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PERFORMANCE TEST OF DIESEL ENGINES USING ETHANOL-DIESEL FUELS BLENDS

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مستخلص— **أجريت التجارب المعملية باستخدام محرك ديزل (لستر) رباعي الأشواط باسطوانة واحدة ، نظام الوقود فيه مضخة حقن الوقود. أجريت اختبارات الأداء للحصول على استهلاك الوقود ، القدرة الفرملية ، الكفاءة الحرارية الفرملية ، الكفاءة الحرارية البيانية ، الكفاءة الميكانيكية ، متوسط الضغط الفعال الفرملي ، متوسط الضغط الفعال البياني واستهلاك الوقود النوعي الفرملي باستخدام خليط الايثانول والديزل بنسب مختلفة من الخليط ومقارنة النتائج المتحصل عليها مع الديزل عند أوضاع مختلفة (حمولات مختلفة).**

***Abstract*— Experimental tests of diesel engine using Ethanol–Diesel Fuels blends have been done on a four stroke, one cylinder, water cooled C.I. Engine (Lister Engine) with a pump injection fuel system. Performance tests were conducted for fuel consumption rate, brake power, engine torque, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, brake mean effective pressure, indicated mean effective pressure, and brake specific fuel consumption, using different load and pure unleaded diesel at different load.**

Keywords— **diesel engine; diesel oil; ethanol oil; performance.**

I. INTRODUCTION

In the last two decades of the 20th century, major advances in engine technology have occurred, leading to greater fuel economy in vehicles. The reduction of emissions from engines has become a major factor in the development of new engines. Therefore, manufacturers are focusing on considerable energy and resources in order to meet emissions standards specified by the US Environmental Protection Agency (EPA) and by the EU. As a result, the use of non- conventional fuels as suitable to meet these requirements has generated much attention [1].

The world in the 21st century presents many critical challenges. One of the most important challenges is the environment. As population increases and the standard of living improves, there is growing concern that there will be shortage of energy to heat our homes and power the vehicle on which we so heavily depend on. We must also remember the need for clean air, clean water, clean burning fuels, and biodegradable fuels. Therefore, considerable researches have been oriented towards renewable materials. Advances in technology have allowed development of alternative energy sources. Alternative energy sources are renewable, cleaner and more dependable than traditional fuels [2].

II. LITERATURE REVIEW

A. Ethanol

In ancient times ethanol was known as an intoxicating drink. In United States (US), ethanol is produced mainly by the fermentation of corn. It is the same alcohol used as beverages but meets fuel – grade standards. Ethanol that is to be used as a fuel is "denatured" by adding a small amount of diesel to it, this makes it unfit for drinking.

Ethanol is an alternative energy source. It is alcohol made by fermenting corn or any another similar biomass material. Ethanol in its liquid form, called, ethyl alcohol, can be used as a fuel when it blends with diesel, or gasoline or in its original state. It can also be used as a raw material in various industrial processes. Ethanol is made by fermenting almost – any material that contains starch or sugar. Grain such as corn and sorghum are good sources; but potatoes, sugar cane, Jerusalem artichokes, and other farm plant and plants wastes are also suitable. About 2 billion gallons of ethanol are produced annually in the United States (U.S) [2].

Brazil and Sweden are using large quantities of ethanol as a fuel. Some Canadian provinces promote ethanol use as a fuel. In France, ethanol is produced from grapes that are of insufficient quality for wine production [3].

Ethanol is the most important member of a large group of organic compounds that are called alcohols. Alcohol is an organic compound that has one or more hydroxyl (OH) groups attached to a carbon atom. Alcohol is symbolized as: C – O – H or C – OH.

In its pure form, ethanol is a colorless clear liquid with a mild characteristic odor which boils at 78^{o}C (172^{o}F) and frees at -112^{o}C (-170^{o}F). Ethanol has no basic or acidic properties. When burned, ethanol produces a pale blue flame with no residue and considerable energy, making it an ideal fuel [3].

Ethanol is a product of fermentation. Fermentation is a sequence of reactions which release energy from organic molecules in the absence of oxygen. In this application of fermentation, energy is obtained when sugar is changed to ethanol and carbon dioxide.

B. Diesel Engines

An engine is a device which transforms one form of energy into another form. When the products of combustion generated by the combustion of fuel and air within the cylinder from the working fluid, it is called an internal combustion engine (I. C. E) [5]. The cross section of a four – stroke compression ignition is shown in fig. 1 the major components of the engine are:

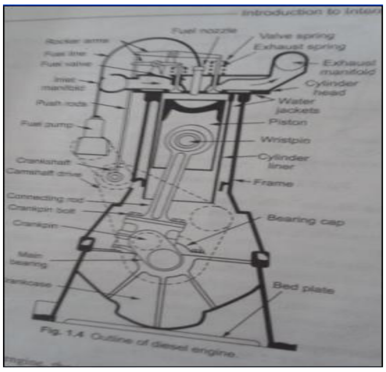

Fig. 1 Four – Stroke Compression Ignition Engine

* **Piston**:
It is a cylindrical component fitted into the cylinder forming the moving boundary of the combustion system.

***Cylinder:**
It is a cylindrical vessel in which the piston reciprocates.

*** Combustion chamber:**
It is the space between the cylinder and the piston top where combustion takes place.

***Connecting Rod:**
It is used to interconnect the piston and the crank to transmit force from the piston to the crank shaft.

***Crank Shaft:**
It is used to convert reciprocating motion of the piston into rotary motion of the output shaft.

In the C.I. engines, air is compressed through a larger compression ratio during the compression stroke raising highly its temperature and pressure. At this stage one or more jets of fuel are injected in the liquid state, compressed to a high pressure by means of a fuel pump. Any time as the fuel droplet enters the hot air it is quickly surrounded by an envelope if its own vapor and after an appreciable interval, it is inflamed at the surface of the envelope. As soon as this vapor and air is in contact with each other the mixture reaches a certain temperature ignition takes place [6].

Diesel fuels are used for C.I Engines. These are a petroleum fraction that lies between kerosene and lubricating oils.

The main desirable characteristics of diesel fuels are:

* Cleanliness – carbon residue, contamination, sulphur, etc.….
* Ignition quality – cetane number.
* Fluidity- viscosity, pour point, etc…

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* Volatility – flash point, carbon residue [7].
The rating of a diesel fuel is measured in terms of cetane number which is a straight chain paraffin with good ignition quality and is arbitrarily assigned a rating of 100 – cetane number. It is mixed with methyl naphthalene, hydrocarbon with poor ignition quality which is assigned zero – cetane number. This defined as the percentage of volume of cetane in a mixture of cetane and a methyl naphthalene that produce the same ignition lay as the fuel being tested in the same engine and under the same operating conditions [7].

III. EXPERIMENTAL WORK

The equipment is available in the Heat engine laboratory in the Department of Mechanical Engineering, Faculty of Engineering and Technology, Nile Valley University.

- **The Device consist of:**
- Gauge of fuel. Fig. 2.
- Engine. Fig. 3.
- Stop watch timing. Fig. 4.
- Dynamometer. Fig. 5.
- Stop watch of measuring speed. Fig. 6.
- Tachometer. Fig. 7.

Fig. 2 Gauge of fuel

Fig. 3 Engine

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Fig. 4 Stop watch timing

Fig. 5 Dynamometer

Fig. 6 Stop watch for measuring speed

Fig. 7 Tachometer

The engine specifications is:
* Type: engine (Lister 1 – 8) number 127 – 4708
* Diameter of cylinder: 114.3 mm
* Length of piston stroke: 139.7 mm
* Displace volume: 1.4433 lit.
* Max. Speed: 856 rev / min

The dynamometers:
* The capacity of dynamometers: 31.8 amps
* The max speed: 2500 rev/min
* The length arm torque: 220 mm
* Energy equation: F (Newton) * N (rev/min) / 43.41
* Power source: 220 volt DC
* Speed ratio: engine / dynameters = 1: 2.5
* Capacities of fuel gauge: 25 – 50 – 100 ml
* Device of speed gauge: smith Venture 10: 3000 rev/min

The device of fuel consumption: It is a graded glass tube device to measure the quantity of fuel. The device is connected with a pipe to fuel tube through a valve, in addition to engine exhaust valve. When the engine is loaded the device starts working so as to let a suitable quantity of fuel to flow to engine from fuel tank.

The electrical dynamometer: It is electrical device function as a generator, working with (D.C) and also considered as starter of (I.C.E). The device consists of constant coil and rotor member when the electrical current flows the rotor member remains moving and when the electrical current is disconnected then the electrical current – flows only to constant coil and therefore causing magnetic field to produce electrical current for resistance.

Fuels: Two different fuel samples were experimentally investigated during study; unleaded diesel has been obtained from Nile gas station and ethanol (E) from Kenana sugar factory. In these experiments five types of fuels have been individually applied on the test engine. One of them is pure unleaded diesel or E0 and it has been utilized for comparison purposes. The four types are ethanol diesel blends, blended fuels states as follow**:**
* E0: 0 % Ethanol and 100 % Pure unleaded diesel.
* E5: 5 % Ethanol and 95 % Pure unleaded diesel.
* E10: 10 % Ethanol and 90 % Pure unleaded diesel.
* E15: 15 % Ethanol and 85 % Pure unleaded diesel.
* E20: 20 % Ethanol and 80 % Pure unleaded diesel.

Experiment procedures:
1. Check fuel and lubrication of engine.
2. Check all the apparatus of experiment and ensure the status of zero reading of engine.
3. Open the valve coolant.
4. Start the engine for ten minutes so as to complete the warm up.
5. Startup loading the engine gradually.
6. Taking the readings

Repeat the procedure above with eight reading for different loads.
A sample of readings is shown in tables 1 and 2 below.

Table –1 E0: (Pure unleaded diesel)

Load No.	Volume gauge (ml)	Time (t) sec	Speed (N) rev/min
1	25	327	764
2	25	295	755
3	25	256	753
4	25	226	748
5	25	196	746
6	25	169	745
7	25	148	739
8	25	127	735

Force (N)	Voltage (v)	Current (Amp)
7	146	0
15	144	2.75
25	144	6
35	148	9
47.5	150	12
62.5	152	16
75	154	18.5
92.5	156	22

Table –2 E 10: (10% Ethanol: 90% pure unleaded diesel)

Load No.	Volume gauge (ml)	Time (t) sec	Speed (N) rev/min
1	25	372	770
2	25	349	765
3	25	309	764
4	25	273	761
5	25	253	756
6	25	220	752
7	25	197	749
8	25	184	745

Force (N)	Voltage (v)	Current (Amp)
5	110	0
9.5	108	2
14	110	4.2
21	110	7
28	111	9.5
37.5	118	12
48.5	120	15
60	122	17.5

Calculation of experimental results:

- Brake horse power (BHP)

Electrical Method: BHP = 1*V (watt)
Mechanical method: BHP = F *N (watt) / K
When: I = current (Amp)
V = voltage (v)
F = force (N)
N = speed of dynamometer (rev/min)
K = 43.41

- Indicated horse power (IHP)

IHP = BHP+ FHP
FHP = Mechanical losses
Also: IHP = PLAN (kW) / 2 * 60
P = I.m.e.p. (kN/m^2)
L: length of piston stroke (m)
A: piston area (m^2)
N: speed of engine (rev/min)

- Fuel consumption (V)

V = 3600* V_g / t
V = fuel consumption (lit / hr)
Vg = volume gauge (ml)
t = time of consumption volume gauge (sec)

- Brake Specific fuel consumption (bsfc)

bsfc = V / BHP (liter / k w h)
bsfc = brake specific fuel consumption (liter / k w h)
V = fuel consumption (liter / k w h)
BHP = brake hours power (kW)

- Mechanical Efficiency (η_m) = BHP/ IHP
- Thermal efficiency (η_{th})

Brake thermal efficiency (η_{bth})

η_{bth} = BHP/ fuel power = 0.1011/ Vs (For diesel)

Vs = specific fuel consumption = V/ BHP

Indicated thermal efficiency (η_{ith})

η_{ith} = IHP/ fuel power= η_m / η_{bth}

Sample of calculation: Assume the test engine runs with E.10 fuel blend the estimated parameters will be as follow:

Brake Horse Power: BHP =

$$\frac{F*N}{k} = \frac{28\times 756}{43.41} = 0.488\,kw$$

Torque power:

$$T = \frac{N*L}{1000} = \frac{20\times 220}{1000} = 6.16\,Nm$$

Brake specific fuel consumption:

$$bsfc = \frac{v}{BHP} = \frac{0.356}{0.488} = 0.73\,liter\,/\,hr$$

Brake thermal efficiency:

$$\eta_{bth} = \frac{0.1011}{bsfc} = \frac{0.1011}{0.73} = 13.85\%$$

Brake mean effective pressure:

$$bmep = \frac{60*2*BHP}{N*vs} = \frac{60*2*0.488}{756*1.433} = 54.05\,kN/m^2$$

IV. DISCUSSIONS

The data acquired from each experimental set up is shown in tables 1 and 2, it was then converted to excel data sheet to calculate the engine performance parameters such as brake torque, fuel consumption rate, brake specific fuel consumption, brake power, indicated power, brake mean effective pressure. Indicated mean effective pressure, brake thermal efficiency, indicated thermal efficiency and mechanical efficiency.

Experimental Results: Table 3 show the calculated (T, V, bsfc, BP, IP, bmep, Imep, η_{bth} , η_{ith} and η_m) an example when using Ethanol - diesel fuel blend E10.

Table –3 E 10: (10% Ethanol: 90% Pure unleaded diesel)

Load No.	T (Nm)	V (Lit/h)	bsfc (Lit/Kwh)	Bp (Kw)	IP (Kw)
0	1.1	0.242	2.72	0.089	0.889
1	2.09	0.258	1.545	0.167	0.967
2	3.08	0.291	1.183	0.246	1.046
3	4.62	0.330	0.897	0.368	1.168
4	6.16	0.356	0.75	0.488	1.288
5	8.25	0.41	0.631	0.65	1.45
6	10.67	0.457	0.547	0.837	1.637
7	13.2	0.49	0.476	1.03	1.83

bmep (KN/m^2)	Imep (KN/m^2)	η_{bth} (%)	η_{ith} (%)	η_m (%)
9.68	96.7	3.7	37	10.01
18.28	105.85	6.54	37.9	17.27
26.96	114.63	8.55	36.35	23.52
40.5	128.53	11.28	35.8	31.51
54.05	147.92	13.85	36.54	37.9
72.38	161.45	16.02	37.54	44.83
93.6	183.1	18.48	36.14	51.13
115.78	205.65	21.24	37.73	56.3

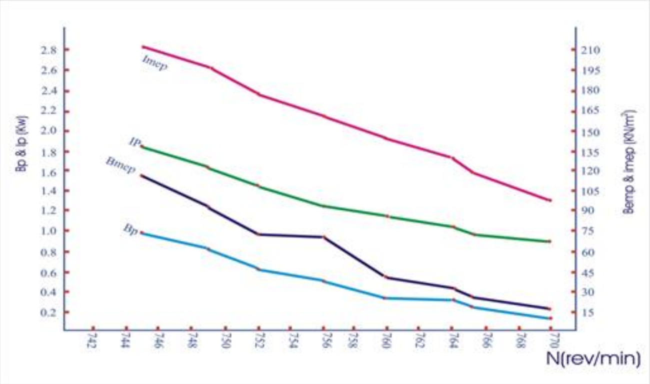

Fig. 8 bp, Ip, Bemp, Iemp & N of (E10) blend

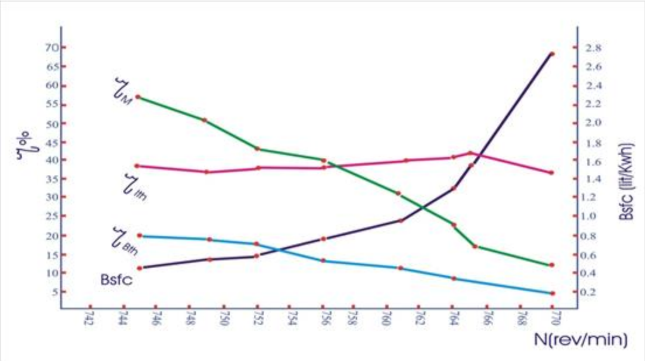

Fig. 9 η% & bsfc of (E10) blend

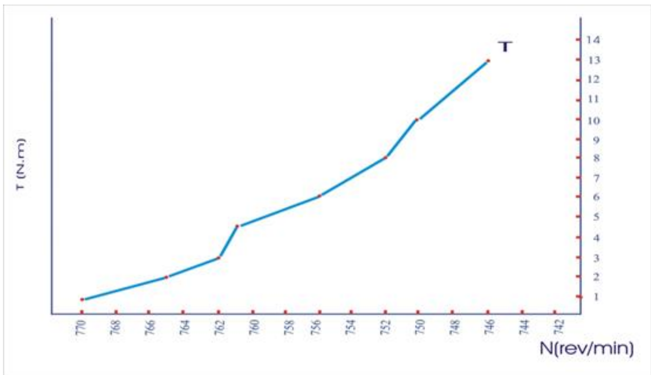

Fig. 10 Torque and speed of (E10) blend

Brake Torque:
Fig 10 shows a slight increase in torque in low speeds and a high increase of torque in high speeds.
Brake power and Indicated power:
Fig. 8 shows a slight decrease in brake power and brake indicated power with speed. This is because the brake power is significantly dependent on engine speed. It also shows that the brake power and indicated power in pure unleaded diesel is greater than brake power and Indicated brake power in Ethanol – diesel blended fuels. This may be attributed to the increase in power torque and pressure.
Brake mean effective pressure and indicated mean effective pressure:
Fig. 8 shows slight decrease in brake mean effective pressure and indicated mean effective pressure as the engine speed increases and shows that the bmep and Imep in pure unleaded diesel is greater when compare with the bmep and Imep at different ethanol – diesel blended fuel.
Mechanical efficiency:

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Fig. 9 shows slight a decrease in mechanical efficiency due to the increase in engine speed.

Brake thermal efficiency and indicated thermal efficiency:

Fig. 9 shows slight decrease in brake thermal efficiency as the engine speed increases.

Brake specific fuel consumption:

Fig. 9 shows an increase in brake specific fuel consumption due to the increase of engine speed and the increases of brake mean effective pressure and show that the increase of brake specific fuel consumption when test engine has experienced different ethanol – diesel blended fuels compared to pure unleaded diesel. This may be due to lower heating value of fuel blend per unit mass of the ethanol fuel, which is actually lower than that of the unleaded diesel fuel.

V. CONCLUSIONS

The engine performance in terms of brake torque, brake power, brake mean effective pressure, indicated mean effective pressure, brake thermal efficiency indicated thermal efficiency, Mechanical efficiency, brake specific fuel consumption of C.I. engine have been investigated by using four types of ethanol – unleaded diesel blended fuels. The test engine used is Lister and the engine has been run with pure unleaded diesel (E0) for comparison purposes.

From the experimental and the results which was obtained during testing four different blends. It can be concluded that, the optimum alternative fuel for CI engine that has been investigated by this experimental study is the pure unleaded diesel fuel.

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