

Remote Controlled Pneumatic Door Opening System

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Abstract

This project is intended to design and develop a Remote-Controlled Pneumatic Door Opening System that is smart, secure, and touch-free, which is essential for the development of smart infrastructure. The system utilizes a pneumatic actuator, solenoid valves, and a wireless remote control system to effectively and efficiently open and close the door. Due to the rise in security issues, hygiene, and the need for automation in various fields, the proposed system is a convenient solution to replace the traditional manual operation and expensive sensor-based door systems. Pneumatics are used because they are simple, robust, and require little maintenance, providing linear motion for door operation. The remote control system ensures that only authorized persons are allowed access to the door, thereby improving security and eliminating the need for manual operation. Existing systems include manual doors, electromechanical actuators, and sensor-based automatic doors that require regular maintenance, are expensive to install, and lack the required flexibility and user control. The proposed system overcomes all the above problems by effectively using remote control and pneumatic operation, providing a cost-effective and easy-to-implement system. The project also intends to minimize the risks associated with the frequent handling of door handles, particularly in sensitive areas such as hospitals. The remote control pneumatic door opener is intended for use in offices, hospitals, industries, shopping complexes, restricted areas, and other restricted zones. The system is particularly beneficial for the elderly and the physically challenged. Moreover, the simplicity of the system and the reliability of the design are major contributions to the advancement of modern technology. In conclusion, the system provides convenience, security, reduces physical strain, and reduces the chances of contamination, thereby improving the system over the traditional door access system.

Keywords: Pneumatic Cylinder, Solenoid Valve, Air Compressor, Pneumatic Fitting & Tubing, FRL Unit.

INTRODUCTION

Over the years, the need for automation and smart access control systems has risen significantly across various domains, including residential, commercial, hospitals, industries, and infrastructures. The increased concern for security, hygiene, and efficiency has led to the replacement of manually operated doors by automated systems. The constant touch of door handles, particularly in public areas, also raises hygiene issues, especially for places like hospitals, where contamination control is of utmost importance. This problem, therefore, calls for a reliable, cost-effective, and touch-free door-operating solution that can minimize manual effort and ensure controlled access.

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Received Date: March 30, 2026

Accepted Date: May 22, 2026

Published Date: June 12, 2026

Citation: R.S. Dange, Sakshi K. Shinde, Vinod B. Vishwakarma, Avishkar D. Jadhav, Aniket P. Bhandalkar. Remote Controlled Pneumatic Door Opening System. Journal of Mechatronics and Automation. 2026; 13(2): 31–38p.

Automation is an integral part of engineering today, which helps to reduce labor, speed, and

maintain accuracy. Pneumatics is an engineering system that is considered to be simple, robust, and durable. It is commonly used for different applications, including industrial applications. The basic idea behind the application of pneumatics is the controlled application of compressed air, which can generate motion. This makes it an ideal solution for applications that need smooth, quick, and precise motion, such as opening or closing doors [1].

The Remote Controlled Pneumatics Door Opening System is developed with the aim of incorporating the advantages of using pneumatics with the advantages of using remote control. This system can allow people to control doors from a distance with the help of a customized remote. Unlike other door opening or closing systems, which are usually based on electro-mechanical systems, the application of pneumatics is considered to be clean, safe, and efficient. The application of the remote control system makes it an advantage, especially for the elderly, physically challenged people, or where frequent interactions need to be reduced. This system is considered to improve security, where only specific people can access the door opening or closing mechanism.

The existing door opening mechanisms, including manual doors, automatic sliding doors with sensors, and electromechanical actuators, have their own disadvantages, ranging from hygiene concerns, installation costs, wear, and tear, to flexibility. The proposed solution using the pneumatic door system with wireless control overcomes the disadvantages of existing door opening mechanisms by providing an efficient, trouble-free, and user-friendly solution. This project intends to design and implement an efficient door opening system using the proposed solution, not only providing convenience to the system operators but also ensuring security, reduced physical strain, and contributing to the development of advanced engineering technologies. In the context of rapidly evolving engineering technologies, the development of the proposed solution, i.e., the pneumatic door opening mechanism, is an example of the constant pursuit of smarter, efficient, and technologically advanced machinery [2-3]. Automation is becoming an integral part of life, with door opening mechanisms playing an important role in providing comfort, security, and satisfying the expectations of advanced engineering technologies. This project is an example of an efficient contribution to the development of advanced door opening systems.

PRESENT THEORIES AND PRACTICES

A Review of Pneumatic Actuators (Modeling and Control)

Detailed Description

This review paper is a detailed study of the pneumatic actuators and their working mechanisms, along with the dynamic responses and suitability of the actuators in the automation process. The paper describes the conversion of compressed air into linear or rotary motion and the benefits of using such actuators in the system, including their reliability, low maintenance, and quick response time. It covers the various types of actuators, including single-acting and double-acting cylinders, rotary actuators, air muscles, and vacuum actuators, along with the components of the actuators, such as pistons, valves, and air chambers [1]. A major portion of the paper is dedicated to the control mechanisms of the actuators, including flow control, pressure control, electro-pneumatic switching, and proportional valve control. It also covers the difficulties faced by the actuators, including air leakage, air compressibility, friction, and shock absorption. This paper is highly relevant to the pneumatic door project because it covers the parameters for selecting the actuators, including force calculation, stroke length, air consumption, and dynamic loading [4-5].

Design of Pneumatic System for Automatic Door Opening and Closing

Detailed Description

This paper deals with the complete design and fabrication process for an automatic door system using pneumatics [2]. In the paper, the construction process for an automatic door system using a basic pneumatic circuit with components such as a compressor, air reservoir, solenoid-operated direction control valve, and a double-acting cylinder is explained. In addition, the authors have explained how the system can be made automatic using sensors or switches. A significant amount of the paper is

focused on the selection process for components, i.e., the level of air pressure, the time taken by the valves, the strength of the components, the diameter of the piston, and the arrangement for the door. In addition, the difficulties encountered during the construction process, such as smooth closure without jerks, controlling the leakage of air, sealing, and noise reduction during the stroke, are explained [6-7].

Various safety issues, such as the load capacity of the cylinder, controlling the speed using throttling valves, and using shock absorbers, are shown. This paper is directly useful because it provides actual measurements of a prototype, diagrams, and fabrication steps that correspond to the pneumatic mechanism used in your project.

Design and Analysis of Automated Pneumatic Door System

Detailed Description:

This paper is all about the application of pneumatic actuators, particularly in vehicle doors like buses, vans, and other industrial transport vehicles. It discusses how pneumatic systems are effective in providing linear motion, especially for heavy doors, unlike electro-mechanical systems that become weaker over time[3]. It also talks about the compressor, pneumatic pipes, and air filter regulators, which help in maintaining constant pressure. It also includes calculations like force requirement, i.e., $F = P \times A$, cylinder sizing, response time, flow rate, and energy consumption. This paper is particularly useful in understanding the engineering and safety standards required in implementing an automated door system in high-risk environments. This paper also provides useful testing data in terms of door opening time, pressure drop analysis, and durability in continuous usage, which can be used to enhance the reliability of your pneumatic door project [8-9].

Mathematical modeling and practical implementation of automatic pneumatic sliding door systems involve the analysis of internal pneumatic mechanisms using flow rate equations, valve coefficient calculations, and pressure–displacement characteristics. Such systems typically employ sensors and microcontroller-based control units for automated operation. Performance evaluation is often carried out by comparing simulation results with experimental observations. Detailed studies of pneumatic cylinder behavior under varying operating conditions help in understanding system dynamics and improving efficiency through the use of flow control valves and mufflers. Additional features commonly incorporated into these systems include soft-start functionality, adaptability to different door dimensions, and emergency shutdown mechanisms. The analysis of these parameters provides valuable insights for students and researchers seeking to understand pneumatic automation systems and incorporate technical graphs, equations, and performance analyses into their documentation.

The integration of wireless control technology with pneumatic systems enables automated operation through remote signal transmission and reception. In such systems, a wireless transmitter communicates with a receiver unit, which controls solenoid valves responsible for regulating airflow direction and actuator movement. The operation involves electronic interfacing with low-voltage solenoid valves and incorporates switching mechanisms for reliable control. Important aspects of these systems include the working principles of RF communication devices, safety considerations, and the automation of pneumatic functions. Comparative analyses of different pneumatic automation approaches help evaluate system performance and effectiveness. Particular attention is often given to the selection of suitable RF devices based on factors such as operating frequency, transmission range, power output, coding techniques, and resistance to noise and interference. Supporting documentation typically includes block diagrams, pneumatic circuit layouts, electronic interfacing schematics, and implementation photographs. The combination of wireless communication and pneumatic automation contributes to reduced physical effort, improved hygiene, enhanced accessibility, and increased operational security.

PROBLEM STATEMENT

In environments such as hospitals, factories, shopping centers, and transport networks, opening doors manually results in several issues, including inconvenience, lack of hygiene, increased human effort,

and efficiency. For instance, physically opening doors can sometimes be cumbersome, especially for the elderly or disabled. In addition, opening doors can spread diseases due to frequent touching of door handles. Current door-opening systems, which are automatic, often employ electrical components, which can sometimes be costly, hard to maintain, and dependent on power. In industrial environments, where compressed air is readily available, it would be desirable to have an alternative system that is efficient, cost-effective, and requires minimal maintenance. Thus, the problem is to design and develop an automatic door-opening system using compressed air, which can function smoothly, quickly, and without touching the door. The system is expected to be energy-efficient, safe, easy to install, and can function within industrial environments while keeping operating costs and maintenance low.

METHODOLOGY

The working model includes three subsystems: pneumatic powertrain, electrical control and remote interface, and mechanical door linkage. The powertrain includes a small air compressor or a centralized plant, an air receiver or reservoir to regulate pressure, a pressure regulator, a main shut-off valve and filter assembly consisting of an air filter and a moisture separator, and a directional control valve consisting of a solenoid 4/2 or 5/2 valve used in double-acting cylinders. The double-acting cylinder is selected in accordance with door types: swing door or sliding door using simple calculations: force required $F = (\text{mass} \times \text{desired acceleration}) + \text{friction force} + \text{safety factor}$, and cylinder bore size $A = F/\text{desired working pressure}$. Flow control valves and needle valves on cylinder ports allow speed control while extending and retracting the door to eliminate jerks. Exhaust mufflers are used on cylinders to reduce noise levels [11]. All pneumatic devices have standard push-in connectors with service ports to facilitate easy maintenance and testing for leaks. The reservoir and regulator are selected to operate stably in relation to cycle rates; a small compressor with intermittent rating is used in low-frequency doors in buildings, but a larger machine or central plant is used in high-traffic area (Figure 1).

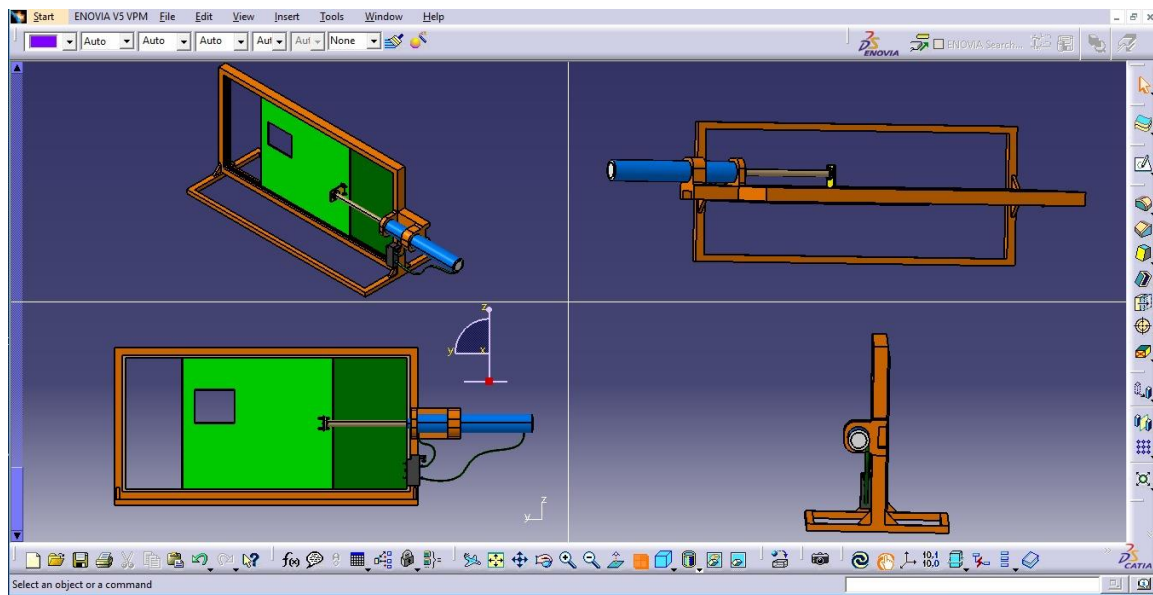


Figure 1. Pneumatic Door opening System

The electronic control and remote interface layer is responsible for user authorization, time and sequencing, and safety. A small control board contains a receiver module that could be RF, Wi-Fi, or Bluetooth, depending upon the range and level of security required. The module receives the code from the remote transmitter and sends it to the microcontroller that performs the access function and sequencing. Driver circuits are also present for the solenoid valves, and status indicators are also present. After the authorization of the remote control, the system checks the safety conditions and actuates the solenoid valve that allows the compressed air to go into the cylinder and open the door. After the door is fully open, the valve is closed, or the system waits until the close function is initiated.

Soft start and soft stop are achieved by pulsating or modulating the valve or by the flow control system. Limit switches or reed switches are present to ensure that the door is fully open or closed and that the power is cut off from the solenoid valves, thereby saving energy and reducing heat. To further improve the level of security, rolling code is used, or coded-pairing techniques can be used. In the remote protocol, and the system can be enhanced by keypad access, RFID, or building management system integration. The power for the electronic device is provided by a small AC-DC power supply, 12/24 VDC, depending on the voltage required for the solenoid, and a battery backup or UPS option for safe operation during power loss, and for pneumatic systems, a manual override lever can be provided for operation even if both power sources are lost.

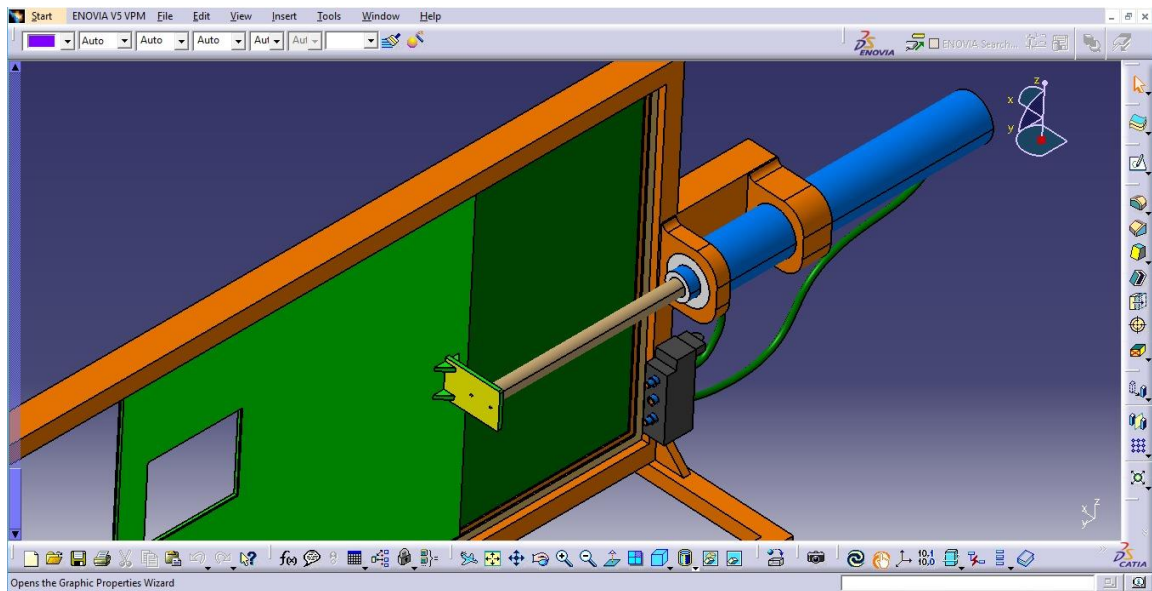


Figure 2. Pneumatic Door Opening System (Detailed View)

The mechanical linkage and installation finalize the working model, considering safety and usability issues in the real-world application. For the swinging door, the piston rod is mechanically linked to the door by means of a clevis and a mechanically robust arm or rack-and-pinion adapter (Figure 2). For the sliding door, the cylinder is mechanically linked to the door by means of a carriage or a linear actuator arrangement. Door speed and stroke are adjusted to ensure controlled inertia and momentum. Soft dampers or buffer stops are included to control door closure energy. Safety is ensured by means of mechanical stops, photoelectric sensors or pressure sensing edges to detect obstacles, which immediately reverse or stop the door motion, and an emergency release to disengage the cylinder from the door [12]. The prototype is expected to undergo several cycles to measure opening/closing time, air consumption per cycle, leakage rate, and estimates of servicing intervals. Acceptance criteria for performance are expected to cover smooth motion (no more than a specified jerk), position sensing, less than 5% variation in cycle time, and noise level within an acceptable range. A schedule of filter replacements, topping of the lubricator, leak tests, valve coil temperature monitoring, and servicing of the compressors provides for long life and safety. The overall working model shows a pragmatic solution of pneumatic power, wireless safety, robustness, and safety features applicable for offices, hospitals, and even industrial gates, depending on the choice of components.

RESULT

Prototype Model Calculation (Sliding Pneumatic Door)

Given Data:

Door Type: Sliding

Mass of Door (m): 2 kg

Pressure (P): 5 bar = 5×10^5 Pa

Stroke Length (L): 0.3 m

Time (t): 2.5 sec

1. Force Required to Move Door:

$$F = m \times g = 2 \times 9.81 = 19.62 \text{ N}$$

Considering friction (30%):

$$F_{\text{friction}} = 0.3 \times 19.62 = 5.88 \text{ N}$$

$$\text{Total Force} = 19.62 + 5.88 = 25.5 \text{ N}$$

2. Cylinder Force:

Assume cylinder diameter (D) = 16 mm = 0.016 m

$$\text{Area } A = (\pi D^2)/4 = 2.01 \times 10^{-4} \text{ m}^2$$

$$\text{Force } F = P \times A = 5 \times 10^5 \times 2.01 \times 10^{-4} = 100.5 \text{ N}$$

3. Safety Factor:

$$\text{SF} = 100.5 / 25.5 = 3.94$$

4. Velocity:

$$\text{Velocity} = \text{Stroke} / \text{Time} = 0.3 / 2.5 = 0.12 \text{ m/s}$$

5. Air Consumption:

$$\text{Air} = A \times L = 2.01 \times 10^{-4} \times 0.3 = 0.0603 \text{ Liters/cycle}$$

6. Power Required:

$$\text{Power} = P \times Q = 5 \times 10^5 \times 0.0005 = 250 \text{ W}$$

Final Result:

Required Force = 25.5 N

Cylinder Force = 100.5 N

Safety Factor = 3.94

Velocity = 0.12 m/s

Air Consumption = 0.060 Liters/cycle

Industrial Real-Time Model Calculation

Given Data:

Door Weight (m): 50 kg

Pressure (P): 6 bar = 6×10^5 Pa

Stroke Length (L): 1 m

Cylinder Diameter (D): 50 mm = 0.05 m

1. Force Required:

$$F = 50 \times 9.81 = 490.5 \text{ N}$$

Considering friction (20%):

$$F_{\text{total}} = 490.5 + 98.1 = 588.6 \text{ N}$$

2. Cylinder Force:

$$\text{Area } A = (\pi D^2)/4 = 1.96 \times 10^{-3} \text{ m}^2$$

$$\text{Force } F = P \times A = 6 \times 10^5 \times 1.96 \times 10^{-3} = 1176 \text{ N}$$

3. Safety Factor:

$$SF = 1176 / 588.6 = 2.0$$

4. Velocity:

$$\text{Velocity} = 1 / 3 = 0.33 \text{ m/s}$$

5. Air Consumption:

$$\text{Air} = 1.96 \times 10^{-3} \times 1 = 1.96 \text{ Liters/cycle}$$

Final Result:

Required Force = 588.6 N

Cylinder Force = 1176 N

Safety Factor = 2.0

Velocity = 0.33 m/s

Air Consumption = 1.96 Liters/cycle

CONCLUSION

The Remote Controlled Pneumatic Door Opening System is a successful example of the application of pneumatic technology in automation. The project meets the requirements of designing a system for smooth and efficient door operation using a remote-controlled pneumatic system.

The integration of mechanical parts with electrical parts, such as a solenoid valve and a relay, enables the system to convert electrical signals into controlled pneumatic movements. The double-acting action of the cylinder ensures smooth opening and closing of the door.

The project demonstrates the advantages of using a pneumatic system, including cost-effectiveness, simplicity, safety, and easy maintenance. It proves the viability of pneumatics as a replacement for automation systems for medium-load applications where cleanliness and quick response are essential.

The project is a successful example of designing a cost-effective and efficient system for automation applications in industries, hospitals, and smart buildings. With further enhancements, the system can be converted into a fully automated smart door system.

DECLARATION OF INTEREST

All authors declare that there are no conflicts of interest regarding the publication of this paper.

ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to Prof. R.S. Dange and Prof. Dr. S. K. Pawar, Head, Department of Mechanical Engineering, SCSCOE for their invaluable guidance and support throughout this work.

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