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Effect of Equivalence Ratio on ITM 285 Tractor engine performance at nominal rpm

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ABSTRACT: In this research work, one of the most widely used agricultural diesel engines (scientific name of 4.248G) placed on ITM 285 tractor is analyzed experimentally. This paper focuses on the effect of equivalence ratio on this engine performance parameters at nominal rpm **(**Speed of 2000 rpm). Equivalence Ratio was varied from ϕ=0.197 to ϕ=1.23 at speed of 2000 rpm. From the acquired results show that the equivalence ratio was greatly influences on the engine performance. It was shown that by increasing the equivalence ratio, the output power and mean effective pressure in the cylinder at first increases and then decreases. The lowest brake specific fuel consumption occurs at equivalent ratio $\phi \cong 0.7$. Maximum Brake thermal efficiency was obtained equal to 31.45% and a significant relationship was not found between equivalence ratio and volumetric efficiency. The results obtained in this study can be used to optimize 4.248G diesel engine performance at nominal rpm.

***Keywords*:** Air Fuel Ratio, Output Power, Brake Thermal Efficiency, Brake mean effective pressure, Brake Specific fuel consumption, Volumetric Efficiency

INTRODUCTION

ITM 285 Tractor is one of the most widely used agricultural machinery in Iran that four-cylinder diesel engine (4.248G) placed on it and likely to increase several fold in the next decade. Air fuel ratio (AFR) is the mass ratio of air to fuel present in an internal combustion engine. The fuel-air equivalence ratio of an engine is defined as the ratio of the stoichiometric Air fuel ratio to the actual Air fuel ratio. It is an important measure for reducing pollution and engine performance tuning. In a diesel engine, too much fuel (a high equivalence ratio) means smoke and higher engine temperatures. Not enough fuel (a low equivalence ratio) means clean running and lower engine temperatures. Managing the supply of fuel-air equivalence ratio combustion chamber is an important process to reliable performance of modern diesel engines. This management encompasses all aspects that affect the quantity, composition, temperature, pressure, engine performance and cleanliness of the combustion air at the start of the heat release period. Performance of diesel engines in nominal rpm due to special operation is of particular importance. Also, variations in equivalence ratio is the parameter that Most of the engine performance parameters associated with its. To this end the effect of equivalence ratio on 4.248G diesel engine performance at nominal rpm was investigated. In a study, effect of equivalence ratio on the performances and emissions of diesel engine was investigated. The engine is the 2L-II Toyota diesel engine, which is tested at 2400, 3000, 3500, 4000 and 4200 rpm, respectively. The results show that by increasing the equivalence ratio, engine power increases. The lowest brake specific fuel consumption and the highest fuel conversion efficiency occur at equivalence ratio close to unity (Sangsawang et al., 2012). In one study, effects of equivalence ratio and engine speed on the performance of a spark ignition engine were investigated. The obtained results indicated that in very rich mixtures, brake mean effective pressure decreases, brake specific fuel consumption increases and brake thermal efficiency decreases.

The correlation between volumetric efficiency and equivalence ratio is shown to be very weak (Al-Baghdadi, 2004). In another study, effect of equivalence ratio on the performance of a spark ignition running at various speeds fuelled with gasoline and natural gas was investigated. The obtained results indicated that by increasing the equivalence ratio and engine speed of using two fuels, output power, thermal efficiency and mean effective pressure at first increases and then decreases (Yousufuddin et al., 2012). In a research, impact of equivalence ratio on the performance of a diesel engine (DI) fueled with biodiesel blended diesel fuel was investigated. Their results showed that by increasing equivalence ratio, Brake mean effective pressure and brake thermal efficiency at first increases and then decreases (Sayin & Gumus, 2012). In another study, Performance of diesel engine using gas mixture with variable specific heats model from ϕ=0.5 to ϕ=0.9 was evaluated. The acquired results show that by increasing the engine speed and equivalence ratio, brake thermal efficiency and brake mean effective pressure increases. Also, volumetric efficiency too low changes (Sakhrieh et al, 2010). In another study, effect of equivalence ratio on the performance of a SI engine using ethanol unleaded gasoline blends, was evaluated. Their results showed that by increasing the equivalence ratio, power, brake mean effective pressure and brake thermal efficiency at first increases and then decreases (Yousufuddin & Mehdi, 2008).

In the present work, performance parameters of a 4.248G diesel engine at speed of 2000 rpm (nominal rpm) and various equivalence ratios experimentally have been investigated. The objective if this study is to investigate the effect of equivalence ratio at nominal rpm on the performance of this engine.

MATERIALS AND METHODS

The experiments in this study were done in Motorsazan Research Corporation from subset dependent of Tabriz Tractor Producing Company. First a 4.248G diesel engine was transferred from production line of the factory to the engine research laboratory. We used hexadecane fuel for combustion with the air. The engine was placed in the test cell and the engine was connected to a magnetic dynamometer that held the engine speed at 2000 rpm. Various sensors were attached to the engine. Key sensors for acquiring data were: Pressure transducer in the cylinder, air flow rate sensor, exhaust temperature sensor and crank angle encoder. In order to account for cycle-to-cycle variation, from a pressure signal processing system (the Indiskop) was used. Normal injection pressure of the fuel was set to 175 bars. The engine first was turned on for half an hour at a speed of 1500 rpm under 50% load to reach the normal operational temperature. Then effect of equivalence ratio on performance was measured by varying part loads at 2000 rpm.

In computational of diesel cycle analysis, combustion of hexadecane fuel with 100% theoretical air in 4.248G diesel engine cylinder was considered. Combustion reaction of hexadecane with the air is as follows which proposed (Pulkrabek, 2005):

$$C_{16}H_{34} + 24.5\left(O_2 + 3.76N_2\right) \rightarrow 16CO_2 + 17H_2O + 24.5(3.76N_2) \quad (1)$$

The air fuel ratio is the most common reference term used for mixtures in internal combustion engines (Pulkrabek, 2005; Rahman et al., 2009):

$$AFR = \frac{m_a}{m_f} = \frac{\dot{m}_a}{\dot{m}_f} \quad (2)$$

Air-Fuel equivalence ratio, ϕ, is the ratio of stoichiometry AFR to actual for a given mixture (Pulkrabek, 2005; Rahman et al., 2009):

$$\phi = \frac{(AFR)_{stoichiometry}}{(AFR)_{actual}} \quad (3)$$

(ϕ = 1.0 is at stoichiometry, rich mixtures ϕ > 1.0, and lean mixtures ϕ < 1.0).

Brake mean effective pressure (BMEP) for the four stroke engine can be written as in (4). (Pulkrabek, 2005; Rahman et al., 2009):

$$BMEP = \frac{2p_b}{NV_d} \quad (4)$$

where p_b is the brake power, N is the rotational speed and V_d is the cylinder displacement volume in per cycle. Brake thermal efficiency (η_b) can be defined as the ratio of the brake power p_b to the engine fuel energy as in (5) (Pulkrabek, 2005; Rahman et al., 2009):

$$\eta_b = \frac{p_b}{\dot{m}_f (LHV)} \tag{5}$$

where $\dot{m}_f$ is the fuel mass flow rate and LHV is the lower heating value of hexadecane equal to 43980 KJ/Kg. The brake specific fuel consumption (BSFC) represents the fuel flow rate $\dot{m}_f$ per unit brake power output and can be expressed as in (6) (Pulkrabek, 2005):

$$BSFC = \frac{\dot{m}_f}{p_b} \tag{6}$$

The volumetric efficiency (η_V) of the engine defines the mass of air supplied through the intake valve during the intake period ($\dot{m}_a$) by comparison with a reference mass, which is that mass required to perfectly fill the swept volume under the prevailing atmospheric conditions, and can be expressed as in Eq. (7) (Pulkrabek, 2005):

$$\eta_V = \frac{\dot{m}_a}{\rho_{ai} V_d} = \frac{n\dot{m}_a}{N \rho_{ai} V_d} \tag{7}$$

where ρ_{ai} , n and N are the inlet air density, number of revolutions per cycle and engine speed, respectively. In table 1, the geometric characteristics of the 4.248G diesel engine are shown.

Table 1. Geometric characteristics of the 4.248G diesel engine

Specifications	Units	Values
Number of cylinders	-	4
Capacity of the cylinders	Lit	4
Diameter of the cylinder	mm	101
Cylinder stroke length	mm	127
Compression ratio	-	16
The total capacity of the lubrication system	Lit	7.5
The cooling system capacity	Lit	16
Total weight of the engine	Kg	447

Analysis of experimental data was investigated in MATLAB software and the following results were obtained:

RESULTS AND DISCUSSION

Figure 1 shows the effect of equivalence ratio on the output power and brake mean effective pressure. The equivalence ratio was varied from very lean mixtures limit (ϕ= 0.197 where the air fuel ratio, AFR= 75.51) to a rich mixtures limit (ϕ = 1.23 based on AFR= 12.15). It can be seen that by increasing the equivalence ratio, power increases due to the greater of torque from the fuel consumption and then decreases. Maximum engine power occurred at the equivalence ratio of 1.02 equal to 43.66 KW. At very low equivalence ratios the combustion process is limited by the available fuel. At equivalence ratios that are too high the combustion process is limited by the availability of oxygen. At intermediate equivalence ratios the combustion process is limited, to a degree, by the ease of forming free radicals. Running slightly rich means that there is more fuel available to accomplish this. These factors combine to cause the observed maximum in the BMEP as a function of equivalence ratio (Heywood, 1988)**.** For the 4.248G engine Maximum BMEP is observed close to stoichiometric equal to 654.4 KPa. This may have to do with the intermediate turbulence and mixing characteristics of the combustion chamber as well as mixture preparation and charge cooling.

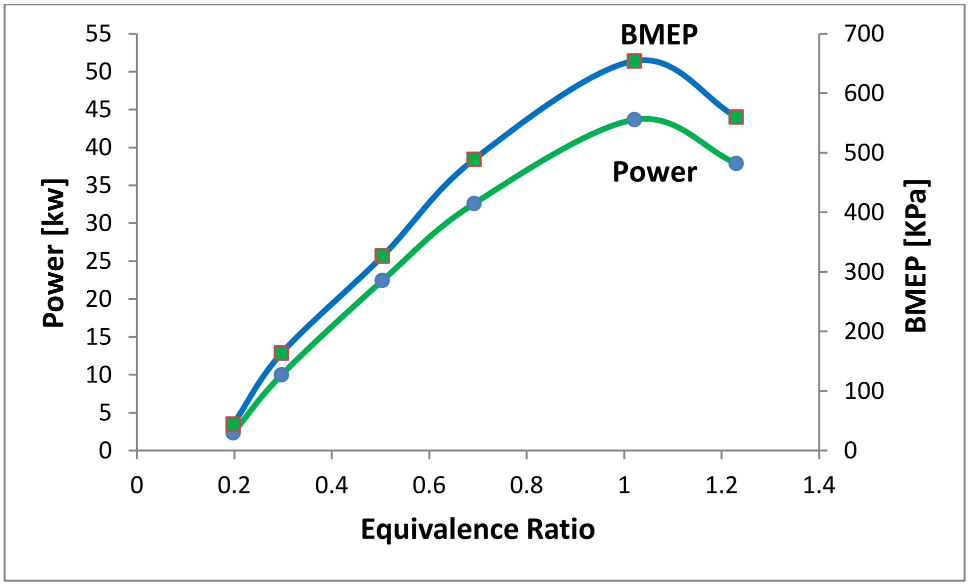

Figure 1. The relationship between BMEP and output Power versus Equivalence ratio

Figure 2 shows that thermal efficiency (η_b) tends to decrease and brake specific fuel consumption (BSFC) tends to increase with equivalence ratio over the range studied. As the mixture is made richer a greater amount of the fuel does not burn. The energy contained in the bonds of this fuel is counted in the energy-in term but does not contribute to the work-out since it does not burn, thus the thermal efficiency decreases. At equivalence ratios that are too lean, the power output drops significantly causing the thermal efficiency to decrease. This behavior can be more clarified by referring to Figure 1, where the brake power reduced considerably at very lean operation conditions. These two factors cause there to be a maximum value of thermal efficiency at an intermediate equivalence ratio. Maximum engine thermal efficiency is observed at the equivalence ratio of 0.692 equal to 31.45%**.** BSFC is the mass flow rate of fuel divided by the power output. Very lean mixtures have a low mass flow rate of fuel but also have low power output. This is because of very lean operation conditions can lead to unstable combustion and more lost power due to a reduction in the volumetric heating value of the Air/ Hexadecane mixture. Very rich mixtures have a greater mass flow rate of fuel but the additional fuel does not contribute to power output. These two factors cause there to be a minimum in BSFC at an intermediate equivalence ratio (ϕ=0.7 to ϕ=0.85). At very lean conditions, higher fuel consumption can be noticed.

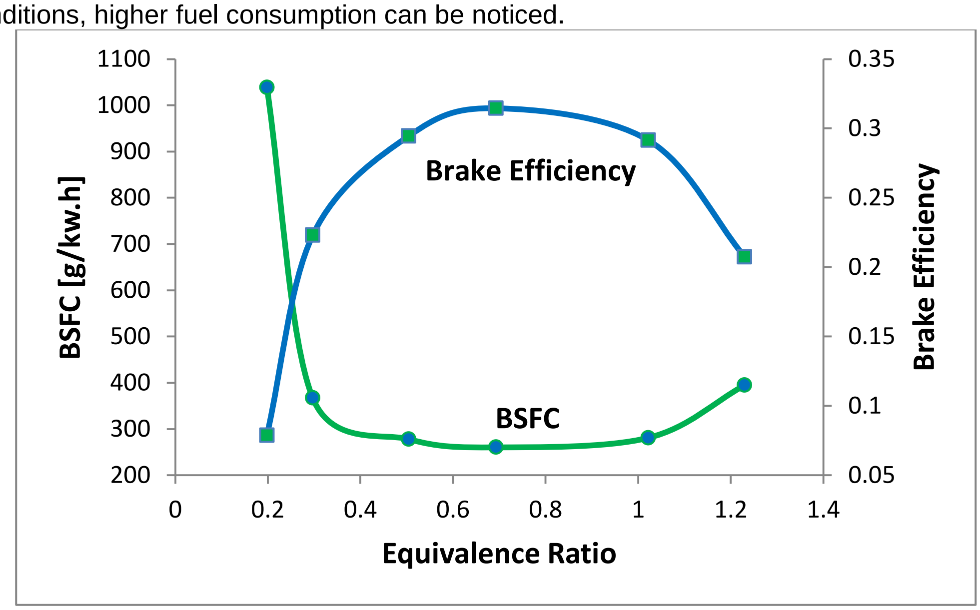

Figure 2. The relationship between Thermal Efficiency and BSFC versus Equivalence ratio

Figure 3 shows the effect of equivalence ratio on the volumetric efficiency. The correlation between volumetric efficiency (η_V) and equivalence ratio is shown to be very weak. There is a weak trend that the volumetric efficiency tends to decrease slightly as you move to values of the equivalence ratio that are either rich or very lean. At very lean conditions there is very little fuel in the mixture. This means that the cylinder takes in a greater amount of air for a given amount of mixture. At high equivalence ratios the effects of charge cooling are significant. This decrease in temperature increases the density of the mixture, thus, the volumetric efficiency drops too low.

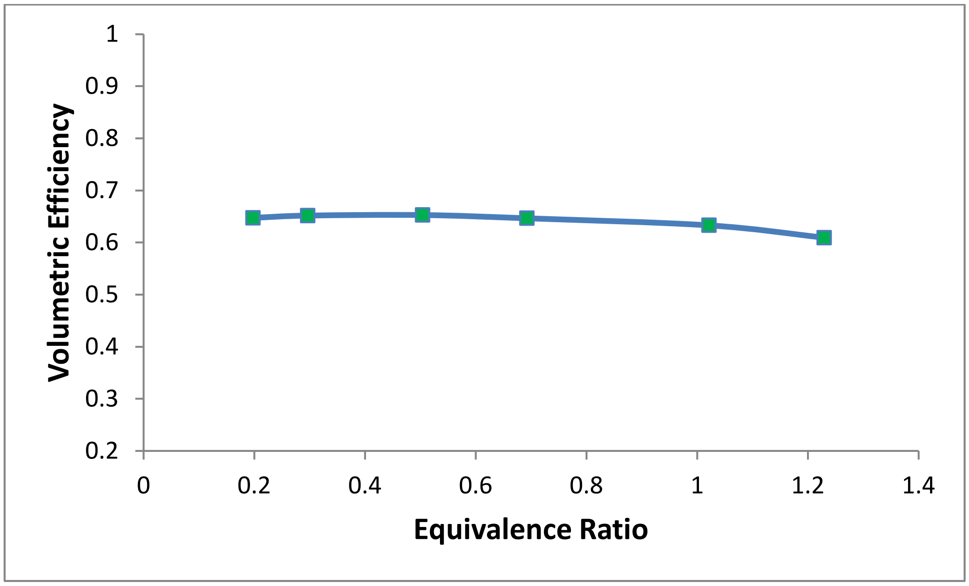

Figure 3. The relationship between Volumetric Efficiency and Equivalence ratio.

CONCLUSION

In this study, the effect of equivalent ratio on the engine performance of ITM 285 tractor at nominal rpm using diesel fuel (Hexadecane) was experimentally investigated. Based on the results of this study, the conclusions can be drawn as follows:

1) Maximum values of brake power and mean effective pressure at equivalence ratio close to the stoichiometric are obtained.
2) In rich mixtures and particularly very lean mixtures, values of the BSFC and thermal efficiency are not acceptable.
3) Acceptable values of specific fuel consumption and thermal efficiency in the range of equivalence ratios (ϕ=0.504 to ϕ=1.02) are observed that makes reducing pollution and engine performance tuning**.**
4) Equivalence ratio has very little impact on the volumetric efficiency.

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