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PERFORMANCE TEST OF DIESEL ENGINES USING JATROPHA-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 الجتروفا والديزل بنسب مختلفة من الخليط ومقارنة النتائج المتحصل عليها مع الديزل عند أوضاع مختلفة (حمولات مختلفة).**

Abstract: - Experimental tests of diesel engine using Jatropha–Diesel fuels blends have been executed. A four stroke, one cylinder, water cooled C.I. engine (Lister Engine) with a pump injection fuel system has been used for conducting this Study. 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; jatropha oil; performance.**

I. INTRODUCTION

A major problem for Sudan rural areas is the inadequate supply of power for lighting, heating, cooking, cooling, water pumping, radio or TV communications and security services. Petroleum product supplies, including diesel, kerosene and LPG are irregular and often subject to sudden price increases. Sudan is a large agricultural country with various climates differs from arid in the north to dry savanna climate in the south.

Sudan has the longest river with its extended tributaries (i.e. River Nile) among the third world countries. Diversity of climate resulted in producing different oil seeds (peanut, sesame, sunflower, cotton seed and watermelon seed). Some other oil seeds such as Jatropha, castor, bitter melon, roselle, laloub, and some melon seeds could also be produced. These latest seeds are used in producing biodiesel. Sudan lands are suitable for Jatropha plantation as the plant grows naturally as a native plant in many regions here. Middle and south of the country have the best conditions for Jatropha to grow. Jatropha is found in Sudan in many areas such as Khartoum State in Central Sudan, Kassala State in the East and Kordofan State in the West.

II. DIESEL ENGINES

The basic task in the design and development of engines is to reduce the cost and to improve the efficiency and power output. In order to achieve the above tasks. The engine should be compared with other engines in terms of its power output and efficiency. Towards this end should be tested for determining the measurements of relevant parameters that will reflect the performance of the engine.

I.C engine generally operates with in a high range of speeds. Some engines are made to run at fixed speed by means of speed governor, which is its rated speed. The performance of the engine depends on the inter -

relationship between the power developed, speed and specific fuel consumption at each operating condition within the useful range of speed and load.

The Purposes of testing of I.C engines

- To determine the rated power output with respect to the fuel consumption in kg/kw.hr of brake power output.
- To determine the mechanical and thermal efficiencies of the engine.
- To observe the performance of the engine when loaded at different loads.
- To determine the quantity of lubricating oil required per bp. kw.hr.
- To determine the over load carrying capacity of the engine.

Engine power: The energy flow through the engine expressed in three distanced terms they are:

- Indicated power i_p
- Friction power f_p
- brake power b_p

The indicated power can be computed from the measurements of force in the cylinder, brake power from the measurement of forces in the crank shaft of the engine, and the friction power can be estimated by motoring the engine or from the difference between indicated power and brake power.

Indicated mean effective pressure (P_{im}): It may be defined as, the constant pressure acting over the full length of stroke and capable of producing the same amount of work, and is actually produced during the complete cycle of the engine. it is generally denoted by (P_{im}) or (i.m.e.p).

Brake mean effective pressure (bmep): It may be defined as the mean effective pressure acting on the face of piston, which would develop brake power equivalent to that during actual varying pressure condition. It is generally denoted by P_{bm} or b.m.e.p.

Friction mean effective pressure P_{fm} (fmep): It is mean the portion of mean effective pressure (P_{im}) which is required to overcome friction losses and brake mean effective pressure is the portion which produces the useful power delivered by the engine.

Calorific value (cv): Calorific value of fuel is the thermal energy released per unit quantity of the fuel when the fuel is burned completely and the products of combustion are cooled back to the initial temperature of the combustion mixture. Other terms used for calorific value are heating value and heat combustion when the products of combustion are cooled to 25^{o}C practically all the water vapor resulting from the combustion process is condensed.

Mechanical efficiency: It may be defined as the ratio of the power obtained at the crank shaft. Mechanical efficiency takes into account the mechanical losses in an engine. Mechanical losses of an engine may be further subdivided into the following groups:

Friction losses as in case of pistons, bearings, gears, valve mechanisms. With development in the bearing design and materials, improvements in gears…. etc. these losses are usually limited from 7 to 9 percent of the indicated power output.

Indicated thermal efficiency: It may be defined as the ratio of heat converted into indicated work to the heat energy supplied by the fuel during a specific period of time.

brake thermal efficiency: It may be defined as the ratio of heat equivalent to brake power (bp) to the heat energy supplied by the fuel during a specific period of time.

Volumetric efficiency: The volumetric efficiency is a measure of the success with which the air supply and thus the charge, is induced into the engine cylinder. It is very important parameter since it indicates the breathing capacity of the engine.

Determination of indicated and brake power: To find out the indicated power, an indicator is used to find the out the mean effective pressure, this method is used for low speed engines. given mean effective pressure and given engine operating conditions. The necessary formula may be developed from the equation of network based on the mean effective pressure and piston displacement.

Indicated network per minute = $P_{im} \times L \times A \times N$

P_{im} : indicated mean effective pressure
L : length of the stroke
A : area of the piston
N : speed of engine in revolution per minute

Brake power: The brake power is usually measured by attaching a power absorption device to the drive shaft of the engine. Such a device sets up measurable forces counteracting the forces delivered by the engine and the determined value of these measured forces is an indication of the forces being delivered.

Friction power: The friction power is nearly constant at a given engine speed. Friction has a dominating effect on the performance of the engine. Frictional losses are dissipated to the cooling system as they appear in the form of heat.

Preparation of tests: The engine should be completely stripped and examined physically so that design features and also the conditions of the various parts may be noted before test. After physical examination the dimensions of the main working parts should be checked and recorded:

- Cylinder head
- Valves, valves seats, valve spring and valve guides.
- Cylinder liner
- Connecting rod small end, big end bearing and connecting rod bolts
- Piston assembly

Crank shaft including bearings and journals.

III. JATROPHA

Jatropha curcas is a shrub or small tree grows to a height of 3-5 meters and sometimes, when suitable climatic conditions prevail, grows up to 8-10 meters. The tree is a affiliated to the herbaceous plants, and its leaves resemble grape fruits and its fruit is in the form of a nut, in the size golf ball, containing seeds that produce bitter taste oil. Jatropha curcas is a good crop and can be obtained with little effort. Depending on soil quality and rainfall, the kernels consist of oil to about 60 percent.

The oil can be combusted as fuel without being refined. It burns with clear smoke-free flame, tested successfully as fuel for simple diesel engine. Medically it is used for diseases like cancer, piles, snakebite, paralysis, dropsy etc. and uses in addition to soap making and some types of glycerin and fertilizers. Jatropha grows wild in many areas of India and even thrives on infertile soil. A good crop can be obtained with little effort. Depending on soil quality and rainfall, oil can be extracted from the jatropha nuts after two to five years.

Jatropha in Sudan: Jatropha research started in Sudan as early as 1972 with studies concerning the molluscicidal effect of the plant. Jatropha Project exists in Kutum, North Darfur, with participation of the German Development Service. The experimental and pilot project, known as Kutum was launched in North Darfur with participation of a German research center. The pilot project has proved that although Jatropha is an equatorial plant, it still can grow in all types of soils found in the Sudan.

Presently, Ministry of sciences is executing project for biofuel production in Sudan, which Northern State has embarked on its implementation through HOI-Mea holding company, a branch of Saudi based Bagshan Group, to cultivate Jatropha plant in area of 250 feddans in the region of Nubi Lake, 75km west of the Nile, 180km north-east of Northern State capital Dongola.The project is aimed at cultivating 259 feddans of Jatropha. Recently 145,000 plants have been cultivated in an area of 63 feddans because water network is ready for trickle irrigation and that efforts are ongoing to import new types of seeds adaptable to desert climate. Jatropha cultivation project has started in 2010, disclosing that water is available in accordance with mineral water European standards without treatment. The water has the characteristics of being extracted under normal temperatures not less than 10°C. The Jatropha tree have an age ranges between 40-50 years with annual production not less than 8 kilograms. The directors of the projects are planning to generalize Jatropha to the Sudanese farmers to be grown side by side with groundnuts, sesame and gum Arabic.

Seeds: The seeds become mature when the capsule changes from green to yellow, after two to four months. Fig. 1 below shows a typical jatropha seeds.

Fig. 1 Jatropha seeds

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Jatropha as a biofuel: When jatropha seeds are crushed, the resulting jatropha oil can be processed to produce a high-quality biofuel or biodiesel that can be used in a standard diesel car or further processed into jet fuel, while the residue (press cake) can also be used as biomass feed stock to power electricity plants, and as fertilizer (it contains nitrogen, phosphorus and potassium), or as animal fodder. The cake can also be used as feed in digesters and gasifiers to produce biogas.

Characteristics of Jatropha Oil: Table 1 below shows the abbreviated characteristics of Jatropha oil that can act as internal combustion engine fuel:

Table –1 Characteristics of Jatropha Oil

Properties / constituents	units	Standards
Density at 15°C:	900-930 km/m^3	According to DIN EN ISO 3675 / 12185
Flash point: min.	220°C	According to DIN EN ISO 2719
Kinematic viscosity at 40°C: max.	36.0 mm^2/s	According to DIN EN ISO 3104
Calorific value: min.	36,000 MJ/kg	According to DIN 51900-1, -2, -3
Ignite: min.	39	
Carbon: max.	0.40%	According to DIN EN ISO 10370
Iodine value	95-125 g / 100 g	According to DIN EN 14111
Sulphur content	10 mg/kg	According to DIN EN ISO 20846 / 20884
Variable properties		
Total contamination	24 mg/kg	According to DIN EN 12662
Acid number	2.0 mg KOH / g	According to DIN EN 14104
Oxidation stability at 110°C: min.	6.0 h	According to DIN EN 14112
Phosphorus content: max.	12 mg/kg	According to DIN EN 14107
Total magnesium and calcium: max.	20 mg/kg	According to DIN EN 14538
Ash content (Oxidasche): max	0.01%	According to DIN EN ISO 6245
Water: max.	0.08%	According to DIN EN ISO 12937

IV. EXPERIMENTAL WORK

Description and elaboration of experimental setup, equipment used and the steps taken in conducting performance analysis of diesel engines using Jatropha – Diesel fuel blends were cited below. The apparatus is available in the Heat engine laboratory in the department of Mechanical engineering, Nile Valley University, Atbara, Sudan.

The objective of experimental: Test of the performance of engine at different conditions of loadings using Jatropha Diesel fuels blends.

The device used in experimental work consists 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


Fig. 4 Stop watch timing


Fig. 5 Dynamometer

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Fig. 6 Stop watch for measuring speed

Fig. 7 Tachometer

Engine specification:
* Type: engine (Lister 8/1) number 127 – 4708
* Diameter of cylinder: 114.3 mm
* Length of piston stroke: 139.7 mm
* Displace volume: 1.4433 lit.
* Maximum 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 / dynamometer = 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 start 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 fields 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 jatropha from Africa city for research. In these experiments two blends of fuels have been individually applied on the test engine:

0% Jatropha and 100 % pure unleaded diesel.

50 % Jatropha and 50 % Pure un leaded 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 of coolant.
4. Start the engine for ten minutes so as to complete the warm up.
5. Startup loading the engine gradually.
6. Take the readings of the following:

i. Velocity of dynamometer N (rev/min)
ii. The load of dynamometer device F (Newton)
iii. The time taken of fuel consumption t (sec)

Repeat the procedure 6 above with eight readings for different loads. A sample of readings is shown in tables 2 and 3 below.

Table –2 0% Jatropha - 100% pure diesel

Load NO.	Current (Amp)	Voltage (V)	Power (N)	Speed (N) r/m	Time/ Min
1	3	140	12	757.2	4.56
2	6	140	21	748.3	4.25
3	9	140	33	742.88	3.5
4	12	140	44	738	3.2
5	15	140	59	735.3	2.57
6	19	140	72	727.7	2.39
7	21	140	88	723.4	2.02
8	24	140	101	718.27	1.53

Table –3 50% Jatropha - 50% pure diesel

Load NO.	Speed (N) r/m	Power (N)	Voltage (V)	Current (Amp)	Time/ Min
1	750.88	12	140	3	4.4
2	745.55	21	140	6	4.09
3	743.9	34	140	9	3.45
4	735.44	45	140	12	3.14
5	731	60	140	15	2.45
6	727	74	140	18	2.32
7	725.3	90	140	21	2.06
8	715	104	140	24	1.5

Calculation of experimental results:

Brake horse power-BHP(Mechanical method):

BHP = F *N (watt) / K

Where:

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 (m2)
N: speed of engine (rev/min)
Fuel consumption (V)
Where:
V = 3600* V_g / t
V = fuel consumption (lit / hr)
V_g = 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}

Table 4 below shows a sample of calculations when using 50 percent jatropha – diesel fuel blend.

Table –4 The calculations when using Jatropha- diesel fuel blend (Jatropha 50%)

num	v (lit/hr)	BHP	IHP
1	0.682	207.57	1307.57
2	0.733	360.67	1460.67
3	0.870	582.64	1682.64
4	0.955	762.38	1862.38
5	1.224	1010.37	2110.37
6	1.293	1239.30	2339.30
7	1.456	1503.73	2603.73
8	2.000	1712.97	2812.97

ηm	Vs (lit/W.hr)	Brake ηth	Indicated ηth
0.15874	0.00328	30.778296	0.00516
0.24692	0.00203	49.7118	0.00497
0.34627	0.00149	67.741169	0.00511
0.40936	0.00125	80.673245	0.00507
0.47876	0.00121	83.420891	0.00574
0.52977	0.00104	96.893408	0.00547
0.57753	0.00097	104.39207	0.00553
0.60895	0.00117	86.590601	0.00703

V. DISCUSSIONS

For the evaluation of the engine performance there are parameters chosen and the effect of various operating conditions, design concept and modifications on these parameters are studied.

The basic performance parameters are power, mechanical efficiency, mean effective pressure, torque, and fuel consumption.

In fact, the fuel quality and specifications have a major effect in the diesel engine performance beside the other factors such as the air inlet temperature, compression ratio …. Etc.

This study is based on the use of jatropha oil as a replacement of diesel in the diesel engine and the purpose is to get the same better performance.

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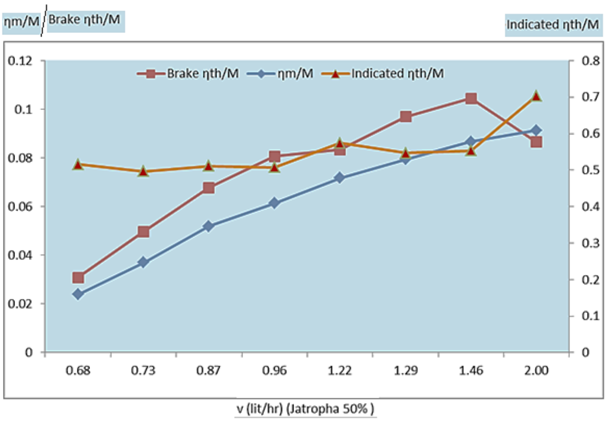

Fig. 8 Engine mechanical performance for Jatropha 50%

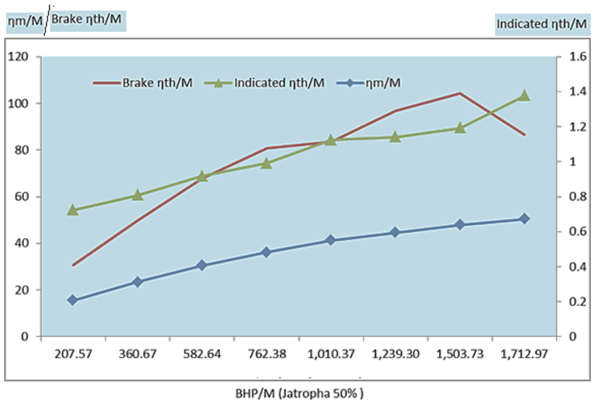

Fig. 9 Engine mechanical performance for Jatropha 50%

After the experiments have been proceeded to test the diesel engine performance using Jatropha as a replacement fuel. The produced results are shown in figs. 8 and 9 above.
Power graphs started from lower values and increases gradually according to the decrease in engine speed with a difference between the experiments readings and the ideal curves due to the above-mentioned factors.
The mechanical efficiency curves started to increase gradually till a certain value. Same attitude takes place in the ordinary diesel experiment but a higher value of efficiencies will occur in the bio fuel case.
The rate of fuel consumption also is lower in case of using the bio fuel than the ordinary diesel due to the combustion quality. It is higher in the case of bio fuel due to the calorific value of bio diesel compared with ordinary diesel, which means less quantity of fuel is required to ensure a combustion that will produce the needed power to give the rated efficiency.
From the study we can say that the main effect of using a biodiesel instead of ordinary diesel is appeared in the indicated power, which indicates the chemical side of the engine performance, a good chemical specification leads to a good combustion quality hence considerable efficiency compared with the ordinary petroleum fuel source.
The cost of Jatropha oil and its effect on the environment compared to diesel when used in diesel engines**:** It has been proven by scientific experiments that the Jatropha oil release upon combustion one fifth of co_2 (carbon dioxide) in comparison with petroleum. This means it excludes four fifth of the cost and damage of co_2.

VI. CONCLUSIONS

Jatropha is one of herbal plants which its seeds can be used as a replacement for the diesel in its liquid phase. Therefore, a good effort must be exerted to take care of these plants under the concept of power growing demands. This oil can reduce the reliability on the diesel fuel.
experiments have been done on a diesel engine in order to compare the performance of diesel fuel oil with jatropha oil. The blended fuel improves power and efficiencies compared with pure diesel fuel.

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