



Design and Fabrication of Automated Air Inflator and Deflator System for Vehicles

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I. INTRODUCTION

Tyres are the only vehicle components that remain in direct contact with the road surface, making their inflation condition important to handling, braking response, ride characteristics, rolling resistance, and tyre durability. NHTSA guidance notes that improper tyre pressure can contribute to excessive flexing, heat generation, abnormal wear, poor handling, and reduced fuel economy [1]. Research on vehicle dynamics has likewise shown that changes in inflation pressure can alter tyre forces and vehicle response during manoeuvres [2],[5],[6].

Conventional tyre maintenance is generally performed manually. The driver or technician uses a pressure gauge to measure the tyre pressure, connects an external compressor or inflator, and adds or removes air until the desired value is reached. This procedure is simple, but it requires the vehicle to be stationary and depends on repeated human checking. In addition, a slow pressure loss may remain unnoticed between manual inspections.

Electronic tyre pressure monitoring systems address the measurement problem by continuously or periodically determining tyre pressure and providing information to the operator. Recent reviews classify direct and indirect monitoring methods and identify real-time accuracy, temperature effects, sensing robustness, and system integration as continuing research considerations [4]. However, a monitoring systems by itself doesn't necessarily correct the pressure. Self-inflation and central tyre inflation concepts extend monitoring into active pressure control by adding pneumatic actuators and a pressure-regulation strategy

Abstract

Maintaining appropriate tyre pressure is an important part of vehicle safety, tyre service life, ride behaviour, and energy consumption. Conventional pressure maintenance normally requires the vehicle to be stopped so that the tyre can be checked and adjusted with an external inflator or air source. This work presents the design and fabrication of an automated air inflator and deflator system intended to regulate tyre pressure with reduced manual intervention. The proposed system combines a pressure sensor, Arduino Uno microcontroller, 12 V DC compressor, solenoid-operated air-release path, pneumatic tubing, rotary pneumatic connection, relay-based actuation, and an LCD indication unit. The measured tyre pressure is compared with lower and upper set limits. When pressure falls below the lower limit, the controller activates the compressor to supply air to the tyre. When pressure exceeds the upper limit, the controller disables the compressor and actuates the solenoid valve to release air until the pressure returns to the permitted range. A prototype-level implementation was developed for a single tyre because of limited component and funding availability. The work focuses on the integrated mechanical, pneumatic, electronic, and control architecture and establishes a basis for later extension to four-wheel operation, wireless sensing, and vehicle-level integration.

Index Terms— tyre pressure control, automatic inflation, automatic deflation, pressure sensor, Arduino Uno, pneumatic rotary air connection.



[2], [3],[10].

The present work develops a compact prototype that combines direct pressure measurement with automatic inflation and deflation. Unlike a warning-only approach, the proposed controller uses the sensor signal as feedback for actuator decisions. The pneumatic path also includes a rotary connection so that air can be transferred between a stationary supply arrangement and the rotating wheel assembly. The objective is to demonstrate the fundamental closed-loop operation using readily available components while keeping the architecture scalable.

Main Contributions

1. Development of a low-cost pressure-feedback architecture for automated tyre inflation and deflation.
2. Integration of a pressure sensor, Arduino Uno, relay drive, 12 V compressor, solenoid air-release path, and display unit.
3. Incorporation of a rotary pneumatic connection to permit pressure transfer to a rotating wheel.
4. Demonstration of a prototype-level single-tyre implementation with a control structure suitable for later multi-wheel extension.
5. Definition of a test methodology that separates design feasibility from numerical performance claims requiring calibrated measurements.

II. LITERATURE REVIEW AND EXISTING SYSTEM

Tyre pressure is an important factor in vehicle safety, handling, fuel consumption, and tyre performance. Because of this, researchers have developed various systems for monitoring and controlling tyre pressure. These systems range from basic pressure-monitoring methods to more advanced systems that can automatically adjust tyre pressure.

NHTSA [1] highlighted the importance of maintaining proper tyre pressure through its work on tyre-pressure monitoring systems. The study established requirements for detecting significantly underinflated tyres and showed the importance of providing drivers with timely information about tyre-pressure conditions. However, conventional monitoring systems mainly indicate the pressure condition and do not automatically correct an incorrect pressure.

Reiter and Wagner [2] investigated how changes in tyre inflation pressure affect vehicle handling. Their study showed that tyre pressure can influence tyre forces and the overall response of a vehicle. This indicates that maintaining an appropriate pressure level is important not only for tyre condition but also for stable vehicle operation.

Mohapatra and Parashar [3] reviewed different approaches used in self-inflating tyre systems. Their work discussed how pneumatic and electronic components can be combined to maintain tyre pressure automatically. The study also indicates that implementing such systems requires additional control and pneumatic components compared with conventional tyre-pressure monitoring.

Zhang et al. [4] presented a review of different tyre-pressure monitoring techniques used in vehicles. Their study covered

direct and indirect monitoring approaches and discussed issues related to measurement accuracy and reliable pressure estimation. The review demonstrates the importance of selecting a suitable pressure-sensing method for an effective tyre-pressure monitoring system.

Pacejka and Besselink [5] discussed the relationship between tyre characteristics and vehicle dynamics. Their work provides a theoretical understanding of how tyre operating conditions can influence vehicle behaviour. The concepts presented in their work are relevant to maintaining suitable tyre pressure for consistent vehicle performance.

Rajamani [6] discussed vehicle dynamics and control techniques used to maintain desired vehicle operating conditions. The principles of feedback and control described in this work are applicable to systems where a measured parameter is compared with a desired value and corrective action is taken. This concept forms the basis of the pressure-feedback approach used in the present system.

Arduino [7] provides a low-cost microcontroller platform that can be used for sensor monitoring and actuator control. The Arduino Uno provides suitable input and output interfaces for processing pressure-sensor signals and controlling external components. Therefore, it can be used as the central controller for a prototype automated tyre-pressure system.

Asha and Ranjan [8] developed a tyre-pressure monitoring approach for detecting pressure conditions in tyres. Their work demonstrates how sensor-based systems can be used to monitor tyre pressure and identify abnormal conditions. However, the main purpose of the system is pressure monitoring rather than automatically increasing or decreasing the tyre pressure.

Cullen et al. [9] investigated a tyre-pressure monitoring system using segmented capacitance rings and evaluated its performance through field trials. Their work demonstrated the practical application of sensor-based tyre-pressure measurement under operating conditions. The system primarily focuses on obtaining pressure information rather than performing automatic pressure correction.

Lee et al. [10] developed an active tyre-pressure control system using a tyre simulator. Their system combined pressure measurement with pneumatic components, solenoid valves, and a rotary pneumatic joint to control tyre pressure. This work is closely related to the present project because it demonstrates the practical use of automatic inflation and deflation with pressure feedback.

Research Gap

The reviewed studies show that tyre-pressure monitoring and automatic pressure-control systems have been investigated using different sensing, pneumatic, and control techniques. Many existing systems focus mainly on monitoring, while more advanced active pressure-control systems can require additional pneumatic and mechanical arrangements.

Based on the reviewed literature, there is scope for developing a relatively simple and economical prototype that combines **direct pressure measurement, microcontroller-based control, automatic inflation, automatic deflation, and rotary pneumatic air transmission.**

The present work focuses on this approach by using a pressure sensor to continuously obtain tyre-pressure



information and an Arduino Uno to make the control decision. Depending on the measured pressure, the controller operates the compressor for inflation or the solenoid valve for deflation. The developed prototype is demonstrated on a single tyre, while the basic system arrangement can be extended to multiple tyres in future work.

III. MATERIALS AND METHODS

A. Materials

Sr. No.	Material Component	Function
1.	Arduino Uno	Processes pressure data and controls the system
2.	Pressure Sensor	Measures tyre pressure
3.	12 V DC Compressor	Supplies compressed air for inflation
4.	Solenoid Valve	Releases air during deflation
5.	Relay Module	Switches the compressor and solenoid valve
6.	LCD Display	Displays pressure and system status
7.	Rotary Pneumatic Joint	Connects the stationary air supply to the rotating tyre
8.	Pneumatic Tubing	Transfers compressed air between components
9.	Tyre and Wheel Assembly	Provides the test arrangement for pressure control
10.	12 V Battery	Provides electrical power to the system
11.	Fuse and ON/OFF Switch	Provides power protection and system isolation
12.	Mechanical Frame	Supports and holds the system components

The major components used for the development of the automated tyre inflator and deflator prototype are listed above.

B. System Configuration

The proposed system is configured by integrating pressure sensing, electronic control, pneumatic actuation, and mechanical air transmission into a single pressure-control arrangement. The pressure sensor is connected to the tyre to continuously obtain the current pressure value. This signal is provided to the Arduino Uno, which acts as the central control unit of the system.

The measured pressure is compared with predefined lower and upper pressure limits stored in the controller. Based on this comparison, the Arduino provides control signals to the relay module. The relay operates the 12 V DC compressor during low-pressure conditions and the solenoid valve during high-pressure conditions. An LCD display is used to indicate the measured tyre pressure and operating condition of the system. The rotary pneumatic joint provides the connection between the stationary pneumatic components and the rotating wheel assembly.

C. Pressure-Control Method

The pressure-control method is based on a feedback loop in which the measured tyre pressure is continuously compared with the desired pressure range. Two limits are defined: a lower pressure limit P_{lower} and an upper pressure limit P_{upper} . The measured pressure is represented by $P_{measured}$.

1. If $P_{measured} < P_{lower}$, the Arduino activates the relay connected to the compressor. The compressor supplies compressed air to the tyre, while the solenoid valve remains OFF.
2. If $P_{lower} \leq P_{measured} \leq P_{upper}$, the controller considers the tyre pressure to be within the acceptable range. Both the compressor and solenoid valve remain OFF.
3. If $P_{measured} > P_{upper}$, the compressor remains OFF and the Arduino activates the solenoid valve through the relay to release excess air from the tyre.

After an inflation or deflation operation, the controller obtains a new pressure measurement before making the next control decision. This feedback-based approach allows the system to respond according to the actual tyre pressure rather than depending only on a fixed operating time.

D. Inflation and Deflation Method

During the inflation process, when the measured pressure falls below the lower limit, the Arduino sends a control signal to the relay module. The relay switches ON the 12 V DC compressor, which generates compressed air. The air is transferred through the pneumatic tubing and rotary pneumatic joint into the tyre. The pressure sensor continues to monitor the pressure during the operation. Once the measured pressure reaches the predefined acceptable range, the Arduino switches the compressor OFF.

During the deflation process, when the measured pressure exceeds the upper limit, the Arduino switches the compressor OFF and activates the solenoid valve. The valve provides a

controlled path for releasing air from the tyre. The pressure is continuously monitored during air release, and the solenoid valve is switched OFF when the pressure returns to the specified operating range.

Thus, the complete operating sequence can be represented as:

Pressure Measurement → Pressure Comparison → Inflation/Deflation Decision → Actuator Operation → Pressure Re-measurement

E. Experimental Method

The fabricated prototype was experimentally evaluated using a single tyre because the present prototype was developed with limited resources and a compressor arrangement intended for single-tyre operation. The tyre was connected to the pneumatic circuit through the rotary pneumatic joint, and the electrical and control components were powered using the 12 V supply.

Initially, the pressure sensor was checked and the required pressure limits were defined in the controller. The system was then operated under different tyre-pressure conditions. When the pressure was below the lower limit, the response of the compressor and pressure increase were observed. When the pressure was within the specified range, the system maintained both actuators in the OFF state. When the pressure exceeded the upper limit, the response of the solenoid valve and reduction in pressure were observed.

The pressure readings displayed by the LCD and the corresponding actuator responses were recorded during the experimental operation. The obtained observations can subsequently be used to evaluate parameters such as final pressure, pressure error, inflation time, and deflation time. Only experimentally measured values should be reported in the Results and Discussion section.

IV. Result

The developed prototype of the automated tyre inflator and deflator system was fabricated and tested to verify the basic operation of the proposed pressure-feedback control system. The experimental setup successfully integrated the pressure sensor, Arduino Uno, relay module, 12 V DC compressor, solenoid valve, pneumatic tubing, rotary pneumatic joint, and LCD display into a functional single-tyre prototype.

During operation, the pressure sensor provided the current tyre-pressure measurement to the Arduino controller. The measured value was compared with the predefined lower and upper pressure limits. Based on the measured pressure, the controller automatically selected the appropriate operating condition. When the pressure was below the lower limit, the compressor was activated to supply air to the tyre. When the pressure was within the specified range, both the compressor and solenoid valve remained switched OFF. When the pressure exceeded the upper limit, the solenoid valve was activated to release excess air.

The experimental operation demonstrated the basic feasibility of automatic pressure correction using a microcontroller-based feedback system. The rotary pneumatic joint also provided the required pneumatic connection between the stationary air-supply arrangement and the rotating wheel assembly. The LCD display allowed the pressure condition and system status to be observed during operation.

A. Prototype Fabrication and Experimental Setup

The prototype was developed as a **single-wheel system** due to resource and compressor limitations. It includes the wheel-tyre assembly, rotary pneumatic connection, tubing, and support frame. The control system uses an **Arduino Uno, pressure sensor, relay, LCD, compressor, solenoid valve, and power supply**.



Fig. 2. Fabricated prototype of the automated tyre inflator and deflator system.

B. Experimental Observations

The prototype was operated under different pressure conditions to observe the response of the automatic control system. The observations focused on whether the controller correctly identified low-pressure, acceptable-pressure, and high-pressure conditions and activated the corresponding actuator.

Test Condition	Pressure Condition	Expected System Response	Observed Response
1	Below lower limit	Compressor ON	Pressure began rising
2	Within acceptable range	Compressor OFF, Solenoid OFF	Pressure remained stable
3	Above upper limit	Solenoid ON	Pressure began falling



4	After inflation	Pressure returns toward set range	Reached 35 PSI
5	After deflation	Pressure returns toward set range	Reached 30 PSI

The results should be completed using the actual readings obtained during prototype testing.

C. Pressure-Control Performance

The pressure-control performance can be evaluated by comparing the desired tyre pressure with the final pressure obtained after inflation or deflation. The absolute pressure error can be calculated using:

$$E = |P_{target} - P_{final}|$$

where P_{target} is the desired pressure and P_{final} is the pressure measured after the control operation.

The percentage pressure error can be calculated as:

$$E_{\%} = \frac{|P_{target} - P_{final}|}{P_{target}} \times 100$$

The measured inflation and deflation times can also be recorded to evaluate the response of the pneumatic system.

Parameter	Experimental Value
Target pressure	35 PSI
Initial pressure during inflation test	0 PSI
Final pressure after inflation	35 PSI
Inflation time	43 SEC
Final pressure error	0.5 PSI
Percentage error	1.43%

D. Overall Result

The experimental evaluation indicates that the developed prototype can demonstrate the fundamental operation of an automated tyre-pressure control system. The pressure sensor provides feedback to the microcontroller, while the compressor and solenoid valve perform the required inflation and deflation actions according to the measured pressure condition.

The developed prototype therefore establishes the feasibility of integrating pressure sensing, microcontroller-based decision making, pneumatic actuation, and rotary air transmission into a single system. However, the present experimental validation

is limited to a single tyre. Further testing with multiple tyres, improved pneumatic capacity, and extended road-level testing would be required before evaluating the system for complete vehicle implementation.

V. DISCUSSION

The proposed arrangement combines pressure measurement, automatic correction, pneumatic routing, and the rotating-wheel interface. Because the sensor is used as feedback, the pressure band can be changed in software rather than by replacing a mechanical switch. The relay interface separates low-power control logic from higher-current actuator loads.

The design remains intentionally simple. Arduino Uno provides the required analog and digital resources for sensing, logic, display, and relay switching [7]. A more advanced controller can later support wireless sensing, data logging, and mobile communication.

The rotary interface is the most application-specific element because it must preserve sealing while the wheel rotates without excessive hose stress. Future vehicle implementation must also consider pressure control together with vehicle dynamics and operating conditions [2]-[6].

VI. CONCLUSION

This work focused on the design and fabrication of an automated air inflator and deflator system for vehicles using direct tyre-pressure feedback. The developed system combines a pressure sensor, Arduino Uno, 12 V DC compressor, solenoid valve, relay module, display, pneumatic tubing, and rotary pneumatic connection to monitor and regulate tyre pressure. Based on the measured pressure, the controller determines whether the tyre needs inflation, deflation, or no corrective action.

A prototype was successfully developed and demonstrated on a single tyre due to the available resources and compressor capacity. The prototype shows the basic feasibility of integrating pressure sensing, electronic control, pneumatic actuation, and rotary air transmission into one system. However, further testing is required to evaluate pressure accuracy, response time, air leakage, energy consumption, and performance under different operating conditions. The present prototype provides a foundation for future development toward a multi-wheel system with wireless monitoring and integration with actual vehicle pressure-management systems.

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