Development of the external indirect pressure control system in pneumatic tires

Andrey Mikhailovich Ivanov, Vyacheslav Mikhailovich Prikhodko, Sergey Sergeevich Shadrin

Moscow State Automobile and Road Technical University, Federal State Budgetary Educational Institution of Higher Professional Education "Moscow State Automobile and Road Technical University (State Technical University – MADI)", Leningradskiy Prospect, 64, Moscow, 125319, Russia.

Abstract. The article reviews the existing tire-pressure monitoring systems and it also describes the basic algorithms used in the indirect system. Results of the experiment with use of the combined algorithm for start on the external devices of the vehicle are given.
[Ivanov A.M., Prikhodko V.M., Shadrin S.S. **Development of the external indirect pressure control system in pneumatic tires.** *Life Sci J* 2014;11(12s):336-338] (ISSN:1097-8135). http://www.lifesciencesite.com. 69

Key words: vehicle, pneumatic tire, tire-pressure monitoring system, TPMS.

Introduction

Development and improvement of the tire-pressure monitoring system (TPMS) are very important, because the correct tire pressure plays a defining role in the formation of the point of contact with the supporting surface [1]. Provided there is a tire-pressure monitoring system any unexpected emergencies can be minimized, besides both tires service life and vehicle fuel efficiency will improve.

The existing tire-pressure monitoring systems are divided into two groups:
- direct or directive (directly measuring the tire pressure using relevant sensors);
- indirect or indirective (measure the relative level change of the tire pressure using indirect factors).

Determination of the insufficient tire pressure

The indirect tire-pressure monitoring system, based on the analysis of the wheel turning radius, uses the fact that the dynamic roller radius of the wheel is reduced when there is a tire pressure drop [2]. This is perhaps the most intuitive way to detect the underinflation by monitoring the wheels angular velocity.

A determining factor, referred to by the vehicle control elements, is the parameter z. Difference of this parameter from zero is a tire pressure deviation signal from the recommended values. One of the most common examples is the so-called "axial" algorithm (3), described by the following formula:

$$z_o = \frac{\omega_1}{\omega_2} - \frac{\omega_4}{\omega_3} \quad (1)$$

The wheels angular velocity ω_i is indicated as follows:

ω_1 – angular velocity of the front left wheel (wheel 1);

ω_2 – angular velocity of the front right wheel (wheel 2);

ω_3 – angular velocity of the rear right wheel (wheel 3);

ω_4 – angular velocity of the rear left wheel (wheel 4).

Pressure losses are detected in the instance when in the result of the test the value z_o is not equal to zero. Hence immediately derives disadvantage: the test may not detect the equal loss of pressure in one axis or side of the vehicle, as well as, it is not possible to determine what specific tire is flat.

The vehicle electronic control unit (ECU) calculates linear wheels velocity, the values of which are present in a high-speed CAN bus, proceeding from the originally registered in ECU memory of the ECU the wheels radii at the recommended pressure (r_0). Then, the formula (1) can be converted as follows:

$$z_o = \frac{\omega_1}{\omega_2} - \frac{\omega_4}{\omega_3} = \frac{v_1 \cdot r_0}{r_0 \cdot v_2} - \frac{v_4 \cdot r_0}{r_0 \cdot v_3} = \frac{v_1}{v_2} - \frac{v_4}{v_3} \quad (2)$$

where: v_i is the value of the linear wheels velocity, whose signals are present in high-speed CAN bus.

There is another algorithm, based on the same principle, which is called "diagonal" [4]. The indicator z_d for "diagonal" algorithm will be described by the following formula:

$$z_d = \frac{\omega_2}{\omega_4} - \frac{\omega_1}{\omega_3} = \frac{v_2}{v_4} - \frac{v_1}{v_3} \quad (3)$$

The lack of "diagonal" algorithm: the test may not detect the equal loss of pressure in one axis or diagonally of the vehicle, as well as, it is not possible to determine what specific tire is flat.

A combination of "axis" and "diagonal" algorithms can exclude that lack of pressure on one side of the vehicle and diagonally of the vehicle, but still there is an unsolved problem of the equal pressure loss in one axis of the vehicle [5]. Also it is possible to determine what tire is flat. Method for determination of flat tire by the values of the parameters z_o and z_d is presented in table 1.

Table 1. The flat tire determination on the indicators z_o and z_d.

Flat tire	z_o	z_d
front left (1)	>0	<0
front right (2)	<0	>0
rear right (3)	>0	>0

To test the efficiency of these stated algorithms the natural experiment was planned, prepared and carried out using the following object-to-be-tested – vehicles of category M1 – Chevrolet Orlando 1.8 LT AT of 2012 production year, equipped with the system of data collection and recording with on-board high-speed CAN of the transfer data [6, 7]. The following equipment was used (fig. 1):
- high speed CAN bus decoder "NI-8473s" (National Instruments);
- car compressor MegaPower Automotive;
- laptop, connecting cables.

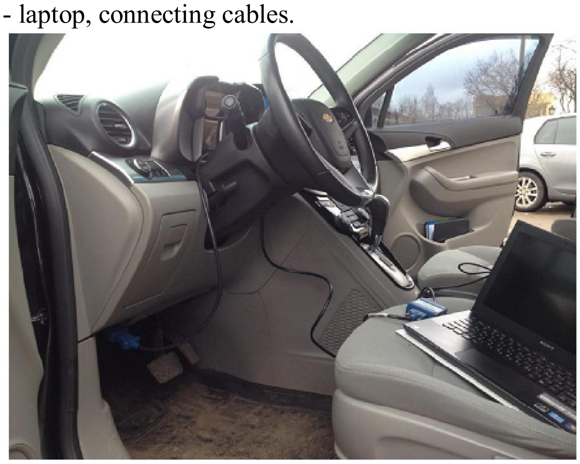

Fig. 1. Connecting the equipment to the vehicle

The vehicle in question, as well as the majority of modern wheeled vehicles, is equipped with the original equipment high-speed CAN bus of the data transfer, which, in this case, applies to CAN buses of class "C" with the data transfer rate 500 Kbit/s. Individual wheel speed values do not apply to OBD standardized parameters and, accordingly, may not be obtained by standard requests sent to ECU of the combustion engine. However, it is known that the vehicle is equipped with ABS, which presupposes the existence of the appropriate sensors for the wheels speed, and so the wheel speed values are presented in the onboard CAN bus. For the determination of CAN messages, containing the wheels speed values of the tested vehicle know-how of State Technical University "method of the data decoding transmitted via CAN-buses of the transport and technological machines" was applied.

11-bit message identifiers were applied in the CAN bus architecture. The following data have been decoded and later they were used in the TPMS algorithms:
- the linear speed of the vehicle movement;
- linear velocity of four wheels;
- steering-wheel angle;
- throttle pedal position;
- brake pedal position.

The tests were conducted under conditions of traffic in the urban environment [8] with speed within 60 km/h with the closed loop path, and with length of 2.46 km. 10 rides were performed with different pressure in pneumatic tires. The recommended tire pressure for the object-to-be-tested was 2.4 kg/cm2, the test program is provided in table 2, the number of wheels is identical to that given in equation (1). The aim of the experiment was to detect a flat wheel by using two of the above mentioned algorithms

Table 2. Test procedure.

#	Ride start time	Tire pressure (# wheels - pressure)	File data
1	14:32	1, 2, 3, 4-2.4 kgf/cm^2 (recommended)	o1.mat
2	14:43	1, 2, 3 - 2.4 kgf/cm^2 4 - 2.2 kg/cm^2	o2.mat
3	14:53	1, 2, 3 - 2.4 kgf/cm^2 4 - 2.0 kgf/cm^2	o3.mat
4	15:05	1, 2, 3 - 2.4 kgf/cm^2 4 - 1.5 kg/cm^2	o4.mat
5	15:14	1, 2, 3 - 2.4 kgf/cm^2 4 - 1.0 kgf/cm^2	o5.mat
6	15:30	1, 2 - 2.4 kgf/cm^2 3 - 2.0 kgf/cm^2 4 - 1.5 kg/cm^2	o6.mat
7	16:01	1, 2 - 2.4 kgf/cm^2 3, 4 - 2.0 kgf/cm^2	o7.mat
8	16:12	2 - 2.4 kgf/cm^2 1, 3, 4 - 2.0 kgf/cm^2	o8.mat
9	16:23	1, 2, 3, 4 - 2.0 kgf/cm^2	o9.mat
10	16:36	2, 3, 4 - 2, 4 kg/cm^2 1 - 1.5 kg/cm^2	o10.mat

A condition was introduced to eliminate errors in the determination of a flat tire, according to which the proportion of insufficient pressure signals per one wheel must be at least 40% of a low pressure signal falling on all wheels.

The algorithm design of the system of the pressure in pneumatic tires indirect determination was in MatLab. To avoid false activation limits have been placed on the control actions of the driver and the minimum threshold speed of the vehicle to start the system. The developed algorithm has made it possible to determine the maximum flat wheel in the rides # 4, 5, 6, 10.

As a result of the research, the external system of the pressure in pneumatic tires indirect determination with the following characteristics was developed to test object: the definition of the flat tire in urban driving within 1 minute (10 seconds for the definition, 50 s for the confirmation) when pressure drop in one of the wheels is more than 30% from the recommended (from 2.4 kgf/cm^2).

Results and conclusions

Thus, as a result of the study there was:

1. Specified the possibility of using the values of the parameters vehicle movement, received in real time with high speed CAN-bus, for external applications [9].
2. Developed the algorithm of indirect determination of tire pressure.
3. The experimental results have confirmed the capacity of the proposed approaches, allowing to detect a pneumatic tire with insufficient pressure. The system response time was 1 minute by driving in the urban environments.

In the future, for the selected object-to-be-tested, it seems appropriate to develop an algorithm of the indirect determination of the pressure in the pneumatic tire using the method of resonant frequencies [10] for comparison with the developed one. This material may be useful for the educational purposes.

Corresponding Author:
Dr. Ivanov Andrey Mikhailovich
Moscow State Automobile and Road Technical University, Federal State Budgetary Educational Institution of Higher Professional Education "Moscow State Automobile and Road Technical University (State Technical University – MADI)", Leningradskiy Prospect, 64, Moscow, 125319, Russia.

References

1. Ivanov, A.M., A.A. Revin, E.N. Nikulnikov, E.V. Balakina, A.A. Barashkov, S. A. Losev, S.S. Shadrin and Y.N. Kozlov, 2009. Experimental verification of the methods to evaluate the effectiveness of ATC vehicle stability control. Automobile industry, 7: 31-33.
2. Persson, N., et al., 1999. Tire Pressure Estimation. International patent application WO0187647.
3. Tire Pressure Special Study: Methodology, 2001. United States Department of Transportation, National Highway Traffic Safety Administration.
4. Persson, N., et al., 2002. Indirect Tire Pressure Monitoring Using Sensor Fusion, Society of Automotive Engineers, 2002-01-1250.
5. Braun, F., et al., 1999. Method and apparatus for monitoring the tire pressure of motor vehicle wheels, EP 938987.
6. Shadrin, S.S. and A.M. Ivanov, 2014. The possibility of using the on-board vehicle data transmission networks in intelligent transport systems. Automobile operating company, 5: 43-46.
7. Shadrin, SS., 2013. Parameter identification of resistance to movement of the wheeled vehicles in use. Izvestiya MGTU "MAMI", 2/16(1): 248-251.
8. Shadrin, S.S., 2013. Calculation-experimental method of determining the angles of rotation of the vehicle steering wheels while conducting field tests. Bulletin of State Technical University, 4(35): 13-17.
9. Ivanov, A. M. and S.S. Shadrin, 2013. Development of the system of inter-object communication of the means of transport. News Volgograd State Technical University. Series "Ground transport systems", Issue 7. Volgograd: VSTU, 21(124): 74-77.
10. Persson, N. and F. Gustafsson, 2001. Event Based Sampling with Application to Vibration Analysis in Pneumatic Tires, ICASSP.

7/25/2014