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Nano technology applications in textile to improve puncture resistant of fabrics

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Abstract:
Nanotechnology is an evolving technology, resulting in significant difference in product behavior. Applications of Nano materials in textiles are constantl growing to improve performance and create unparalleled textile functions fo their enormous technical, economic and ecological advantages. It is expecte that Nano materials will either enhance existing properties or add ne functionalities to textiles such as dirt and water repellent, breathability, U protection, conductive and anti-static properties, wear and wrinkle resistanc or stain resistance or bacteria. Due to advancement in manufacturing of Nan materials, a new developed materials specified in the area of protection ha been discovered such as; carbon Nano tube (CNT) and Graphene CNT ha unique mechanical properties, particularly in improving tensile strength, an is one of the strongest known materials used in high-performanc nanocomposites due to their unique mechanical properties. And its propertie make it the best to reinforce polymers and have a great potential for use in th manufacture of ballistic-resistant materials. Graphene is an allotrope o carbon that exists as a two dimensional sheet. graphene is as a single layer o graphite, where all the carbons exist in a regular hexagonal array, it's the firs two dimensional materials to be available. It is both the lightest know substance and the strongest ever produced. The ability to be solid, strong an flexible at the same time gives this incredible potential for use as a bod armor or shielding. **Research Aim:** Develop and improve puncture resistan factor for cotton fabrics using Nano technology in Egypt. **Results an discussion:** The most important results are as follow: Emphasize the effectiv role of Nano technology in puncture resistant in textiles.Through Nan technology and Nano additives a wide range of properties could be added t fabrics. The impact proof treatments of fabrics and material developmen have several applications. The mechanical properties of textile fibers can b enhanced by incorporation of nanoparticles in fiber, such properties includ increasing puncture resistant.

Keywords:
Nano technology
textile
***puncture resistant*.**

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Introduction

Nanotechnology is an evolving technology, resulting in significant differences in product behavior. Applications of Nano materials in textiles are constantly growing to improve performance and create unparalleled textile functions for their enormous technical, economic and ecological advantages. It is expected that Nano materials will either enhance existing properties or add new functionalities to textiles such as dirt and water repellent, breathability, UV protection, conductive and anti-static properties, wear and wrinkle resistance or stain resistance or bacteria.

Due to advancement in manufacturing of Nano materials, a new developed materials specified in the area of protection has been discovered such as; carbon Nano tube (CNT) and Graphene

CNT has unique mechanical properties, particularly in improving tensile strength, and is one of the strongest known materials used in high-performance nanocomposites due to their unique mechanical properties. And its properties make it the best to reinforce polymers and have a great potential for use in the manufacture of ballistic-resistant materials.

Graphene is an allotrope of carbon that exists as a two dimensional sheet. graphene is as a single layer of graphite, where all the carbons exist in a regular

hexagonal array, it's the first two dimensional materials to be available.
It is both the lightest known substance and the strongest ever produced. The ability to be solid, strong and flexible at the same time gives this incredible potential for use as a body armor or shielding.

Research issue:

Insufficiency of puncture resistant Nano treated fabrics in the Egypt.

Study Objective:

Develop and improve puncture resistant factor for cotton fabrics using Nano technology in Egypt.

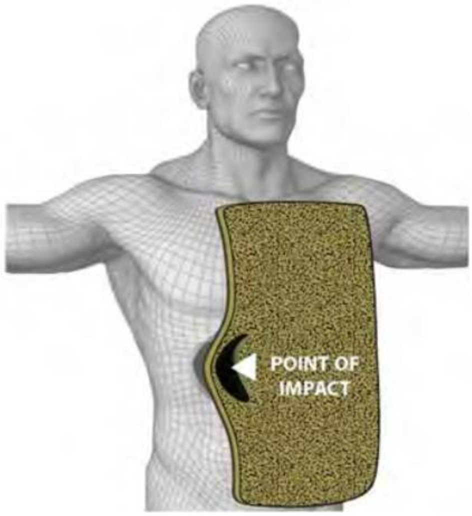
Research methodology:

Experimental method.

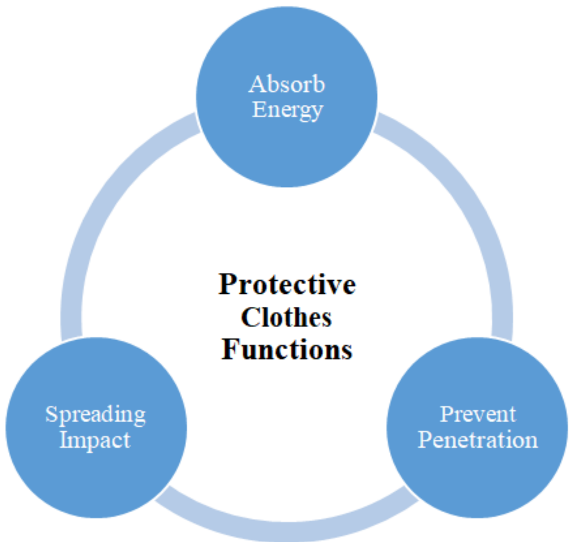
Literature Review

Impact and puncture explanation on human body:

Clothing has been used for protecting the human body from physical, social, emotional, and spiritual threats, actual and imagined.
Protective clothing is used according to the user's needs to increase its functionality depending on the level of protection needed and is usually used to define clothing and clothing accessories focusing on physical protection for the body. [(1)]
As an example of protective clothing, the bullet proof vest is designed to protect the main body organs from damage caused by the impact of bullets. A bullet although it's small it causes damage because it moves at an incredibly high velocity so it has a huge amount of kinetic energy.
If the bullet penetrates the body, the tissues in the organs are compressed and displaced while temporary and permanent cavities are created. Since the human body is unable to dissipate the energy quickly enough, this is what causes the damage. The human tissues function as a semi-fluid when the bullet causes pressure and shock waves that affects the internal organs and may fracture it or you may suffer serious internal bleeding. Just because the outside of body looks intact, it doesn't mean it's fine, this is known as blunt trauma." blunt trauma. is the initial trauma, from which develops more specific types such as contusions, abrasions, lacerations, and bone fractures, it is contrasted with penetrating trauma, in which an object such as a projectile or knife enters the body. [(2)]
More elastic and more cohesive tissues such as skeletal muscle, lung, empty intestine, nerve, blood vessel and to some extent bone can survive from the temporary cavitation blunt trauma. But less elastic, less cohesive organs, such as the liver, brain and heart, do not tolerate (Figure 2)-Protective Clothes Functions



(Figure 1)-Blunt Trauma Resulting from Excessive Impact Deformation [(3)]



(Figure 2)-Protective Clothes Functions

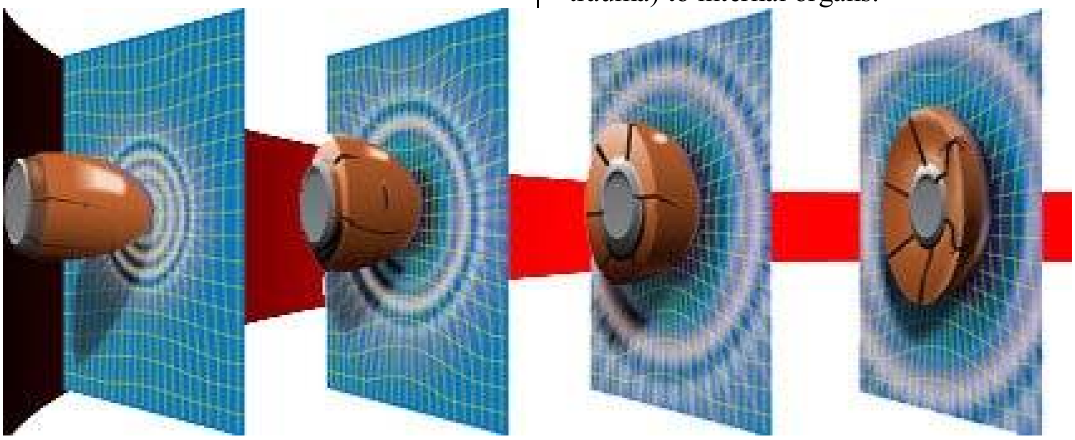
temporary cavitation blunt trauma well. Due to this, bullet impact does considerable damage to the human body even if does not touch the skin (Figure 1).
Impact and puncture Resistance is one of the primitive ideas of inventing body armors that was invented to protect the body from the strong impact generated by bullets or fragments.
the function of the body armor is preventing bullets or fragments from penetrating the human body. However, blunt trauma caused by the impact of the bullets can cause fatal injury as well, it can cause severe internal damages or bruises and even death (Figure 3).

(2-2) Damaging Effects of Shock and Shock Resistance:

Shock occurs when a relatively high impact force is applied in a short time, resulting in an energy wave that causes injury or damage to individuals

or objects on the receiving end of the shock wave. Such adverse effects happen when the shock energy is transmitted to the affected object from the source of the impact force.
Transferring harmful shock energy from an impact force causes damage and injury and eventually resulted in rework, waste and downtime. And effectively absorbing shock energy is a must to avoid the damaging effects of shock[4].

Once the bullet hits the body armor, it is caught in a "web" of very powerful fibers and the impact energy of the bullet is absorbed and dispersed by the material until the bullet deformed and Additional energy is absorbed by each successive layer of material in bullet proof vests, until such time as the bullet has been stopped, hard materials which are made from ceramic or metal plates help to protect from non-penetrating injuries (blunt trauma) to internal organs.


(Figure 3)-The transfer of damaging shock energy

Since the fibers work together in the individual layer as well as with other layers of material in the vest, a large area of the bullet proof vest is involved in preventing penetration of the bullet. This also helps to dissipate the forces that do not penetrate ''it is the result of an irreversible process that takes place in homogeneous thermodynamic systems. A dissipative process is a process in which energy "internal, bulk flow kinetic, or system potential" is transformed from some initial form to some final form; the capacity of the final form to do mechanical work is less than that of the initial form (Figure 3)' [5]
Bullet proof jackets may offer protection at a variety of levels to overcome the most common low and medium impacts. and designed to defeat rifle fire is of either semi rigid or rigid construction,
hard materials such as ceramics and metals It is impractical for routine use due to its weight and bulkiness and is reserved for use in tactical situations when confronted with higher-level threats, it is worn externally for short periods of time.

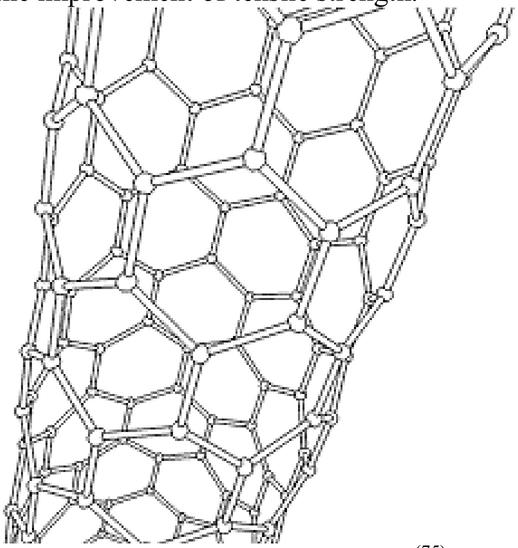
Protective clothes producing materials:
Protective clothes could be made from wide variety of materials depending on the level of protection required by the wearer, for example the protection needed for a person might exposed to the threat of shooting might be secured by using heavy armor which is brilliant to defend against penetrating jabs and low to medium fire power, but while impact a huge amount of energy will still be transferred to wearers body. The armor would disperse the energy all over the surface, but otherwise the impact will not be decreased and the wearer will be hurt.

Nanotechnology Applications in Textiles:
Due to the advancement of nanotechnology in the production of fibers and yarns, including the improvement of fabric finishes, applications in the textile industry are widespread. Recent advances in fabric finishes and processing have contributed significantly to the advancement of nanotechnology [6][7].
By combining the nanoparticles with the organic and inorganic compounds, the surfaces of the fabrics treated with abrasion resistant, water repellent, ultraviolet (UV), electromagnetic and infrared protection finishes can be appreciably modified., Titanium-dioxide (TiO2) nanoparticles have been utilized for the UV protection. The usage of Nano engineered cross-link agents during finishing process enhances the wrinkle resistance of cotton fabrics. The newly developed micro encapsulation technique is being used in textile industry for flame or fire retardant agents. Microcapsules using silver nanoparticles (Silver Cap) have been developed for providing anti-microbial effects and for odor control. [8][9]
Therefore, new techniques for manufacturing protective clothes introduced and developed recently using Nano materials and Nano manufacturing.

Carbon nanotubes (CNTs);

One of the most important factors in the production of protective material is the ability to absorb energy during deformation before fracture., that is representing its toughness factor, High toughness materials can find a range of important applications such as aerospace, airplanes, buildings, and bulletproof vests. Traditional composite materials, such as composites reinforced with glass fiber and carbon fiber, are often strong but not tough. Exploring new tough materials is therefore highly demanded. (10)

CNT has unique mechanical properties especially on the improvement of tensile strength.



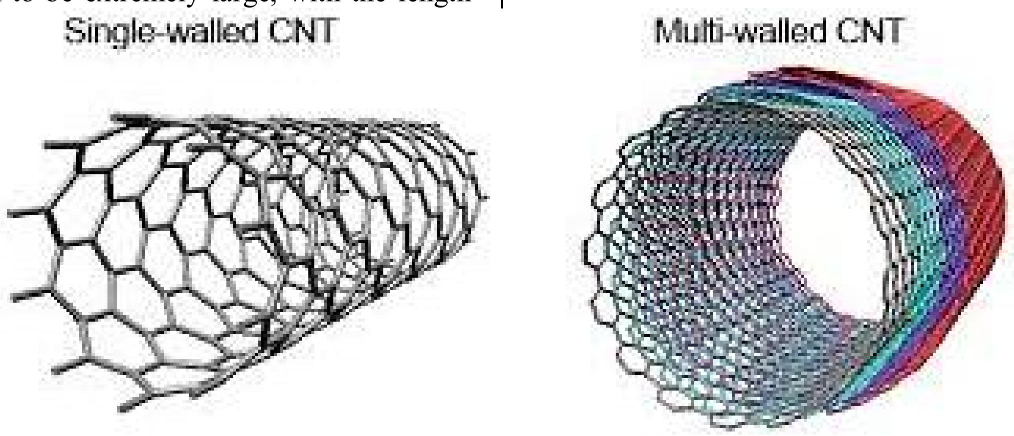
(Figure 4)-CNT construction (75)

Carbon nanotubes (CNT) are cylindrical, beehive-shaped structures that are chemically related to graphite. The beehive structure of the nanotube is formed with hexagonal rings of carbon, and contains a "cap" at the end of each cylinder (Figure 4). (11)

The length- diameter ratio of a nanotube (CNT) has known to be extremely large, with the length being millions of times larger than the diameter. Even though nanotubes are exceptionally light and tiny, it's hundred times as strong as steel. This exceptional strength is due to the covalent bonds (80) molecular bond", Is a chemical bond involving the sharing of atoms of electron pairs. These electron pairs are known as shared pairs or bonding pairs, and the stable balance of attractive and repulsive forces between atoms that form within the carbon atoms in a single tube. Nanotubes are entirely composed of sp2 bonds which are even stronger than the sp3 bonds found in diamond. Individual nanotubes naturally align themselves into "ropes" due to the weak Van der Waal Forces to define the attraction of intermolecular forces between molecules that form between tubes that allow for the rolling up of nanotubes, rather than individual sheets.(81)(82) When placed under high pressure, nanotubes will fuse together. In this case, some sp2 bonds will trade for sp3 bonds, and produce strong wires in unlimited length.

Enhance the ballistic performance of a body armor using CNT:

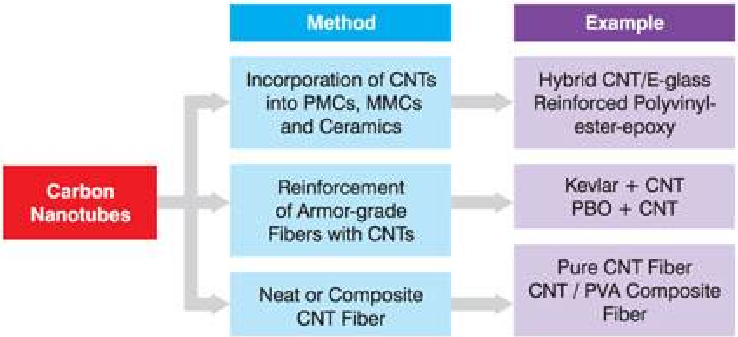
Millions of carbon nanotubes are made up of carbon nanofibers that are woven together to produce an extremely light material. They absorb energy incredibly well without permanent deformation or degradation, which is why carbon nanotubes are perfect for a bulletproof vest. The high elasticity module of carbon nanotubes is extremely flexible (12) developed a new material that is actually capable of rebounding the force of a bullet Single-walled nanotubes (SWNTs) are preferred over the multi-walled nanotubes for the purpose of manufacturing



(Figure 5)-MWCNT with different radices

bullet proof vests. They are composed of a single rolled graphene sheet (Figure 5).

A study on the ballistic resistance capacity of different carbon nanotubes. It showed that nanotubes with larger radii could withstand higher bullet speeds, and nanotubes with larger lengths could absorb more energy. They also found that the energy absorption and rebound is highest when the bullet hits the middle of the nanotubes.

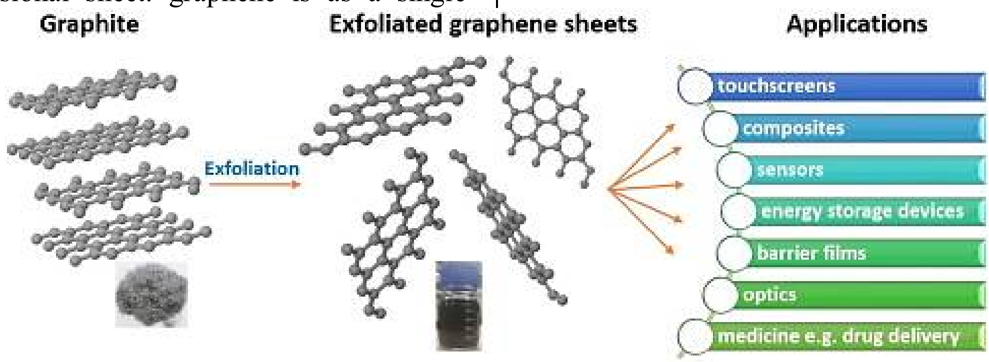


(Figure 6)-Methods of employing carbon nanotubes for ballistic armor applications [13]

And there is many Approaches for utilizing CNT to enhance the ballistic performance of a body armor

Graphene:

Graphene is an allotrope of carbon that exists as a two dimensional sheet. graphene is as a single layer of graphite, where all the carbons exist in a regular hexagonal array, it's the first two dimensional materials to be available (Figure 7). [14]



(Figure 7) -General overview of graphene: Production, properties and application in polymer composites [101]

It is both the lightest material known to man and the strongest material ever discovered, making graphene very promising for the future in many areas.

Graphene comes from the splitting of the naturally occurring graphite, into thin slices until it becomes one atomic layer thick. This single atomic layer holds carbon atoms together through single bonded sp2 level bonds which are 0.142 nanometers apart and each carbon possesses one free electron. This free electron is an essential component of graphene as it's above the plane of the sheet in a p-orbital. This leads to each hexagon on the sheet possessing 2 delocalized pi-electrons which aids in many properties, especially electrical conductivity [15] .

Being composed of carbon makes graphene a nonmetal, but it possesses semiconducting properties that means it often characterized as a quasi-metal. There are many forms of graphene available today, ranging from single layer, bilayer and multi-layer graphene to graphene Nano platelets (GNPs).

graphene Nano layers are just a single atom thick, however, there really isn't enough space for impurities or defects to weaken the material, tearing it or puncturing a hole in graphene requires putting in enough energy to break all of the relevant carbon-carbon covalent bonds, which is why graphene is so strong for its size.

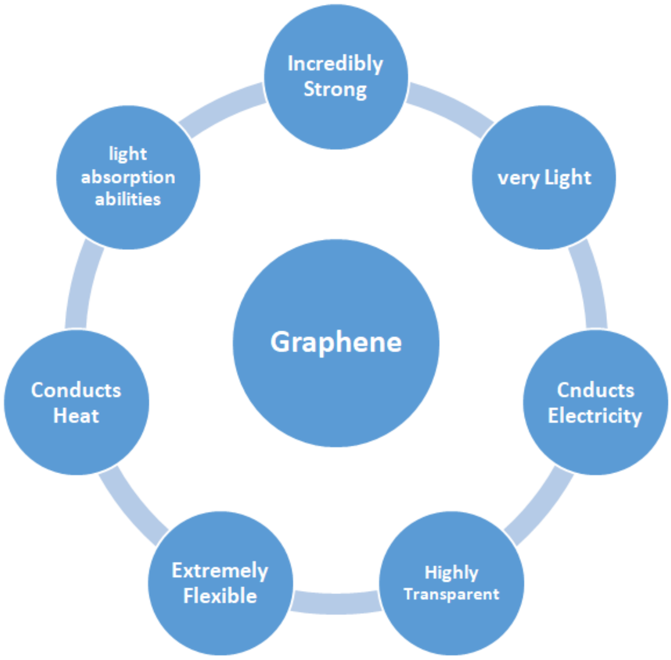
(1-4-5-1) Graphene Properties:

Graphene has many interesting properties such as a high surface area per mass of 2630 m2/g, the strongest electrical conductivity known material, an impermeability to gas, and an immense capability of transmitting light with a transparency of about 98% and optical, transparency

graphene possesses not only an excellent electrical conductivity but also a high charge carrier mobility and a high thermal conductivity, beneficial properties, including a high degree of flexibility and high mechanical tensile strength, it's tensile strength is known to be 200 times greater than steel, and it is also 10 times better than steel at dissipating energy [16]

These properties make graphene the most highly anticipated and most useful material to be developed today.

Its vast range of properties has enabled graphene to be implemented in wide range of applications, including batteries, sensors, solar cells, conductive inks and even as a composite material in bicycle frames (Figure 8). [17]



(Figure 8)-Graphene Properties

studies into graphene focused on its tensile strength – the fact that it can be pulled taught with tremendous force before snapping makes it useful for its ability to resist impact would be key for any use in body amour.

Graphene has the ability to spread kinetic energy quickly and across a wide area. The deadly, penetrative quality of a bullet owes to the fact that its kinetic energy is overwhelmingly transferred to a very small impact area, the aim of body armor is to distribute the force across as large a region as possible. The high thermal conductivity of the graphene lattice means that it distributes kinetic energy quickly before fragmenting.

sound waves travel three times faster through graphene than they do through steel, and this means it can withstand ten times the kinetic energy that steel can.

While some scientists and engineers venture to find methods of large scale production, others have begun testing its practicality and applications into everyday life. Graphene can be advantageous in a variety of uses including electric conductivity, structural foundation, and bulletproofing. [106] [107]

(1-4-6) Graphene usage in advanced body armor materials:

One of the most advantageous uses for graphene is its replacement of Kevlar in bulletproof vests. the outdated aramid fibers used for bulletproofing have many flaws in design and performance.

the vests help little in dispersing and dissipating the force applied to the wearer once the bullet has been stopped. This is a huge issue due to the fact that big impacts will exert massive amounts of force on the body, even without penetration, that can easily rupture internal organs. There is also a very large chance that high velocity objects will penetrate the vest completely, as most are designed to stop small to medium force impacts as pistol rounds, which possess much less kinetic energy and are therefore more easily absorbed by the vests. While Kevlar is a revolutionary technology providing a huge step up from its predecessors, it still does not fully protect the user, as severe blunt trauma wounds are common. Stopping the bullet itself is vital, but the force that it applies must also be stopped in order to ensure full protection. [18]

Experimental part:

Hematite (Iron III Oxide) Nanoparticles were applied to cotton fabrics.

The treatment enhanced the mechanical properties of treated samples

The mechanical properties of textile fibers can be enhanced by incorporation of nanoparticles in fibers, such properties include increased puncture resistance, tensile strength, tearing strength, wrinkle recovery and stiffness of textiles. Researchers all over the world has reported that these properties can lead to the production of high performance fiber with enhanced strength, wrinkle recovery and increased wear and tear resistance of a fabric

Application of TiO2, Ag, Cu and Zn Nano-particles to textile fabrics to apply in-house synthesized Nano Hematite (Iron III Oxide) particles to cotton textiles. The treated fabric was morphologically observed by scanning electron microscope, of normal and treated cotton fabric. Effect of Nano iron particles on various properties of fabric examined by standard methods.

Materials and Methods:

Materials:

Fabric Mill scoured and bleached cotton fabric with specifications given in Table 1 were procured from local market and used for the study. The procured fabric was further thoroughly washed, neutralized and air dried.

Chemicals:

process for the preparation of polyurethane cold cure foams by reacting a mixture of polymer polyols optionally containing fillers with poly functional isocyanates, amines, crosslinking agents, catalysts, blowing agents and stabilizers, wherein the stabilizers used are siloxane compounds of the general formula

The development of highly reactive polyether polyols and, if appropriate, the additional use of crosslinking agents make it possible on the other hand to carry out the preparation of the foam in the mold owing to the rapid curing on supplying relatively little heat. Such foams are therefore referred to as cold cure foams

Owing to the different raw material bases, cold cure foams have very typical physical properties which distinguish them from hot cure foams.

Polyurethanes are produced by mixing two or more liquid streams. The polyol stream contains catalysts, surfactants, blowing agents, the two components are referred to as a polyurethane system, the isocyanate is commonly referred as the 'A-side' or the 'iso '. The blend of polyols and other additives is commonly referred to as the 'B-side' or as the 'poly' This mixture might also be called a 'resin' or 'resin blend'. Resin blend additives may include chain extenders, cross linkers, surfactants, flame retardants, blowing agents, pigments, and fillers. Polyurethane can be made in a variety of densities and hardnesses by varying the isocyanate, polyol or additives.

A mixture of polyol, poly functional isocyanate, amine activator, tin or zinc catalyst, stabilizer, blowing agent (either water for the formation of CO_2 and, if necessary, addition of physical blowing agents), optionally with addition of flame retardants, color pastes, fillers, crosslinking agents or other customary processing auxiliaries, is reacted for the preparation of a flexible PU foam.

Cold cure foams properties:

- (a) a latex-like touch,
- (b) a higher resilience than the conventional hot cure foams, which is why these foams are also referred to as “high-resilience foams” (HR foams),
- (c) a compressive strength characteristic differing from hot foam (higher SAG factor) and therefore provide better comfort for sitting when used as upholstery material (furniture foam),
- (d) good long-term performance with only little tendency to suffer fatigue, which is of considerable interest particularly in the automotive sector,
- (e) better flame retardance than conventional hot cure foams, owing to their melt behavior,
- (f) more advantageous energy balance and shorter molding times in foam molding.

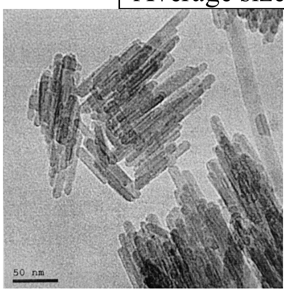
Nanomaterial:

Hematite (Iron III Oxide) Nanoparticles (NT-Fe_2O_3NP)

Size & Shape: TEM (transmission electron microscopy) were performed on JEOL JEM-2100 high resolution transmission electron microscope at an accelerating voltage of 200 KV.

(Table 1)-prepared Hematite Nanoparticles Properties

Nano material Properties	
Appearance (color)	Brownish Red
Appearance (forum)	Solid
Solubility	Dispersed in water /Ethanol
Shape	Needles & Rods like shape
Average size (TEM)	500±50 (L) and 15±5 (w) NM



(Figure 9)-TEM image of as prepared Hematite Nanoparticles (50nm scale)

Experimental methods:

Treatment with Hematite (Iron III Oxide) Nanoparticles:

The cotton fabric samples were cut to the required dimensions (size :30 cm X 30 cm) and placed in the standard testing temperature and humidity.

The coating solutions containing Nano iron particle were prepared using 1gpl, 5 gpl, and 10 gpl concentration.

For example, for 1 gpl concentration :0.1 gm Nano particles were added with 7 gm poly and 3gm iso as a cold cure poly urethane binder.

The mixture of Nano particles was then stirred with poly at 250 rpm for 10 minutes at 27ºC temperature, Likewise, all concentration solutions were prepared.

The formula of treated poly and iso was then stirred at 250 rpm for 10 seconds at 20ºC temperature and then was applied to cotton fabric samples that was prepared in the mold, the samples were air dried and finally cured at 100°C for 27 min in a preheated curing oven.

Treated Samples numbering:

(Table 9)-Treated Samples numbering

Thickness	Concentration /100mm			
	0 mg	1 mg	5 mg	10m
1mm	1	2	3	4
5mm	5	6	7	8
10mm	9	10	11	12

Testing and Analysis

Fabric characterization techniques:

The surface morphology of the Nano iron loaded cotton fabric was observed on scanning electron microscope(SEM) instrument

Determination of physical properties of cotton fabric:

Before physical testing the samples were dried and conditioned at 65± 2% RH and 27 ± 2°C temperature.

(Table 7)- **Cotton fabric specification**

Sample	**Weave**	**Weight in gm/sq.m**	**Thickness (mm)**
100% Cotton	Twill	352 g	0.3

Determination of square meter weight:

(Table 7)- samples square meter weight

samples	GSM		
	1mm	5mm	10mm
Cotton/(0 gpl) nano iron	1313	1957	3896
Cotton/(1 gpl) nano iron	1330	1973	3964
Cotton/(5 gpl) nano iron	1340	1926	3871
Cotton/(10 gpl) nano iron	1330	2020	3948

Determination of thickness:

(Table 2)-samples thickness

Thickness				
Cotton/(0 gpl) Nano iron				
Sample no	A	B	C	Avg
(no 6)	5.8	5.7	5.6	5.7
(no 7)	5.7	5.89	5.96	5.8
(no 8)	5.23	5.28	5.18	5.3

Geotextiles and geotextile-related products - Static puncture test (CBR test):

Specifies a method for the determination of puncture resistance by measuring the force required to push a flat ended plunger through geotextiles. Applicable to most of products, but not to geotextiles with apertures greater than 10 mm. The test is normally carried out on dry specimens conditioned in the specified atmosphere

Sample dimension: 10*20 cm

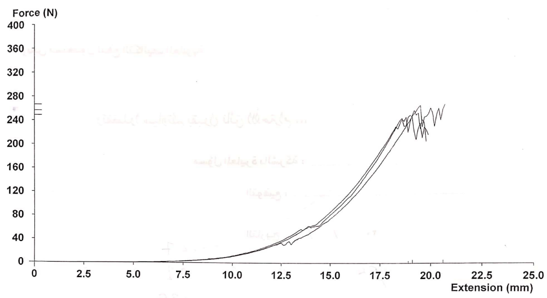
(Table 3)- Static puncture test (CBR test)

Static puncture test (CBR test)	
Test standard	ISO 12236:1996
Load range	500N
Displacement limit	100mm
Test speed	50mm/min
preload	0.1 N
Break detect	50 %
Auto reverse	on

(Table 4)- Static puncture test (CBR test) sample no 6

Trial no	Maximum force N	Displacement mm
1	266.4	20.60
2	249.0	18.90
3	256.8	19.10
Avg	257.4	19.53

(Figure 10)-Static puncture test (CBR test) sample no 6

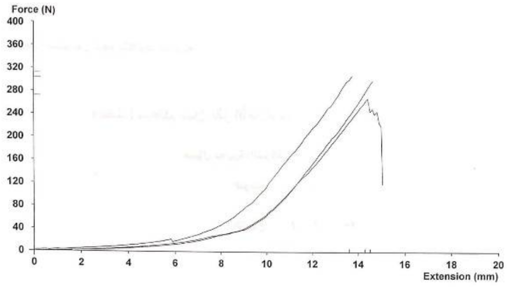


(Table 5)- Static puncture test (CBR test) sample no 7

(Figure 11)-Static puncture test (CBR test) sample no 7

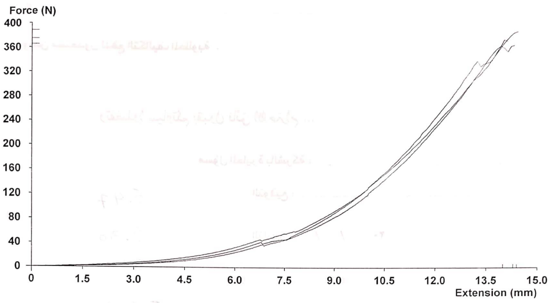
Trial no	Maximum force N	Displacement mm
1	272.0	14.30
2	303.6	14.51
3	311.6	13.60
Avg	295.7	14.14

(Table 6)- Static puncture test (CBR test) sample no 8



(Figure 12)-Static puncture test (CBR test) sample no 8

Trial no	Maximum force N	Displacement mm
1	388.4	14.40
2	374.8	13.99
3	356.6	14.30
Avg	376.3	14.23



Results and discussion:

Nano materials in textiles are constantly growing industries to improve performance and create unparalleled textile functions and with for their enormous technical, economic and ecological advantages, and with applying Nano treatments to technical textiles a wide range of beneficial properties is found.

Effect of Nano iron on physical properties of cotton fabric lead to Changes in physical properties of Nano iron loaded cotton fabric was evaluated in terms of puncture resistance and compared with the untreated cotton fabric.

puncture resistance: The results given in Table 4,5,6 shows that the introduction of iron Nano particles into the structure of the polyurethane binder between cotton fabric cause an improvement in the load bearing capacity of the fiber.

Conclusion:

In-house synthesized Nano silica powder was successfully applied to cotton fabric.

The puncture resistance was found improved in Nano iron loaded cotton fabric compare to the pure cotton fabric.

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