The design of lightweight armour sheets

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The design of lightweight armour sheets developed for protection from both sudden projectile impact and pressure wave at explosion will be presented. The sheet is based on aluminium foam which is reinforced with small ceramic platelets on the impact side and with steel mesh on the reverse side. The ceramic parts are embedded in the surface of aluminium foam. This design reduces dynamic stresses arising from impacted ceramics, thus protecting neighbouring ceramic parts. The reinforcing steel mesh on the reverse side stops the spreading of tensile cracks in the foam and allows for larger volume of the foam to be plastically deformed at localized impact. This leads to significantly improved impact energy absorption than in a case without reinforcements. The constituents are bonded together with aluminium foam during foaming in one technological operation, which makes the production cost-effective. Moreover, the absence of adhesives between ceramic and foam increases temperature resistance of the armour. The sheets can be prepared as flat panels or shaped shields.

1 Introduction

Over recent years the governments of many advanced countries (mainly among the armies of NATO member states) pay a great attention to humanitarian missions and to peace keeping operations in fight against terrorism. The results of the research and development of advanced materials with enhanced ballistic protection as well as armour protection systems are immediately applied on protection of soldiers and newly developed military equipment. Because of the strict requirements on the tactical mobility and airlift of military vehicles, the further increase in the armour weight is unacceptable. However, the weight reduction is the program priority in spite of continuous increase of the anti-armour weapon penetration capability. The change of conditions of military equipment usage is connected with the change in priorities in the area of its protection. In accordance with experience achieved from last humanitarian missions the main emphasis is placed on protection against sudden impact of blast waves at explosions of mines together with assurance of protection against small arms and splinters at least. Combat vehicles, fighter aeroplanes and helicopters have to be designed in such a way as to provide an optimised ballistic protection, armament and mobility according to the rational needs outgoing from analysis expected activities.

The search for weight reductions of armoured vehicles and possibility to improve the efficiency of vehicle protection against sudden impact of projectiles and splinters at mine explosions has led to development of new concepts for design of vehicular structures using sandwich constructions by the combination of various advanced materials, e.g. metallic foams and ceramics. The recently developed technique for foaming of shaped aluminium foam parts reinforced with expanded stainless steel sheet [1] offers an enormous application potential in lightweight construction of armoured vehicles. This technique enables new concepts in the design of future vehicles based on frameless

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monocoque structures with significantly reduced weight and improved blast protection. Moreover, the use of such structures in new military vehicles, fighter aeroplanes and ships can offer a unique combination of properties, e.g. high stiffness and low weight, high crash energy absorption capacity, good electromagnetic shielding and vibration and noise attenuation, that cannot be achieved by any conventional constructional approach.

2 Principals of the ballistic protection of armoured vehicles

Because the antipersonnel mine protection by armoured plates is mostly limited by its weight, the protected vehicles are designed to deflect blast and to assure survival of the crew, e.g. by:

- using antisplinter lining limiting the danger area in the case of penetration of projectiles and splinters
- prevention against consequences of explosion of transported ammunition by alignment of danger splinters trajectories
- protection against fire by using of fire-resistant and non inflammable materials that don´t evolve toxic fumes in the fire
- attenuation of blast waves effect at mines explosions by suitable constructional design using absorptive materials.

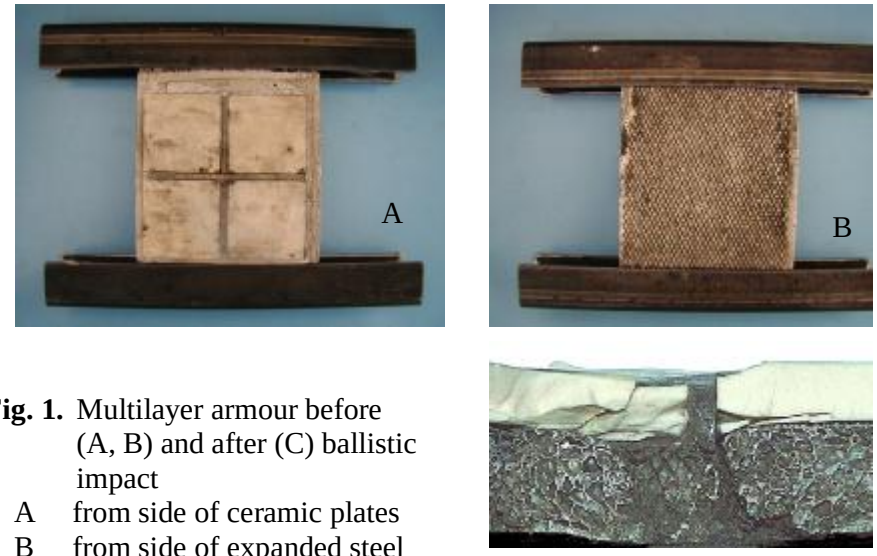

Fig. 1. Multilayer armour before (A, B) and after (C) ballistic impact
A from side of ceramic plates
B from side of expanded steel sheet

Recent heavy armoured carriers and combat vehicles did not use metallic foam for the purpose of ballistic protection. There were developed and implemented various new types of light armours based on aramid, glass and polyethylene laminates. The foam itself, of course, does not have the ability to absorb the energy of projectile or splinter because the projectile loading is realized on very small area. The combination of metallic foam with other advanced materials could not be effectively realized up to now.

Most ballistic requirements to bullet proof military are set by state standards (e.g. DIN, NIJ, STANAG 4569). Many organizations take part in the development of ballistic requirements. A threat level of a bullet is determined based on the bullet caliber, type, mass and velocity. The lightweight component for ballistic protection which uses reinforced aluminium foam as blast absorbing material should effectively satisfy the following requirements for body armour defined by STANAG (threat level I) standard: Rifles 7.62 × 51 NATO Ball, distance: 30 m, velocity: 833 m/s, elevation 0 – 30°. Fig. 1 shows behaviour of this multilayer armour at ballistic impact of projectile with 7.62 mm caliber.

3 Design of lightweight armour

The architecture of the component for blast protection has to be optimally designed with respect on required properties and expected effect. A typical lightweight component for ballistic protection should consist of (as shown in Fig. 2):

- surface layer capturing the pieces of fragmented ceramics
- layer of ceramic plates
- both absorption and adhesive layer of metallic foam reinforced with expanded stainless steel sheet
- layer of primer armour

The adhesive layer of aluminium foam reinforced with expanded stainless steel sheet is suitable for this purpose because of its enhanced ability to absorb blast energy. This layer provides damping of impact on the ceramics without transmission of stress peaks onto the neighbouring plates. The reinforced aluminium foam creates not only a tight bed for the ceramic plates but enables also the diffusive bonding of Al-foam with surface metal sheet. This multilayer armour can be therefore prepared during foaming in one technological step, which makes the production cost-effective. Moreover, the absence of adhesives between ceramic and foam make the armour fireproof, heat resistant and non inflammable. The sheets can be prepared as flat panels or shaped shields. The layer of primer armour should be the steel sheet or composite material with polymer matrix, eventually combination of both. The advantages of multilayer armour can be summarized as follows:

- considerably larger area of foam is deformed by using ceramic plates from impact side
- ceramics reduces penetration effect of projectile by blunting of its sharp spike
- undesirable tensile stresses can be minimized by reinforcing of foam with expanded steel sheet from backward side
- ceramic plates are tightly embedded in the aluminium foam - drop out of fragmented ceramics is avoided
- foam provides damping of impact on the ceramics without transmission of stress peaks onto the neighbouring plates
- aluminium foam enables diffusive bonding of absorption layer with surface metal sheet
- multilayer armour can be prepared during foaming in one technological step
- absence of adhesive increases temperature resistance of the armour

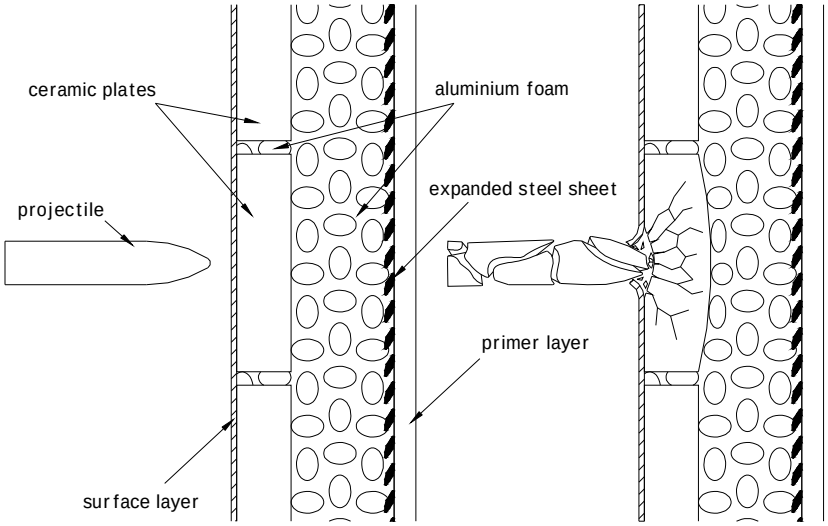

Fig. 2. Component for ballistic protection

4 Conclusions

According to this contribution there is a real possibility for applying of aluminium foam reinforced with expanded stainless steel sheet in design of future military vehicles, fighter aeroplanes, helicopters and ships. This new concept of their design which can be based even on frameless monocoque structures enable to reduce the weight by significantly improved blast protection mainly against sudden impact of blast waves at explosions of mines together with assurance of protection at least against small arms and splinters.

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