COMPARATIVE STUDY OF ABRASION RESISTANCE EVALUATION FOR TEXTILE AND OTHER FLEXIBLE MATERIALS – A REVIEW

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Abstract: *Abrasion is a serious problem for various technical textiles as well as for home textiles like as carpets and upholstery fabrics and apparels. Abrasion ultimately results in the loss of performance characteristics such as strength, appearance and overall performance of the products. Various types of abrasion testers and abrasion methods are used to determine the abrasion of varieties of textile materials. In this paper, critical appraisal of the various types of abrasion testers and abrasion method used to determine the abrasion resistance behavior of varieties of textile and other flexible materials are provided. Based on the nature of deformation of textile material, right kind of abrader and mode of abrasion is decided. Further assessment of damage to textile materials after abrasion is also required to be adopted based on the application of the material.*

Keywords: *abrasion; fabric; textile; Abrasion Test Methods; ISO and ASTM standards.*

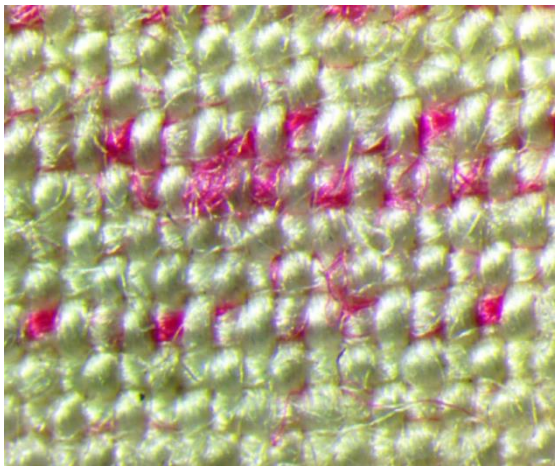
1. Introduction

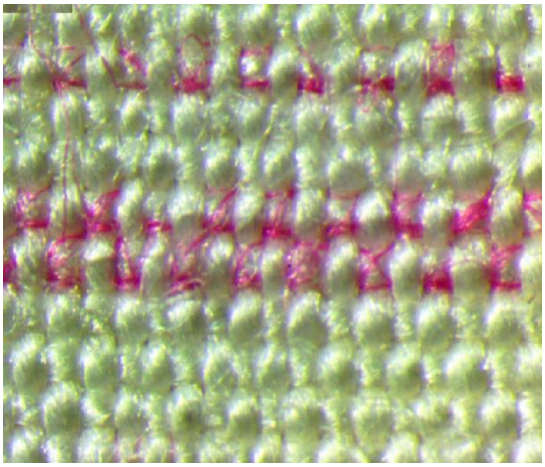
Textile materials are flexible materials and cannot be refurbished if worn outdue to several wearing factors. Abrasion is one of the most important wear causing factors in textile materials. Abrasion is the physical destruction and degradation of fibres, yarns and fabrics, due to rubbing of a textile surface over another surface (Abdullah et al., 2006).The textile material is frequently exposed to various abrasion forces which can degrade its various mechanical properties (tensile, flexural, torsional and frictional). Abrasion leads to loss of performance characteristics and mechanical properties, such as strength, but it also affects the appearance of the fabric (Collier & Epps, 1999). The strength of textile material is treated as one of major factor leading to wear performance or resilience as encountered in the actual use of the material.The endurance of textile materials to “abrasion” as evaluated on a testing apparatus in the laboratory. The two frequently related terms “abrasion” and “durability” varies with different end uses, and different factors may be necessary in any calculation of predicted durability from specific abrasion data (ASTM D 4966). The abrasion resistance is quantified in terms of the number of cycles on an abrasion tester, using a specified procedure or method to produce a specified degree or amount of abrasion. The durability of textile material can be specified as the capability of material to endure deterioration or wearing out in use, including the outcomes of abrasion.

Abrasion is a significant problem for home textile materials such as carpets, upholstery fabrics, socks and technical textiles. In case of clothing and other apparels, abrasion generally occurs while wearing, using, cleaning or washing process and this may distort the fabric. Due to distortion of fabrics, the fibers or yarns could be pulled out or fiber ends tends to be eradicate from the surface (Hu, 2008; Kadolph, 2007) as shown in **Figure 1**. Especially certain parts of apparel, such as collar, cuffs and pockets may get worn out after some time. Apart from apparels, abrasive damage in case of fabrics normally occurs in various applications including medical, sports, automotive, filtration, aerospace, upholstery, hospitality, decorative, geological applications, protection, defense and numerous others. The key aspects that lead to diminishing of service life of the textile materials remain comprehensively reliant on its end use.

The abrasion in textile materials can be flat abrasion, edge abrasion, or flex abrasion. Abrasion can also occur in various modes like dry, wet, and saturated (semi wet or semi dry) mode. Dry abrasion can be seen everywhere wherever textile materials are used such as dry abrasion occurs for apparel while we sit, sleep, while moving, while working, etc. The saturated abrasion (partially dry or wet)comes in play when clothes become partially wet during working, playing sports, doing workout and roaming in rainy days when apparels get wet in the rain. After taking a bath the person uses towel then partially wet towel and skin get abraded by each other. While playing sports and doing workout at gym, semi wet abrasion of fabric with fabric and/or skin can be easily noted. Saturated abrasion can easily noticed at locations where high level of humidity exists. The fully wet abrasion (when textile material is 100% saturated with the water) can be observed during washing of the cloths, during swimming, in rainy days as well as the wiping cloths will become fully wet while wiping. In similar way, one can find numerous applications of textile material where the textiles are abraded in dry, wet, or in saturated conditions. Hence the abrasion resistance behavior of textiles in dry, wet and saturated condition is of a great concern for textile technologist, manufacturer and the user.

(a) Verge of jeans pant





(b) (c)

Surface appearances of fabrics (b) & (c) after the abrasion test

Figure 1. Abraded textile materials

2. Literature review

Several instruments had been designed for last few years to evaluate the abrasion resistance of the textile material out of which some of them are very popular and are widely available. Some organizations, academic institutes and research laboratories are using them for their exploration objectives. Abrasion tester instrument can be classified in several ways, based on the nature and mode of abrasion. The abrasion on textile materials can be categorized as flat abrasion, edge abrasion and flex abrasion. In flat abrasion, the textile material gets abraded in mode of reciprocating, rotary or multidirectional direction. Edge abrasion takes place when the wear or abrasion occurs along the fabric edge, generally a folded edge, such as on the edge or fold of the collar of a shirt or the cuff of a sleeve or trousers such as shown in Figure 1.In case of flex abrasion, rubbing is accompanied by flexing and bending on textile materials.

Abrasion resistance evaluations on most of the instruments depend on the application of energy on the fabrics and measuring its response. The energy transfer mode from machine to the fabric may vary from one machine to another machine, but the basic principles of transferring the energy will remain same (Abdullah et al., 2006). Consequently, various abrasion resistance evaluation techniques have been described by the category of abrasion, drive of test head or testing device system. The differences among the techniques include the type of equipment, abradant (the material that rubs against the specimen), material used during testing (including woven, nonwoven, and knitted apparels, household fabrics, industrial fabrics, and floor coverings) and assessment method. However in all abrasion resistance evaluation techniques, the test sample is rubbed in a specific manner against an abradant (worst wool fabric or a emery sheet) for either a certain amount of time or number of cycles/strokes (Kadolph, 2007). Abrasion resistance also depends upon the conditions in which the specimen is tested, i.e. in standard atmospheric conditions having 21 ± 1°C temperature and 65 ± 2% relative humidity (RH).The test sample may be in saturated condition (partially wet or dry) i.e. initially wet condition (wet the fabric in a separate dish and then place it on the tester for testing) or in fully wet condition i.e. keeping the specimen 100% wet throughout the testing.

The measurement of the resistance to abrasion of textile and other materials is very complex phenomenon. The abrasion resistance gets affected due to the nature of abradant, variable action of the

abradant over the area of abraded specimen, the tension between the specimen and abradant, the dimensional variations in the specimens (cross-section of the fibres) the moisture level existing in the specimen. The resistance to abrasion is also affected by following factors the inherent mechanical properties of the fibres and the type, kind and amount of finishing material added to the fibres, yarns or fabric. In Table 1, various abrasion test methods and relevant test equipment are given. However, using any of these methods or techniques listed in the table, no linear relationship has been found out between successive measurements and progressive amounts of abrasion (Saville, 1999).

3. Method of assessment

For assessing the effects of abrasion, following two approaches have been exercised for assessing the effects of abrasion.

- Abrade the sample until a predetermined end-point such as a hole or flaw, and record the time or number of cycles to this.
- Abrade for a set time or number of cycles and assess some aspect of the abraded fabric such as change in appearance, loss of mass, loss of strength change in thickness or other relevant property.

Generally, first approach agrees to most technicians' point of view to the end point of abrasion but the length of the test is indeterminate and requires the sample to be regularly examined for failure in the absence of a suitable automatic mechanism. This need for examination is time consuming as the test may last for a long time. The second approach promises a more precise measurement but even when the sample has rubbed into a hole the change in properties such as mass loss can be slight. However none of the above assessment methods produces results that show a linear or direct comparison with one another. Neither is there a linear relationship between successive measurements using any of these methods and progressive amounts of abrasion. Many different abrasion tests exist, though the correlation between them is often poor. It is essential that the abrasion reflects the end-use of the material and that the abrasion test used across samples is consistent. There are many machines for abrasion testing. Each tries to replicate a different type of abrasion that might be encountered in use. The International Organization for Standardization (ISO) and American Society for Testing and Materials (ASTM) have introduced several methods or techniques for evaluation of abrasion resistance of abraded fabrics. Various abrasion test methods and relevant test equipment are being used however, using any of these methods or techniques no linear relationship has been found out between successive measurements and progressive amounts of abrasion (Saville, 1999).

4. Factors responsible for abrasion of textiles

The recent innovations of high quality textile materials which are fabricated according to the advanced technological processes opened the new avenues of making the fabrics distinguished with superior physical and mechanical properties. Moreover, high quality textile materials are manufactured in accordance with its fabric resistance against different impacts in use. The fabric at the same time should retain its textile properties, such as color fastness, dimensional stability, strength, appropriate abrasion resistance etc. These materials when reproduced in the form of clothing's, textile cartridges for shoes or any other end-use product must offer the retention of good looks and should be useful for extended periods. However, in regards to satisfying the prerequisites of soldiers, policemen, mountaineers and many other specific users (where the life of person depends upon good abrasion resistance of textile materials), higher performance of textile materials attain a completely different meaning. A higher performance textile material tends to be a no longer mystery; it is just a matter of time when the upcoming generation will get better and smarter fabrics. As seen in routine life, people adore to be surrounded with textile materials which have property of retaining their original properties for longer time including high wear resistance under the conditions of use and higher abrasion resistance (Maja Somogyi Škoc and Emira Pezelj, 2012). Shilpi Akter (2017) investigated on different physical properties of fabrics and reported that the weight loss decreases with the increases of weft count, the abrasion resistance of the woven fabric increases. The pilling and wrinkle recovery were slightly affected by the increase of weft count and weave structure. It is essential to select the best method and appropriate procedures to test and evaluate them. The outcomes of tests should be expressed in the proper manner as well. This may be a good starting point for the development of new test methods and procedures for evaluation of abrasion resistance of fabrics. It will also be an impulse for the construction of appropriate measurement equipment for abrasion resistance.

5. Conclusions

Today, there are several different types of abrasion testers available for carrying out abrasion resistance tests of textile materials as described in table 2. They have progressed over time to time to incorporate various types of loading conditions and testing materials, in order to be actual and closer to real conditions.

However, their results are still not mutually equivalent and often opposing results have been reported using different instruments. In different moisture conditions the same textile material may behave in a different way due to various reasons like type of fibre employed, yarn structure, fabric structure, physical and chemical properties of fibre, yarn and fabric, finishing treatments done to material, absorbency property of the material. For instance, cotton fibre gains some strength in wet condition and viscose loses and some of the fibres get swollen in wet condition. The effect of abrasion of textile material should be inspected in various moisture conditions. The research study done by N C Ray et. al (2016) reveals that that the more deterioration of surface appearance does not necessarily mean more amount of fabric mass loss. It may be noted that in case of fancy yarn fabrics, visual assessment is more important as it gives more emphasis on the change of appearance or effect retention than the change in strength or mass loss of the product.Hence, there is a scope that an universal abrasion tester system could be fabricated which can test all types of flexible materials in dry, wet and partially wet or dry conditions condition as well as the same tester can test the abrasion resistance of various types of fabrics in multidirectional planes. Moreover, its visual assessment could also be carried out for the complete abrasion analysis.

6. References

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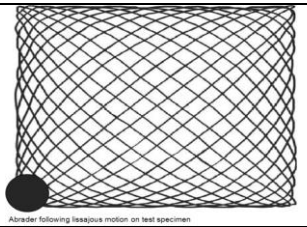
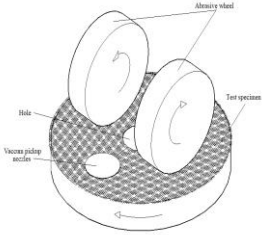
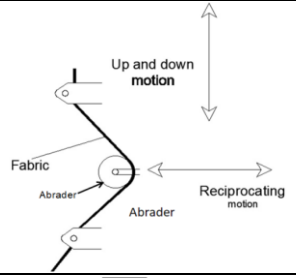
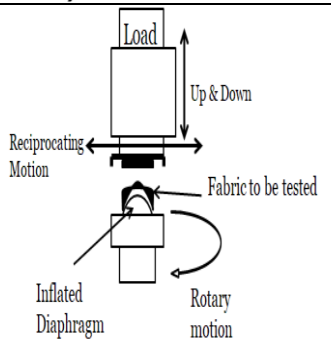
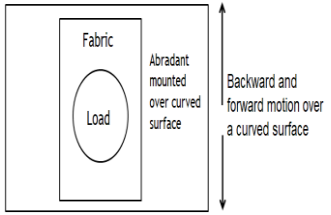
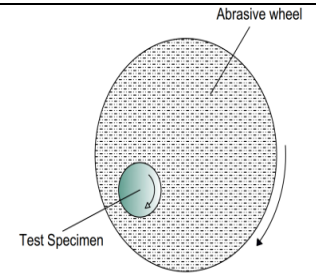
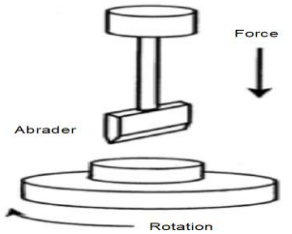
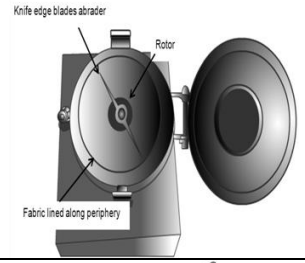
Table 1. Comparative abrasion methods and standards for abrasion evaluation of all types of textile materials

S.No	Test Method	Test Standard	Test Specimen Material	Abrasion Direction (Motion)	Abrader material	State of test	Practical Applications	Evaluation technique	Mechanism Representation
1	Martindale Abrasion Tester	ASTM D4966	Woven, Non-woven & Knitted Fabrics	Multi-Directional (Lissajous)	Plain weave, Crossbred worsted wool fabric	Dry and wet	Resistance to wear, everyday fabrics, air permeability, polyester membrane (laminated textiles), super durable polyamide fabric	Number of cycles to rupture, Change in shade or appearance, Mass loss, Percent loss in breaking strength	
2	Rotary Platform Abrader	ASTM D3389	Coated Fabrics & Pile fabrics	Multi-Directional (Circular)	Rubber, Felt, Tungsten Carbide, Leather, Aluminium Wheel, Sandpaper Strip	Dry	Painted lacquered, powder coated, electroplated surfaces, sheer silks, heavy upholstery and carpeting; and solid materials such as metals, stone and ceramics	Weight loss, Visual inspection	
3	Flexing and Abrasion Method	ASTM D3885	All textile fabrics	Uni-Directional (Reciprocating)	Rubber gasket, Flex block	Dry	Apparel, furnishings and industrial products	Percent loss in breaking strength, Number of cycles to rupture	
4	Inflated Diaphragm Abrasion Tester	ASTM D3886	Woven & Knitted Fabrics	Uni& Multi-Directional (Circular & Reciprocating)	Abrasive paper, Abrasive fabric	Dry	Clothing, footwear, All Hosiery textiles, paper, leather and plastics garment industries	Number of cycles to rupture	

5	Oscillatory Cylinder Method	ASTM D4157	Woven, Nonwoven & Knitted Apparel Fabrics	Uni-Directional (Reciprocating & Oscillating)	Abrasive material of cotton duck	Dry	Automobile decorating material and synthetic leather	Percentage loss in breaking load, Number of cycles to rupture	
6	Uniform Abrasion Method	ASTM D4158	Nonwoven textile materials	Multi-Directional (Circular motion)	Standard abrasives, Emery cloth, Sandpaper, Duck canvas	Dry and wet	Carpets and garments materials	Wear loss, Mass loss, Thickness loss, Percentage loss in breaking strength	
7	Pico Abrader Method	ASTM D2228	Thermoplastic elastomers and elastomeric materials	Uni-Directional (Reciprocating)	Tungsten carbide cutting knives	Dry	Vulcanized (thermo-set) rubbers	Number of cycles to rupture	
8	Accelerat or Method	AATCC-93	Flexible textile materials	Multi-Directional (Rubbing of specimen against itself as well as the liner)	Knife edged Abrader	Dry and wet	Edges of sleeves, collars of shirts and the folds in pants	Weight loss of the specimen , The loss in grab strength of the specimen broken at an abraded edge	
9	Rotating cylindrical drum device	ISO 4649	Rubber, vulcanized or thermoplastic	Multi-Directional (Test specimen is rotated while it is moved laterally across the rotating cylinder)	Drum Abrader	Dry and wet	Tires, Conveyor belts, Automotive belts, Hoses, Footwear, Flooring and Bushings	Volume loss of the specimen