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# Incorporation of a Secondary Wheel Assembly using Novel Zigbee based Traction Control System for Vehicle Stability during Tire Blow-Outs

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**ABSTRACT:**

*Tire blow-outs or puncture during the operation of the vehicle is one of the major root causes of road accidents. The drivers lose his/her control of the steering wheel when the tire get punctured or busted leading towards loss of stability of the vehicle causing adverse effects to the vehicle and the passenger. Due to the rapid change in the pressure range within the tyres, the rim of the wheels come in contact with the road surface causing loss of traction and stability of the vehicle leading to accidents. Despite, the rapid advancements witnessed in the field of automobile industry stating from autonomous vehicles to electronic stability unit, a proper solution addressing the issue of accidents caused due to tire blow-outs remains unanswered. In this proposed study, automatic activation of an additional secondary wheel/roller assembly mounted to the chassis using a custom made Zigbee based smart traction system in order to address the traction and stability issues based on the real-time pressure of the tyre is presented. The real-time pressure of the wheels is monitored by the control system which then decides on scheduling the activation of the secondary wheel/roller assembly using a battery operated pneumatic system which will prevent the vehicle from losing its stability. The proposed traction control system consisting of the secondary roller assembly could also be considered as a lifesaving add-on to the passenger vehicle and a replacement for the wheel replacement jack emphasising the market demand of the proposed solution which is a robust and a cost-effective solution.*

**KEYWORDS:**

*Feasibility analysis; Wheel assembly; Tire blow-outs; Vehicle stability; Zigbee*

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## 1. Introduction

In elastic rubber wheeled vehicles, mechanical cooperation between directing hand-turned haggle wheels gives controlling related input to the driver. The torque nourished back to the driver over the direct linkages and guiding hand turned wheel, which is called, steering feel, helps the driver with a passive feedback by assisting him/her to make appropriate decisions on controlling the motion of the vehicle [1]. Highly efficient temperature independent pressure sensors [2] are used for monitoring tire pressure which is considered as a base idea incorporated into the smart traction control system proposed in this paper. The designers of vehicle manufacturing industries are focused towards building simple engineering solutions leading towards minimization of the time and money [3]. The use of microcontroller based hardware setups for controlling instruments to subjective the use of automation or smart systems is highlighted in many researches [5].

In general, Ackerman steering mechanism is one of the common types of steering mechanism used in vehicles. Based on their kinematic constraints, it is difficult to easily manoeuvring a four wheeled vehicle successfully within the confined working space, physical boundaries such as trees and obstacles in the road [6]. Typically, the optimum threshold of pressure range of the tire of locomotive vehicles is between 30 to 50 psi. This pressure estimated ceaselessly utilizing piezo resistive type pressure sensor. This sort of sensor is more compactable and can be used to effectively monitor the settling pattern within the tire ranging within 0-50psi. The output from the sensor is transmitted wirelessly using Zigbee. The transferred data is processed by the controller to compute the pressure and correspondingly activate the pneumatic cylinder. The exact pressure is also display on the LCD display. Considering these observations obtained from the literature, the need of a smart traction system to prevent adverse impact during a tire blow-out were highlighted which then lead to the evaluation of the impact of load distribution on the chassis and its influence in the tire blow-out scenarios.

Finite element analysis carried out using ANSYS clearly indicated the stress impact of the passenger's comfort during adverse scenario of tire blow-out. Analytical modelling of the impact phenomena need to be mutually combined to estimate the entity of dynamic loads and the interchangeable state of stress. The conclusions derived from the analysis helped us making choices of the type of dominant cause of defect, bending fatigue during the blow-out scenario [4]. A prototype of the simulated vehicle was fabricated in order to experimentally evaluate the simulated results. Section 2 explains the fabrication of the rapid prototype used for evaluating the feasibility study of the impact of a secondary roller/wheel using an automated traction control unit. Section 3 explains about the traction control unit in detail explaining about the transmitter/receiver architecture of the proposed system. Section 4 presents the results and concludes the paper.

## 2. Vehicle development

A prototype of a four wheeled vehicle is the fabricated using the low-cost aluminium solutions, considering the feasibility of fixing the secondary wheel/roller assembly unit to the vehicle. The chassis of the four wheels vehicle along with the steering system is fabricated. Automotive chassis is the base structure of a vehicle. The mechanical parts like engine, tires, axle assemblies, brakes, steering etc. are fixed in the automotive chassis so in order to evaluate the feasibility of the system we constructed a rapid prototype with the basic frame and the steering setup so that we can evaluate the proposed solution of the novel traction system. In automobiles the most important part is the chassis or the frame, which is the most pivotal component that gives quality and steadiness to the vehicle under various conditions. The outer structure of the car gives quality and adaptability to the vehicle. It is generally made of a steel outline which keeps a vehicle rigid, stiff and unbending. Auto chassis ensures low levels of noise, vibrations and harshness throughout the automobile. There are three main designs widely used in terms of the chassis in the automotive industry. Based on the type of folding of the material it is classified as, an open-ended cross-section, either C-shaped or hat-shaped (U-shaped) or "boxed" frames containing chassis rails that are closed, either by somehow welding or by using pre-manufactured metal fitting. The ladder frame is one of the most commonly used method and it is selected for this work. The CAD model of chassis frame is shown in Fig. 1(a). The fabricated vehicle frame is shown in Fig. 1(b).

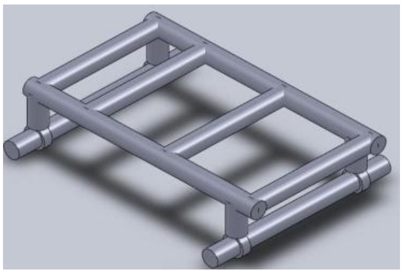

**Fig. 1(a): CAD Model of chassis frame**

**Fig. 1(b): Fabricated chassis frame**

The most conventional steering arrangement is to turn the front wheels utilizing a hand-operated controlling wheel which is situated before the driver, by means of the steering section, which may contain widespread joints (which may also be part of the collapsible steering column design), to allow it to deviate somewhat from a straight line. Other arrangements are sometimes found on different types of vehicles, for example, a tiller or rear-wheel steering. Different courses of action are at times found on various kinds of vehicles, for instance, a tiller or rear-wheel guiding. Followed by vehicles, like bulldozers and tanks more often they utilize the principle of differential steering, the tracks are made to move at various speeds or even in inverse ways, utilizing grasps and brakes, to achieve an alter obviously or course. The segments of a typical guiding framework are appeared in Fig. 2. The types of steering system commonly used in vehicles are (a) rack and pinion, (b) re-circulating ball and (c) worm and sector.

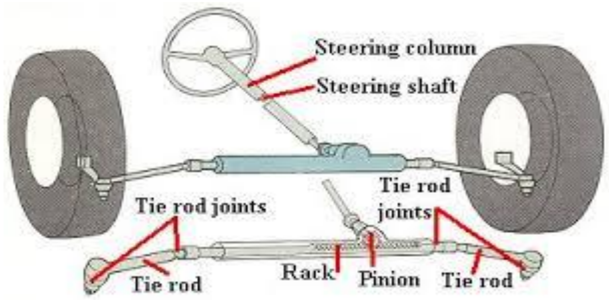


**Fig. 2: Steering system components**

A rack and pinion setup consists of a linear actuator that comprises a pair of gears which convert rotational motion into linear motion. A circular gear called "the pinion" engages the teeth on a linear "gear" bar called "the rack", which in turn converts the rotational motion applied to the pinion to move relative to the pinion, thereby translating the rotational motion of the pinion into linear motion. A rack and pinion setup is commonly used in the application of steering vehicles. Reduced backlash and feedback of the rack and pinion setup provides a mechanically less efficient model in comparison with the other mechanisms such as re-circulating ball. The mechanism may be power-assisted, by a hydraulic or electrical motor controlling the movement of the rack in relevance to the pinion. Considering these advantages a rack and pinion based steering system is selected considering its simplicity and cost-effective parameters.

## 3. Secondary wheel assembly

In addition to the steering and the chassis, the model also consists of a secondary wheel assembly which is fixed to the chassis at appropriate location for its function during emergency. The wheel has to move down to touch the ground when it is required and it should be placed above the ground during normal operation. For the movement of the wheels the pneumatic system with double acting cylinder setup is used. Pneumatic cylinders are mechanical devices which use the power of compressed gas to produce a force in a reciprocating linear motion. Like hydraulic cylinders, something forces a piston to move in the desired direction. The cross-sectional representation of a double acting cylinder is shown in Fig. 3. The piston is a disc or cylinder, and the piston rod transfers the force it develops to the object to be moved. The secondary wheel assembly also consists of a solenoid valve which is electromechanically operated. Solenoid valves are the most frequently used control elements in fluidics for performing the task of shut off, release, dose, distribute or mix fluids. Solenoids offer fast and rapid switching characteristics, highly reliable, less power consuming and long life. The solenoid value used to control the double acting cylinder that moved the secondary up and down is shown in Fig. 4. A small solenoid is capable of generating a limited force that can open and close the valve which is used to move the wheels in the proposed system. The pneumatic components related to the secondary wheel assembly are welded with the chassis frame as shown in Fig. 5.

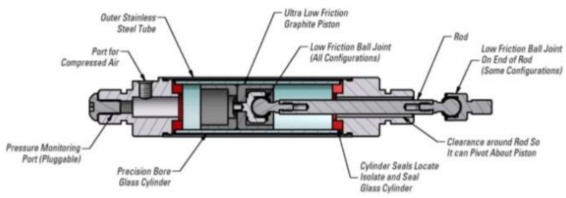


**Fig. 3: Cross sectional view of double acting cylinder**

**Fig. 4: Solenoid valve**

**Fig. 5: Pneumatic cylinder with secondary roller**

## 4. Proposed traction control system

The stability of the vehicle during the emergency of a tire blow-out is maintained by ensuring the additional wheel movement in relationship to the pressure range of the tires. Simulated mechanical analysis proved that the inclusion of an addition wheel reduces the impact to traction and stability when the tire is blow-out. In order to add an additional wheel in the proposed system a new novel, Zigbee based traction control system is proposed. Looking for the time available to control the secondary wheel movement in fraction of seconds the emergency situations is considered. A smart PID based electronic controlling control system is proposed to activate the pneumatic cylinder causing the downward motion of the wheel. The movement of the wheels ensure that the disturbances caused to burst with reference to the steering are reduced. So the driver in an emergency of tire bursting or puncture can smoothly park the car without any adverse impact. Authors believe that this cost-effective simple solution can save hundreds of lives in the future.

The proposed traction control system consists of an input device which in this case is the piezo resistive pressure sensor (MPXM2053) which gets the tire pressure value and sends to the control unit using Zigbee controllers explained below to control the lowering of the secondary wheel and also alerts the driver so that he can park the car without any hassle. The silicon based piezo resistive pressure sensor provides highly accurate, linear output voltage which corresponds to the pressure of the tyre. The sensor consists of a single, monolithic silicon diaphragm which acts as a strain gauge and a thin-film resistor network integrated on-chip that converts the pressure into corresponding voltage. The chip is laser trimmed for precise and offset calibration, in addition to this the sensor is also temperature compensated so the heat of the tires would not impact the proposed solution. The schematic diagram of the traction unit is given in Fig. 6.

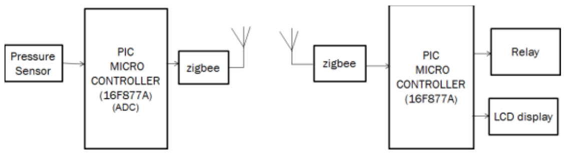


**Fig. 6: Block diagram of the proposed traction control unit**

The output voltage of the differential or gauge sensor shown in Fig. 7 increases with increase in tire pressure applied from pressure in one side (P1) [outer surface of the tire] relative to the vacuum side (P2) [inner side of the tire], resulting in a voltage corresponding to the pressure difference. In the proposed architecture of the traction control system, we use a PIC16F887 as the central controlling unit considering its rapid interfacing capabilities and the cost-effective nature. The system also consists of a Zigbee trans receiver (cc2500) which helps in communicating the status of the pressure range of the tire and lets the main control unit make a decision on when to activate the solenoid based secondary wheel/roller system. At present, near field wireless communication technology has been used widely, especially Bluetooth, wireless local area network (WLAN), infrared, etc. But, they have many disadvantages in terms of, complexity, large power dissipation, short distance, networking which is overcome by the use of the Zigbee based systems.

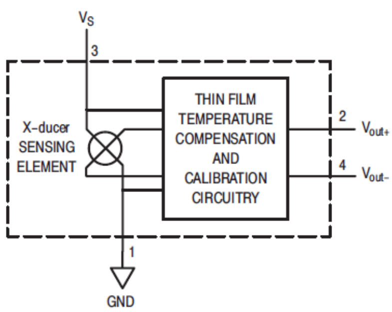


**Fig. 7: Temperature compensated pressure sensor module**

Zigbee devices are the combination of application (such as light sensor, lighting control etc.), Zigbee logical (co-ordinator, router, end device), and Zigbee physical device types (full function device and reduced function device). The proposed system consists of two units called the transmission and receiver unit which is placed in the following locations of the system. The transmission unity is mounted to the tire where the sensor tracks the pressure and sends it to the main controller or the master micro-controller which is the receiver unit that is connected to the linear actuator and solenoid value that controls the movement of the secondary wheel assembly. Fig. 8 and Fig. 9 indicate the transmission unit and the receiver unit of the proposed traction control system with the secondary wheel assembly respectively.

**Fig. 8: Transmission unit**

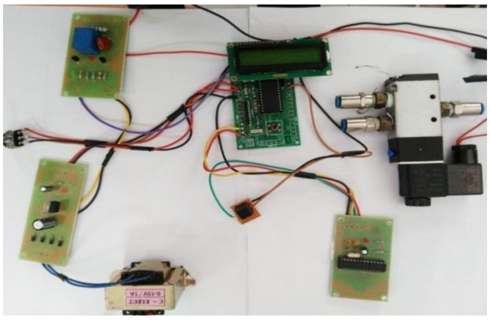

**Fig. 9: Receiver unit**

Pressure sensor will be placed inside the tyre. Supply to the sensor is given with the help of battery. Sensor is connected to PORT-A of PIC microcontroller. The output of the sensor is in terms of analogue voltage. It is converted to digital data using a DAC. PORT-B is initialized as output port and Zigbee is connected to this port. It transmits the pressure value to another PIC controller in the receiver unit. Vss and Vdd are given to PORT-E which is the input port. LCD display is connected to PORT-D which is a debug tool used for the feasibility analysis that was carried out. The data transmitted is received and processed in the receiver unit. In the receiver unit the Zigbee is connected to PORT-C. This receives the data and gives an output signal which operates the relay controlling the linear actuator and the solenoid value operating the secondary value. Regulated supply required for the operation of the system is given with the help of bridge rectifier attached to the circuitry of the system powered by a 9V battery.

PORT-B is assigned as output port and the microcontroller code receives the live data transmitted every second from the transmission unit and passes into the control unit which decides on the action/output of the system. Once the intelligent control unit triggers the output the relay which operates on the principle of electromagnetic induction is connected to PORT-B triggers. The output from the relay is used to activate the solenoid valve which in activated the lowering of the secondary wheel assembly. The voltage is converted to pressure in terms of psi programmatically and it is displayed on the LCD unit for us to do feasibility test of the proposed system. The shaft (piston) of the pneumatic actuator will act as a jack which could also be triggered form a mobile app that could be a replacement for the conventional jack used for replacement of wheels.

## 5. Conclusion

The novel Zigbee based traction control unit for in cooperating a secondary wheel assembly to enhance vehicle safety during tire blow-out is discussed in the manuscript. PIC microcontroller where used to evaluate the operation of the proposed system. An abrupt change in pressure inside the tyre is sensed and a signal is sent by the controller to the relay to activate the pneumatic cylinder (jack) that lowers down the secondary wheel assembly to increase the stability of the vehicle. We can also replace the wheel easily without using an external jack using the mobile application that allows us to lower the assembly to lift the car. Thus the proposed system can be low cost ads on to the vehicles that could save lives and also reduce the hassle in finding a jack for replacement of wheels.

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