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Spectra Fibre Reinforced Composite - A Review

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Abstract: ***In any country they would be in a need to protect them from other countries attacks and wars due to various reasons. Due to this kind of threat, all the developed and developing countries are participating in the weapon race to safeguard themselves. Beyond the common man civil life, the engineering and technological advancements are clearly visible in defence sector. Especially in the developments of warhead battlefield equipments, forecasting and prevention systems, rescue and transportation system and self defence armours are flying in high level. For a country's defence sector always it has been a challenge to make perfect protective armour. Protective armours applied for various purposes like army battle tank, defence helicopters body armour and body vest. To design and manufacture the protective body armours with synthetic fibre reinforced composites, a better understanding of the molecular mechanism of ballistic impact is required. Good armour has a ability to absorb the high level of kinetic energy of the bullet fired, should be light in weight and cost effective. This research paper highlights the various fibres that have been used as reinforcement in body armours in past, present and shows a research gap for the future. The improved properties of spectra fibre as reinforcement over kelvar fibre in bullet proof vest are detailed. The results of the future fibre were revealed and it is spot out for our county's defence research development.***

Keywords: Armour, synthetic fibre, Kevlar fibre, Spectra fibre, Ballistic

1. Introduction

A composite material is made by combining two or more different materials. They are combined in such a way that the resulting composite would possess superior properties, which are not obtainable with a single constituent material. The components do not dissolve or completely merge. They maintain an interface between each other and give a improved, specific or synergistic characteristics not obtainable by any of the original components acting singly. The phase that receives the insert in the phase composition is the continuous phase and is called matrix. The purpose of adding the insert is generally to improve the mechanical properties of the matrix or to make it cost-effective. If the insert is added to improve the mechanical properties, it is called reinforcement but if added to make it cost-effective or to change a property other than mechanical properties, it is called a filler.

2. Composite Material Classification

Composite materials may be broadly classified into natural and synthetic composite materials. Figure 1 schematically shows the classification of composite materials. Synthetic composite materials are generally prepared by taking the ingredients constituents separately and physically combining them by different techniques and random or oriented arrangement of fibres. Two ingredients may be composed together as (i) layered composition in which layers of ingredient materials are bonded to one another, and (ii) phase composition in which one ingredient is inserted into the other ingredient. The phase that receives the insert in the phase composition is the continuous phase and is called matrix.

A. Based on type of matrics

Based on matrics the composites can be classified as metal matrix, ceramic matrics and polymer matrics composites.

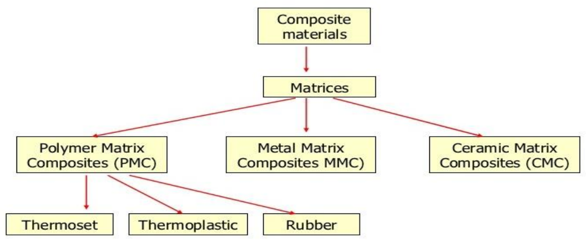

Figure 1: Classification of composites based on matrics

B. Based on type of reinforcement

It is the reinforcement material that gives strength, stiffness and other mechanical properties to the composite material. Composite materials can be classified as follows based on reinforcements:

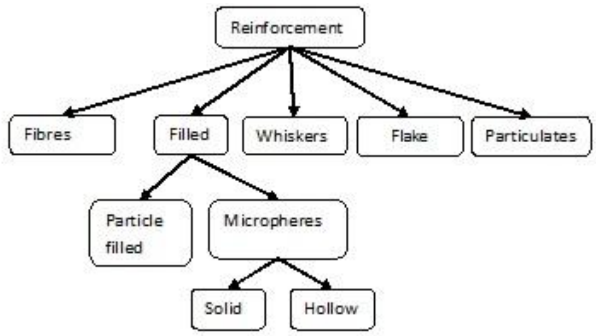

Figure 2: Classification Of Composites Based On Reinforcement

3. History of Body Armours

Over the centuries, different cultures developed body armor for use during war. Mycenaeans of the sixteenth century B.C. and Persians and Greeks around the fifth century B.C. used up to fourteen layers of linen, while Micronesian residents of the Gilbert and Ellice Islands used woven coconut palm fiber until the nineteenth century. In other place, armors were made from the hides of animals: the Chinese-as early as the eleventh century B.C. -wore rhinoceros skin in four to six layers.

Brigandine armor consisted of small rectangular iron or steel plates riveted onto leather strips that overlapped like roof tiles. The result was a comparatively light, supple jacket. Many believe brigandine bulletproof vest as the forerunner of today's body armors. The Chinese and Koreans had similar armor around A.D. 700, and during the period of fourteenth century in western countries, it was the widespread form of body armor.

With the beginning of firearms, armor crafts workers at initially tried to compensate by reinforcing the cuirass with thick steel plates and a second heavy plate over the breastplate, providing some protection from weaponry. Usually, though, weighty armor was discarded wherever firearms came into military use. Investigational study into efficient armor against gunfire continued, most notably during the American Civil War, World War I, and World War II, but after the plastic revolution of 1940’s only the effective bullet proof jackets was available to military personnel, and others. The vests of those days were made up of ballistic nylon and supplemented by plates of glass fibre, steel, ceramic, titanium, Doron, and glass fibre reinforced ceramic composites, the last being the most effective.

4. Major Fibres In Use For Body Armor

Currently, there is no perfect thing called as a bulletproof vest. We have vests which can only resist bullet and reduce the effect, in other words we can call it as “Bullet Resistant” simply because there is always some type of weapon that can penetrate even the latest advancements in shielding technology. For last few decades, the synthetic fiber Kevlar has been the major material for making bullet-resistant vests. But researchers are constantly looking for new ideas and new materials to make a real bulletproof vest.

A. Glass fibre

These days, glass fiber reinforced composites, are important in structural and non-structural aircraft applications used in the military. Specific applications include aircraft flooring, interior panels, wing-to-body farings, helicopter blades, radomes and cargo liners. Braided sleeving and tubing is used extensively for electrical and heat insulation in military aircraft. Glass fiber composite armor systems find its applications in military vehicles and weapon systems in both land- and naval-based operations.

B. Kevlar fibre

Kevlar fibre is a high strength, high performance material which is still not understood even though its many years of application in bullet proof garments. In kevlar the molecules form into sheets that then pile themselves around the center of a fiber similar to spokes. The inspiration behind using this as a bullet proof material was to pile several layers of the material collectively in a weave pattern. The weaving would then grab the bullet by allowing the fibers to shatter apart layer by layer and take up the kinetic energy of the bullet. Though, this was mostly effective when bullets were slower and had less total velocity, making them easier to bring it to idle position. Now, our troops and law enforcement officials face much more technically superior weaponry with bullets flying at greater speeds and constructed from harder metals. This means that vests made up of kevlar are stretched to its fullest capacity and sometimes even penetrated completely by these powerful weapons. The only answer with this material is to thicken the layers of weave, which make the material even bulkier, heavier, and less flexible.

C. Spider silk fibre

It is one of the strongest, most flexible materials in nature, and has also been called the next big thing in bullet proofing. It's not quite as strong as Kevlar, but it's 10 times more elastic, meaning it can bounce back and absorb the energy of a bullet much better. Though, getting spider silk on a bulk scale is not easy. So inventors are mixing spider DNA with goats, which then secrete the web protein in their milk. After milking, the protein is extracted and then processed to generate a fiber known as BioSteel. If you made a vest using both BioSteel and Kevlar, you could have one very tough, and very flexible bulletproof solution.

D. Spectra fibre

Spectra are a completely different technology. The material is about 40% lighter than Kevlar, making it more comfortable from the start. On top of that, it is not a woven structure, meaning that several layers are not necessary, further reducing weight and bulk. At the same time, Spectra is ten times stronger than steel. The performance of Spectra seems to be unaffected by chemicals and moisture.Spectra fiber is made from ultra high molecular weight polyethylene (UHMWPE), a outstandingly durable and rugged material. It has got following unique properties:

- Pound for pound, ten times stronger than steel.
- More durable than polyester.
- Up to forty percent greater specific strength than aramid fiber.
- Higher melting temperature than standard polyethylene (150ºC/300ºF).

Due to its unique viscoelastic properties, the strength and stiffness of Spectra fibre is strain-rate dependent. This enables Spectra fibre, as well as Spectra fibre based composites, to achieve remarkably well against high velocity impact such as rifle rounds and shockwaves. The advanced fibre reacts to impact by rapidly moving the kinetic energy away from the impact area, shielding those placed in harm's way.

This battle-tested fiber is proven to provide high levels of performance for vibration damping, flex fatigue, and internal fiber friction characteristics at a reduced weight. Spectra fiber also has been proven to have extraordinary durability as it exhibits superior resistance to chemicals, water, and ultraviolet light.

In body vest made of spectra fibre, parallel strands of fiber are bonded in place with an advanced resin system. This unidirectional tape is then covered with other identically constructed tapes at right angles (0ϕ/90ϕ) and fused into a synthesized structure in presence of heat and pressure. The resulting material, Spectra Shield composite, demonstrates excellent multi-hit performance in ballistic tests with considerably reduced back face deformation. By keeping the fibers in a straight and parallel arrangement, the energy of the bullet swiftly dissipates along the length of the fiber. While Spectra is a comparatively new material and most ballistic body armor till now, As time goes on, the classic use of Kevlar will most likely be replaced by the lighter weight Spectra material that is also stronger, especially as the technology improves and allows for the creation of full body armor. The important thing is that both materials are used properly as necessary so that the safety of troops and police forces are not compromised, and if that means sticking with proven materials, then that should be the solution.

E. M5 Fibre

M5 fiber is a high performance fiber at first developed by Akzo Nobel (Brew et al, 1999; van der Jagt and Beukers, 1999; Sikkema, 1999; Lammers et al, 1998; Klop and Lammers, 1998; and Hageman et al, 1999) and at present manufactured by Magellan Systems International (Magellan). Unlike other high strength fibers; the M15 fiber features distinctive covalent bonding in the main chain direction, however it also features a hydrogen bonded system in the lateral dimensions [Klop and Lammers, 1998]. M5 fibers have an average modulus of 310 GPa, (i.e. significantly higher than 95% of the carbon fibers), and average tenacities currently higher than aramids (such as Kevlar or Twaron) and on a same level with PBO fibers (such as Zylon), at up to 5.8 GPa.

A fiber for this application should possess a high tensile and compressive modulus, compressive strength and high tensile, low specific weight, high damage tolerance, good adhesion to matrix materials and a superior temperature resistance. Till the discovery of M5, no single fiber has existed with all of these superior properties in one molecular structure. These armor systems were estimated to have slightly inferior property to that of aramid armor systems. However, M5 armors based on these fibers have been shown to offer performance almost the best composite materials ever manufactured for fragmentation protection. The fragmentation protective armor systems based on M5 will decrease the areal density of the ballistic component of these systems roughly by 40-60% over Kevlar KM2 fabric at the same level of protection (Philip M. Cunniff et al,).

5. Comparison of Properties of Major Fibres

The various properties of major fibres used for body amour are consolidated. The table 1 shows the values of various properties for two major fibres i.e., kelvar fibre and spectra fibre.

Table I

Properties	Kevlar Fibre	Spectra Fibre
Density(g/cm^3)	0.97	1.44
Tensile strength(GPa)	3.25	2.9
Tensile modulus(GPa)	116	135
Elongation at break (%)	2.9	2.8
Specific modulus(GPa/g/cm^3)	120	94
Max use temp(^{0}C)	100	250
Water absorbtion(%)	0.01	3.7

The graph showing comparison between two fibres parameters wise are shown:

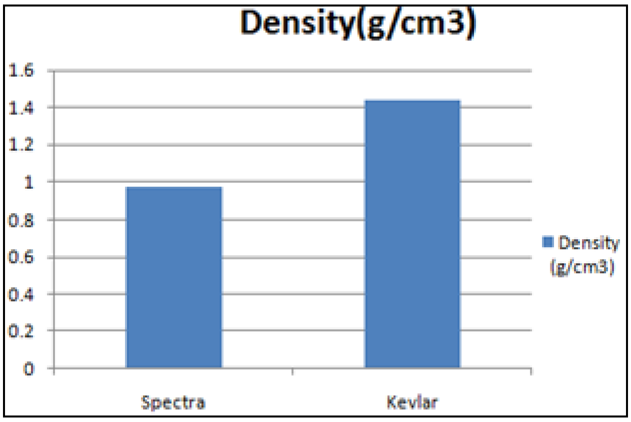

Figure 3: Comparition of densities of Kevlar and Spectra Fibre

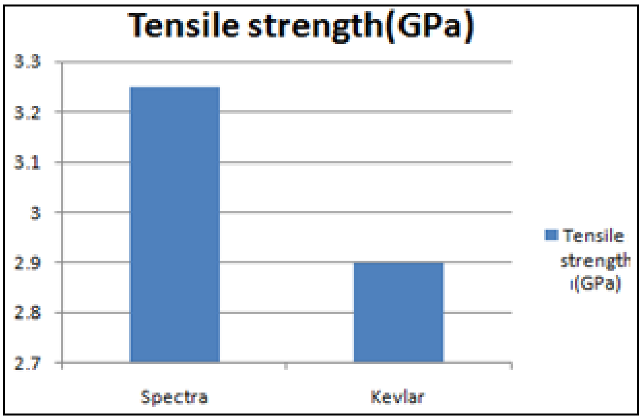

Figure 4: Comparition of Tensile strength of Kevlar and Spectra Fibre

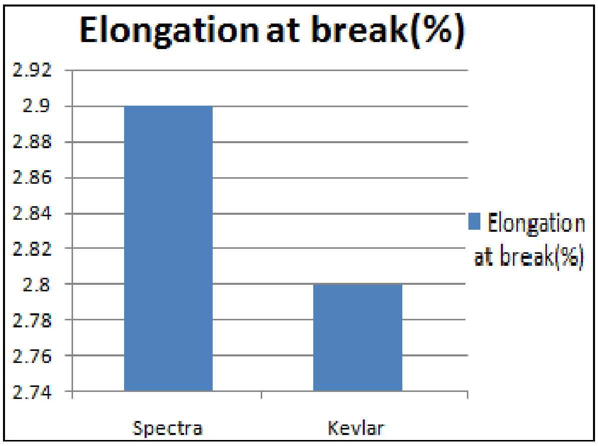

Figure 5: Comparition of percentage elongation at break of Kevlar and Spectra Fibre

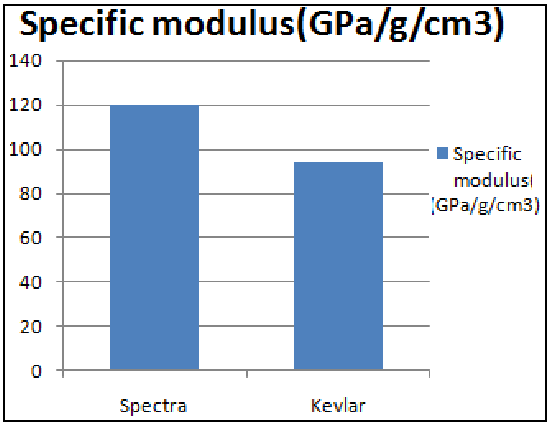

Figure 6: Comparition of Specific modulus of Kevlar and Spectra Fibre

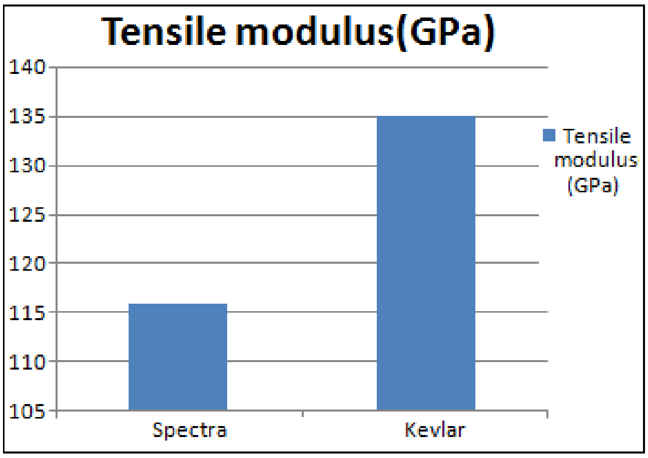

Figure 7: Comparition of Tensile modulus of Kevlar and Spectra Fibre

6. Conclusion

1) It could be seen that synthetic fibre reinforced composite materials have good impact resistance at low density. Thus theses fibres have attracted many researchers across the globe.
2) It can be seen that Kevlar and spectra fibre are dominating the world of body armours due to its low density, good energy absorption property and high tensile modulus.
3) It can be observed that spectra fibre is an emerging fibre in the field of body amour and have better properties then Kevlar as it has almost negligible moisture absorption and also chemically inherent.

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