"Design & Analysis of Pneumatic Engine"

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Abstract - *Conventional engine produces a large amount of harmful gases* ***like Carbon dioxide, Carbon monoxide, SO2*** *etc. which is harmful for environment condition and causes global warming and it consumes enormous non-renewable energy. Metropolitan cities are increasing rapidly mostly because of the increased number of fossil fuel powered vehicles. Many alternative options are now being studied throughout the world. One of the alternative solutions can be a* ***Pneumatic Engine****. This engine works on compressed air only, no fossil fuel is required. This paper describes the research, design & analysis of pneumatic engine as a pneumatic actuator that converts one form of energy into another. We compress normal air into a cylinder the air would hold some energy within it. This energy can be utilized for useful purposes. When this compressed air expands, the energy is released to do work. So, this energy in compressed air can also be utilized to displace a piston. Linear motion can come from either a diaphragm or piston actuator, while rotary motion is supplied by either a vane type air motor, piston air motor, air turbine or gear type motor. Additionally, regenerative braking can also be used in conjunction with this system.*

Key Words: *Carbon dioxide, Carbon monoxide, SO2, Pneumatic Engine*

1. INTRODUCTION

A Compressed-air engine is a pneumatic actuator that creates useful work by expanding compressed air. A compressed-air vehicle is powered by an air engine, using compressed air, which is stored in a tank. Instead of mixing fuel with air and burning it in the engine to drive pistons with hot expanding gases, compressed air vehicles (CAV) use the expansion of compressed air to drive their pistons. They have existed in many forms over the past two centuries, ranging in size from hand held turbines up to several hundred horsepower. For example, the first mechanically-powered submarine, the 1863 Plunger, used a compressed-air engine. The laws of physics dictate that uncontained gases will fill any given space. The easiest way to see this in action is to inflate a balloon. The elastic skin of the balloon holds the air tightly inside, but the moment you use a pin to create a hole in the balloon's surface, the air expands outward with so much energy that the balloon explodes. Compressing a gas into a small space is a way to store energy. When the gas expands again, that energy is released to do work. That's the basic principle behind what makes an air car. Some types rely on pistons and cylinders, others use turbines. Many pneumatic engines improve their performance by heating the incoming air, or the engine itself. Some took this a stage further and burned fuel in the cylinder or turbine, forming a type of internal combustion engine.

1.1 Objectives

The objective is to develop Pneumatic engine which can be run by the compressed air. A normal single cylinder engine can be run on compressed air with a few modifications. Main advantage of compressed air engine is that no fossil fuel required so no combustion processes, forming a type of internal combustion engine. Another benefit is that it uses air as fuel which is available abundantly in atmosphere. . Thus, this engine will play vital role in reducing air pollution and also in reducing temperature of earth.

2. CONSTRUCTION & WORKING

The project methodology is to: parameter calculation, pneumatic design, electric design, mechanical analysis, stress calculation. The following components are required: A. Crank shaft

B. Connecting rod

C. Piston cylinder

D. Valves

E. Roller bearing

A. CRAK SHAFT

The crankshaft, sometimes casually abbreviated to crank, is the part of an engine which translates reciprocating motion into rotary motion or vice versa. Crank shaft consists of the shaft parts which revolve in the main bearing, the crank pins to which the big ends of the connecting rod are connected, the crank webs or cheeks which connect the crank pins and the shaft parts.

B. CONNECTING ROD

Connecting rod is a part of the engine which is used to transmit the push and pull from the piston pin to the crank pin. In many cases, its secondary function is to convey the lubricating oil from the bottom end to the top end i.e. from

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 11 | Nov 2020 www.irjet.net p-ISSN: 2395-0072

the crank pin to the piston pin and then for the splash of jet cooling of piston crown. The usual form of connecting rod used in engines has an eye at the small end for the piston pin bearing, a long shank, and a big end opening which is usually split to take the crankpin bearing shells.

C. PISTON & CYLINDER

In mechanical engineering, sliding cylinder with a closed head (the piston) that is moved reciprocally in a slightly larger cylindrical chamber by or against pressure of a fluid, as in an engine or pump. The cylinder of a steam engine is closed by plates at both ends, with provision for the piston rod, which is rigidly attached to the piston, to pass through one of the ends covers plates by means of a gland and stuffing box.

D. VALVES

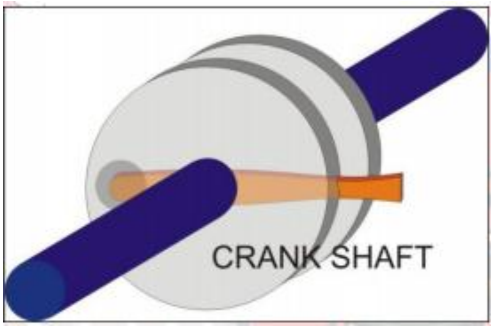
A valve is a device or natural object that regulates, directs or controls the flow of a fluid by opening, closing, or partially obstructing various passageways. Valves are technically fittings, but are usually discussed as a separate category.

E. ROLLER BEARING

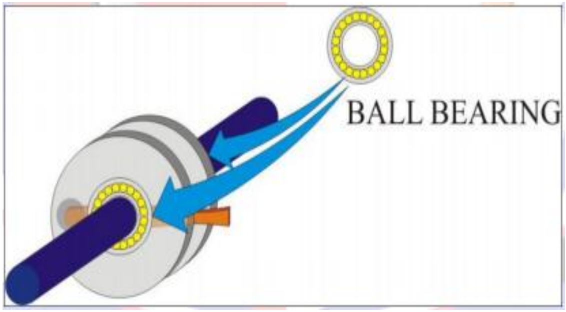
The concept behind a bearing is very simple: Things roll better than they slide. The wheels on your car are like big bearings. If you had something like skis instead of wheels, your car would be a lot more difficult to push down the road. That is because when things slide, the friction between them causes a force that tends to slow them down. But if the two surfaces can roll over each other, the friction is greatly reduced.

2.1 Procedure of Fabrication:

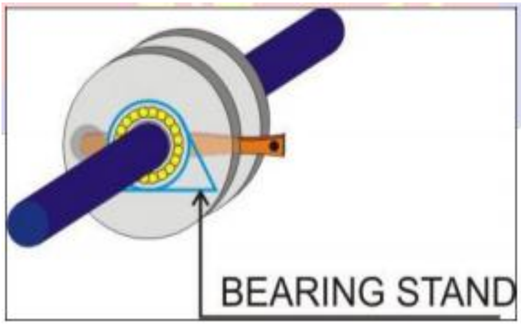
1. Procurement of crank from the market



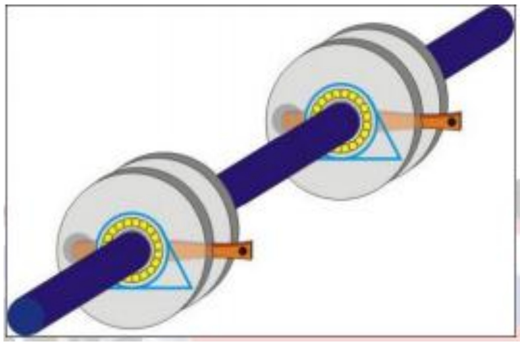
2. Fitting of bearing on the crank assembly.



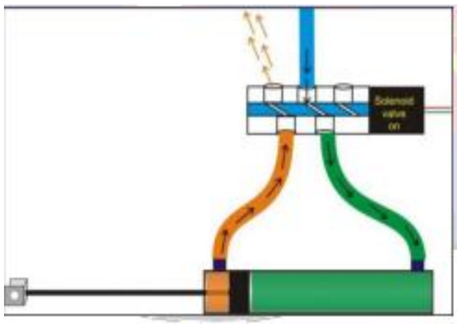
3. Fixing of Bearing stand on the crank assembly.



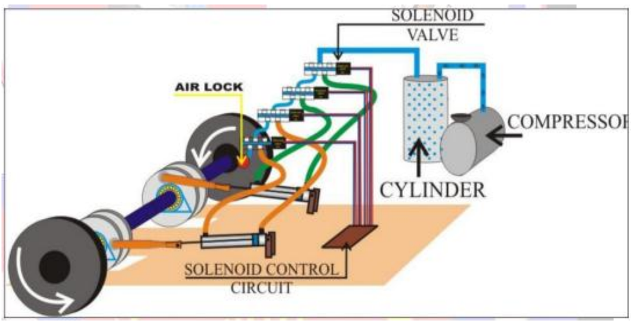
4. Welding of two crank shafts



5. Fixing of solenoid valves with pneumatic cylinder.



6. Powering the assembly with the electronic circuit and thus having the complete model.



2.3 Experiment

1. Designing a piston cylinder for the following requirements:

Power: 100 W Working Pressure: 5 Bar = 50 N/cm2 Step 1: Finding the appropriate Length of Stroke

Case I Bore Dia: 10 mm (Assumed) = 1 cm Speed of Engine: 180 rpm (Assumed) = 3 rps Length of Stroke:

Power (P) = Pressure (p) x Volume x Speed of Engine 100 = 50 x 3.14/4 x 12 x Ls x3/100 Ls = 84.92 cm

Case II Bore Dia: 50 mm (Assumed) = 5 cm Speed of Engine: 180 rpm (Assumed) = 3 rps Length of Stroke:

Power (P) = Pressure (p) x Volume x Speed of Engine 100 x 100 = 50 x 3.14/4 x 52 x Ls x 3 Ls = 3.39 cm

Case III Bore Dia: 25 mm (Assumed) = 2.5 cm Speed of Engine: 180 rpm (Assumed) = 3 rps Length of Stroke:

Power (P) = Pressure (p) x Volume x Speed of Engine 100 x 100 = 50 x 3.14/4 x 2.52 x Ls x 3 Ls = 13.58 cm

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. To select the material of the cylinder

For thick cylinder t/d ratio should be greater than 1/15

i.e. t/d > 1/15

where, t: Thickness of cylinder wall d: Bore Dia

In case of the bore dia being 2.5 cm, the thickness of the cylinder wall to be taken as thick cylinder should be greater than 0.16 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

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

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

$$\text{find } \sigma t \text{ (max)} = \left[\frac{50 \times 2.5^2}{4 \times 1.25^2}\right] \times \left[\frac{(4 \times 1.25^2 + 2.9^2)}{2.9^2 - 2.5^2}\right]$$

=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

On the basis of 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.

3. To calculate radial stress and shear stress

Max Radial Stress is given by, σr (max) = **-** Pi

where, Pi : Internal Pressure

σr (max) = **-** 50 N/cm2

Max Shear Stress at internal walls of the cylinder

$$\tau \max = \left[\frac{P_i \times {d_o}^2}{{d_o}^2 - {d_i}^2}\right]$$

$$= \left[\frac{50 \times 2.9^2}{2.9^2 - 2.5^2}\right]$$

= 194.67 N/cm2

4. Thickness of Cylinder Head

The thickness of the cylinder cap or cylinder head secured firmly to the cylinder is given by,

$$t'' = d_i \times \left[\frac{P_i}{6\sigma_t}\right]^{\frac{1}{2}}$$

Where, σt : Allowable working stress on the cover plate For Cast Iron, σt = 20.6 MN/m2 = 2060 N/cm2

And, t'' = 1.59 mm

5. Design of Piston and Piston Rod

As the cylinder is to be used as pneumatic cylinder, there should be negligible clearance between the cylinder and the piston as this could lead to leakage of air.

So, the dia of piston is taken to be same as that of the bore dia of the cylinder.

So, Dia of piston = 2.5 cm

= 25 mm

And, Dia of piston rod is given as

dpr = $d_i \times \left[\frac{P_i}{\sigma_t{}^*}\right]^{\frac{1}{2}}$

Now, For σt* Using Gray Cast Iron as the material for piston rod

σut = 166 MN/m2

σt = 1/8 x 166

= 20.75 MN/m2

And, for double acting cylinder, the factor of safety is taken as 10.

So, Actual working tensile stress in piston rod,

σt /10 = 20.75 / 10

= 2.075 MN/m2

= 207.5 N/cm2

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

2.4 Merits & De-merits

Merits: The advantages are well publicized since the developers need to make their machines attractive to investors. Compressed-air vehicles are comparable in many ways to electric vehicles, but use compressed air to store the energy instead of batteries. Their potential advantages over other vehicles include:

a) Air, on its own, is non-flammable.

b) High torque for minimum volume.

c) The mechanical design of the engine is simple and robust.

d) Low manufacture and maintenance costs as well as easy maintenance.

e) Compressed-air tanks can be disposed of or recycled with less pollution than batteries.

f) Compressed-air vehicles are unconstrained by the degradation problems associated with current battery systems.

g) Lighter vehicles would mean less abuse on roads. Resulting in longer lasting roads.

De-Merits:

a) A pneumatic device is sensitive to extreme changes in temperature as well as vibration.

b) Compressed air is more expensive than electricity

c) It is essential to ensure that there are no leaks in a pneumatic system because compressed air escaping leads to energy loss.

d)Pneumatic systems are known for making a loud noise. As a solution, you can install a silencer in every dump line.

e) Installation cost increases when the instrument requires speciality pipes.

f) Pneumatic systems are not upgradable to become compatible with smart electronics

3. CONCLUSIONS

The model designed by us is a small-scale working model of the pneumatic engine. When scaled to higher level it can be used for driving automobiles independently or combined (hybrid) with other engines like I.C. engines.

Main advantages of Pneumatic engine (P.E) are:

1.Zero emission. 2. Use of renewable fuel. 3. Zero fuel cost (the cost is involved only in the compression of air).

But the Pneumatic engine (P.E.) has some disadvantages, which are:

1. Less power output 2. High pressure of compressed air may lead to bursting of storage tank. 3. Probability of air leakage.

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