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DESIGN, ANALYSIS, AND WORKING OF A PNEUMATIC ENGINE

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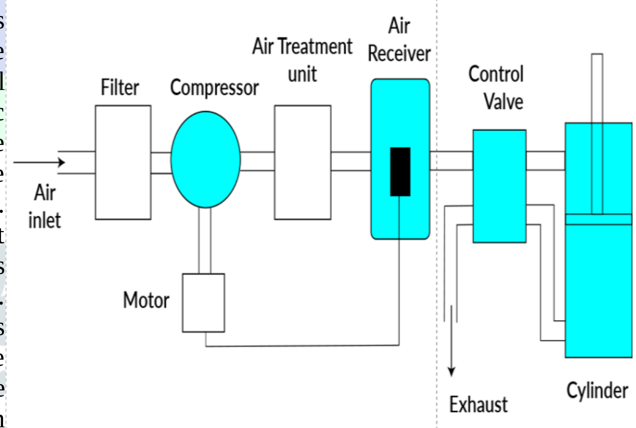
Abstract: I show a pneumatic-powered air engine system that can power a vehicle's engine and propel it forward. This device consists of a pneumatic cylinder coupled to a wheel via a customized rack and pinion arrangement. An electronic circuit controls the compressor, which distributes air through pipes and valves to control the movement of the pneumatic cylinder. The cylinder's piston goes forward and backward, driving the wheel via the rack and pinion system. To avoid obstruction, cylindrical wheels ensure that the rack does not touch during the return stroke. Bearings and a robust frame provide support for the rotating wheel and horizontally aligned pneumatic cylinder. This configuration exhibits the air engine principle in a small and efficient manner.

INTRODUCTION

Pneumatic power systems employ compressed air to transmit power. Their operation is comparable to hydraulic power systems. An air compressor turns the primary mover's mechanical energy into pressure energy in the compressed air. This change makes it easier to transfer, store, and control energy. After compression, the compressed air should be ready. Pneumatic cylinders, often known as air cylinders, are mechanical devices that use compressed gas to generate force in reciprocating linear motion. A force moves a piston in the desired direction, just as it does in hydraulic cylinders. The piston is a disc or cylinder, and the piston rod transmits the force it generates to the object being moved. Engineers sometimes favor pneumatics because they are quieter, cleaner, and require less room for fluid storage. Because the operating fluid is a gas, leakage from a pneumatic cylinder does not trickle out and contaminate the environment, making pneumatics more suitable in areas where cleanliness is required. For example, pneumatics are employed in the Disney Tiki Room's mechanical puppets to keep fluid from dropping beneath the puppets.



OBJECTIVES

- To understand the working and constructing of pneumatic-powered air engines.
- To store compressed air inside a tank.
- To showcase that a normal single-cylinder engine can be run on compressed air with a few modifications.
- To show that no fossil fuel is required so no combustion processes, forming a type of internal combustion engine.
- To use air as fuel which is available abundantly in the atmosphere.
- To play a vital role in reducing air pollution and also in reducing the temperature of the earth.

MATERIALS REQUIRED

- Compressor
- Air Storage Tank
- Control Valve
- Metal Sheet

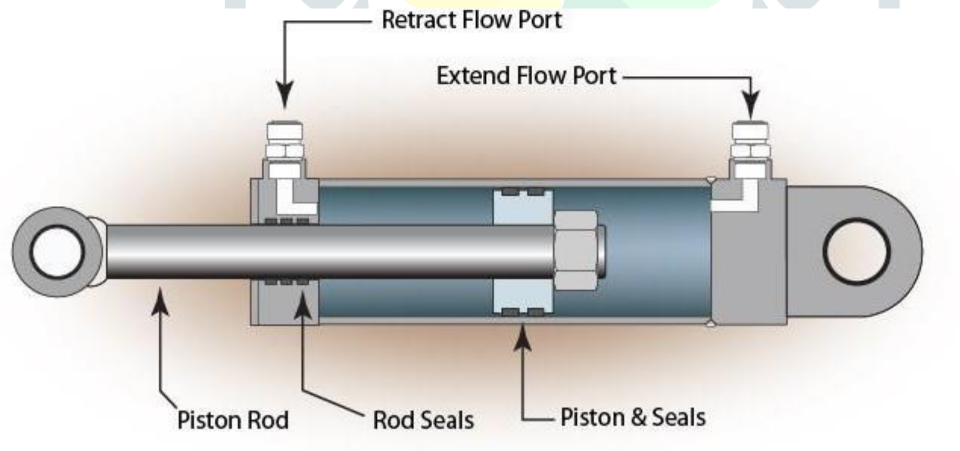
- Nut and Bolt
- Bearings

WORKING

working process 7 main stages:

- Compressed Air Storage: Compressed air is stored in a tank, replacing the fuel-air mixture used in traditional engines.
- Energy Storage and Release: The work done by the pump gets stored as pressure energy in the compressed air. When allowed to expand, this energy converts to kinetic energy, causing propulsion.
- Two-Stroke Operation: The engine works in two strokes—intake and exhaust—using compressed air as the working fluid.
- Intake Stroke: The piston moves from the top dead center to the bottom dead center as compressed air enters the cylinder, exerting pressure and expanding.
- Exhaust Stroke: The piston moves from the bottom dead center to the top dead center, pushing out using compressed air through the exhaust valve.
- Piston and Valve Mechanism: Valve positions and cam actions control the intake and exhaust strokes, enabling continuous engine operation.
- Compressed Air Flow: Compressed air is admitted from the storage tank through a valve, controlled by an electric circuit acting as a timer mechanism.

- Conversion of Motion: The linear movement of the piston, caused by the high-pressure compressed air, is converted into rotary motion using a rack and pinion (sprocket) arrangement.
- Wheel Rotation: The sprocket is mounted on a wheel supported by a frame, resulting in the wheel's rotation and driving the vehicle, without any fuel combustion.



3. CONSTRUCTION

The following components are required:

- Flywheel
- Air cylinder
- Connecting rod
- Valves
- Roller bearing
- Metal Sheet

Flywheel

Flywheels are commonly utilized to provide constant power output in systems with intermittent energy sources. In a reciprocating engine, a flywheel is utilized to moderate the crankshaft's quick angular velocity oscillations. In this scenario, when a firing piston exerts torque on a crankshaft flywheel, the energy is stored and then returned to the piston to compress a fresh charge of air and fuel.

Pneumatic Cylinder

Pneumatic cylinders (also known as air cylinders) are mechanical devices that use compressed gas to generate force in reciprocating linear motion. Like hydraulic cylinders, something causes a piston to move in the desired direction. The piston is a disc or cylinder, and the piston rod transmits the force it generates to the object being moved. Engineers sometimes favor pneumatics because they are quieter, cleaner, and require less room for fluid storage. Because the operating fluid is a gas, leakage from a pneumatic cylinder does not trickle out and contaminate the environment, making pneumatics more suitable in areas where cleanliness is required.

Types of pneumatic cylinder

Although pneumatic cylinders vary in form, size, and purpose, they often fit into one of the categories listed below. However, there are various additional types of pneumatic cylinders available, many of which are intended to perform specific and specialized tasks.

Single-acting cylinder

A single-acting cylinder (SAC) has a single port through which pressurized air enters and the rod moves only in one direction. As the cylinder chamber fills with compressed air, the rod extends due to the high pressure. When the pressurized air exits the cylinder through the same port, the rod returns to its original position.

Double-acting cylinders

Double-acting cylinders (DAC) use air pressure to move in both extend and retract strokes. They have two air intake ports: one for outstroke and one for instroke. Stroke length is not limited with this design, although the piston rod is more prone to buckling and bending. Additional computations should be done as well.

Multi-stage, telescoping cylinder

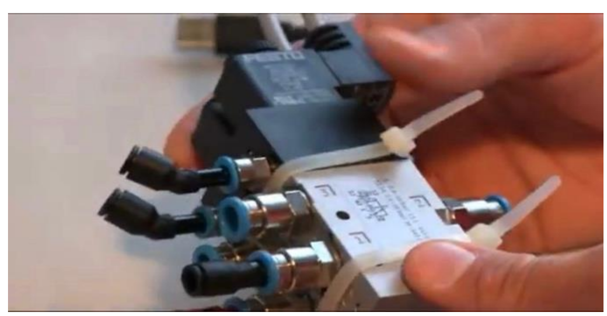
Pneumatic telescoping cylinder, 8-stages, single-acting, retracted and extended Telescoping cylinders, also known as telescopic either single or double-acting.

connecting rod

A connecting rod is a component of a piston engine that connects the piston and crankshaft. Together with the crank, the connecting rod transfers the piston's reciprocating action into crankshaft rotation. The connecting rod transmits the piston's compressive and tensile forces.
In its most prevalent form, internal combustion energy, it allows for pivoting at the piston end and rotation at the shaft end. Internal combustion engines and steam engines are the most prevalent applications for connecting rods.

valve (pneumatic)

A valve is an apparatus that, through opening, closing, or partially obstructing different passageways, regulates, directs, or controls the flow of a fluid (gases, liquids, fluidized solids, or slurries). Fluid moves from greater pressure to lower pressure through an open valve. The word comes from the Latin valve, which is the door's moving component. Volver means to turn or roll. A freely hinged flap that swings down to block fluid (gas or liquid) flow in one direction but is pulled up by the flow itself when the flow is traveling in the opposite direction is the most basic and ancient type of valve. Given that it "checks" or stops the flow in one direction, this device is known as a check valve. Modern control valves may regulate pressure or flow downstream and operate on automation systems.

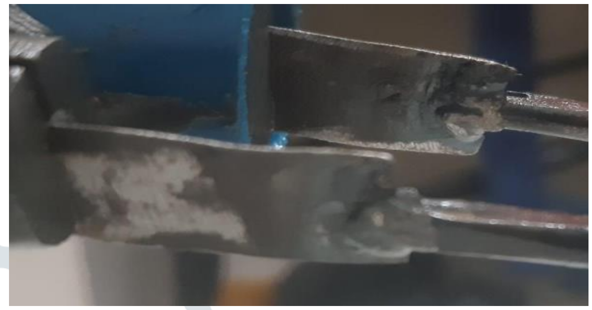


Bearing

A bearing is a portion of a machine that lowers friction between moving parts and restricts relative motion to only the desired motion. The bearing's design may, for instance, permit the moving part to move freely in a linear direction or to rotate around a fixed axis; alternatively, it may stop motion by regulating the vectors of normal forces acting on the moving parts. Most bearings reduce friction to enable the intended motion. In general, bearings are categorized based on how they operate, the motions they permit, or the loads (forces) that are applied to their components.

Metal sheets

Metal that has been thinned and flattened, usually through industrial processes, is called sheet metal. One of the basic materials used in metalworking is sheet metal, which can be bent and cut into a wide range of shapes. There is a wide range of thicknesses: foil or leaf is the term for very thin sheets, while plate, or structural sheet, refers to parts thicker than 6 mm (0.25 in), such as plate steel. Sheet metal comes in coiled strips or flat pieces. A continuous sheet of metal is fed through a roll slitter to create the coils.



EXPERIMENTAL DETAILS

1. Designing a piston cylinder for the following requirements:

100 W of power Operating Pressure: 50 N/cm^2 at 5 Bar Step 1: Establishing the Proper Length of the Stroke

Case I: Got Bored Diameter: 1 cm x 10 mm (Assumed) Engine speed: 3 rps (180 rpm, assumed). Length of Stroke: 50 x 3.14/4 x 12 x Ls x 3/100 Ls = 84.92 cm is the result of Power (P) = Pressure (p) x Volume x Engine Speed (100).

Case II: Uninterested Dia: 2.5 cm x 25 mm (assumed) Engine speed: 3 rps (180 rpm, assumed). Length of stroke: 100 x 100 = 50 x 3.14/4 x 2.52 x Ls x 3 Ls = 13.58 cm; Power (P) = Pressure (p) x Volume x Engine Speed Considering the values, the most appropriate value seems to be in the Case III, when the bore dia was taken as 2.5 cm and length of stroke comes out to be "13.58 cm".

2. When choosing the cylinder material for a thick cylinder, the t/d ratio should be more than 1/15, or t/d > 1/15. wherein,t: Cylinder wall thickness d: Bore Dia
If the bore diameter is 2.5 cm, the thickness of the cylinder wall that will be considered thick should be more than 0.16 cm. Where, σt: The cover plate's permissible working stress σt = 20.6 MN/m2 = 2060 N/cm2 for cast iron Moreover, t = 1.59 mm

3. Design of Piston and Piston Rod

Since the cylinder is intended to be used as a pneumatic cylinder, there shouldn't be any space between it and the piston because doing so could cause air to leak. Therefore, it is assumed that the piston's diameter and the cylinder's bore diameter are the same. Thus, the piston diameter is 2.5 cm or 25 mm. Additionally, dpr = is the piston rod's diameter. Using gray cast iron as the piston rod material, we get σt* = 1/8 x 166 = 20.75 MN/m2 for σut = 166 MN/m2. Additionally, the factor of safety for a double-acting cylinder is assumed to be 10. Consequently, the piston rod's actual working tensile stress is σt /10 = 20.75 / 10 = 2.075 MN/m2 = 207.5 N/cm2, where Dia of the piston rod is given as dpr = $d_i \times \left[\frac{P_i}{\sigma_t^*}\right]^{\frac{1}{2}}$

Therefore, dpr = $2.5 \times \left[\frac{50}{207.5}\right]^{\frac{1}{2}}$
= 1.225 cm
Thickness of piston head, t ph = 0.43 x d i x (P i / σ)1/2 t

= 207.5 N/cm2
Therefore, tph = 0.43 x 2.5 x (50/207.5)0.5
= 0.53 cm We consider the thickness to be 0.2 cm.
Therefore, Outer Diameter (do) = 2.5 + 2 x 0.2 = 2.9 cm 25 So by Lame's Equation

σt = $\left[\frac{P_i \times d_i^2}{4r^2}\right] \times \left[\frac{(4r^2 + d_o^2)}{d_o^2 - d_i^2}\right]$

where σt: Tangential Stress of the material Pi: Internal Pressure di: Bore Dia do: Outer dia of the cylinder r: Radius at which the stress needs to be find σt (max) = $\left[\frac{50\times 2.5^2}{4\times1.25^2}\right] \times \left[\frac{(4\times1.25^2+2.9^2)}{2.9^2-2.5^2}\right]$

=107.04 N/cm2

So, the tangential stress faced at the internal walls of the cylinder is around 107.04 N/cm2.

By the relation, σut = 8 x σt

= 8 x 107.04

= 856.32 N/cm2

= 8.56MN/m2

Based on the ultimate stress value, the material selected is "Grey Cast Iron" whose ultimate stress value is 166 MN/m2, which is more than enough to bear the stress produced.

RESULT AND DISCUSSION

My project ensures the future of efficient, greener technology. The method eliminates the need for fuel, leaving the environment pollution-free. The compressed air powers an air engine, which turns the vehicle's wheels; after compression, the air is stored in a tank. The air is used when the vehicle needs energy, such as when it is starting up or accelerating. In the future, we will be able to employ vehicles with various changes such as increased tank capacity, the use of high-strength composite materials, the weight of sections such as the chassis and storage tank being reduced, resulting in a lighter vehicle; and the reduction of airflow losses through nozzles, pipes, and other components. With the improvements listed above, the vehicle's performance and distance can be increased.

CONCLUSION

Compressed air engines are environmentally clean and cost-effective, addressing fuel shortages and pollution concerns. The engine's performance peaks with rising rotation speed before rapidly falling, making it efficient at low speeds. While compressed air vehicles may appear futuristic, the public is drawn to them because of their environmental benefits. Unlike electric vehicles, compressed air vehicles store energy in compressed air rather than batteries. The advantages include lower production costs, simpler engine design, lower manufacturing and maintenance expenses, and convenient storage tank recycling. These vehicles generate no hazardous gasses and create less road damage, encouraging sustainability while lowering maintenance costs. Efforts should be focused on making them lightweight, safe, and cost-effective.

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