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Compressor-Equipped Tyre Pressure Monitoring System

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Abstract: In India, where one in every three houses owns a two-wheeler, around 15 million two-wheelers are sold each year. Each year, the nation manufactures 20 million two-wheelers. A severely underinflated tyre may experience mechanical and thermal stress as a result of overheating, which can quickly result in the tyre blowing out. Failures of this kind may lead to risks and accidents that put everyone nearby at danger in addition to the rider. According to average country estimates, under-inflated tyres lead to tread separation and tyre failure, which result in 40,000 accidents, 33,000 injuries, and over 700 fatalities each year.

The population of India, however, may cause these numbers to increase because more individuals own 2-wheelers, have less time to personally check, and are unable to get their autos regularly inspected at a repair facility. The aforementioned problems will happen more frequently if the riders are unaware of them. The goal of this project is to develop and build a direct tyre pressure monitoring system (TPMS), which measures tyre pressure directly using a pressure sensor. When the TPMS notices a drop in tyre pressure, the rider does not have to exit the vehicle and manually pump air into the tyres because the TPMS and compressor unit are working together to supply the air to the tyre. The device receives power from a dynamo or a backup battery. The major components must be calibrated to guarantee consistency and accuracy in reporting the pressure and giving the tyre enough air. This prototype is a potential product for usage in the real world, despite the many difficulties and limitations.

Keywords: TPMS, compressor, Tire pressure, two-wheelers.

I. INTRODUCTION

Safety is unquestionably the most important feature of a vehicle. A vehicle may break down for a variety of reasons. Tyre blowouts are most frequently caused by inadequate tyre air pressure. Around 75% of tyre burst incidents are caused by under-inflation, but over-inflation is still not a concern. Studies show that driving with under-inflated tyres significantly raises both fuel consumption and CO2 emissions. Unavoidable tyre wear develops during use and is influenced by the type of vehicle, the tyre's properties, the type of road, the surrounding environment, and the driving circumstances.

A tyre burst typically occurs when pressurised air rapidly escapes from the tyre. When the tyre's structural integrity is compromised, it cannot contain all that air inside. As a result, the compressed air catches fire and rapidly rips through the tyre, severely destroying the surface. Regular car maintenance can lessen the severity of all these problems; there are several ways to do this. One of the most important systems (TPMS) is the tyre pressure monitoring system. In reality, lowering tyre pressure could shorten tyre life, impair a vehicle's ability to stick to surfaces, increase stopping distances, or even result in an unexpected tyre failure.

Tyre wear and tear generates a sizable amount of garbage, and the growing use of plastics—which are immune to hydrolysis, decomposition, and biological degradation—is causing an ecological problem on a grand scale. This makes the disposal of the majority of plastics a very challenging issue. Waste associated with tyres is categorised as a sort of garbage that requires industrial processing. The world is seeking for methods to increase the safe operation of tyres and make better use of them. The driving habits of braking, accelerating, and keeping the incorrect tyre pressure had the biggest impact on tyre wear, followed by cornering manoeuvres and driving speed.

Thus, it would seem that monitoring tyre pressure and avoiding sudden acceleration and braking could significantly cut down on tyre wear. This is why it's crucial that we find a solution for the safety of riders and passengers. It will also have a compressor unit to fill the tyre in case of an emergency. The user has a better experience because to the joint efforts of the TMPS and Compressor unit.

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II. LITERATURE REVIEW

[1] This study employed a "hybrid" technique that uses a single pressure sensor to calculate the tyre pressure for each vehicle tyre. As a result, a solution of this kind has well-balanced measurement performance and system cost. The proposed system is based on the use of a single tyre pressure sensor in conjunction with an estimator that makes use of other vehicle data, in contrast to typical direct and indirect TPMS. In contrast to regular iTPMS, by doing this, a tire's absolute pressure is evaluated in addition to its deflation being acknowledged. Reduced tyre pressure can limit tyre life, impact how well a vehicle adheres to surfaces, lengthen stopping distances, or even result in unexpected tyre failure.

[2] The newly created remote tyre pressure monitoring system (TPMS) for a fleet of vehicles is described in this study. Tyre wear can be decreased by using monitoring data. In the study, a comparison is made between the investigation into tyre pressure and friction-related tread deterioration for a fleet of cars with and without monitoring. The study claims that using monitoring data to inform decisions reduces waste from tyres that are worn out too soon. Unmonitored tyre wear reached 70%, whereas monitored tyre wear ranged from 7% to 13%. Let's say that 50% of Polish travel agencies follow the suggested monitoring method.

[3] This study provides information on the amount of tyre wear that is released into the environment and the significance of the multiple factors that affect tyre wear. It is possible to utilise this information to develop a methodology to estimate the rate of abrasion and to determine what has to be done to reduce microplastic emissions into the environment. Events including braking and accelerating, cornering manoeuvres, and driving speed had the worst influence on tyre wear. This suggests that avoiding abrupt acceleration and braking could considerably minimise tyre wear.

[4] This study describes the transfer of 13.56MHz and proposes a dual-slope ADC. This study examines the drawbacks of employing batteries for TPMS, including their limited lifespan, inability to conduct real-time surveillance, and lack of stability and reliability assurances. These problems can be fixed with a whole CMOS module without the need for batteries. The three methods for implementing battery-free TPMS are piezoelectricity technique, electromagnetic coupling method, and surface acoustic wave battery-less wireless sensor method. Close coupling, inductive coupling, and electromagnetic coupling systems were a few of the wireless power transmission techniques that were covered. The inductive connection in the battery-free TPMS is selected after taking the frequency, transmitting range, and power consumption into account.

[5] A water-gas heat exchanger, a refrigerator, a cooling tower, a circulating pump, and a suction pre-treatment system are all part of this project. The water-gas heat exchanger's suction air can be cooled using low-temperature water produced by the cooling tower and refrigerator. The best air compressor designs currently focus the use of cutting-edge structures or materials to either lower the temperature of the compressed air or absorb heat from it during compression. For the vast majority of applications, the air compressor's maximum load requirement was taken into consideration during design. Due to its frequent operation at partial capacity, an air compressor driven by a fixed frequency motor has a low energy efficiency.

[6] The LiFi theory and the most recent studies in this field are examined in this essay. LiFi, a form of wireless optical communication (WOC) technology, has the potential to solve the problems 5th and higher generation mobile networks are now experiencing. High-speed up- and down-link transmission can be done simultaneously with LiFi, a wireless two-way communication technology. High-speed data transfer is possible with LiFi, but it has many drawbacks, such as coverage. A hybrid WiFi/LiFi network can thus benefit from LiFi's speed and range. These technologies can be used in conjunction to overcome each one's limitations and improve network performance.

[7] In this experiment, the negative-pressure system acted as a regulator. Based on how the system is set up, the minute flow check valve was selected as a check valve. Because of its thorough compression and restoration, the tube's material has good physical characteristics and resistances. A computer-aided engineering (CAE) model was created after the creation of a tube performance tester in order to compare the outcomes. The tube and regulator now have a better-looking exterior. The investigation's veracity was ultimately established by the prototype test. High-performance and secure tyres may be produced using the machinery and technologies now in use.

[8] A complete vibro-acoustic analysis of compressor surge evolution is used as the first step in this study, and then a quick Fourier transform is used to show how frequency characteristics change over time. The results demonstrate that pressure pulsation at the centrifugal compressor outlet is primarily responsible for the rise and fall of the total sound pressure level during deep surge. Investigations are made into the erroneous noise's sources in the near-surge and deep-

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surge zones. Then, a mathematical model that includes an additional volume and takes into account variations in sound speed is used to analyse the centrifugal compressor surge.

[9] Control of the flow channel by the solenoid valve for a predetermined time. The flow characteristics of a 3/2 way solenoid valve in a ship's 4 stroke propulsion engine are computed. Commercial software called ANSYS CFX 12.0 was employed for the simulation. The reel can be moved by pushing the solenoid valve's hand-operated button or by sending an electric signal. The valve under study reacts to the moving reel with a very short response time. A superspeed valve, that is. the solenoid's body's midsection, where the reel is located, rotating.

[10] This study offers a non-intrusive method for diagnosing solenoid valve failure. In order to combine time-frequency analysis and time domain analysis of the current signal, this method employs a solenoid valve failure pattern identification algorithm together with an eigenvalue extraction methodology. The study team constructed a working solenoid valve model with a magnetic circuit, circuit, and spool motion (normal, spring broken, spool stuck, and slightly stuck) in order to investigate four typical solenoid valve states. The researchers recorded current signals during the solenoid valve's activating and shutting processes for each of these states.

III. METHODS AND MATERIALS

The following actions are taken into consideration in order to control maximum heat because temperature impacts tyre pressure: For both the front and back tyres, different limit ranges are specified before adding air. Displays for monitoring the entire procedure, Buzzer alarms are typically used in emergencies to prevent additional consequences, for data collecting, communication, data processing, etc., pressure sensors should be used, compressors for tyre air inflation, Microcontroller for improved sensor communication.

A. Proposed System

The block diagram of the transmitter and reception unit is shown below.For continuous tyre pressure monitoring, the transmitter of the TPMS is attached to the valves at the front and rear tyres.The display unit is what makes up the receiver. A wired connection connects the transmitter and receiver.

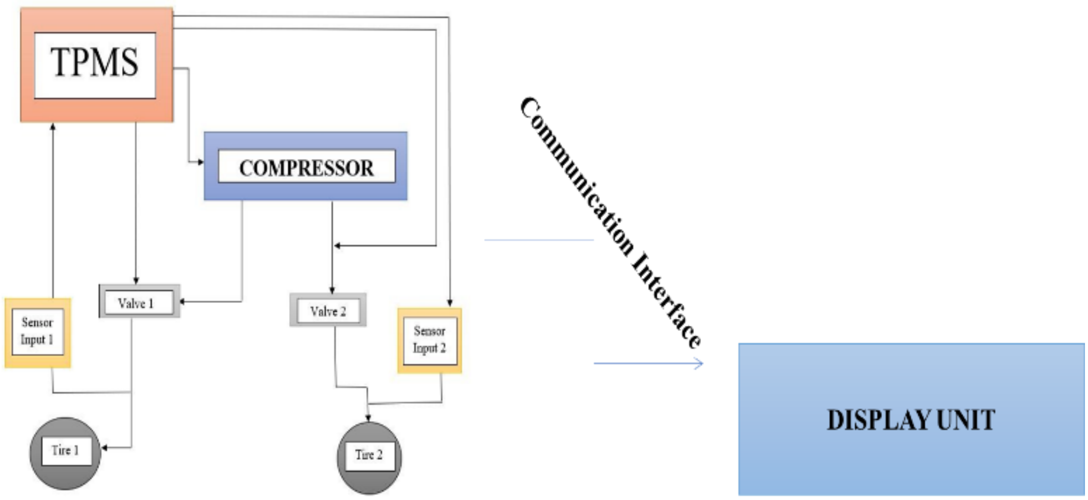

Fig. 1 Block diagram of Proposed system

B. Device Mechanism

The flowchart outlining the Electronic Control Unit's device mechanism can be found below. The solenoid valve's opening and closing is managed by the ECU, and the electric supply to the valves is controlled in accordance with the device mechanism algorithm. Both digital and analogue methods are used to show the sensor outputs and alarms.

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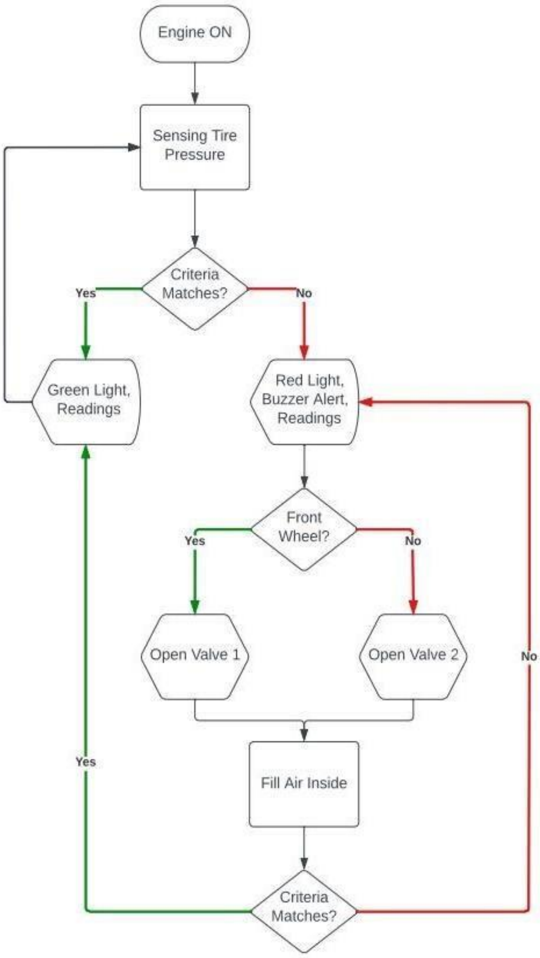
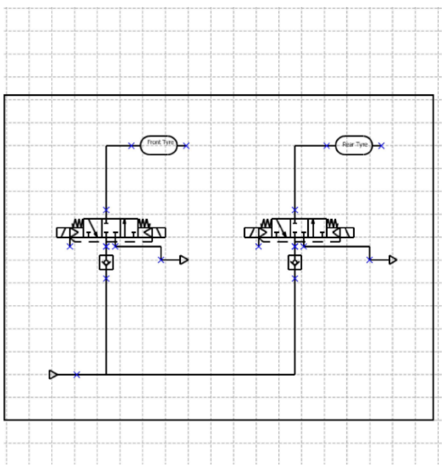


Fig. 2 Device mechanism

C. Pneumatic Circuit

The compressor unit's pneumatic circuit is shown below. The compressor and two valves make up the pneumatic circuit, and the pneumatic back line compressor connects the valves to the pneumatic pipeline, which is connected to the wheels, and the pressure sensor is connected between the valve and the tyre. When a pressure is sensed by the pressure sensor, the TPMS receives a response, and if the pressure is below a threshold, the valve is opened and the compressor is also opened. Once the tyre pressure is sufficient, the valves are closed and the compressor is turned off. Air is injected into the wheel to raise tyre pressure.



Code	Name
V1	3-port,3-Position,Closed center,Spring
V2	3-port,3-Position,Closed center,Spring
P1	Air source
F1	Check valve
F2	Check valve
P2	Air tank
P3	Air tank
P4	Vacuum source,Release to atmosphere
P5	Vacuum source,Release to atmosphere

Fig. 3 Design of the pneumatic circuit

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D. Wheel setup

Below is the 2D illustration of the wheel and the axle. The valve end of the hose travels the circumference of the tire. Axle end of the hose perform the circular motion at the point. We will transverse at this point circular motion to the TPMS using a L-shaped bearing coupler or straight bearing coupler.

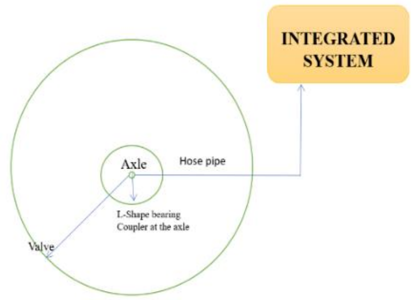

Fig. 4 Illustration of wheel setup

E. Circuit diagram

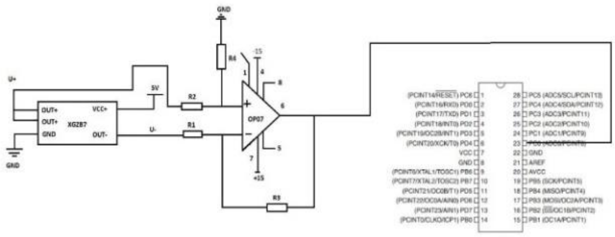

Fig. 5 Circuit diagram of sensor unit

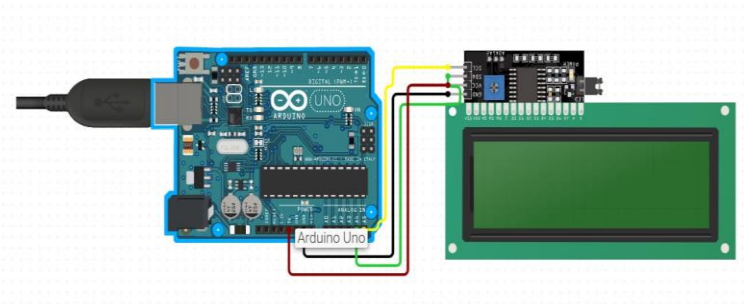

Fig. 6 Circuit diagram of display unit

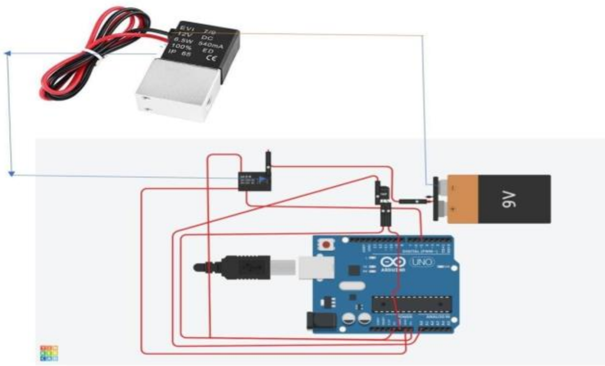

Fig. 7 Circuit diagram of solenoid valve

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F. Flowchart

The algorithm flowchart for the ECU is shown below: The sensor input is concurrently read and displayed, and it is then contrasted with the PSI range that has been defined for each tyre. If the sensor input complies with the requirements, the display displays a green light; otherwise, the solenoid valve supplies electricity to the tyres. The tyre pressure is checked repeatedly until it falls within the acceptable range.

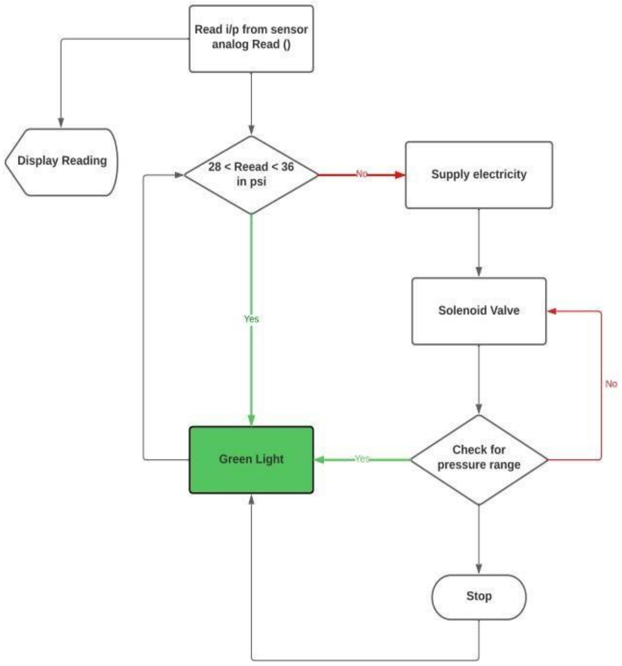

Fig. 8 Flow chart of the algorithm

G. Experiment setup

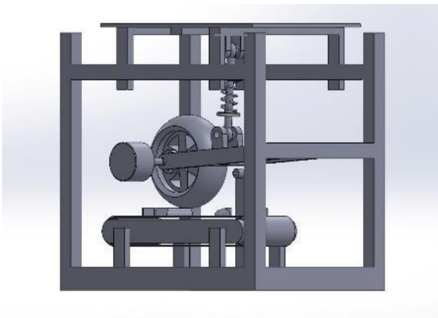

Fig. 9 Diagram of Experimental setup

The experimental setup consists of a frame to which a support arm us connected which is then connected to the wheel setup.The support arm is connected to suspensions which is then connected to the weight plate. The wheel and motor are connected to support arm. And under the wheel is a treadmill like setup. The treadmill setup and weights constitute to replicate real time performance for analysis.

IV. RESULTS AND DISCUSSION

A. Expected outcome

The system will be feasible with most of the 2-wheeler vehicles, To provide users with a smooth experience of inflating the tyre without having to go through a long procedure. The system will have alerting features with few tire health monitoring features as well.

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B. Market analysis

The tire's temperature and air pressure are monitored by an electronic device called the Tyre Pressure Measuring System, which also displays those numbers on the screen in real time. By doing so, the vehicle's driver is informed of the change in tyre pressure. The main effects of lowering vehicle pressure include decreased mileage, safety, performance, and limited tyre life.

The use of TPMS has increased fuel efficiency, tyre longevity, and driver skill in controlling the vehicle, all of which have contributed to a decrease in accidents. Batteries for TPMS devices have a lifespan of six to ten years. The manufacturing of the gadget decreased as a result of the pandemic, according to the market. The demand is anticipated to increase once more in the future, though the market is already returning to normal. For a period, the TPMS market was shut down, but today, several countries have provided leverage for import-export deals. According to estimates, the tyre pressure monitoring systems (TPMS) industry would be worth $5.67 billion in 2021. The value of TPMS is expected to reach 13.60 billion USD in the Asia Pacific region by 2027.

B. Barriers To Enter The Market

1) *Natural or structural barriers:* It will be extremely difficult to enter the market because the established corporations have already started moving into the Indian two-wheeler market. Companies who are active in the market have expanded their networks both with high-end and low-end businesses. Therefore, it might allow us to exploit the market or the Me network to a limited extent. It will be very challenging to get control over the raw material network.

2) *Artificial or Strategic Barrier:* when already-existing businesses establish cheap prices for high output. Consequently, it will be difficult to start off profitable. In order to stand out in a crowded market, we must develop our brand identity. And for our portion of the target market to accept the motorcycle industry's product. Contracts, patents, and licences all need to adhere to government rules and regulations, and obtaining a licence can be challenging. when the current businesses have licences for further contracts and patents.

3) *Technology:* How quickly is technology developing, and will it be able to replace our product in the next five years? One of our greatest threats in the coming years could be the scientific development of non-punctureable tyres. A smaller, simpler version of our device without the branding might likewise pose a danger to the development of our product.

4) *Branding:* In order to stand out in a crowded market, we must develop our brand identity. Additionally, we need the motorcycle companies—the other half of our target market—to accept the product.

5) *Competition:* In the already oversaturated market, there would be fierce competition from numerous manual and practical air inflator products.

C. Players in market:

Valour TPMS, Delphi Automotive, DENSO Company, Continental AG ZF TRW.In February 2022, Continental AG strengthens the safety solution for India. Continental is largely focused on providing cutting-edge safety technology, like ADAS and TPMS, in India, which has the largest two-wheeler market in the world. For its Combine Master and Combine Master VF tyres, which go on sale in May 2022, Continental has developed a new combine-tire monitoring system. They monitor the temperature and the pressure of the tyres.

Fleeca India Private Limited, a startup based in Jaipur, unveiled its Fleeca Kawach smart truck tire-pressure monitoring system in February 2022. This TPMS is an electrical device mounted on the rim that monitors both the rotational speed of the wheel and signals coming from the outside of the tyres.

D. Target audience

Because our product combines an inflator and a tyre pressure monitoring system, the audience will range widely, from the general public to the supplier.TVS, Bajaj, Suzuki, Honda, Royal Enfield, Hero Motocorp, Jawa Motorcycles, Boom Motors, and others are potential buyers. We can also link it with common motorcycle sale shops to reach a larger audience, as well as sell it separately through online and offline platforms to reach the general public.

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V. CONCLUSIONS

In conclusion, tyre pressure plays a critical role in the performance and efficiency of a vehicle. Improper tyre pressure can result in heat buildup, mechanical overload, and tyre failure, which could be dangerous for the rider and those around them. While compressing and installing a monitoring system in a 2-wheeler without compromising performance or accuracy is a challenge, doing so in larger vehicles is simple. The recommended gadget would have alerting and tyre health monitoring capabilities to give users a simple, quick experience when inflating tyres. The system is designed to work with the majority of two-wheeler vehicles, providing users with safer and more efficient journeys.

Additionally, installing the device in 2-wheelers can help to increase vehicle stability, decrease fuel consumption, and prolong tyre life. By identifying and fixing any tyre issues early on and preventing the need for costly repairs or replacements, the device can also save riders money and time. Additionally, the device is easy to incorporate into the current 2-wheeler system, providing riders with a comfortable and affordable alternative. Tools for tracking tyre health can help motorcycle riders keep tabs on their tyres' condition and prevent any unforeseen collisions.

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REFERENCES

[1] S. Formentin, L. Onesto, T. Colombo, A. Pozzato, and S. M. Savaresi, “h-TPMS: a hybrid tire pressure monitoring system for road vehicles,” Mechatronics, vol. 74, Apr. 2021, doi: 10.1016/j.mechatronics.2021.102492.

[2] B. Szczucka-Lasota, T. Węgrzyn, B. Łazarz, and J. A.Kamińska, “Tire pressure remote monitoring system reducing the rubber waste,” Transp Res D Transp Environ, vol. 98, Sep.2021, doi: 10.1016/j.trd.2021.102987.

[3] Y. Liu et al., “Impact of vehicle type, tyre feature and driving behaviour on tyre wear under real-world driving conditions,” Science of the Total Environment, vol. 842, Oct. 2022, doi: 10.1016/j.scitotenv.2022.156950.

[4] X. Bai, L. Wu, X. Zhang, and C. Jia, “Wireless power transfer and a dual-slope ADC design for battery-less TPMS,” in WOCC2010 Technical Program - The 19th Annual Wireless and Optical Communications Conference: Converging Communications Around the Pacific, 2010. doi: 10.1109/WOCC.2010.5510654.

[5] J. Shen, Z. Li, N. Tan, and Y. Xiao, “Design and analysis of a suction pretreatment system for the air compressor,” Energy Convers Manag, vol. 263, Jul. 2022, doi: 10.1016/j.enconman.2022.115675.

[6] M. R. Ghaderi, “LiFi and Hybrid WiFi/LiFi indoor networking: From theory to practice,” Optical Switching and Networking,vol.47, Feb. 2023,doi:10.1016/j.osn.2022.100699.

[7] M. Jun Kim et al., “DEVELOPMENT OF A VALVE AND OPTIMIZATION OF A TUBE FOR SELF-INFLATING TIRE,” International Journal of Automotive Technology, vol.18, no. 6, pp. 973–981, 2017, doi:10.1007/s12239−017−0095−4.

[8] S. Chen, S. Zuo, Z. Wu, and C. Liu, “Comprehensive vibro-acoustic characteristics and mathematical modeling of electric high-speed centrifugal compressor surge for fuel cell vehicles at various compressor speeds,” Mech Syst Signal Process, vol. 178, Oct. 2022, doi: 10.1016/j.ymssp.2022.109311.

[9] T. Kim, S. Yang, and S. Kang, “Numerical Study on the Flow Characteristics of a Solenoid Valve for Industrial Applications.” [Online]. Available: http://cfdlab.donga.ac.kr

[10] D. Ma, Z. Liu, Q. Gao, and T. Huang, “Fault Diagnosis of a Solenoid Valve Based on Multi-Feature Fusion,” Applied Sciences (Switzerland), vol. 12, no. 12, Jun. 2022, doi: 10.3390/app12125904.

[11] P. Sojka and V. Jaros, “Design of a wireless communication based on low power RF transceivers,” in Transportation Research Procedia, 2019, vol. 40, pp. 505–510. doi: 10.1016/j.trpro.2019.07.073.

[12] S. A. Moezi, M. Rafeeyan, E. Zakeri, and A. Zare, “Simulation and experimental control of a 3-RPR parallel robot using optimal fuzzy controller and fast on/off solenoid valves based on the PWM wave,” ISA Trans, vol. 61, pp. 265–286, Mar. 2016, doi: 10.1016/j.isatra.2015.12.005.

[13] D. Hu, J. Liu, F. Yi, Q. Yang, and J. Zhou, “Enhancing heat dissipation to improve efficiency of two-stage electric air compressor for fuel cell vehicle,” Energy Convers Manag, vol. 251, Jan. 2022, doi: 10.1016/j.enconman.2021.115007.

[14] N. N. Hasan, A. Arif, and U. Pervez, “Tire pressure monitoring system with wireless communication,” in Canadian Conference on Electrical and Computer Engineering, 2011, pp. 000099–000101. doi: 10.1109/CCECE.2011.6030417.

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[15] G. Sandoni and M. Ringdorfer, "ELECTRONIC REGULATION OF AN AUTOMATED CAR TYRES PRESSURE CONTROL SYSTEM."
[16] I. Rouf et al., "Security and Privacy Vulnerabilities of In-Car Wireless Networks: A Tire Pressure Monitoring System Case Study."
[17] C. Saad, E. A. Cheikh, B. Mostafa, and H. Abderrahmane, "Comparative Performance Analysis of Wireless Communication Protocols for Intelligent Sensors and Their Applications," 2014. [Online]. Available: www.ijacsa.thesai.org
[18] L. L. Trudsø et al., "The need for environmental regulation of tires: Challenges and recommendations," Environmental Pollution, vol. 311, Oct. 2022, doi: 10.1016/j.envpol.2022.119974.
[19] N. Makki and R. Pop-Iliev, "Battery-and wire-less tire pressure measurement systems (TPMS) sensor," in Microsystem Technologies, Aug. 2012, vol. 18, no. 7–8, pp. 1201– 1212. doi: 10.1007/s00542-0121480
[20] L. Wang, G. X. Li, C. L. Xu, X. Xi, X. J. Wu, and S. P. Sun, "Effect of characteristic parameters on the magnetic properties of solenoid valve for high-pressure common rail diesel engine," Energy Conversion and Management, vol. 127. Elsevier Ltd, pp. 656– 666, Nov. 01, 2016. doi: 10.1016/j.enconman.2016.09.057.