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(Review Article)

Design and fabrication of air brake system using IC engine exhaust gas

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Abstract

The aim of this project is to design and fabricate an Air Brake System based on Exhaust gases of an IC engine. The main objective is to reduce the workloads of the engine drive to operate the air compressor, because the compressor is not operated by the engine drive. A turbine is placed in the path of exhaust from the engine. The turbine is connected to a dynamo by means of coupling, which is used to generate power. Depending upon the airflow the turbine will start rotating, and then the dynamo will also start to rotate. A dynamo is a device which is used to convert the kinetic energy into electrical energy. The generated power can be stored in the battery and then this electric power has loaded to the DC compressor. The air compressor compresses the atmospheric air and it stored in the air tank and the air tank has pressure relief valve to control the pressure in the tank. The air tank supplies the compressed pneumatic power to the pneumatic actuator through solenoid valve to apply brake. The pneumatic actuator is a double acting cylinder which coverts pneumatic pressure into linear motion. The generated electric power from the turbine used to compress the air in the DC compressor then supplied the pneumatic power to the air braking system. The exhaust gas was effectively utilized to perform the air braking system in addition to the conventional braking system and found the improvement in the braking performance.

Keywords: Air Brake; Exhaust; Pneumatic actuator; Dynamo; Solenoid valve; Kinetic energy

1. Introduction

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction.

Most brakes commonly use friction between two surfaces pressed together to convert the kinetic energy of the moving object into heat, though other methods of energy conversion may be employed. For example, regenerative braking converts much of the energy to electrical energy.

Friction brakes on automobiles store braking heat in the drum brake or disc brake while braking then conduct it to the air gradually. When traveling downhill some vehicles can use their engines to brake.

An air brake or, more formally, a compressed air brake system, is a type of friction brake for vehicles in which compressed air pressing on a piston is used to apply the pressure to the brake pad needed to stop the vehicle. Air brakes are used in large heavy vehicles, particularly those having multiple trailers which must be linked into the brake system, such as trucks, buses, trailers, and semi-trailers in addition to their use in railroad trains [1].

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2. Material and methods

2.1. Engine

As shown in figure 2.1, an engine is a machine designed to convert chemical energy into useful mechanical motion. Heat engines, including internal combustion engines and external combustion engines (such as steam engines) burn a fuel to create heat, which then creates motion. The internal combustion engine is classified into two types and they are diesel engine and petrol engine. Originally, an engine was a mechanical device that converted force into motion [3].

In this project, we use 59.9cc Spark Ignition four stroke single cylinder engine. it consists of a piston that moves within the cylinder fitted with two valves. The distance moved in one direction is called stroke and the cylinder diameter is bore. The piston is said to be at the top dead centre position the volume of the cylinder is minimum.

Figure 1 IC Engine

2.2. Air brake system

Air brake systems are typically used on heavy trucks and buses. The system consists of service brakes, parking brakes, a control pedal, and an air storage tank. For the parking brake, there's a disc or drum brake arrangement which is designed to be held in the 'applied' position by spring pressure. Air pressure must be produced to release these "spring break" parking brakes. For the service brakes (the ones used while driving for slowing or stopping) to be applied, the brake pedal is pushed, routing the air under pressure (approx. 100–120 psi or 690–830 kPa or 6.89-8.27 bar) [2] to the brake chamber, causing the brake to be engaged. Most types of truck air brakes are drum brakes, though there is an increasing trend towards the use of disc brakes in this application. Figure 2.2 shows the nomenclature of a typical air brake system.

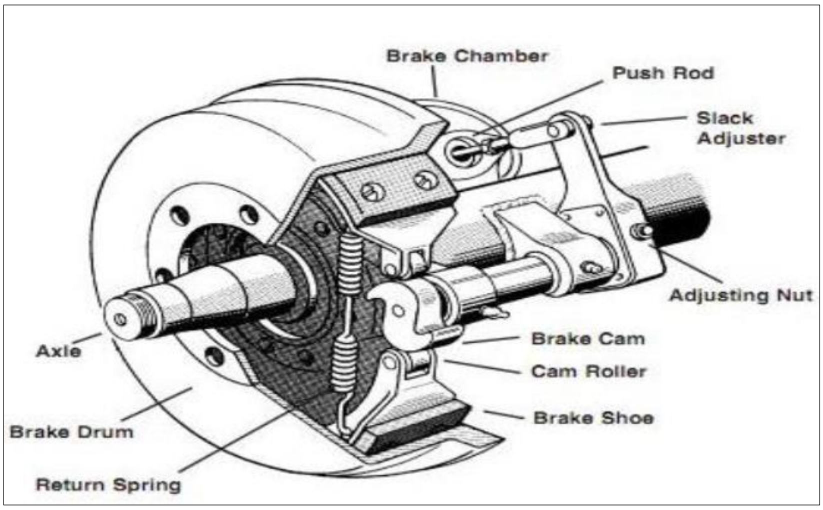

Figure 2 Air brake system

2.3. Air compressor

Figure 2.3 shows an air compressor which is a device that converts power (using an electric motor, diesel or gasoline engine, etc.) into potential energy stored in pressurized air (i.e., compressed air). By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When tank pressure reaches its engineered upper limit the air compressor shuts off. The compressed air, then, is held in the tank until called into use. The energy contained in the compressed air can be used for a variety of applications, utilizing the kinetic energy of the air as it is released and the tank depressurizes. When tank pressure reaches its lower limit, the air compressor turns on again and re-pressurizes the tank.

An air compressor must be differentiated from an air pump which merely pumps air from one context (often the surrounding environment) into another (such as an inflatable mattress, an aquarium, etc.). Air pumps do not contain an air tank for storing pressurized air and are generally much slower, quieter, and less expensive to own and operate than an air compressor. The compressor that we are using in the project has a capacity to withstand 300psi of pressure.

Figure 3 Air compressor

2.4. Pneumatic cylinder

As shown in figure 2.4, a pneumatic cylinder(s) (sometimes known as air cylinders) are mechanical devices which use the power of compressed gas to produce a force in a reciprocating linear motion.

Like hydraulic cylinders, something forces a piston to move in the desired direction. The piston is a disc or cylinder, and the piston rod transfers the force it develops to the object to be moved. Engineers sometimes prefer to use pneumatics because they are quieter, cleaner, and do not require large amounts of space for fluid storage.

Because the operating fluid is a gas, leakage from a pneumatic cylinder will not drip out and contaminate the surroundings, making pneumatics more desirable where cleanliness is a requirement.

Figure 4 Pneumatic cylinder

2.5. Solenoid valve

A solenoid valve is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid: in the case of a two-port valve the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports. Multiple solenoid valves can be placed together on a manifold.

Solenoid valves are the most frequently used control elements in fluidics. Their tasks are to shut off, release, dose, distribute or mix fluids. They are found in many application areas. Solenoids offer fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design [5].

Besides the plunger-type actuator which is used most frequently, pivoted-armature actuators and rocker actuators are also used.

Figure 5 Solenoid valve

2.6. Battery

A rechargeable battery, storage battery, secondary cell, or accumulator is a type of electrical battery which can be charged, discharged into a load, and recharged many times, as opposed to a disposable or primary battery, which is supplied fully charged and discarded after use. It is composed of one or more electrochemical cells. The term "accumulator" is used as it accumulates and stores energy through a reversible electrochemical reaction. Rechargeable batteries are produced in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of electrode materials and electrolytes are used, including lead–acid, nickel–cadmium (Ni-Cd), nickel-metal hydride (NiMH), lithium-ion (Li-ion), and lithium-ion polymer (Li-ion polymer). Figure 2.6 shows a typical rechargeable battery.

Figure 6 Battery

2.7. Pneumatic pipes

Pneumatic tubes (or capsule pipelines; also known as pneumatic tube transport or PTT) as shown in figure 2.7, are systems that propel cylindrical containers through networks of tubes by compressed air or by partial vacuum. They are used for transporting solid objects, as opposed to conventional pipelines, which transport fluids. Pneumatic tube networks gained acceptance in the late 19th and early 20th centuries for offices that needed to transport small, urgent packages (such as mail, paperwork, or money) over relatively short distances (within a building, or at most, within a city). Some installations grew to great complexity, but were mostly superseded. In some settings, such as hospitals, they remain widespread and have been further extended and developed in the 21st century. We have used 8mm pneumatic pipes currently for the passage of air into the cylinder in order to actuate the movement.

Figure 7 Pneumatic pipes

2.8. Dynamo

Dynamo is an electrical generator. This dynamo produces direct current with the use of a commutator. Dynamo was the first generator capable of generating power in the industries. The dynamo uses rotating coils of wire and magnetic fields to convert mechanical rotation into a pulsing direct electric current. A dynamo machine consists of a stationary structure, called the stator, which provides a constant magnetic field, and a set of rotating windings called the armature which turn within that field. On small machines the constant magnetic field may be provided by one or more permanent magnets, larger machines have the constant magnetic field provided by one or more electromagnets, which are usually called field coils. The commutator was needed to produce direct current. When a loop of wire rotates in a magnetic field, the potential induced in it reverses with each half turn, generating an alternating current. However, in the early days of electric experimentation, alternating current generally had no known use. The few uses for electricity, such as electroplating, used direct current provided by messy liquid batteries. Dynamos were invented as a replacement for batteries. The commutator is a set of contacts mounted on the machine's shaft, which reverses the connection of the windings to the external circuit when the potential reverses, so instead of alternating current, a pulsing direct current is produced.

2.9. Methodology

An IC engine powered by petrol is used to produce exhaust gas. Here we are placing a turbine in the path of exhaust from the silencer. The turbine is connected to a dynamo, which is used to generate power.

Depending upon the airflow the turbine will start rotating thus rotating the dynamo. A dynamo is a device which is used to convert the kinetic energy into electrical energy. The generated electric power is stored in a battery after rectification. Thus, the stored electrical power is use to run the DC compressor. The compressor compresses the air from the exhaust. When the brake is applied the 5/2 solenoid valve is activated and it allows the air to actuates the pneumatic cylinder thus the brake is applied [1]. Figure 2.9 shows the block diagram of the workflow of the project.

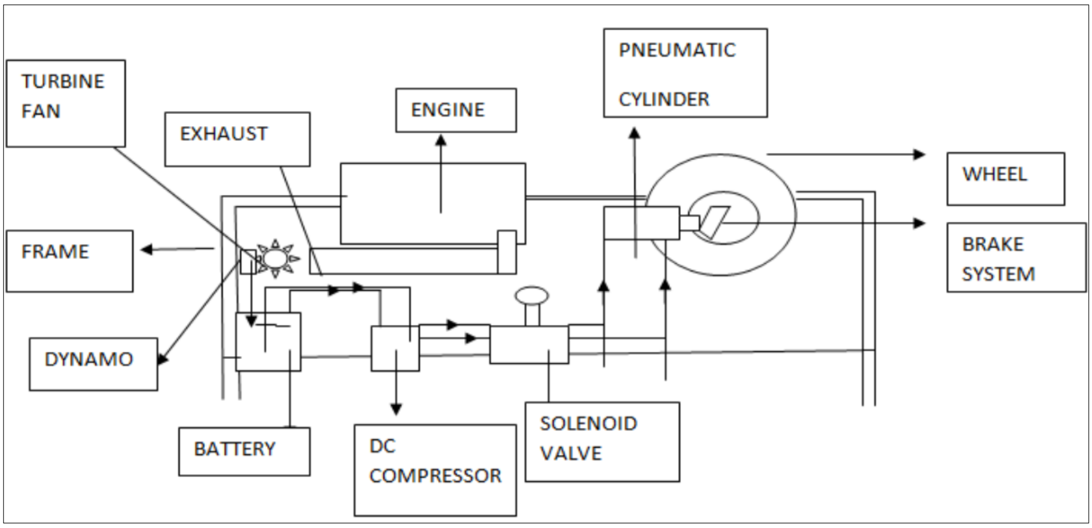

Figure 8 Block diagram

3. Results and discussion

The temperature and pressure increase when the load is increased depending upon the operating conditions. Pressure and temperature will vary depending on load conditions as well as voltage will vary. Therefore, the voltage should be checked by using a multi-meter. The voltage is measured by using a multi-meter during variable condition. The below calculation is calculated based on the literature survey. The battery is used for charging and it is tested. Voltage is measured by using a voltmeter. The current is measured by ammeter while energy is recovered from the exhaust gas. The area of turbine is measured and calculated on the basis of design criteria. The power available at the turbine is calculated by below formula.

Formula

- Swept Area, $A = \pi r^2$
- R = radius of turbine = 27.5x10^{-3}m
- Velocity of the Turbine = (π x D x N)/60
- Were,
- D= turbine diameter = 55x10^{-3}m
- N= rpm
- Cp = power co-efficient
- Turbine power,
- P= $\left(\frac{1}{2}\right)$ x Density x (Velocity) 3 x Cp x Area

3.1. Model Calculation

Swept area (turbine),

$$A = \pi r^2$$

$$= \pi \text{ x } (27.5\text{x}10^{-3})^2$$

$$=2.37\text{x}10^{-3} m^2$$

Velocity of the turbine, Velocity

$$= \frac{\pi \text{ x D x N}}{60}$$

$$= \frac{\pi \text{ x } 55\text{x}10^{-3}\text{x } 95}{60}$$

= 0.2735 m/s

Power available at the turbine

$$= (\frac{1}{2}) \text{ x Density x Area x (Velocity) 3 x cp} = 0.5 \text{ x} 1.25 \text{ x } 2.37\text{x}10^{-3}\text{x } (0.2735) \text{ 3 x } 0.5 = 1.51\text{x}10^{-5}\text{watts}$$

4. Conclusion

The above calculation show the result of our project i.e. in the 1st trial at RPM 1500 the dynamo rotated at the speed of an RPM 95 And power generate was $1.51\text{x}10^{-5}$watts. We can conclude that whenever RPM of the engine is increased RPM of the dynamo will also increase and power generation will be more. We can also recover the energy that is being discharged from the exhaust gas without any change in performance.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors certify that they have No Conflict of Interest in the subject matter or materials discussed in this manuscript.

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