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PLANTOGRAF V12 WITH OPTIMAL SIZE DETERMINATION SENSOR ELECTRODES AND ITS USING FOR PRESSURE DISTRIBUTION BETWEEN TIRE AND ROAD

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Abstract: This document describes the new construction of Plantograf V12. In this report, the design of electrodes and using pressure distribution measurements between the tire and road contact surface are discussed. The resulting measurements will be applied when designing new road and agricultural vehicle tires.

Keywords: Plantograf, conductive elastomer, electrodes, pressure distribution, tire.

1. INTRODUCTION

Plantograf V12 is a tactile transducer, which is able to pick up tactile information of a particular object and transfer this information into an electrical signal. This sensor is applied in the following applications: measurement of static and dynamic pressure distribution, human steps analysis, sitting position analysis, pressure distribution on a flat human foot and analysis of status of big joints.

Plantograf V12 has to fulfil the following conditions: the sensor cannot affect measured pressure distribution results, has to measure static and dynamic load, and has to have sufficient sensitivity and accuracy in each point of the sensor matrix for the given applications.

The contribution is focused on the description of the Plantograf V12 matrix construction, description of the electronic circuits which contain the sensor matrix and optimal electrode size determination in the point where a thin film made of conductive silicon elastomer is used to transfer load to electrical signal.

2. TRANSDUCER DESCRIPTION

Construction of the Plantograf V12 was designed with regards to minimize influence on the matrix measuring points and maximisation of the matrix point sensitivity. The matrix construction is displayed in a patent application [1].

A part of the Plantograf V09 cross section is shown in Fig.1. Both electrodes are corroded onto one cuflex film placed on the bottom part of the sensor matrix. Between the electrodes, changes of elastomer resistance are measured.

Every electrode is covered with the conductive elastomer over its whole surface. The electrodes with these conductive elastomers are protected by non-conductive flexible material which protects the elastomers from mechanical wear.

Currents which flow in the sensor matrix and the direction of current are shown by indicators displayed in Fig. 1 and 2

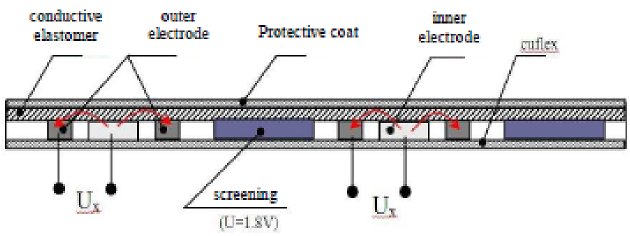


Fig. 1 Cross section of Plantograf V12

It means that the current flow from the inner electrode flows through the conductive elastomer to the outer electrode.

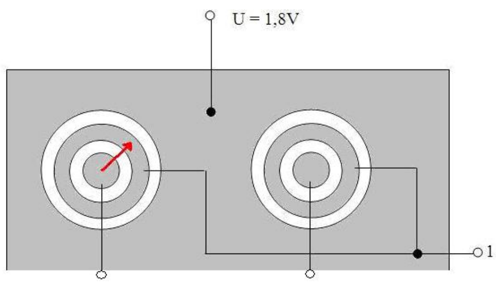


Fig. 2 Two tactile sensor of Plantograf sensor matrix

3. PLANTOGRAF V12 ELECTRIC CIRCUIT

The previous Plantograf V05 construction had several drawbacks that we tried to remove in the new advanced type. The V05 model had high current consumption causing it to heat-up and there was a dependency of power consumption proportionally changing with the applied load. Also, the construction incorporated high speed digital converters and relatively complicated circuits. In the new version, all A/D converters were replaced by a simple RC circuit discharged in the sensor resistance. The connection operates as a resistance to time converter. All functions and controls are integrated in a Xilinx Spartan 3 FPGA. These changes allowed miniaturizing the whole system and improving measurement rates significantly. The estimated rate is currently approximately 1000 frames/s during online measurement and 5000 frames/s in offline measurement where the data is stored on a memory card.

4. DETERMINATION OF OPTIMAL ELECTRODE SIZE

A basic measurement task was carried out to determine the optimal electrode type for the application to give the sensors maximum measuring sensitivity.

A special modular system dedicated for tactile sensor measurement was used for measuring the points placed on the sensor matrix. This system measures the load applied on the matrix points in real time [2].

Simultaneously rate resistance is measured by means of SW and electronic circuits. Resistance can be in values between 0 – 255.

The six different models of the sensor matrix were measured during determine testing process. The sensor matrix had following size:

ØE=2mm, Ød=0,4mm, M=0,1mm – LH
ØE=2mm, Ød=0,1mm, M=0,1mm – PH
ØE=2,5mm, Ød=0,4mm, M=0,25mm – LD
ØE=2,5mm, Ød=0,1mm, M=0,25mm – PD
ØE=3,5mm, Ød=0,4mm, M=0,25mm, separated measuring points – OB
ØE=3,5mm, Ød=0,4mm, M=0,25mm, connected measuring points – SB

Varying model sizes are displayed in Fig.3.

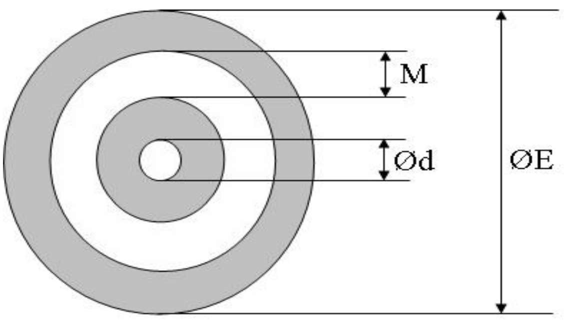


Fig. 3 Sizes of Measured Electrodes

Construction numbers 5 and 6 have the same electrode size. Construction number 5 has the conductive elastomer only at the measuring spots. Construction number 6 has got the conductive elastomer over its whole surface of the sensor matrix.

Every model was measured in the following way:

- Three measurements were done on every model.
- Every point was measured three times in a range of 0,5 – 9,5N (10 measurements) loads.
- Every point was measured tree times in range 0,5 – 9,5N (10 measurements) without any loads.

The average values from the measurements are shown in the Fig.4.

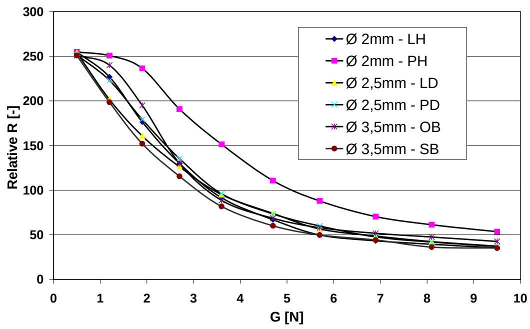


Fig. 4 Measured values of different electrode types

5. USING TO PRESSURE DISTRIBUTION MEASUREMENT OF TIRES

The Plantograf was used for pressure distribution and contact area between the tire and road measurements. A special presser was used for the process. The tire was fixed in its original axle mounting holes and pressed to the transducer Plantograf under varying loads and tire pressure ratings. The loads were selected in a range from 4000 N to 10 000 N and tire pressure ratings in the range from 80 kPa to 260 kPa (Fig. 9).

The testing of BARUM POLARIS 2 165/70 R13 a 165/70 R13 BF Goodrich Touring and tractor BARUM 13,6 / 12-36PR tires continued restricted upon the maximum load on the Plantograf V09. Figs. 6 and 7 display the prints of the tested tires. The results difference between the classic procedure of making tire prints of bigger terrain tires using colouring and hard paper and the new procedure using the Plantograf is shown in Fig. 8. Fig. 9 shows the correlation between the size of the tire print and the pressurization of the tire and proves the hypothesised linear correlation trend of the pressurization and contact area of the tire. There is a difference between the deformation of certain types of tires for road vehicles depending on the elasticity of the used material (summer and winter tires). During the testing of a winter tire at 29°C, the resulting contact area of the tire was about 10 cm^2 greater compared to an equally large summer tire under the same conditions during testing.

The Plantograf can be used to monitor the distribution of pressures in the contact surface of the tire with the base surface (Fig. 10), which cannot be done using the classic way of making tire prints. Tire manufacturers can use this sophisticated data in the development of new patterns of the contact surface of a tire, for example during construction of tractor tires with consideration of a self – cleaning effect. These electronic tire prints also enable diagnosis of the tire contact surface patterns and monitoring the progress of mechanical wear of the tire surface in different places of the contact area.

Fig. 5 Laboratory stand for recording tire prints

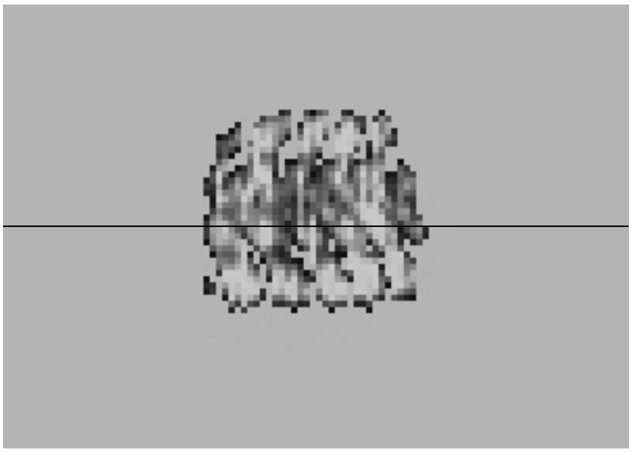


Fig. 6 Print of BARUM POLARIS 2 165/70 R13 (pressurized to 220kPa, 400 kg load)

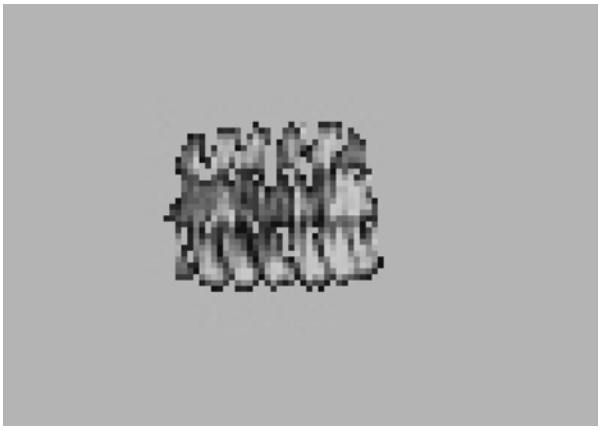
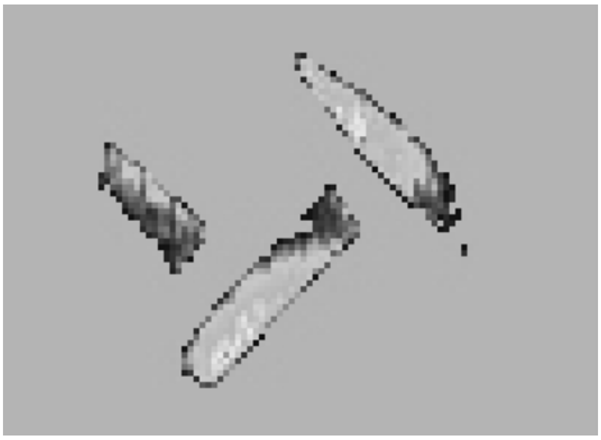


Fig. 7 Print of BF Goodrich Touring 165/70 R13 tire (pressurized to 220 kPa, 400 kg load)



a)

b)

Fig. 8
Print of BARUM 13,6/12-36PR tire
(air pressure 160 kPa, loading 800kg);
a) Plantograf,
b) classic form of getting a print

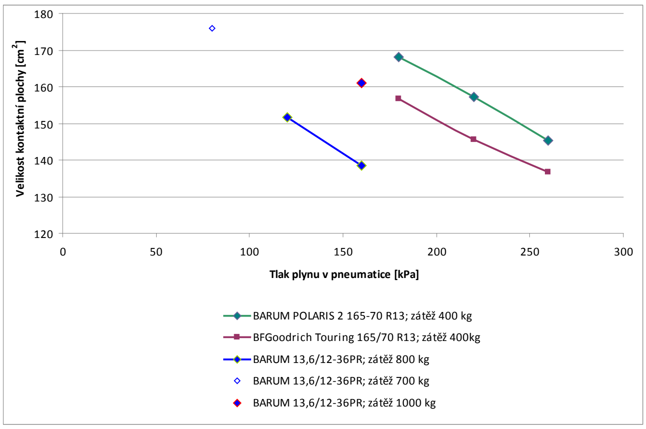


Fig. 9 Graph of dependence between tire contact area and tire pressure

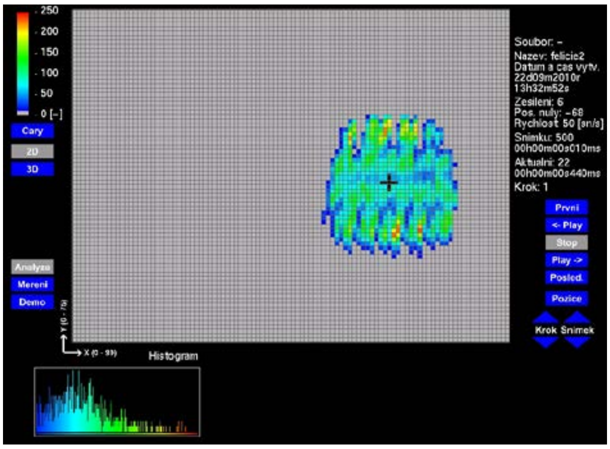


Fig. 10 Pressure distribution on tire BARUM POLARIS 2 165/70 R13

6. CONCLUSION

The construction of the tactile transducer Plantograf V12 is the newest of the Plantograf Vxx line. It is designed to. improve the features of the tactile sensors Plantograf V05 and Plantograf V07.

Measurement results show that sensor sensitivity varies with the used construction type of the sensor matrix. Construction type PH has got the lowest sensitivity (Fig.1). Construction type SB has got the highest sensitivity.

The results confirmed the possibility to use miniature sensors in a Plantograf system to measure the pressure between the tire and transducer. For the presented results a transducer with an active sensing area 300x400 mm was used. For future Plantograf measurements, a sensing area of 500x500 mm will be used.

7. ACKNOWLEDGEMENTS

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