

Exploration of new age materials used in the manufacturing of bullet proof vests

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by

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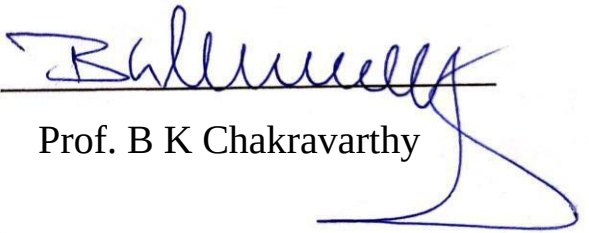
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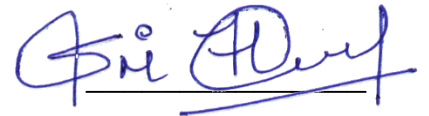
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Exploration of new age materials used in the manufacturing of bullet proof vests

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Abstract-- Numerous materials have been invented to protect a person against impact of projectiles. Amongst the materials, woven fabrics made from synthetic fibers are the most prevalent. This paper is an exploration of various materials used in manufacturing antiballistic protective clothing. The anatomy of bullet proof vests, working mechanism, physical properties, chemical properties, manufacturing process, body armor performance standards involved in these specialized materials are discussed.

Index Terms—Ballistic proof, blunt force trauma, polymer, projectiles, stab resistance.

I. INTRODUCTION

The bulletproof vest also called as ballistic vest or bullet resistant vest, is a personal armor that helps to stop penetration of firearm-fired projectiles into the body and absorb the impact. It is worn on the torso. Soft vests are made of many layers of woven or laminated fibers and can protect the wearer from shotgun projectiles, small-caliber handgun and small fragments from explosives like hand grenades. These vests often have a ballistic plate made of metal or ceramic is inserted into the vest, providing additional protection against rifle rounds, and metallic components or tightly woven fiber layers can give soft armour resistance to stab and slash attacks from knives and similar close-quarter weapons.

II. ANATOMY OF BULLET PROOF VEST

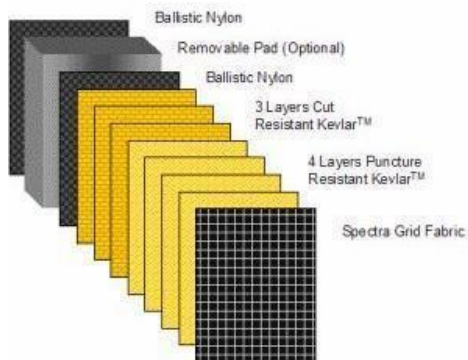


FIGURE 1
Layers in bullet proof jacket

A bulletproof vest consists of a panel that is composed of many layers of either Kevlar or Spectra Shield. The layers of

woven Kevlar are sewn together using Kevlar thread, while the nonwoven Spectra Shield is coated and bonded with resins such as Kraton and then sealed between two sheets of polyethylene film. It is placed inside of a fabric shell that is usually made from a polyester/cotton blend or nylon. The side of the shell facing the body is usually made more comfortable by sewing a sheet of some absorbent material such as Kumax onto it. A bulletproof vest also has nylon padding for extra protection. Bulletproof vests intended for dangerous situations have built-in pouches to hold plates made from metal or ceramic bonded to fiberglass. Various devices are used to strap the vests on like elastic webbing, metallic buckles or Velcro closures.

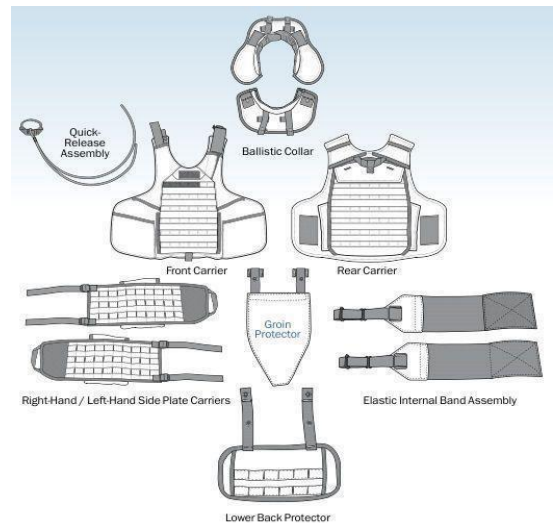


FIGURE 2
Components of a bullet proof vest

III. WORKING MECHANISM OF BULLET PROOF VESTS

Ballistic vests use multiple layers of very strong fibers to stop and deform a bullet, and spreading its force over a larger portion of the vest fiber. The vest absorbs the energy from the deforming bullet, bringing it to a stop before it can completely penetrate the textile matrix. The fibers work together both in the individual layer and other layers in the vest, to prevent the bullet from penetrating. This also helps in dissipating the forces among multiple. Unfortunately, at this time no material exists to construct body armor from a single ply of material.

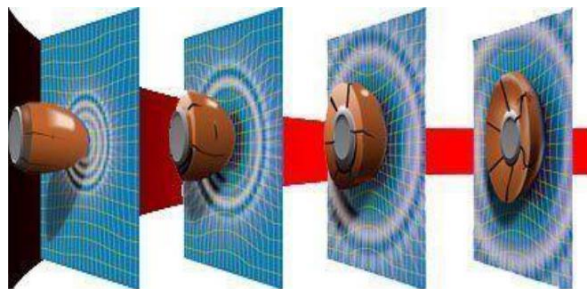


FIGURE 3
Energy absorbed by each successive layer in the ballistic proof panel

IV. MATERIALS USED IN BODY ARMOUR

Several global manufacturers are competing fiercely to develop the most durable and lightest body armor materials possible. In a combat environment a difference in vest weight of 1 kg or less can mean the difference between life and death as soldier could carry an extra ammunition, food or water.

A. Kevlar

DuPont™ has developed Kevlar, first developed in 1965, and was the first material identified for use in the concealable bulletproof vests. Kevlar is a manmade hydrocarbon fiber, with properties like high strength and low weight, along with cut, flame and chemical resistance. The fiber is unaffected by immersion in water. Kevlar XP™, used in soft body armor provides a comfortable vest design with a 10% reduction in overall weight. Kevlar XP™ provides a 15% reduction in back face deformation, reducing trauma to the wearer. DuPont™ Kevlar® XP™ S104 maintains its strong ballistic performance and comfort even in wet conditions ideal in tropical climates. DuPont created Kevlar KM2 Plus provides superior resistance against bullets and fragments, while maintaining a lighter weight for increased comfort and mobility. When woven into a fabric, it helps to contribute to fabric flexibility and has excellent thermal stability at temperature extremes. When Kevlar is spun, the resulting fiber has a tensile strength of about 3,620 MPa and a relative density of 1.44. The polymer owes its high strength to the many inter-chain bonds. These intermolecular hydrogen bonds form between the carbonyl groups and NH centers. Additional strength is derived from aromatic stacking interactions between adjacent strands.

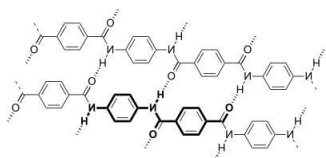


FIGURE 4
Molecular structure of Kevlar

The production of Kevlar starts with the polymer poly-para-phenylene terephthalamide produced in the laboratory through *polymerization*, which involves combining molecules into long chains. The resultant liquid with polymers is then extruded

through a spinneret to form Kevlar yarn. The Kevlar then passes through a cooling chamber to aid the hardening process. After water being sprayed, the synthetic fiber is wound onto rolls. The Kevlar is put onto throwsters, which twist the yarn to make it suitable for weaving. Kevlar cloth is made by simple woven pattern, plain or tabby weave, which is merely the over and under pattern of threads that interlace alternatively.

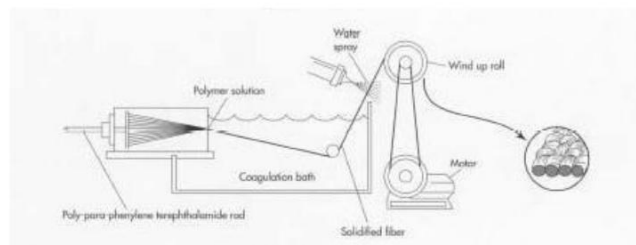


FIGURE 5
Manufacturing process of Kevlar

B. Honeywell's Spectra Shield

Spectra Shield® product line have been protecting military and law enforcement personnel for the past 20 years:

- i. SA-1211 is designed to meet the comfort and flexibility demands of the user, while maintaining strong ballistic performance and reducing the effects of blunt trauma.
- ii. SR-1214 is the standard Spectra Shield® hard armor product used in plate, helmet and vehicle applications.
- iii. SR-3124, a Spectra Shield® II hard armor product, incorporates high-strength Spectra® 3000 fiber into a hard armor shield construction, providing the highest levels of protection for breastplate and helmet applications.
- iv. SA-3118 and SA-3113 are the Spectra Shield® II soft armor products, providing ballistic protection for military and law enforcement vest applications. SA-3118 maximizes ballistic performance, while SA-3113 was designed for added flexibility and comfort, while maintaining high levels of performance in body armor materials.

Spectra used in bulletproof vests is not woven. Rather, the strong polyethylene polymer filaments are spun into fibers that are then laid parallel to each other. Resin is used to coat and seal the fibers to form a sheet of Spectra cloth. Two sheets of this cloth are then crossed to one another and bonded, forming a laminated fabric that is then sandwiched between two sheets of polyethylene film. The vest shape is later cut from the material.

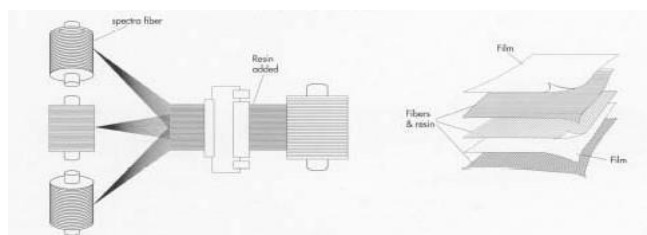


FIGURE 6
Manufacturing process of Spectra

C. Honeywell's Gold Shield® GA-2010

Gold Shield® GA-2010 combines Honeywell's patented Shield technology with aramid fiber. It consists of two plies of unidirectional aramid fiber cross plied at 0°/90°, and sandwiched in a thermoplastic film. Gold Shield is currently made in three types: Gold Shield LCR and Gold Flex, which are used in concealable bulletproof vests and Gold Shield PCR, which is used in the manufacture of hard armor, such as ballistic panels and helmets.

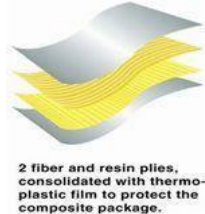


FIGURE 7

Construction of Honeywell's Gold Shield® GA-2010

D. Twaron(Teijin Aramid)

Akzo has produced various forms of its aramid fiber Twaron, for bullet proof vests. This fiber uses more than 1,000 finely spun single filaments to act like an energy sponge by absorbing the bullet's impact and quickly dissipating that energy through adjacent fibers. Since more filaments are used, the impact is dispersed more quickly. This Microfilament technology allows maximum energy absorption at minimum weights, enhancing comfort and flexibility. Akzo Nobel maintains that the use of Twaron in a bulletproof vest significantly reduces the overall weight of the finished product, thus making the bullet proof vests more comfortable.

E. Dyneema

Manufactured in the Netherlands, Dyneema is a polyethylene fiber with an extremely high strength-to-weight ratio (a 1-mm-diameter rope of Dyneema can bear up to a 240-kg load). The fiber is light enough to float on water and has high energy absorption characteristics. Dyneema is a popular body armor materials among premium body armor manufacturers. Dyneema Force Multiplier Technology is the latest innovation from DSM Dyneema resulting in vests that are up to 25% lighter. Dyneema is used in civilian armour, ballistic helmets, ballistic plates and inserts, anti-stab vests, ballistic shields.

V. OTHER ASPECTS RELATED TO BODY ARMOUR

A. Types of body armour

- i. **Ballistic-resistant** body armor protects against bullet penetrations and the blunt trauma associated with bullet impacts. These vests include soft body armor that protects against handgun bullets and less flexible tactical armor composed of soft and hard components that protect against rifle bullets.
- ii. **Stab-resistant** body armor protects against knives and spikes. Manufacturers also make combination armor that protects against both types of threats.

B. Limitations

- i. A vest can prevent bullet penetration, but both the wearer and vest still absorb the bullet's impulse.
- ii. Even without penetration, heavy bullets have enough force to cause Blunt force trauma under the impact point. Blunt force trauma is physical trauma to a body part, either by impact, injury or physical attack.
- iii. Vests designed for bullets offer less protection against blows from sharp implements, such as knives, arrows as the impact force of these objects stays concentrated in a relatively small area, allowing them to puncture the fiber layers of most Bullet-resistant fabrics used in soft armor.
- iv. Stab vests provide better protection against sharp implements, but are generally less effective against bullets. Concealable bullet proof vests only provides protection against common low and medium-energy handgun rounds.
- v. Bullet proof vests designed to defeat rifle fire is of either semi rigid or rigid construction, incorporating hard materials such as ceramics and metals. Because of its weight and bulkiness, it is impractical for routine use.

C. Testing body armour

A Textile armor is tested for two things to meet the ballistic standards i.e. **Penetration resistance** offered by the armor from bullets and the impact **energy** felt by the wearer.

D. Body armour performance standards

Despite there being a multitude of standards, only few standards are used extensively worldwide. One of widely-accepted standards include the U.S. National Institute of Justice stab. Countries will use these standards and incorporate the basics and modify them to fit the bullets of the area for the test. The Ballistic Resistance of Body Armor NIJ Standard-0101.06 and Stab Resistance of Personal Body Armor, NIJ Standard-0115.00 have certain body armor performance standards for law enforcement. This ballistic standard rates vests on a scale against penetration and blunt trauma protection. Along with the NIJ, the standards set forth by the United Kingdom's Home Office Scientific Development Branch are widely used in several countries and HOSDB, the German Police Technische Richtlinie (TR) Ballistische Schutzwesten also has a standard.

VI. CONCLUSION

It's important that the materials intended to protect persons to be lightweight with maximum wearing comfort. However, the antiballistic effectiveness often conflicts with the wearing comfort and needs a balance of both the factors based on the application it is intended for.

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