Cut-resistant uniform for paramilitary forces

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The riot-control para-military forces use impact and stab-resistant body protectors (Figure 1), however the uniform (or undergarments) worn underneath body protectors are not cut or slash resistant which may lead to damage of important body organs especially the groin and below naval area while controlling mob or aggressive individuals. Also, the body protectors are designed to be worn on top of the uniform and are rigid in nature which makes side edges under arm and neck area vul-nerable to the potential attacker which could attach away from the body protector (1).

In such cases, a cut-resistant uniform can be used to provide protection against sharp edged weapons (knife, screw drivers, blades, pointed stones, broken glass, sheet metals, injection moulded plastics, etc). These uniforms can be worn throughout the shift and can be designed for both male and female para-military forces. Further, the cut-resistant uniforms can also be recommended for jail/traffic controllers, private security forces or bodyguards dealing with violent/aggressive prisoners, protecting properties, events or people. This innovative cut-resistant

uniform can also be useful for bikers/two-wheeler riders for protection against road crashes.

Figure 1: Body Protector

In this part of the paper, we have discussed development of cut-resistant uniform made-up of HPT Flex? yarn based knitted fabric, further work is being done on using woven structures which will be introduced in our next paper. This newly designed cut resistant fabric is lighter and comfortable in comparison with currently used uniforms.

Figure 2. Cut-Resistant Undershirt/Uniform

Materials & Methods Materials: The currently designed fabric is

manufactured using HPT Flex? yarn which is composed of Ultra high molecular weight polyethylene filaments (UHMWPE/HPPE), also called as high performance polyethylene fibres (HPPE), or sometimes extended chain polyethylene fibres (e.g. Spectra® by Honeywell, Dyneema? by DSM) blended with polyester and multifilament core component to produce high strength cut-resistant composite structure. The properties of HPPE/UHMWPE filaments are shown below (Table 1).

Table 1: Properties of HPPE/UHMWPE filaments

Property (HPPE/UHMWPE)	
Molecular weight (10^6 g/mole)	2-6
Melting temperature (°C)	125-138
Specific gravity	0.93-0.95
Tensile strength (g/den)	28-38
Elongation (%)	2.7
Water pick-up	None
Resistance to acids, alkali, sea water	Excellent
Resistance to gasoline, toluene, insecticide	Excellent

Testing of cut performance: The BS EN 388:2016 standard was used to study the abrasion resistance, blade cut resistance, tear resistance of newly developed cut-resistant uniform. The cut-performance was conducted as per ISO 13997. Table 2 shows comparison of various cut-performance standards which are used globally (2,3) and Table 3 demonstrates comparison between different test standard methods and their similarity/connection with each other. Currently three standards are used for measuring cut resistance; these standards are ASTM F1790-04, ISO 13997 and CEN 388. In ASTM F1790-04, ISO 13997 standard, the cut resistance is identified as the cutting force to be applied to a straight blade that slides to cut through the sample in a 20 mm blade stroke.

Table 2: Comparison of cut-performance standards (4)

BS EN 388:2003	BS EN 13997:1997	BS EN 1082-3:2000
Cut Resistance Performance level 1 to 5	Cut resistance measured in Newtons	Cut-resistance measured in mm
Movable counter rotating blade with alternating motion	Blade drawn across	Blade held in a guided falling block
Circular bladed used	Sharp edge type knife blade	Sharp edge type knife blade
Cut Resistance is measured according to cycles need to cut though	Force required to cut through the material during a 20mm cutting stroke	Depth of penetration in mm is considered as cut resistance
Performance level 4	Cutting load ≥ 13N	Blade is either 0.65J, 1.47J, 2.45J based on sample performance level
Performance level 5	Cutting load ≥ 22N	
5N Fixed load	Variable load	Fixed load
Fabric sample size in mm width 60±6 & length 100±10	Fabric sample size in mm width 25 & length 100	Tubular shape sample with length of 100 mm & 100±10 mm

Results & discussions The cut-resistant uniform discussed in this paper is a lightweight and comfortable fabric, which provides protection underarm area, legs, spine, ribs and all major arteries and key vulnerable areas from slash/cut hazards. The body protector used on top of these uniforms to provide protection against stab injuries is discussed in previous part of the paper (1). The newly-developed uniform can be worn throughout the shift and is washable at room temperature providing durability of over three years (2,3). Table 4 shows the abrasion, cut, tear results of this uniform as per EN 388 standard. The puncture and impact test were not applicable for this uniform.

Table 3: Different test standard methods and their similarity/connection with each other:

TEST STANDARDS					
CURRENT : ISEA105-2011		NEW: ANSI/SEA 2016		EUROPE: EN388-2016	
ASTM F1790-2014 (CPPT)*		ASTM F2992-15 (TDM)*		ISO 13997 (TDM)	
CPPT or TDM		TDM ONLY		TDM ONLY	
LEVEL	GRAMS	LEVEL	GRAMS	LEVEL	NEWTONS
1	≥ 200	A1	≥ 200	A	2
2	≥ 500	A2	≥ 500	B	5
3	≥ 1000	A3	≥ 1000	C	10
		A4	≥ 1500	D	15
4	≥ 1500	A5	≥ 2200	E	22
		A6	≥ 3000	F	30
5	≥ 3500	A7	≥ 4000		
		A8	≥ 5000		
		A9	≥ 6000		

It is worthwhile to mention that the strength, hardness, slipperiness of yarns contribute to the overall cut-resistance of textiles. Our HPT Flex? yarns are manufactured using high strength Ultra high molecular weight polyethylene (UHMWPE/HPPE) reinforced with multifilament core component e-glass which is hard and brittle in nature (5,6). The natural lubricity of HPPE filaments help blades and other shard edges slide pass through the textiles (7). During cut-testing, the sharpness of the blade degrades even after single use, so blade should be changed for each new sample for testing (9). Also, it's well established fact that the cut resistance level should be determined using range of loads, not just using only one load (5,9). The yarns can be reinforced with stainless steel or tungsten wire to achieve higher cut performance as compared to e-glass reinforced yarns used in the current study (8, 10, 12).

Table 4: EN 388:2016 testing of cut-resistant uniform

Sl. No	EN 388 Parameters	Performance Levels
1	Abrasion	Level 4
2	Cut-Resistance (Coupe Test)	NA
3	Tear Resistance	4
4	Puncture	NA
5	Cut-Resistance (TDM)	Level C
6	Impact Resistance	NA

Although glass, basalt, steel wire/tungsten are used to reinforce HPPE yarns to achieve higher cut-performance, none of the above mentioned products can be used alone to manufacture effective cut-resistant gloves, i.e. steel wire alone would break and glass would fracture while knitting (2,3,6). For this reason, it's important to use steel wire or glass in core and HPPE on sheath to produce a composite yarn which is more cut-resistant than it's components.

A new technology is developed where glass is introduced in the core of a

HPPE based ring spun yarn technology (11,12). This will also enable to have HPPE inside core and cotton/nylon/polyester fibres on sheath which can be easily dyed in any colour as HPPE can't be dyed due to its inertness towards chemicals (Figure 3). Furthermore, the innovative HPT Flex? yarn can also be designed to manufacture new generation of uniforms which can provide both slash/cut alongwith stab protection to the end-users (13,14). Aramid fibres can be used in place of HPPE fibres if there is requirement of protection against thermal hazards such as conductive heat, molten metals, etc (4,6,9,10).

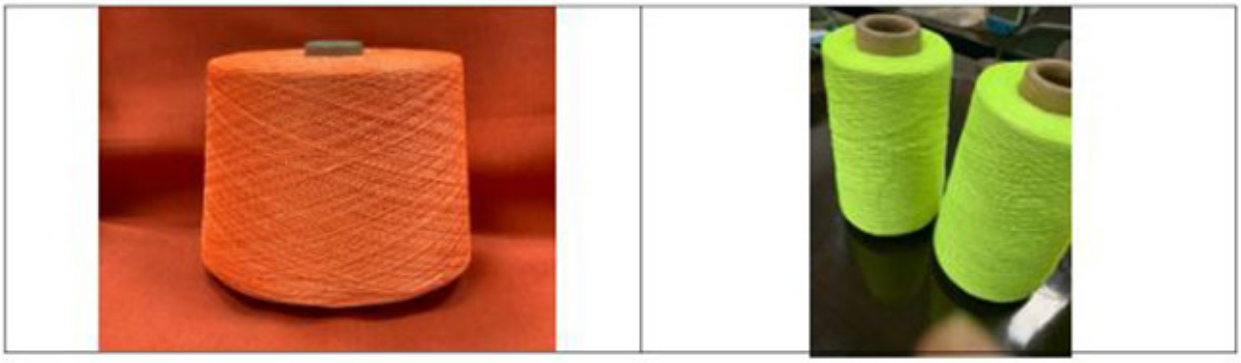

Figure 3. HPPE in core with Hi-vis nylon orange and green on sheath

Conclusions The newly-developed cut-resistant uniforms can be used by para-military forces or two-wheeler bikers for protection against sharp weapons or objects. The uniforms can be designed for both male and female end-users in different colours. Owing to its knitted structure, they are comfortable to the end users and allow better air circulation alongwith higher level of abrasion and cut/slash resistance. These uniforms are anti-bacterial and anti-fungal in nature due to presence of HPPE/UHMWPE which is hydrophobic in nature. Further, research is being done on recycling of these composite yarns so that the uniforms can be recycled once discarded after multiple use. It would be worthwhile to develop light weight stab-resistant panels which can be incorporated with cut-resistant uniforms to replace the currently used body protectors.

References 1. Development of Stab-Resistant Body Protector in India, N.

Kumar, TechTex India, BCH, April-June 2013;

2. Performance Study of E-glass Reinforced HPPE and Cotton Cut-Resistant Gloves with Repeated Laundering & Industrial Use, J Jajpura, J Kaushik, A Bhardwaj, N. Kumar, Man-Made Textiles in In-dia, 303-309, September 2018;

3. Cut-Resistant Performance of E-glass Reinforced Para-Aramid Gloves with Repeated Laundering & Industrial Use, J Jajpura, J Kaushik, A Bhardwaj, N. Kumar, International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 5, Issue X, 297-301, 2017;

4. Heat Protection Performance of E-glass Reinforced Para-Aramid gloves after Repeated Laundering and Continual Industrial Use, J Jajpura, J Kaushik, A Bhardwaj, N. Kumar, International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 5 , Issue X, 291-296, 2017;

5. New Third-Generation Protective Clothing from High Performance Polyethylene Fibre, K. M. Kirk-land, T.Y. Tam, High Tech Fibrous Materials, ACS Symposium, 457, 1991;

6. Protection against Mechanical Hazards: HPT Flex? Gloves & Fabrics, A. Katyal, N. Kumar, Asian Textile Journal, August 2019;

7. A New Test Method to Evaluate the Cut-Resistance of Glove Materials, J. Lara, Performance of Pro-tective Clothing: Vol 5, ASTM STP, 1996;

8. Personal Protection: Protecting our Skilled Hands Against Heat & Mechanical Risks, N. Kumar, Textech Communique, Vol 1, Issue 3, September 2012;

9. Personal Protection: HPT Aracore? Gloves for Protection Against Thermal & Mechanical Hazards, N. Kumar, Man Made Textiles, India, August 2017;

10. Technical Textiles for Protection Against Thermal Hazards EN 407-

2004, A. Katyal, N. Kumar, Indian Textile Journal, 51-55, April 2020;

11. Innovative Textiles for Personal Protection (Indian Provisional Patent Application Number 201911016122) N Kumar, 2019;

12. Balanced Ring Spun Core Yarn, Indian Provisional Patent Application Number 202011004920, N Kumar, 2020;

13. A Three-Dimensional Textile & a Process of preparing the same, 202011012314, N Kumar, 2020;

14. An Airlaid Textiles with Improved tensile strength, Indian Provisional Patent Application Number 202011013836, N Kumar, 2020.

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