Ballistic Protection Fabric Ballistic Protection Fabric

Article · July 2018

3 authors, including:

Tanveer Malik
Shri Vaishanav Institute of Technology & Science

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By: Tanveer Malik & Shyam Barhanpurkar,

Department of Textile Technology
Shri Vaishnav Institute of Technology and Science

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By: Tanveer Malik Asst. Professor, Shyam Barhanpurkar, Lecturer
Department of Textile Technology
Shri Vaishnav Institute of Technology and Science

INTRODUCTION

Humans throughout recorded history have used various types of materials as body armour to protect themselves from injury in combat and other dangerous situations. The first protective clothing and shields were made from animal skins. As civilizations became more advanced, wooden shields and then metal shields came into use. Eventually, metal was also used as body armour, what we now refer to as the suit of armour associated with the knights of the Middle Ages. However, with the invention of firearms around 1500, metal body armour became ineffective. Then only real protection available against firearms was stonewalls or natural barriers such as rocks, trees, and ditches.

Fig. A traditional full-body gothic knight armour   Fig. Modern ballistic armour.

It was not until the late 19th century that the first use of soft body armour in the United States was recorded. At that time, the military explored the possibility of using soft body armour manufactured from silk. The project even attracted congressional attention after the assassination of President William McKinley in 1901. While the garments were shown to be effective against low-velocity bullets, those travelling at 400 feet per second or less, they did not offer protection against the new generation of handgun ammunition which travelled at a velocity of 600 feet per second, being introduced at that time. This, along with the prohibitive cost of silk made the concept unacceptable. The U.S. Patent and Trademark Office lists records dating back to 1919 for various designs of bulletproof vests and body armour type garments. One of the first documented instances where law enforcement officers demonstrated such a garment for use was detailed in the April 2, 1931 edition of the Washington, D.C., Evening Star, where a bulletproof vest was demonstrated to members of the Metropolitan Police Department. It was not until the late 1960s that new fibers were discovered that made today's modern generation of cancellable body armour possible. The National Institute of Justice or NIJ initiated a research program to investigate development of lightweight body armour that on-duty police officers could wear full time. The investigation readily identified new materials that could be woven into a lightweight fabric with excellent ballistic resistant properties. Performance standards were set that defined ballistic resistant requirements for police body armour.

BALLISTIC PROTECTIVE MATERIALS

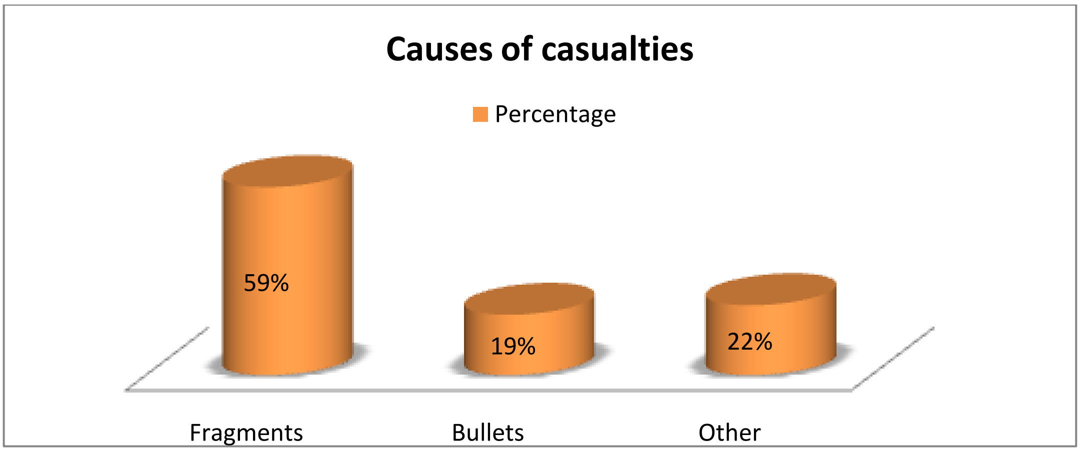
The purpose of the ballistic protective materials is not to just stop the speeding bullets but to protect the individual from fragmenting devices as well, i.e. from grenades, mortars, artillery shells, and improvised explosive devices. We should note that the injury caused to the civilians is mainly due to two factors,

- High velocity bullets from rifles, machine guns that are mainly shot from a long range.
- Low velocity bullets from handguns, which are shot from close range.

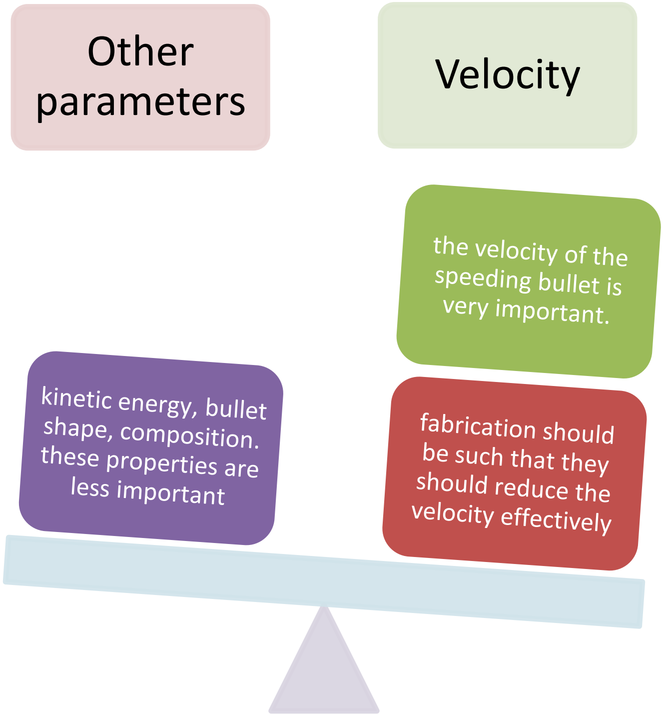
However, when it comes to military personnel, there are three main factors:-

- Fragments
- Bullets
- Others

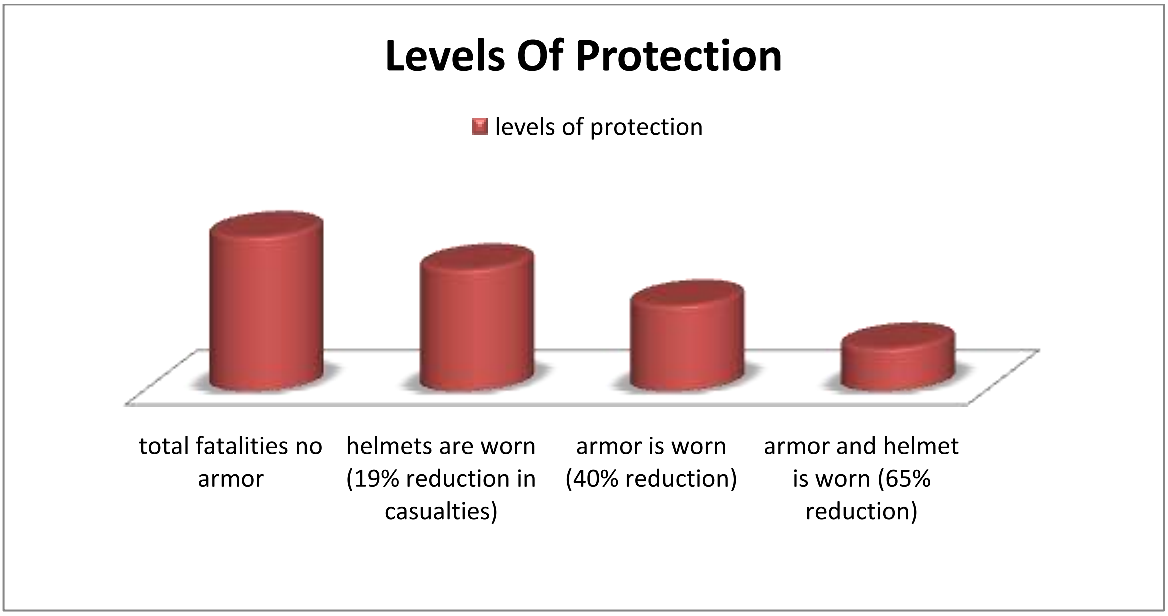
The percentage of casualties caused by the afore-mentioned factors is given below:



The technical people who are working on the protective textiles should understand that the velocities of the bullets possess more weight age than the kinetic energy, bullet shape and the composition of the bullet.



Another point in this is that, the understanding of the raised levels of protection by the use of the armour and helmet today from the day when there was no armour at all.



This experimentation is done on troops standing in open ground threatened by a mortar bomb.

How Does Body Armour Works?

When a handgun bullet strikes body armour, it is caught in a "web" of very strong fibers. These fibers absorb and disperse the impact energy that is transmitted to the vest from the bullet, causing the bullet to deform or "mushroom." Additional energy is absorbed by each successive layer of material in the vest, until the bullet has been stopped.

Because the fibers work together both in the individual layer and with other layers of material in the vest, a large area of the garment becomes involved in preventing the bullet from penetrating. This also helps in dissipating the forces, which can cause no penetrating injuries (what is commonly referred to as "blunt trauma", to internal organs. Unfortunately, at this time no material exists that would allow a vest to be constructed from a single ply of material.

Currently, today's modern generation of concealable body armour can provide protection in a variety of levels designed to defeat most common low- and medium-energy handgun rounds. Body armour designed to defeat rifle fire is of either semi rigid or rigid construction, typically incorporating hard materials such as ceramics and metals. Because of its weight and bulkiness, it is impractical for routine use by uniformed patrol officers and is reserved for use in tactical situations where it is worn externally for short periods when confronted with higher-level threats.

FIBERS USED IN BALLISTIC PROTECTION

Earlier, woven silk fabrics were used for ballistic protection. More recently high modulus aliphatic nylon 6.6 with high degree of crystalline and low elongation was developed and widely used in body armour and as textile reinforcement in composite helmets.

KEVLAR

Developed by DuPont, this is widely used in the modern generation of lightweight body armours. It consists of long molecular chains produced from poly-phenylene terephthalamide. The chains are highly oriented with strong inter chain bonding that results in unique combination of properties, which include high tensile strength at low weight, low elongation at break, high modulus, low electrical conductivity, high chemical resistance, low thermal shrinkage, high toughness, excellent dimensional stability, high cut resistance and flame resistance. It does not melt and is unaffected by moisture. It is five times stronger than steel on an equal weight basis.

TWARON

This is another pararamid fiber. The yarn uses 1000 or more finely spun a single filament that acts as an energy sponge, absorbing a bullet's impact and quickly dissipating its energy through engaged and adjacent fibers. Because more filaments are used, the impact is dispersed more quickly.

SPECTRA

This fiber is an ultra high strength polyethylene fiber. Ultrahigh molecular weight polyethylene is dissolved in a solvent and fibers are produced through gel spinning process. These fibers are 10 times stronger than steel, more durable than polyester and has a specific strength 40% greater than aramid fibers.

DSM DYNEEMA

It has extremely high strength to weight ratio and is light enough to float on water. It has high-energy absorption characteristics and dissipates shock waves faster.

METHODS OF CONSTRUCTION

Typically, concealable body armour is constructed of multiple layers of ballistic fabric or other ballistic resistant materials, assembled into the "ballistic panel." The ballistic panel is then inserted into the "carrier," which is constructed of conventional garment fabrics such as nylon or cotton. The ballistic panel may be permanently sewn into the carrier or may be removable. Although the overall finished product looks relatively simple in construction, the ballistic panel is very complex.

Ballistic fabric is available from a number of manufacturers in various styles and compositions, each type having unique ballistic resistant properties. The body armour manufacturer may construct a given model of ballistic panel from a single fabric style or from two or more styles in combination. The location and number of layers of each style within the multiple-layer ballistic panel influence the overall ballistic performance of the panel. In addition, some manufacturers coat the ballistic fabric with various materials. For example, the manufacturer may add a layer of nonballistic material for the sole purpose of increasing blunt trauma protection. Even composites of two or more different ballistic materials are available. Therefore, it is impossible to compare one product with another based solely on the number of fabric layers in the ballistic panel.

The manner in which the ballistic panels are assembled into a single unit also differs from one manufacturer to another. In some cases, the multiple layers are bias stitched around the entire edge of the panel; in others, the layers are tack stitched together at several locations. Some manufacturers assemble the fabrics with a number of rows of vertical or horizontal stitching; some may even quilt the entire ballistic panel. No evidence exists that stitching impairs the ballistic resistant properties of a panel. Instead, stitching tends to improve the overall performance, especially in cases of blunt trauma, depending upon the type of fabric used.

Body armour intended for routine use is most often designed to be worn beneath the normal uniform shirt. Again, manufacturers tend to design different methods of attaching armour to the body. Hook-and-pile fasteners are common, as are "D" ring tightening straps. With the exception of metal fasteners of any type (which can deflect a bullet on impact and pose a hazard), the method of attachment is a matter of personal preference.

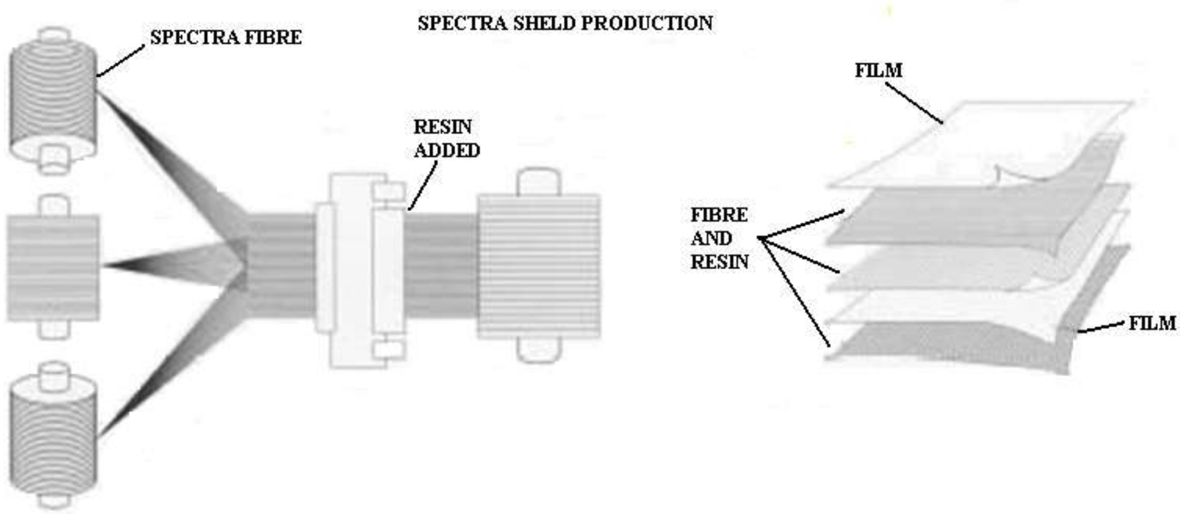
THE MANUFACTURING PROCESS

Some bulletproof vests are custom-made to meet the customer's protection needs or size. Most, however, meet standard protection regulations, have standard clothing industry sizes (such as 38 long, 32 short), and are sold in quantity.

Making the Panel Cloth

- To make Kevlar, the polymer poly-Para-phenylene terephthalamide must first be produced in the laboratory. This is done through a process known as polymerization, which involves combining molecules into long chains. The resultant crystalline liquid with polymers in the shape of rods is then extruded through a spinneret (a small metal plate full of tiny holes that looks like a showerhead) to form Kevlar yarn. The Kevlar fiber then passes through a cooling bath to help it harden. After being sprayed with water, the synthetic fiber is wound onto rolls. The Kevlar manufacturer then typically sends the fiber to thrusters, who twist the yarn to make it suitable for weaving. To make Kevlar cloth, the yarns are woven in the simplest pattern, plain or tabby weave, which is merely the over and under pattern that interlace alternatively.

- Unlike Kevlar, the Spectra used in bulletproof vests are usually not woven. Instead, the strong polyethylene polymer filaments are spun into fibers that are then laid parallel to each other. Resin is used to coat the fibers, sealing them together to form a sheet of Spectra cloth. Two sheets of this cloth are then placed at right angles to one another and again bonded, forming a nonwoven fabric that is next sandwiched between two sheets of polyethylene film. The vest shape can then be cut from the material.



Cutting the Panels

- Kevlar cloth is sent in large rolls to the bulletproof vest manufacturer. The fabric is first unrolled onto a cutting table that must be long enough to allow several panels to be cut out at a time; sometimes it can be as Kevlar has long been the most widely used material in bulletproof vests. To make Kevlar, the polymer solution is first produced. The resulting liquid is then extruded from a spinneret, cooled with water, stretched on rollers, and wound into cloth. A recent competitor to Kevlar is Spectra Shield. Unlike Kevlar, Spectra Shield is not woven but rather spun into fibers that are then laid parallel to each other. The fibers are coated with resin and layered to form the cloth. Long as 32.79 yards (30 meters). As many layers of the material as needed (as few as eight layers, or as many as 25, depending on the level of protection desired) are laid out on the cutting table.

- A cut sheet, similar to pattern pieces used for home sewing, is then placed on the layers of cloth. For maximum use of the material, some manufacturers use computer graphics systems to determine the optimal placement of the cut sheets.

- Using a hand-held machine that performs like a jigsaw except that instead of a cutting wire it has a 5.91-inch (15-centimeter) cutting wheel similar to that on the end of a pizza cutter, a worker cuts around the cut sheets to form panels, which are then placed in precise stacks.

Sewing the Ballistic Panels

- While Spectra Shield generally does not require sewing, as its panels are usually just cut and stacked in layers that go into tight fitting pouches in the vest, a bulletproof vest made from Kevlar can be either quilt-stitched or box-stitched. Quilt-stitching forms small diamonds of cloth separated by stitching, whereas box stitching forms a large single box in the middle of the vest. Quilt stitching is more labor intensive and difficult, and it provides a stiff panel that is hard to shift away from vulnerable areas. Box stitching, on the other hand, is fast and easy and allows the free movement of the vest.

- To sew the layers together, workers place a stencil on top of the layers and rub chalk on the exposed areas of the panel. After the cloth is made, it must be cut into the proper pattern pieces. These pieces are then sewn together with accessories (such as straps) to form the finished vest. Making a dotted line on the cloth. A sewer then stitches the layers together, following the pattern made by the chalk. Next, a size label is sewn onto the panel.

Finishing the Vest

- The shells for the panels are sewn together in the same factory using standard industrial sewing machines and standard sewing practices. The panels are then slipped inside the shells, and the accessories—such as the straps—are sewn on. The finished bulletproof vest is boxed and shipped to the customer.

QUALITY CONTROL

Bulletproof vests undergo many of the same tests a regular piece of clothing does. The fiber manufacturer tests the fiber and yarn tensile strength, and the fabric weavers test the tensile strength of the resultant cloth. Nonwoven Spectra is also tested for tensile strength by the manufacturer. Body armour manufacturers test the panel material (whether Kevlar or Dyneema) for strength, and production quality control requires that trained observers inspect the vests after the panels are sewn and the vests completed.

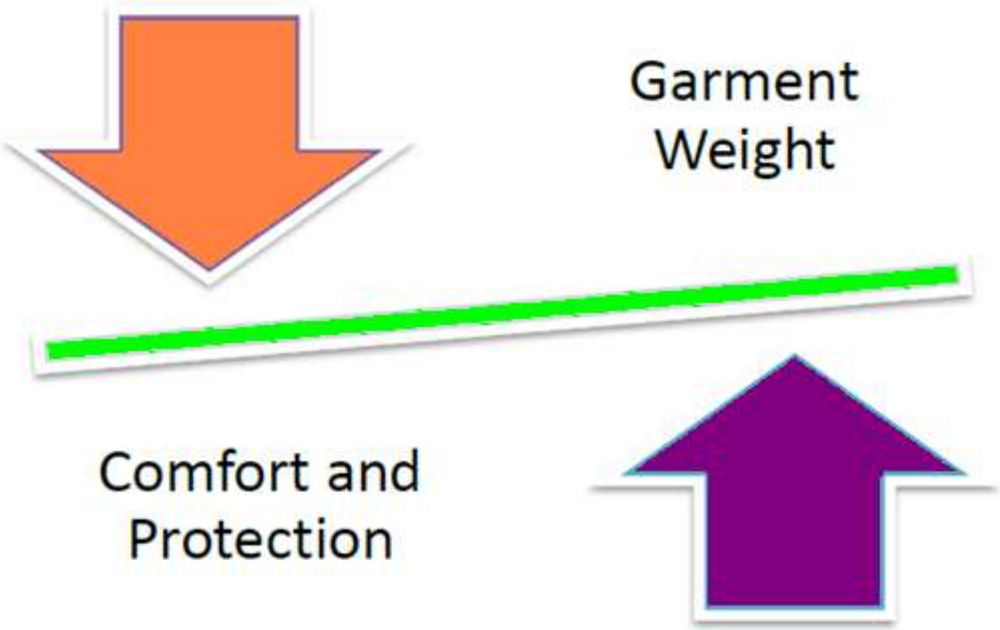
Bulletproof vests, unlike regular clothing, must undergo stringent protection testing as required by the National Institute of Justice (NIJ). Not all bulletproof vests are alike. Some protect against lead bullets at low velocity, and some protect against full metal-jacketed bullets at high velocity. Vests are classified numerically from lowest to highest protection: I, II-A, II, III-A, III, IV, and special cases (those for which the customer specifies the protection needed). Each classification specifies which type of bullet at what velocity will not penetrate the vest. While it seems logical to choose the highest-rated vests (such as III or IV), such vests are heavy, and the needs of a person wearing one might deem a lighter vest more appropriate. For police use, a general rule suggested by experts is to purchase a vest that protects against the type of firearm the officer normally carries.

The size label on a vest is very important. It includes size, model, style, manufacturer's logo, and care instructions as regular clothing does. It should also include the protection rating, lot number, date of issue, an indication of which side should face out, a serial number, a note indicating it meets NIJ approval standards, and—for type I through type III-A vests—a large warning that the vest will not protect the wearer from sharp instruments or rifle fire.

Bulletproof vests are tested both wet and dry. This is done because the fibers used to make a vest perform differently when wet. Testing (wet or dry) a vest entails wrapping it around a modeling clay dummy. A firearm of the correct type with a bullet of the correct type is then shot at a velocity suitable for the classification of the vest. Each shot should be three inches (7.6 centimeters) away from the edge of the vest and almost two inches from (five centimeters) away from previous shots. Six shots are fired, two at a 30-degree angle of incidence, and four at a 0-degree angle of incidence. One shot should fall on a seam. This method of shooting forms a wide triangle of bullet holes. The vest is then turned upside down and shot the same way, this time making a narrow triangle of bullet holes. To pass the test, the vest should show no sign of penetration. That is, the clay dummy should have no holes or pieces of vest or bullet in it. Though the bullet will leave a dent, it should be no deeper than 1.7 inches (4.4 centimeters).

When a vest passes inspections, the model number is certified and the body armor manufacturer can then make exact duplicates of the vest. After the vest has been tested, it is placed in an archive so that in the future vests with the same model number can be easily checked against the prototype.

INCOMPATIBILITIES



The main incompatibility faced by ballistic protection fabric is that the fabric needs to be of low bulk, also be lightweight, and yet provide protection against the various threats in the battlefield. Along with this, the ballistic protection textiles are impermeable to air. This makes it very uncomfortable for the wearer. This is one region where research is going on for the reduction of weight and make the fabric more permeable to air.

FUTURE DEVELOPMENTS

- The Defence Department of Canada posted a contract tender Monday asking companies for proposals for high-tech body suits that could help Canadian soldiers carry bigger loads into battle.

- The Pentagon agency eventually awarded a contract to Sarcos, a Salt Lake City, Utah, and company now owned by Raytheon, which produced a test version this year. Known as the XOS Exoskeleton, it uses a single engine and hydraulics to assist movement. Included in the Pentagon's Future Warrior Concept are a powerful exoskeleton, a self-camouflaging outer layer that adapts to changing environments and a helmet, which translates a soldier's voice into any foreign language. The future soldier will also benefit from 'intelligent' armour, which remains light and flexible until it senses an approaching bullet, then tenses to become bulletproof.

- Bulletproof brassieres designed to be comfortable and injury-proof have been issued to 3,000 policewomen in Germany for their protection. The brassieres are made of cotton or polyester and are padded. Unlike bulletproof vests, they have no metal or plastic under-wire or fasteners that can pierce skin and injure the wearer when a bullet hit the body armour.

- Super carbon nanotube vest, which bounces back the incoming projectiles, have been developed in the University of Sydney.

Fig.Bullet-proof brassieres

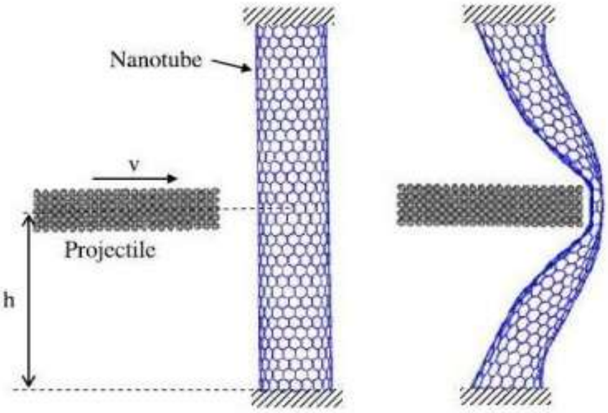
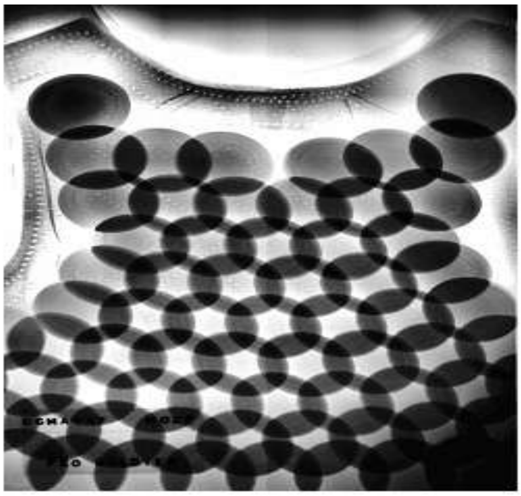


Fig. Nano tube Vest

- Dragon Skin is a type of ballistic vest made by Pinnacle Armor. It is currently produced in Fresno, California. It is characteristic two-inch-wide circular discs overlap like scale armor, creating a flexible vest that allows a good range of motion and can allegedly absorb a high number of hits compared with other military body armor. The discs are composed of silicon carbide ceramic matrices and laminates, much like the larger ceramic plates in other types of bullet resistant vests.



The dragon skin armour

- The armor is available in three basic protection levels: SOV-2000, which has previously had certification to Level III protection; SOV-3000, which is rated as Level IV by the manufacturer, but has not officially certified as such; and a rating-unspecified "Level V" variant not available to the general public.

- SOV-2000 armour is made of an imbricate overlapping configuration of high tensile steel discs encased in an aramid textile cover. Different layout configurations with variations in coverage are available.

CONCLUSION

The main military nations have research programs geared towards future combat and protective clothing as integrated systems. The programs tend to be led by military threats or capability gaps doctrine, rather than exploitation of new technologies for the sake of it. The systems approach involves all the major stakeholders, including, strategic planners, users, equipment capability managers, operational analyzers, R&D scientists, producers, contracts staff etc. The important parameters to be kept in mind are:-

- Improve protection against natural and battlefield threats.
- Maintain thermo-physiological comfort or survival in extreme conditions.
- Improve compatibility between and within different clothing components.
- Reduce weight and bulk of materials.
- Integrate functionality so that fewer layers provide multi layer protection.
- Reduce life cycle costs by making systems more effective, durable, and recyclable and by buying few components in the system.

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