Volume XXIII 2020
ISSUE no.2
MBNA Publishing House Constanta 2020

Scientific Bulletin of Naval Academy

SBNA PAPER • OPEN ACCESS

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To cite this article: Catalin Adetu and Alina Elena Adetu, Scientific Bulletin of Naval Academy, Vol. XXIII 2020, pg.195-200.

ISSN: 2392-8956; ISSN-L: 1454-864X

doi: 10.21279/1454-864X-20-I2-027

Current requirements and solutions for ballistic protection of military helicopters

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Abstract. This article presents the current requirements and solution for ballistic protection of military helicopters, in order to protect the crew and the passengers. The ballistic protection is considered as the assembly of plates designed to provide protection against bullets, enemy projectiles or their sketches. Different types of shields and current ballistic protections solution installed on helicopters will be presented.

1. Introduction

Nowadays, the ballistic protection of helicopters represents a major issue. Regarding the fact that helicopters are performing attack and transport missions, they must be protected against air defense systems, in order to protect the crew and the passengers.

The history of armored technology is a history of projectile/armor competition. Thus, although there have always been pieces of artillery, ammunition or mine capable of destroying the armor, although it has often been declared useless and outdated, the ballistic protection has never been abandoned [7].

Basically, the ballistic protection is considered as the assembly of plates designed to provide protection against bullets, enemy projectiles or their sketches.

2. Types of shields

A number of criteria are used to classify shields [5]. Thus, depending on the impact behavior, we find the following types of shields:

- ***Homogeneous shielding***

The homogenous shields were the first types of shields used. The demands imposed on them often had a contradictory character, trying to find an optimal relationship between tenacity, hardness and breaking behavior with a pronounced ductile character.

- ***Layered shields***

The layered shields contain a succession of layers of materials with different modes of behavior due to the different physical-mechanical characteristics. The resistance of the shield is given by the mechanical resistance of the materials and by the variation of the density, in other words, by the succession of the layers, from the outside to the inside, on a probable trajectory of a penetrator [3].

The stratified shields are made in two constructive variants: in homogeneous package and in non-homogeneous package.

In the case of the shields layered in a homogeneous package, each layer shows structural homogeneity from the point of view of the physical-mechanical characteristics [2]. The simplest constructive variant is the homogeneous contactless stratified shield, its diagram being presented in figure 1.

The evolution of the layered shields registered an important qualitative leap by realizing the stratified shields in a non-homogeneous package, with a wide variety of plate combinations. The diagram of this type of shield is shown in figure 2. In modern shields, this intersection was occupied with composite materials, and these shields were called “composite shields”.

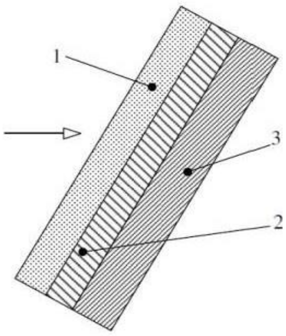

Figure 1. Structure of homogeneous stratified shield: 1-base shield plate; 2-gap that can be filled with air or fuel; 3-plate shield

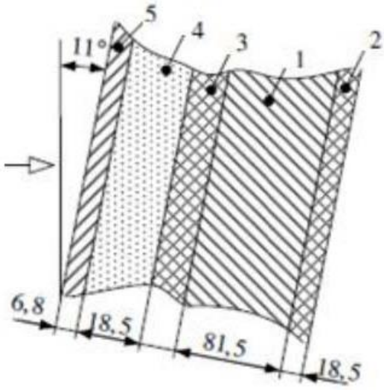

Figure 2. Structure of non-homogeneous stratified shield: 1-base plate; 2, 3-plate made of synthetic material; 4-gap with liquid, 5-outer plate made of hard steel

The concept of stratified shield was developed by experimenting with shields having contact plates. Experimental tests have shown that due to the alternation of structures with different densities, shear and bending efforts are attenuated.

Such a layered shield has different materials in its composition. These can be:

• shielding steel, homogeneous;
• ceramic materials;
• composite materials;
• air layers;
• low density polymeric materials, with or without insertions from thin sheets or metal powders;
• hard plastic material (as the last layer).

Other materials, which are used more and more frequently in the production of stratified shields, are composite materials. These are:

• structural composites, with matrix of epoxy resins reinforced with glass fibers and carbon fibers (they have the advantage of a reduced mass by 30 - 50% compared to steel);

• carbon - carbon composites, with graphite matrix, reinforced with carbon fibers structured in fabrics (they have the advantage of very good behavior at high temperatures);

• ceramic - ceramic composites, with matrix made of mixtures of carbides, nitrides, borons, or carbon fibers (they have the advantage of a reduced mass). For example, when using aluminum oxide, the mass of a shield plate is reduced, up to the case of steel use, by up to 55% at the same degree of protection, thus, a mass efficiency of up to 2.2 is obtained.

For the space shields, are used thin sheets of weak alloy steel or aluminum alloy.

- ***Composite shields***

Composite shielding consists of alternative layers, of different materials, usually metals, plastics, ceramics and air, in order to block the penetration of explosive projectiles, being lighter than equivalent steel versions, but sometimes occupying a higher volume and higher cost. Currently, versions of composite armor have appeared in the form of removable or replaceable blocks, which can be applied even to lightweight combat vehicles.

The shield structure is shown schematically in figure 3.

1 - high strength steel base plate;
2 - an outer plate (of steel);
3 - a layer made of an epoxy resin;
4 - ceramic plates incorporated in 3;
5 - Aluminum casing or plastic table in which 4 are coated;
6 - the layers are fixed to each other with the screws securing the layers.

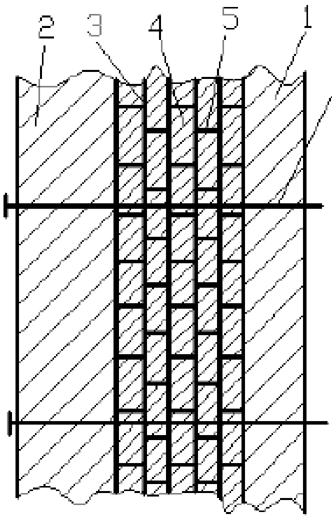

Figure 3. Chobham shield scheme

The solution of modularized composite shielding allows a subsequent modernization, as new solutions are developed.

Composite shields combine the effect of projectile deflection when traversing environments with different densities, with the effect of high hardness ceramic plates and good resistance to high temperatures.

Heavy metals were added to further enhance the strength of the armor, which gives a higher shockwave absorption capacity.

- ***Ceramic shields***

The exigencies in the field of protecting the military vehicles have determined the realization of shields from layers superposed of different materials: one of very hard material, mounted on the face of the shield and the other of soft material, as a support of the hard layer. Depending on the nature of the material used in the construction of the hard layer, the shields are known as ceramic shields or laminated ceramic facing shields, shown in figure 4. In relation to the steel shield, it possesses a remarkable protection property, ensuring, under equal mass conditions, a superior perforating resistance.

Figure 4. Ceramic plates

The hardness of the ceramic shield is significantly higher than the usual steel shields due to the mounting on a support that, in most cases, absorbs or cancels the remaining energy of the projectile. When the hardness exceeds certain limits, the material becomes brittle, and at the shock caused by the projectile, the armor is broken into several pieces or its cracking over large lengths. The progress made has allowed the widespread use of ceramic layer shields, especially for ballistic protection at impact.

- ***Composite materials***

Due to their unique characteristics, composite materials have many applications in various fields, such as: aerospace and aeronautical structures, construction of cars, cars and ships, medicine, chemistry, electronics and energy, consumer goods, optics and more [4].

The technology of fiber-reinforced composite materials has developed over the past 40 years, producing structures for a large number of aerospace applications. These composite materials, usually consisting of fiberglass, Kevlar or graphite (carbon) in a resin matrix, have been successfully used in the construction of aircraft, spacecraft and missile structures [1].

The main categories of fiber reinforced composites are the following: polymer matrix composites, metal matrix composites, ceramic matrix composites, carbon-carbon composites and sandwich composites.

The most commonly used materials are:

• for full cores (figure 5): balsa or cellular wood, various cellular foams or resins mixed with hollow glass microspheres, called syntactic foams;

• for hollow cores (figure 6) mainly honeycombs and profiles: light metal alloys, kraft paper (whether or not coated with resin) or polyamide paper, Nomex paper, etc.

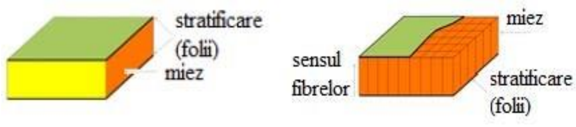

Figure 5. Sandwich materials with full cores

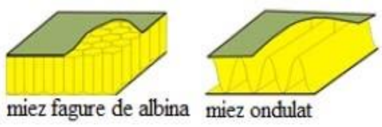

Figure 6. Sandwich materials with hollow cores

Due to the good physico-chemical mechanical characteristics and the low costs, the use of composite materials has increased substantially since 1980 [8].

In the process of making a composite material, the following material properties must be taken into account: modulus of elasticity, tension of flow and rupture, hardness and wear resistance, ductility, brittleness of rupture, resistance to fatigue, creep characteristics, resistance to oxidation and corrosion, electrical and magnetic properties, thermal expansion and conductivity, density, etc. [6].

3. Current ballistic protection solutions

The addition of ballistic protection systems on helicopters, in order to protect the crew and passengers, when carrying out missions in war zones, has always been a compromise between installing an additional element of protection and increasing the helicopter’s mass, while reducing its payload.

The mass of the helicopter is an extremely important factor, especially during high altitude operations, where the engine performance decreases due to lack of oxygen. In order not to affect the helicopter's flight configuration, first of all, ballistic protection systems must have a low mass. Therefore, composite materials are used in the manufacture of these shields, which at the same time offer low weight and increased protection.

The ballistic protection system consists of plates, some of small size, some of larger size, depending on the arrangement of each one, precisely for their mobility and the ease with which they can be changed, if they are hit or simply are upgraded. Also, the helicopter having a monocoque cylindrical construction, increased protection on a larger surface area can only be provided by a larger number of small plates.

For example, the *helicopter AH-1Z,* built by the american company Bell Helicopters, has a kevlar plate (30 cm x 40 cm) plate protection, 12 mm thick, placed inside the aluminum casing, on the sides, behind and below the pilots, as well as in the area of engine transmission and combustion, the manufacturer estimating that this protection is capable of withstanding 25 mm caliber strokes.

Over the years, the United States Department of Aviation Integration and Arms Research (AMRDEC) has developed ballistic protection systems for several helicopters, notably *Boeing CH-47 Chinook* and *Sikorsky UH-60 Black Hawk*. Using composite materials, they managed to develop low mass ballistic protection systems, while providing protection against small arms up to 7.62 mm. On a *CH-47 Chinook* helicopter, this reduced the ballistic protection mass by approximately 900 kg, to a current mass of 1587 kg. The protection includes the floor of the cockpit, cargo cabin, side panels and armored windows. A similar reduction in mass was also achieved for the ballistic protection of the *UH-60 Black Hawk* helicopter, with approximately 227 kg [9].

According to [10], *UH-60 Black Hawk* benefits from increased ballistic protection of the cargo compartment (figure 6), the cockpit floor (figure 7,8) and the side walls (figure 9). Sikorsky presents this ballistic protection system based on composite materials as one of the most advanced systems at the moment, being characterized by a low mass, resistant to multiple blows and high durability. The maximum mass of the protection can reach 532 kg.

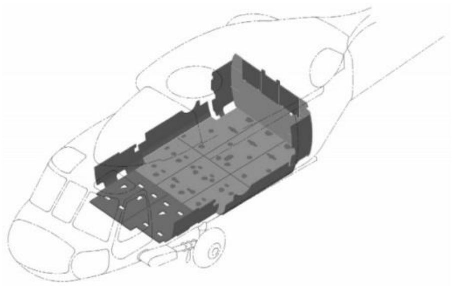

Figure 6. UH-60 Black Hawk cargo floor

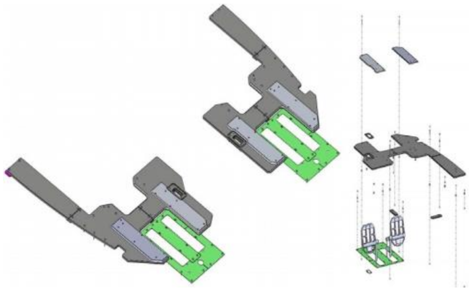

Figure 7. UH-60 Black Hawk cockpit floor

Figure 8. UH-60 Black Hawk cockpit floor

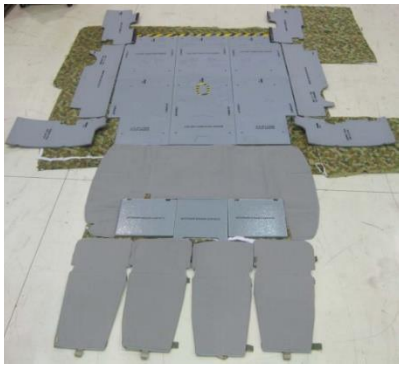

Figure 9. UH-60 Black Hawk side walls

In the case of the *AH-64 Apache* helicopter, according to Teledyne Ryan Aeronautical, the ballistic protection provider, the shield is made up, as shown in Fig. 10, of successive layers (from the outside to the inside), which withstand 23 mm caliber blows: ballistic naylon shell, lightweight boron carbide core (high-hardness boron-carbon ceramic, produced by Ceradyne) and the inner kevlar lining. The pilot's seats are also protected with kevlar (manufactured by Simula) and at the bottom of the cabin and between the pilot's seats is an anti-explosion-fragmentation acrylate shield (Sierracin brand), as well as a transparent component, in the front window (PPG Industries brand) [11].

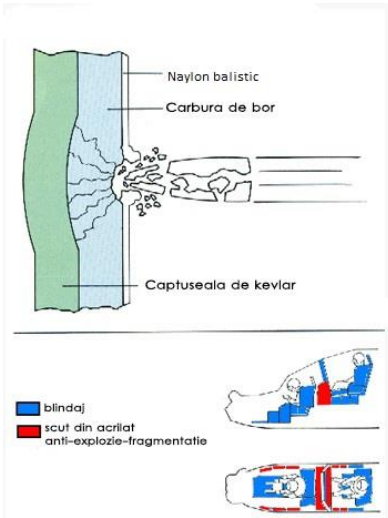

Figure 10. AH-64 Apache ballistic protection

4. Conclusions

The current ballistic protection solutions are in continuous development, through ongoing research, through the optimization of previous solutions and the discovery of new materials.

Nowadays, ballistic protection systems, which are installed on some military helicopters, are modular plate systems, mounted in its critical areas, which provide an increased level of protection, both for the aircraft and the crew.

The mass of the helicopter is an extremely important factor, especially during high altitude operations, where engine performance decreases due to lack of oxygen. In order not to affect the helicopter's flight configuration, first of all, ballistic protection systems must have a reduced mass. Therefore, composite materials are used in the manufacture of these shields, which at the same time offer reduced mass and increased protection.

Aknowledgment

This work is supported by the project ANTREPRENORDOC, in the framework of Human Resources Development Operational Program 2014-2020, financed from the European Social Fund under the contract number 36355/23.05.2019 HRD OP /380/6/13 - SMIS Code: 123847

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