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Design of air-brake system adopting engine exhaust

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Abstract
The investigation was carried out to create an exhaust gas-based air brake system. The aim of the study was to reduce the workload on the engine drive. A dynamo used to produce electricity was coupled to a turbine that was installed in the engine's exhaust stream. The turbine will begin rotating based on the airflow, and then the dynamo will follow. The mechanism used to transform kinetic energy into electrical energy is known as a dynamo. The battery can be used to store the generated power, which is subsequently loaded into the DC compressor. The ambient air is compressed by the air compressor and stored in an air tank with a pressure relief valve to regulate tank pressure. In order to apply the brakes, the pneumatic actuator receives compressed pneumatic power from the air tank via a solenoid valve. The pneumatic actuator, which converts pneumatic pressure into linear motion, is a double-acting cylinder. Automobile friction brakes progressively transfer braking heat from the drum or disc brake to the air after storing it during braking. Some cars have the ability to brake using their engines when going downhill. In a modern car with hydraulic brakes, pressing the brake pedal against the master cylinder causes a piston to push the brake pad against the brake disc, slowing the wheel. Similar effects occurred when using a brake drum since the cylinder forces the brake shoes up against the drum, slowing the wheel in the process.

Keywords: Two stroke engine, exhaust gas, pressure relief valve, braking system, engine, cylinder

Introduction

A mechanical brake is a device that prevents motion by sapping the power from a moving system. It is used to slow down or stop a moving vehicle, wheel, or axle, or to prevent its motion. Friction is most frequently utilised to achieve this. Although other methods of energy conversion may be used, the majority of brakes typically use friction between two surfaces that are pressed together to convert the kinetic energy of the moving object into heat (Srivatsan *et al*., 2009) [1]. Regenerative braking, for instance, transforms a significant portion of the energy to electrical energy (Bowlin, 2006) [2]. Other processes transform kinetic energy into potential energy in forms that can be stored, like pressurised oil or air. In the brake disc, fin, or rail, eddy current brakes use magnetic fields to transform kinetic energy into electric current, which is then transformed into heat. Even more braking techniques even change the form of kinetic energy, for instance, by transferring it to a rotating flywheel (Ishida and Hongguang, 1994) [3]. The majority of the time, brakes are applied to spinning axles or wheels, but they can also be applied to other surfaces, such as the surface of a flowing fluid (flaps spread into the air or water). Some vehicles use a combination of braking systems, such as drag racing cars that use both wheel brakes and a parachute or aeroplanes that land using both wheel brakes and drag flaps that are raised into the air. Automobile friction brakes progressively transfer braking heat from the drum or disc brake to the air after storing it during braking. Some cars have the ability to brake using their engines when going downhill. In a modern car with hydraulic brakes, pressing the brake pedal against the master cylinder causes a piston to push the brake pad against the brake disc, slowing the wheel (Pilavachi, 2000) [4]. Similar effects occur when using a brake drum since the cylinder forces the brake shoes up against the drum, slowing the wheel in the process.

A variety of irreversible engine operations prevent it from achieving a well-balanced efficiency. High temperature differences, turbulent UID motions, and significant heat transfers from the UID to the piston crown and cylinder walls are all results of the gases inside the cylinder expanding quickly. In order to prepare the cylinder for various activities, the quick expansion generates exhaust gases with pressure that exceeds atmospheric level and is expelled (Pilavachi, 2000) [4]. The heated gases created by the combustion process can then be easily directed through the exhaust valve and manifold by doing this.

To boost the engine's work output. We are able to use a significant amount of the depleted gas energy stream. As a result, several nations have implemented rules that require greater efficiency, reduced fuel consumption due to improved fuel economy, emitting fewer exhaust emissions, and lowering noise pollution. According to one estimate, the amount of waste heat created by a petrol engine during the thermal combustion process that escapes to the environment through the exhaust pipe can reach up to 30 to 40 per cent (Ramadhas, 2006) [5]. The wheels and other accessories with technical descriptions will also be driven with 12–25 percent of the fuel's potential energy.

From a socioeconomic point of view, the world's population growth rate suggests that there will likely be a rise in global energy demand because energy consumption is strongly correlated with economic growth and population size in a nation. In modern automobile engines, the exhaust gas is a significant source of thermal energy. In a car, waste heat accounts for two-thirds of the energy from combustion, 40% of which is wasted as hot exhaust gas. the most recent innovations and technology in internal combustion engine (ICE) exhaust gas waste heat recovery.

The internal combustion engine's exhaust gas is where a significant quantity of energy is lost. Investigations revealed that just 10.4% of fuel energy was transformed into productive work, and around 27.7% of that energy was wasted thermally as exhaust gas. According to the second law, 9.7% of the energy from the fuel is turned into brake power (Subramanian, 2006) [6]. And 8.4 percent of the exhaust 18.6% of the total combustion energy was stated to be the value of exhaust gases in another study. Additionally, it was discovered that installing a heat exchanger to recover engine exhaust energy could result in fuel savings of up to 34%.

A significant amount of energy is lost from internal combustion engines through the exhaust gas in the form of heat. Additionally, research shows that only 10.4% of fuel energy is converted into useful work, and that about 27.7% of thermal energy is lost through exhaust gas (Saidur, 2012) [7]. Fuel energy is transformed to brake power at a rate of around 9.7% and to exhaust at a rate of about 8.4%, according to the second law analysis of fuel. Exhaust gas value was reported to be 18.6% of total combustion energy in another study.

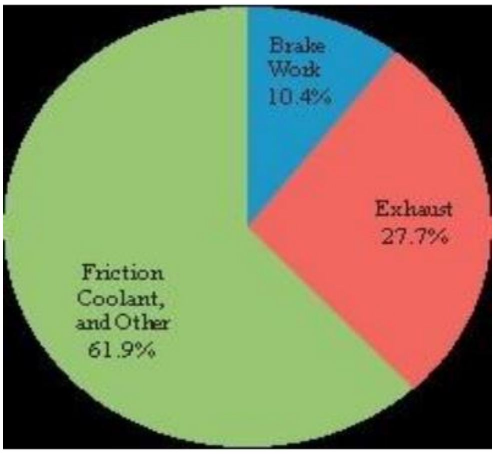


Fig 1: Energy Distribution in Air Brake System Using Exhaust Gas

Utilising combustion engine exhaust waste heat is one technique that might work. Waste heat recovery using a thermoelectric generator makes this possible. The temperature differential is transformed into useable voltage by a thermoelectric generator, which can then be utilised to power auxiliary systems like air conditioners and small automotive electronics (Saidur, 2012) [7]. Even yet, the alternator's size that uses shaft power can be decreased. The same amount of driving energy would be saved if about 6% of exhaust heat could be transformed into electrical power. Since fuel consumption can be reduced by about 10%, AETEG systems can be profitable for the auto industry.

Methodology

Two Stroke Petrol Engine

The two-stroke petrol engine is chosen in the suggested model due to its mechanical simplicity, light weight, high power to weight quantitative ratio, and ability to complete a full cycle in every two piston strokes as opposed to four in a four-stroke petrol engine(Yang, 2014) [8]. The fuel tank will provide the engine with pressurised petrol, and the engine will transform the chemical energy into power as shown in the figure by the movement of the piston during its up- and down-strokes.

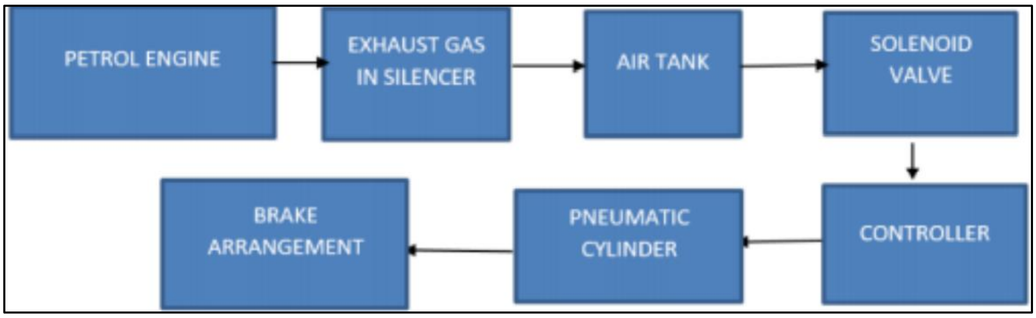


Fig 2: Flow Chart of Air Brake System Using Exhaust Gas

Turbine and Dynamo

The purpose of the turbine is to rotate; in this case, we are positioning the turbine in the path of the exhaust flow, causing it to begin rotating and causing the dynamo to rotate as well (Rajoo, 2017) [9]. An instrument called a dynamo metre transforms kinetic energy into electrical energy. Dynamometers serve a variety of purposes other than determining the torque or power characteristics of the machine being tested (Fazlizan, 2015) [10]. Dynamometers can be used as part of a testbed for a number of engine development tasks, including the calibration of engine management controllers and in-depth analyses of combustion behaviour and tribology. Dynamometers are typically used for simple power and torque measurements.

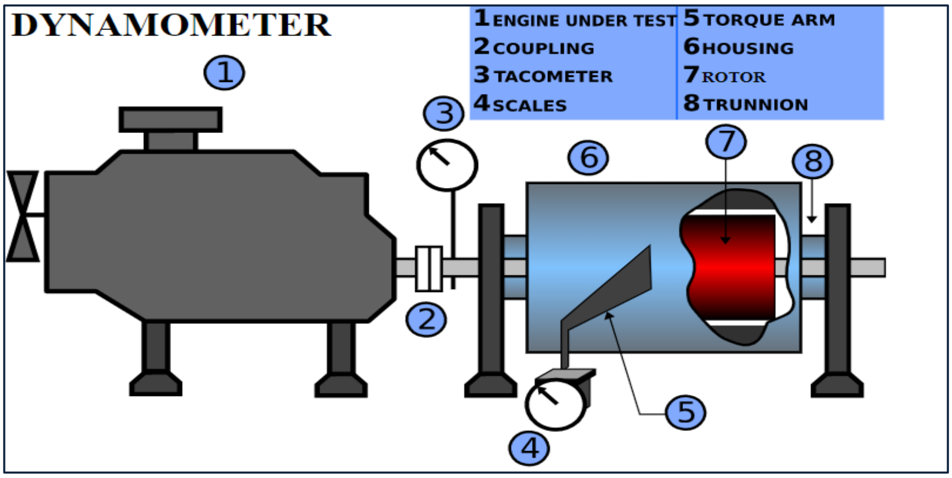


Fig 3: Dynamometer and its Parts

Dryer

In the suggested model, the dryer's job is to remove any moisture from the ambient air in order to prevent corrosion on the air tank and other objects. Additionally, before compressor discharge air reaches the air brake reservoirs, the majority of liquid and water vapour are removed (Nivethan, 2016) [12]. This prevents air-line freeze-ups by ensuring that the air brake system only receives clean, dry air.

Fig 4: Air Dryer

Pneumatic Cylinder (Double Acting Single Piston)

It comprised of a cylinder in which, like a single acting cylinder, a piston with a single piston rod reciprocates. The bore's surface is extremely well-finished and has tight tolerances (Nivethan, 2016) [12]. A and B ports are both present. Due to the fluid's pressure force, the pressurised fluid enters through port A. From Left Dead Centre (LDC) to Right Dead Centre (RDC), the piston moves. The flow through port A ceases when the piston hits the RDC.

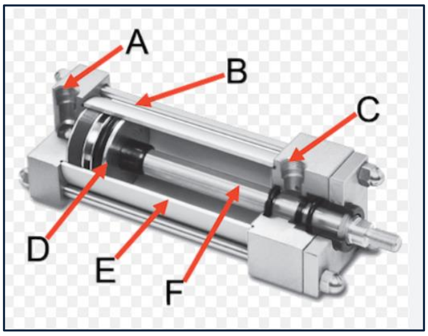
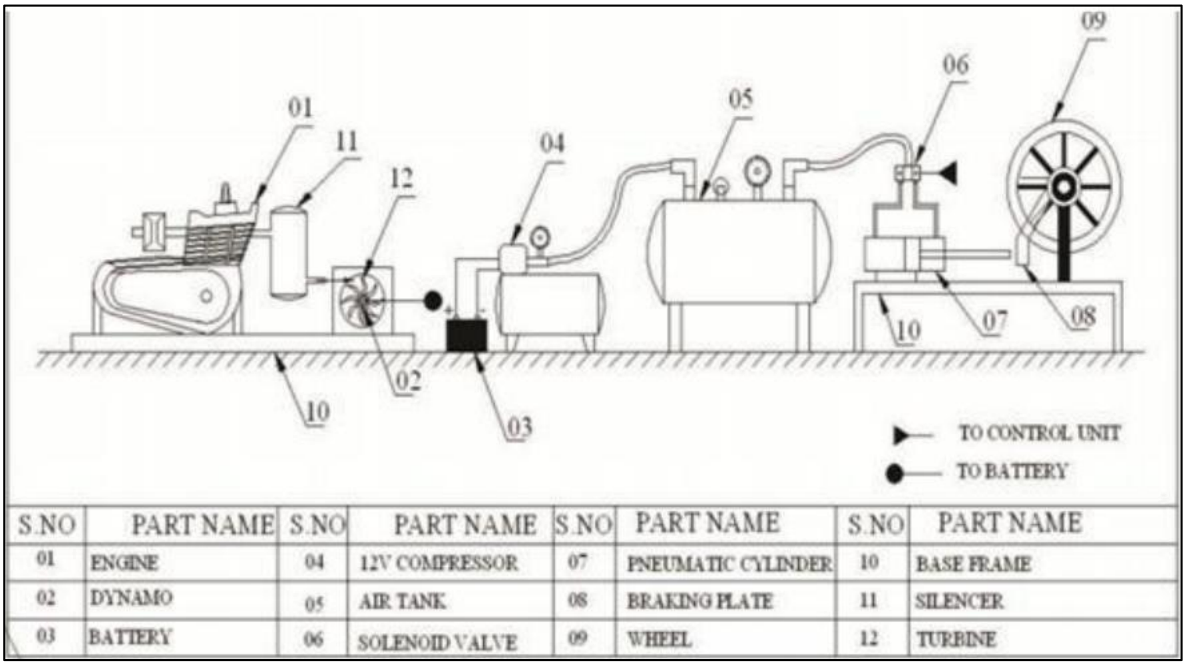


Fig 5: Pneumatic Cylinder



S.NO	PART NAME	S.NO	PART NAME	S.NO	PART NAME	S.NO	PART NAME
01	ENGINE	04	12V COMPRESSOR	07	PNEUMATIC CYLINDER	10	BASE FRAME
02	DYNAMO	05	AIR TANK	08	BRAKING PLATE	11	SILENCER
03	BATTERY	06	SOLENOID VALVE	09	WHEEL	12	TURBINE

Fig 6: Schematic Diagram of Working Parts in Air Braking System

Figure.6 above illustrates how the air braking system from exhaust gas operates. A turbine that functions as a dynamo is powered by exhaust gas, and because the turbine fan is composed of a lightweight material, it can operate with very little air pressure. Thus, the turbine generates millivolts of charge, which is displayed by an LED. To have a one-way flow of current, a diode is attached to the dynamo's circuit, which is coupled to a battery. As a result, power from a battery is used to power a 12-volt DC compressor, which in turn activates an air solenoid valve (Fazlizan, 2015) [11]. The solenoid valve serves as the braking system's switch. As a result, a drum brake's braking capability is provided by utilising a pneumatic cylinder. Air brakes are particularly effective since they simply need to be activated by a solenoid valve, which needs little force in comparison to other braking systems.

Experimental Setup

The wheels with exhaust gas braking are joined to the two-stroke gasoline engine. To keep the exhaust gas under the necessary pressure, a pressure tank is used. By altering the valve, also known as a flow control valve, the braking speed can be changed.

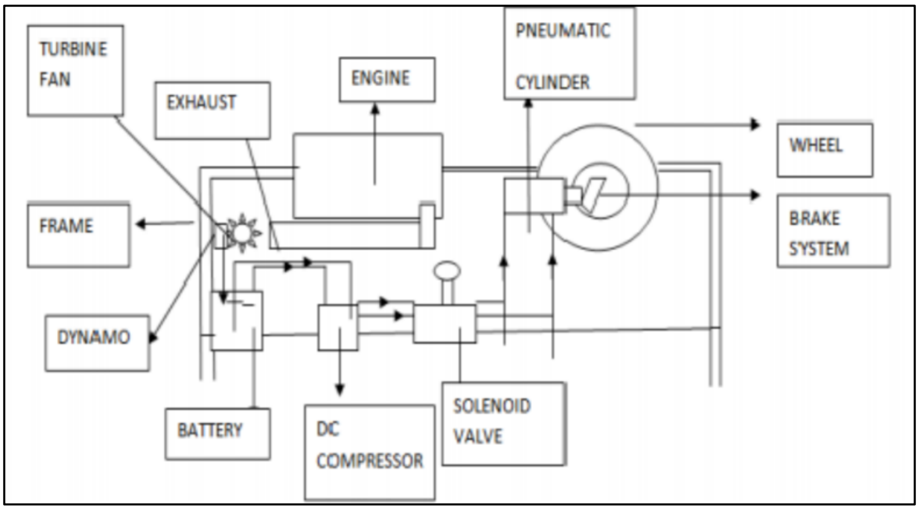


Fig 7: 2D View of Air Brake System Using Exhaust Gas

The pressure tank is where the exhaust gas is kept while the engine is running. The pressure relief valve will open if the tank's pressure rises above a specified threshold. It is utilised to keep the pressure in the pressure tank at the necessary level. Control circuit receives the signal when the brake is applied and opens the solenoid valve. The pneumatic cylinder is activated by exhaust gas that has been stored in the pressure tank. The actuator's other end is attached to the brake lever (Srivatsan, 2009) [1]. The brake is applied to the wheels when the brake lever is operated by the pneumatic cylinder. The cam mechanism is attached to the brake pad. Lever turns the cam, which results in the brake show opening. If not needed, the brake lever will return to its original position. When not needed, DCV is employed to retract the pneumatic cylinder.

Results and Discussion

The braking system is one of the most crucial components of vehicle safety. The key factor in it is the braking force, which is expressed as $F_b = T_b / R_W$, where F_b stands for braking force, T_b for braking torque, and R_W for brake radius.

Regarding vehicle safety, it is the most crucial. The design of the brake system is a crucial braking force factor. $F_b=T_b/ R_W$ Fb is the braking force. Braking torque is Tb. wheel radius R_W As Tb rises, Fb rises as well, but only as far as the road's adhesion will allow. F_b max = UB_W, then. where UB = road adhesion coefficient. The results of a braking performance test give a driver an intuitive understanding of braking distance and vehicle stability.

Best braking performance often refers to a situation where a vehicle stops within the shortest distance possible without deviating from its intended path. As a result of acceleration and braking, weight is dynamically transferred. We must create the braking system in a way that will allow us to disperse the force needed to apply the brake in order to counteract the effect of weight transfer.

Calculation of Braking Force

Vehicle Mass (m) = 350 kg, Vehicle velocity (v) = 20 m/s

Work done (W) = Kinetic energy = ½ mv2 = ½ × 350 × 202 = 70000 J

Work done (W) = F (Brake Force in N) × s (Stopping distance in m)

Assume the vehicle is moving in uniform velocity so s = 10 m

W= F x s (Nm) F = W / s = 70000 / 20 = 3500 N

Therefore, Force required to apply brake is 3500 N

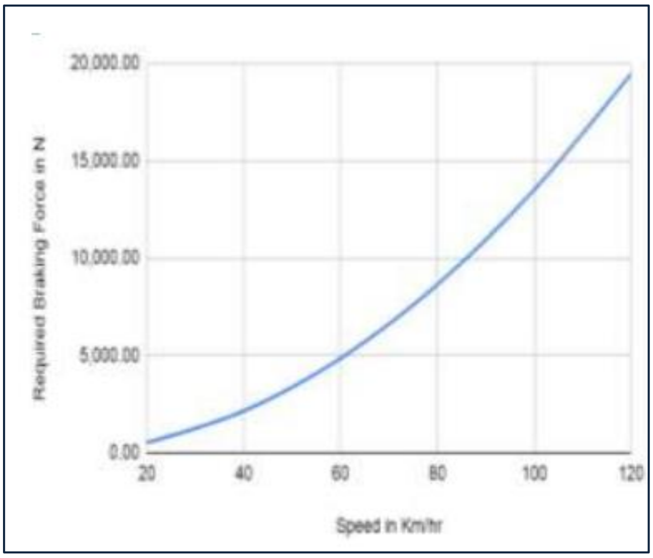


Fig 8: The Braking Force required (N) Vs Speed (Km/h)

The above graph has been plotted for Required Braking force (N) Vs Speed (Km/hr), speed of the vehicle is varied linearly and required braking force has been checked. As the speed of the vehicle varies the required braking force also varies linearly as shown in table 1 below.

Table 1: Required Braking Force (N) Vs Speed (km/h)

Sl. No.	Speed (km/h)	Required Braking Force (N)
1.	20	200
2.	40	800
3.	60	5000
4.	80	8000
5.	100	13000
6.	120	19000

Conclusion

With the help of this research, engine exhaust system waste energy may be recovered without compromising engine performance. The use of waste exhaust gases that are vented into the atmosphere offers significant potential for energy savings. This entails capturing and reusing waste exhaust gases from internal combustion engines and using them to produce electrical work. This can be applied to a big vehicle's air braking system. Hybrid automobiles can also use this method. The operating pressure of the turbine, which primarily limits shaft power, suggests that the turbine needs to be modified in order to operate better. With the use of engine exhaust gases from a two-stroke petrol engine, we discovered that the brake is applied in the proposed model. Compared to the prior air brake system, it increases engine efficiency. Additionally, the cost of the setup was lessened as a result. Utilising an air filter also aids in lowering air pollution. With better design, this may be more research on diesel engines. It was also seen from the result that the required braking force will increase with respect to the increase in speed of the vehicle.

Future Scope

Engine exhaust gases can be used to power a generator that is installed on the turbocharger's shaft and afterwards stored in a battery. This technology is suitable for internal combustion engine and battery hybrid vehicles.

In order to manage the pneumatic resources (exhaust gas), micro controller switches are used. We utilise the filtered gas as the source because it helps to reduce atmospheric pollution by filtering the hazardous impurities from the exhaust gas using an air filter (Nivethan, 2016) [12]. By adding a nozzle to raise the pressure before it is delivered to the brake cylinder, additional work can be done. For higher absorption and increased exhaust gas filter performance, low pressure EGR filters like radial and cone filters can be used (Pulkrabek, 2004) [13]. The weight of the air tank can be decreased by using low density composite materials.

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