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Modern Defence Textiles

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Abstract

Special clothing is used by defence for a long past to maintain law and order for acquiring more power by controlling the other nations. Developments in different kinds of equipment and surveillance technologies are promoting innovations in industrial requirements and individual protection and battlefield related systems and structures. Technical textiles offer invaluable properties for military land forces in particular who are required to move, live, survive and fight against hostile environments. Military uniforms must meet specific protective performance requirements. There has been substantial development and growth in the military textiles sectors after the period of 2ed World War. Material development for desired technical textiles to lower attrition due to the harsh environment and battle hazards have been possible through R and D works. Through nanotechnology, new personal camouflage systems can be possible that can change patterns and colours as the environment changes. The fundamental challenge in the development of smart textiles is that drape ability and manufacturing of smart textiles should not be affected.

Keywords*: - Piezoelectric fabrics, Functional properties, Crampons, Moisture failure, Thermal shrinkage, Critical requirements*

INTRODUCTION

In defence, protective garments were used from long back. In the early days, protective garments provided defence personnel, starting with the heavy metal gears used by the rulers of the past to modern day's lightweight armours. Defence forces on land, sea and air are reliant on technical textiles. These may be woven, knitted or nonwoven, as well as

they may be coated or laminated. These fabrics have invaluable properties to make use of military forces. Defence personnel who are engaged in work in all parts of the glove in the variable environmental conditions such as rain, snow, fog, wind, lightning, sunlight, dust, heat, cold, wet, high UV areas and wind chill, for the different classes of protective garments are manufactured. Different types of textile fibres like Kevlar, Tyron, Spectra and DSM Dynama are suitable for making defence textiles. Defence textiles are used for various protections like environmental protection, thermal protection, camouflage, waterproofing, flameproofing, ballistic protection, biological and chemical protection and many more [01].

Textiles are applied in military items in various ways. There are more than 1000 items used in the US Defence Department in its inventory made of textiles. These include items like combat uniforms, protective clothing, parachutes, sweaters, socks, gloves, coveralls, sandbags, sheets, blankets and hospital items. The applications in defence, textiles are basically of two types, such as protective clothing and individual equipment and the other one is defence systems and weapons. In personal protection, the requirements can be of four types like battlefield protection, environmental protection, physical protection and physiological protection requirements. Soldiers need to be protected from bullets and other projectiles like shrapnel's, metal fragments and flying penetrating debris of different sizes, shapes and velocities. Development in the protection of high-strength polymers has been a phenomenal change. Ballistic protection is offered by Aramids, high-crystal-based fibres like Kevlar, Twaran, Technora and spectra [02].

The military textiles under the category of functional grouping have a wide range, including physical, camouflage, environmental, flames, threats from heat and flash and economic considerations. The incompatibilities in military materials systems are continuously a matter of efforts to solve by the scientists and technologists. Environmental protection for military clothing has a topmost priority. The undergarment for military personnel is also considered to be the primary concern from the viewpoint of hygiene. The perspiration and the handling properties of knitted underwear materials are extremely critical for mobile land forces such as infantry soldiers, marines and special forces. Presently available combat clothing systems are made of layer principle in which each layer performs a

specific function in the Combat Soldier 95 Assembly [03].

Carville Ballistic Fabric products of military-grade are applied across an increasingly diverse range of personal protection equipment (PPE) used within the military civil forces and emergency services, including protective clothing, load-carrying kit, reinforcement for bomb disposal suits, helmet covers and lining [04]. These fabrics must be of lightweight and the products are often used in many types of ancillary equipment in active services throughout the military systems like ballistic blankets, ammunition bags, stowage bags and portable and temporary shelters. Carville has the capabilities to produce complex military-grade fabrics woven from high-performance ballistic yarns through their integrated processes like weaving, finishing, coating and fabrication.

Presently in defence textiles, more emphasis is given to the development of decontaminated textiles. This is a process of neutralizing or removing the chemical or biological agent from people, equipment and the environment. For military purposes, decontamination must restore the combat effectiveness of equipment and personnel as quickly as possible. The present R & D work is focused on developing the decontamination method through a broad spectrum of CB agents from all surfaces and materials. The scientists of the Naval Research Laboratory's Centre for Bio/Molecular Science and Engineering have developed a new cost-effective self-decontaminating ultra-thin material coating that actively destroys pesticides and related chemical agents contact [05]. After the 2nd World War, there has been tremendous growth in the military textiles throughout the world. The application of technical textiles has been widely recognized for boosting the performance of the fighters and saving their lives in the war. A fighter carries more than 10 batteries to run different types of equipment. Hence they need reliable electric power, which is easier to carry. Such materials need to be developed that can convert sunlight or artificial light into electrical energy. Garments using e-textiles have been introduced that would be just like skin and have the ability to find out the composition of the soldier's body. Improvements have been initiated through research to develop an ultimate uniform for the soldiers in the war. There are various tasks that military uniforms need to perform compared to normal garments. The latest military uniforms are

lightweight, moistening, quick-drying, stain-resistant and control odours using the silver anti-microbial technology in the fabrics [06].

For the military soldiers, the harshest terrains are the mountain environment with treacherous terrains having extreme cold and hypoxia, desert areas with extreme heat stress, the depth of underwater can pose life threat situation in case of distressed casualties and therefore, clothing gives the first layer of protection for the wearer, forms an important protective measure in military operations against combat and hazardous environmental situations [07].

As per the news received, it is reported that the Ministry of Defence (MoD) has taken a policy to involve the participation of indigenous companies manufacturing technical textiles for Armed Forces. The specific products considered are bulletproof jackets, bulletproof patka and high-altitude inner clothing for defence. Many other items like, three-layered gloves, multi-purpose boots, snow boots, crampons, and sleeping bags, are included in the technical textiles list. As per the internal report from Amrita University, Coimbatore, foreign companies like Boeing, EADS, Airbus, Lockheed, Martin, Bombardier, etc. are involved in developing high-performance thermoplastic. Carbon fibre composite for applications in aviation and defence and that Amrita University was at the forefront of this technology globally. That is good to learn that technical textiles are being introduced into Armed Forces for specialized products, as mentioned above [08].

Improvements in fabric technology have seen a huge change in clothing for military textiles after the Second World War. Textiles play an important role in military textiles. Fabrics can be used to protect soldiers from cold, heat, snow, wind and rain, against ballistic impact, nuclear, biological agents and chemical threats. Textiles worn by the soldiers during war play the role of camouflaging in the visible spectrum and also in ultra-violet and infrared wavelengths. Due to the advent of technical textiles in military clothing, the functional and performance characteristics have changed the application of defence textiles in aerospace, marine, medical, safety, etc. These textiles have to perform a broader range of functions than other types of clothing. These include camouflage, high-strength, lightweight, moisture management and temperature

control along with the property like protection against ultra-violet rays [09].

Dye-sensitized solar cells are the new class of thin-film solar cells in which a dye-sensitized n-type semiconductor oxide film is deposited on a transparent conducting glass substrate, which is called a working electrode or photoanode. In the fabrication of electrode by the use of ID nanowires, nanobelts, nanofibres and nanotubes for DSSCs (dye-sensitized solar cells) application, different techniques such as metal-organic chemical vapour deposition, hydrothermal synthesis, vapour transport and electrospinning have been reported. Among these, electrospinning is proved to be the most effective and versatile technique, but the lack of adhesion of electrospun fibres on fluorine-doped tin oxide (FTO) substrate limits its application in DSSCs [10].

OVERALL VIEW OF DEFENCE TEXTILES

The requirements for personal protection of the military soldiers are grouped into four categories, namely, Battlefield protection: from chemical agents, flames, thermal radiation, ballistic impacts and detection; Environmental protection like waterproof, snow shedding, windproof, air-permeable and insulation; Physiological protection like heat stress, low weight and bulk, moisture vapour permeability, air-permeability and insulation; Physical protection like low-weight and bulk, durability, soil-resistant, and maintenance [02]. For nuclear protection in the US Army, 65/35 polyester/cotton blended fabric is used because it has the advantage of better durability in the decontamination process. The first requirement of heat flash protection is to have a flame-resistant outer layer, which is able to reflect the maximum amount of radiation back. It should be intact as long as possible to give protection from incident radiation while the portion already absorbed is transferred to the inner layer.

Soldiers need to be protected from bullets and other projectiles such as shrapnel, fragments of metals or flying penetrating debris of various shapes, sizes, and velocity. A personal army system for ground troops (PASGT) vest is made from 13 layers of type II Kevlar 29 [14 oz/yd sq (475 g/m sq)] ballistic fabric covered by 8 oz/yd sq (271 g/m sq) of camouflage ballistic nylon fabric. For camouflage protection, only the visible and the near-infrared regions of the spectrum are an essential requirement. For this purpose, camouflage fabric is made from a spun-

bonded nonwoven fabric; one side of it, a number of randomly oriented metal fibrils, is attached and is finally coated both sides with PVC impregnated with specific pigment. To get protected from chemical and biological warfare agents of the soldiers, permeable, semi-permeable and impermeable materials are employed. Mostly nylon tricot base fabric coated with polyurethane foam integrated with activated charcoal to provide an absorbing surface for chemical vapour agents are used. Protective gloves are normally made from butyl rubber, natural rubber, neoprene and PVA or PVC. These gloves do not provide flame retardant or POL resistance. To protect soldiers from extremely cold weather US Army, Natick Research Development and Engineering Centre has developed an Extended Cold Weather Clothing System. This can perform well within the temperature between -60 degree F and -25 degree F. A 3-D textile in the name of Intelligent Insulation System has been developed by DCTA, UK, in which two conventional layers of fabric are separated by a special fibre and it can expand or contract with the fall or rise in temperature to keep regulated insulation.

The perspiration and handling of knitted underwear materials are extremely critical for mobile land forces such as infantry soldiers, marine and special forces. Sweat wetted clothing is uncomfortable, but in the worst situations, the loss in dry thermal insulation and the wind chill effect on wet skin and clothing can rapidly lead to hypothermia in cold, wet conditions. The cold/dry areas, including the Arctic, Antarctic and Mountaineering region, require the carriage and uses of clothing, Sleeping bags and other personal equipment that possess a high level of thermal insulations. An efficient insulator will be composed of 10-20% of fabric and 80-90 % of air and the fibre acts as a buffer to trap air [03]. Physiological problems may occur when impermeable clothing is worn by the soldiers, marines and special forces. Water vapour permeable barrier fabrics are of three classes like high density woven fabrics, microporous coatings and film and hydrophilic solid coatings and films. Snow has uniform high reflectance at all visible wavelengths, that is, it appears white, but it also continues to have a high reflectance in UV regions. In practice, each nation in their military systems has adopted its visible colours and patterns, which are like Khaki, Green, Brown and black, with additional colours like Olive, Yellow, Orange, Pink, Grey Beige and Sand. Most textile fibres can be dyed to match the

visual shades of a standard pattern. The new infra-red region (NIR) of the spectrum covers the wavelength range from 0.7-2.0 micrometer, although current camouflage requirements concentrate on the 0.7-2.0 micrometer range. The chlorophyll rice or edge has to be matched by the dyes and pigments used in the camouflage textiles. There is a complex problem as few dyes, coatings and pigments exhibit this behaviour in the NIR.

Arville Military grade fabric products are applied across an increasingly diverse range of personal protection equipment (PPE) used within the military, civil and emergency services, including protective clothing, load-carrying keel, reinforcements for bombs disposal suits, helmet covers and linings. Under these conditions, fabric performance is very important needs to be lightweight. These products are used in ballistic blankets, ammunition bags, stowage bags, and portable and temporary shelters. Complex military-grade fabric pieces woven from high-performance ballistic yarns are manufactured. They have the integrated capabilities of weaving, finishing, coating and fabrication, makes them produce ideally complex fabrics [04].

In the US military, wool is required for their uniforms and they require it in bulk quantity. The reasons are that wool has a self-extinguishing quality and when it burns, it will dispel off quickly, whereas synthetic fibres will stick to the skin. Moreover, wool breathes better than synthetic fibres. Cold weather wind jackets used by the military protect them from wind and sand and also control moisture. It is airy also. They have developed water-resistant jackets and trousers, which repel water and light and also comfortable [06]. Tents are available manufactured from such fabrics that can give protection in extremely cold weather. This tent is stitched with a rubberized sheet at the base level to protect against dampness. The colour of such tents serves the purpose of camouflaging in different situations. Nylon corduroy, which is a double durable material, is best to use for the manufacturing of military bags, bulletproof vests, footwear shoes and backpacks. Especially designed flame resistant flight uniforms have been developed for pilots with high-tech fabrics called Nomax.

TECHNICAL TEXTILES FOR DEFENCE PRODUCTS

Du Pont developed Kevlar, the new generation textile fibre, which is used in

the modern lightweight armour. It consists of long molecular chains from poly-phenylene terepthalamide. It has high tensile strength at a 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. Twaron is another para-aramid fibre. The yarn is manufactured from 1000 spun finely single filaments, which acts as an energy sponge, can absorb a bullet's impact and quickly dissipate its energy through engaged with adjacent fibres. DSM Dyneema is extremely high strength to weight ratio fibre and light yarn to float on water. It also has high energy absorption property and dissipates shock waves faster [01].

The most demanding customers of technical textiles in the world are the members of fighting forces and army personnel with critical requirements. The primary areas of protection under all environmental conditions include ballistic, chemical/biological and micro-organisms. Apart from the protection, the gear must have the protection from sun, resist mildew, withstand static propensities in a number of applications and other properties of water repellent, excellent durability to resist abrasion, tear and breaks, good air permeability, resistance to oil and lubricant and good washing fastness [05].

In harsh military terrains, operations of armed forces personnel for an extended tenure period necessitate protection from elements and battlefield hazards. These types of terrains exert profound effects on the physical and physiological performance of the soldiers, which can impart serious impacts on the health conditions and due to such effects, the mission operations by the soldiers fail and cause loss of lives. Such terrains are supposed to be mountain region environment characterized by treacherous terrains with extreme cold and hypoxia, desert areas by extreme heat stress, depth of underwater can pose life-threatening situations in case of a submarine, aviation hazards. Such type of clothing has the first layer of protection for the wearer, forms an important protective measure in military combat and environmental hazards. The important clothing used under the above conditions is extended cold weather clothing ensemble, high altitude pulmonary edema chambers, anti-G-suits, flame retardant overalls, submarine escape suits, chemical warfare ensemble, liquid-

cooled garment, etc., which are all from technical textiles.

According to the information received that in a meeting held in Mumbai, under the aegis of the Ministry of Commerce, which was attended by the Army when details of other areas were worked out, it was surprisingly noticed that items like high altitude inner clothing, three-layered gloves, multi-purpose boots, snow boots, crampons and sleeping bags were the matter of discussion regarding poor quality performance of these items. The decision of these for the indigenous manufacturer of the new bulletproof jackets was taken only last year based on the Amrita University, Coimbatore proposal to DRDO and the joint propel TDF-DRDO sent to MoD and Dr. Santanu Bhowmik, Head of Research & Projects, Department of Aerospace Engineering and Dr. Manohar Parikar that the proposal needed to be progressed expeditiously since similar research was ongoing by foreign companies like Boeing, EADs, Airbus, Lock Head Martin, Bombardier, etc. for developing high-performance thermoplastic carbon fibre composites for various applications in aviation and defence, and that Amrita University was in the forefront of this technology globally [08].

APPLICATION OF ADVANCED TEXTILE TECHNOLOGY IN DEFENCE

Textiles perform a huge number of roles in the military performance in and out of the defence jobs. As we know that fabrics for defence are tailored for different purposes, namely protection against extreme weather or environmental conditions like heat, cold, wind, rain, snow etc. against ballistic impacts, against nuclear, biological and chemical threats. Camouflage textiles can protect against the visible spectrum as well as in ultra-violet and infrared wavelengths. Textiles have applications in other areas, including parachutes, safety harnesses, ropes, and tent clothes. All these items together are known as military textiles [09]. A drastic a huge in clothing worn by soldiers have taken place since the Second World War. Therefore, the introduction of a new generation of textiles has emphasised on the performance of the soldiers to take edge over their counterparts in the war field compared to the past. One of the most important developments took place in the recent past in military clothing in their low weight dresses with better wear comfort. One such material is Du Pont's Kevlar impact control facilitates the manufacturer of lighter, more flexible and more comfortable garments. The application of

nanotechnology in military clothing is an effort to make the armed forces more mobile and better protected from enemy assaults. Chameleon camouflage allows the soldiers to become a mirror of his surroundings. Another important development includes the use of nanotechnology fibres which can stimulate muscles and thereby give soldiers greater strength for lifting or jumping.

Modern military devices that heavily rely on electrical energy are sensors, actuators, communication devices and sighting systems and many more. The source of such devices is the battery and it affects the mobility of the soldiers when they are in operation. To solve such problem, a new concept has been adopted through textile clothing to corporate devices like piezoelectric devices into the uniform of the soldiers. The piezoelectric devices are able to convert mechanical work into electrical vice versa. In this area, polymers, PVDF (poly Vinylidene Flouride), was the first piezoelectric polymer material which is consisting of four phases, among which beta-phase shows a strong piezoelectric effect discovered. Recently phase-changing material (PCM) has also attracted great interest in the thermal energy storage. PCMs have problems with encapsulation (from fatty acids), which increases their operating costs. To overcome such limitations various polymer matrices like polymethylmethacrylate, polyethylene oxide have been investigated to support PCMs [10].

Dye-sensitive solar cells are the new class of thin-film solar cells, in which a dye-sensitized n-type semiconductor oxide film is deposited on a transparent conducting glass substrate, which is called a working electrode or photoanode. A platinum-coated glass substrate placed parallel to the photoanode acts as a counter electrode. It is reported that for the fabrication of electrode by the use of ID nanowires, nanobelts, nanofibres and nanotubes for DCSCs(Dye Sensitive Solar Cells} application, various technologies like metal-organic chemical vapour deposition, hydrothermal synthesis, vapour transport and electrospinning have been worked out. Among all these methods, electrospinning has proved to be the most effective and versatile alternatives, but the lack of adhesion of electrospun fibre non-FTO (Fluorine Tin Oxide) substrate limits its application.

Textile materials presently used in military clothing is most vulnerable to diseases caused by microorganisms. Usually, drug

loading into textile materials can be achieved by incorporating drugs during the preparation of the textile materials or after the formation of the clothing incubation drug in them. Researchers have found to extensively use chitosan due to its favourable physiochemical and biological properties like biocompatibility, non-toxicity and anti-bacterial behaviour. Drug release for the chitosan system can be done by three mechanisms, such as release from the surface, release due to surface erosion and diffusion through the swollen matrix. The bacterial property of copper nanoparticles has been studied on fabricated polyurethane nanofibres containing nanoparticle. By the process of controlling environmental conditions performance of military personnel can be improved. These conditions can be tailored by providing them dresses like waterproof, flame retardant, chemically protected, thermally insulated and embedded with sensors and electromagnetic shielding materials. For such dresses, recently, more improvements have been focused on superhydrophobic surfaces with the contact angle (CA) of 150 degrees for the application in a protective coating, self-cleaning surfaces, anti-icing or anti-snowing and microfluidic systems.

To maintain a constant temperature of the body, it is essential to homeostasis because most enzymes are sensitive to temperature and function only in a narrow temperature region. In hot conditions, heat must be continuously dissipated and regulated to maintain normal body temperature. Therefore, thermal protective clothing is needed to protect defence personnel against climatic influences. PI (Polyamide) is now a widely used material in high-temperature applications because of its stability. Armour materials are used to provide protection against ballistic as well as fragments of ballistic and armour itself. Research groups have developed new armour layering concepts. This layering concept is based on the combination of four layers and these are such as a very hard layer, layer to slow down and layer to provide restriction to the porous layer. Smart textiles include interdisciplinary research areas like materials research, sensor technologies, engineering, electronics, computer applications, biosensors,, etc. Therefore, with the current pace of development in smart textiles will form a ubiquitous part of defence lifestyles.

CONCLUSION

The military nations in the world have their research programs planned for future

combat and protective clothing as an integrated system. The programs are based on the involvement of all-round efforts from all departments related to defence activities. More developments are needed for better protective garments for the military personnel. New technologies and innovations will have a lot to offer in the future. The solution for this is the use of most advanced technical textiles for military personnel. The critical life requirements for protecting individuals from environmental and battlefield threats have ensured that most nations in the world are expanding their resources significantly for it. The main threats to military personnel are fragmenting projectiles rather than bullets. The most demanding customers of textile materials in the world are the members of our fighting forces and army personnel who are always with the critical requirements. There has been substantial development and growth in this area after the 2nd World War. Harsh military terrains exert profound effects on the physical and psychological performance of the soldiers. India's contribution to the global technical textiles industry is significant. The developments in military clothing include progress made in minimizing weight and maximizing wear comfort. The development of smart textiles may affect many aspects of defence personnel lives.

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