Smart Tyre Pressure Monitoring System For Modern Vehicles

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Abstract: A Tire Pressure Monitoring System (TPMS) is an electronic device that monitors the air pressure in a vehicle's tires and displays tire pressure information to the driver in real time. This device assists drivers in maintaining proper tire pressure, which is critical for fuel efficiency, tire lifespan, and safety. TPMS can also warn the driver of low tire pressure or other problems, thereby preventing accidents and reducing vehicle damage. TPMS is typically made up of sensors mounted in the tires, a receiver in the vehicle, and a display or warning light. The sensors measure the pressure within the tire and send the information to the receiver, which displays it for the driver.

Index Terms – Pressure, tire.

I INTRODUCTION:

With miles to go, every voyage, whether in a little vehicle or a commercial truck, is fraught with the fear of a tire puncture. Our roadways, which are littered with iron debris, potholes, and vehicle parts that have fallen off, raise severe concerns about the dreaded tire puncture. While a TPMS cannot prevent a tire puncture, it can alleviate your stress about an imminent flat tire caused by a slow air leak and the dangers that follow. Vehicles become difficult to manage with an underinflated tire, and they may lose control after a violent brake. Accidents at high speeds caused by tires blowing out due to a rise in temperature gradual air leak can result in a flat tire if driven unattended, permanently damaging the tire. With a fast-paced economy that requires you to convey goods and travel at the highest possible speeds, only a TPMS can provide you with real-time information about your tire health, allowing you to drive with confidence and worry-free. The TPMS automatically warns the motorist if there is a slow air leak or a rise in tire temperature before the tire becomes unsafe.

Benefits:

Improved Fuel Efficiency: Maintaining optimal tire pressure reduces rolling resistance, leading to better fuel economy.

Extended Tire Life: Underinflated tires wear unevenly and can lead to premature replacement, while TPMS helps prevent this.

Enhanced Safety: Low tire pressure can compromise handling and braking performance, potentially leading to accidents. TPMS alerts drivers to potential safety issues.

Reduced Damage: Underinflated tires are more prone to damage, including punctures and blowouts, which TPMS helps prevent.

Types of TPMS:

Direct TPMS (DTPMS): Uses sensors mounted directly on the tire valve stem to measure pressure.

Indirect TPMS (ITPMS): Measures tire pressure indirectly by monitoring the vehicle's wheel speed and rotation.

II.LITERATURE SUMMARY:

"A Smart Tyre Pressure Monitoring Using Android Phones": G. Prasanthi, V. S. Felix Enigo: This study presents an Android-based TPMS that enables real-time tire pressure monitoring and alerts via smartphones, enhancing user convenience and safety.

"Tire-Pressure Identification Using Intelligent Tire with Three-Axis Accelerometer": Bing Zhu, Jiayi Han, Jian Zhao
The research explores the use of three-axis accelerometers within tires to accurately identify tire pressure changes, contributing to the development of intelligent tire systems.

"Nonlinear Sliding Mode Observer for Tire Pressure Monitoring"This paper introduces a nonlinear sliding mode observer approach for indirect TPMS, aiming to enhance estimation accuracy and system robustness.

"Design and Implementation of Tire Pressure and Temperature Monitoring System for Hatchback and Multi-Purpose Vehicle Based on IoT":Hendy Briantoro, Anang Budikarso, arifin, Md. Mahbubur Rahman:The study details an IoT based TPMS that monitors tire pressure and temperature, transmitting data to cloud servers for real-time access via smartphones and computers.

"Tire Health Monitoring Using the Intelligent Tire Concept":Pooya Behroozinia, Saied Taheri, Reza Mirzaeifar
This research focuses on the intelligent tire concept, utilizing embedded sensors to monitor tire health parameters, thereby enhancing vehicle safety and performance.

"An Intelligent Online Vehicle Tyre Pressure Monitoring System":Santhosh Krishna Venkata, Pankaj Kumar Bhowmik: The paper presents a TPMS that employs MEMS pressure sensors and fuzzy logic algorithms, implemented on an FPGA platform for real-time monitoring and alerts.

III PROBLEM DEFINITION:

Maintaining proper tire inflation pressure improves tire performance and fuel economy. Correct tire inflation pressure allows drivers to enjoy tire comfort, durability, and performance that is tailored to the needs of their cars. Tire deflection (tread and sidewall flexing where the tread makes contact with the road) will remain as designed, with no excessive sidewall flexing or tread wiggle. Heat accumulation will be minimized, and rolling resistance will be adequate. Proper tire inflation pressure stabilizes the structure of the tire, combining its responsiveness, traction, and handling.

An underinflated tire loses its form and becomes flatter than planned when in contact with the road. If a vehicle's tires are underinflated by merely 6 psi, the tires may fail. Additionally, the tire's tread life could be reduced by up to 25%. Lower inflation pressure causes the tire to deflect (bend) more when it rolls. This generates internal heat, increases rolling resistance, and reduces fuel economy by up to 5%. You would feel a substantial reduction in steering precision and cornering stability. While 6 psi may not appear to be an overly low pressure, keep in mind that it typically represents roughly 20% of the tire's recommended pressure.

The need of the hour is the system which constantly monitors the pressure of the system and is economically feasible to a common man and we focused on developing a low cost system which has been prepared by keeping our Indian middle class in mind.

An overinflated tire is hard and unyielding, with a smaller footprint in touch with the road. If a vehicle's tires are overinflated by 6 psi, they may be more readily damaged when hitting potholes or debris on the road. Higher-inflated tires cannot effectively isolate road disturbances, resulting in a rougher ride. However, greater inflation pressures typically increase steering responsiveness and cornering stability up to a point.

This is why street tire users in autocrosses, track events, and road races experience greater than average inflation pressures. The pressure must be verified with a quality air gauge, as the inflation pressure cannot be accurately determined by visual inspection.

PRESSURE MONITORING SYSTEM:

A Pressure Monitoring System (PMS) typically uses sensors to detect pressure and sends the results to a central unit for analysis and display. These systems may be either direct or indirect. Direct PMS measures pressure directly through sensors embedded in the tire (or other monitoring device). Indirect PMS detects changes in tire pressure depending on wheel rotation speed.

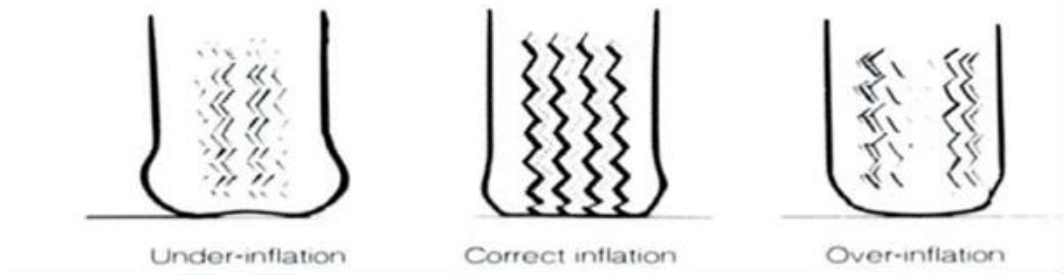

Fig 1: Abnormal tire wear

Key Considerations for Pressure Monitoring Systems:

Accuracy: The accuracy of the pressure measurement is crucial for reliable system operation.
Reliability: The system should be reliable and capable of operating under different conditions.
Ease of Use: The system should be easy to use and understand for drivers.
Durability: The system should be durable and able to withstand the rigors of driving

IV. EXPERIMENTAL SETUP:

Bias:

Bias tire (or cross ply) construction uses body ply cords that extend diagonally from bead to bead, often at angles ranging from 30 to 40 degrees, with succeeding plies laid at opposing angles to form a crisscross pattern to which the tread is applied. The design allows the entire tire body to flex readily, resulting in the primary benefit of this construction: a smooth ride on uneven terrain. This cushioning feature also contributes to the key disadvantages of bias tires: increased rolling resistance and reduced control and traction at higher speeds.

Belted Bias:

A belted bias tire starts with two or more bias-plies to which stabilizer belts are bonded directly beneath the tread. This construction provides smoother ride that is similar to the bias tire, while lessening rolling resistance because the belts increase tread stiffness. The plies and belts are at different angles, which improve performance compared to non-belted bias tires. The belts may be cord or steel.

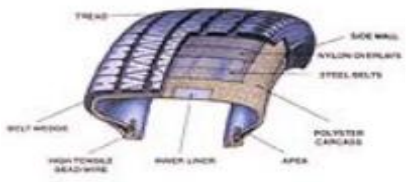

Fig 2: Belted Bias

RADIAL:

Radial tire construction utilizes body ply cords extending from the beads and across the tread so that the cords are laid at approximately right angles to the centerline of the tread, and parallel to each other, as well as stabilizer belts directly beneath the tread. The belts may be cord or steel. The advantages of this construction include longer tread life, better steering control, and lower rolling resistance. Disadvantages of the radial tire include a harder ride at low speeds on rough roads and in the context of off-reading, decreased "self-cleaning" ability and lower grip ability at low speeds.

SOLID:

Many tires used in industrial and commercial applications are non-pneumatic, and are manufactured from solid rubber and plastic compounds via molding operations. Solid tires include those used for lawn mowers, skateboards, golf carts, scooters, and many types of light industrial vehicles, carts, and trailers. One of the most common applications for solid tires is for material handling equipment (forklifts). Such tires are installed by means of a hydraulic tire press.

SEMI PNEUMATIC:

Semi-pneumatic tires have a hollow center, but they are not pressurized. They are light-weight, low-cost, puncture proof, and provide cushioning. These tires often come as a complete assembly with the wheel and even integral ball bearings. They are used on lawn mowers, wheelchairs, and wheelbarrows. They can also be rugged, typically used in industrial applications, and are designed to not pull off their rim under use.

Tires that are hollow but are not pressurized have also been designed for automotive use, such as the Twee (a portmanteau of tire and wheel), which is an experimental tire design being developed at Michelin. The outer casing is rubber as in ordinary radial tires, but the interior has special compressible polyurethane springs to contribute to a comfortable ride. Besides the impossibility of going flat, the tires are intended to combine the comfort offered by higher-profile tires (with tall sidewalls) with the resistance to cornering forces offered by low profile tires. They have not yet been delivered for broad market use.

TUBELESS TIRES:

These are basically similar to the tube tire but this tire has no tube and it is directly attached to the rim. The air chamber is completed by the rim itself. The tire is inflated by the high pressure air and these are the new trend emerging with the automobile and they are not suitable for the wheels with spokes.

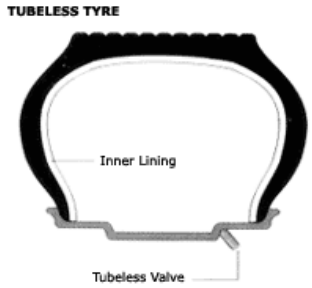

Fig 3: Tubeless tire.

INFLATION PRESSURE:

Tires are specified by the vehicle manufacturer with a recommended inflation pressure, which permits safe operation within the specified load rating and vehicle loading. Most tires are stamped with a maximum pressure rating. For passenger vehicles and light trucks, the tires should be inflated to what the vehicle manufacturer recommends, which is usually located on a decal just inside the driver's door or in the vehicle owner's handbook. Tires should not generally be inflated to the pressure on the sidewall; this is the maximum pressure, rather than the recommended pressure. High performance and dynamic drivers often increase the tire pressure to near the maximum pressure as printed on the sidewall. This is done to sacrifice comfort for performance and safety. It is definitely very dangerous to allow tire pressure to drop below the

recommended placard vehicle pressure, although this is commonly done temporarily when driving on sand to reduce chance of bogging. The reason for this is that it increases the amount of tire wall movement as a result of cornering forces. Should a low pressure tire be forced to perform an evasive maneuver, the tire wall will be more pliable than had it been of a higher pressure, and thus it will "roll" under the wheel. This increases the entire roll movement of the car, and diminishes tire contact area on the negative side of the vector. Thus only half the tire is in contact with the road, and the tire may deform to such an extent that the side wall on the positive vector side becomes in contact with the road. The probability of failing in the emergency maneuver is thus increased.

Further, with low tire pressure due to the side wall being more pliable the tire will absorb more of the irregular forces from normal driving, and with this constant bending of the side wall as it absorbs the contours of the road, it heats up the tire wall to possibly dangerous temperatures, as well as degrades the steel wire reinforcement; this often leads to side wall blow-outs. In an extreme case of this phenomenon, the vehicle may drive into a pot-hole, or a hard elevation in the road. Due to the low tire pressure, the side wall at the contact area will temporarily collapse, thereby wedging the tire between the wheel and road, resulting in a tire laceration and blow-out, as well as a damaged wheel. High tire pressures are more inclined to keep its shape during any encounter, and will thus transmit the forces of the road to the suspension, rather than being damaged it. This allows for an increased reaction speed, and “feels" the driver perceives of the road. Modern tire designs allow for minimal tire contact surface deformity during high pressures, and as a result the traditional wear on the center of the tire due to reasonably high pressures is only known to very old or poorly designed tires.

Feathering occurs on the junction between the tire tread and side wall, as a result of too low tire pressures. This is as a result of the inability of the tire to perform appropriately during cornering forces, leading to aberrant and shearing forces on the feathering area. This is due to the tire moving sideways underneath the wheel as the tire pressures are insufficient to transmit the forces to the wheel and suspension. It may be that very high tire pressures have only two downsides: The sacrifice in comfort; and the increased chance of obtaining a puncture when driving over sharp objects, such as on a newly scraped gravel road. Many individuals have maintained their tire pressures at the maximum side wall printed value (inflated when cold) for the entire lifetime of the tire, with perfect wear until the end. This may be of negative economic value to the rubber and tire companies, as high tire pressures decrease wear, and minimize side wall blow outs.

Many pressure gauges available at fuel stations have been de-calibrated by manhandling and the effect of time, and it is for this reason that vehicle owners should keep a personal pressure gauge with them to validate the correct tire pressure.

During the early stages of tire engineering, and with current basic tires, the tire contact patch is readily reduced by both over-and-under inflation. Over-inflation may increase the wear on the center contact patch, and under-inflation will cause a concave tread, resulting in less center contact. Most modern tires will wear evenly at very high tire pressures, but will degrade prematurely due to low pressures. An increased tire pressure has many benefits, including decreased rolling resistance. It has been found, that an increased tire pressure almost exclusively results in shorter stopping distances, except in some circumstances that may be attributed to the low sample size. If tire pressure is too low, the tire contact patch is changed more than if it were over-inflated. This decreases rolling resistance, tire flexing, and friction between the road and tire. Under-inflation can lead to tire overheating, premature tread wear, and tread separation in severe cases.

Tires are not completely impermeable to air, and so lose pressure over time naturally. Some drivers inflate tires with nitrogen, instead of simple air, which is already 78% nitrogen, in an attempt to keep the tires at the proper inflation pressure longer, though the effectiveness of this is debatable.

LOAD RATING:

Tires are specified by the manufacturer with a maximum load rating. Loads exceeding the rating can result in unsafe conditions that can lead to steering instability and even rupture. For a table of load ratings.

SPEED RATING:

The speed rating denotes the maximum speed at which a tire is designed to be operated. For passenger vehicles these ratings range from 99 to 186 miles per hour (159 to 299 km/h). For a table of speed ratings.

SERVICE RATING:

Tires are often given service ratings, mainly used on bus and truck tires. Some ratings are for long haul, and some for stop-start multi-drop type work. Tires designed to run 500 miles (800 km) or more per day carrying heavy loads require special specifications.

TREAD WEAR RATING:

The tread wear rating or tread wear grade describes how long the tire manufacturers expect the tire to last. A Course Monitoring Tire (the standard tire that a test tire will be compared to) has a rating of "100". If a manufacturer assigns a tread wear rating of 200 to a new tire, they are indicating that they expect the new tire to have a useful lifespan that is 200% of the life of a Course Monitoring Tire. The "test tires" are all manufacturer-dependent. Brand A's rating of 500 is not necessarily going to give you the same mileage rating as Brand B's tire of the same rating. The testing is non-regulated and can vary greatly. Tread wear ratings are only useful for comparing Brand A's entire lineup against itself. Tread wear, also known as tire wear, is caused by friction between the tire and the road surface. Government legal standards prescribe the minimum allowable tread depth for safe operation.

ROTATION:

Tires may exhibit irregular wear patterns once installed on a vehicle and partially worn. Furthermore, front-wheel drive vehicles tend to wear the front tires at a greater rate compared to the rears. Tire rotation is the procedure of moving tires to different car positions, such as front-to-rear, in order to even out the wear, thereby extending the life of the tire.

WHEEL ALIGNMENT:

When mounted on the vehicle, the wheel and tire may not be perfectly aligned to the direction of travel, and therefore may exhibit irregular wear. If the discrepancy in alignment is large, then the irregular wear will become substantial if left uncorrected. Wheel alignment is the procedure for checking and correcting this condition through adjustment of camber, caster and toe angles.

RETREAD:

Tires that are fully worn can be re-manufactured to replace the worn tread. This is known as retreading or recapping, a process of buffing away the worn tread and applying a new tread. Retreading is economical for truck tires because the cost of replacing the tread is less than the price of a new tire. Retreading passenger tires is less economical because the cost of retreading is high compared to the price of new cheap tires, but favorable compared to high-end brands.

V. RESULTS AND DISCUSSIONS:

The LED is made up of a chip of semiconducting material doped with impurities to form a p-n junction. Current flows readily from the p-side, or anode, to the n-side, or cathode, just like in other diodes, but not the other way around. Charge carriers (electrons and holes) flow into the junction from electrodes of varying voltages. When an electron collides with a hole, it moves to a lower energy level and emits energy in the form of a photon.

The wavelength of the emitted light, and hence its color, is determined by the band gap energy of the materials used to construct the p-n junction. For silicon or germanium diodes,

LEDs are typically constructed on an n-type substrate, with an electrode attached to the p-type layer placed on the surface. P-type substrates are also present, albeit less frequently. Many commercial LEDs, employ sapphire substrates.

Most of the materials used in LED manufacture have extremely high refractive indices. This means that a large amount of light will be reflected back into the substance at the interaction with the air. Thus, light extraction in LEDs is a key part of LED manufacture that is being extensively researched and developed.

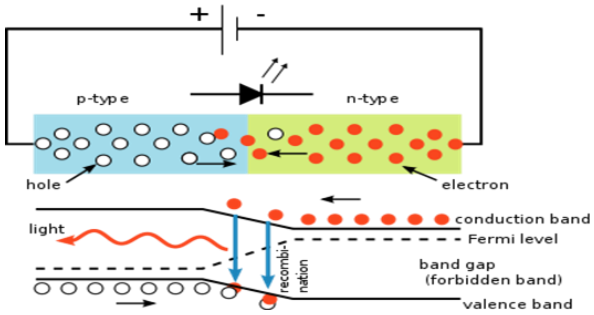

Fig 4: Working of Pressure monitoring system

A piezoelectric sound component's sound source is often a piezoelectric diaphragm. A piezoelectric diaphragm is made up of a ceramic plate with electrodes on both sides and a metal plate (such as brass or stainless steel). Adhesives are used to adhere a piezoelectric ceramic plate to a metal plate. The figure depicts the oscillating system of a piezoelectric diaphragm. Applying direct current voltage between the electrodes of a piezoelectric diaphragm generates mechanical deformation due to the piezoelectric effect. For a misshaped piezoelectric element, the distortion expands radially. And the piezoelectric diaphragm bends in the way depicted in Fig 5.

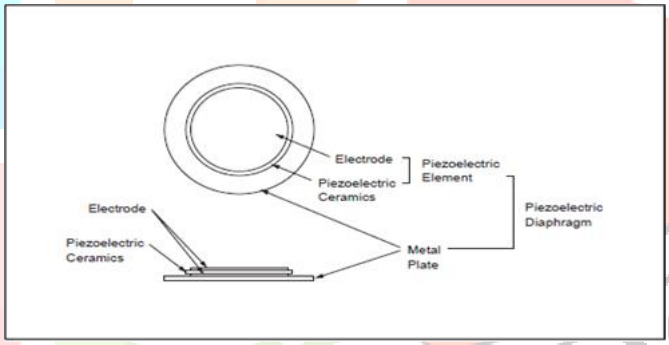

Fig 5: Working of wheel pressure

VI. CONCLUSION:

There is only one true advantage to TPMS hardware, and it is a significant one: it can save your life and/or your tires. TPMS is designed to alert you via a dashboard light when any of your tires go below 25% of the car manufacturer's specified pressure. This will alert you to a problem before your tire's sidewalls begin to fold over and rub together, which is typically the first tactile indication of a problem. By this point, your tires are irreparably damaged and hazardous. The most common way to balancing is redistributing mass, which can be performed by adding or removing mass from various machine elements. There are two main types of unbalancing: rotating unbalance and reciprocating unbalance, which may occur alone or in combination.

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