Testing the electrostatic characteristics of polypropylene fabric with metallic yarns, intended for use in coal mines threatened by the explosion hazard. Part 1: Laboratory tests

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Abstract. The aim of this paper was to assess electrostatic safety of polypropylene fabric with metallic yarns intended for use in coal mines. Such fabrics have not been used in the Polish mining industry yet. The tests conducted have been divided into two subgroups: laboratory tests and tests in a coal mine. This paper presents the results of laboratory tests, which comprise charge transfer tests, impact of washing and mechanical stress on the resistance and resistance-to-ground at the manufacturer’s site. Some problems with measuring the resistance are highlighted and discussed. The results obtained allow a reliable assessment to be made of the risk of using fabrics with metallic yarns in the explosive atmosphere, which often occurs in coal mines.

1. Introduction
Polypropylene fabrics with metallic yarns have not been used in the Polish mining industry yet and so far no criteria have been established to assess electrostatic safety of fabrics with metallic yarns. Consequently, a wide range of tests were arranged that have been divided into two subgroups: the laboratory tests and tests in a coal mine. The main objective of the work was to assess the risk of using fabrics with metallic yarns for mining applications. In this paper the results of laboratory tests are presented. Problems with measuring the resistance of fabrics with metallic yarns are highlighted and discussed. We also present the results of charge transfer tests, as well as the impact of washing and mechanical stress on the resistance and resistance-to-ground at the manufacturer’s site.

The object tested was a composite, where conductive yarns made of stainless steel were present inside a matrix of highly resistive base fabric (polypropylene), as shown in Figure 1.

Figure 1. Structure of the fabric tested.
The EN 13463-1 Standard [1] describes the basic testing methods and requirements of non-electrical equipment to be used in a potentially explosive atmosphere and procedures for measuring surface resistance and charge transfer. To assess plastic fabrics intended for use in coal mines the EN 61340-2-3 Standard [2] describes procedures for measuring surface, volume and point-to-point resistance. Technical Report CLC/TR 50404 [3] recommends testing the impact of washing and the mechanical stress on the resistance of materials such as fabrics with metallic yarns. Requirements of flexible intermediate bulk containers (FIBC), which are usually made from materials such as the tested fabric, are given in the EN 61340-4-4 Standard [4], where the method of measuring resistance-to-ground is described.

2. Laboratory tests

2.1. Resistance tests

Surface resistance measured with the parallel stripe electrodes described in the EN 60079-0:2009 Standard [5], strongly depends on the direction of the electrodes in relation to the direction of the yarns [7]. The parallel electrodes are 100 mm long, 1 mm wide and separated by a distance of 10 mm. Tests were conducted with four configurations of electrodes in relation to the yarns. However, the results showed that this type of electrode arrangement is not applicable for materials such as fabrics with metallic yarns.

EN 61340-2-3 Standard [2] specifies a ring probe to measure surface resistance and point electrodes to measure point-to-point resistance as well as the resistance to a groundable point (see Figure 2).

As regards the surface resistance probe, it is also not applicable for fabrics with metallic yarns, because the outer ring of the probe which is 3 mm wide (Figure 3), does not make good contact with the yarns and the results can differ by eight orders of magnitude depending on the location of the probe, which is random. Only point electrodes make good contact with metallic yarns and can be used to measure point-to-point resistance as well as the resistance-to-ground. Tests of resistance-to-ground conducted using the point electrode are given in this paper later.

2.2. Charge transfer tests according to the EN 13463-1 Standard

The charge transferred in a single discharge was measured according to the EN 13463-1 Standard [1] by two independent accredited laboratories. Results are summarized in Table 1 [7].

Climatic conditions of the tests were as follows: temperature 23°C and relative humidity below 30%. The idea of the test is to measure charge Q transferred in a single discharge, as the ball electrode approaches the sample tested. Samples are charged by three methods: rubbing with polyamide cloth, method and the highest value measured was accepted as the final result. More about this subject can be
found in [6]. Some differences between values obtained by the two laboratories have been noticed, although, all the results obtained met the criterion (60 nC [1]). Potential reasons for the differences have not yet been determined, because this was not the project objective; however possible factors include the following: human factor (personnel with individual features including speed and pressure of rubbing), relative humidity and different samples of material tested. Additional interesting information about errors in charge transfer measurement can be found in [8] and [9].

| Laboratory | Sample | Polyamide cloth rubbing | Cotton cloth rubbing | Corona charging |
|------------|--------|-------------------------|----------------------|-----------------|
| A          | 1      | 2.9                     | 4.2                  | 4.3             |
| A          | 2      | 5.9                     | 3.8                  | 5.7             |
| A          | 3      | 3.9                     | 3.6                  | 4.1             |
| B          | 1      | 2.94                    | 13.72                | 15.68           |
| B          | 2      | 34.30                   | 30.38                | 16.66           |

2.3. Impact of washing and the mechanical stress on the resistance
Technical Report CLC/TR 50404 [3] recommends testing the impact of washing and mechanical stress on the resistance of materials such as fabrics with metallic yarns. Climatic conditions of the tests were the same as in section 2.1. The fabric was washed for 1 hour in water flowing at a rate of 1 dm³/min. The resistance value after washing was the same as before.

To assess the impact of mechanical stress on the resistance of the fabric, the material was tested on the strength machine, where samples of fabric were elongated by 5%, 10% and 15% of their length for 60 seconds. The resistance value after the mechanical stress tests was the same as before. Besides, there was no rupture of the material, which could result in the appearance of isolated patches of the basic fabric.

2.4. Resistance-to-ground at the manufacturer’s site
Resistance-to-ground was measured at the manufacturer’s site for two cases: for empty bags and for bags filled with just prepared material, as shown in Figure 3.

Figure 3. Tests of resistance-to-ground at the manufacturer’s site.
model 850 (Figure 2) and with clip electrode. Both of the electrodes had good contact with the yarns and the results for both were consistent with most of order $10^4 \Omega$.

3. Results

Problems were encountered with using parallel stripe electrodes and the ring probe electrode to measure surface resistance of fabrics with metallic yarns. Neither is suitable for such kinds of fabric. Resistance-to-ground can be measured with point or clip electrodes. For this project we used point electrodes [2]. In the laboratory tests, charge transferred in a single discharge was tested in two independent laboratories using 5 different samples of materials. The worst result was 34.30 nC, which is well below the criterion of 60 nC [1]. Additional tests of washing and mechanical stress impact on the resistance were carried out in the laboratory, as recommended in Technical Report CLC/TR 50404 [3]. Post-test resistance values for both washing and mechanical stress were the same as before. Also, no rupture of the material was observed during the course of the tests. Resistance-to-ground was measured at the manufacturer site for empty bags and bags filled with just prepared material. Most of the results were about $10^6 \Omega$.

4. Conclusion

The tested object was the composition of conductive yarns made of stainless steel and highly resistive base polypropylene fabric. To assess the electrostatic safety of this kind of material charge transfer test, resistance to ground test and test of washing and mechanical stress impact on the resistance should be carried out in the laboratory. In our opinion it is also very important to verify the resistance-to-ground in real conditions of using fabric, which is a coal mine environment in this case.

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References

[1] EN 13463-1:2010 Non-electrical equipment for use in potentially explosive atmospheres Part 1: Basic method and requirements
[2] EN 61340-2-3:2002 Electrostatics - Part 2-3: Methods of Test for Determining the Resistance and Resistivity of Solid Planar Materials Used to Avoid Electrostatic Charge Accumulation
[3] CLC/TR 50404 Electrostatics. Code of practice for the avoidance of hazards due to static electricity
[4] EN 61340-4-4:2006 Electrostatics - Part 4-4: Standard test methods for specific applications – Electrostatic classification of flexible intermediate bulk containers (FIBC)
[5] EN 60079-0:2009 Explosive atmospheres - Part 0: Equipment - General requirements
[6] U. von Pidoll, E. Brzostek und H.-R. Fröchtenigt, Determining the incendivity of electrostatic discharges without explosive gas mixtures, IEEE Transactions on Industry Applications, 40 (2004), 1467-1475
[7] S. Makarski, M. Rasek, L. Orzech, M. Talarek, Badania tkaniny polipropylenowej z przepletem metalowym stosowanej w wyrobiskach górniczych w aspekcie zagrożenia wybuchem związанныm z elektrycznością statyczną, Wiadomości Górnicze, Katowice (Poland), 9/2009
[8] J. N. Chubb, Measurement of charge transfer in electrostatic discharges, J. Electrostatics, 64 (2006) 321-325
[9] H. L. Walmsley, Induced-charge errors in charge-transfer measurement, J. Electrostatics, 67 (2009) 320-325