Future Tasks of Lightweight-Polymer Combat Helmets

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***Abstract*—In the military and police sector, the endangerment for the forces has risen over the last decades. Especially police forces are facing new threats due to increased terrorist activity in western European cities and a rising propensity to violence. This development makes it necessary to provide state of the art protection for patrol officers. This includes helmets made of ultra-high molecular weight polyethylene (UHMWPE) to lower the overall weight of equipment and increase the combat value of the forces by providing more comfort and possibilities for attachments. However, at the moment these types of helmets are not ready to provide the required level of protection against projectiles. The intention of this paper is to provide background information about those new threats and to mention first ideas how to tackle the emerging problems of current UHMWPE combat helmets.**

Keywords-applied research; fiber-reinforced plastics; optimization; armor systems; ballistic trials.

I. Introduction

Combat helmets are a key factor in personal protection for military and police forces. Rapidly changed threats on missions, especially for police patrol officers [5] and soldiers in stabilization missions [1], prove that protection needs a new ability profile. This work in progress provides background information to specify the problems and first ideas how to solve these problems. The overall aim is to create a ballistic combat helmet that meets the union of test center for armored materials and constructions 3 (Vereinigung der Prüfstellen für Angriffshemmende Materialien und Konstruktionen 3) (VPAM 3) regulations and the technical directive "System Ballistic Helmet" 5/2010 [2].

A. *Structure of the Paper*

The paper is structured as follows. In Section II, there will be brief information about the history of combat helmets and their materials through time. In Section III, threats for ballistic protection will be mentioned. Section IV is about the disadvantages of current UHMWPE combat helmets and Section V is about the advantages of lighter polymer combat helmets. In the final section, Section VI, the aim will be concretized and explained.

II. History

Combat helmets have a long tradition. Before the invention of gunpowder, they were used as a protection against blunt trauma and cuts. They were designed to deflect, e.g. a sword, so there was less residual energy on the head. Later on, helmets were mainly worn for pageantry and unit recognition until the First World War began.

A. *Combat Helmets in the 20th Century*

Due to the massive use and increased lethality of artillery, the German forces introduced the "Steel Helmet Modell 1916" in 1915. All fractions introduced nearly the same helmet models in mode of action at this time, which were made out of basic steel. These helmets were only able to stop the primary threat of that time: fragmenting projectiles of artillery bombs, they were not able to stop bullets because of the available materials. During the Second World War, the U.S Military introduced the M1 in 1942, which was made out of "Hadfield steel". This helmet was used by the German armed forces until the 1990s. Problems with this type of steel helmet occurred because the helmets were too heavy and reduced the view, hearing and mobility of the wearer. The M1 was followed by a very new generation of combat helmets, which was made of aramid. Aramid was the first synthetic bulletproof material and was invented in the 1960s by DuPont.

B. *Combat Helmets in the 21st Century*

As a replacement of the M1, the German armed forces introduced the "Combat Helmet, Ground Forces" made of aramid. In addition, they used the new retention system "NOSHA", which provided a better shock absorption and air circulation. The next stage of development was – again – a totally new material: the ultra-high molecular weight polyethylene fibers (UHMWPE). With hybridization techniques, the U.S Military developed a new generation of combat helmets in 2010, the so-called "Future Assault Shell Technology" (FAST). The German armed forces also use FAST with the name "Combat Helmet Special Forces". Also, FAST helmets were added to the concept "Infantry of the Future" (see Figure 1) [6]. Moreover, this generation has

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Figure 1. FAST helmet with the concept “Infantry of the Future” [6].

improvements at the retention system with a multi-pad and four-point retention system. In addition to the reduced weight, the FAST helmet provides higher comfort.

III. NEW THREATS

A. *Changed Threats for Police Forces*

Threats for police forces and the military have changed a lot over the last decades. Police forces face international terrorism, especially in western European cities. More and more, terrorists are military trained and equipped with military weapons and gear. Time is the most crucial point in chaotic situations, so patrol officers have to engage first [6]. Only a combination of ballistic vests and ballistic helmets provides the necessary level of protection in such situations. Especially patrol officers are facing unpredictable threats on duty so their helmets have to provide protection against multiple threats. Apart from ballistic threats, hits with blunt and sharp weapons, fire and chemicals are common threats for them. The willingness of patrol officers in Baden Wurttemberg to wear their helmets also in common situations like brawls and skirmishes make it necessary to provide good shock absorbing attributes against blunt trauma [5].

B. *New Threats for Military Forces*

But also, military forces are facing changed threats. Statistics of the American Operations in Afghanistan and Iraq show that head and neck wounds are increasing. The distribution of wounds shows that 30% of all wounds are in the head and neck area (based on injuries/treatments from hospitalization, including persons who died of wounds) [1]. The main threats at patrol missions are improvised explosive device (IED) attacks and ambushes with assault rifles. Due to the increased use of IEDs, blast associated head injuries, e.g., fragments, have increased compared to gunshot wounds. Furthermore, the characteristics of the fragments have changed compared to mortar and artillery shells. This can lead to a different impact behavior. In addition, blunt traumatic injuries have increased because they are linked to blast events. Nevertheless, blunt trauma is also associated with noncombat situations like vehicle crashes, parachute drop accidents or falls. Common blunt trauma threats have an impact velocity of 6.1m/s, which is equal to a drop of 1.9m [1]. The primary ballistic threat is caused by assault rifles of type AK-47 (7.62x39-mm) and owing to the increased close combat situation pistols emerging as threats, for example Makarov (9x18-mm) or Tokarev (7.62x25mm). Altogether, the America Department of Defense locates the main threat of infantry weapon at 5.56-mm and 7.62-mm rounds at muzzle velocity from 735m/s to more than 800m/s. This corresponds approximately VPAM 6 to VPAM 7 [1].

IV. DISADVANTAGES OF ACTUAL UHMWPE COMBAT HELMETS

A. *Back-face Deformation*

Back-face deformation is one of the main problems of the actual UHMWPE combat helmets. On the one hand, the material has very good attributes against bullet penetration. On the other hand, the energy of the bullet is not well dispersed (see Figure 2). This leads to the so-called back-face deformation, the material indent and the residual energy appeals on the head. For German police helmets, the residual energy has a maximum tolerance limit of 25 Joule [5]. The residual energy could lead to possible head injuries like long linear skull fractures or closed head brain trauma. At the moment, it is unclear whether the injuries occur from the deforming of the helmet onto the head or from acceleration loads transmitted through the helmet padding to the head. In addition, the test methodology with clay to display back-face deformation is not totally linked to head injuries. The human skull behavior in such situations is inadequately represented in the actual test methodology with clay. Especially in the area of back-face deformation there is a lot of potential for necessary improvements.

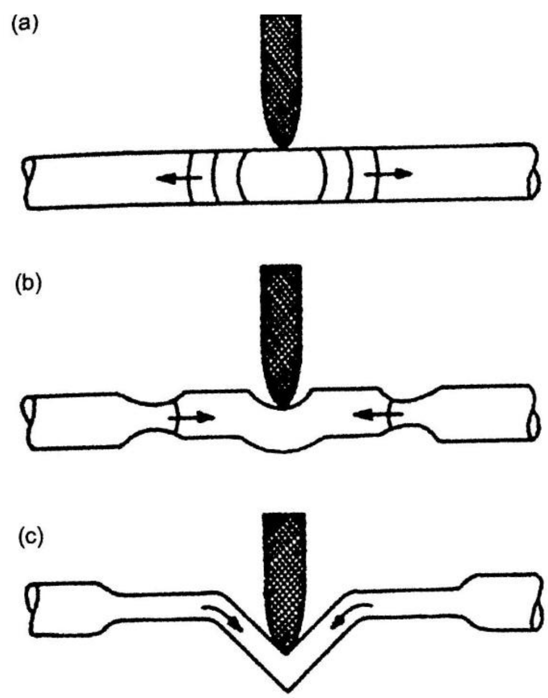

Figure 2. Energy distribution in a fiber impacted by a projectile [3].

B. Blunt impacts

In addition, the current generation of UHMWPE combat helmets have deficits with blunt impacts. The current combat helmets can only absorb impacts with a velocity of 3m/s or 45J drop energy [1]. As mentioned earlier, common blunt traumas occur with a velocity of 6.1m/s. In fact, blunt traumas occur especially in noncombat and training situations. Therefore, there needs to be an improvement, because most of the time the wearer of the helmet is in such a situation.

V. COMBAT HELMET AS MODULAR HEADGEAR SYSTEM

Combat helmets will evolve from a device only used for protection to a multi useable platform to increase the survivability and efficiency of the wearer. This includes basic attachments like active ear protection, flashlights or counter weights to provide a stable weight balance. Moreover, the helmet platform can be used to increase the leading ability of the group by adding integrated voice radio, a head up display with important mission information or health sensors to monitor the group vital functions. This would increase the situational awareness of the group leader and would lead to an overall increase of safety during missions. Also the combat value of every solider or policeman can be increased by adding feeder plates for night vision, the ability to wear protective masks against warfare agent or attaching standardized rails like MIL-STD 1913. Of course, the possibilities are limited due to the weight the wearer can handle over the duration of the mission. So, if the combat helmet weighs as little as possible, there are more possibilities for attachments and this leads to earlier mentioned advantages.

VI. AIM OF THE PROJECT

First of all, the aim is to create a UHMWPE combat helmet, which meets the regulations of the police institute of the German police academy in Muenster, this regulation is based on the technical directive “System Ballistic Helmet” (Technische Richtlinie “Gesamtsystem Ballistischer Schutzhelm”) [2] of 5/2010. That implies that the project has the focus on police helmets.

A. Threats Which the Helmet has to Withstand

The main focus of the research is on the ballistic attributes of the helmet. So the helmet has to provide protection against soft-core projectiles 9mmx19 fired by small arms and machine pistols. This is comparable to VPAM 3. Overall, our aim is also to meet the regulations of VPAM 4 to compete with the current generation of titanium helmets and provide a state-of-the-art alternative [6]. The mentioned titan helmet, which is actually used, by the state of Baden Wuerttemberg is the “Hoplit” model by Ulbrichts Witwe GmbH (see Figure 3). As mentioned, earlier protection against blunt trauma is also a challenge for combat helmets. The residual energy has to be lower than 25 Joule.

Figure 3. “Hoplit F” by Ulbrichts Witwe GmbH [5]

B. Constructional Problems

At the moment, the material has a reliable protection against projectile penetration. Also, the material in a possible helmet shape provides a reliable protection. It has to be verified in which areas the protection is effective. Especially near the edges of the calotte, it is possible that the protection efficiency is much lower compared to the central areas. The actual titanium helmets have an efficiency distance of 10mm to the edges. All in all, these helmets provide an effective protection area of 90% [5]. As with aramid helmets, which have a much lower protective area, the fiber structure of the UHMWPE could also be a crucial point to provide a protection area as big as titanium helmets [4].

C. Possible Solutions

The main problem is back-face deformation. The residual energy dispensation of the material is too low in the current configuration. Now three possibilities to increase the dispensation have to be tested. Varying the direction of the material layers may mitigate the deformation. This has to be balanced between penetration and deformation of the material. The best penetration protection is provided when the layers are rotated by 90 degrees. Another idea is to use energy-absorbing materials under the calotte and as helm pads to reduce the residual energy. So, this means to integrate strictly the inlay into the helmet. Another possibility is to use two calottes, the first one as a ballistic shell and the second one as a shell to disperse the residual energy and to add absorbing material between the shells. The next step would be to precise the ideas and test their efficiency. After this, a combination of ideas could reduce the residual energy to a value lower than 25 Joule. Finally, the aim is to meet the regulations of VPAM 3.

VII. CONCLUSION

There are three main risks for ground forces: the main blast, blunt trauma and ballistic threats. Especially ballistic threats are challenging the UHMWPE helmets because of a high amount of residual energy. This leads to back-face deformation, which could result in live risking head injuries. In addition, this characteristic of injuries appears with blunt traumas. Some of the mentioned ideas could also lower the risk of blunt traumas even if the main challenge is to reduce back-face deformation. Moreover, an advantage of lighter helmets is, in addition to more comfort, the ability as a multi role carrier for attachments. This ability could improve the survivability and efficiency of the wearer. Nevertheless, the focus is to reduce back-face deformation to meet the regulations of VPAM 3. Possible ideas are to verify the direction of the layers, using energy-absorbing materials for the helmet inlay or using two decoupled shells with energy absorbing materials in between. Therefore, a combination or balance between the mentioned ideas is necessary. This means that the first step is to test how we can construct such a helmet with these possible solutions integrated. After this, ballistic tests are necessary to get an overview over the efficiency and how practical the solutions are. Especially the findings relating to the test methodology of the Review of Department of Defense Test Protocols for Combat Helmets [1] could be implemented into the test cycle. To conclude, back-face deformation is current the main problem of UHMWPE helmets due to the residual energy transmitted through the inlay. As mentioned in Section IV, also, the test methodology, to investigate the relation between back-face deformation and head injuries, has to be beheld and then maybe adjusted.

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