SEAT COVER INTEGRATED PRESSURE SENSOR

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1. INTRODUCTION

In the context of autonomous vehicle, the driver and the passengers will refocus their activities in other area than driving. Therefore, their attention will move away from the features displayed on the dashboard. The seat is the nearest component to the user and the seat cover is the surface in permanent contact with him/her. Therefore, the seat cover becomes the ideal interface to collect data from the users and to transmit them to the on-board computer. In this study, we were focusing on the integration of pressure sensors in the seat cover in order to be as close as possible to the driver.

2. MATERIAL AND METHOD OF THE APPROACH

2.1. Pressure sensor: design and technical integration

There are three types of flat pressure sensors: capacitive sensors, piezoelectric sensors and piezo-resistive sensors. After a comparative study between these three types, the piezo-resistive sensor has been chosen as the most suitable for our application: it is sensitive enough, less expensive and requires low voltage and less complex electronics. It is composed of two electrodes separated by a material that changes electrical resistance when it is exposed to mechanical stress. The electrodes are electrical conductors and can be made of conductive fibers or conductive inks or films. Weaving, embroidery or sewing make the electrodes visible on both sides of the cover but the printing has the advantage of printing the electrode on the non-visible face of the cap. The screen-printing method has been chosen as integration technique. This paper deals with the presentation and the validation of conductive ink preparation (lower resistance) based on metal particles and of piezoresistive ink based on graphite addition (piezo-resistive behavior)

All the measurements have been done with the following condition, 10 replicates, calculation of the mean value and of the standard deviation with a constant temperature of 23°C.

2.2 Threshold of electric percolation for the conductive ink

The electric percolation threshold is the critical value for obtaining electrical conductivity. In order to study this threshold, 3 inks have been prepared with respectively 20%, 25% and 30% in weight of metallic pigment.

2.3. Conductive Ink Preparation

We have worked on preparation parameters such as the stirring speed, the agitator type and the duration to obtain an ink with the adequate viscosity. 4 samples have been developed and are presented in table 1:

Table 1: Preparation parameters of the conductive ink

Parameters/ Sample number	1	2	3	4
Agitator type	paddle	paddle	magnetic	orbital
Speed (tr/min)	2000	2000	1250	1360

Duration (minutes)	10	20	60	60

2.4 Thermosetting process for conductive ink

Thermal treatment of the ink is performed to evaporate the water, to polymerize the resin and to make the ink solid. This process is essential to promote connection between the conductive particles. The optimal thermosetting temperature depends on the formulation of the ink and the concentration of the metal particulate in it. The different used temperature are temperatures 160°C, 180°C and 200°C, it has been done in an infrared oven with ventilation.

2.5 Resistivity calculation

The resistivity is given by the formula 1:

$$\rho = R\frac{S}{l}\,[\Omega.\mathrm{m}]. \qquad (1)$$

With ρ the resistivity, R the resistance, S the section and l the length of the conductor.
In order to evaluate the influence of the dimensions of printed strips, the electrical resistivity of the conductive ink has been measured thanks to numerical ohmmeter (GDN-8341).

2.6 Mechanical characteristics

The mechanical performance of the printed tracks essentially depends on the nature of the print support and on the characteristics of the ink. Different samples of the tracks printed on 3 types of textile support have been prepared. The size of the textile support is 150 x 70 mm². The resistivity of the tracks has been measured at rest, and after fatigue tests (tensile – relaxation). The maximum force applied is 5N, 140 cycles have been performed on each sample (corresponding to 60 minutes of tensile-relaxation loads). Three kinds of textile support have been tested, Twill fabric A – 280g/m², Twill fabric B – 200g/m² and Complex fabric C (Twill fabric B, foam, knitted fabric).

2.7 Calibration of the piezo-resistive ink

In order to study the piezo-resistive ink behavior, a pressure sensor prototype has been developed using printing technique. This prototype has a round size of 1 cm². On a car seat, the force applied by the weight of the person does not exceed 350 g/cm² on the higher-pressure areas [1]. To test the performance of our prototype over this measurement range, we measured its electrical resistance according to applied pressure ranging from 0 to 350 g/cm². The step of increasing pressure is 30 g/cm².

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Threshold of electric percolation for conductive ink

Table 2: Resistance vs metallic particles percentage

% metallic particles	20%	25%	30%
Electrical resistance	∞	∞	6,50 Ω

For the following of the study, the percentage of metallic particles has been chosen to 30% metal pigment.

3.2 Ink preparation

The measurement of the electrical resistance after printing is summarized in table 2

Table 3: Resistance measurements

Sample	1	2	3	4
Electrical resistance	6,88 Ω	6,59 Ω	8,67 Ω	9,03 Ω

We can conclude that the minimum value of the resistance is obtained when the ink preparation is done using a paddle agitator with a speed of at least 2000 rpm for at 10 minutes.

3.3. Thermosetting process

Based on the previous results the ink has been prepared using the following conditions: paddle agitator, rotation speed: 2000 rpm and duration: 10 minutes

Table 4: Thermosetting temperature

Temperature	160°C	180°C	200°C
Electrical resistance	6,98 Ω	6,40 Ω	6,54 Ω

The results show that the optimum result is obtained for 180°C. This temperature will be the one used for the end of the study

3.4 Resistivity calculation

Table 5: Measurement of resistivity of conductive ink

Sample	Dimensions (mm)	Mean resistivity (Ω.m)	Standard deviation (Ω.m)
1	L= 100 l= 3 e= 0,2	$1,5 \times 10^{-5}$	0,12
2	L= 170 l= 3 e= 0,2	$1,4 \times 10^{-5}$	0,22
3	L= 170 l= 5 e= 0,2	$2,3 \times 10^{-5}$	0,20

Based on the following results, the average resistivity of the conductive ink is 1.73 Ω.m (standard deviation: 0.49 Ω.m). This value will be taken as reference for the fatigue influence measurement.

3.5 Mechanical characteristics

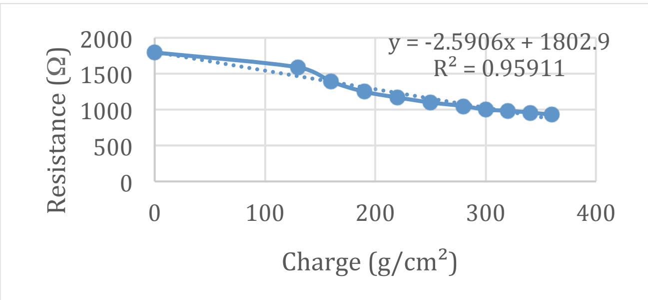
The resistivity increase (in %) has been calculated based on the resistivity measurements perform after fatigue tests.

Table 6: Resistivity increase after fatigue test

Support type	Characteristics	Average % of resistivity increase	Standard deviation
A	Deformation at 5N : 12%	+ 3.4	0,43
B	Deformation at 5N : 8%	+ 2.2	0,3
C	Deformation at 5N : 8%	+ 1.8	0,23

It can be concluded that the more the support is deformed the more the resistivity increased. The complex support shows the lower increase in resistivity than that on the other two supports.

3.5 Calibration of the piezo-resistive ink



Graph 1: Pressure sensor prototype calibration

The calibration curve (graph 1) highlights a linear behavior of the piezo-resistive prototype sensor. This behavior will be useful for the application in smart car development.

4. CONCLUSIONS

In this study, the formulation, the choice and the validation of the preparation and the printing conditions of the conductive ink has been carried out. Moreover, the piezo-resistive ink has been characterized.

To summarize the obtained results, it can be said that the conductive ink is composed of 30% of metallic particles, it is prepared using a paddle agitator with a speed of 2000 rpm and a duration of 10 minutes and cure at 180°C. The average resistivity of the ink is 1.73 Ω.m. This resistivity is changing (increase) when the textile support is submitted to fatigue tests (max 3.4%).

The developed piezo-resistive sensor prototype presents a linear behavior that will be useful for the end of the study

5. REFERENCES

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