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Study of Cut-Resistant material, their mechanism, characteristics and evolution performance

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ABSTRACT

Garments or textile related products that are worn, that prevents a person from, and/or reduces the risk of exposure to hostile elements or environments or machinery are known as protective clothing. While all clothing is protective to some degree, but protective clothing doesn't concern with routine needs, such as clothing for warmth, rainwear, or routine work clothing. Protective clothing focus is on more sophisticated needs, protection in situations where hazards or risks are present that have the potential to be life threatening or pose considerable potential for injury or damage to the person working in and around the hazard. In some cases, such as clean rooms, we may be equally concerned about protecting the product we are working with as well as the worker. This paper is all about protective clothing and special concern is on cut protection. Cut protection clothing protects user from being cut when they need to challenged with sharp moving objects. In this paper there is all study about cut resistant gloves, cut resistance, mechanism, material, standards for evaluation, and current industry status about cut resistant gloves.

Keywords: Textile, Cut-Resistant, Cut-Protection, blades.

INTRODUCTION

Protective clothing is the special clothing which protects human body from harsh climatic conditions. Though protection is provided via many protective equipments depending upon kind of seriousness and level of protection required but protective clothing is the most essential and primary way of protection of human body. Design, composition and construction of protective clothing is used protection to human body depends upon type and level of risk for eg: protection against extreme cold condition, Environmental Hazard Protective, Biological, Chemical and Radiation (BCR) Hazard Protective, Injury Protective, Medical-functional, Therapeutic and Rehabilitative Clothing, Bio-sensing Clothing etc.

Cut protection is the type of protection which is required to prevent a worker from being cut when challenged with sharp moving object. Basic properties required in cut resistant material such as cut resistance, tear strength, and abrasion resistance as well as properties such as grip and dexterity are all important aspects of cut protection. However, cut protection is also very important for some other important factors which are not related to protective apparel but play an important role such as machine guarding, workplace set-up, working conditions, and worker training [2, 15].

Cut resistance is defined as the ability of a material to resist damage when challenged with a moving sharp edged object [2, 15].

Fig. 1: cutting behaviour of cut resistant material

Cut resistance can be measured by using standard testing equipments, it's often used when comparing the safety of various products. However, more than just the material properties of the glove or garment (i.e. cut resistance) must be considered when evaluating cut protection.

HISTORY

In older times gloves and other protective clothing made by metal wire mash steel, leather, some alloys etc. used as conventional method of protection against cut. But these conventional material of gloves are very heavy to wear and very uncomfortable to wear. Apart from these, conventional methods meet low level of protection.

But now in new methods of protection, number of high performance polymers and materials have been invented and used commercially. High modules, high strength polymers such as p-aramid, PBI and ultra high density polythene have been introduced. These materials are very light in weight, more flexible, pliable, easy to fabricate, and ideal for wearing with very high level of protection than conventional method. Increased cut protection can be achieved with the use of high performance textile and use of composite yarns made with varying combinations of high performance fibers with stainless steel, fiberglass. The level of cut resistance provided by the reinforcing yarns depends on the way in which they are incorporated in the textile substrate. So the technology of textile structure (woven, knitted or nonwoven) is depends upon the level of protection required. Most common structure used in cut protective clothing is knitted structure [2, 15].

Mechanism of cut resistance textile

The cutting process, which is referred to as the moving of fibre material away from the fibre/blade contact point, involves the application of mechanical forces in the direction transverse to the fiber axis. A sliding sharp edge penetrating material is one of the most dangerous cases of cutting because it requires the smallest applied load [12]. Standard test method ISO 13997 and ASTM test method F1790-04 are based on the principle of measuring the distance that a straight blade sliding horizontally travel to cut through a material under a constant applied normal force [16].

The resistance to cutting of a material in the presence of both normal force and sliding movement of a sharp object is strongly controlled by the coefficient of friction [7].

An increase in the friction coefficient can enhance or reduce the cut resistance, depending on the thickness, the Young modulus, and the micro structure of the material [7, 12].

Cutting resistant material is contributed by intrinsic strength of material and frictional forces. There are two types of frictional forces takes place or we can say total energy required to propagate the cut is depends upon the two types of energies:

1- A microscopic friction induced by gripping of material and by applied normal force on two sides of blades. Or a lost energy dissipated by the gripping force exerted by the material on blade sides.
2- Sliding friction associated with cut through the material that occur along the face of blade tip Or essential cutting energy at the tip of blade

These two energies give opposite effect on cutting resistance. Cutting resistance increases when increase in energy dissipated by gripping force exerted by material on blade sides. Cutting resistance decreases when increase in energy at the tip of blade or frictional force increases at blade's edge [12].

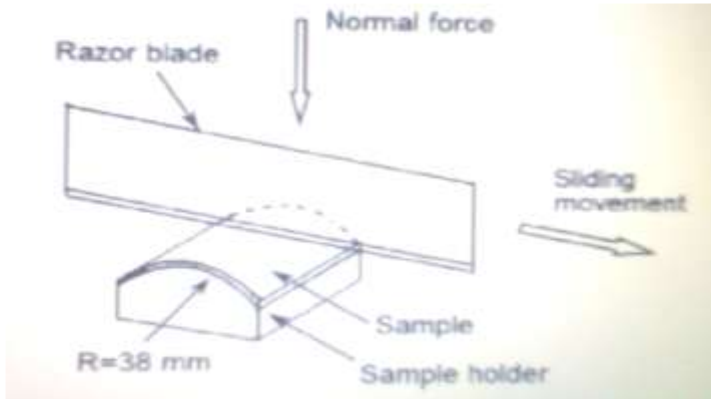


Fig. 2: Principle of international standard ISO 13997 cut test [12]

For most materials, frictional forces due to lateral gripping could be several times greater than the friction due to the applied normal force. Thus, the cutting energy required for breaking molecular chains is much smaller than the energy dissipated for friction. The elastic modulus, the structure of the material as well as the sliding velocity have significant influence on the friction, therefore all these properties can affect the cutting resistance of fiber [15].

Cutting resistance behaviour of textiles: Under applied normal loads, where blade penetrates in the sample, the shear stress at contact angle has to overcome the molecular cohesion & hysteresis friction arising from visco elastic behavior of the material [12,17,18] and the elastic contact exerted by the sample on two sides of the blade.

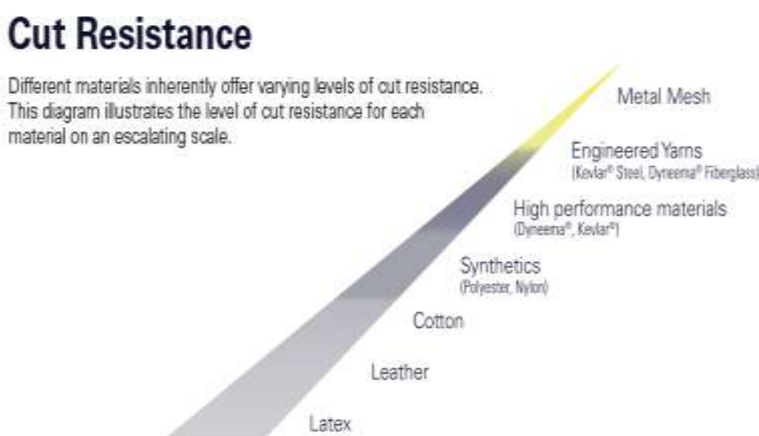


Fig. 3: Cut Resistant Behaviour of Different Fibers

There are two frictional forces are exerted. One is the microscopic friction induced by gripping of material & by applied normal force on two sides of blade. And other is the sliding friction associated with cut through the material that occurs along the blade tip. Pressure due to applied normal force is very high at vicinity of tip [19]. But diameter of tip is very small. So the frictional force is also very small. The lost energy dissipated by friction on sides of blades is higher than energy required for cutting intrinsic material [7]. But on microscopic scale sliding frictional force is related to the contribution of adhesion and hysteresis. The adhesion friction is due to the formation and breakage of adhesive junctions, which are result of molecular interaction on contact surface. The hysteresis friction is the internal is the internal friction of material, which arises from dissipation of energy during cyclic deformation of microscopic protuberance of surfaces and depends on only on the relative mobility of molecules but also on orientation on such movement [12, 20]. When substrate is very smooth and clean the mechanism for friction is solely due to molecular adhesion at the interface [12, 21, 22].

The type of deformation undergone by the textile during the cutting process appears to have a very much plastic lateral compressive deformation with the evidence of actual failure in either transverse tension or shear, and higher work of deformation means higher cut resistance. Hence, the greater is the work required to deform the material. "In the transverse compression, the higher is the energy dissipated which implies better cut resistance of the material. The cut resistance of all the materials depends strongly on slice angle. Cut energy drops sharply when the slice angle deviates from 90 degree, falling about 50-75 percent at 82.5 degree, and decreases further, but more gradually at lower angles. At a 45degree slice angle, cut energies are from 3-10 per cent of 90 degree values. The cut resistance depends strongly on blade sharpness. At a 90 degree slice angle, a blade with a 2 micrometer tip radius requires 47-75 per cent less energy to cut the yarns than a 20 micrometer blade, and at a slice angle of 45 degree only 17-35 percent"[15].

The higher strength of yarns is recommended for improving the cut resistance. And also, with the increase of the weaving density, the numbers of the principal yarns will be increased and will improve the stab resistance. The resistance to cut depends on the material, the cross-section of the strengthening threads and the support points in the base fabric. Most standardized cutting test methods use a blade, circular or straight blade, that slides on the sample materials to be cut through, when a given force is applied. The forces that are present in a cutting process are:

(i) A normal force which is applied at the blade-material point of contact.
(ii) A frictional force, which develops when the blade slides and penetrates the material.
(iii) The resultant cutting force, which is the resultant vector of normal and frictional force. In case of rubber material, the coefficient of friction is much higher than normal force. [12,15]

In case of knitted fabric, normal force is higher than the frictional force. The magnitude of these forces, which differs from material to material are important when selecting the right test method for evaluating the cut resistance of protective materials [15].

Evaluation of performance

The following three methods are in use to determine cut resistance:

i. ASTM F1790-97 (Standard for the US).
ii. ASTM F1790-05 (standard for the US)
iii. ISO 13997 (International Standard).
iv. EN 388 (European Standard) [14, 23].

The ASTM F1790 and the ISO 13997 test methods use the CPP and TDM test method, which consists of a straight blade that is slide along the length of a sample with three different weights. The sample is cut five times and the data is used to determine the required load needed to cut through a sample at a reference distance of 20 mm (0.8ö).

The EN 388 test method uses the Coup-test, which consists of a circular blade with a fixed load that is moved back and forth across the fabric to determine how long it takes to cut through. Again, 5 cuts are used to determine the cut index. Coup-test method: The EN388 standard describes the Coup-test method for cut resistance, which is based on a totally different principle than the CPP/TDM method [13, 14].

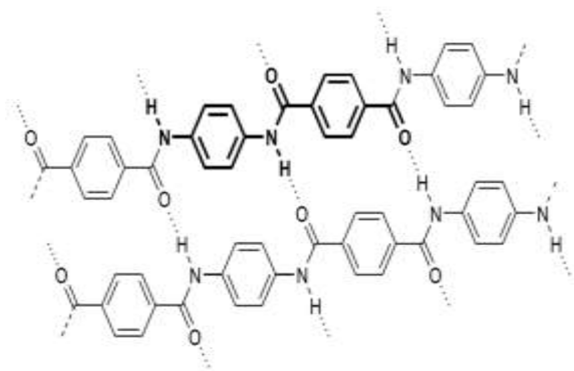
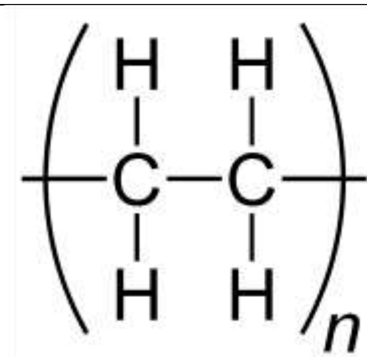
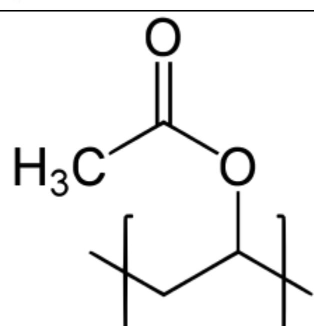
Current industry Standards:

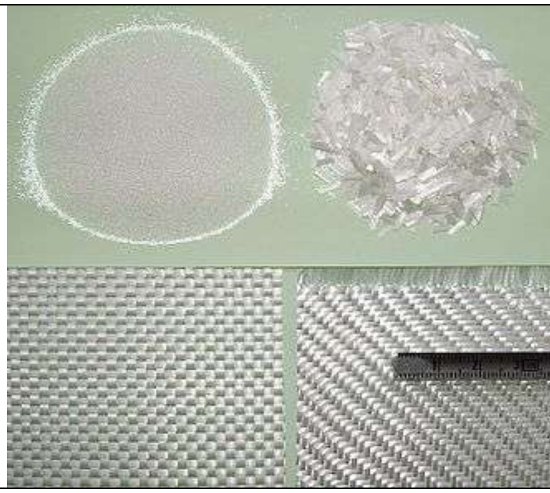
To help guide PPE purchasers, both the American National Standards Institute (ANSI) and the European Union (EU) have developed standards for cut-resistant materials. The U.S. standard is ANSI/ISEA 105 ("American National Standard for Hand Protection"), which rates gloves and other cut protective clothing on a consistent numeric rating scheme for mechanical, thermal, chemical, dexterity, and other performance criteria.

Although the use of the ANSI/ISEA selection criteria is not mandatory in the United States, most safety managers choose to follow it in selecting the right protection for their employees.

The EU standard EN 388 ("Protective Gloves Against Mechanical Risks") rates gloves and other cut protective clothing for puncture, tear, blade cut, and abrasion resistance. Beyond the European Union, this standard is also recognized globally [14, 15, 23].

Table 1: Characteristics of cut resistant fibers

SR. No.	Material	Chemical Structure	Characteristics
1.	**P-aramid–** Kevlar, Twaron		• Good resistance to abrasion • Good resistance to organic solvents • Nonconductive • No melting point, degradation starts from 500 °c • Low flammability • Good fabric integrity at elevated temperatures • Sensitive to acids and salts • Sensitive to ultraviolet radiation • Para-aramid fibers, such as kevlar and twaron, provide outstanding strength-to-weight properties • High young's modulus • High tenacity • Low creep • Low elongation at break (~3.5%) • Difficult to dye – usually solution-dyed[24, 25]
2.	**Dyneema**		• It is a type of polyolefin • High tensile strength • High crystallinity (39%-75%) • High orientation (95%) • High melting point (130-136) • Highly hydrophobic**[24' 27]**
3.	**Poly Vinyl Acetate**		• The degree of polymerization of poly(vinyl acetate) is typically 100 to 5000 • It's ester groups are sensitive to base hydrolysis and will slowly convert PVAc into polyvinyl alcohol and acetic acid. • Under alkaline conditions, boron compounds such as boric acid or borax cause the polymer to cross-link, forming tackifying precipitates or toys such as Slime and Flubber. • It can damage by filamentous fungi however there are also algae, yeasts, lichens and bact eria that have been shown to degrade polyvinyl acetate [24, 28]

4.	**Fiberglass:** Glass reinforced plastic		• Very stiff and strong • Very high temperature(180-200) • It is weak in shear across its axis. • Initial modulas is very high [24, 26]

CONCLUSION

Cut-resistance fabrics are gaining popularity in the field of protective fabrics. Recently developed cut resistance fabric products such as gloves, and aprons have many advantages over the conventional material like metal. One has to select a suitable cut resistance fabric to meet the end use. For low puncture-resistant materials (typical for gloves), it is important to have a high tear resistance to guarantee the longevity of the glove, While selecting the most suitable gloves for an application [15].

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