DESIGN AND DEVELOPMENT OF A COMPRESSED AIR MACHINE USING A COMPRESSED AIR ENERGY STORAGE SYSTEM

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ABSTRACT

The world is in an ongoing energy crisis. Fossil fuel reserves are in critical condition and the environment is being bombarded with all kinds of pollution. Therefore, it is easy to see why any technology that brings solutions to these problems is considered to be a bounty. Among the solutions is compressed air driven machine technology. This solution does not require any type of fossil fuel and is driven by compressed air as a fuel source. A general four stroke petrol engine (IC engine) is converted to a two stroke air compressed machine. The power output is examined by supplying compressed air from the air compressor. This method will demonstrate the concept of a green, environmentally-friendly new engine technology for future generations. The experimental results show a promising maximum efficiency percentage of 23.60 under 4.5 bar pressure under a maximum load condition.

Keywords: compressed air, compressed machine, power output.

INTRODUCTION

As civilization grows, transport becomes an essential part of life. The world population is increasing very fast and so is the number of vehicles, in order to meet the growing transportation needs. Engines are the main component of vehicles and all types of engines use fossil fuels to run the engine (Patel, Barot, Shah, & Sharma, 2011). Fossil fuels are a non-renewable energy source, whereas on the other hand compressed air is an alternative technology produced from freely available resources in the environment (Seela, Raoa, & Raoa, 2013). The sources of non-renewable energy in this world are limited. Nowadays the use of non-renewable energy such as petrol, diesel or gas has increased rapidly. All automobiles, industries, manufacturing companies, and power plants use fossil fuel to produce energy. If these fossil fuels are used so rapidly, then it is possible their reserves will not last. So it is high time to find alternate sources of energy. A new compressed air technology provides an environmentally-friendly solution for vehicles by using air as the source of fuel. The main advantage of this is that it is clean air technology and that it is effective for reducing global warming. Researchers have already carried out many noble works in the field of compressed air technology, all aimed at providing a renewable energy source for vehicles. A piston type compressed air technology used on a motor vehicle converts the four stroke engine to a two stroke engine with valve timings of -100 to 800, -100 to 1200, and -100 to 1500. However, its travel is limited to 5 km (Wang, You, Sung, & Huang, 2014). A compressed-air driven piston engine provides a resourceful idea for the development of compressed air technology with the inlet valve opening and closing at times of the valve angle being 150°, leaving 20° for isentropic expansion. After moving of the exhaust valve, the piston moves from 150° to 170°. Finally, the closing point for the exhaust is 340°. The flow rate of air is much lower and makes the engine output lower, while the angle of valve timing is shorter (Huang, Hu, Yu, & Sung, 2013). On the other hand, the piston type compressed air engine provides valve timings of for the intake valve and exhaust opening and closing of 0° to 100°, and 180° to 300°. The lifting of the intake valve and exhaust valve is 6 mm and 8 mm during operation time of the engine. The main limitation of the system is lower valve angles and lower mass flow rate (Yu, Cai, Shi, & Fan, 2014).The conversion of a petrol engine to a compressed air engine means the engine receives air instead of petrol, and experimentally the vehicle runs about 2 km/h. The original shape of the cylinder should be changed to a two sided lobed shape. The maximum operating pressure is 4500 psi at a weight of 18.5 kg. The main disadvantages of this system is that it requires too much compressed air for running a higher mileage and the extensive cooling of piston that is needed results in a longer operating time (Arjit Mourya, 2014). The compressed air technology for a single cylinder engine has thus far reached a maximum speed of 50 km/h (Mistry Manish K., 2012). The motor development international launches a new i-pod car that is being operated by compressed air originally and this system originates a new era of compressed air technology. Prominent milestones in the research of compressed air technology have been due to Motor Development (Creutzig, Papson, Schipper, & Kammen, 2009), where a totally pollution vehicle was produced reaching a speed of 110 km/h, and with a range of 200 km. The main modification of this engine was replacement of a conventional crankshaft with a modified split crankshaft. The manufacturers tried to increase the time of the piston in an ‘out crank’ position, enabling the degree of filling in

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the cylinder by compressed air for the conversion of work. This modification reduces the losses in the expansion system. The solution is pneumatic piston engines that contain split crank mechanisms which provide the place for the piston at the upper extreme point. The main disadvantage is that the split crankshaft and piston do not lie in the same plane. Further, accelerations occur during the expansion and compression strokes, and thus inertia forces effect the consumptions cooperating pairs and strength of construction. In a new modified Wankel rotary engine (Higashi *et al.*, 2009), a compressed air engine with lower parts is used, maintaining the original engine operation through the combustion process. The modified inlet and outlet valve timings of the exhaust port is 6° (Figure-1) before the closing of the exhaust manifold, with 226° of rotation of the engine crankshaft. This process is repeated with 5° cover phases of filling and emptying by a second outlet window. This type of modification has already been done in many engines such as the JAWA 50 Engine and the FIAT 126P 650 Engine (Szoka & Szpica, 2012). In this research, a design is proposed for the modification of a vertical, 4-stroke petrol engine (Figure-2) to a compressed air machine for the analysis of its performance parameters. This proposed design also compares the modified engine's performance to the conventional engine's one.

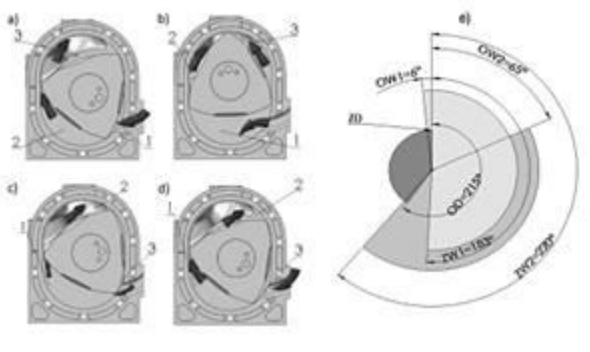

Figure-1. Modified Wankel engine: a, b, c, i d – phases of load Exchange – circular graph of timing phases (Szoka & Szpica, 2012).

Figure-2. Modified vertical, 4-cylinder, in-line, air cooled, diesel cycle engine.

MODELLING OF LOW COST AIR COMPRESSED ENGINE

The main objective of this study is to run an engine (in this case a petrol engine) by compressed air without any fuels such as diesel, petrol or natural gas. In this research, the opening and closure of both the inlet and exhaust valves are controlled by the revolution of the lobe as well as the camshaft. The camshaft gear is messed with crankshaft gear and is driven by crankshaft gear. As crankshaft gear's total revolution is 720 degrees, and the intake and exhaust valves open once, the camshaft gear must revolve 360 degrees while the crankshaft gear revolves 720 degrees. Therefore the camshaft gear must be larger than the camshaft gear, and the number of teeth of the camshaft gear must be twice the number of teeth of the crankshaft gear. For this reason, the camshaft rotates 360 degrees while the crankshaft rotates 720 degrees, and this is the method of opening the intake and exhaust valves once while the crankshaft rotates through two revolutions. Suction and power and Exhaust stroke. In the power stroke, the compressed air is supplied from the compressed air tank through the intake manifold with a very high velocity and force (pressure) because when the air is compressed, its volume decreases but its pressure and temperature increases. For a continuous running operation and fast response, air flow is simply controlled by a proper cam design mechanism in many response CAE systems (Yu, Shi, & Cai, 2014). Here, compressed air comes through a narrow pipe (intake manifold) to a bigger space (engine cylinder), resulting in a big thrust force on the piston. In other words, it pushes the piston with a high velocity and as a result, the piston moves downwards (TDC to BDC). As the piston begins to move downwards and reaches the BDC, a power stroke is produced. With this power stroke engine, the flywheel absorbs some energy. When the piston moves upwards due to the release of absorbed energy from the flywheel and kinematic momentum of the flywheel, the exhaust valve opens and air exits the engine cylinder. This is the exhaust stroke. From the above discussion, it is seen at the beginning that the inlet valve opens and compressed air enters the engine cylinder, pushing the piston downwards (TDC to BDC) and causing the cranks to begin revolving. When the piston is at BDC, the crank completes its 180 degree revolution. Subsequently, the piston begins to move upwards (BDC to TDC), causing the exhaust valve to open and the compressed air to exit from the cylinder. The crank then finishes another 180 degree revolution and so completes one total revolution (360). Hence in this case, both the intake and exhaust valves open and close once while cranks and crank shaft revolve 360°. The opening and closing of the valve is controlled by the lobe, which is attached to the camshaft. The camshaft gear is driven by the crank shaft gear. In the case of the conventional engine, the crankshaft gear is smaller than the camshaft gear. Let the teeth of crankshaft gear be T1, and teeth of camshaft gear be T2. As discussed earlier, the relation T2 = 2T1 is derived, so that 2N1 = N2. Therefore, when crank shaft gear revolves 720°, the camshaft gear revolves 360°

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and from every 720° of rotation of the crankshaft, a single power stroke is obtained. However, when the engine is run by compressed air, one power stroke occurs every 360° of rotation of the crankshaft. An arrangement was made to get a single power stroke every 360° of rotation of the crankshaft by changing the camshaft lobe shape. The normal lobe shape is an oval or egg shape (Figure-3 and Figure-4), but the lobe shape was changed to an eye shape (Figure-3 and Figure-4).

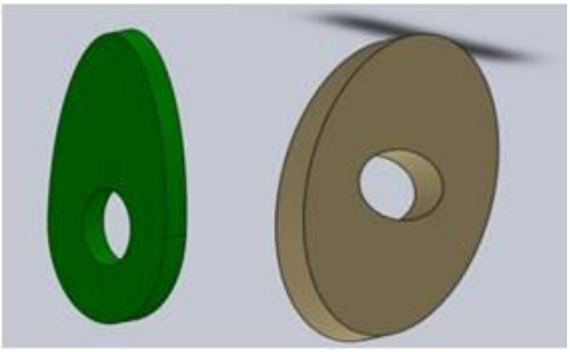

Figure-3. General egg shape cam and modified eye shape cam.

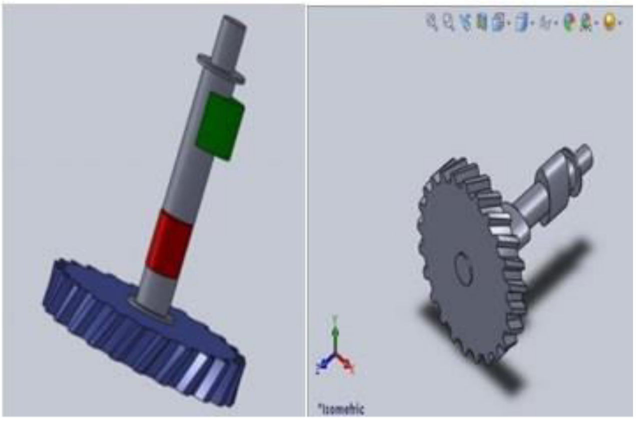

Figure-4. General camshaft with cam lobe and camshaft gear; modified camshaft with cam lobe and camshaft gear.

Due to change of the camshaft lobe shape, the intake and exhaust valves opened twice during the camshaft's revolution of 360°. From the relation 2N1 = N2, it is clear that if the crankshaft gear rotated 20°, the camshaft would rotate 10°. Hence, when the camshaft gear rotates from 0° to 90°, the inlet valve opens once and the piston moves from TDC to BDC, giving one power stroke. Again, when the camshaft gear rotates from 90° to 180°, the inlet valve closes and the exhaust valve opens once. Then when the crankshaft gear rotates from 180° to 360°, the piston moves back from BDC to TDC, giving an exhaust stroke. The same procedure continues when camshaft gear rotates from 180° to 360° and again when it rotates from 360° to720°. Therefore two power strokes occur during the camshaft's total rotation of 360° and the crankshaft's total rotation of 720°. One power stroke occurs every 360° of rotation of the crankshaft. Another small modification was made at the air intake path. A narrow pipe was used as the intake manifold for the air intake, which would be attached correctly at the path of the air intake into the engine cylinder. A compressed air controlling valve was used, which was attached at the beginning of the pipe coming from the compressed air tank. The function of this valve was to regulate the entering of compressed air into the engine.

EXPERIMENTAL SETUP

Compressed air is used as a high pressure energy source for this experiment. Compressed air has a tendency to increase or decrease the inside temperature of compressible gas of the engine (Zhang *et al.*, 2014). Compressed air is an potential emerging technology which provides increased efficiency of energy for the primary user by reducing gaseous emissions (Li, Wang, Li, & Ding, 2012).The main performance parameter for indicating any engine's performance are: air fuel ratio, brake power, brake thermal efficiency and specific fuel consumption (Mattarelli, Rinaldini, & Cantore, 2013). For a low cost air engine, the engine is run only by compressed air. Therefore, only the brake power and efficiency were needed to indicate this compressed air engine's performance. Torque was needed to measure brake power. An arrangement was made to measure the torque of the engine. The engine was bound strongly to a wooden bed (Figure-5) so that it could not vibrate during running. A pressure gauge was connected near the inlet manifold to measure the pressure of the entering air. A belt was coupled with the output shaft. A weight dial gauge was set with the bed structure and the other end of the belt was connected to the weight dial gauge. When the engine was running, force was applied to the string. The weight dial gauge indicates the amount of force which was applied on the string. The perpendicular distance from the point of application of force was applied on the string. The perpendicular distance from the point of application of force was measured carefully. Torque is the product of force with the perpendicular distance from the point of application of the force. Hence, multiplication of force with the perpendicular distance was done. The RPM of the flywheel was measured using a tachometer. From the RPM and torque, engine brake power was calculated.

Figure-5. Experimental setup of a vertical, 4-cylinder, in-line, air cooled, diesel cycle.

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RESULTS AND DISCUSSION

An advanced modified design of an air compressed machine and proper installation for an individual test operation was carried out at Rajshahi University of Engineering And Technology, Bangladesh. Testing was done for a maximum load of 44.54 N. In this experiment, operational time and torque of the modified air compressed machine were recorded and measured by a stop watch and a digital taco meter. The rating of the air compressed machine performance during test operation shows data such as maximum speed, brake power and highest efficiency of the machine. Graph 1 shows the different results of speed in comparison with different torques of the air compressed machine, in which a different supply of air pressure was given from the compressor. A low speed (rpm) of 1254 was achieved by supplying 2 bar pressure with a maximum brake power of 1170 kW under a load of 44.54 N, shown in Figure-7. On the other hand, the maximum efficiency of this air compressed machine was 53.42 %, with the addition of 2 bar air pressure and after maximum load addition, the highest efficiency of this air compressed machine was 23.60% after adjusting for a maximum flow rate of 4.5 bar pressure, shown in Figure-9. In Figure-8, a comparison of air pressure (in bars) and efficiency from different air pressures is shown. The specifications of this engine is given in Table-1.

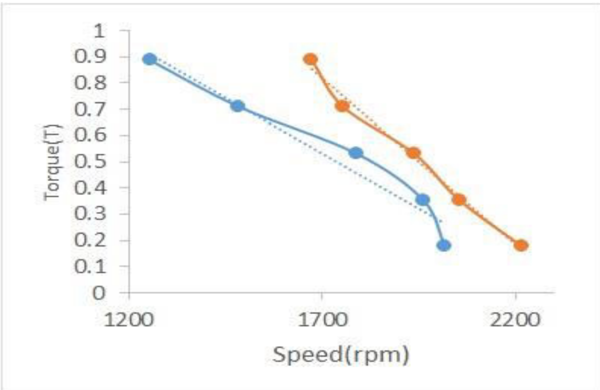

Figure-6. Comparison of speed and torque from different air pressures.

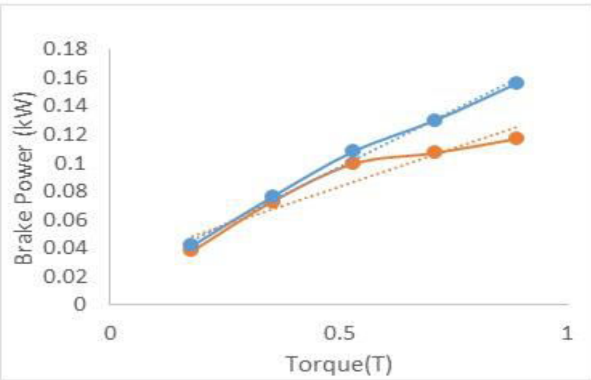

Figure-7. Comparison of brake power (kW) and torque from different air pressures.

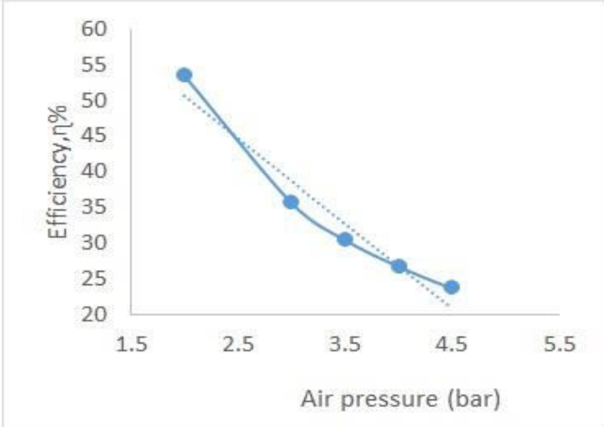

Figure-8. Comparison of air pressure (bars) and efficiency from different air pressures.

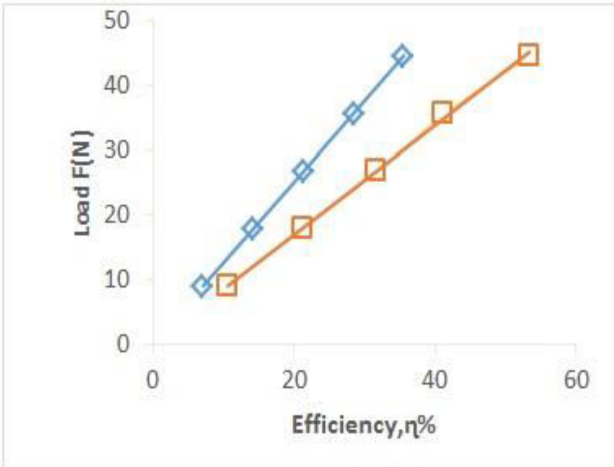

Figure-9. Comparison of efficiency and load from different intake valve timings up to 4.5 bars of air pressure.

CONCLUSIONS

In the field of automotive technology, it is revolutionary for the future design of hybrid fuel air engines to have a compressive air engine. Few automobile companies are already trying to design an 'air car' for future generations, such as MDI international in France, Tata motors in India and Engine Depiero in Australia.In this experiment, the main objectives were to design, modify and run a petrol engine by compressed air without any fuel. For this purpose, some changes of the engine were done involving camshaft lobe modification. A test operation of this engine was carried out, demonstrating the feasibility of this engine for vehicle applications. However, some drawbacks showed during the experiment such as low pressure compressor air supply. Producers of motor vehicles will benefit by using air compressed machines, especially when integrated with conventional IC engine.

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