3D MEMS SENSOR ON TRUCK TYRES FOR SAFETY CRITICAL APPLICATIONS

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I. Introduction

This review focuses on automotive embedded systems, especially on trucks. There are plenty of safety critical electronic systems on trucks, such as Slip Control Systems, Emergency Braking System (EBS), Electronic Stability Programme (ESP), Adaptive Cruise Control (ACC) to name a few. Slip control systems (like ABS), ESP and EBS use slip and friction values. If some of their sensors (e.g. accelerometers) fail, the slip and friction values have to be estimated somehow, consequently the need arises to substitute the corresponding measurements by the estimations. Inverse method is a good choice in these cases, because it is able to estimate sensor values from other measurements if their relation or model are known. This is called analytic redundancy. Nowadays, there is more and more attention placed on researching the intelligent tyre, which is able to fulfill this task for slip control and stability systems.
In the framework of the ENIAC project, the Institute for Technical Physics and Materials Science (MFA) from the Research Centre for Natural Sciences (part of Hungarian Academy of Sciences) reserched and developed a special MEMS based 3D force sensor, which can be integrated into vehicle tyres to measure forces. The future research will use this sensor to substitute or supplement some instruments, which are already deployed on trucks.
In the following sections we will present the latest researches on intelligent tyres, then will introduce the sensor designed in the ENIAC project followed by an outlook of the possible future research.

II. Summary on intelligent tyres

There are two types of approaches for estimating the friction coefficient: indirect and direct methods. The indirect method does not monitor tire deformation while the direct method does. In most indirect methods, the friction coefficient is determined based on the vehicle velocity, wheel angular speed, and normal and tractive forces applied to the tire, axis and wheel. Since the relationships among tire parameters are heavily nonlinear and complex, analytic relations are difficult to acquire [1]. Therefore, algorithms such as a fuzzy logic controller [2] or Kalman filter [3] are used to estimate tire parameters. Yi et al. [4] used the wheel slip, vehicle velocity, and normal load on the tire to determine the friction coefficient and develop a control scheme for emergency braking maneuvers. Miyasaki et al. [5] measured the four-axis direction force by attaching strain gages to improve the ABS efficiency. Ohori et al. [6] measured the strains applied to the wheel to estimate the six force components in the tire.
Direct sensor allows a precise measurement of tire deformation or strain. Surface acoustic wave (SAW) sensors have been proposed for monitoring the deformation during road contact [7]. SAW devices use metallic interdigital transducers arranged on the surface of a piezoelectric substrate. Palmer et al. [8] demonstrated the embedment of fiber optic sensors in an automobile tire for monitoring tire strain and captured and measured the onset of skid. Tjiu et al. [9] used microelectromechanical system (MEMS) sensors, including a pressure sensor, accelerometer and temperature sensor for a tire condition monitoring system. Without attaching sensors, Matsuzaki et al. [10] presented a self-sensing method using the tire structure itself as a parallel circuit of a capacitor and resistor.

III. Introduction of the sensor, developed within the framework of ENIAC project

In the MEMS laboratory of MFA in collaboration with WESZTA-T Ltd, from 2009 to 2011, a 3D force sensor has been developed, that can be used in an automotive tire for the measurement of longitudinal and lateral forces [11] [12]. The silicon single cristal force sensor has been encapsulated into rubber patches to be able to fix it on the sidewall of tires. Several succesful tests have been performed with the sensor in laboratory conditions on a test benchs and on vehicles equipped with the sensor. This icludes test on cars and trucks too.

The positive results of the tests makes the sensor convenient to apply as a redundant sensor for the earlier mentioned safety critical applications on trucks.

IV. Future researches

With the given sensor and the corresponding measurement system the following steps will be carried out in the close future:

- Explore the potencial sensors on trucks that can be substituted or complemented by the 3D MEMS sensor.
- Test measurement on trucks, with reference measurements, eg. with accelerometers. This test series will be performed with the support of Knorr-Bremse Brake Systems Ltd.

V. Conclusion

Until the present state of this research, the goals were to explore the latest similar researches, to get knowledge about the sensor developed by MFA, finally set the potential resarch targets.

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