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QUO VADIS COMBAT HELMET?

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ABSTRACT
First protective helmets appeared 1 000 years ago, but their mass usage began with First World War. Modern combat helmet made from composite material was put on the market at the beginning of new millennium. Usage of composite materials for combat helmet production gained several benefits: helmet became lighter, more comfortable to wear, easier to maintain and what is the most important - the level of ballistic protection significantly enhanced. In this paper the authors tried to give the new perspective on combat helmet. Also, the methods for ballistic testing of combat helmets are described.
Keywords: combat helmet, ballistic, trauma

1. INTRODUCTION
Helmet is a head cover which main assignment is to protect the head from bomb fragments, infantry firearms and all kinds of hard high velocity flying objects. It is mostly round shaped, made from metal, leader, textiles, plastic or composite material, with different accessories like visor, neck cover, etc. There are two basic reasons why combat helmet has become the main element of basic military equipment for every army soldier in the world. The first reason is because the head is the most sensitive part of the human body. The second reason is connected with the result of army investigations that showed that 80 % casualties in war are from bomb fragments and only 20 % from bullets. Also, 45 % of all bombshell fragment injuries are on soldier's head. [1]

But, despite of all endeavours of helmet producers, it is necessary to stress that it is still impossible to achieve the full ballistic head protection (protection against high velocity rifle bullets). There are two main reasons for that: for full ballistic protection the weight of combat helmet would be unacceptably high, and the kinetic energy of bullet would break soldier's neck. [2]

2. MODERN COMBAT HELMETS
Although at the beginning there was an idea that one helmet can be used for all the purposes, soon it became clear that because of all the demands that helmet must fulfil, it is necessary to have at least five different helmets. These five types of helmets and some of their demands are specified in Table 1. One of the most complex problems connected with design of new combat helmet is the compatibility between helmet and the rest of military equipment. Designers must bear in mind the nature of soldier's assignments, his comfort and of course the level of ballistic protection. One way for solving these problems is close connection between designers and soldiers. [3]

Inner equipment of combat helmet must be comfortable and easily adjustable. Also it has to allow necessary head ventilation. Type of material used for helmet production always depends on technical compatibility and level of ballistic protection. Today, combat helmets are mostly produced from aramid fibres, which compared with steel plate, *PA*, polyester or glass fibres meet strict army demands. Test results have showed that aramid materials have very high ballistic resistance and low weight. [4] Comparison of mechanical properties of materials used for combat helmets production is presented in table 2.

Table 1. Types of helmets [3]

Priority number	Infantry helmet	Parachute helmet	Tank helmet	Police helmet	Bomb squad helmet
1.	comfort	weight	good tightening	ballistic surface	fragments protection
2.	fragments protection	stroke protection	compatibility	stroke protection	striking wave protection
3.	bullet protection	safe tightening	stroke protection	comfort	ballistic surface
4.	compatibility	stability	fragments protection	compatibility	communication
5.	stroke protection	fragments protection	comfort	weight	stroke protection
6.	weight	compatibility	weight	visor	compatibility
7.	stability	comfort	price	stability	price
8.	price	stability		price	

Table 2. Mechanical properties of fibres [4]

Material	Tensile strength N/tex	Tensile modulus N/tex	Elongation %	Density g/cm^3	Temperature stability ºC
Zylon®	5.8	280	2.5	1.56	650
Kevlar®	2.8	120	2.4	1.44	550
Dyneema®	3.3	99	3.7	0.97	150
Glass fibre	1.35	72	5.2	2.50	-
Carbon fibre	1.9	134	1.4	1.85	-
Steel thread	1.77	25	1.2	7.86	-
PA fibre	0.8	5	20	1.14	110
PP fibre	0.6	6	20	0.90	110

3. BALLISTIC TESTING

Ballistic demands for military and police protection are defined with national standards. Every state with big army forces has its own ballistic demands and testing procedures and methods. But in most cases the testing methods are similar to *NATO* standard. The biggest differences are in types of ammunition used for testing. There are two ballistic standards that are mostly used: *N.I.J. Standard 0101.04* and *STANAG 2920*. [5,6]

N.I.J. standard is applicable to all ballistic resistant materials (armour) intended to provide protection against gunfire. Many different types of armour are now available, which range in ballistic resistance from those designed to protect against small-calibre handguns to those designed to protect against high-powered rifles. Ballistic resistant materials are used to fabricate portable ballistic shields, body armour and helmets. The ballistic threat posed by a bullet depends, among other things, on its composition, shape, calibre, weight, and impact velocity. Because of the wide variety of cartridges available in a given calibre, and because of the existence of hand loads, armours that will defeat a standard test round may not defeat other loading in the same calibre. For example, armour that prevents penetration by a 357 Magnum test round may or may not defeat a 357 Magnum round with a higher velocity. Similarly, for identical striking velocities, no deforming or armour-piercing rounds pose a significantly greater penetration threat than an equivalent lead core round of the same calibre. The test ammunitions specified in table 3 represent common threats to the law enforcement community. [5]

The aim of *STANAG 2920* is to standardise guidelines for determining the ballistic limit protection of body armours, helmets and the materials used in the manufacture of these items. The test results are intended to aid comparison of degree of ballistic protection provided by the various body armours. The test projectile may be any bullet against the armour is intended to give protection but in case of fragment protective armours, it should be one of the series of fragment simulating projectiles defined in *US MIL-P-46593*. The *V50* ballistic limit velocity for the material or armour is defined as that velocity for which the probability of penetration of the chosen projectiles is exactly 50 %. [6]

Table 3. N.I.J. Standard 0101.04 Ballistic resistance of personal body armour (2001) [5]

Threat Class	Test bullet	Bullet weight (g)	Bullet velocity ($\pm 9.14\ ms^{-1}$)	Max. back face deformation (mm)
I	.22 calibre LR LRN .380 ACP FMJ RN	2.6 6.2	329 322	44
IIA	9 mm FMJ RN 40 S&W FMJ	8.0 11.7	341 322	44
II	9 mm FMJ RN 357 Mag JSP	8.0 10.2	367 436	44
IIIA	9 mm FMJ RN 44 Mag SJHP	8.2 15.6	436 436	44
III	7.62 mm NATO FMJ	9.6	847	44
IV	.30 calibre M2 AP	10.8	878	44
LR LRN – long rifle lead round nose, JSP - jacketed soft point, FMJ – full metal jacketed, SJHP – semi jacked hollow point, RN – round nose, AP – armour piercing				

4. COMBAT HELMET *ŠESTAN - BUSCH*

Combat helmet *Šestan – Busch* (Figure 1) is laminated composite product made out off aramid prepreg layers according to specially developed cutting and assembling plans. The number of layers depends of the wanted level of ballistic protection, i.e. more layers - higher ballistic protection. Process used for helmet shell production is compression moulding. After pressing, shell can be painted or a special UV stable foil can be put on the shell's outer surface. The next step is assembling of inside equipment to the shell. Task of inside equipment is to absorb energy of a projectile (bullet, fragment) and to provide maximum comfort to a soldier.

Figure 1. Company Šestan – Busch *and its helmets*

Also, company *Šestan-Busch* has a new production process named *EBSP* process. The active (conventional) process uses only 50 % of the material of the helmet shell for the absorption of the ballistic energy, after the shot channel has been cracked open. The *EBSP* – process uses 100 % of the material of the helmet shell for the absorption of the ballistic energy, after the shot channel has been cracked open. These differences are showed in Figure 2.

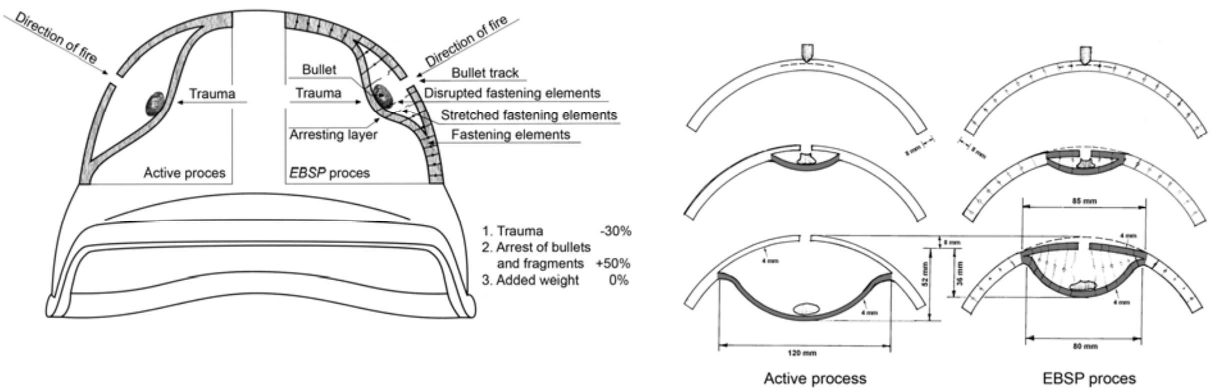

Figure 2. Comparison of active helmets production process and EBSP production process

Classic way to fix inside equipment to a shell is by using three or more bolts. Nevertheless there is a possibility that projectile hits helmet exactly in the place where bolt is positioned, so instead one projectile there will be two. This is called secondary fragmentation. To avoid that, new combat helmets made in *Šestan –Busch* have no bolts. No bolts technology combined with EBSP production process results in the best helmet there is (for the moment being). Figure 3 presents a comparison of classic helmet and helmet with no bolts technology. Both helmets were shot with *Para 9 mm* bullets. Velocity of bullets was 426 ms^{-1}. In case of helmets with bolts (top line) a bullet penetration point is visible while in case of no bolts technology helmet there are no penetration points and the trauma is much lower.

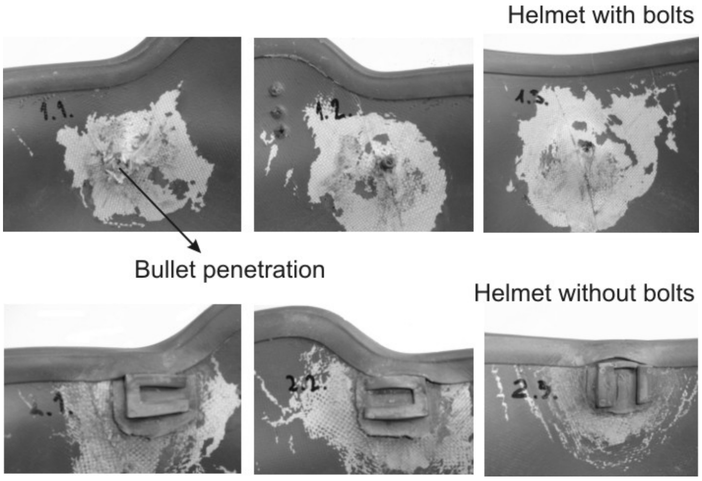

Figure 3. Comparison of classic helmet and no bolts technology helmet

5. CONCLUSION

Human head, centre of nerve system, is the most sensitive part of a body, so with its protection the possibility of injury decreases, while possibility of surviving in all of dangerous and hazard environment increases.

First helmets were made of hard fabrics strengthened with metal plates. Parallel with weapons development, protective body armour was also improving with special intention to the best possible protection and comfort of a soldier.

Except above mentioned reasons, helmet improvement is also the result of war method and location. Battles are starting to be fought in the streets of cities. Because of that, the new helmet has to have the high resistance to rifle bullets (high velocity, high weight, special construction).

Finally it must be noted that despite all efforts and new materials which are continuously developing, there is no combat helmet on the world that is comfortable and light, and that can stop high velocity projectile. So the process of developing and producing helmets is compromise between many confronting demands.

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