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Potential of Utilizing Compressed Air as Energy Sources for Single Cylinder Reciprocating Engine.

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Abstract

In this work, experimental study has been conducted on the potential of utilizing the compressed air as an alternative of energy source to operate the single-cylinder reciprocating engine. The compressed air availability, economy, and environment friendly make it one of the important sources of future alternative energy resources.

Results show that the compressed air engine operated at an air pressure from 3 to 15 bars, and the output power produced about 62.39 hp. The engine efficiency and the volumetric efficiency are measured based on the engine parameters and size, and the volumetric efficiency found to be about 66%. Although the efficiency and output power are not closed to the normal engines.

The results indicated several factors, including that the torque generated by the air motor was acceptable; in addition to that, the overall performance with respect to the normal engine was also within acceptable ranges.

Keywords: Compressed Air, Energy Saving, Performance, Brake Power, Pollution, Engine Load.

1. Introduction

Nowadays, the major challenge faced most of the countries of the world is the availability of energy resources. This is due to fast growth of the world's population and the increasing of the standard of living of human beings, which increase the demand for energy. Jordan is a developing non-oil production country with 96% imported energy from the outside. Its energy demand consists of fuels like diesel, gasoline, natural gas, which are being depleted rapidly. Also, when burned, these fuels have a bad impact as a result of its products, which have greenhouse effect and other pollutants that harm the environment and human life.

The impact of fuels on the environment and its high cost put the decision makers and researchers under pressure to develop new alternatives energy resources, especially in transportation sector. So, new technologies like hybrid vehicles and hydrogen-fueled power cars used. The possibility of using the compressed air method powered car becomes now one of the important alternatives. Because air is free from pollutants and available in nature, and can be compressed to higher ranges of pressure at a very low cost, and it forms an important option with a light weight.

The research methodology is based on arriving at a design with a process of checking the dependence of the compressed air engine's performance, and in most cases, it depends on the pneumatic actuator through the expansion of compressed air.

The principle of the experimental investigation was directly based on the air engine, which was also of the piston type. In addition, the cylinder was based on the installation and was adopted for power purposes. Through the load to the engine, which is variable, the engine performance is measured. There have been numerous studies in this field. Manish et al [1] study on-air experiment provided several proofs and methodologies, including that the four-stroke single-cylinder engine, in addition to that, provided an essential component to the compressed air engine, not forgetting that, according to the hydrocarbon fuel, air pressure must be taken into account. Singh and Onkar [2,7-17] presented a paper deal with the study of alternative fuel for automobile engines, emphasizing compressed air-driven engines. A proposal has been put forward for developing automobile running on compressed air engine. Yadav and Singh [3] The compressed air engine was used, as this engine does not depend on natural gas and petroleum, and the principle of currency is relied only on compressed air.

This replaces. An even, single chamber low-speed motor, a proto sort, was altered to run on packed air. Since this motor runs just on high tension-packed air, its fumes are without a doubt just air, making it a zero-contamination motor. A. Lal [4] conducted an experimental study on a single cylinder compressed air engine. There are numerous studies and conclusions on this subject, as Huang [5] the test showing the engine to the piston has been pushed through compressed air, which is described as an internal combustion rate of 100 cm^3 and was relied on in these experiments on a bench for the purpose of checking the energy

The temperature of the compressed air engine was at pressures 5 to 9 bar, and by relying on the use of a cam system, which was relied on to operate by relying on a crankshaft, the engine was modified to a two-stroke [6]. Direct Injection of Methane Bosch is leading a consortium to develop and improve CNG injection systems. Direct injection can be used not only in diesel and gasoline engines. This fuel delivery system has the potential to make compressed natural gas (methane) engines more economical and environmentally friendly. Compared with existing systems that use multipoint gas injection, the promising direct fuel injection system is able to increase torque by up to 60% at low revs and will be able to improve the dynamic performance of future CNG vehicles. However, there is still no technology for direct injection of natural gas into the engine's combustion chamber. In the Direct4Gas project, researchers are trying to develop a direct injection system for engines that run exclusively on pressurized methane.

Modern CNG vehicles can run on both gasoline and gas. The engines of these cars are equipped with a gasoline injection system, and when working on methane, these cars use an additional fuel system. “The problem with this situation is that neither the combustion process, efficiency indicators, nor emissions generation can be improved. Methane, like gasoline, must be injected directly into the combustion chamber,” says Dr. Andreas Berkefeld, Direct4Gas project manager at Robert Bosch GmbH. Because methane and gasoline behave differently with direct injection, optimizing the methane combustion process."

In the Direct 4 Gas project, researchers and engineers are working to develop a direct injection system that is capable of being reliable, sealed, and particularly robust and measures the exact amount of gas to be injected. Modifications to the engine itself are kept to a minimum so the industry can continue to use the same components used in gasoline engines. The project team equips experimental gas engines with a newly developed high-pressure injection valve. The system is meant to be tested in the lab and live on vehicles. Researchers also study the composition of the air-fuel mixture, the ignition control process, and the composition of toxic gases. According to engineers, direct injection is able to increase torque by 60% at low engine speeds.

2. Materials and Methods

Compressed air can be considered as safe and clean medium as well as simple and efficient. There are no dangerous if it used as a utility. Also, it can be considered as non-combustible material without any pollution. When the atmospheric air compressed by a from 1 bar to a high pressure, the increment in pressure approaches an ascent in hotness, and compacting air makes a relative expansion in heat and from thermodynamics we realize that when the volume of a gas (air) parts during pressure, then, at that point, the tension is multiplied and as per Charles' law the volume of a gas changes aberrant extent to the temperature [3]. The laws of physics dictate that uncontained gases will fill any given space, and the air expands outward with so much energy. Compressing a gas into a small space is an efficient method generate energy, and when this gas expands again, that energy will be released to do some work [3]. Compressed air engine shown in figure 1 mainly consist of the following components cylinder, pneumatic solenoid valve, actuator, air compressor, storage tank, crank shaft, connecting rod, and bearings. Pneumatic cylinder is a device which used to as this leads to a strong production with its movement by relying on compressed gas, it is operated

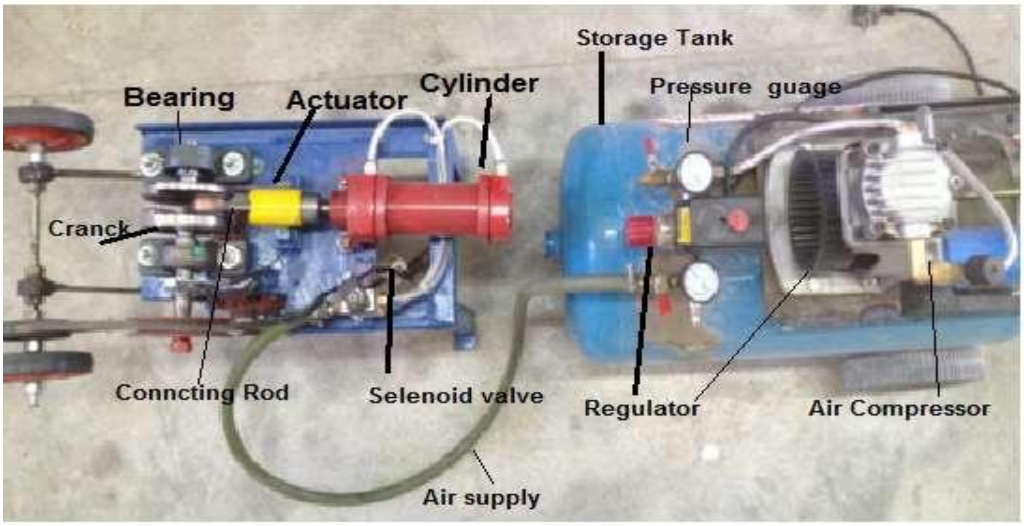

Figure 1. Actual system setup of the compressed air engine

In order to perform its main function, as the pneumatic cylinders transfer the force by relying on the conversion to the potential energy of the compressed gas into kinetic energy as shown below in the figure where this result is obtained by relying on the expansion in the capacity of the compressed gas. The presence of the pneumatic expansion leads to the movement of the board in the right direction. As the compressed air enters, it enters one end of the piston when it is running, which leads to an increase in force [5].

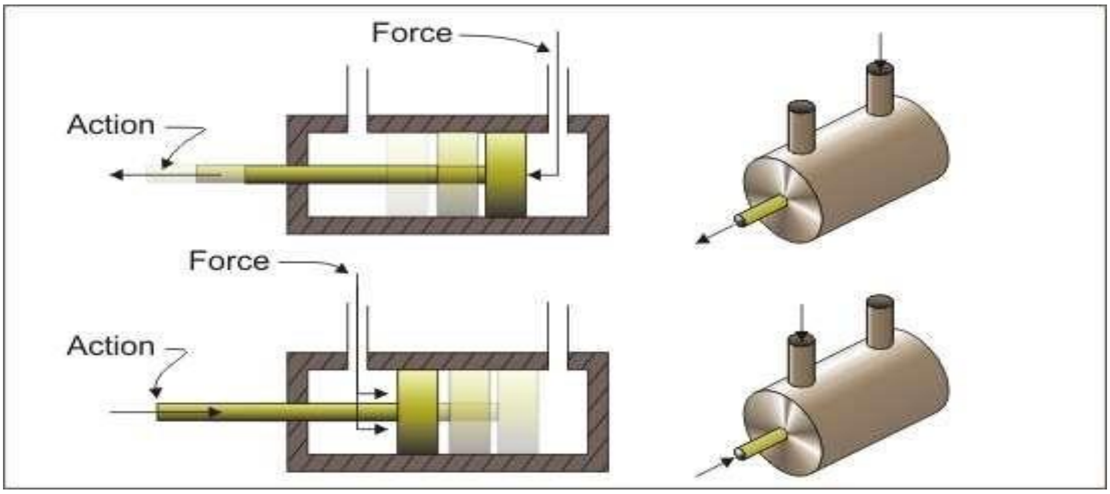

Figure 2. Force transmission through Pneumatic system

The changing state is defined as an indication of the opening or closing of the valve, which occurs in itself, and there are several reasons for it, and the main reason is the pressure gradient, which is in greater pressure if compared with the pressure of the atmosphere and this leads to the movement of the piston in the ideal direction [5]. The crankshaft is relied upon in order to move the piston's regressive movement into rotation. It also contains crankpins where the axle is displaced from the crank axis and through the suspension of the large end that returns to the connecting rods for each cylinder.

Connecting rod is the arm used to transfer the force to and from the cylinder then to the transmission system. Regulators were used to connect the compressed air tanks and engine to adjust the air pressure valve installed before the engine intake host controls the flow by adjusting the air flow rate—the configuration of compressed air engine regulators, actuator, and solenoid shown in figure 3. When the compressed air comes from the pressure vessel (air tank), it will go through the piping system or hoses to the engine and entering the piston-cylinder assembly. Pneumatic systems are designed to move loads by controlling pressurized air in distribution lines and pistons with mechanical or electronic valves. Air under pressure possesses energy that can be released to do useful work. It is necessary to pass the air to treatment device before entering the cylinders and valves to remove dust and moisture.

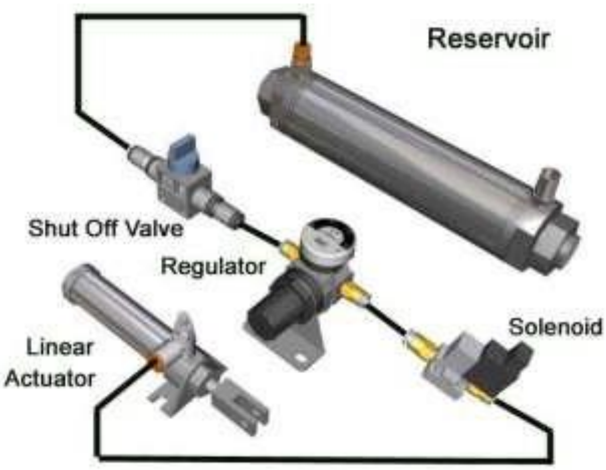

Figure 3. Assembly of cylinder with regulator and solenoid

It is also necessary to use the relief valve or a safety valve to maintain the desired pressure. The cylinder used a double-acting one that does not contain a return spring, movements in both directions are powered by compressed air. The actuator has experienced a seizing action due to the design and the length of the connecting rod; the seizing action here stands for working for a short period of time and then come to a full stop position or an irritated if you refer to the machine design; the problem would be clear and easy to solve.

3. Results and Discussion

After installing the compressed air engine, the test drive has been performed inside university labs and the engine torque and speed recorded. The evaluation of engine performance during test drive uses the data including speed different supplying air pressure (as working pressure). Lower supplying pressure is 3 bars.

The following dimensions are referred to the engine used in this investigation:

- Cylinder diameter: 5.57 cm
- Cylinder length: 13 cm
- Piston diameter: 5.5 cm
- Piston thickness: 2 cm
- Pin diameter: 1.3 cm
- Pin length: 7 cm
- Connecting rod length: 10 cm

General equations used to calculate the system performance, and the results presented in the following figures.

The variation of the engine speed with pressure shown in figure 4. As the applied pressure increases, engine speed will increase because higher forces applied to the piston will increase the crankshaft load and increase the potential energy to store in the flywheel, where it changes kinetic energy again.

Figure 5 display the variation of engine speed with applied load, which is the similar trend as well as figure 4 because increasing the pressure at constant area will increase the force, which represent the load here

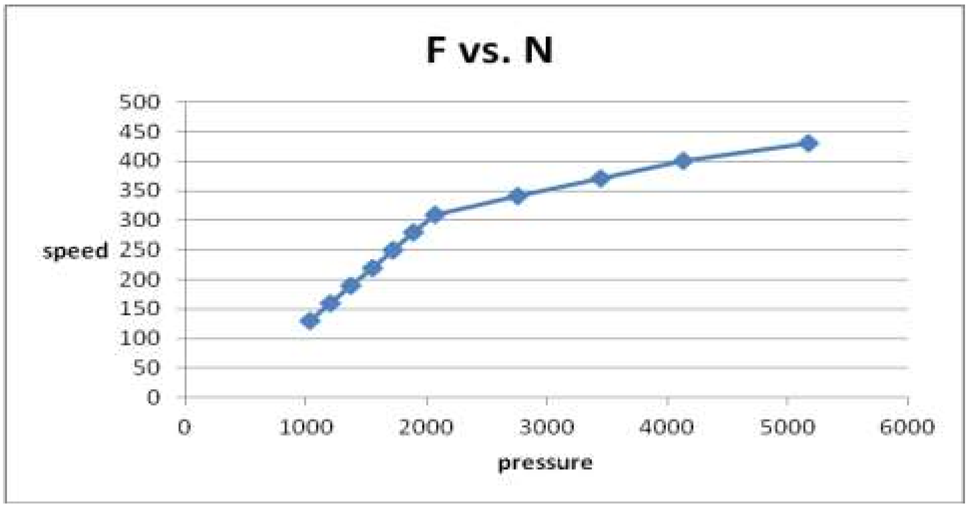

Figure 4. Variation of engine speed with pressure

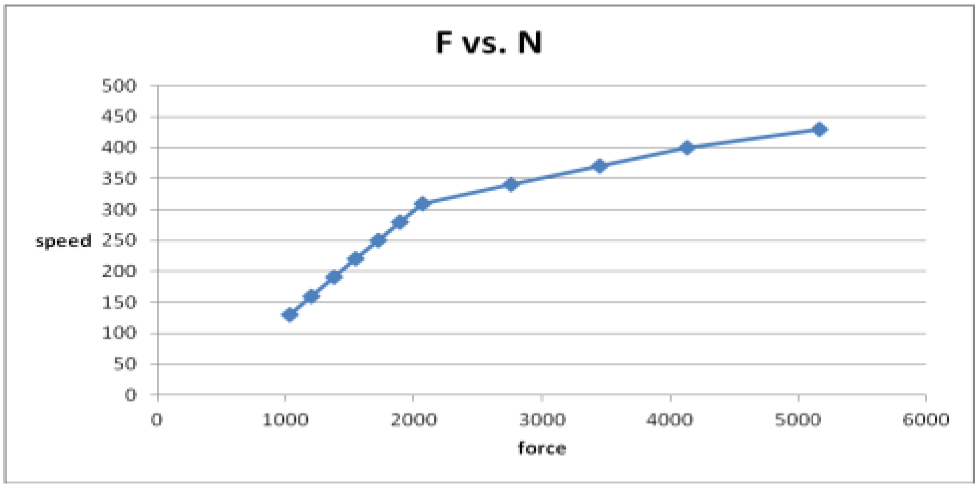

Figure 5. Variation of engine speed with load

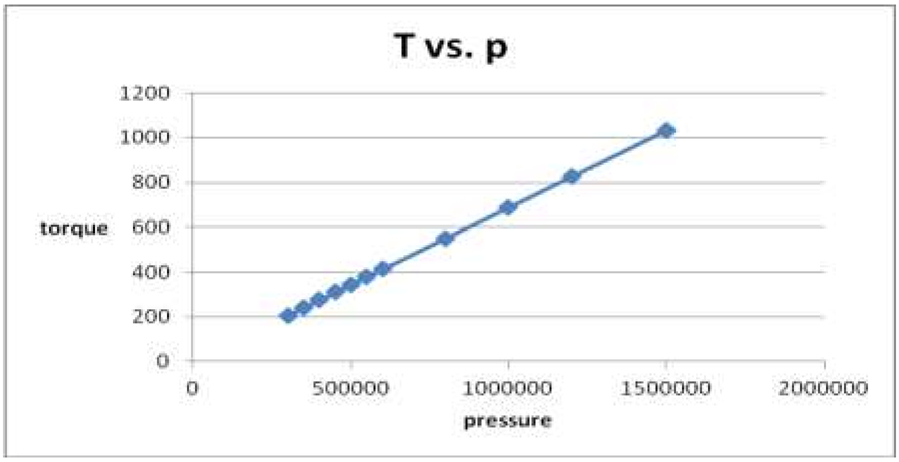

Figure 6. Variation of engine torque with pressure

The figure above shows the effect that is applied to the torque. It shows us through the figure that depending on the increase in the indicated power, the torque increases with it directly, and this indicates the existence of a direct relationship between them in addition to the existence of a direct relationship between the inlet pressure at the load with the energy that is referred to

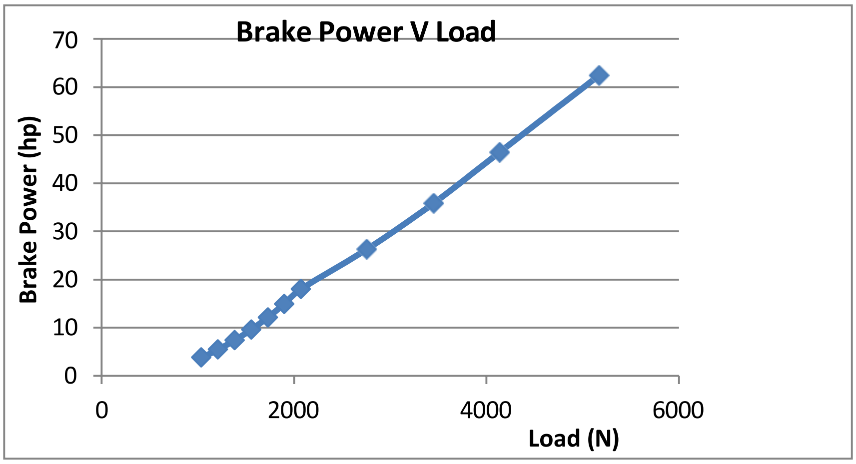

Figure 7. Variation of engine power with load

Figure 7 display the variation of engine brake power with load. From the above graph, it is concluded that brake power increases with the increase in load at particular inlet pressure. Because the brake power is a function of torque, and torque is directly proportional to load.

The below graph in figure 8 shows the effect of change in pressure on brake power and indicated power at 3 bar inlet pressure to 15 bar. It is concluded that brake power and indicated power is increases with different ranged due to different friction load and different engine speed because the variation of engine speed will change the friction load.

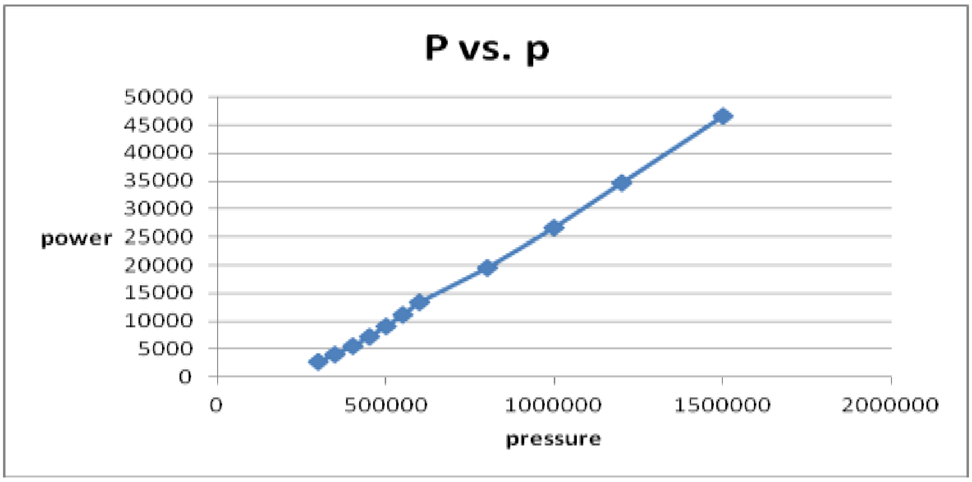

Figure 7. Variation of engine power with pressure

We conclude from the above result in the figure that

1. there is a direct relationship between the brake power with the increase in the load, in addition to the existence of the same type of relationship between the torque and the load
2. A direct relationship between brake power and load application
3. When there are different inlet pressures, we notice a difference in energy
4. There is a direct relationship between the output power and the load, meaning that the energy increases with the increase in the load

Conclusions

This work tests the performance of single cylinder compressed air engine at variable pressure applied to the engine. For testing the performance of engine, the important parameters are the power, inlet pressure, load, and the efficiency. As the inlet pressure increases, the output power increases as well as engine load. There is direct relationship between the output power and load. Using compressed air as an alternative source of power to the engine becomes very important due to its economy and zero-emission.

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