped to insure all test rig activity . the laboratory contain insulated room with acoustic insulation and main jet engine system, assistance systems, electrical systems, and control systems. all systems are linked in such a way as to facilitate the tests in a convenient manner as can be seen in figure 1. the block diagram shows the biodiesel fuel inputs to the main fuel atomizer and then injected throw combustion chamber. while, the ultra sonic atomizer system use the air inlet diffuser to mix the kerosen and air through the compressor and then to the combustion chamber that leading to a combustion reaction then transferring the momentum to the turbine wheel. energy that formed from the combustion process was flow to the turbine at high flow properties such as temperature, pressure and thrust force. that measured with air flow rate, fuel flow rate, thrust force, however all parameters used to determine the engine performance data and engine emissions areconnected to a micro controller throu a computer.

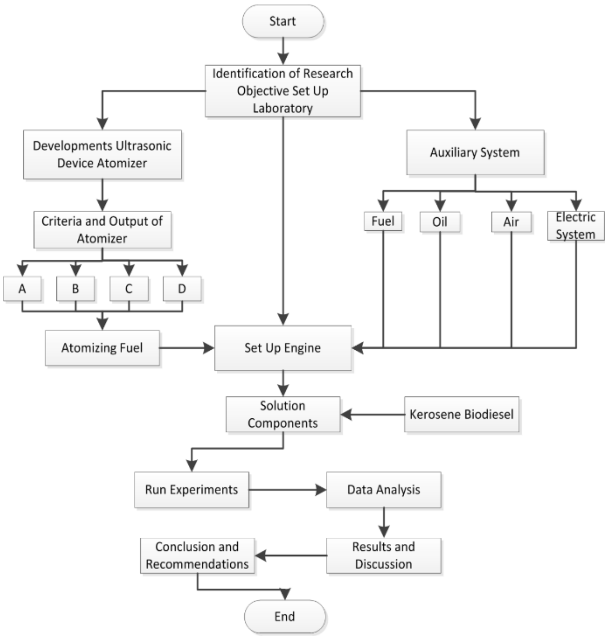

Figure 1: Flowchart of the methodology

Table 1. Biodiesel properties.

Fuel type	Density @ 25°C	Cloud point	Kinematic viscosity @ 40°C	Pour point	Flash point
Diesel	0.8339	0	3.5819	0	90
Kerosene	0.7822	-53.8	1.2144	-54	47
B20 Kerosene +Biodiesel 80:20	0.8006	-3.5	1.5832	-12	N/A
B50 Kerosene +Biodiesel 80:20	0.8219	6.5	2.1677	0	89
B75 Kerosene +Biodiesel 80:20	0.8576	6.9	3.2677	6	62
B100 pure Biodiesel	0.8649	11.2	4.339	15	97

III. RESULTS

This engine was tested under fossil fuel Kerosene fuel as conventional and Biodiesel blendsB20, B50, B75 to 100% of Biodiesel respectively. Table 1 illustraite the properties of fuel that are usining in this study.

3.1 Emission Data Measurements

The emission (CO, CO_2, NO, NO_2) results obtained by using the normal and ultrasonic atomization process for atomizing the different fuels employed in the current study, including diesel, kerosene, B20, B50, B75 and B100 are reported in this section. It is worth noting that the gasses produced through the exhaust were collected at a special point and the gasses were cooled through the manifold of a heat exchanger.

3.1.1 CO Emission

Incomplete combustion of CO_2 results in CO formation in the exhaust gas. If the combustion is incomplete owing to air inhibition or due to low gas temperature, CO will be formed. Mostly, some factors such as air-fuel ratio, engine speed, injection timing, injection pressure and type of fuels have an impact on CO emission [11]. Variation in the CO emission for different fuel types injected through the normal and ultrasonic atomization process is presented in Figure 4.11.

Meanwhile, it can be evidenced that the CO emission for the kerosene fuel in both the normal and ultrasonic fuel atomization conditions were lower than that of the biodiesel fuels, hence with decreasing content of kerosene in the biodiesel blends, CO emission increased. The finding above can best be explained by the higher absorption of heat produced when kerosene fuel evaporates as compared to the biodiesel fuels. Elsewhere [12], it was reported that the higher density and kinematic viscosity of biodiesel causes poor fuel atomization, thus leading to rise in exhaust gas emission.

Generally, it can be observed that the across all the tested fuel types, the ultrasonic atomization process exhibited the highest CO emission than the normal process. With reduction in the droplet size of the fuel with the ultrasonic atomization process the time taken for combustion became shorter and comparatively less complete combustion occurred relative to the normal process. Hence, CO emission was higher for the ultrasonic atomization process across the entire engine load for the different fuels than the CO emission produced by using the normal process.

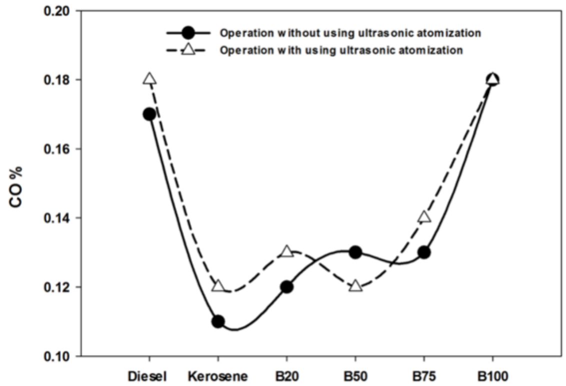

Figure 4.1: Plots of CO emission against the engine load for all the different fuel type at low load thrust force.

3.1.2 CO_2 Emission

In Figure 4.12 it can be observed that the Co concentration is high in diesel fuel and B100 at low load thrust, nevertheless the low value of Co is being in Kerosene and B50, noted that when ultrasonic atomization is slightly high in diesel, kerosene B20 and B75.

Co percentage that shown in Figure 4.13 is slightly high in case of using Kerosene, B20, B75 and B100 respectively regarding ultrasonic atomization, however it is same value of CO concentration in diesel and B50.

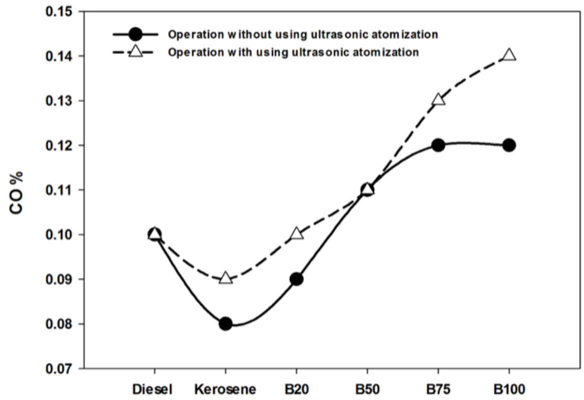

Figure 4.2: Plots of CO emission against the engine load for all the different fuel type at medium load thrust force.

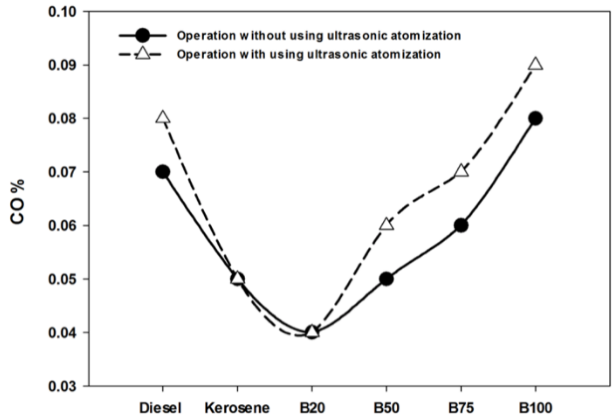

Figure 4.3: Plots of CO emission against the engine load for all the different fuel type at maximum load thrust force.

3.1.3 CO_2 Emission

Complete combustion of fuel produces more CO_2 in the exhaust. The concentration of CO_2 has opposite trend to that of concentration of CO owing to improvement of combustion process [4]. Variation in the CO_2 emission for different fuel types injected through the normal and ultrasonic atomization process is presented in Figure 4.12.

Similar to the results obtained for the CO emission, it can be evidenced that the CO_2 emissions for the kerosene fuel in both the normal and ultrasonic fuel atomization conditions were lower than that of the biodiesel fuels. The finding above can be attributed to the complete combustion that occurred as a result of high oxygenation characteristic of biodiesel fuels. More so, it can be evidenced that CO_2 emissions increased with decreasing content of kerosene in the biodiesel fuels tested for both the normal and ultrasonic fuel atomization conditions. This can best be ascribed to the finding of[3],where the higher oxygen content in the biodiesel fuel was reported to have improved the quality of combustion. Hence, the pure biodiesel exhibited the highest value for CO_2 emissions relative to other tested fuels.

Contrary to the CO emission and with the exemption of the kerosene fuel, it can be observed that the ultrasonic atomization process for the biodiesel fuels exhibited the highest CO_2 emission than the normal process between the engine loads of 1.7-2.3 kg_f while beyond this point, CO_2 emission for the ultrasonic atomization process decreased relative to the normal process. With reduction in the droplet size of the biodiesel fuel for the ultrasonic atomization process, the time taken for complete combustion at higher load became shorter and the oxygenation tendency of the biodiesel fuels was reduced. Hence, CO_2 emission for the biodiesel fuels decreased at higher engine load for the ultrasonic atomization process as compared to the normal process.

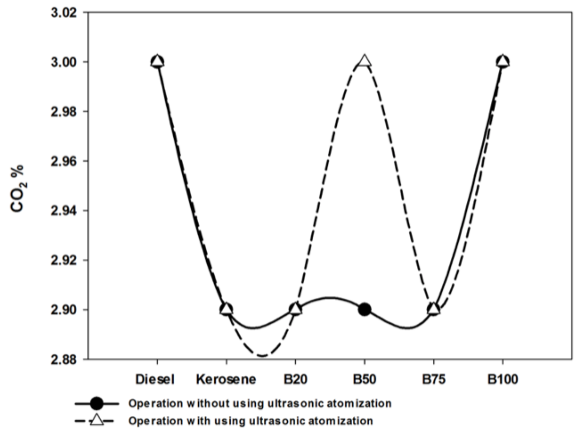

Figure 4.4: Plots of CO_2 emission against the engine load for all the different fuel type at low load thrust force.

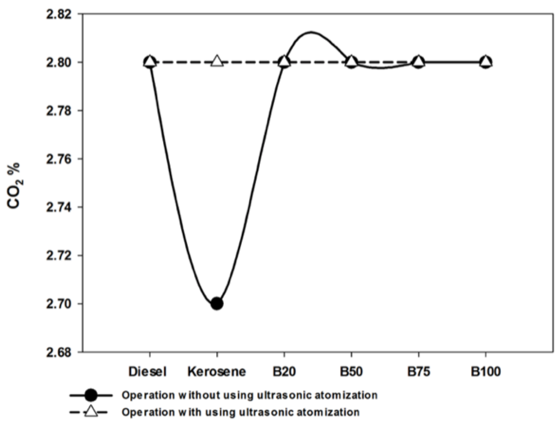

Figure 4.5: Plots of CO_2 emission against the engine load for all the different fuel type at medium load thrust force.

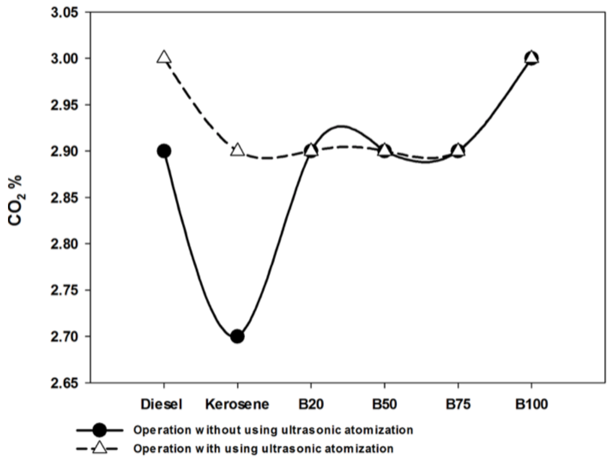

Figure 4.6: Plots of CO_2 emission against the engine load for all the different fuel type at maximum load thrust force.

3.1.4 NO Emission

Nitrogen and oxygen produces NO_x at elevated temperatures during the combustion process. The oxides of Nitrogen in the exhaust emissions contain nitric oxide (NO) and nitrogen dioxide (NO_2). The formation of NO_x depends so much on the in-cylinder temperatures, concentration of oxygen, and residence time for the reaction to occur [10]. Variation in the NO emission for different fuel types injected through the normal and ultrasonic atomization process is presented in Figure 4.13.

Contrary to the CO and CO_2 emissions, it can be evidenced that the NO emission for the kerosene fuel in both the normal and ultrasonic fuel atomization conditions were higher than that of the biodiesel fuels. The finding above can be attributed to the reduction in radiated heat transfer wing to decreased soot formation, shorter ignition delay and higher heat release rate. Hence, the NO emission increased more in the kerosene fuel relative to the biodiesel counterparts tested for both the normal and ultrasonic fuel atomization conditions.

Generally, it can be observed that the ultrasonic atomization process for the biodiesel fuels exhibited the lower NO emission than the normal process with the pure biodiesel (B100) fuel having the lowest values across the entire engine load. Meanwhile, for the kerosene fuel, the NO emission at 1.7kg_f for the ultrasonic atomization process was lower than that of the normal process. While beyond this point, NO emission for the ultrasonic atomization process increased relative to the normal process.

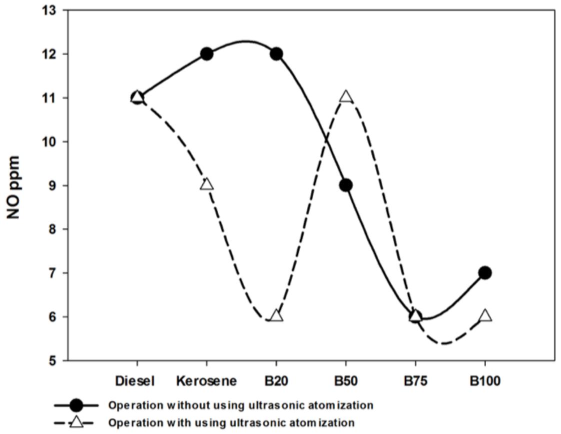

Figure 4.7: Plots of NO emission against the engineload for all the different fuel type at low load thrust force.

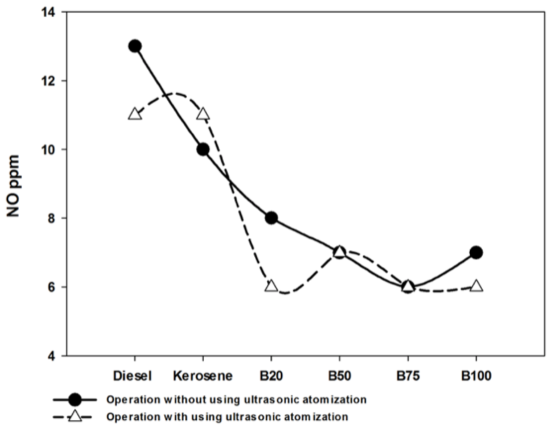

Figure 4.8: Plots of NO emission against the engine load for all the different fuel type at medium load thrust force.

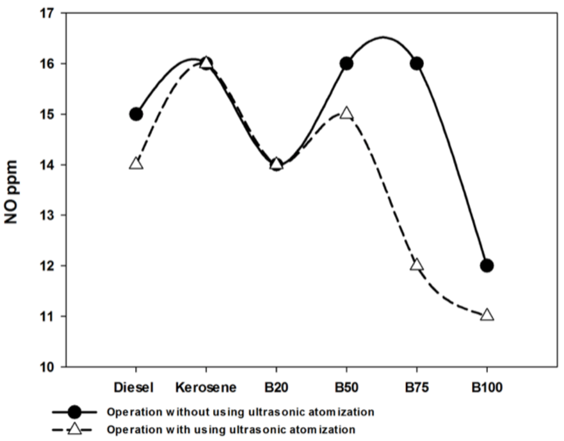

Figure 4.9: Plots of NO emission against the engine load for all the different fuel type at maximum load thrust force.

3.1.5 NO_2 Emission

Figure 4.14 shows the variation in the NO_2 emission for different fuel types injected through the normal and ultrasonic atomization process. Meanwhile, it can be evidenced that the NO_2 emission for the kerosene fuel in both the normal and ultrasonic fuel atomization conditions were lower than that of the biodiesel fuels, hence with decreasing content of kerosene in the biodiesel blends, NO_2 emission increased.

Generally, it can be observed that the across all the tested fuel types, the ultrasonic atomization process exhibited the highest NO_2 emission than the normal process. With reduction in the droplet size of the fuel with the ultrasonic atomization process the time taken for combustion became shorter and comparatively high temperature generation occurred relative to the normal process. Hence, NO_2 emission was higher for the ultrasonic atomization process across the entire engine load for the different fuels than the NO_2 emission produced by using the normal process. A similar observation where oxides of nitrogen formation relied on high temperatures and reaction time was reported by [3].

IV. COMBUSTION ANALYSIS

The gas pressure in the engine cylinder is dependent on the rate of combustion during the combustion phase. The phase is often regulated by the period of ignition delay and spray pattern of fuel which are mostly regulated by volatility and viscosity properties. The engine combustion analysis for the different types of fuel and fuel injection methods used was investigated based on the cylinder gas pressure (combustion pressure) and heat release (combustion temperature).

Figures 4.15 and 4.16 show the plots of combustion pressure and combustion temperature against the engine load for the different fuel types and injection methods. It can be observed that for all the fuels used, both the combustion pressure and combustion temperature increased with rising engine load for both the ultrasonic atomization process and the normal process. More so, combustion pressure and combustion temperature values for the kerosene and B20 fuels were higher for the ultrasonic atomization process than the normal process across the entire engine loads tested.

However, no significant difference can be observed for both the combustion pressure and combustion temperature with decreasing kerosene content in the other biodiesel fuels even though the engine loads were higher for the ultrasonic atomization process than the normal process. The early injection timing and the concurrent reduction in the ignition delay period resulted in a longer premixed burning phase and produced higher cylinder temperature.

The finding above can be attributed to the report of [9] where rapid gasification and lighter weight compounds in the fringe of the spray spreads out the jet, ignited earlier and reduced the ignition delay. Hence, it can be concluded in general terms that the ultrasonic atomization process was effective in achieving better combustion results as compared with the normal process.

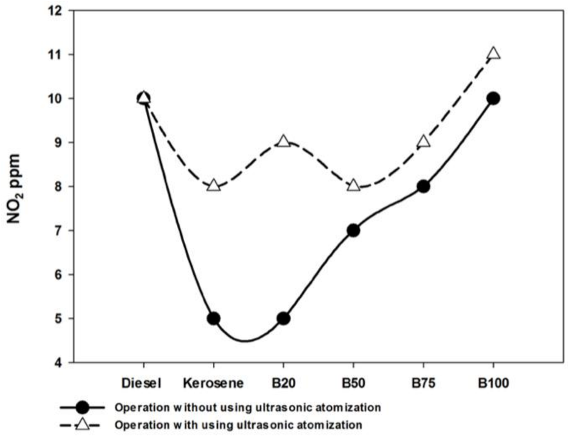

Figure 4.10: Plots of NO_2 emission against the engine load for all the different fuel type at low load thrust force.

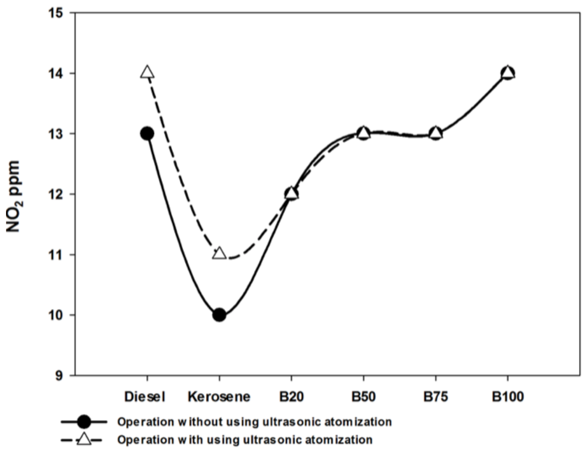

Figure 4.11: Plots of NO_2 emission against the engine load for all the different fuel type at medium load thrust force.

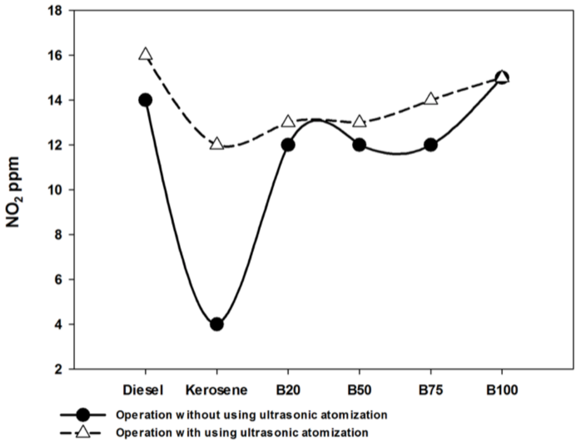

Figure 4.12: Plots of NO_2 emission against the engine load for all the different fuel type at maximum load thrust force.

V. CONCLUSION

An experiment was investigated using a single-cylinder diesel engine four stroke. The biodiesel was formed from sheep fats. All tests were conducted on fossil diesel and biodiesel blends. The effect of combustion and emission of the diesel engine was observed and the results of this study concluded as following:

- In the case of the engine emission measurements, CO and NO_2 emissions for all the fuel types were higher for the ultrasonic fuel atomization process than the normal process due to shorter combustion created by the ultrasonic system.
- For the CO_2 emission, the ultrasonic fuel atomization process exhibited lesser value beyond the 2.3 kg_f engine load mark relative to the normal process. More so, for the NO emission, the ultrasonic fuel atomization process exhibited lesser value up to the 1.7 kg_f engine load mark relative to the normal process.
- Combustion analysis results showed that the ultrasonic atomization process was effective in achieving better combustion pressure and temperature as compared with the normal process. Meanwhile, at approximately similar value, the engine load generated by the micro jet engine was much higher for the ultrasonic fuel atomization process than the normal process.

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