

Development in India of a Stab-Resistant Body Protector

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Introduction

The 'body protectors', also known as a 'riot-control' dress are most commonly used by the Indian para-military forces as personal protective equipments to protect them against various threats such as petrol bombs, knife, stabs and stone pelting while controlling mob. These stab-resistant equipments are also used by the jail security forces that face a common threat of getting attacked by knife or other sharp edged weapons. Very briefly, stab threats can be classified into two categories as puncture and cut/slash. 'Puncture' refers to the penetration by instruments with sharp tips but no cutting edge, such as a spike or screw-drivers while 'cut' or 'slash' refers to contact with knives or scissors with continuous cutting edge.

The currently available body protectors in India (as shown in Fig. 1) are manufactured using polycarbonate sheets (3mm thickness) and rubber/foam inserts (2mm thickness) stitched with 'coated' flame-retardant fabric.



Fig. 1- Body Protector

Although, widely accepted in India by major para-military forces, there is an urgent need to improve the design of currently used body protectors for the following reasons:

- The currently used trauma inserts comprise of polycarbonate sheets and rubber inserts which can't be wrapped around the whole torso area especially with areas which move with the body movement making them vulnerable to stab attack. This also restrict movements while performing any rigorous activities
- Owing to the use of polycarbonate sheets and rubber inserts, the currently used trauma inserts are not breathable which makes them uncomfortable to wear for longer hours especially during summer
- Various body parts such as neck, armpit and lower abdomen areas in the currently designed body protectors are only protected by the rubber/soft plastic inserts, hence providing no protection to the wearer against stab (puncture) attack by screw-drivers or spikes
- These body protectors are uncomfortable to wear in a sitting position as the lower edges often press firmly against the stomach, hip and side areas of the wearer and top of the shield places pressure on the wearer's throat and chin area
- The weight of body protectors cause significant fatigue to the security forces over the working shift
- The currently available body protectors are bulky and not designed as per female para-military forces;

- These body protectors are not designed to be worn concealed under outer clothing if required for discreteness. Since the worn body protectors can't be concealed, the potential attacker is more likely to stab/slash vital areas away from the vest such as the neck or head area
- The woven fabrics (*Khaki* drill cloth) which are currently being used to manufacture outer cover of body protectors are neither 'inherent' flame-retardant nor cut/slash resistant, i.e. flame-retardancy of 'coated' fabric may be washed out after few washings and this can easily be cut-through with sharp edged weapons

Design Improvements: (Innovation Defined)

A body protector has two important parts:-

- Outer cover/garment:** Currently, woven khaki drill cotton fabric (220 gsm) is being used to manufacture outer cover of body protector. These fabrics are 'treated' with flame-retardant chemical finishes (e.g. phosphorus or bromine based chemicals) which retard burning by interfering with the combustion cycle. However, unlike 'inherent' FR fabrics, the chemically 'treated' FR fabrics may have their flame-retardant properties diminished or removed completely depending on how garments are laundered or which chemicals they are exposed to in the work environment which would further pose threat with ageing. Also, the sewing threads currently being used for stitching are not flame-retardant.

A very basic sampling was done using our *Dualtec*[®] yarn (combination of aramid/carbon/stainless steel wire – 50 micron) to develop an 'inherent' flame-retardant fabric (230 gsm) with high levels of 'cut-resistance' property (Level 5 as per EN 388). Further, Fig. 2 & 3 shows 'burning' behaviour of both *Dualtec*[®] yarn based fabric and cotton drill fabric after 30 seconds. The newly designed fabric can be used either

Dualtec[®] yarns are manufactured using patented technology where filaments are incorporated during spinning. These yarns are designed to manufacture clothing or other protective equipments (such as gloves, socks, balaclava, sleeve, cuffing, aprons or jackets as well as sporting wear for sports such as fencing) for heat and cut protection while retaining softness and comfort to the touch.

Examples:

- *Dualtec* HT (high temperature short term >350°C): Aramid/carbon with wire or glass
- *Dualtec* FR (good thermal resistance >200°C): Aramid/modacrylic with wire or glass
- *Dualtec* ABR (high abrasion resistance with heat and cut): Para-aramid / modacrylic / polyamide with wire or glass

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single layered or multilayered in the final body protector design. It is further intended to optimize various variables such as core components, as well as fibre blend compositions to make it light-weight and cost-effective.

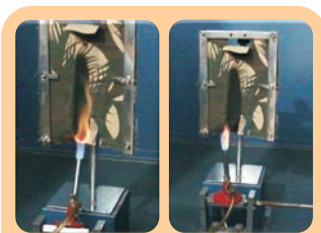


Figure 2. Currently used FR 'treated' fabric before and after burning for 30 seconds

b. Flexible trauma insert:

With a view to replace the currently used polycarbonate sheets, a prototype of flexible trauma insert has been designed, shown in Fig.4 which is a multilayered structure with woven e-glass filament (34 tex) and steel wire which could be used by placing one over another in the multiaxial direction to provide 'stab' or 'puncture' protection. Further, a para-aramid needle-punch nonwoven and para-aramid woven structure has been developed to cover the newly developed 'trauma insert' from both sides as shown in Fig. 5.

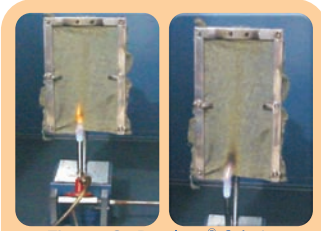


Figure 3. Dualtec® fabric before and after burning for 30 seconds



Figure 4. Woven glass filament (E-glass and steel wire)



Figure 5. Multilayered trauma insert (Needle punch p-aramid/ wire mesh/woven p-aramid)

The areal density of fabric layers is currently being evaluated and optimized as per requirements of the stab-resistant test (HOSDB Body Armour Standards for UK police *Part 3: Knife and Spike Resistance*). Additionally, the methods of joining of multiple layers either only at edges or throughout the structure require a detailed study prior to development of a commercial sample. Both newly developed 'flexible trauma insert' and

'inherent' FR fabric with cut-resistant property can also be used to develop a prototype of knee, elbow, groin and neck guard.

Currently, it is only a 'laboratory or concept' development for both woven fabric (for outer cover) and a flexible 'puncture-resistant trauma insert' to design 'improved' body protector which also needs a detailed study on comfort issues.

Additionally, it is of interest to develop a 'unique' design of body protectors especially for female para-military forces. The comfort and wearability of the newly developed body protectors would be assessed by wearer trials, which would further help in providing subjective information on wearability, design and also to compare sizes of trauma inserts. The newly designed body protectors prepared with different trauma inserts would be tried and ranked by wearers for both comfort and fit.

The objective would be to select the body protector with the optimum degree of dexterity and form fitting to the body without the wearer feeling too tight or too loose. The wearers would rate all the samples which would be averaged and reported. Based on these trials, a 'size-chart' would be prepared to manufacture trauma inserts in different sizes. The chart would also provide dimensions of trauma insert for front, back, groin, knee, neck, and elbow to manufacture body protectors in three sizes, i.e. small, medium and large. Additionally, similar study would be conducted to design body protectors for female para-military forces.

Conclusions and Further Work

- As demonstrated, the *Dualtec*® yarn based fabric performs better than that of currently used FR treated fabric as an outer cover (garment) for body protectors
- An innovative flexible trauma insert has been developed which needs further assessment by wearer trials
- There is a need to design the flexibility test for trauma inserts. The results of this test would be compared to the subjective manual test. Additionally, an ergonomic wearer trial would be conducted on body protectors as per ISO 14876-1 (2002) where these protectors would be assessed by both male and female volunteers. This would help to establish a correlation between the mechanical flexibility tests, manual assessment and that of wearer trials
- Further evaluation of areal density of trauma insert and each layer is required to test the stab-resistant performance (as per HOSDB Body Armour Standards for UK police *Part 3: Knife and Spike Resistance*)
- The methods of joining of multiple layers require a detailed study prior to the development of a commercial sample

Culimeta-Saveguard

We are a Culimeta-Saveguard, U.K. Group Company which specializes in the manufacturing of technical composite yarns for Personal Protective Equipment (PPE) market, specifically for hand protection for global gloves industry. Recently, we have initiated manufacturing of both '*Dualtec*®' and '*Powerguard*®' range of yarns in India for domestic market which are designed to provide protection against heat and mechanical risks (abrasion, cut, tear and puncture). We aim to develop a stab-resistant (cut/slash & puncture) body protector to protect wearer against injury from penetration by knives, edged weapons, and sharp-pointed weapons while ensuring that the movement of the wearer is not overly restricted. The protected area ensures coverage of the vital organs, in particular, the heart, liver, spine, kidneys and spleen. Further, a cut/slash-resistant woven fabric with 'inherent' flame-retardant properties is envisaged to be used as an outer cover. A feasibility study has been conducted as discussed in this article and we would like to invite companies interested in co-developing this product for commercial manufacturing through this article. ■