Variable Tyre Pressure for Braking System –
A New Approach

R. Rewanth
Department of Automobile Engineering,
Sriram Engineering College, Anna University,
Chennai, India.
rewanthrao@gmail.com

B. Rajendra Prasath*
Department of Automobile Engineering,
Sriram Engineering College, Anna University,
Chennai, India.
Tel.: +91-44-27689364
*Correspondence: br_prasath@rediffmail.com

Abstract - In recent decades many safety systems are used for automotive braking system, which is rightly from a conventional drum brake system to an electronically controlled Anti-lock braking system (ABS). This indicates that a factor of safety of automobiles improved to the higher end. This paper describes a new approach in braking system which will reduce the stopping distance by reducing the tyre pressure instantly while applying sudden brake during emergency situation. The newly proposed variable tyre pressure for braking system (VTPBS) carry the improvement over the braking system employed in most of high end cars. This system is based on the principle that increase in the contact area of the tyre increases the co-efficient of friction between the road and the tyre, which results in reduced stopping distance when applying sudden brake. The sudden deflation of tyre pressure is obtained by connecting the mouth of the tyre to a vacuum chamber which is operated by a valve. The valve will be triggered when it senses the signal from an emergency braking system which is controlled by Electronic Control Unit (ECU). The deflated tyre can be inflated by an air cylinder which is present in the vehicle itself automatically controlled by valves and Electronic Control Unit (ECU). This will help to maintain the tyre pressure automatically without any manual concern, which reduces the risk of bursting of tyre due to high pressure or low economy because of a vehicle driving in an under inflated tyre.

Keyword: Anti-lock Braking System (ABS), Electronic Control Unit (ECU), Variable Tyre Pressure for braking system (VTPBS)

1. Introduction

Since the development of the first motor driven vehicle in 1769 and the occurrence of first driving accident in 1770, engineers were determined to reduce driving accidents and improve the safety of vehicle (Reference). It is obvious that efficient design of braking systems is to reduce accidents. Vehicle experts have developed this field through the invention of the first mechanical antilock braking system which have been designed and produced in aerospace industry in 1930 in 1945, the first set of ABS brakes were commonly installed in airplanes, soon after in the 1960 high end automobiles were fitted with ABS and with the rapid progress of microcomputers and electronics technologies the trend explored in the 1800s (Reference). Today all wheel ABS can be found on the recent model vehicles and even on a selected motorcycles.

ABS is recognised as an important contribution to road safety as it is designed to keep a vehicle steerable and stable during heavy braking moments by preventing wheel lock. It is well known that wheels will slip and lockup during severe braking or when braking on a slippery road surface, this usually cause a long stopping distance and sometimes the vehicle will lose steering stability. The emergency brake assistance system is one of the major safety systems which come in handy during the application of emergency braking. This system is triggered when the ECU senses there is an emergency braking while the rate of in which the braking pedal is pressed. The VTPBS systems uses the same sensors to detect the emergency braking, this both the system will be triggered by the emergency braking. The Emergency braking system will increase the braking effort by applying brake force via motor and ABS, the VTPBS will helps to maximise the effort produced by these systems combined and produce more braking effect, by increasing the traction between the tyres and roads.

The objective of VTPBS is to manipulate the wheel slip so that a maximum friction is obtained and the steering stability is maintained. That is used to support the vehicle stop in the shortest possible distance while the ABS maintains the directional control. The ideal goal for the control design is to regulate the tyre pressure according to the need of
emergency braking. The design of a VTPBS will contain vehicle’s physical brakes, an electronic control unit, vacuum chamber, air cylinder, solenoid valves, rotation joints.

2. Emergency Braking Assisted system:

Brake assistance system will help in emergency situations by increasing braking force. Based on the speed and force with which the pedal is pressed, the advance brake assistance system detects the emergency situations. Drivers press the brake pedal quickly during emergency situations. This is done by analysing the speed, with which the pedal is pressed active the advance brake assistance system will detect the emergency condition and applies full braking force even though driver did not press the brake fully. This advance brake assistance system has to be used with ABS and Electronic Stability Program (ESP) equipped cars in order to increase the control of the car while emergency braking. It will also increase the brake pressure until the ABS regulation intervenes to prevent the wheels from locking. In this way greatest possible braking effect can be achieved and the brake path is significantly short.

3. Anti-lock Braking System:

ABS system is a device which is used to prevent the wheel from locking due to the application of heavy brakes. Because when there is a wheel lock that is skidding occurs which will lead to increased stopping distance and also the control over the vehicle is lost. The ABS archives this by monitoring the speed of all the four wheels and applying brake to the faster moving wheel and removing the brake from the wheel at low speed. This will prevent the wheel which is at low speed from locking. The ABS functions with the help of ECU, speed sensors and brake fluid control valves. This is the most trending advanced technology in the automobile safety. This system is employed in all the recent model cars and some of the selected bikes.

4. Variable Tyre Pressure for Braking System:

The operation of automobiles under inflated tyre causes many problems such as low fuel economy, reduced control and manoeuvrability. Even though the stopping distance is less in case of an under inflated tyre, this may prevent accidents and save passengers. In order to get the trade-off between the performance of the automobiles and effective braking system, the variable tyre pressure to be maintained. The use of variable tyre pressure for braking system (VTPBS) is the optimised solution between the engine performance and braking system. Emergency Brake assistance system (EBS) (Reference) and ABS are also used during the braking but the efficiency of this system can also improve by implementing VTPBS, this will maximise the combined effort of ABS and EBS which will lead to decreased braking distance which reduces the risk of accident. This system regulates the tyre pressure, during a sudden braking it deflates the tyre and when the braking is success and then the vehicle starts to move again, it will automatically re-inflate the tyres to the optimisedtyre pressure prescribed by the vehicle manufacturer. This reduces the risk of accidents and also prevents the damages caused by the underinflated tyres.

5. Major Components of VTPBS

The developmental stage VTPBS will contain ECU, air cylinder, air pump, vacuum chamber, vacuum pump, solenoid valves controlled by ECU, and sensors. The vacuum chamber is used to remove the air from the tyre as soon as possible. There is a pump which connected to the chamber to create a vacuum in the chamber. The air cylinder is used to re-inflate the tyre once the vehicle returns to normal scenario. The air pump boosts the pressure in the air cylinder. These are all controlled by a ECU which works on the data from the sensors. The ECU controls the solenoid valves. These all are the main components for the VTPBS.

The VTPBS will be activated when, the vehicle is travelling more than the nominal speed (usually 50 mph) and there is a sudden apply of a brakes which is detected by the emergency brake assistance system’s sensors, this same sensor triggers the VTPBS. Once the system is triggered it will first open the valves that connect the tyre to the vacuum chamber. This will remove the air from the tyre instantly, thus by reducing the tyre pressure so that the contact surface of the tyre is increased. It increases contact surface area, which will increase the grip to the road surface, so the skidding effect is considerably reduced even without the ABS. It also increases friction between the road and the surface which will lead to superior grip and the stopping distance is reduced. After the vehicle completely stops, the tyres will have a low pressure, the vehicle cannot drive on an underinflated tyre. The installed
air cylinder, which re-inflated the tyre and it is powered by the air pump. The air pump obtains power from the engine and air pump could be mounted with respect to the space available of the vehicle. The ECU then closes the valve opening to the vacuum chamber and opens the valve to the air cylinder, to inflate the tyre to the optimum pressure prescribed by the vehicles manufacturer. Figure 1 demonstrates the variable tyre pressure for braking system.

![Figure 1 Schematic of VTPBS](image)

6. Theoretical considerations of VTPBS

The major principle in VTPBS is that the increase in contact surface increases the co-efficient of friction between the tyre and road, which will lead to superior grip. The stopping distance in influence by drivers speed of reaction, concentration, experience and immediate mental and physical condition. The driver does not change direction or speed of a vehicle during the phase from noticing instance to the stopping of the vehicle the stopping distance is determined by several factors which affect tyre grip such as weather conditions (rain, fog, lighting, snow), geography (slope traverse plane), speed, quality and type of tyre. The drive scope is influenced by density of transport flux, the drivers view of traffic flow, topography and environment.

The driver is required to drive only at a speed able stop before an obstacle is suddenly revealed ahead. The distance travelled by the vehicle from the moment of the obstacle appearing to the vehicle standstill is called trajectory required to stop a vehicle, it is influence by the driver’s ability to respond to the technical and structure status of the braking system, drivers speed and tyre design. The stopping distance (s) can be calculated using the following formula:

\[
    s = (t_r + t_0)v + v \cdot t_n - \frac{bN \cdot t_n^2}{2} + \frac{v_N^2}{2 \cdot b}
\]

- \(t_r\) - driver response time [s] - the period between the driver noticing and touching on the service brake pedal,
- \(t_0\) - delay time of brakes [s] - for vehicles with hydraulic brakes application takes the value of 0.05s,
- \(t_n\) - increased time of braking deceleration [s] - for vehicles with hydraulic brakes application of the vehicle during braking increasing. Because of increases from 0 to full value can be determined as a half of full average braking deceleration.
- \(b\) - braking deceleration of the vehicle during braking increasing. Because of increases from 0 to full value can be determined as a half of the full average braking deceleration [m/s²]

This equation describes the stopping distance, consisting of sections since the point of driver reaction time to the time to stop the vehicle. Stopping a vehicle during emergency consists of the following phase:

**PHASE 1** – reaction of driver \(t_r\)(Time take by the driver to react once he notices the obstacle)

**PHASE 2** – delay braking performance \(t_0\)(Time taken by the brake to engage)

**PHASE 3** – attack braking deceleration, (Initial deceleration rate)

**PHASE 4** – full braking effect fully developed deceleration (Complete functioning of the brakes)

Distance required to stop vehicles is influenced by:

**Driver:** physical and mental condition, age level of training and experience affect the length of reaction time of the driver and as well distance covered by vehicle without direction and speed moment correction. This practice in turn affects responses
suitability. A quick but incorrect response is worse than the slow but correct response.

**Vehicle** – technical condition, (condition of braking parts), design of the suspension and brake systems specification, technical condition and used tyres design.

**Road**- the kind of surface (asphalt, concrete panels, natural terrain) road surface condition (dry, wet, icy or snow, flat bumpy or wavy surface).

Tyres are basic condition affecting the braking vehicle. These are in fact the only part that connects vehicle with the ground. The ability to transmit force to the tyre base determines how big the vehicle deceleration is achieved. Size of load depends on the type and construction of the tyre and the wear speed, but also varies according to the inflation pressure. Each of the previously listed properties significantly affects the distance of tract to stop the vehicle and thus drive safety. Tyre pressure is a parameter that 2/3 drivers do not reach. Therefore, the aim of this paper is to show the influence of tyre pressure on the stopping distance of the vehicle and how to vary the tyre pressure instantly during the time of emergency braking by the new tech Variable tyre pressure braking system (VTPBS). This will directly affect the stopping distance in front of an obstacle or it encounters a residual rate.

Vladimír Rievaj et al [2] conducted the experiment exclude the influence of the human factor, the measurement of stopping distance consisting of phase 2, 3 and 4 is performed. The outcome of their experiment is as follows

<table>
<thead>
<tr>
<th>Name of Results</th>
<th>Average value of Braking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tyre inflation pressure Decreased (20%)</td>
</tr>
<tr>
<td>Stopping Distance [m]</td>
<td>14.138</td>
</tr>
<tr>
<td></td>
<td>Prescribed tyre inflation pressure</td>
</tr>
<tr>
<td></td>
<td>14.154</td>
</tr>
<tr>
<td></td>
<td>Tyre inflation pressure Increased (20%)</td>
</tr>
<tr>
<td></td>
<td>16.5</td>
</tr>
<tr>
<td>Initial Velocity [kmph]</td>
<td>50.1</td>
</tr>
<tr>
<td></td>
<td>50.022</td>
</tr>
<tr>
<td></td>
<td>53.474</td>
</tr>
<tr>
<td>Brake Time[s]</td>
<td>1.93</td>
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<tr>
<td></td>
<td>1.918</td>
</tr>
<tr>
<td></td>
<td>2.188</td>
</tr>
<tr>
<td>Average deceleration [m/s²]</td>
<td>7.938</td>
</tr>
<tr>
<td></td>
<td>7.814</td>
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<tr>
<td></td>
<td>7.236</td>
</tr>
</tbody>
</table>

![Figure 2 Vehicle Operating condition with stopping distance](image2)

![Figure 3 Vehicle Operating condition with initial velocity](image3)

![Figure 4 Vehicle Operating condition with brake time](image4)
From the result show it would seem that driving on underinflated tyres is beneficial in terms of stopping distance. The change in the size of contact surface of tyre with an influence the factor of hysteresis and abrasion of treads rubber. This is claimed to be a reason why under-inflated tyre transfers greater brake forces and allows shorter stopping distance.

The differences arising between the braking distance can be explained through 3 factors on interaction between tyre and road surface that participate in the transfer of forces. The size of contact surface changes according to the inflation pressure the decrease in the presser in fated leads to an uncared of contact surface.

The first factor represents friction.it reaches 80-85% of all transferred forces. Its magnitudes depend on the force pushing tyre to the base, then on mutual distance of surfaces and the cleanness. The size of surface has no impact on the magnitude of friction.

The second factor is hysteresis. It builds up 10-15% of the total transferred force between the surface and tyre. The hysteresis intensity creates a diffusion pressure on the leading and trailing side of inequality. Its magnitude dependent on the attributes of rubber.

The third factors represent abrasion. The particular factor builds up to 5-10% of all the transferred forces between tyre and base. It is formed as a result of work needed to pull out the particles from treads rubber.

7. Conclusion:

The new design procedure has a unique advantage over the existing technology which inevitably helps in reducing the braking distance which can reduce the accidents rate inevitably, this system is a development and a co-system for the emergency braking system, this system triggers whenever the emergency brake assistance system is triggered, this will reduce the complication for ECU system that is needed by VTPBS. This system uses ABS and Emergency brake assistance system as a co-supplementary system. By including this design, we can reduce the stopping distance to a great extent which will reduce the rate of accidents, thereby increasing the factor of safety.

Demerits and ways to overcome:

Since the deflation of the tire reduce the stopping distance. It may also cause some side effect such as less control. Since we have a power steering the loss of control will be compromised, so that there won’t be any deviation in the path of the vehicles. Due to under inflation there may be possibility of skidding, since the ABS is installed this will prevent the locking of the wheel. Like the way it does with the emergency braking assistance system. These both system works combined since the increase the braking effort which in order to reduce the stopping distance.

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First Author
R. Rewanth, Department of Automobile, Sriram Engineering College, Anna University. Participated in several National Level Conferences and Symposia. Recently received the runner-up in the State Level project expo conducted by the Chennai Science City, Government of Tamil Nadu.

Corresponding Author
B. Rajendra Prasath, Graduated Bachelor of Engineering (Mechanical Engineering) in the year 2000 from Madurai Kamaraj University and Master of Engineering (Internal Combustion Engineering) in the year 2003 from College of Engineering, Guindy, Anna University, Chennai. Obtained Ph.D degree from Anna University, Chennai. Currently working as a Professor & Head of Automobile Engineering in Sriram Engineering College affiliated with Anna University, Chennai, India. Area of specialization includes IC engine simulation, IC engine heat transfer, Alternate fuel especially biodiesel. Dr. B. Rajendra Prasath is a life member in Indian society for technical education (ISTE). Also the Scientific board member of Industrial & Mechanical Engineers from 2011 onwards in International Institute of Engineers. Having more than one and half decades of teaching experience, published more than 30 papers in various international/national journal/conference. Conducted many short term courses/seminars/workshops/conference etc.
E-mail address: br_prasath@rediffmail.com