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A System to Measure Both Inner and Outer Car Tire Temperatures "in situ"

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Abstract In the paper, a system for the complex analysis of the internal and external tire temperatures and pressure of sporty tires is presented. Tests were performed on the test circuit of a tire producer. The CTPA 05 measuring system (complex temperature-pressure analyzer) enables simultaneous measurements of the internal temperature and pressure in a passenger or sports tire. The experimentalist determines that the CTPA 05 can be used to measure independently the external temperature of the overcoat on the front wheel driving tires at three points. Measurements of both the internal tire temperature and pressure, as well as of the external tire temperature, are collected together with GPS (global position system) data. The system of measurement is fully automatic and contactless. The obtained results are in very good agreement with those obtained by independent methods.

Keywords Pressure analysis · Temperature · Tires

1 Introduction

Progress in the construction of modern tires is strongly influenced by theoretical knowledge as well as precise and, if possible, contactless measurement of their properties. A tire is a composite material consisting of rubber, textile, and metal. It is clear that, in such a complicated case, each theoretical or FEM model has to be verified by

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experiment. Some sophisticated systems for the evaluation of tires under dynamic conditions are described in [1–3].

Tire deformation (accompanied by hysteresis) and friction create in such a composite structure heat that depends on many factors, such as material properties, pressure, and construction [4,5]. The heat in the tire under driving conditions could create a dangerously high local temperature leading to destruction of the tire. This is why it is necessary to know the distribution of the temperature on the tire surface as well as inside it. For these reasons, it is clear that tire development has an increasing need for modern temperature and pressure monitoring systems as well as the electronic components of an intelligent wheel.

Monitoring systems for ‘smart tire’ light vehicle products [6] are designed to provide accurate and up-to-date tire information at the driver’s fingertips and activate an alert or warning when tire pressure or temperature irregularities are detected. The system, produced ad hoc for original equipment applications, is particularly suitable for ‘Run Flat’ tires as it permits optimal management of the parameters related to driving on the flat tire following a puncture.

Recently, Pirelli and Schrader Electronics [7] developed an economical and technologically advanced alternative to the “onboard” direct electronic tire pressure monitoring systems (TPMS) currently available on the market. The system allows the principal tire identification data such as its size, the type of summer or winter tread, and other information such as the tire temperature and pressure and the residual flat running distance to be monitored and transferred to the car and driver in real time. The new sensor allows the tire to interact with the car, enabling the parameters of the on-board electronic systems to adapt to the information received, thereby enhancing safety and performance.

In this paper, we present a contactless and automatic measuring system for the external and internal tire temperatures, as well as pressure. This system offers the tire constructors “in situ” and “just in time” testing of personal tires from the point of view of the actual heat generation in the tested tire.

2 Experimental Conditions and System Description

The CTPA measuring system (complex temperature-pressure analyzer) enables simultaneous measurements of the internal temperature and pressure in a passenger or sports tire. The measurements are done in parallel on all four tires in real time. A schematic of the apparatus appears in Fig. 1. In addition, the CTPA measures independently the external temperature of the outer surface of the front-wheel driving tires in three locations.

Measurements of the internal temperature and pressure, as well as the external temperature, are collected together with GPS (global position system) data that provides speed as well as position information at a given time.

A notebook computer (see Fig. 2b), complete with the necessary hardware and software, collects the measured data from all the sensors and the GPS, and provides graphical outputs of the dependence of the external and internal temperatures and

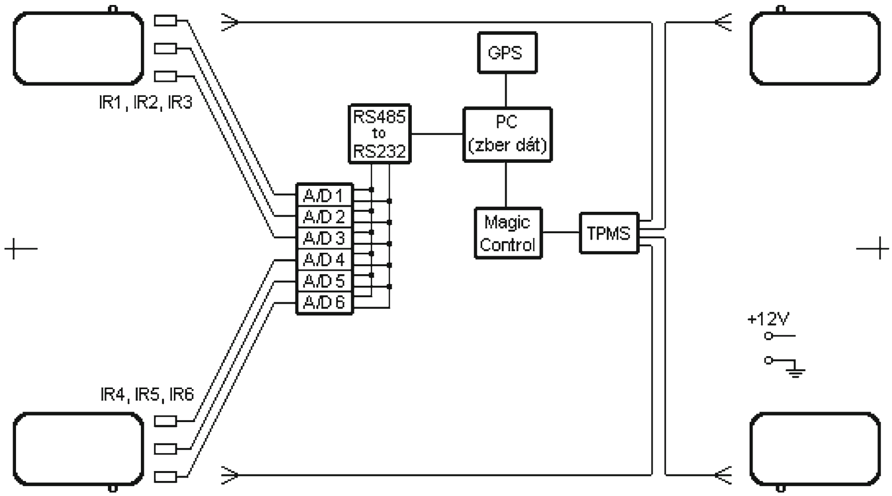

Fig. 1 Schematic of the CTPA

pressure on time or on the speed of the car. The measurements are fully automated, and do not require an operator. The computer is supplied with energy from a car battery.

The whole system, especially the fixtures for the external temperature sensors (Fig. 2a), was developed for the Mitsubishi evolution. However, with some adjustments to the external temperature sensor holder, the CTPA can be adapted to other cars.

As we have said, the CTPA consists of three independent measuring loops. The first measuring loop represents the contactless measurement of the external tire temperature by six radiation thermometers (Raytek THERMALERT MID 02, see Fig. 1). Three sensors are located near each front tire; two are near the edges of the tread, and the third one at its center. The temperature range of the sensors is from −40 °C to 600 °C, the spectral response is from 8 μm to 14 μm, the response time is 150 ms (95 % response), and the accuracy is ±1 % or ±1 °C (±2 °F), whichever is greater.

The second measuring loop is for the internal tire pressure and temperature and uses the MTPM-200 (TPMS, Magic Control) with radio frequency data transmission from four sensors (MTPM-TX4) located inside each tire (see Fig. 1). The transmitter frequency is 433.92 MHz, it has a 32-bit ID-code, the operating voltage is 3 V, and the operating temperature is from −40 °C to +120 °C.

The third measuring loop is the global positioning system located on top of the car, which permits the measurement of car velocity and thereby provides the possibility to create pressure-temperature-velocity dependences.

We have chosen real conditions for testing the CTPA—a dry asphalt road and an air temperature of 25 °C (in summer). The velocity of the car was recorded simultaneously and it is indicated in the graphs. The test car was a sporty model equipped with slick tires. The photographs of Fig. 2 provide a good illustration of the sensor installation, the car, and the test track.

The CTPA 05 was tested at the Matador testing circuit in Puchov (Fig. 2c), Slovakia. The test car was driven around a skid-pad with a diameter of 50 m for a total

Fig. 2 Details of the measurement: (**a**) gripping of the sensors, (**b**) placement of the measuring computer, and (**c**) testing circuit

of eight laps. The results obtained were compared with those collected by standard contact and non-contact ‘professional’ equipment with a precision of ±2 °C.

3 Results and Discussion

The experimental results obtained with the CTPA are presented in Figs. 3–6. The evaluation of the measured data was realized interactively. From the presented data, it is possible to see that all sensors are simultaneously active and offer the operator many

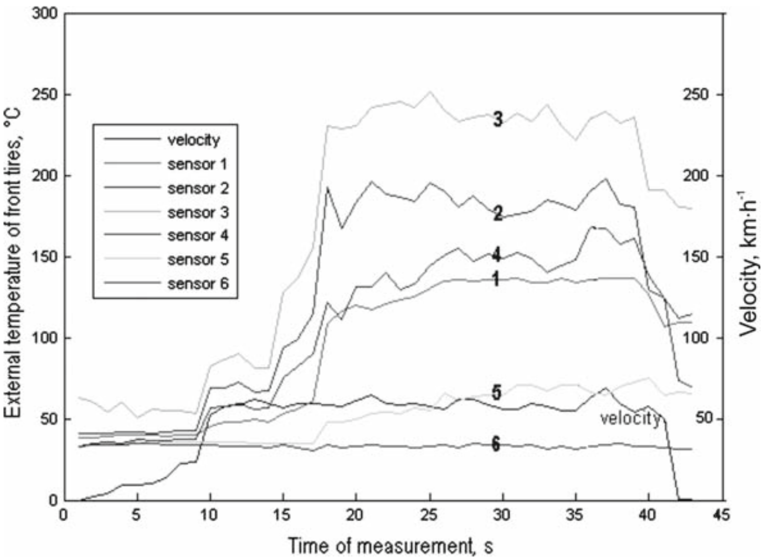

Fig. 3 Time dependence of external tire temperature and car velocity

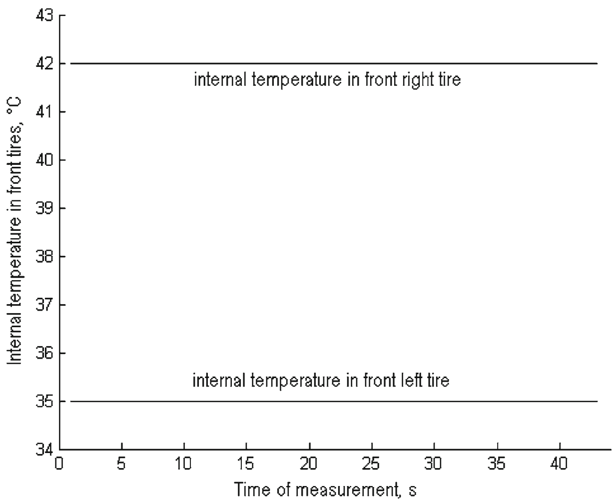

Fig. 4 Time dependence of internal temperature of front tires

possibilities for the detailed analysis of the tire "in action." The system packages the data in a form that is easily transferable to other software, such as Excel, where the operator can further study the tire behavior during various portions of the road test. In Fig. 3, the time dependences of the car velocity and the external tire temperature as measured by six sensors are shown. Sensors 1 to 3 measured the external temperature of the front right tire from right to left. Sensors 4 to 6 measured the external temperature of the front left tire from right to left. In Fig. 4, the time dependences of the internal temperature of the front left and front right tires are shown. In Fig. 5,

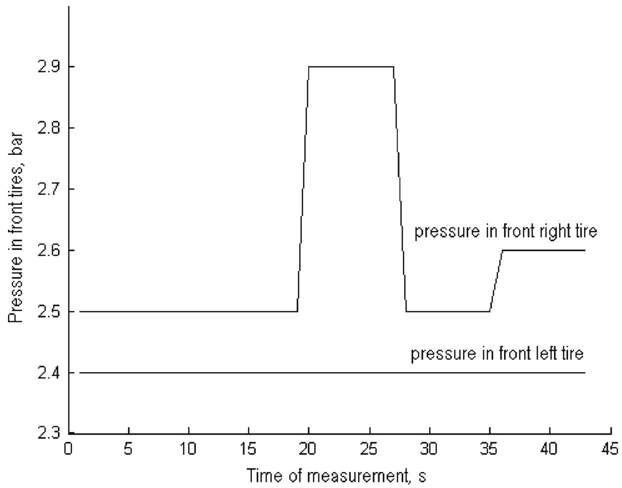

Fig. 5 Time dependence of pressure in front tires

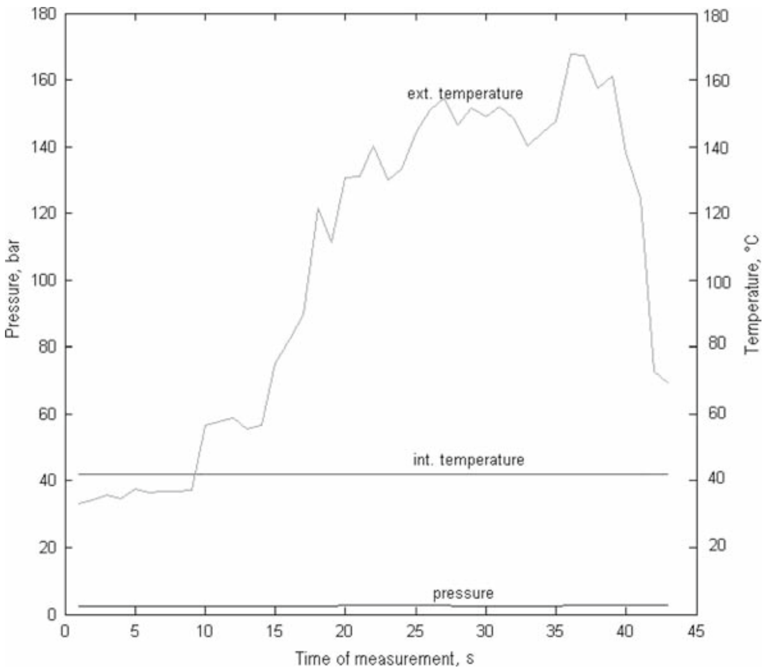

Fig. 6 Time dependence of pressure, internal temperature, velocity, and external temperature of front right tire

the time dependences of the pressure in the front tires are shown. In Fig. 6, the time dependences of all the parameters of the front right tire are shown.

4 Conclusions

From the presented technical description and measurement results, it is clearly seen that the CTPA provides simultaneous temperature-pressure-velocity measurements, offering a detailed analysis of tire behavior under real conditions. Such results can strongly enhance the quality of tire production.

The obtained experimental results were compared with those collected by classical contact techniques that are standardized for such applications. These comparative measurements were in very good agreement with those of the CTPA05.

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