Proposal for the Design and Testing of an Automatic Tyre Inflation System in Real-World Scenarios

Project Title:

Design and Testing of a Prototype Automatic Tyre Inflation System

Applicant:

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Project Duration:

12 months

Introduction

Maintaining proper tyre pressure is a critical factor in ensuring vehicle safety, fuel efficiency, and tyre longevity. Under-inflated or over-inflated tyres can cause uneven tread wear, reduced traction, increased fuel consumption, and higher risks of blowouts. Despite the availability of manual inflation systems and tyre pressure monitoring systems (TPMS), there is a growing need for an automatic solution that can actively adjust tyre pressure while the vehicle is in motion.

In addition, during the process of air exchange it helps to control the air temperature by providing a cooling air to avoid unnecessary tyre expansion especially during the sunny hours

This proposal outlines the design, fabrication, and real-world testing of an **Automatic Tyre Inflation System (ATIS)** that maintains optimal tyre pressure under varying load and driving conditions. The system will use a centralized air compressor connected to each tyre through rotary joints and flexible hoses. It will monitor tyre pressure using pressure sensors and automatically adjust pressure through an embedded system-based algorithm. The proposed system aims to enhance road safety, improve fuel economy, and extend tyre life through real-time pressure adjustments.

The project will be executed in **three key stages**:

1. **Stage 1:** Design and Simulation
2. **Stage 2:** Fabrication and Bench Testing
3. **Stage 3:** Real-World Installation and Testing

Objectives

The primary objectives of this project are:

- To design and develop a working prototype of an automatic tyre inflation system.
- To maintain tyre pressure within a preset optimal range of **22 psi – 45 psi**.
- To improve vehicle fuel efficiency by reducing rolling resistance.
- To enhance tyre lifespan by ensuring consistent regulated pressure distribution.
- To reduce tyre-related road accidents caused by under or over-inflation.

Justification

Several studies have shown that under-inflated tyres can reduce fuel efficiency by **up to 3%** and increase tyre wear by **25%**. Moreover, improper tyre pressure is a leading factor in **flat tyres, blowouts**, and **poor vehicle handling**. Existing TPMS solutions only monitor tyre pressure but do not adjust it in real-time. This project will address these limitations by providing an active solution that adjusts tyre pressure automatically, thus enhancing vehicle performance and safety.

Scope of Work

The scope of this project covers the following areas:

- Design and development of a prototype automatic tyre inflation system.
- Integration of pressure sensors, embedded system, and air compressors into a single system.
- Real-time pressure adjustment during vehicle motion.
- Compatibility with both passenger cars and commercial vehicles.
- Real-world testing under different driving and load conditions.

Technical Approach

System Design

The automatic tyre inflation system will consist of:

- **Centralized Air Compressor** – Supplies air to all tyres through rotary joints.
- **Embedded systems** – Controls the compressor and regulate pressure balances through the aid of pressure sensors.
- **Pressure Sensors** – Monitors tyre pressure and sends data to the microcontroller.
- **Rotary Joints and Hoses** – Allows air transfer to rotating tyres.
- **Non-Return Valves** – Prevents backflow of air.
- **Display Unit** – Provides real-time feedback on tyre pressure levels.

Project Execution Plan

Stage 1: Design and Simulation

This stage involves the conceptual design, component selection, and system simulation using computer-aided design (CAD) software. The microcontroller programming and algorithm development will be tested through simulation before moving to hardware integration. Additionally, a **miniature working prototype** will be designed and built to test the system functionality on a small scale before full-scale implementation.

Item	**Description**	**Cost (₦)**
Design Software	Proteus and SolidWorks Licenses for circuit design and simulation	2,500,000
Microcontroller Programming	Development of the control algorithm for pressure adjustment	1,000,000
Simulation and Performance Testing	Virtual testing of system behavior using MATLAB and Proteus	1,500,000
3D Modelling	Creation of 3D models for system components using CAD	2,000,000
Miniature Prototype	Development of a small-scale working prototype for functional testing	6,000,000
Engineering Labor	2 Engineers @ ₦750,000 each for 2 months	1,500,000
TOTAL (Stage 1)		**14,500,000**

Stage 2: Fabrication and Bench Testing

This stage covers sourcing materials, assembling components, and conducting initial bench tests to verify system operation. All components will be integrated on a test rig for debugging and calibration.

Item	Description	Cost (₦)
Compressor	12V DC air compressor, 35 L/min capacity	1,200,000
Pressure Sensors	Digital pressure sensors (4 units)	800,000
Rotary Joints	High-pressure stainless steel rotary joints (4 units)	600,000
Embedded system	Microcontroller, microprocessors and other active component	1,200,000
Software development	Programmable software to initiate and activate the system	2,000,000
Hoses and Fittings	Flexible high-pressure hoses and clamps	500,000
Valves	Non-return solenoid valves	450,000
Power Unit	12V DC power supply	300,000
Control Circuit	Transistors, relays, and operational amplifiers	600,000
LCD Display	2x16 LCD for pressure monitoring	150,000
Brushless Motor	Compressor drive motor	1,000,000
Mild Steel and Cast Iron	Material for mounting and framework	800,000
Engineering Labor	2 Engineers @ ₦750,000 each for 3 months	1,500,000
TOTAL (Stage 2)		**11,100,000**

Stage 3: Real-World Installation and Testing

This stage involves installing the system in a real vehicle, conducting road tests, and evaluating performance under different driving conditions (urban, highway, and rough terrain).

Item	**Description**	**Cost (₦)**
Vehicle Purchase	Toyota Corolla (Test Vehicle)	10,000,000
Installation Labor	2 Engineers @ ₦1,000,000 each for 2 months	2,000,000
Road Test	Fuel consumption and tyre wear analysis	1,500,000
Performance Monitoring	Data logging and analysis using Arduino-based telemetry	1,000,000
Safety Certification	Vehicle roadworthiness certification	800,000
Documentation and Reporting	Performance report, data analysis, and findings	1,500,000
TOTAL (Stage 3)		**16,800,000**

Summary of Project Costs

Stage	**Cost (₦)**
Stage 1: Design and Simulation	14,500,000
Stage 2: Fabrication and Bench Testing	8,300,000
Stage 3: Real-World Installation and Testing	16,800,000
TOTAL PROJECT COST	**49,505,010**

Technical Requirements

Component	Specification
Compressor	12V DC, 35 L/min, max 60 psi
Pressure Sensor	Digital, range 0 – 50 psi, accuracy ±0.5 psi
Microcontroller	Arduino-based, 5V, 10-bit ADC
Rotary Joints	Stainless steel, 3000 psi rating
LCD Display	2x16 LCD module

Presentation

The proposed project aims to design, develop, and test a fully functional Automatic Tyre Inflation System (ATIS) that actively maintains optimal tyre pressure in real-time under varying driving and load conditions. Proper tyre pressure is a critical factor influencing vehicle performance, fuel efficiency, tyre lifespan, and overall road safety. However, existing solutions such as Tyre Pressure Monitoring Systems (TPMS) are limited to monitoring pressure without the ability to adjust it actively. This project seeks to bridge that gap by introducing a centralized, microcontroller-based system that not only monitors but also regulates tyre pressure automatically during vehicle operation.

The project is structured into three well-defined stages: design and simulation, fabrication and bench testing, and real-world installation and testing. The first stage focuses on the detailed design of the system using advanced CAD and simulation software to ensure technical accuracy and operational efficiency. The development of a miniature prototype will allow for early-stage testing and validation of the control algorithms, component interaction, and pressure regulation efficiency. The inclusion of a comprehensive simulation phase will enable the identification of potential design flaws and optimization opportunities before moving to full-scale production, ensuring a cost-effective and technically sound approach.

The second stage of the project involves the physical fabrication of the system components, including the air compressor, microcontroller, pressure sensors, rotary joints, and non-return valves. The components will be assembled and tested on a dedicated test rig to evaluate system performance under controlled conditions. Bench testing will provide valuable insights into the mechanical and electronic integration of the system, enabling necessary adjustments and calibration to optimize response time, pressure accuracy, and overall system reliability. The ability to test and refine the system in a controlled environment will reduce the risk of failures and malfunctions during real-world deployment.

The final stage involves the installation of the system in a real vehicle, specifically a Toyota Corolla, to assess its performance under actual driving conditions. This stage will allow the project team to gather real-time data on tyre pressure adjustments, fuel consumption, tyre wear, and vehicle handling. Testing will be conducted under various driving scenarios, including city driving, highway cruising, and rough terrain, to ensure that the system performs consistently across different environments. Data logging and telemetry analysis will enable a comprehensive evaluation of the system's effectiveness, with a focus on long-term reliability and durability. Any issues or inconsistencies identified during road testing will be addressed through system updates and refinements to enhance overall performance.

One of the key strengths of this project lies in its potential for practical application and scalability. An automatic tyre inflation system has wide-ranging implications for both passenger and commercial vehicles. Fleet operators, logistics companies, and public transportation services stand to benefit from improved fuel efficiency and reduced tyre replacement costs, leading to significant cost savings over time. Additionally, the system's ability to enhance vehicle stability and handling under varying load conditions will contribute to improved road safety and reduced accident rates.

From an economic perspective, the cost-effectiveness of the proposed solution makes it an attractive investment. The total project cost of **₦49,505,010** is well justified given the technical complexity, material costs, and labor requirements involved in developing and testing a high-performance system. The inclusion of a real-world testing phase ensures that the final product meets industry standards and can withstand the demands of daily vehicle use. Furthermore, the potential for local manufacturing and mass production offers opportunities for job creation, technology transfer, and the development of a domestic supply chain for automotive components.

The environmental benefits of this project are equally significant. By maintaining optimal tyre pressure, the system reduces rolling resistance, leading to lower fuel consumption and reduced greenhouse gas emissions. This aligns with Nigeria's commitment to reducing carbon emissions and promoting sustainable transportation solutions. Additionally, extending tyre lifespan through consistent pressure maintenance reduces waste generation and the environmental impact associated with tyre disposal.

In terms of technological advancement, the integration of microcontroller-based pressure regulation, real-time data processing, and automated adjustment mechanisms positions this project at the forefront of automotive innovation. The successful implementation of this system will open avenues for further research and development in the fields of smart vehicle systems, automated driving technologies, and integrated vehicle diagnostics.

The proposal underscores the project's technical feasibility, economic viability, and societal relevance. The structured approach, which combines thorough design, controlled testing, and real-world validation, ensures that the final system will be robust, reliable, and scalable. The multidisciplinary nature of the project, involving mechanical engineering, electrical engineering, and data analysis, reflects the collaborative effort required to bring a complex automotive solution to market.

Conclusion

This proposal presents a detailed plan for developing an Automatic Tyre Inflation System. The proposed system will enhance vehicle safety and performance, reduce fuel consumption, and improve tyre lifespan. The successful execution of this project will provide a cost-effective, reliable, and technologically advanced solution to a long-standing automotive challenge. By actively regulating tyre pressure in real-time, the system will enhance vehicle performance, improve safety, reduce operating costs, and contribute to environmental sustainability. The structured execution plan, experienced project team, and comprehensive testing strategy ensure a high likelihood of success, with potential for future commercialisation and industry adoption. This project represents a significant step toward the development of smart vehicle technologies in Nigeria and beyond, setting the stage for future innovations in automotive engineering and intelligent transportation systems.