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Narrow fabrics as conductors for monitoring systems of textile based architectural structures

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ABSTRACT: Electroconductive narrow fabrics provide the opportunity for a cost-saving and highly flexible data and energy transport for monitoring systems in textile structures. At the Institut für Textiltechnik (ITA) der RWTH Aachen University, Germany several narrow fabrics for such use have been developed and tested, results are given.

1 INTRODUCTION

Civil structures such as pavilion roofs, marquees, stadium roofs or reinforcement fabrics in embankments are made of textile materials due to their drape ability, light weight structure and optical appearance. Special geometries can be created by these textiles. Furthermore membrane textiles can cover large areas without the need of supporting structures e.g. pillars.

In many cases textile membranes are used for the roofing of stadiums. These textiles protect the audience against certain weather conditions like strong winds, rain an sunlight. Depending on the civil structure and the application, the conductor is exposed to extreme temperatures, high humidity, rain or acting forces caused by wind. In case of failure of the roof there is a high risk for the audience underneath the textile membrane.

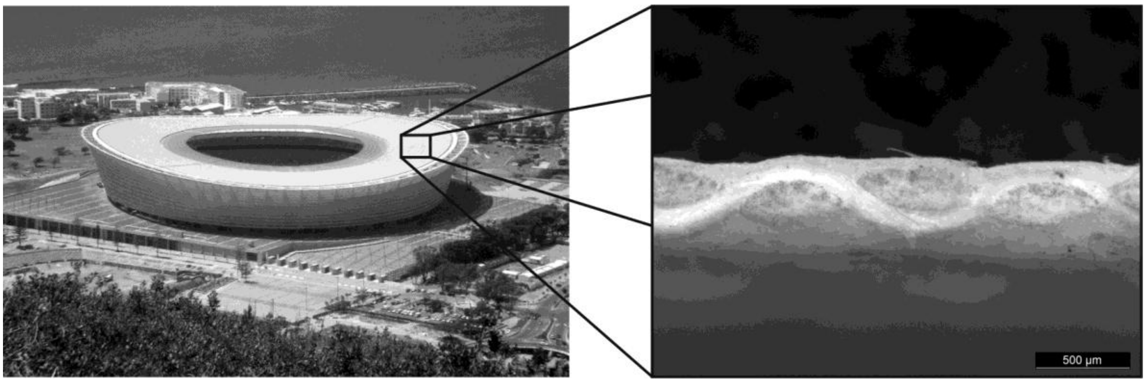


Figure 1: World Cup soccer stadium in Cape Town, SA (left) and microscopic cross section of used PTFE-coated glass fabric (right)

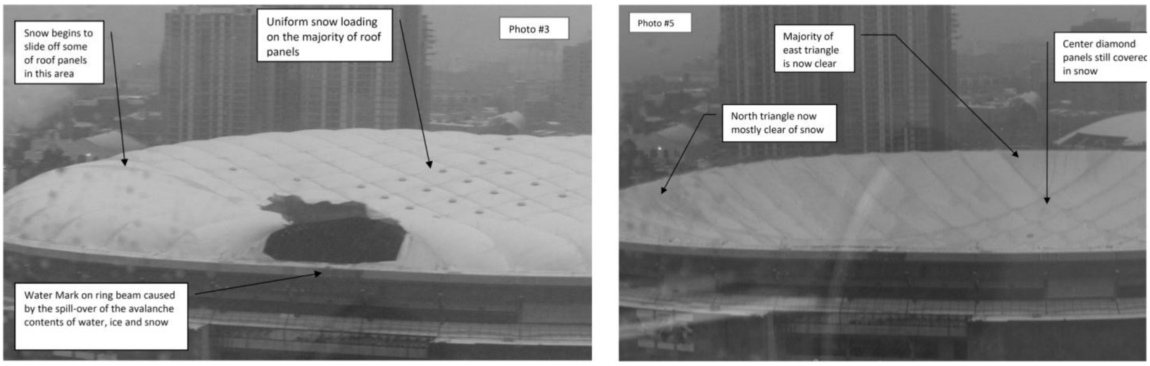


Figure 2: BC roof break (left) and deflation (right) [1]

On the 5th of January, 2007, the textile based roof of the BC Place in Vancouver, Canada, collapsed. Because of a cut inside the membrane textile the roof collapsed within 10 minutes. During this incidence occurred no event took place inside the BC Place so that no one was hurt. During the Olympic Winter Games 2010 in Vancouver up to 55.000 people were inside the stadium under the roof. In case of a roof failure and collapse during such an event it would probably have caused several injuries. This incident evidently shows the necessity for monitoring systems which are part of textile roofs. [1]

2 TEXTILE BASED MONITORING SYSTEMS

Research has focused on the development of textile based monitoring systems to be implemented into textile structures. Non-textile based conventional monitoring systems do not have the same textile structure as well as textile properties such as drape ability, optical appearance or structure. Undesirable cables disturb the optical appearance and the textile character of the final product. Textile based monitoring systems can be attached to the textile structure by ready in use technology (e.g. sewing, stitching, weaving), no major weight is added to the system and the textile characteristics remained.

The principal operation of textile based monitoring systems is outlined figure 3. The sensor detects the critical data while it is supplied with electric energy by a communication channel. The selected data of the sensor is transmitted to an evaluation device and passed on to subsequent systems e.g. alarm systems, police etc. The data transfer as well the electrical supply and the sensors can consist of textiles structures.

Such textile based monitoring systems have already been invented for health monitoring systems. They can either be used for the stimulation of nerves or the monitoring of body functions. In contrast monitoring systems of architectural structures need much longer conductors for the applications. Depending on the system, wires can be applied in addition to textile based conductors [2, 3].

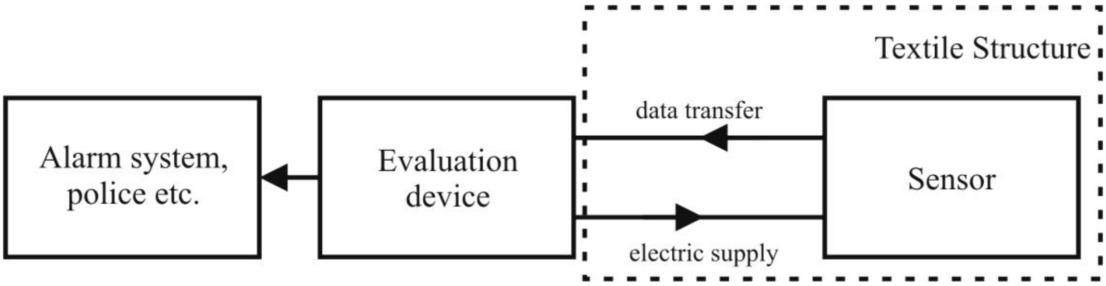


Figure 3: Principle operation of monitoring systems

3 NARROW FABIRC AS CONDUCTOR

Narrow fabric is a term used to describe fabrics with a width of 2 – 40 mm. Electroconductive narrow fabrics provide the opportunity for cost-saving and highly flexible data and energy transport for monitoring systems in textile structures. The use of narrow fabrics as conductors offers several advantages. The textile character of the textile based structure is retained. Furthermore the narrow fabric can easily be attached to the manufactured good (e.g. pavilion roof) by joining in a subsequent process. Therefore a drop-in solution in existing production chain can be comprised. The conductivity of the fabric can be adjusted through patterning; the local density of the conductive warp yarn or the choice of different conductive warp yarn parameters e.g. fineness, material and of course the conductivity of the yarn itself. Choices may vary from especially coated yarns to textile metal rovings made of copper or other metals.

3.1 Produced narrow fabrics

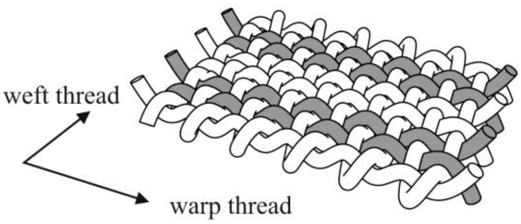
At the ITA special narrow fabrics with conductive materials have been produced and their electrical properties have been evaluated. To determine the influence of the number of conductive yarns in the weaving structure on the conductive properties of the narrow fabric, 3 narrow fabrics have been designed. As conductive material silver coated Polyamid 66 filaments (592 dtex) have been used. During production woven threads were replaced by this material. The warp threads as well as the remaining woven threads consist of insulating material. Aramid and Polyester (377 dtex) were used in this process.

The basic material of narrow fabric 1 (NF 1) is Aramid. Two woven threads were replaced by the conductive yarn on two strips along the fabric. Aramid has been used as warp threads for narrow fabric 2 (NF 2). All weft of this narrow fabric have been replaced by the silver coated material. Narrow fabric 3 (NF 3) consists of Polyester. 8 woven threads were replaced by the silver coated Polyamid 66 filaments on two strips along the fabric. Figure 4 shows an example of produced narrow fabric 3.

3.2 Conducted experiments

In this case the characteristic value for electrical conductivity is the electrical resistance. A low electrical resistance indicates high conductivity. The resistance has been measured for the different narrow fabrics at the distances of 300 mm, 600 mm and 900 mm respectively. A multimeter has been used to determine the electrical resistance.

Furthermore the washability of narrow fabric 3 (NF 3) has been tested. The sample underwent 20 washing cycles according to the international standard DIN EN ISO 6330: 2010-01 with the selected procedure 4A. After washing the sample was dried by flat atmospheric drying. The sample has been conditioned for 24 hrs at standard atmospheric condition before the electrical resistance was determined at the distances of 50 mm, 100 mm, 200 mm, 300 mm, 400 mm and 500 mm. These tests should indicate the usability of the materials when exposed to strong weather conditions.



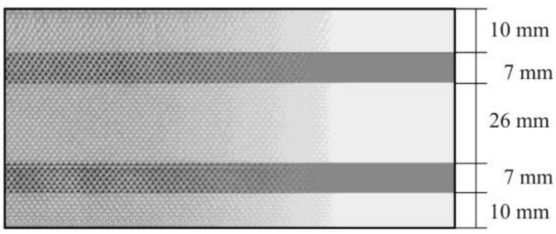


Figure 4: Example of produced conductive narrow fabric (NF 3)

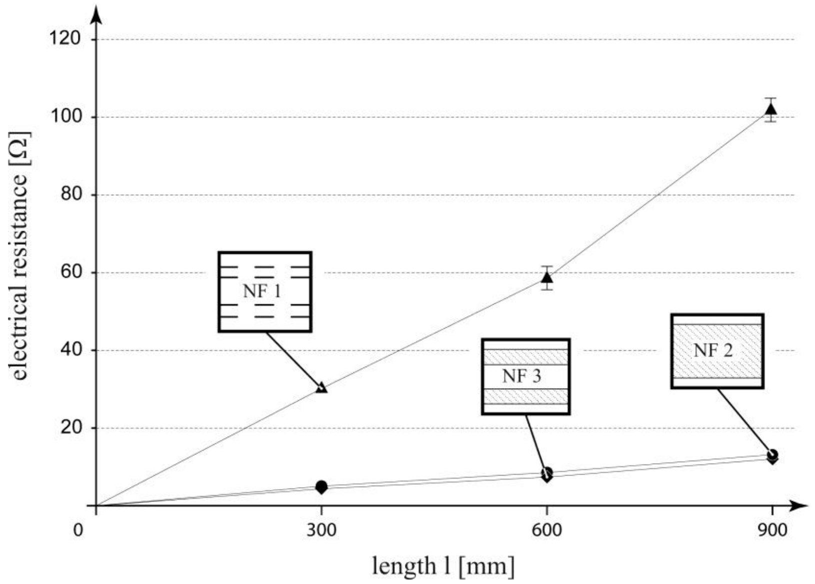


Figure 5: Electrical resistances of narrow fabrics

4 RESULTS AND DISCUSSION

The electrical resistance along the narrow fabric length indicates the feasibility of the fabrics as conductors. The electrical resistance after several washing cycles is an indicator for the usability of these fabrics when exposed to certain weather conditions.

4.1 Electrical resistance of different narrow fabrics

The results showed an increase of electrical resistance along the length for all three narrow fabrics. In figure 5 the results are shown. Narrow fabric 1 (NF 1) had a very high electrical resistance compared to NF 2 and NF 3. This high resistance is caused by the fact that only two woven threads have been subjected by the electric conductive yarn. There seems to be a critical value for the amount of conductive yarn in the fabrics cross section according to the results. Low electrical resistances have been measured for NF 2 and NF 3 with no significant differences between the two.

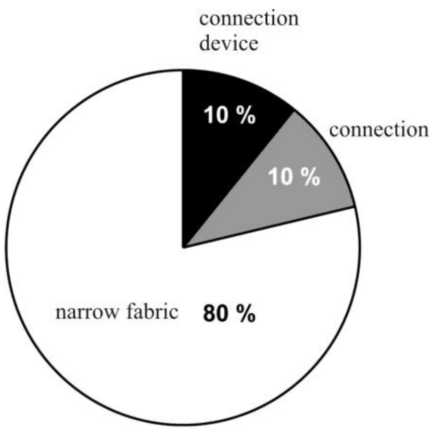


Figure 6: Percentage of connection parts of the overall electrical resistance

Figure 6 shows the percentage of different connection parts which add together to the overall electrical resistance. 10 % of the overall resistance is caused by a connection device while an additional 10 % are a result of the connection itself. The narrow fabric causes with 80 % the majority of the overall resistance (80 %). The narrow fabric is the critical element for the resistance and therefore the performance of the connection between sensory elements and an evaluation device depends on it.

4.2 Electrical resistance of narrow fabrics after different washing cycles

The electrical resistance of the narrow fabrics was generally reduced through the washing cycle. In figure 7 the effect of washing cycles on electrical resistance of narrow fabric 3 is given for several distances. It is evident that the number of washing cycles clearly enhances the electrical resistance of the narrow fabric. The increase of electrical resistance for small distances (0 – 50 mm and 0 – 100 mm) is linear whereas the increase for longer distances (0 – 400 mm and 0 – 500 mm) shows an exponential curve.

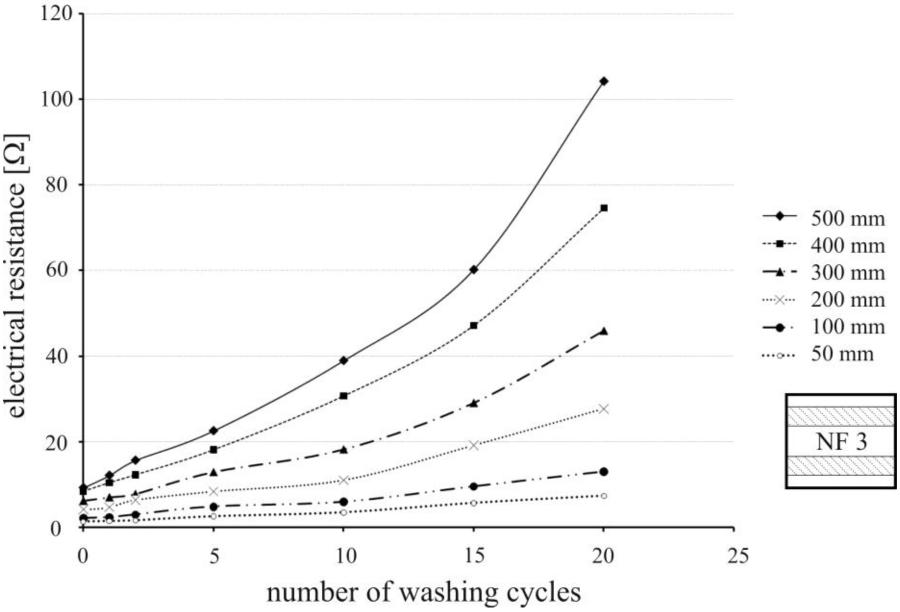


Figure 7: Effect of washing on electrical resistance of narrow fabric 3 at different distances

The increase of electrical resistance after intensive washing can be explained by the removal of the Polyamid 66 silver coating. During the washing process the fabrics are exposed to intensive mechanical friction. The friction causes a reduction of the silver coating and therefore reduces the amount of conductive material on the yarn. The exponential increase of electrical resistance for long distances in figure 7 is due to the washing cycle, which breaks and removes conductive material coated on the yarn. For long distances more material is exposed to friction and therefore more silver coating is removed along the narrow fabrics length.

In figure 8 an SEM picture of the silver coated Polyamide 66 filaments of narrow fabric 3 is shown after 20 washing cycles. It is evident that after 20 washing cycles the silver coatings have been removed at different places.

The achieved resistance is relatively high compared to applied wire systems especially for long distances in architectural structures. For practical use the resistance of the conductor should be reduced to 1 – 2 Ω per meter material or even less. Active sensors application (e.g. strain gauge, acceleration sensors, temperature sensors) for monitoring systems need adequate power supply.

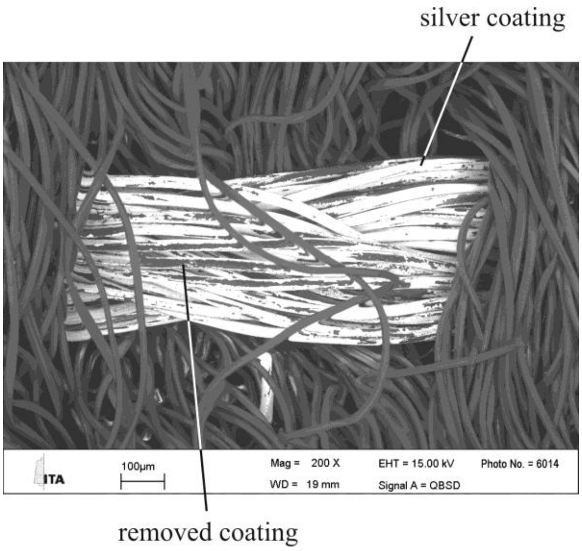


Figure 8: SEM picture of silver coated Polyamide 66 filaments of narrow fabric 3 after 20 washes

Passive sensors transmit signals without power supply. Therefore the applied sensor systems influence the requirements very much. Furthermore the evaluation device requires additional requirements. A combination of wire and narrow fabrics can reduce the resistance as well. Thus a general prediction on the applications of the narrow fabrics cannot be stated. So far sensors with need of only low power supply could be used with pure textile based conductors. However several examples of applied silver coated Polyamid 66 as electrical conductors or even sensor elements over long distances show the potential of the material. To achieve lower resistance the electric conductive face of the material needs to be increased. This could be achieved by either thicker coating or electric conductive materials inside the yarns polymer (e.g. CNT, Polyaniline) [4].

5 CONCLUSION

When using conductive materials the fabrics need additional testing concerning the electrical properties. Depending on the civil structure and the application, the conductor is exposed to extreme temperatures, high humidity, rain or acting forces caused by wind. The parameters need to be tested accordingly. The electrical supply or data transfer is mainly caused by the conductive material. Silver coated Polyamide 66 filaments showed the feasibility for electrical energy transport. However, only minor electrical powers can be transported with these materials. Efficient conductive textile material has yet to be developed to fulfill the required needs.

References

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