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THE REACTION OF CYLINDER FIBROUS COVER TO EXPLOSION OF CHARGE WITH FRAGMENTS

The methodology and results of several cylinder-shaped, fibrous covers were presented with various cushioning layers, subject to charge explosion. The charges included 200 g TNT slabs and various number and kinds of fragments and balls of various diameters. The reactions of cylinder fibrous covers to the explosions were presented as well, as the screens located behind them. Protective performance of various cylinder models was determined.

1. Introduction

The goal of using the explosion-proof covers is to isolate the dangerous charges and reducing their explosion results to a minimum. The explosion-proof covers feature variable design, fibrous or non-fibrous material applied to manufacture them, protective performance and the purpose. [1, 2].

The products are very important element of the equipment for special military and police units, to the fight against terrorism and criminal terror. The usability in a given country depends strictly on local criteria, like kinds of explosion threats – real or potential ones.

On a basis of the statistical data from Police Headquarters, gathered in years 2003÷2005, one could say, that the level of terrorist threat is very low in Poland; however the violence is expected to escalate in the nearest years, especially within organized crime. [3].

Therefore it is extremely important to start every kind of prevention activities, which allow for maximum protection, even against supposed threats, with potentially most dangerous included – those with explosive charges. This comes, among others, from the fact, that the results of striking impact of explosion on the human bodies and the environment surrounding are tragic very much.

With those premises kept in mind, the Institute of Security Technology „MORATEX" has developed within a scope of their R&D project and produced the fibrous cover, which is a peculiar solution of the explosion-proof covers. It was subject to detailed tests of resistance to explosion of a charge with fragments, according to the methodology established within the Military Institute of Armament Technology (WITU).

2. Developing and producing the cylinder fibrous cover

The cover developed should:

- provide protection against model of terrorist bomb and make possible to stop fragments appearing at blast,
- be flexible and made basically of ballistic fibres fabric,

- be easy to fold and transport without any special equipment like small crane, elevator etc.

The developed cover design makes use of results of preliminary computer simulation with Hydrokod 1D and 2D programs, that allow for shock wave propagation in the air simulation as well, as its influence on walls of cylinder cover regarding both various explosives and charge volume (Hydrokod 1D) and fragments driving process and their influence on walls of cylinder cover (Hydrokod 2D) [4, 5].

Within the „MORATEX" Institute several versions of cylinder fibrous covers have been developed and produced, of which three are the subject of the consideration. The main element of each was the cylinder made of numerous layers of ballistic fabric of special structured aramide fibres, with a chamber formed inside to allow for cushion layer placement. Its purpose is to reduce the effect of degrading the resistance of cylinder textile packet as a result of air shock wave and products of terrorist bomb explosion. Moreover, the design of the cylinders takes advantage of aluminized fabric of glass fibres, and of cotton fabric made flame-retardant.

The individual cylinder fibrous cover versions had the following additional elements:

1. version I – cushion layer of shredded plastics and the lid made of several layers of ballistic fabric (Fig. 1a),
2. version II – cushion layer of ballistic PE goods (Fig. 1b),
3. version III – protective layers i.e.:
   - St-3 steel sheet stripes located inside cylinder,
   - aramide inserts, coated with rubber mixtures, placed on the way of 3 mm balls flight including:
     - one on the internal side of steel sheets,
     - another one on the external side of steel sheets and above them,
   - amide insert, coated with rubber mixtures, placed on the way of 4 mm balls flight on the external side of steel sheets (Fig. 1c).

All of the cylinder versions had the same sizes, i.e.: external diameter ~ 910 mm and height ~450 mm, while the lid of cylinder cover version 1: external diameter ~ 920 mm and side part height ~ 100 mm. The weights of covers were: version I – 32,7 kg, version II – 31,02 kg i version III – 51 kg.

a b c

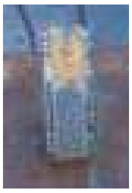
Fig. 1. Cylinder fibrous covers: a - version I, b - version II, c - version III

3. Methodology of tests

In order to carry out the tests of the newly-designed cylinder fibrous covers at WITU, a methodology was developed [6], including:

- the tests objects: three versions of fibrous covers,
- the site of tests: proving ground,
- the test bed: stiff, made of St-3 steel 2000x1000x3 mm sheets and 1000x1000x3 mm for covers placement on them and an extra armour plate, size 300x200x20 mm for charge with fragments placement;

- charges with fragments used for testing with cylinder cover versions as follows:
  - I – 200g TNT slab, size of 100x50x25 mm with 400 steel bearing balls, 2÷5 mm diameter, stuck on the sides of slab (Fig. 2);
  - II – 200g TNT slab, size of 100x50x25 mm with 100 standard fragments (Fig. 1), stuck on the sides of slab (Fig. 3);
  - III – 200g TNT slab, size of 100x50x25 mm with 200 steel bearing balls, diameter 3 mm and 200 steel bearing balls, diameter 4 mm, stuck on the sides of slab (Fig. 4);


a

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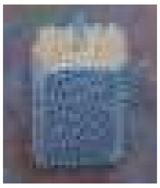
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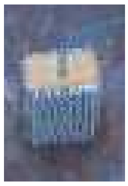
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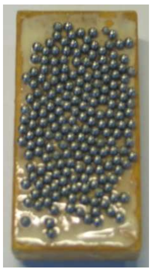
Fig. 2. TNT slab with bearing balls on its sides: a - Ø2 - 100x25 mm - 100 pcs, b - Ø3 - 100x25 mm - 100 pcs, c - Ø4 - 100x50 mm - 100 pcs, d - Ø5 - 100x50 mm - 100pcs

Fig. 3. TNT slab 100x50 mm with 100 pcs of standard fragments placed on two sides


a

b

Fig. 4. 100x50 mm TNT slab with bearing balls placed on two sides; a - 200 balls Ø 4mm, b - 200 balls Ø 3mm

- charge placement: in the middle of cylinder covers;
- charge ignition method: with an electric ERG fuse,
- fabric screens 2,5 m high, disposed around the cylinder covers at a range of: 1 m, 2 m, 3 m and 4m from their center (Fig. 5, 6) and every 90^{o} within next sectors. They allowed for testing all the range of lethal elements flight, including the area outside of cylinder covers;
- Two cardboard shields – soldier silhouettes (Fig. 6), set vis-a-vis ~ 10 m away from the explosion centre for verification is it a safe distance for people when exploding the charge with fragments inside the cylinder covers;
- the way of recording the reaction of fibrous covers to the explosion of charge with fragments: with high-speed camera able to shoot frames every 0,01 s.

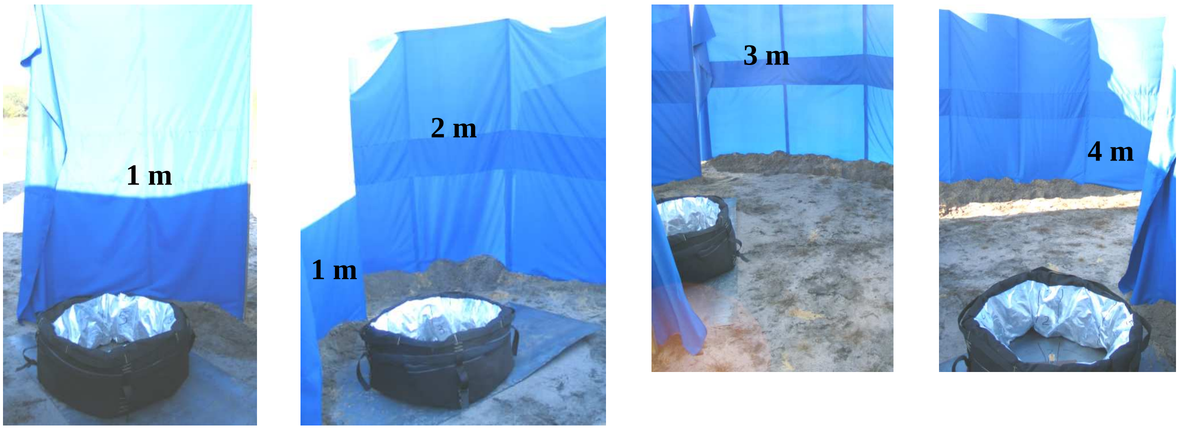


Fig. 5. The view of fabric screens located around the cylinder cover before test

Fig. 6. The view of fabric screens (a) surrounding the cylinder cover with the TNT and fragments before explosion and the shields – soldier silhouettes (b) located ~ 10 m away from the explosion centre

The test has been executed on a stiff bed, since it avoided penetration the ground with fragments, steel balls, nails, nuts etc., and interference in propelling them.

4. Tests results

The cylinder fibrous cover (with its lid) has been placed on the metal sheet and surrounded with the screens of a fabric. On an armour plate, in the middle of the cylinder the charge was located (Fig. 7), to detonate it afterwards.

The tests were carried out with three versions of cylinder fibrous covers. The results achieved illustrate reactions of the covers to the explosion of charges with fragments, and consequently the effects of fragments propelled by the explosion on the covers.

Cylinder fibrous cover - version I

Fig. 7. Cylinder fibrous cover version I view before explosion: a – with TNT slab and balls, without lid; b – with the lid put; c – surrounded with screens of a fabric

After the charge explosion the individual layers of cylinder and the lid were analyzed regarding their protective performance, including the nature of destructions found. The number of layers perforated by the balls was written down, as well, as the number of screens and cardboard shields perforations. The view of destructed cylinder, lid, and the fabric screens is shown in the Figures 8 i 9.

a b c

Fig. 8. A view to destruction of cylinder fibrous cover version I and the screens after the explosion: a – cylinder cover; b – cover lid; c – fabric screens

Fig. 9. A view to sample of destructed surface of cylinder fibrous cover version I

As a result of analysis it has been concluded, that all layers of the cylinders were perforated, white only two last external layers of the lid remain not perforated. There were a lot of visible signs of hits by a bearing ball on the metal sheet. The bottom of cylinder was destroyed too. This proves that big number of bearing steel balls escaped out of the cylinder between this part and the metal sheet. The balls stopped by fabric layers of covers layers were found undergone minor deformations.

Number of perforation signs on the fabric screens of those versions of covers are presented in Table 1. Cardboard soldier's silhouettes remain intact – not punctured by any balls.

Table 1. Number of punctures of fabric screens appeared during test of three versions of cylinder fibrous cover

Distance between a screen and the charge with fragments, m	Number of punctures of fabric screens		
	cover version I	cover version II	cover version I
	Number of holes / Steel ball diameter	Number of holes	Number of holes / Steel ball diameter
1	26 / 5	7	6 / -
2	51 / 3	12	109 / 4
3	101 / 4	0	0 / -
4	83 / 2	25	11 / 3
Total	261	44	126

Behaviour of the cover during explosion of the charge was recorded by high-speed camera, and the examples are shown in Figures 10 and 11.

Fig. 10. Cylinder jump-up, *t*=0,08 s

Fig. 11. Cylinder fall-down, *t*=5,47 s

Cylinder flew up to ~ 6 m and fell ~2 m away of the explosion centre, while the lid flew ~ 10 m up and fell ~ 20 m away.

Cylinder fibrous cover - version II

After the charge explosion (Fig. 12) the analysis was carried out with the conclusion, that the cylinder was pierced with fragments till the half of its layers starting from the charge side. The cushion layer was found pierced with a single fragment too. External layers of the cylinder remain not pierced. The examples of destroyed surface covers and its cushion layer are shown in Figures 12÷14.

The signs of fragments hit were visible on the metal sheet, so part of them has escaped from under the cylinder during explosion. Fragments have undergone “mushroom” deformation as a result of penetrating fabric layers of cylinder (Fig. 15).

a

b

Fig. 12. A view to destruction of cylinder fibrous cover version II and screens after the explosion: a – cylinder cover; b – fabric screens

Fig. 13. A view to sample of destructed surface of cylinder cover version II

Fig. 14. A view to destruction of cushion layer of cylinder cover version II

Fig. 15. A view to deformed, standard fragments

Behavior samples of the cover version II during explosion of the charge recorded by high-speed camera are shown in Figures 16 and 17.

Fig. 16. Cylinder after charge explosion, *t*=0,32 s

Fig. 17. Cylinder after charge explosion, *t*=0,88 s

After charge explosion with fragments, the cover did not jump up, just moved ~ 1 m away from starting point. Fabric screens were partially perforated (Table 1), and the cardboard shields remain intact.

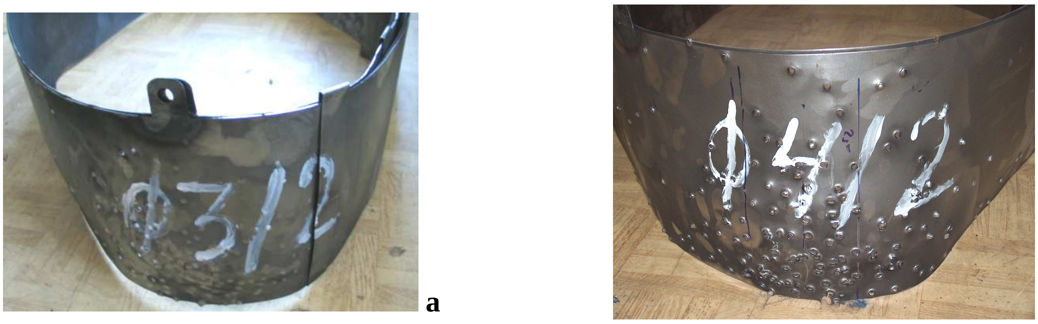
Cylinder fibrous cover - version III

Views to the cylinder cover version III after tests are shown in Fig. 18, while the cylinder components destruction samples after the tests are shown in Figures 19÷21.


a


b

Fig. 18. Post-explosion view to: a – cylinder fibrous cover version III; b – fabric screens



a b

Fig. 19. View no. 2 to outer side of metal sheet after (a) 3 mm and (b) 4 mm fragments hits

a b

Fig. 20. View to outer side of cylinder where the (a) 3 mm and (b) 4 mm bearing balls operated

a b

Fig. 21. View to inner side of cylinder where the (a) 3 mm and (b) 4 mm bearing balls operated

The inspection after the tests showed that the bearing balls punctured covers internal layers no matter their diameter and stopped in the sheets. The external layers of the cover remain intact. Aramide inserts located inside cylinder were pierced, unlike those behind metal sheets. Bearing balls were found slightly deformed. Some of them apparently escaped from under cylinder, as the visible signs on the metal sheet prove. The behaviour of cylinder cover version III during the explosion of charge with fragments was similar to the previously tested cylinder. However it did not move from its first position, since it was weighted with metal sheets at bottom. The fabric screens were partially punctured, but the cardboard shields remain intact (Table 1).

5. Conclusions

On the basis of the tests carried out, the following conclusions may be stated:

1. Stopping lethal balls of various diameters is harder, than stopping standard fragments.
2. Metal layers applied into the cylinders improve effectively their protective performance.
3. Out of the three newly-designed fibrous covers subject to the test of resistance to explosion of charges made of 200 g TNT slab and variable kinds of fragments (standard ones and steel balls) the two i.e. versions II and III belong to the designs able to reduce effects

of explosions on persons and environment 4m away, yet minimize lethal results of explosion and originating fragments within a range of ~ 10 m.

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