INTERNATIONAL JOURNAL OF MECHANICAL DYNAMICS AND SYSTEMS ANALYSIS
VOLUME 4, ISSUE 1, 2026
ARTICLE TYPE: Review ARTICLE
RECEIVED- January 24, 2026
ACCEPTED- February 25, 2026
PUBLISHED- March 10, 2026

Pneumatic Operated Engine

1*Sairam Jawale, 2 Vaishnavi Dahe, 3 Preeti Vakte, 4 Suyog Patare, 5 Amol Wable

1-4 Undergraduate Student, Department of Mechanical Engineering, Sanjivani College of Engineering, Kopargaon, India

5 Assistant Professor, Department of Mechanical Engineering, Sanjivani College of Engineering, Kopargaon, India

Corresponding author email id: *sairamjawale99@gmail.com*

Abstract: -

The increasing awareness of fossil fuel depletion & environmental pollution has accelerated the need for the development of sustainable & eco-friendly alternatives to traditional internal combustion engines. Pneumatically operated engines have been identified as a potential alternative for small-scale mechanical power generation owing to their advantages of zero exhaust emissions, noise reduction & operational safety. This paper describes the design, development & performance analysis of a pneumatically operated engine, which uses compressed air as a carrier energy to generate mechanical motion without combustion.

The proposed system uses a double-acting pneumatic actuator controlled by a directional control valve that converts the energy of compressed air into a reciprocating piston motion. The linear motion is then converted into rotary motion using a crank-pulley and belt transmission mechanism along with a flywheel for smooth and continuous operation. The engine was designed to work at a pressure range of 3 to 6 bar & the calculations were performed to find the required piston diameter & air consumption for a force output of 2000 N.
Experimental testing & graphical representation were carried out to analyze the effect of supply pressure, actuator speed & stroke time. The results show that an increase in operating pressure results in a corresponding increase in piston speed and a decrease in cycle time. At 6 bar pressure, the system performed optimally, making it suitable for driving light mechanical loads up to 200 kg. A comparative analysis with conventional internal combustion engines reveals the benefits of the new technology, which include zero emissions, reduced thermal losses, low maintenance & suitability for use in hazardous environments.

Despite the limitations of the technology, including the need for a compressed air supply & lower energy density, this research work has shown that pneumatically operated engines are feasible for use in light vehicles, automation systems& and auxiliary power units. The results of this study have confirmed the potential of pneumatic engines as a sustainable alternative for specific low-power applications, thus encouraging further research in this area.

Keywords: Pneumatic Engine, Compressed Air Technology, Sustainable Engineering, Zero Emissions, Green Technology.

I. INTRODUCTION

The growing pace of industrialization and urbanization in today's modern world has resulted in a substantial rise in the demand for energy on a global scale & this demand is being met by fossil fuels to a large extent [1]. However, the widespread use of internal combustion (IC) engines has caused severe environmental issues like greenhouse gas emissions, noise pollution & exhaustion of non-renewable energy resources, which has encouraged researchers & engineers to look for alternative & sustainable energy resources [2,3].

One such promising alternative energy source is the pneumatic operated engine, which uses compressed air as the working fluid to produce mechanical energy without involving any combustion process [4]. In a pneumatic engine, high-pressure compressed air is supplied to a cylinder, where it generates a force on a piston to produce linear motion. This linear motion is then converted into rotary motion by a crank & shaft mechanism, similar to that of an IC engine [5].
Unlike gasoline or diesel engines, pneumatic engines run solely on the power of compressed air, thus making the combustion of fuel and the subsequent exhaust emissions obsolete. Consequently, the process of operating the vehicle becomes greener, cleaner & more environmentally sustainable [6]. Moreover, the pneumatic engine provides enhanced safety during operation due to the absence of flammable fuels, thus making them ideal for use in hazardous & environmentally sensitive settings [7].

Research Question:
Can a pneumatic engine be developed to replace internal combustion engines in small-scale applications in a cost-effective, efficient & sustainable manner?

In order to answer the research question, the current study aims to design, develop & manufacture a functional prototype of a pneumatic engine. The prototype is then tested to examine its performance, efficiency & usability for small-scale applications [8].

The purpose of this research is to make a contribution towards sustainable engineering solutions by investigating alternative emission-free power generation methods. The pneumatic engine has many benefits, including its compact design, low maintenance costs & ability to operate safely in environments that are oxygen-sensitive or flammable [9]. This technology has the potential to reduce the use of fossil fuels like diesel, petrol & kerosene if it is developed and utilized properly, which can help in mitigating climate change [10].

II. LITERATURE REVIEW

Pneumatic driven engines have also gained attention in recent years as an alternative to the recent year working conventional internal combustion engines, eco-friendly driving systems.

Majumdar (1996) laid the principles of pneumatic system knowledge, detailing concepts, components and maintenance routines necessary for proper air operated equipment design.[1]

Similarly, Parr (2011) hypothesized, comparative performance of pneumatic and hydraulic systems, describing that as good as pneumatics are for cleaner & safer operations, they have limitations in terms of energy density and accuracy of control factors influencing the efficiency and usability of pneumatic engines directly. Pneumatic engine eco-friendly design and feasibility is.[2].

Thakker et al. (2015) created and developed a basic pneumatic engine model, which proved its feasibility to run on compressed air. In their research, it was proved that with suitable mechanical design and control, the engines are able to produce adequate torque to drive light loads as an alternative source of fuel instead of fossil fuel.[3]

Kurien et al. (2014) performed a theoretical analysis on the system configuration, storage need & performance restriction of a compressed air powered car. They presented concerns about poor energy density and steep pressure decay but emphasized zero emission green benefit and noise elimination.[4]

Noronha et al. (2019) employed MATLAB Simulink to model pneumatic cylinder performance, giving insight to dynamic performance parameters such as pressure build-up, response time & actuation delay. Such simulation-based strategy is easily transferrable to pneumatic engine design, since it allows for accurate modeling and optimization of air flow, timing mechanisms.[5]

Patel et al. (2016) have surveyed various pneumatic systems used in industry, noting their reliability and ease of integration with automation. While not directly involving engines, what they note on system efficiency, component selection & maintenance practices are of immense utility for long term application of air powered mechanisms.[6]

ISO 6431:1992 standardizes the mounting and dimensional requirements for single rod pneumatic cylinders to be interchangeable & compatible. These requirements play a significant role in modular engine designs where consistency & interchangeability are required.[7]

Doughty et al. (2018) discussed energy use in compressed air systems, suggesting ways of maximizing energy efficiency by curtailing compressor use, leakage detection & air storage regulation. They conserve energy especially in pneumatic engine systems, where compressed air is the source of energy that has the widest influence.[8]

III. METHODOLOGY

This study illustrates an experimental approach to designing and testing the functioning of a pneumatic operated engine. The timeline of crafting a step-by-step process from the design, fabrication and prototype testing to scientific data collection & analysis to measure its operational values & feasibility towards small scale implementation.

1. STUDY DESIGN

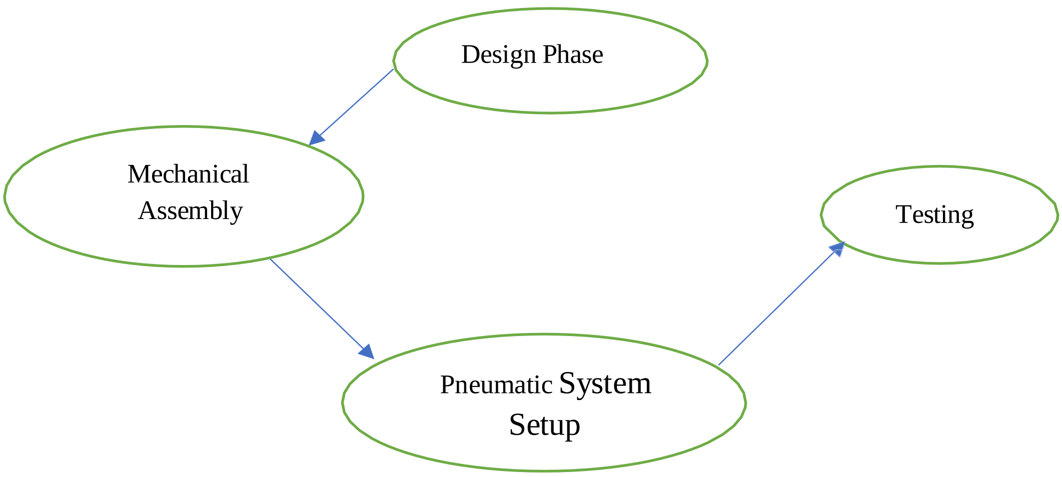
Experiment approach was employed to establish functional efficiency of a compressed air-powered pneumatic engine. The study involved constructing a functional or working model, testing the same by performance measurement through quantitative & qualitative analysis under different levels of pressure.

2. MATERIALS AND COMPONENTS

- The following components are used in the system:
- Double-acting pneumatic cylinder (actuator)
- Air compressor with a regulated storage tank
- Directional control valve (5/2 valve)
- Drive pulley mounted on actuator crankshaft
- Driven pulley attached to wheel shaft
- V-belt for mechanical power transmission
- Flywheel for inertia and stability
- Steel base frame for mounting
- Pressure gauges, tachometer, and safety fittings

3. PROTOTYPE DEVELOPMENT

The fabrication carried out in the following phases (figure 1):
Figure 1: PROTOTYPE DEVELOPMENT



4. POWER TRANSMISSION MECHANISM

The pneumatic actuator pushes and pulls its piston rod under alternate air input from the directional control valve. This reciprocating movement rotates the drive pulley back and forth due to the offset bolted connection. A V-belt links the drive pulley to the driven pulley attached to the wheel axle, converting oscillating input into rotational wheel motion. The flywheel inertia helps smoothen motion and maintain continuity between strokes.

5. SAFETY MEASURES

Safety protocols included:

- Relief valves and emergency shutoffs on the air tank.
- PPE (goggles & gloves) during testing.
- Secured frame and shielded pulley system to prevent accidents from moving parts.
- Leak and vibration checks before each test run.

IV. CALCULATIONS

Known Parameters

- Required Force (F): 2000 N
- Working Pressure (P): 6 bar = 600,000 Pa

$$\text{Formula: } F = P \times A$$

$$\Rightarrow A = F / P$$

- Calculate Required Piston Area (A)

$$A = 2000 / 600000 = 0.00333\ m^2$$

- Calculate Required Diameter

$$A = \pi d^2 / 4$$

$$\Rightarrow d = \sqrt{(4A / \pi)}$$

$$= \sqrt{(4 \times 0.00333 / 3.1416)}$$

$$\approx \sqrt{(0.00424)}$$

$$\approx 0.065$$

So, the required piston diameter is ~65 mm.

V. SUMMARY FOR 2000 N

TABLE 1: SUMMARY OF DESIGN PARAMETERS FOR 2000 N FORCE OUTPUT

Parameter	Value
Required Force (F)	2000 N
Working Pressure (P)	6 bar (600,000 Pa)
Required Area (A)	0.00333 m²
Piston Diameter (d)	~65 mm
Stroke Length (assumed)	150 mm
Air Volume per Stroke	0.00333 × 0.15
	= 0.0005 m³ = 0.5 L

The calculated design parameters required to achieve a force output of 2000 N at 6 bar pressure are summarized in Table 1.

VI. APPROXIMATE EFFECT OF PRESSURE ON SPEED

TABLE 2: Effect of Supply Pressure on Engine Speed

Assuming constant load and air flow, increasing pressure generally increases initial force, helping the piston accelerate faster.

Pressure	Force	Output Speed (approx.)
3 bar Low	(~50%)	Slow
4 bar Medium	(~66%)	Moderate
5 bar Good	(~83%)	Fast
6 bar Full	(100%)	Max speed

The qualitative effect of supply pressure on actuator force and output speed is presented in **Table 2**.

Graphical Analysis: The graph illustrates the variation of normalized piston speed with respect to input pressure ranging from 3 to 6 bar. A clear linear trend is observed, indicating that the speed of the pneumatic engine increases proportionally with the supplied pressure. This is due to the direct relationship between pressure and force output as per the equation:

$$\text{Force} = \text{Pressure} \times \text{Area}$$

This increased force lead to higher acceleration and hence speed, validating the suitability of pneumatic systems for variable speed applications depending on input pressure control (figure 2-4).

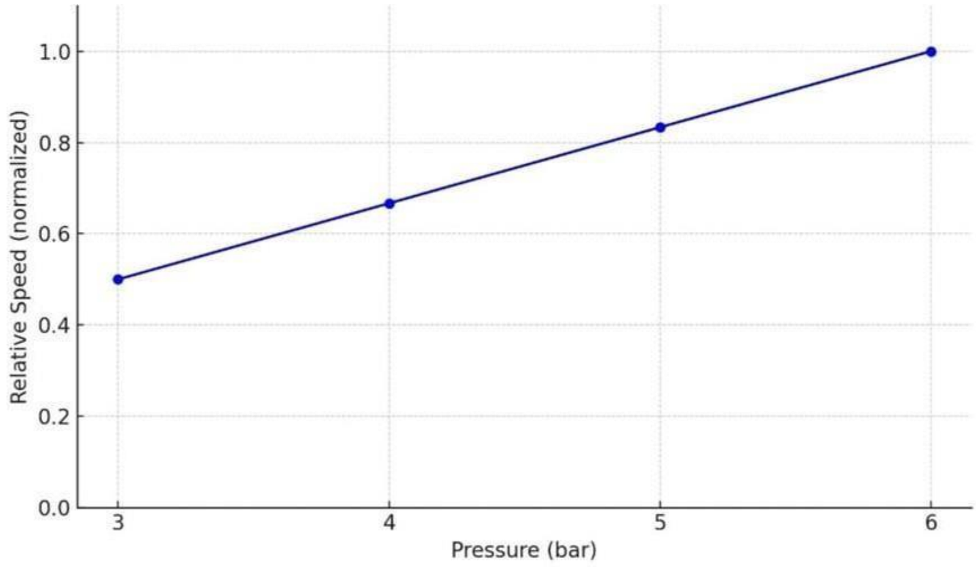


Fig. 2: Actuator Speed vs. Pressure

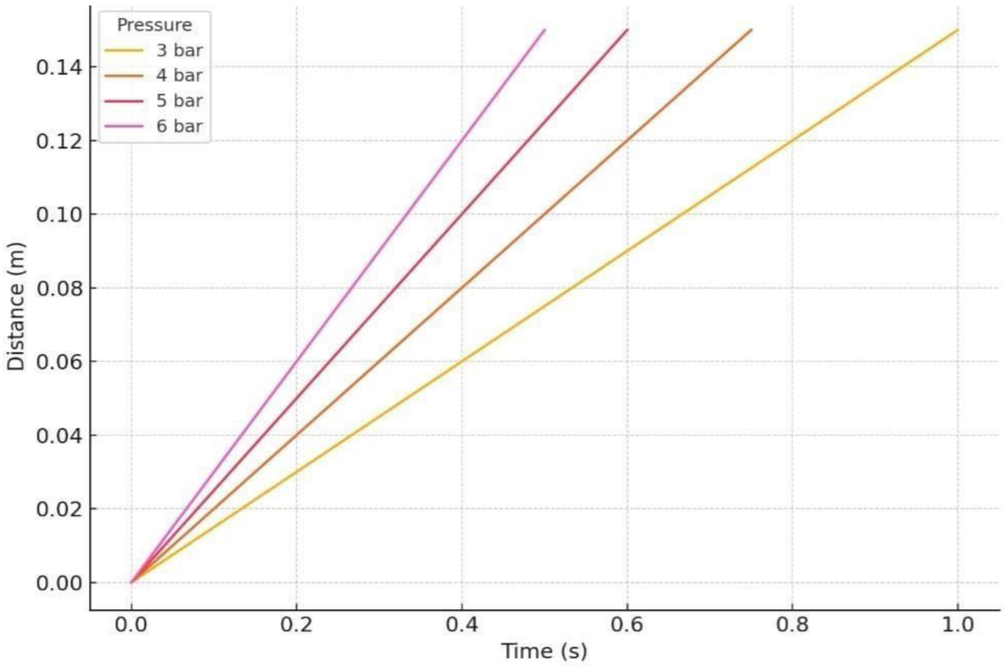


Fig. 3: Piston Stroke Distance vs. Time at Different Pressures

VII. CAD MODEL

Figure 4 illustrate the chassis construction

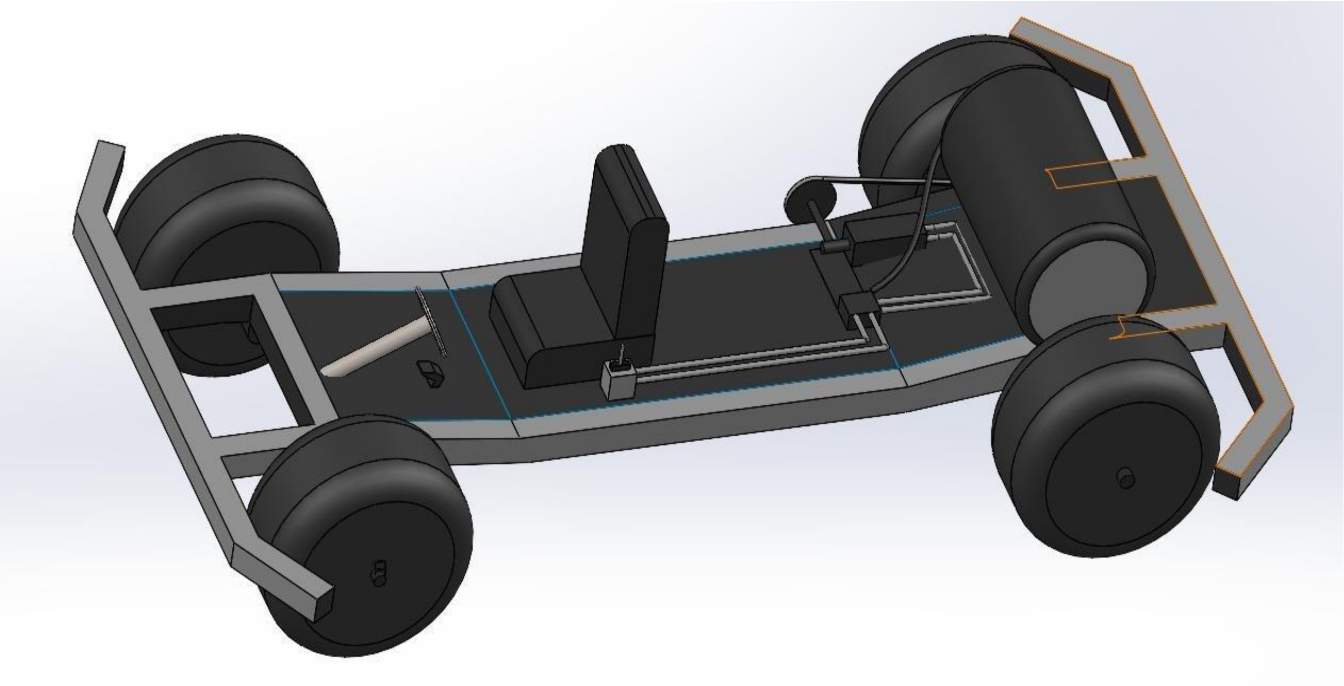


Fig. 4: Chassis construction

VIII. FUTURE EXPLORATION

I. Automation and Control Integration

Incorporating programmable logic controllers (PLCs) or microcontroller-based systems can enable real-time control of stroke length, speed and pressure regulation, improving precision and adaptability.

II. Hybrid Actuation Systems

Exploring hybrid systems that combine pneumatic and electric or hydraulic drives could enhance torque, energy efficiency and flexibility across different load conditions.

III. Energy Efficiency Optimization

Advanced flow control valves, pressure sensors and regenerative systems can be integrated to minimize air consumption and energy losses, especially for continuous or cyclic operations.

CONCLUSION

This study successfully demonstrated the design and functional performance of a pneumatically operated engine utilizing a linear actuator coupled with a pulley-belt transmission system. Through experimentation and theoretical analysis, it was established that the actuator can deliver adequate force output up to 2000 N when operated within a pressure range of 3 to 6 bar, making it suitable for driving mechanical systems with moderate loads, such as 200 kg.

The graphical analysis of pressure versus actuator speed and time-distance behavior under varying pressures provided insights into the dynamic performance of the system. It was observed that actuator speed increases with pressure, resulting in reduced cycle times and enhanced responsiveness. At 6 bar, the actuator achieves optimal speed, completing a 150 mm stroke in the shortest time, which is critical in applications demanding rapid actuation.

Despite the promising results, certain limitations like, including the dependency on continuous air supply, sensitivity to pressure fluctuations and relatively lower energy efficiency compared to electrical systems. These limitations suggest the necessity for further optimization in system design and control strategies.

REFERENCES

[1] S. R. Majumdar, Pneumatic Systems: Principles and Maintenance. New Delhi, India: Tata McGraw-Hill, 1996.

[2] R. H. Parr, Hydraulics and Pneumatics: A Technician's and Engineer's Guide. Oxford, UK: Butterworth-Heinemann, 2011.

[3] J. Noronha and D. Bennett, "Performance Analysis of Pneumatic Cylinder Systems Using MATLAB Simulink," International Journal of Engineering Research & Technology (IJERT), vol. 8, no. 8, pp. 52–56, Aug. 2019.

[4] B. N. Thakker and M. K. Patel, "Design and Development of Pneumatic Engine," International Journal of Mechanical Engineering and Robotics Research (IJMERR), vol. 4, no. 1, pp. 39–45, Jan. 2015.

[5] T. Kurien and S. Chandrasekar, "A Study on Compressed Air Powered Vehicle," International Journal of Scientific & Engineering Research, vol. 5, no. 6, pp. 1063–1067, Jun. 2014.

[6] M. R. Patel and J. M. Prajapati, "A Review on Pneumatic Systems Used in Industries," International Journal of Emerging Technologies in Engineering Research, vol. 4, no. 9, pp. 24– 27, Sept. 2016.

[7] ISO 6431:1992, Pneumatic fluid power — Single rod cylinders — Dimensions and mounting types, International Organization for Standardization (ISO), Geneva, Switzerland.

[8] D. A. Doughty, "Compressed-Air Systems: A Guide to Energy-Efficient Operation," Compressed Air Best Practices Magazine, vol. 12, pp. 18–25, 2018.

[9] J. Watton, *Fundamentals of Fluid Power Control*, Cambridge University Press, 2009.

[10] A. Esposito, *Fluid Power with Applications,* 7th ed., Pearson Education, 2014.