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Development of Nylon, Glass/Wool blended Fabric for Protective Application

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Abstract: *Bullet proof vest is one of the protective application which helps for protection of ballistic impact to the fabric who wears the vest. In previous days hard rigid materials are used to protect the ballistic impact to the wearer, which resist the penetration and dissipated the impact. Then synthetic textile fibres are used for ballistic resistance and in recent days, the high performance textile fibres are used to resist the ballistic impact. Now a day, Kevlar fibre is used to produce bullet proof vest which has some disadvantages of less is compression property. Nylon filament yarn and Carbon nanotube can an alternative for existing Kevlar bullet proof vest. So combining of nylon filament yarn and carbon nanotube can be effectively fulfilling the requirements of ballistic impact and safe the life of wearer. Nylon filament yarn of 858 denier and 1330 denier was taken for the work. The multi layer woven fabric was produced by using nylon filament yarn of two various deniers. The fabric weave structure is plain weave. Double cloth and triple cloth was produced for protection of ballistic impact, because each fabric layer reduces the energy of projectile. The developed multi layer fabrics can be coated with multiwalled carbon nanotube by using textile coating method. The technical test and field test can be carried to existing bullet proof vest, un coated nylon bullet proof vest and coated bullet proof vest. The developed triple cloth will shows more ballistic resist than double cloth.*
The developed plaited Glass/Wool bended fabrc can used for thermal proof application because of high Limiting oxygen Index. Nylon with Carbon nanotube coated fabric can also be used for thermal proof application.
Keywords*: Ballistic impact, Tearing strength, Cover factor , multi layer fabric, thermal conductivity*

I. Introduction to bullet proof vest:

Ballistic vests use layers of very strong fiber to "catch" and deform a bullet, mushrooming it into a dish shape, 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. Some layers may be penetrated but as the bullet deforms, the energy is absorbed by a larger and larger fiber area.

While a vest can prevent bullet penetration, the vest and wearer still absorb the bullet's energy. Even without penetration, modern pistol bullets contain enough energy to cause trauma under the impact point. Vest specifications will typically include both penetration resistance requirements and limits on the amount of impact energy that is delivered to the body.

Vests designed for bullets offer little protection against blows from sharp implements, such as knives, arrows or ice picks, or from bullets manufactured of non-deformable materials, e.g., those containing a steel core instead of lead. This is because 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.

Textile vests may be augmented with metal (steel or titanium), ceramic or polyethylene plates that provide extra protection to vital areas. These hard armor plates have proven effective against all handgun bullets and a range of rifles. These upgraded ballistic vests have become standard in military use, as soft body armor vests are ineffective against military rifle rounds. Corrections officers and other law enforcement officers often wear vests which are designed specifically against bladed weapons and sharp objects. These vests may incorporate coated and laminated para-aramid textiles or metallic components

Technical requirements for bullet proof vest

The bulletproof vest must give maximum protection, comfort and mobility; it must have the following technical specifications. NIJ Testing and Compliance – Bulletproof Vest must pass the NIJ Testing and Compliance. Check the labels of the vest in order to see if it has NIJ certification that proves that it has passed the minimum requirements of safety and protection set by the NIJ. NIJ certification attests the manufacturer's claim on the durability and performance of the Kevlar Bulletproof vest and also evaluates the safety and reliability as well as the compliance to the minimum requirements of the National Institute of Justice. The Kevlar Bulletproof Vest must be able to pass the NIJ standard 0101.06.

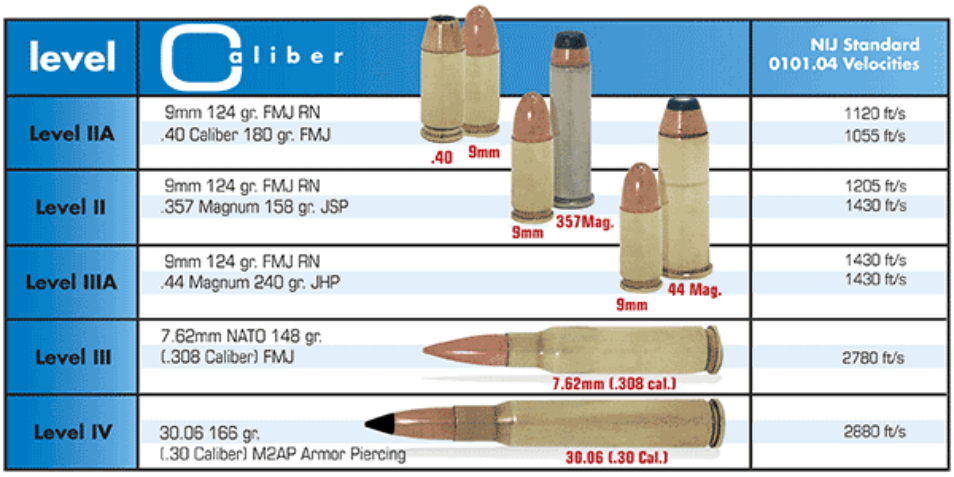
Weight – Your Kevlar Bulletproof vest must be lightweight. It must also pass the average weight standard which is four pounds. The Kevlar Bulletproof Vest must have a minimum 4 pounds weight in order to give good protection.

Thickness – The thickness of your Kevlar Bulletproof vest shall be based on the level of protection you need. Thickness varies with each protection rating. As the protection rating increases, the thicker the bulletproof vest becomes because of the additional layer added that gives more protection.

Table 1.1 Technical specifications of gun used by cop:

Weapon	Projectile type	Diameter (mm)	Weight (gm)	Average velocity (m/s)	Front shape	Kinetic energy (gm2sec-2)
Sub machine gun	Bullet	9	8	350-400	rounded	490000-640000
Magnum pistol	Bullet	9	9.4	425	Rounded-sectioned	849000
M16 rifle	Bullet	5.56	3.52	900	pointed	1425600

Table 1.2 Dimension of pistol and its standard velocity:



Ballistic resist mechanism of Carbon nanotube in a bullet proof vest

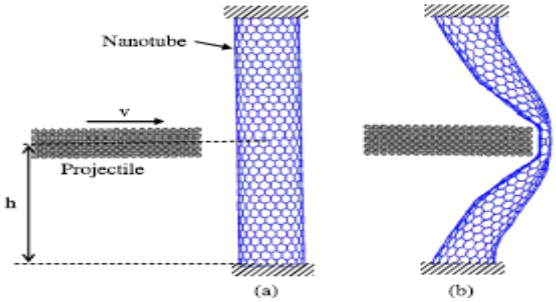


Fig 1.1 ballistic resist of Carbon nanotube in a vest

Energy absorption capacity of carbon nanotubes under ballistic impact: The energy absorption efficiency reaches the minimum when the bullet strikes around a height of 0.5.

Ballistic resistance capacity of carbon nanotubes: ballistic impact and bouncing back process on carbon nanotubes.

(1) nanotubes with large radii endure higher bullet speeds,

(2) the ballistic resistance is the highest when the bullet hits the center of the carbon nanotube,

(3) the ballistic resistance of nanotubes will remain the same even when bullets strike at the same spot as long as there is a small interval between bullet strikes.

Draw backs of Kevlar bullet proof vest

Despite its strength and resilience, Kevlar also has some disadvantages which limit its efficiency. Kevlar fibers quickly absorb moisture, meaning it is more sensitive to its environment than other materials.

Although Kevlar is strong and tensile, its ability to cope with compression is fairly poor and it can be difficult to cut. Specially made scissors are usually required to sever dry fabric and cured laminates can only be pierced by specially made drill bits.

Multi-walled Carbon Nanotube

Multi-walled nanotubes (MWNT) consist of multiple rolled layers (concentric tubes) of graphene. The interlayer distance in multi-walled nanotubes is close to the distance between graphene layers in graphite, approximately 3.4 Å. The Russian Doll structure is observed more commonly. Its individual shells can be described as SWNTs, which can be metallic or semiconducting. Because of statistical probability and restrictions on the relative diameters of the individual tubes, one of the shells, and thus the whole MWNT, is usually a zero-gap metal.

Table 1.3 Comparison of Mechanical properties of Carbon nanotube, Nylon and Kevlar

Material	Young's modulus(TPa)	Tensile strength (GPa)	Elongation at break(%)
Armchair SWNT	0.94	126.2	23.1
Zigzag SWNT	0.94	94.5	17.5
MWNT	0.95	150	---
Kevlar	0.18	3.8	2
Nylon 6	0.004	0.079	35

In this research work, an attempt is made to develop a double cloth and triple cloth of Nylon6 filament yarn, to analyze the technical and ballistic characteristics of nylon6 filament yarn, to overcome the existing ballistic vest drawback and to produce the ballistic vest at low cost.

Table 1.4 Thermal properties of textile materials:

Yarn	Specific heat (Jg-1K-1)	Tg (°c)	Tm(°c)	LOI (%)	Thermal conductivity (Kw/(mk)
Nylon 6	1.43	50	215	21.5	0.25
Glass	0.8	----	---	>100	1.05
Wool	1.36	---	-----	25	0.07

II. Materials and methods

2.1 Materials

In this research work, the following materials were utilized.

2.1.1 Nylon filament yarn

100% Nylon6 filament yarn was used in this work and its linear density were 858 Denier and 1330 denier.

2.1.2 Woven Fabric

The double and triple cloth was woven in a power loom with a weave structure of plain weave.
Plain weave structure fabric is preferred for ballistic application.
Ends per inch of 23,30,34,37 ,38 &50 was Picks per inch of 18,22,23,30,32 &48 is the fabric interlacement

2.1.3 Multi Walled Carbon nanotube

The specifications are:
Diameter: 30nm
Length: 8μm
Bulk density: 0.17g/cm^3

2.1.4 Knitted fabric

Fabric	Wales / inch	Courses / inch	Loop length (inches)	Tightness factor	Spirality (°)	Fabric weight (GSM)
Nylon 6(858 D)	Sample 2 = 17 Sample 4=17	Sample 2=19 Sample 4=19	Sample2= 0.128 Sample 4=0.127	Sample 2=36.89 Sample 4=37.78	Sample 2=2 Sample 4=2	Sample 2=234.51 Sample 4=239.69
Nylon 6 (1330D)	Sample 1=17 Sample 3=17	Sample 1=19 Sample 3=19	Sample 1=0.13 Sample 3=0.13	Sample 1=29.81 Sample 3=29.72	Sample 1=2 Sample 3=2	Sample1=160.34 Sample 1=159.30

2.2 Method of coating the fabric:

Dip method.

Three roll squeeze nip coating is suggested to coat the MWCNT with nylon fabrics.
E-Resin was choosing as cross linking agent.

III. Results and Discussion

Table 3.1 Effect of Cloth cover factor on ballistic performance

Yarn Linear Density (Denier)-Fabric Code	**Fabric Details EPI & PPI**	**Cloth cover factor**
858 –DC	EPI=34 PPI=32	21
858-TC	EPI=50 PPI=48	26
1330-DC1	EPI=38 PPI=22	23
1330-DC2	EPI=30 PPI=28	22
1330-TC1	EPI=23 PPI=18	17
1330-TC2	EPI=37 PPI=48	27

In 1330 Denier nylon woven cloths, triple cloth is more than double cloth. So tearing resistance will be more for triple cloth.

In 858 Denier nylon woven cloths, triple cloth has more cover factor than 858 Denier nylon woven double cloths.

Table 3.2 Effect of fabric weight in GSM on cover factor

Yarn Linear Density (Denier)-Fabric Code	**Fabric Details EPI & PPI**	**Fabric GSM**
858 –DC	EPI=34 PPI=32	243
858-TC	EPI=50 PPI=48	418
1330-DC1	EPI=38 PPI=22	384
1330-DC2	EPI=30 PPI=28	371
1330-TC1	EPI=23 PPI=18	262
1330-TC2	EPI=37 PPI=48	544

The cloth cover factor is more in triple cloth with more picks per inch.
More Grams per square meter fabric will have more cloth cover factor.

Table 3.3 Effect of fabric thickness on number of layers in the cloth:

Yarn Linear Density (Denier)-Fabric Code	**Fabric Details EPI & PPI**	**Fabric thickness (mm)**
858 –DC	EPI=34 PPI=32	0.46
858-TC	EPI=50 PPI=48	0.67
1330-DC1	EPI=38 PPI=22	0.82
1330-DC2	EPI=30 PPI=28	0.56
1330-TC1	EPI=23 PPI=18	1.19
1330-TC2	EPI=37 PPI=48	0.92

The number of layer is more; the thickness of fabric is more.
1330 Denier nylon triple cloth fabric will have more thickness than 1330 Denier double cloth and 858 Denier Nylon double and triple cloth.

Table 3.4 Effect of fabric tearing strength on number of layers:

Yarn Linear Density (Denier)-Fabric Code	**Fabric Details EPI & PPI**	**Fabric Tearing strength (CN)**
858 –DC	EPI=34 PPI=32	279
858-TC	EPI=50 PPI=48	338
1330-DC1	EPI=38	364

	PPI=22	
1330-DC2	EPI=30 PPI=28	372
1330-TC1	EPI=23 PPI=18	384
1330-TC2	EPI=37 PPI=48	404

The 1300 Denier nylon triple cloth is having more tearing strength than 858 Denier nylon double and triple and 1330 Denier double cloth.

Knitted fabric:

The developed Nylon and Glass/Wool knitted fabric can be used for thermal proof fabric. Because thinner the thermoplastic fibre fabric produced less severe burns.

Thicker the fabric made from wool and glass gives good thermal protection.

IV. Conclusion:

In this research work, following finding were found and conclusion was made as

- By producing a bullet proof vest which of combining nylon filament yarn and carbon nanotube will satisfy the technical requirements and it may overcome Kevlar fabric used as bullet proof vest.
- Triple cloth has more tearing strength than double cloth due to increase in the number of yarns that have to break to result the tearing causes higher tensile strength
- More real area of contact between the yarns causes by
    - More number of layers
    - More interlacement per square area
- The developed Glass/Wool knitted fabric and nylon knitted fabric may used for thermal proof material because it can replaces asbestos.

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