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Design and development of electrostatic discharge tester for textile materials

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ABSTRACT

Electrostatic discharge tester has been designed to measure the electrostatic discharge produced in the woven fabric in terms of kilovolts. Various types of fabrics have been tested for their static properties by using Box-behnken design and their values were analysed based on their influencing parameters such as rubbing cycle, pressure and speed. It is observed that the value obtained by the electrostatic discharge tester varies from cotton, silk and polyester depending upon moisture regain values. It has been found that the maximum static discharge value generated for polyester while testing was 3 kilovolts, which was comparatively higher than cotton (2.1 kilovolts) and for silk(1.8 kilovolts) .The optimum values and their regression, correlation co-efficient were also analyzed.

Introduction

Countries with an overall lower humidity level can experience problems with natural fibres becoming statically charged. The problems with statically charged textiles range from a simple uncomfortable sensation to the wearer, to serious hazards in explosive working environments or damage to the sensitive electronic equipment. Thus there is a need to understand and control the generation, accumulation and decay of the static charge on textile materials. Static electricity is generated whenever two materials are in contact with each other. All materials are made of electrical charges in the material atoms. In the universe there are equal amounts of negative electrical charge (electrons) and positive charge (protons). These generally try to stay in balance of equal amounts at every location. However, when two materials are in contact, some of the charges redistribute by moving from one material to the other. This leaves an excess of positive charge on one material, and an equal negative charge on the other. When the materials move apart, each takes it's charge with it. One material becomes charged positively, and the other negatively. If the materials are able to conduct electricity away the charges will dissipate and eventually recombine. In this case, static electricity effects may be too small to be noticed. However, if the charges are separated faster than the material can dissipate them, the amount of electrostatic charge builds up. Textile technologists are concerned about the need to control static charge during modern, high speed textile processes, and consumers are very aware of issues such as the static charge generated in walking on carpet or static cling in fabrics. Despite these negatives attributes, textile static is used in some manufacturing processes such as flocking, selected non-woven fabrics and in electrets filters to assist in the absorption of airborne dust. Given the growing significance of static electrical phenomena in textiles and textile processing, a better understanding of this property is critical to the future of the textile industry. The generation of static electricity, observed in ancient times, was initially characterized in the 1500's. The initial tribo-electric series, developed in the 1757 by Wilche, was ultimately interpreted as the transfer of electrons between two surfaces that are in contact with each other [1 - 2]. The "tribo series", despite its 245-year existence, is still variable; dependent on the literature source [3] and a mechanistic explanation of its origins is still the subject on ongoing research [2 - 5].

In the textile industry, static electricity may cause many problems if it is not under control. These problems may be:

- Electronic equipment can be overloaded and break down.
- Static discharge in an operating room may lead to an explosion.
- Risk of shock.
- Increased production time: In some areas very long textile materials are produced. Because of the static charge on it, roll should be used for some time to allow static charge dissipation.
- Fiber breakage and decreased fabric strength: Spunbond machine during production, before transferring the web to calender bonding, the fabric sticks to the belt. This may cause fabric breaks during production and higher process time [6 - 8].

Some materials such as glass, hair, and Nylon tend to give up electrons and become positively charged. Other materials such as Polypropylene, Vinyl (PVC), Silicon, Teflon, and Silicone tend to collect electrons and become negatively charged.

The ability of material to surrender its electrons or absorb excess electrons is purely a function of the conductivity of the material with which you are working. For example, a pure conductor, such as copper, has a rigid molecular construction that will not permit its electrons to be moved about freely. However, as you approach the semi-conductor range, such as some bond papers, the ability of this material to surrender its electrons is relatively easy and can be accomplished by friction, heat or pressure. As you approach the purely non-conductive materials, such as plastics, it is extremely easy to disrupt the molecular construction and cause the material to charge with the slightest friction, heat or pressure. [9 - 11]

As the pressure or speed of contact and separation (friction) increases, the amount of the static charge buildup (voltage level) increases. Rapidly moving materials - such as plastic trim in a

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pneumatic conveyor or a converted film web - can quickly develop charges of more than 25,000 volts. The second means by which an object or material may be charged is by induction. A highly charged object is surrounded by a static charge field. If an isolated or ungrounded conductive object enters into this static field, it too will become charged. This creates the possibility of electrostatic discharge to some other conductive object, which could result in an arc of sufficient energy to ignite combustibles or destroy sensitive electronic components1999. [12 – 13]

When two solid materials are brought in contact and rubbed against each other then the electrons move across the interface. To determine the polarity of each material that is in contact, the triboelectric series is useful. According to the triboelectric series, every material charges positive against materials below it in the table when the two be rubbed. There are several lists of triboelectric series which are quite different than each other [14-20].

Arita et.al., have used two potential probes measurements were used to calculate the initial potential and Characteristic decay time. Charge generation increases with yarn tension and speed. Increase in yarn tension increases the contact area between the charge pin and the yarn due to yarn degree of flattening that increases with tension. Increase in contact area led to more chance of static charge exchange. They found that transferred charge was linearly proportional to the square root of the normal contact force. Decay times obtained under the temperature of 35°C were excluded from the data because the behavior at this temperature was exact opposite to all other temperatures studied. It was found that characteristic decay time varied significantly with temperature and speed. Relative humidity is affecting charge dissipation not as a main effect but only as interactions with all parameters studied especially much by yarn speed. Decay time becomes shorter when the yarn moved faster, which means static charge decayed faster with yarn speed [21-29].

There are many factors that affect charge generation such as environment (temperature, humidity), structural (polymer type, structure of fabric) and working factors (fabric speed, tension, and contact area between fabric and machine parts, material type that is in contact with fabric). With a good knowledge of these parameters, generation of static charge can be minimized. From the literature survey, there is no suitable static electricity discharge tester for testing the static charge behavior of Textile materials. Hence this research work is to design and development of static electricity discharge tester for testing the Textile materials. Various fabrics have been tested for their static behavior by Box-behnken design and their values were analysed based on their various influencing parameters such as rubbing cycle, pressure and speed of the electro static discharge tester.

Materials and Methods

The electrostatic discharge tester which is consist of Temperature and Humidity Sensor, Electrostatic Sensor, Proximity Sensor liquid crystal with display (LCD), Rectifier, transformer and DC motor as shown in figure 1. The principal of electro static discharge tester is based on friction between the fabric and Teflon roller. When Teflon roller is move over the fabric, the electro static charge is generated on the fabric, then static charge can be sensed by electro static sensors.

The fabric samples of three different materials such as cotton, silk, and polyester with a sample size of 10 inches X 5.5 inches are selected for static discharge tester. Which is placed above a wooden board and air tightened at the edges of the fabric by means of clamps. The required parameters are fed into the electrometer beforehand and the arm consisting the weight at the top and Teflon roller at the bottom is move over the fabric in a linear reciprocating to and fro manner over the fabric. Finally the linear reciprocating movement is stopped after the predetermined values are reached, where the rubbing strokes is sensed by the proximity sensor and the static charge produced on the fabric can be measured by the electrostatic sensor. As per the coulombs law the force, pressure, speed is directly proportional to the amount of charge produced. The range of static charge that can be measured from the electrostatic discharge tester is in the range of 1-15 kilovolts.

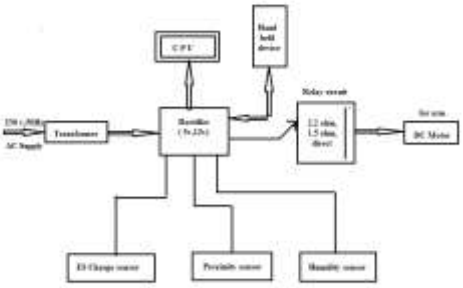

Figure 1: Block Diagram of Electrostatic Discharge Tester

In this study, in order to optimize the process parameters of electro static discharge tester, the following three factors were considered to analyze the electrostatic discharge properties of textile materials i.e.,No of rubbing cycle(X1), Pressure (X2), and Speed (X3) by using Box-Behnken design as shown in the Table 1 and 2. The varying values of rubbing cycle (X1) are 30,50,and 100 strokes, The varying values of pressure (X2) are 200, 300 and , 400 grams. The varying values of speed (X3) are 15, 30 and 50 mpm as shown in Table 1 and 2.

Results and Discussion

The static electricity of the Textile material is mainly deponce up on various factors like temperature, humidity, speed, number of rubbing cycles and pressure. Normally when temperature is high,static charges produced will be high because when heat is generated due to friction charges will be generated to a great extent.When humidity is high,static charge produced will be less because in wet state charges generated will be least. It is observed that cotton material have considerable less static electrification then silk and polyester materials from Table 3 – 5 and the amount, and nature of the odsorption of the moisture by fibres is possibliy of more importance with regard to static electrification than the chemical constitution. The Textile materials increases exponentially with degrees in relative humidity with which it is equalitrium because of this relationship its has been easlly to explain the rapid degrees in the charge generation at high humidity on the basic of charge leakage or increased conductivity along the surface water films. For cotton moisture regain value is 8% ,for silk -11%, for polyester-0.4%.Hence polyester will have higher static discharge value than silk and cotton due to its lower M.R%.when rubbing cycles,speed and pressure are increased,higher static charges were produced.we have used 3 variables such as rubbing cycle,pressure and speed and tests were conducted on 3 different samples namely polyester,silk and cotton. The experiment was conducted using Box-behnken and the results were obtained as follows.The Box-behnken design for 3 variables at 3 levels along with the S3[static charge in KV] are given in table for 3 different fabric.

Influence of rubbing cycles,pressure,speed on S3 values at room temperature of 28^o C and Relative humidity of 35% is shown below.It is found that the higher pressure,speed had significantly influenced the electrostatic discharge.In case of cotton it has higher moisture regain upto 8% so relatively the static charge produced will be less compared to polyester.When number of rubbing cycles are high upto 100 strokes and at a pressure of 400grams - static charge produced will be high.When number of rubbing cycles are high upto 100 strokes and when speed is at 50 mpm again the charges produced will be high.When pressure is applied at 400 grams and the speed is increased to 50 mpm then static charges will be highly produced.In case of silk and polyester also the above results are obtained.But for silk the moisture regain is 11% so the output value will be even more less than cotton and for polyester the moisture regain is 0.4-0.8% as a result the output will be high when compared to silk and cotton. Subsequently at lower levels of 30 Rubbing strokes and 200 grams pressure the least static discharge values were produced .The static output was also produced with least values at 30 Rubbing strokes and with 15mpm speed and with 200 grams pressure and 15mpm speed. Relative humidity increases,the fibre aborb moisture and their electrical resistantance decreases with a consequent reduction electo static charges generation.

The Process Parameters for optimum results of electrostatic discharge values for textile fabrics such as cotton, silk , polyester were identified. The detailed regression analysis shows that when the number of rubbing cycles (100 strokes),Pressure (400grams),Speed(50mpm) is high ,the static charges produced was also high .Higher electrostatic discharge values will lead to problems in the subsequent processing treatments and finishing. As far as the electrostatic discharge values are lower there will be a possibilty of reducing the problems. It has been observed that the optimum values were found at lower rubbing cycles (30), pressure (200), speed (15mpm) to carring out the electro static testing.

Conclusion

Static electricity has many useful applications, but it can also create many risks and problems. The surface potential created by static charge and retained on materials is the parameter of primary practical importance. The potential depends on the quantity of charge transferred to materials and on the character of the materials involved. The maximum surface potential that will arise then depends on both the time for dissipation of charge compared with the time at which the rubbing surfaces separate.

The generation of static charges is high especially in case of conductive fabrics. Hence it is essential to test the amount of static generated from fabric and measure the values based on their influencing parameters such as number of rubbing cycles, pressure, and speed. For testing we have used the Electrostatic discharge tester. The Electrostatic discharge values were analysed using box-behnken design and regression analysis was done. Then the correlation coefficient of the tested fabrics was found to be 0.85 for cotton, 0.88 for silk, and 0.90 for polyester. It was observed that the polyester fabric generated higher static discharge values of 3 kilovolts due to lower moisture regain (0.4%). For cotton static discharge value is 1.8 kilovolts and the moisture regains (8%).For silk static discharge value is 2.1 kilovolt and the moisture regain (11%).

References

1. Philip E., Antistats, In Handbook of Fiber Finish Technology, New York, USA, Marcel Dekker, 1998; 273-274.
2. Bailey, Adrian G., The Charging of Insulators, Journal of Electrostatics, 2001; 51-52, 82-90
3. Castle, G. S. P., Contact Charging Between Insulators, Journal of Electrostatics, 1997; 40-41,3-12
4. Slade, Philip E., Antistats, In Handbook of Fiber Finish Technology, New York, USA, Marcel Dekker, 1998, 275-278.
5. Hersh, S. P., Resistivity and Static Behavior of Textile Surfaces, In Surface Characteristics of Fibers and Textiles. J. M. Schick, ed., New York, USA, Marcel Dekker, 1975, 229-237
6. Arita, Y., Shiratori, S. S., Ikezaki, K., Methods for the Detection and Visualization of Charge Trapping Sites in Amorphous Parts in Crystalline Polymers, Journal of Electrostatics, 2003; 57, 263-271.
7. Harper, W. R., Contact and Frictional Electrification, Oxford University Express, London, 1967.
8. Taylor, D. M., and Secker, P. E., Industrial Electrostatics: Fundamentals and Measurements, John Wiley & Sons, New York, 1994.
9. Clark, D. T., and Feast, W. J., Polymer Surfaces, John Wiley & Sons, New York, 1978.
10. R Gompf "Standard test method for evaluating triboelectric charge generation and decay" NASA Report MMA-1985-79 Rev 2, July 1988
11. J N Chubb “Instrumentation and standards for testing static control materials” IEEE Trans Ind Appl 26 (6) Nov/Dec 1990; 1182-1187
12. C Buhler, C Calle, S Clements, M Ritz, J Starnes “Test methodology to evaluate the safety of materials using spark incendivity” J Electrostatics, 2006; 64-11, 744-751
13. J. N. Chubb "The assessment of materials by tribo and corona charging and charge decay measurement" Inst Physics 'Electrostatics 1999' Confr, Cambridge, IoP Conf Series, March 1999; 163, 329-333.
14. J. N. Chubb "Corona charging of practical materials for charge decay measurements", Journal of Electrostatics, 1996; 37 (1-2), 53-65
15. IEC 61340-2-1 “Measurement methods in electrostatics – Test method to measure the ability of materials and surfaces to dissipate static electric charge” Feb 2000; International Electrotechnical Commission
16. US Federal Test Standard 101C Test Method 4046. EIA Interim Standard IS-A
17. J. N. Chubb, P. Malinverni "Experimental comparison of methods of charge decay “measurements for a variety of materials" EOS/ESD Symposium, Dallas, 1992; 5A-5.1
18. Arita, Y., Shiratori, S. S., Ikezaki, K “Methods for the Detection and Visualization of Charge Trapping Sites in Amorphous Parts in Crystalline Polymers”, Journal of Electrostatics, 2003; 57 (3-4), 263-271
19. J. N. Chubb “Dependence of charge decay characteristics on charging Parameters”, IoP, York, April 3-5 1995; Intl Confr "Electrostatics”
20. Cross, Jean “Electrostatics: Principles, problems and Applications” 1987
21. Berezin, A. Alexander “ Electrification of Solid Materials, Handbook of Electrostatic Processes” 1995, New York, Marcel Dekker
22. Morton, W.E. Hearle, J.W.S “Physical Properties of Textile Fibers” 1993. Manchester, UK : The Textile Institute

23. Vosteen, E. William “A Review of Current Electrostatic Measuring Techniques and Their Limitations”, 1984 Electrical Overstress Exposition
24. Noll, C.G “ Electrostatic Charge Elimination Techniques, Handbook of Electrostatic Processes” New York : M. Dekker,1995
25. Kacprzyk r., Stec C “Measurement of The Surface Charge Density on Moving Webs”, Journal of Electronics, 1997; 40-41, 455-461
26. Seaver, Albert E. “Analysis of Electrostatic Measurements on Non-Conducting Webs”, Journal of Electrostatics, 1995; 35 (2-3), 231-243
27. Durkin, W. J. Dangers in “Interpreting Electrostatic Measurements on Plastic Webs”, Journal of Electrostatics, 1995; 35 (2-3), 215-229

Table 1: Factors and Levels

Sl. No.	Factors	Levels		
		-1	0	+1
1.	Rubbing cycles (strokes)	30	50	100
2.	Pressure (grams)	200	300	400
3.	Speed (mpm)	15	30	50

Table 2: Experimental run Box-Behnken Method

Factor level combination			
Experimental run	X1	X2	X3
1	30	200	30
2	100	200	30
3	30	400	30
4	100	400	30
5	30	300	15
6	100	300	15
7	30	300	50
8	100	300	50
9	50	200	15
10	50	400	15
11	50	200	50
12	50	400	50
13	50	300	30
14	50	300	30
15	50	300	30

Table 3: Static Discharge of Cotton materials

Sl. No.	Rubbing cycle (number)	Pressure (grams)	Speed (mpm)	Static Discharge in (kilovolts)
1	30	200	30	1.230
2	100	200	30	1.470
3	30	400	30	1.220
4	100	400	30	1.490
5	30	300	15	1.120
6	100	300	15	1.410
7	30	300	50	1.240
8	100	300	50	1.510
9	50	200	15	1.180
10	50	400	15	1.100
11	50	200	50	2.100
12	50	400	50	1.320
13	50	300	30	1.310
14	50	300	30	1.310
15	50	300	30	1.310

Table 4: Static Discharge of Silk

S.no	Rubbing cycle (number)	Pressure (grams)	Speed (mpm)	Static Discharge in (kilovolts)
1	30	200	30	1.14
2	100	200	30	1.770
3	30	400	30	1.250
4	100	400	30	1.850
5	30	300	15	2.300
6	100	300	15	1.530
7	30	300	50	1.210
8	100	300	50	1.630
9	50	200	15	1.340
10	50	400	15	1.280
11	50	200	50	1.340
12	50	400	50	1.410
13	50	300	30	1.280
14	50	300	30	1.280
15	50	300	30	1.280

Table 5: Static Discharge of Polyester

S.no	Rubbing cycle (number)	Pressure (grams)	Speed (mpm)	Static Discharge in (kilovolts)
1	30	200	30	1.270
2	100	200	30	2.000
3	30	400	30	2.100
4	100	400	30	2.870
5	30	300	15	1.270
6	100	300	15	2.800
7	30	300	50	1.170
8	100	300	50	2.670
9	50	200	15	1.370
10	50	400	15	2.100
11	50	200	50	2.800
12	50	400	50	3.000
13	50	300	30	2.400
14	50	300	30	2.400
15	50	300	30	2.400