Research Article

Biomedical Science and Clinical Research

Technical and Economic Indicators for Operating Irrigation Pump using Natural Gas

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Submitted: 16 Dec 2022; **Accepted:** 22 Dec 2022; **Published**: 28 Dec 2022

Citation: Shanan, H. A,. E1 Bagoury, K. F,. Abdelmaqsoud, A. M,. E1 Helew, W. K. (2022). Technical and Economic Indicators for Operating Irrigation Pump Using Natural Gas. *Biomed Sci Clin Res,* 1(1), 25-35.

Abstract
This paper presents the experimental for the types of mixers used in mixing natural gas with air to operate the irrigation pump to save energy, many of measurements were carried 2021 year in workshops of Agricultural Engineering Department, Faculty of Agriculture, Ain Shams University, Egypt. Used engine single-cylinder, air-cooled. A new pump with a discharge diameter of 2 inches, which was an Egyptian manufacture. Several types of mixers were manufactured to mix natural gas with air before entering the engine. Using iron pipes of different diameters, three types of mixers were used Mixer with a perforated inner tube of 8, 10. 12cm (L8, L10, L12) . selected determine the four shaft speeds (1750, 2300, 2900 and 3500 rpm) using the engine speed measuring device. The results here dealt with study the analysis of technical indicators for the types of mixers used in mixing natural gas with air to operate the irrigation pump. where the actual power (Braking power) is superior to all types when operating with gasoline was (3.07 kW) A comparison with the use of natural gas, where the mixer type (L10) (2.69 kW) was 10% less than gasoline. the lowest Specific fuel consumption (s. fc) for gasoline was (219.025 gm/Kw.h) at an engine speed of (2900 rpm), The lowest (S.fc) for the types of mixers was the mixer (L10) was (340.144 gm/Kw.h) at an engine speed of (2900 rpm),The highest pump discharge was with the L8 mixer (32.98 m3/h), an increase of 1.8% over gasoline at an engine speed of (3500 rpm), The highest actual hydraulic power with L10 type mixer compared to other type L mixers (0.782 kW) was 12 % lower than that of gasoline. As for the economic indicators the lowest Internal Rate of Return (IRR) was Gasoline (0.44), and the highest (IRR) when carrying the mixer type (L8) was (0.60) an increase of 26.6 % over gasoline. the lowest payback period was the type of mixer (L8) was (1.66 year), and the highest payback period When the Gasoline it was (2.27 year).

Keywords: Pump, Gasoline, Mixer, Engine Speed, Power, Irrigation, Natural Gas

Introduction

Energy assumes an essential part in rustic turn of events. Nonetheless, the cost of oil has crossed 108$ a barrel in the worldwide market and is relied upon to rise further. In this way, the fundamental worry of most researchers as of late is the utilization and accessibility of environmentally friendly power (sunlight based - wind energy - natural gas - biogas - and etc) The interest for energy in rustic Egypt is high and developing as an immediate consequence of monetary turn of events and populace development. An enormous extent of the energy use is from oil, yet an option in contrast to fractional or all out energy not set in stone by the substation. Elective energy sources should be financially practical and harmless to the ecosystem. Lately, the utilization of cleaner elective fills, for example, gaseous petrol, methanol and hydrogen has become more well known, as an answer for ecological issues including an Earth-wide temperature boost impact and lack of raw petroleum holds on the planet. Decreasing power is one of the significant issues in changing a gas motor over to compressed natural gas (CNG) [1]. Natural gas varies depending on the country, the main component (90%–96%) CH_4 (methane). The rest is composed of 2.41% C_2H_6 (ethane), 0.74% C_3H_6 (propane), 0.37% C_4H_{10} (butane), 0.78% N_2 (nitrogen), 0.16% C_5H_{12} (pentane), and 0.08% CO_2 . Furthermore, although (CNG) is a fossil fuel, a reduction of up to 25% can be observed in greenhouse gases due to methane's low C:H ratio [2]. As non-renewable energy source assets, options in contrast to petrol determined energizes should be found for gas powered motors. Packed flammable (CNG) can be an elective fuel as it is more bountiful than oil [3]. It has a high H/C proportion and a high hunt octane number, bringing about cleaner exhaust gases than those created by exemplary fuel ignition. It likewise has high enemy of thump properties yet lower fire speed and more limited start range [4]. As of late, petroleum gas has been seen as a spotless elective fuel for Spark Ignition (SI) motors because of its somewhat high Octane Number. The light ignition of gaseous petrol, which contains generally methane, in SI motors would have worked on warm productivity and decreased emanations contrasted with gas. Because of its high Research Octane Number (RON) of more than 120, petroleum gas takes into consideration higher strain proportion ignition without thumping. It additionally gives a lot of lower CO2 outflows contrasted with other hydrocarbon powers because of its high hydrogen to carbon proportion [5]. In the SI four-phase engine, the ignition cycle is the most significant and complex interaction. This cycle essentially affects motor execution and toxin discharges in light of the fact that in this cycle the chemical energy of the fuel is changed over into thermal energy. In the burning cycle, the term of ignition is a vital boundary that decides the ideal burning interaction. Assuming that the ignition time is too short, the fuel won't be totally singed, so the substance energy of the fuel can't be totally changed over into heat energy, or when the burning time is too lengthy, more thermal energy is lost because of a more drawn out heat move time to the chamber and cylinder [6]. The authors led an exhaustive survey of gaseous petrol as a transportation fuel which is viewed as a promising elective fuel. Albeit port-infused CNG innovation has been attempted and tried, it has not become as famous as traditional fills. One reason other than the absence of framework and refueling stations is the lower force and power yield contrasted with gas in bivalent vehicles. This is because of lower volumetric efficiency as vaporous powers supplant approaching natural air bringing about lower force and power [7]. The extra engine power drop of about 17% when the engine is fueled with natural gas compared to gasoline, due to the decrease in the engine volumetric efficiency [8]. Blending gadgets for gases used in gas engine commonly alluded to as carburetor, for blending air and gaseous fuels are regularly appended to the admission complex of a gas powered motor. In gas carburetor the blending of air and gaseous fuels should be in an appropriate proportion for a specific engine burden and speed. In planning the maker gas carburetor, effortlessness and roughness have been viewed as all of the time as an essential necessity to accomplish simple change and reproducible execution [9]. Power and torque produce from gas powered engine for the most part subject to engine in chamber combination mass and obviously kind of fuel used. Consequently, volumetric productivity assumes one of the main parts while managing contrast properties of fuel with same engine contrasted with the other engine boundaries [10]. Mixing chambers in with a bigger volume than simply a T-Joint cylinder give longer air and fuel maintenance time inside the chamber and a more homogeneous combination becomes essential when the distance between the Mixing and the inlet manifold is short, and hence the Mixing time is adequate, A simple mixing chamber can be used due to the relatively lower flow velocities, more time is available for mixing. Despite the advent of technology and skill via globalization, agriculture still is the vein of developing countries approximately 70% of the people directly rely on agriculture as a mean of living [11]. Irrigation is one of the important and scarce natural resources used for crop production. It helped farmers to enhance their cropping pattern and crop yield. This affects overall betterment of socio-economic condition of the farmers in different regions of the country [12]. The wake of educating about new rural generation advances. This may lead broad deliberation before embracing and to utilize the development advancements speedily [13]. The aim of this research is to:

1- Design a gas mixing device (CNG) into air stream.
2- Modify and convert SI engine to power a water pump for irrigation by using (CNG).
3- Compare the output power of using (CNG) with fuel gasoline.

Materials and Methods

This paper presents the results for the types of mixers used in mixing natural gas with air to operate the irrigation pump to save energy, It was produced in the workshop of the Department of Agricultural Engineering/Faculty of Agriculture, Ain Shams University in Egypt, utilizing iron pipes of different measurements and a blender with a punctured internal cylinder The following materials and methods were used:

Equipment and Instrument

Engine

A new single-cylinder, air-cooled, engine was used, which was purchased from the local market, and the indicated in the following specifications:

Engine Type: *Air-cooled 4-stroke OHV Single Cylinder*
Displacement: *208cc*
Compression Ratio: *8.5:1*
Rated Output: *4. 4.4 kw at 3600 rpm*
Carburetor: *Butterfly*
Dimensions: *14.8 x 12.6 x13.4 in.*
Net Weight: *35 lbs. (16 kgs)*

The Pump

A new pump with a discharge diameter of 2 inches was used, which was an Egyptian manufacture, as indicated in the following specifications:
Model : *SE-50X*
Type: *SE-50X-BDM-0*
Connection dia.: *50 mm 2 inch*
Delivery volume: *560 l/min 147 gal/min*
Total head: *30 m 98 ft*

Engine Modifications

The transformation of the SI engine to natural gas fuel included engine changes where a gas blender was utilized Several kinds of blenders are fabricated to mix natural gas in with air prior to entering the engine , utilizing iron pipes of different measurements and a blender with a punctured internal cylinder. An iron cylinder with a width of (3.81 cm), a length of (13 cm) and a thickness of (1 mm). A pipe of diameter (2.54 cm) is welded perpendicular to it, one from the top and the other from the bottom so that one is opposite to the intake of air from the air filter and the second is connected to the air inlet hole. As for the gas, an iron tube of three lengths (8-10-12 cm) was made and it can be expressed by the following symbols (L8 - L10 - L12)as shown in Figure (1) perforated with a number of holes (15) holes on its perimeter and it is fixed from the bottom of the mixer by means of screws Where the gas is entered into the mixer and then comes out of the nozzles to mix with the air, and thus the mixture enters the engine as shown in Figure (2).

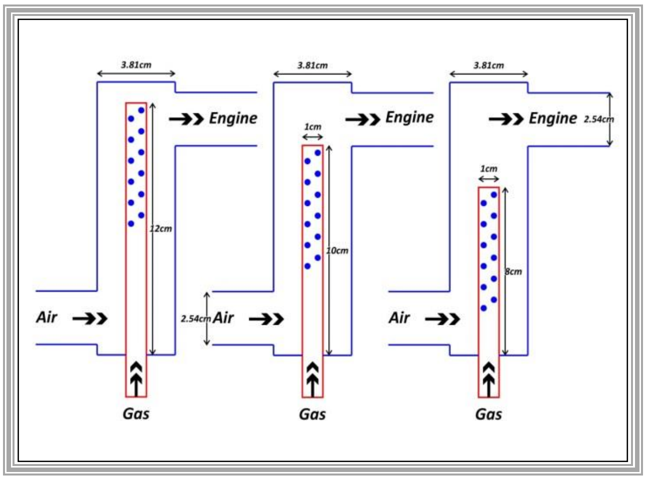


Figure1: Mixer with a Perforated Inner Tube

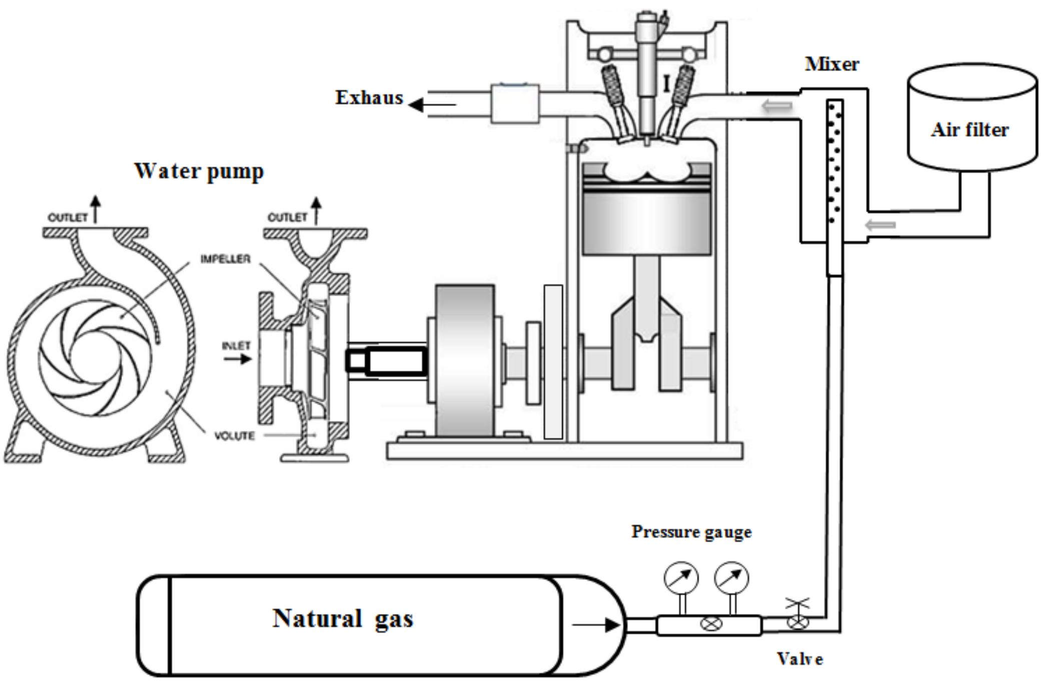


Figure 2: Simplified Diagram Of Natural Gas Engine For Powering Water Irrigation Pump

Experimental Procedures and Measurements

To survey the impact of trial factors and the presentation of the engine and pump work utilizing sorts of fuel (gas - natural gas) and for different engine speeds and for all types of mixers, as for working the engine with natural gas, where the activity was begun with gasoline fuel and then closed the gasoline valve and opened the gas valve step by step until the activity of the engine with gas balanced out Naturally.

After preparing the engine and filling it with gasoline, preparing each of the water barrel with a capacity of (200L) and the tank of disposal measurement (40L) and installing water hoses (the intake hose, the push hose) with a length of (3m) for each of them with a valve with a diameter of (5.08cm) at the beginning of the push hose To control the amount of water leaving the pump. Starting the engine with gasoline to determine the four shaft speeds (1750 - 2300 - 2900 - 3500 rpm) using the engine speed measuring device.

Engine Power

The power developed was measured by a prony brake at various speeds, loads and throttle valve positions, The net power of an engine is the power delivered at crankshaft, torque brake was used in the measurement of engine. The power developed from engine is calculated using by the following equation:-

$$P = T\,.\,\omega\,, \qquad P = \frac{2\pi\, n\, W\, L}{1000}$$

Where: P : power (kW),
n : speed of the pulley in (rpm),
W : load registered by the spring balance in (N),
L - length of the brake arm in (m),
T : torque arm in (N)
ω : angular speed (rev. /s).

Fuel Consumption

The rate of gasoline fuel consumption was measured and then the pump was run once with load and once without load for all engine shaft speeds and calculating the amount of fuel (gasoline) consumed per unit time.

The rate of gas fuel consumption (natural gas) was measured by placing a wind speed measuring device on the gas hose between the gas cylinder and the gas entry hole to the mixer for all types of mixers, for all engine speeds, where the cross-sectional area was calculated with the flow speed gas to determine the amount of gas entering the engine, the following equations were used to calculate the fuel consumption rate [14].

$$F_{BC} = (V / t) \times 0.0036$$

V = Volume of consumed gas fuel (cm^3)
t = Time of operation (s)
F_{Bc} = Rate of gas fuel consumption (m^3/h)

$$s.fc = \frac{FC}{P}$$

s.fc = specific fuel consumption (gm /kw.h)
fc = fuel consumption (gm /h)
p = power (kw)

Pump Discharge Performance

Pump discharge was measured using fuels (gasoline / natural gas (gasoline starting) and for all shaft speeds engine (rpm1 - rpm 2 - rpm3 - rpm4) by placing the intake hose in a barrel filled with water capacity of (200) liters and the outlet (push) hose in the tank to measure the discharge and control the amount of water leaving the valve where the amount of water accumulated in the discharge measurement tank was calculated per unit time calculating the pump discharge Q (m3/s) and take a reading for each (0.1 bar).

Powering Water Irrigation Pump

Where the actual pump power was measured for types of fuel (gasoline - natural gas) for all engine speeds and for all types of mixers and for each pump pressure (0.1 bar), where after calculating the pump performance Q (m3/s) and pump pressure P (bar) the actual pump power was calculated (hydraulic power) with the following equation.

$$HP = \rho . g . Q . h / \eta$$

HP = Hydraulic power or useful water power (kW)
ρ = Water density (kg/ m3),
g = Gravitational acceleration (m/s2)
Q = Pump discharge (m3/s)
h = Total head of the system (m)
η = Efficiency

Economic Indicators

Internal Rate of Return IRR. used to analyze the profitability of a project or investment this is the rate of interest that equates the present value of benefits to the present value of costs, IRR the discount rate that makes the net present value (NPV) of all cash flows from a given project equal to zero. The calculation of the internal rate of return is based on the same NPV formula. Payback period is the time needed for the project to recover the net return (benefits) the cost of the capital investment for the project. In other words, the time needed for the cumulative cash flows to equal investment costs, the following equations were used to calculate (NPV, Payback period):
N.P.V = Total Present Benefits - Total Present Costs
Payback period = investment costs / annual net return (profit)

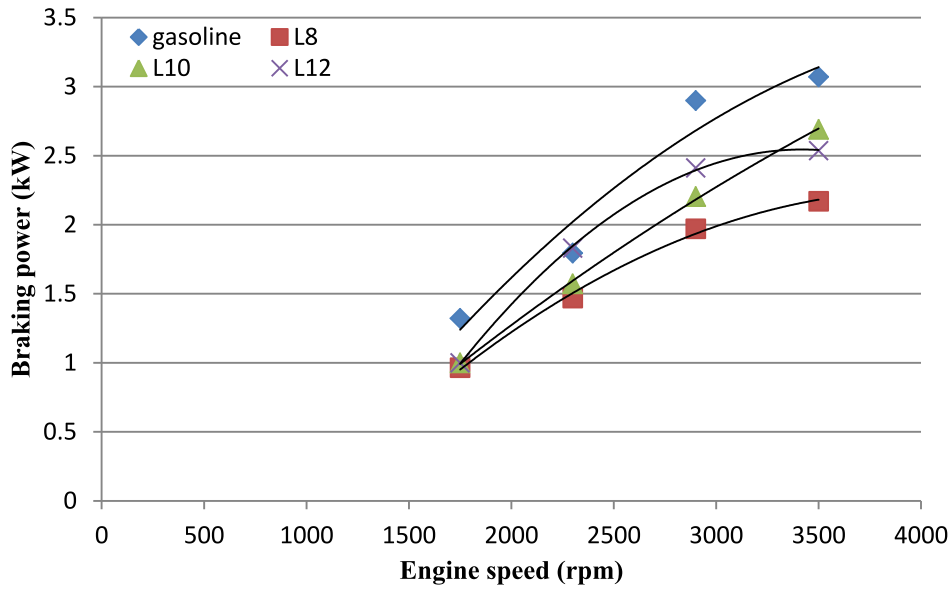
Result and Discussion

The results here dealt with two main parts of the study, where the first part dealt with the analysis of technical indicators for the types of mixers used in mixing natural gas with air to operate the irrigation pump to save energy, while the second part dealt with the analysis of the economic indicators for operating the irrigation pump.

Technical Indicators

Engine Power

Figure (3) shows the relationship between engine speed and the actual power (Braking power) for each of (Gasoline, L8, L10, L12) Where results guarantee that The relationship between engine speed and actual power is a quadratic relationship, As we note with the increase in the engine speed, the power increases in all types of mixers. The actual power is superior to all types when operating with gasoline was (3.07 kW) at engine speed (3500 rpm) A comparison with the use of natural gas, where the mixer type (L10) gave the highest power compared to the types of mixers (2.69 kW) at an engine speed of (3500rpm) was 10% less than gasoline. this is due to reduced volumetric efficiency as the gaseous fuel displaces incoming fresh air resulting in reduced peak torque and power This is consistent with. The higher the engine speed the higher the actual pump power in all types of mixers this is consistent with [15].



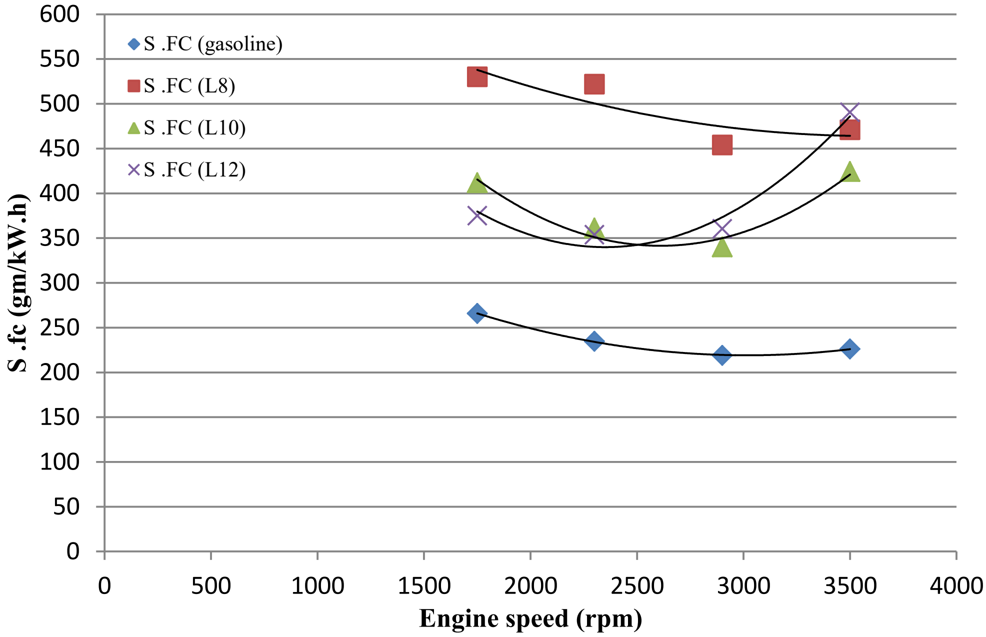
Types mixers	Regression equation	R^2
gasoline	Power = $3E\text{-}07X^2 + 0.0026X – 2.37$	0.949
L8	Power = $-3E\text{-}07X^2 + 0.002X – 1.836$	0.996
L10	Power = $-1E\text{-}07X^2 + 0.0015X – 1.333$	0.999
L12	Power = $-6E\text{-}07X^2 + 0.0038X – 3.69$	0.999

Figure 3: The Relationship Between Engine Speed and The Braking Power For All Types Of Mixers (gasoline – L8 – L10 - L 12 cm)

Specific Fuel Consumption

Figure (4) shows the relationship between engine speed and specific fuel consumption (S.fc) for each of (Gasoline, L8, L10, L12) at deferent engine speed . The relationship between engine speed and specific fuel consumption is of a quadratic function type. When the engine speed is increased, the specific fuel consumption decreases and the values were (226.109 , 471.039, 424.314 , 490.3871gm/kW.h) When using mixers (Gasoline, L8, L10, L12) respectively at engine speed (3500 rbm).

The specific fuel consumption rate ranged (265.727- 219.025 gm/kW.h) for gasoline compared to (530.218 - 340.144 gm/kW.h) with natural gas.We note a decrease in fuel consumption with increasing engine speed this is consistent with [16, 17]. The lowest (S.fc) for gasoline was (219.025 gm/Kw.h) at an engine speed of (2900 rpm), The lowest (S.fc) for the types of mixers was the mixer (L10) was (340.144 gm/Kw.h) at an engine speed of (2900 rpm) and an increase of 35.6. % over gasoline.



Types mixers	Regression equation	R^2
gasoline	S.fc = $3E\text{-}05X^2 - 0.1757X + 484.27$	0.999
L8	S.fc = $2E\text{-}05X^2 - 0.1558X + 744.18$	0.765
L10	S.fc = $0.0001X^2 - 0.5237X + 1024.7$	0.953
L12	S.fc = $0.0001X^2 - 0.5198X + 950.82$	0.968

Figure 4: The relationship between engine speed and specific fuel consumption for each of (gasoline, L8, L10, L12)

Figure (5) shows specific fuel consumption (S.fc) for each of (Gasoline, L8, L10, L12) at engine speed (2900- 3500 rbm). Where results guarantee that Specific fuel consumption using gasoline (226.109 gm/kW.h), and using L12 mixer was (490.387 gm/kW.h) more than that of gasoline by 53.89 %at engine speed (3500 rbm). The lowest specific fuel consumption at the L10 type mixer compared to other type L mixers was (424.314 gm/kW.h) and an increase of 46.7 % over gasoline at engine speed (3500 rbm). The lowest (S.fc) at an engine speed of 2900 using gasoline was (219.025 gm/kW.h) and using natural gas when the type of mixer L10 was (340.144 gm/kW.h).

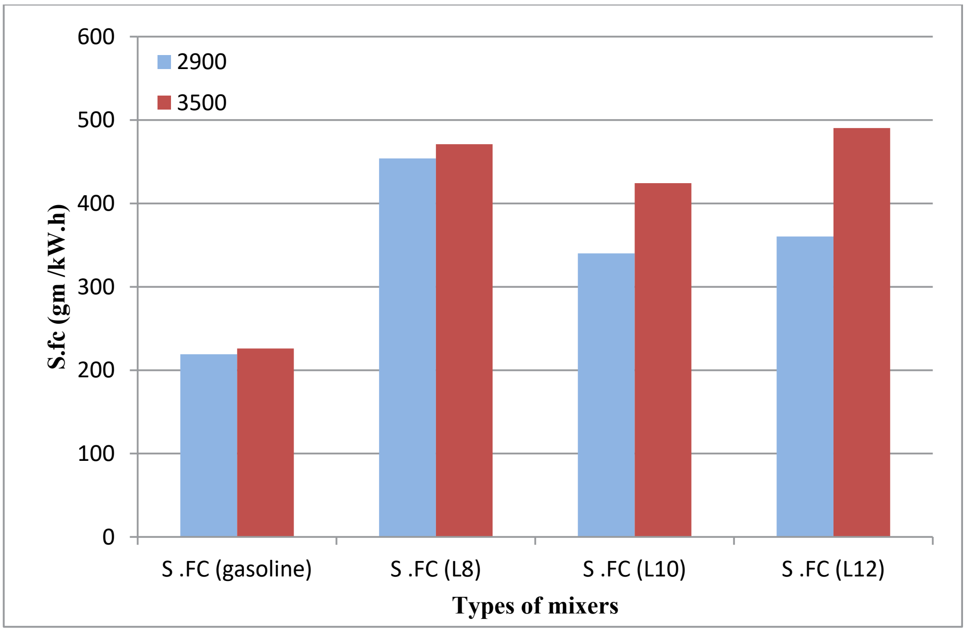


Figure 5: Specific Fuel Consumption For All Types Of Mixers At Engine Speed (2900- 3500) Rpm

Pump Indicators

Power and Discharge of the Pump Using Gasoline

Figure (6) shows the relationship between pump discharge and power and pump pressure for gasoline operating at engine speed (3500 rpm) Where results guarantee the relationship between pressure and pump discharge is inverse, as the higher the pressure, the lower the pump discharge. Maximum discharge using gasoline (32.38 m3/h) at pressure (0.2bar) and minimum discharge (5.66 m3/h) at pressure (1.8 bar).

Figure (6) shows the relationship between pump discharge and the actual hydraulic power to operate using Gasoline at engine speed 3500 rpm Where results guarantee that the relationship between pump discharge and actual power is a quadratic relationship. As the pump discharge increases, The actual hydraulic power increases. The maximum actual hydraulic power was (0.89 kW) at pump discharge of (21.97 m3/h). When the pump pressure was 1 bar, the discharge (23.6m3/h) and the hydraulic power (0.872kW). When the pump pressure was 1.7 bar, the discharge (8.32m3/h) and the hydraulic power (0.522kW), This is suitable for the operation of the drip and sprinkler irrigation system.

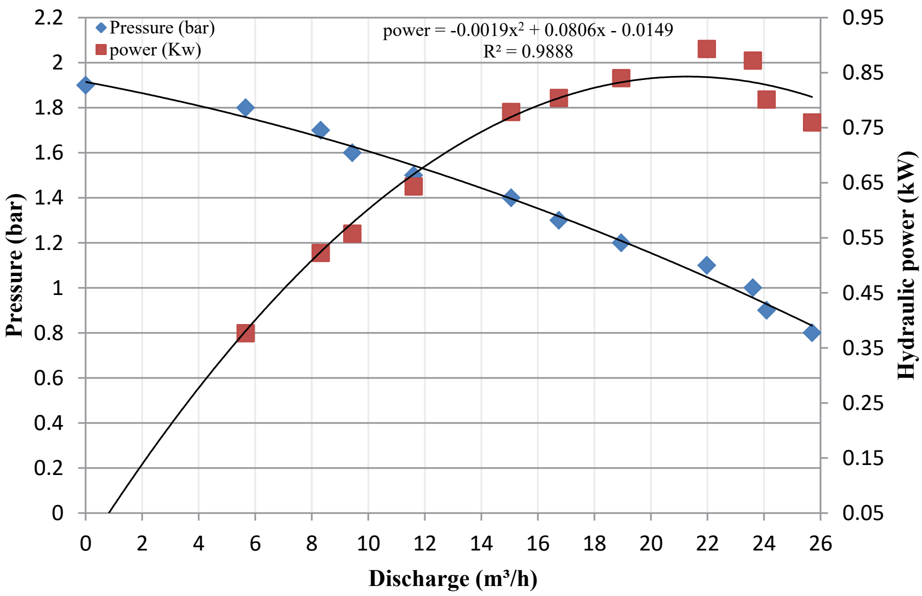


Figure 6: The relationship between discharge, pressure and the hydraulic power of pump operating with gasoline at engine speed (3500 rpm)

Power and Discharge of the Pump Using Mixer Type (L8)

Figure (7) shows the relationship between pump discharge and power and pump pressure for mixer L8 operating at engine speed (3500 rpm) Where results guarantee the relationship between pressure and pump discharge is inverse, as the higher the pressure, the lower the pump discharge. Maximum discharge using L8 mixer (32.98 m3/h) at pressure (0.2bar) and minimum discharge (3.62 m3/h) at pressure (1.8bar).

Figure (7) shows the relationship between pump discharge and the actual hydraulic power to operate using mixer L8 at engine speed 3500 rpm Where results guarantee that the relationship between pump discharge and actual power is a quadratic relationship. As the pump discharge increases, The actual hydraulic power increases. The maximum actual hydraulic power was (0.717 kW) at pump discharge of (19.42 m3/h), and the pump pressure was 1 bar. When the pump pressure was 1.7 bar, the discharge (6.24m3/h) and the hydraulic power (0.391kW).

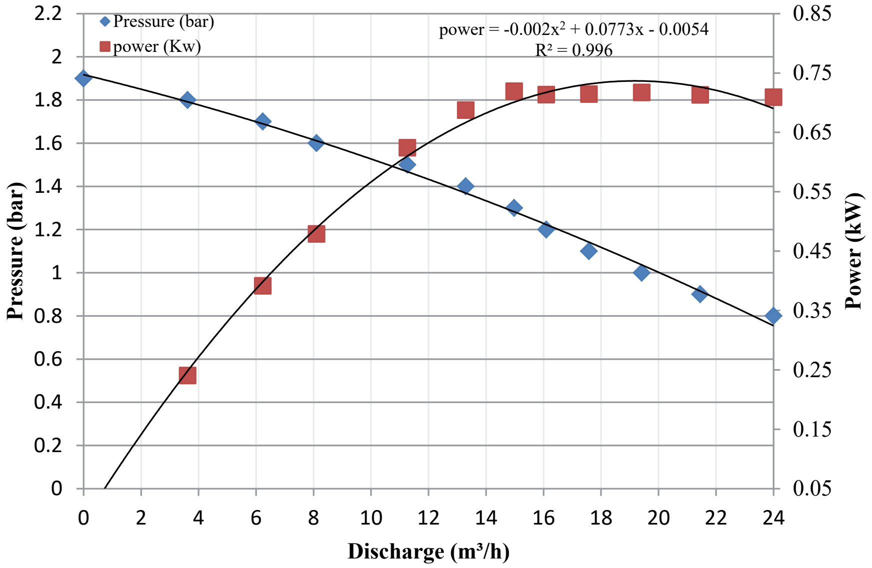


Figure 7: The Relationship Between Discharge, Pressure and the Hydraulic Power of Pump Operating With Mixer Type L8 At Engine Speed (3500 rpm)

Power and Discharge of the Pump Using Mixer Type (L10)

Figure (8) shows the relationship between pump discharge and power and pump pressure for mixer L10 operating at engine speed (3500 rpm) Where results guarantee the relationship between pressure and pump discharge is inverse, as the higher the pressure, the lower the pump discharge. Maximum discharge using L10 mixer (31.37 m3/h) at pressure (0.2bar) and minimum discharge (2.64 m3/h) at pressure (1.8bar).

Figure (8) shows the relationship between pump discharge and the actual hydraulic power to operate using mixer L10 at engine speed 3500 rpm Where results guarantee that the relationship between pump discharge and actual power is a quadratic relationship. As the pump discharge increases, The actual hydraulic power increases. The maximum actual hydraulic power was (0.782 kW) at pump discharge of (23.54 m3/h). When the pump pressure was 1 bar, the discharge (20.5 m3/h) and the hydraulic power (0.756kW). When the pump pressure was 1.7 bar, the discharge (4.73m3/h) and the hydraulic power (0.296kW).

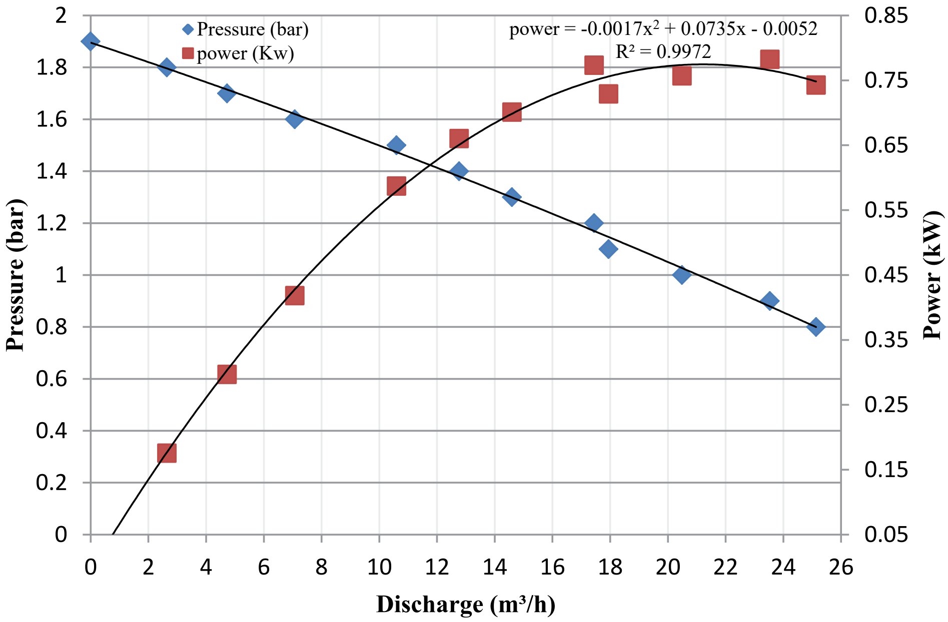


Figure 8: The Relationship Between Discharge, Pressure And The Hydraulic Power of Pump Operating With Mixer Type L10 At Engine Speed (3500 Rpm)

Power and Discharge of the Pump Using Mixer Type (L12)

Figure (9) shows the relationship between pump discharge and power and pump pressure for mixer L12 operating at engine speed (3500 rpm) Where results guarantee the relationship between pressure and pump discharge is inverse, as the higher the pressure, the lower the pump discharge. Maximum discharge using L12 mixer (29.51 m3/h) at pressure (0.2bar) and minimum discharge (2.18 m3/h) at pressure (1.8bar).

Figure (9) shows the relationship between pump discharge and the actual hydraulic power to operate using mixer L12 at engine speed 3500 rpm Where results guarantee that the relationship between pump discharge and actual power is a quadratic relationship. As the pump discharge increases, The actual hydraulic power increases. The maximum actual hydraulic power was (0.473 kW) at pump discharge of (12.81 m3/h), and the pump pressure was 1 bar, the). When the pump pressure was 1.7 bar, the discharge (3.39m3/h) and the hydraulic power (0.212kW).

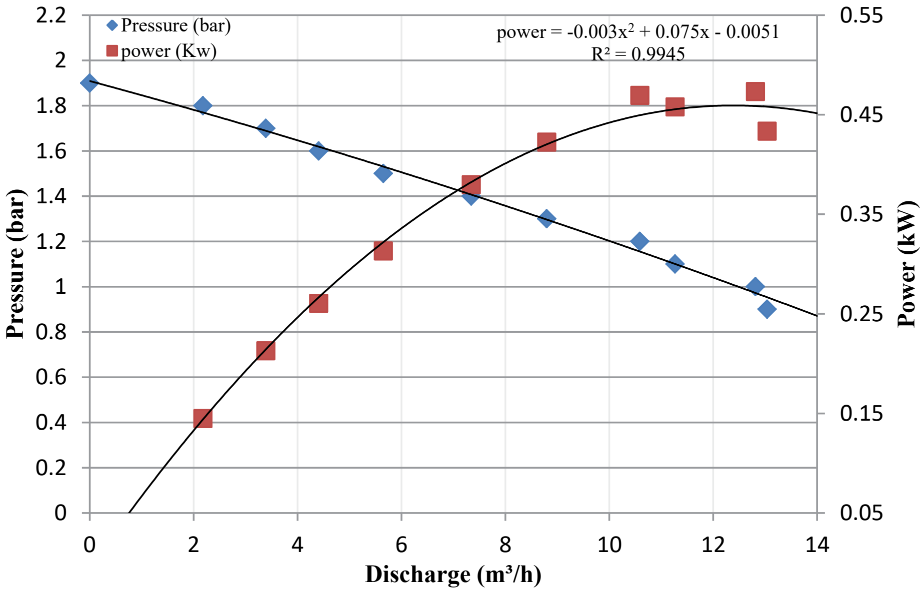


Figure 9: The Relationship Between Discharge, Pressure And The Hydraulic Power of Pump Operating With Mixer Type L12 At Engine Speed (3500 Rpm)

Discharge the pump with the L12 mixer (29.51 m3/h) was 8.8 % lower than that of gasoline at an engine speed of (3500 rpm). The highest pump discharge was with the L8 mixer (32.98 m3/h), an increase of 1.8% over gasoline at an engine speed of (3500 rpm). The actual hydraulic power with L12 mixer (0.473 kW) was 47% lower that of gasoline. The highest actual hydraulic power with L10 type mixer compared to other type L mixers (0.782 kW) was 12 % lower than that of gasoline.

Economic Indicators

Internal Rate of Return (IRR)

Economic metric IRR. this is the rate of interest that equates the present value of benefits to the present value of costs. Figure (10) shows Internal Rate of Return (IRR) with a load for each of (Gasoline, L8, L10, L12) where we note that the lowest (IRR) was the mixer type (Gasoline) was (0.44), and the highest (IRR) when carrying the mixer type (L8) was (0.60) an increase of 26.6 % over gasoline.

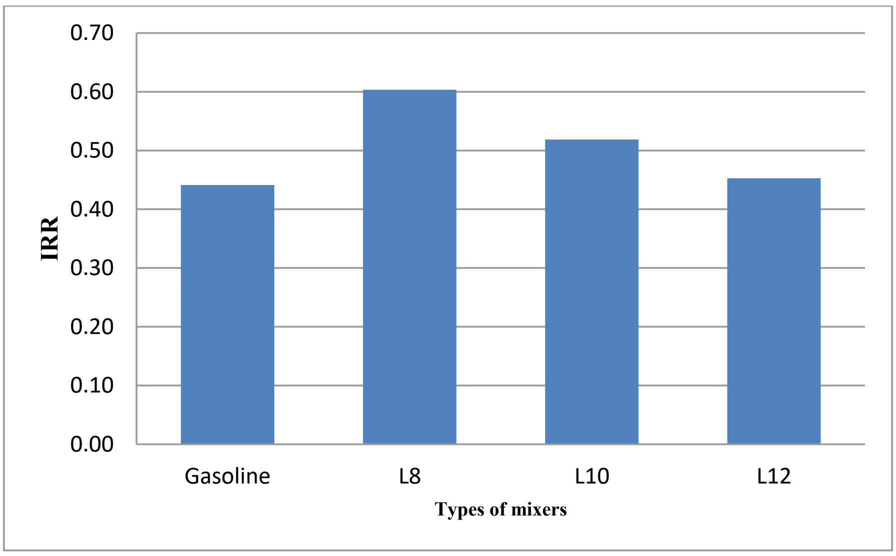


Figure 10: Internal Rate of Return (IRR) For All Types Of Mixers (Gasoline – L8 – L10 – L12) At Engine Speed (3500rpm)

Payback Period

The time needed for the project to recover the net return (benefits) the cost of the capital investment for the project. Figure (11) shows the capital payback period with a load for each of (Gasoline, L8, L10, L12) where we note that the lowest payback period was the type of mixer (L8) was (1.66 year), and the highest payback period When the (Gasoline), it was (2.27 year).

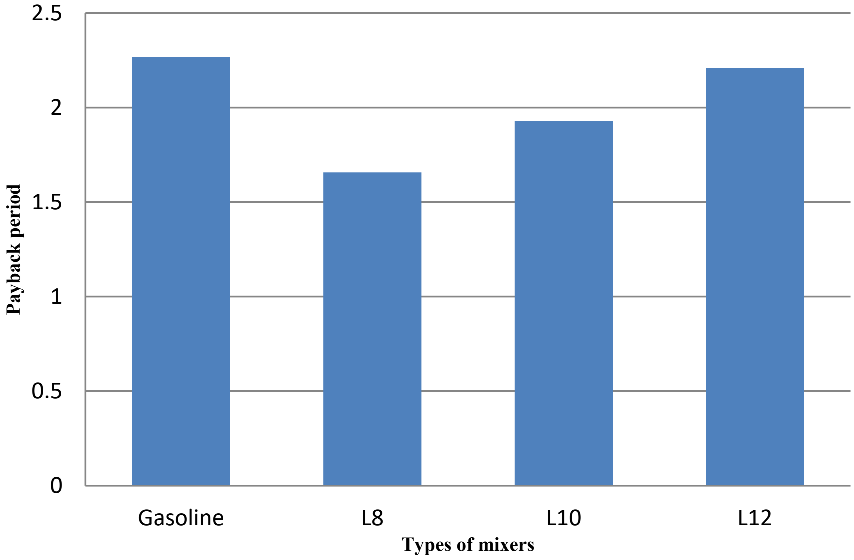


Figure 11: Payback Period (Year) For All Types Of Mixers (Gasoline – L8- L10- L12) At Engine Speed (3500rpm)

Conclusion

In this paper, to solve the deterioration of fuel economy by using natural gas , The goal of tis to improve the fuel/air mixing and combustion process, this study and the main conclusions were summarized as below:

1. Gasoline engines can be converted to work with natural gas with an efficiency (Braking power) of up to 90%.
2. The highest pump discharge was with the L8 mixer (32.98 m3/h), an increase of 1.8% over gasoline at an engine speed of (3500 rpm).
3. The highest actual hydraulic power with L10 type mixer compared to other type L mixers (0.782 kW) was 12 % lower than that of gasoline.
4. As for the economic indicators, the use of natural gas gave a good economic return for all mixers, and the best economic efficiency was for the mixer (L8) an increase of 26.6 % over gasoline.

Recommendations

Recommended to use L10 mixer to reduce fuel consumption and increase the engine power and actual hydraulic power to mix natural gas with air.

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