Brief Review of Modern Devices for Blast Mitigation

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Abstract. Rapid and reliable attenuating the shock wave is the main goal of every protective devices, and it is therefore not surprising that achieving this has received a lot of attention over the past some time. Different options have been suggested; their usefulness varying from a reasonable protection to the opposite, a shock enhancement. In protecting humans and installations from destructive shock and/or blast waves the prime goal is to reduce the wave amplitude and the rate of pressure increase across the wave front. In this study modern blast-protection devices based on physical and geometric methods of shock wave attenuation are considered.

1. Introduction
The need to quickly suppress the damaging factors (high-explosive and fragmentation effects) of the explosion of a detected suspicious device before the arrival of specialists of the appropriate profile, as well as its evacuation, led to the creation of specialized blast-protection devices. Rapid and reliable attenuating the shock wave is the main goal of every blast-protection devices, and it is therefore not surprising that achieving this has received a lot of attention over the past some time. Different options have been suggested; their usefulness varying from a reasonable protection to the opposite, a shock enhancement. In protecting humans and installations from destructive shock and/or blast waves the prime goal is to reduce the wave amplitude and the rate of pressure increase across the wave front. Both measures result in reducing the wave harmful effects.

2. Materials and methods
Currently, a wide range of products designed for localizing explosions is used in special equipment. Each blast-protection model has its own design and implementation features of the protective scheme: ways to protect biological and technical objects from shock wave damaging action can be conventionally divided to geometrical and physical. The geometrical methods of shock mitigation are characterized by special shape of solid structures designed to diminish a shock wave overpressure or to form a special direction of shock propagation. The physical methods of shock mitigation are based on specific features of some materials and structures, for example, the energy-absorbing features of multiphase media.

2.1. Blast-protection devices based on the geometrical methods of shock mitigation
Blast-protection devices made according to this scheme are usually cylindrical chambers or containers made of metal or ballistic fabric, capable of withstanding the high-explosive fragmentation impact of explosion products when explosive devices of a given mass are triggered.
Most of the modern blast-protection devices works on the principle of an open-type metal container (figure 1) [1]. The principle is to form a selected direction of propagation of the blast wave - it is to up (according that people and some other important facilities are located around of device). When an explosion occurs in an open blast-protection devise, the shock wave and striking fragments propagate in this direction. Due to the selected direction, the level of the explosion impact on the surrounding ground objects is reduced.

![Figure 1. The scheme of blast-protection device based on the principle of an open-type metal container.](image)

Another way to suppress the damaging factors of a blast-protection device is to enclose it in a closed solid container like an explosive chamber used in experimental research. In practice, due to the large size and especially the mass of the metal container (several hundredweight to suppress an explosion with a capacity of 1-2 kg), they cannot be placed everywhere on critical infrastructure facilities and in crowded places. In fact, such blast-protection containers are used quite effectively only by security structures when performing the tasks of evacuating explosive objects.

In addition, in cases where the power of a localized, evacuated or suppressed blast-protection device exceeds the nominal value for a solid container, given by its strength characteristics, this container itself is a source of an additional damaging factor (the so-called secondary fragmentation flow from its own parts).

2.2. Devices based on the physical methods
Physical methods, consisting in the use of specialized substances that partially absorb the energy of an explosive shock wave. In this case, the energy of the blast wave can be spent on the movement of a specialized substance, its heating, the destruction of bubbles or particles in multiphase media, the formation of turbulent vortices and other gas-dynamic structures. According to [2-7], the use of dusty gases, especially with particles of high thermal conductivity and heat capacity, as well as filling of solid particles, somewhat reduces the damaging factors of the shock wave. The use of foam, polyurethane foam, and other solid-based foam to protect an object or a person has mixed consequences. As shown, for example, in [8-10], a thin foam layer increases the pressure of the shock wave on the affected surface, which has been tested and confirmed, for example, during experiments on biological objects (sheep, [11, 12]).

In some products designed to suppress shock waves in the immediate vicinity of the place of detonation of an blast-protection device, water and other liquids are used as an explosion-absorbing medium [13, 14]. In addition to a fairly significant reduction in the amplitude of the blast wave (by 2-3 times with a reasonable size and mass of such a device, called an explosion localizer), the use of water and other liquids leads to a partial suppression of the fireball and a decrease in the risk of fire at the site of the explosion (suppression of its thermal actions). Another, less effective way to attenuate the shock wave is to create water mist in the path of its propagation.

3. Materials and discussion
The most widespread blast-protection devices are explosion-proof can of companies SEMA World (France), TNO (the Netherlands), etc. Usually these cans are cylindrical shells made of metal or ballistic fabric open on top (figure 2). In promotional materials for such products, attention is focused
on their compliance with the standards of NATO and other organizations in the field of reducing the flow of fragmentation of explosive devices. The damaging factors of the explosion, however, are not limited to the fragmentation stream - the high-explosive effect of the blast shock wave is no less dangerous for people and technical objects.

Figure 2. A blast-protection device “Ground Bomb Killer” by SEMA World Company (France).

Computational and theoretical studies show that the "selected" direction of propagation of the blast shock wave (upward) is not formed, the blast wave actually goes around the edges of the blast-protection device and spreads further in all directions. The degree of reduction of the main mechanical characteristics of the blast wave, characterizing its damaging effect (overpressure and impulse), is extremely insignificant (1.2-1.5 times at a height of 1-1.5 meters above ground level, which corresponds to the most vulnerable organs human body). Reducing the amplitude of the shock wave by 5-6 times, as well as the impulse of its positive phase by at least 2.5-3 times, which, when using "blast-protection " cans, even with increased dimensions, is not achieved, can be called relatively effective (figure 3).

Figure 3. A mitigation of shock wave in a blast-protection device “Ground Bomb Killer”.

The most modern blast-protection devices based on the physical method of attenuating the shock wave are Russian localizers of the Fountain series [15-18], which are significantly superior to rare world analogues (for example, the developments of the British company LBA). Blast-protection devices "Fountain" (figure 4) are destructible containers for internal placement or covering of explosive devices or other suspicious objects. When an explosive device is triggered, the shell of the "Fountain" product, consisting of a relaxation multiphase media, is destroyed with the absorption of the main part of the explosion energy. The design of the Fountain explosion localizer does not contain
solid elements, so this device cannot serve as a source of secondary fragmentation flow [19] if the charge power exceeds the nominal value. The portability and ease of use of Fountain containers contributes to its widespread distribution.

The main advantage of the "Fountain" blast-protection devices is the multiple decrease in the amplitude and pressure impulse of the blast shock wave, which is achieved when using them [20, 21]. This effect is especially important for explosions in confined spaces, i.e. in conditions of multiple interaction, reflection and possible focusing of blast waves with the effect of multiple amplification. The use of destructible containers based on multiphase media allows avoiding the effect of multiplication (it is well known that a weak shock wave with normal reflection increases its pressure 2 times, and a strong one - up to 7 times). Therefore, for example, the use of Fountain devices in closed volumes of passenger aircraft [22-27] leads to a multiple (up to 200 times) decrease in the load on the fuselage and critical structural elements. This prevents the occurrence of cracks and holes with further destruction of the fuselage, preserves critical structural elements, prevents aircraft crash, death of passengers and crew. Stationary and portable specialized explosion protection devices "Fountain", repeatedly tested on board wide-body ("IL-96") and medium-haul ("IL-114") passenger aircraft, have been officially incorporated into the design of these serially produced aircraft.

![Figure 4. A blast-protection device "Fountain" by Special Material Corp. (Russia).](image)

4. Conclusion

At present time, many blast-protection devices of various degrees of effectiveness have been developed to ensure safety in an emergency associated with an attempted criminal or terrorist explosion.

Each blast-protection model has its own design and implementation features of the protective scheme: ways to protect biological and technical objects from shock wave damaging action can be conventionally divided to geometrical and physical. The geometrical methods of shock mitigation are characterized by special shape of solid structures designed to diminish a shock wave overpressure or to form a special direction of shock propagation. The physical methods of shock mitigation are based on specific features of some materials and structures, for example, the energy-absorbing features of multiphase media.

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