Resistance to Bullets, Knives, Stabs and Needles According to Current Standards, Procedures and Users' Expectations

G. Grabowska, J. Blaszczyk,
I. Kucinska

The Institute of Security Technology "Moratex"

1. INTRODUCTION

Public security menace may be considered on many areas, however two of them certainly mould recognition among the society.

First area subject to social penetrating assessment are so called common crimes; linked with day-to-day threat i.a.: breaking and entering, carjacking, scrimmages and batteries or riots at sports events.

Second area of threat towards public security isn't visible everyday and the information are passed by media. They are violent stick-ups at banks and exchange offices, mafia old scores pay-offs, or most tragic – acts of terror. This group of threats is made by their executors – professionally trained individuals, determined, ready to die theirselves. Mortal casualties and wounded should be expected at such happenings, also among officers.

Protective activities are also implemented in the countries where virtually each clannish, criminal or terrorist fighting squad is armed with armour-piercing grenade launcher and machine guns, and bomb attacks are typical means of propaganda campaign.

2. THE GOAL

The response to threats getting deeper nowadays is elaborating more effective ballistic protection means including protective vests in both domestic and foreign research institutes.

Therefore in the recent years, when designing the protective vests, an aspect of increasing the wearer's body protected area i.a. has been considered. Thus contemporary vests often protect not only front and back of a body, but also sides, neck, inguinal arteries, crotch, arms from elbow to collar-bone, thighs etc.

Moreover, the bulletproof vests are often enriched with knife-, stab-, or needle-proofness, The functionalities are not defined in Polish Standards in due. Therefore inaccurate expressions are often included into tender specifications. This is why the present article attempts to put the matters in order, the test methods are specified as well as the requirements for bullet-, knife- and stab-proofness, and the guidelines for gaining the needle-proofness for protective vests too.

3. TEST METHODS

3.1 Ballistic covers

The matters of ballistic resistance is described i.a. in the following standardising documents:

- PN-V-87000:1999 Ballistic covers. Bullet- and fragment-proof vests. General requirements and tests.
- NIJ Standard 0101.04:2001 Ballistic Resistance of Personal Body Armor.

Contemporary ballistic covers usually feature maximum resistance available for soft ballistic inserts:

- class 3 according to PN-V-87000:1999, protection against 7,62mm lead core pistol 5.5g bullet at the impact velocity of 420^{+15} m/s, shot from 7,62mm Tokarev pistol model 33 TT,
- level IIIA according to NIJ Standard 0101.04, protection against 0,44" Magnum JHP 15.6g bullets at the impact velocity of 436^{+9} m/s and 9 mm Parabellum FMJ 8.2 g bullets at the impact velocity of 436^{+9} m/s.

In order to gain such resistance, one of the worldwide known ballistic materials is mostly applied i.e. based on para-aramide fibres woven or non-woven featuring very high strength (Goldflex®) or non-woven material based on polyethylene fibres featuring very high strength (Dyneema®). Sometimes some anti-trauma liner find appear applicable for decreasing the deflection of background down to 25 mm.

3.2 Knife-proof covers

Despite continuous development of firearms, there is a constant threat of unchanged intensity since the dawn of history; the threat from cold steel: knife, stab, needle.

So the question appeared:

- whether ballistic covers made conformable to class 2 or 3 according to PN-V-87000:1999 Standard and to the level IIIA according to NIJ Standard 0101.04 do protect against cold steel, and
- to what pitch and with what to enrich the ballistic covers of class 3 according to PN-V-87000:1999 Standard or level IIIA according to NIJ Standard 0101.04 in order to provide such protection, with no remarkable increase of their stiffness and mass.

To answer this question the test methods shall be invoked as well as the users' expectation level.

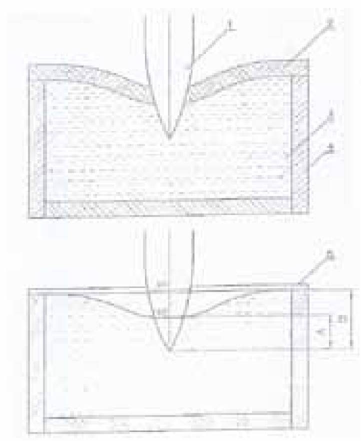
Unfortunately, the Polish Standard PN-V-87000:1999 does not include such tests, therefore the following test procedures have been formulated in the accredited Ballistic Laboratory of „MORATEX" Institute:

- **Procedure ITWW „Moratex" PBB-06:1996 "Impacting tests. Determining the resistance of set of samples to piercing with cold steel" developed on a basis of ISO/DIS 14876-2:1996 Standard "Body armour – Part 2: Stab resistant Vests".**

The compilation of object test conditions according to the above procedure is shown in Table 1.

Table 1. Tested objects' (panels) protection level depending on the number of hits with falling edge of military knife model 92, on angle and on impact energy

Protection level	Kind of test edge	Impact energy [J]	Number of hits at the angle of 0°
1	Military knife model 92	25,0 ± 0,50	
2	Military knife model 92	35,0 ± 0,70	6
3	Military knife model 92	45,0 ± 0,90	



1. edge
2. tested sample
3. basis
4. box
5. metal slat

SG – upper imprint
SD – lower imprint
A – penetration
B – penetration and deformation

Fig. 1. Knife hit – definitions of names and concepts

- **Procedure ITB „MORATEX" PBB – 08:2006 "Impacting tests. Determining the resistance of personal armour to an edge" – procedure compliant with NIJ STANDARD 0115.00**

The compilation of object test conditions according to the above procedure is shown in Table 2.

Table 2. Protection level of tested objects (panels) depending on energy of hit with P1 and S1 edges

Protection level	Energy of hit with E1 [J]	Energy of hit with E2 [J]
1	24 ± 0,50	36 ± 0,60
2	33 ± 0,60	50 ± 0,70
3	43 ± 0,60	65 ± 0,80

Table 3. Number of hits with falling edge P1 and S1 depending on angle and energy of hit (see Table 2)

Number of hits	Angle of hit	Test edge	Energy of hit
1	0°	P1	E1
1	0°	P1	E2
1	0°	S1	E1
1	0°	S1	E2
1	45°	P1	E1
1	45°	S1	E1

Table 4.Number of hits with falling edge (stab) for each of tested panels depending on angle and energy of hit (see Table 3)

Number of hits	Angle of hit	Test edge	Energy of hit
1	0°	Stab	E1
1	0°	Stab	E2
1	45°	Stab	E1

The criteria of assessment is the depth of penetration Gw of the testing edge – the following quantities are assumed acceptable:

For E1 - max Gw = 7 mm
For E2 - max Gw = 20 mm

4. MATERIALS

The tests were executed on the ballistic panels as well as the bullet-, knife- and needle-proof vests with soft inserts, made of:

- fabric based on para-aramid fibres featuring very high strength,
- non-woven material based on para-aramid fibres featuring very high strength - Goldflex®,
- non-woven material based on polyethylene fibres featuring very high strength - Dyneema®.

In some cases the anti-trauma poly-carbonate liners were additionally applied to gain decrease of deflection down to level of 20 mm. In some products were also applied the anti-trauma liners made of para-aramid fibres featuring very high strength and coated with silicon carbide - SRM® .

5. RESULTS AND DISCUSSION

5.1 Knife-proof covers

The comprehensive tests of resistance to piercing with military knife model 92, edge types P1, P2, S1 and S2 as well as with the stab have been done at the accredited Ballistic Laboratory on the ballistic armours of class 2 and 3 according to the PN-V-87000:1999 Standard and of level IIIA according to NIJ Standard 0115.00, following the procedures PBB-06 and PBB-08, respectively.

The results were collected of tests on samples compliant to class 2 according to PN-V- 87000:1999 Standard, made of non-woven polyethylene sheets Dyneema® with anti-trauma liner made of 0.75mm thick polycarbonate. The hit energy of 10 J was achieved for such an arrangement while providing the maximum depth of penetration as low as 3 mm (Fig.1).

The standalone GoldFlex® samples compliant with class 3 according to PN-V-87000:1999 Standard, as well as the samples compliant with class 2 according to PN-V-87000:1999 Standard made of GoldFlex® combined with several-ply liner of SRM® yielded the maximum depth of penetration 20 mm (Fig. 1) at the hit energy of 10 J

The tests above have given results below class 1 of knife-proofness according to the procedure ITWW „Moratex" PBB-06:1999, therefore they are only executed upon customer's explicit request.

Top results have been achieved from tests on the samples compliant with class 3 according to PN-V-87000:1999 Standard, made of non-woven polyethylene sheets Dyneema® pith 0.75mm or 05mm thick polycarbonate anti-trauma liner. The hit energy of 35 J was achieved for such an arrangement while providing the maximum depth of penetration as low as 4 mm (Fig.1) which means class 2 according to the procedure ITWW „MORATEX" PBB – 06:1996.

Samples compliant with class 3 of the PN-V-87000:1999 Standard, made of woven CT 714® aramide fibres were combined with several-ply liner SRM® have been also tested. The hit energy of 45 J was achieved for such an arrangement while providing the maximum depth of penetration as low as 4 mm (Fig.1) which means class 3 according to the procedure ITWW „MORATEX" PBB – 06:1996.

In order to gain resistance within class 1 of knife-proofness according to procedure ITB „MORATEX" PBB – 08:2006. the optimisation research has been done, which allowed for determining the number of plies in the SRM® liner for each sample made of various ballistic materials.

In the course of tests with P1, S1 edge and the stab and applied energy of 24 ± 0,50 J the maximum observed depth of penetration was 17 mm, which does not exceed the limit of 20 mm defined by the procedure. Applying the liner made of SRM® increases the vest's mass by about 1 kg.

The results discussed above have been gained on a basis of flexible textile materials, known at he turn of 2008/2009, further improvement of personal armour's resistance to knife is currently being achieved by applying steel chain mails.

5.2 Needle-proof covers

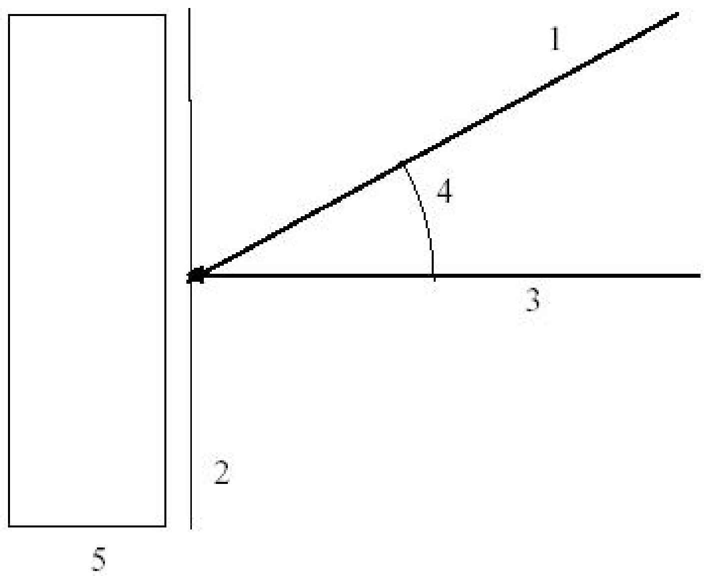
Gaining the resistance to needle is a separate problem.

In the correctional institutions a needle is a big threat, especially in the age of AIDS. The knife-, needle-, and bullet-proof covers are demanded, as well as just needle-proof ones.

World-wide known Standards do not cover the matter, therefore „MORATEX" Institute has elaborated innovative testing procedure, of extra-regional range - PBB-12:2008 Impacting tests. Determining the resistance to piercing with needle.

Table 5. List of conditions of testing the objects

Protection level	Kind of needle	Energy of impact [J]	Mass of carriage [kg]	Number of hits at the angle of 0°
1	- 21 G (0,8mm x 40mm)	2,5 ± 0,1	2,50 ± 0,5 kg	6 (3 on each needle)
2	- 18 G (1,2 mm x 40 mm)	25,0 ± 0,5		



The legend of figure:
1. the line of needle falling
2. the tangent surface
3. the perpendicular to tangent surface
4. the angle of hit
5. the tested sample

Fig. 2 Schematic sketch of angle of hitting a sample with an edge

The tests of needle-proofness executed with the energy of 25+0.5 J allow for the statements:

- only the ballistic insert made of Dyneema® compliant to class 3 of ballistic resistance according to PN-V-87000:1999 is resistant to needles and achieves class 2 of needle-proofness according to the procedure PBB -12:2008,
- for ballistic inserts resistant within class 3 according to PN-V-87000:1999, made of GoldFlex® aramide fibres woven or non-woven, to achieve the class 2 of needle-proofness according to procedure PBB-12, application of several-ply liner of SRM® is necessary,
- several-ply liner of SRM® applied into the ballistic cover of class 3 according to PN-V-87000:1999 makes them knife-proof respectively within class 2 and 3 according to procedure PBB–06 or knife-proofness within class 1 according to procedure PBB-08 and provides also needle-proofness at the hit energy of 25+0.5 J, while achieving class 2 of needle-proofness according to procedure PBB-12:2008 regardless of arrangement together with the ballistic insert or separate,
- applying a several-ply SRM® liner allows for achieving the class 2 of needle-proofness according to the procedure PBB-12 for each ballistic material, no matter which class according to PN-V-87000:1999.

6. SUMMARY

The article presents possibilities of designing various kinds of armour based on world-wide known flexible textile materials.

The following kinds of protection was discussed;

- ballistic,
- ballistic and knife-proof,
- ballistic, knife-proof and needle-proof,
- needle-proof ones.

7. SOURCES

The text makes use of reports of tests executed at the accredited ballistic laboratory of „MORATEX" Institute, which have been in-depth analyzed and discussed in the works done within a frame of statutory activity, entitled „Developing new commercial solutions of design, material and technology for new products of special dedication" – Institute of Security Technology „MORATEX", 2008.

Literature

1. *NIJ STANDARD 0101.04 Ballistic Resistance of Personal Body Armor.*
2. *NIJ STANDARD 0115.00 Stab Resistance of Personal Body Armor.*
3. *PN-V-87000:1999 Ballistic covers. Bullet- and fragment-proof vests. General requirements and tests.*
4. *Procedure ITWW „MORATEX" PBB-06:1996 Impacting tests. Determining the resistance of set of samples to piercing with cold steel.*
5. *Procedure ITB „MORATEX" PBB-08:2006 Impacting tests. Determining the resistance of personal armour to an edge – procedure compliant with NIJ STANDARD 0115.00.*
6. *Procedure ITB „MORATEX PBB-12:2008 Impacting tests. Determining the resistance to piercing with needle.*

Bullet – Proof Vests with the Ballistic Inserts Based on the Fibrous Composites

J. Polak, I. Kucinska, G. Grabowska, J. Blaszczyk, E. Ledwon, R. Romek, M. H. Struszczyk

The Institute of Security Technology "Moratex"

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Key Project No. POIG 01.03.01-10-005/08 entitled: „Modern ballistic body armours and covers for transportation means as well as for buildings made on a basis of textile composites".

Introduction

The Institute of Security Technology „MORATEX" for more than 15 years works the solutions of scientific and research matters as well as design and technology of individual ballistic armour, including torso armour. The Institute has developed a line of protective vests designs, within the frame of research projects as well as scientific and research works of the statutory activity, They were tested in the Institute's laboratories (metrological and ballistic one) accredited by Polish Centre for Accreditation. A big group of those designs are bullet-proof vests featuring enhanced ballistic resistance within the area of hard inserts based on the fibrous composites. A creative idea was behind virtually every aspect of the developed ballistic armour for torso excluding composite bullet-proof panels, which aren't manufactured in Poland yet. However it is necessary to emphasize, that the „MORATEX" Institute has a batch of test-experience of the design of composite ballistic products [1 - 2], including the panels for bullet-proof vests [2]. Thanks to that, among others, it is possible to continue the works within started project No.POIG.01.03.01-10-005/08 "Modern ballistic body armours and covers for transportation means as well as for buildings made on a basis of textile composites", where the composite inserts for vests with selected vest designs are one of the developed products' groups. The above-mentioned project is carried out in Priority Axe 1: Research and developing of modern technologies, 1.3 Activity: Supporting the R&D Projects dedicated to enterprises, accomplished by scientific bodies, 1.3.1 Sub-activity: Development Projects.

1. Recently developed bullet-proof vests with ballistic panels based on fibrous composites

In 2008 some modern solutions of bullet-proof vest designs have been developed and made-up