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The Reaction of Cylinder Fibrous Cover to Explosion of Charge with Fragments

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Abstract: Methods and results of tests on several models of cylinder-shape fibrous covers, subjected to explosion impact, have been presented. The tested covers consisted of layers of ballistic textile made of para-aramide fibres featuring special structure and between the layers a chamber with various shock absorption layers was created. Moreover, methods of tests of cylinder-shape covers' resistance to explosion of charges with fragments were presented, considering various parameters of base under the cylinder, sort, location and ways of charge ignition, manners of registering the area of threat and covers' reaction to the explosions. Having the methods applied, it was shown how the shock absorption layers minimize the effect of decrease of strength of ballistic textile layers of cylinder under the impact of air shock wave, explosion products and metal fragments formed after explosion of charges. In the tests the 200 g TNT bars stuffed with various sorts and numbers of small metal elements, including standard fragments and balls of various diameters, were used. The analysis of both protective capabilities of the covers and the devastation resulting from impact of blast-propelled fragments was performed.

Keywords: ballistic fibres fabric, explosion-proof covers, cylinder fibrous cover, terrorist bomb explosion

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 [1-4].

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 a terrorist threat is very low in Poland; however the violence is expected to escalate in the nearest years, especially within organized crime [1, 2, 5].

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 surroundings may be very tragic.

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).

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) [5, 6].

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 (Figure 1a),
2. version II – cushion layer of ballistic PE goods (Figure 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 distance 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,
   - aramide insert, coated with rubber mixtures, placed on the way of 4 mm balls flight on the external side of steel sheets (Figure 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

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

Methodology of tests

In order to carry out the tests of the newly-designed cylinder fibrous covers, a methodology was developed at WITU [8], 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 were 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 (Figure 2);
  - II – 200g TNT slab, size of 100x50x25 mm with 100 standard fragments (Figure 1), stuck on the sides of slab (Figure 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 (Figure 4);

a **b** **c** **d**

Figure 2. TNT slab with bearing balls on its sides:
a - Ø 2 - 100x25 mm - 100 pcs, b - Ø 3 - 100x25 mm - 100 pcs, c - Ø 4 - 100x50 mm - 100 pcs, d - Ø 5 - 100x50 mm - 100 pcs.

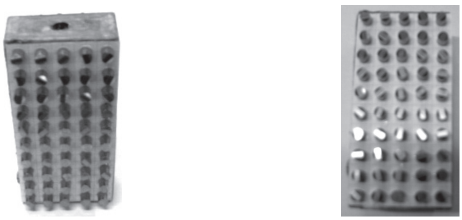
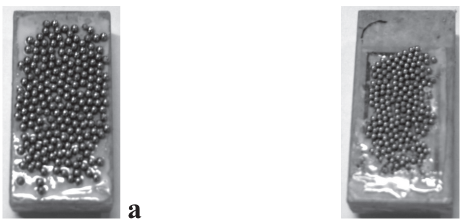


Figure 3. TNT slab 100x50 mm with 100 pcs of standard fragments placed on two sides.



a **b**

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

- 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, 2, 3 and 4 m from their centre (Figure 5-7) and every 90° 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 (Figure 7), set vis-a-vis ~ 10 m away from the explosion centre for verification that it is 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.

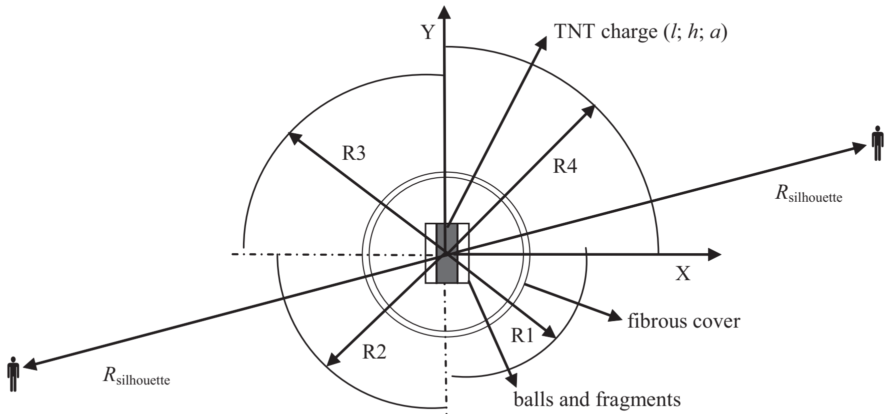


Figure 5. Sketch of the experimental set up: *l*; *h*; *a* – width, height and thickness of the TNT charge, *l* = 50 mm; *h* = 100 mm; a = 25 mm; radius of screen R1= 1 m, R2=2 m, R3=3 m, R4=4 m; $R_{silhouette}$ = 10 m.

Figure 6. The view of fabric screens located around the cylinder cover before test.

a b

Figure 7. 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 carried out on a stiff bed, since it avoided penetration the ground with fragments, steel balls, nails, nuts etc., and interference in propelling them.

Results of the tests

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 (Figure 8), 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

a b c

Figure 8. 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 9 and 10.

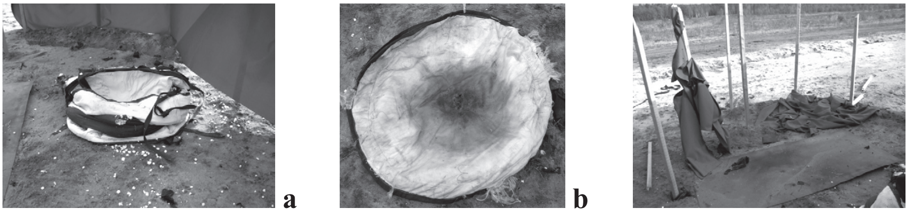


Figure 9. A view of destruction of cylinder fibrous cover version I and the screens after the explosion: a – cylinder cover; b – cover lid; c – fabric screens.

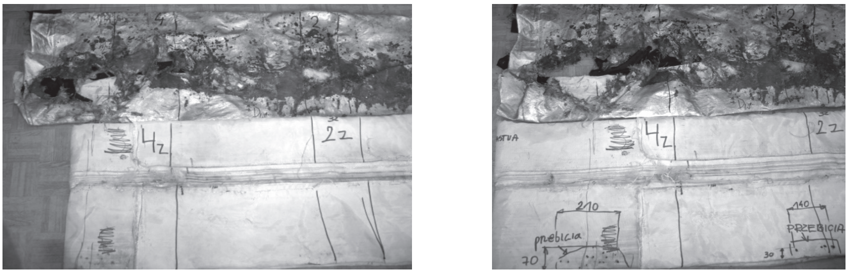


Figure 10. A view of sample of destructed surface of cylinder fibrous cover version I.

As a result of the analysis, it has been concluded, that all layers of the cylinders were perforated, while only two last external layers of the lid remained not perforated. There were a lot of visible signs of hits by a bearing ball on the metal sheet. The bottom of the cylinder was destroyed too. This proves that a 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 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 remained 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 screen and 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 11 and 12.

Figure 11. Cylinder jump-up, t = 0.08 s.

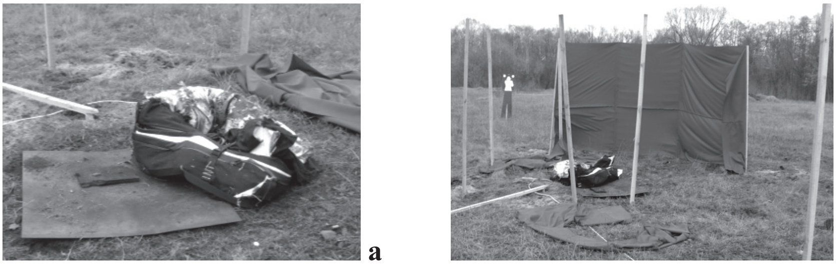
Figure 12. Cylinder fall-down, t = 5.47 s.

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 (Figure 13) the analysis was performed 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 remained not pierced. The examples of destroyed cover's surface and its cushion layer are shown in Figures 13-15.

The signs of fragments hit were visible on the metal sheet, so part of them escaped from under the cylinder during explosion. Fragments underwent "mushroom" deformation as a result of penetrating fabric layers of cylinder (Figure 16).



a b

Figure 13. A view of destruction of cylinder fibrous cover version II and screens after the explosion: a – cylinder cover; b – fabric screens.

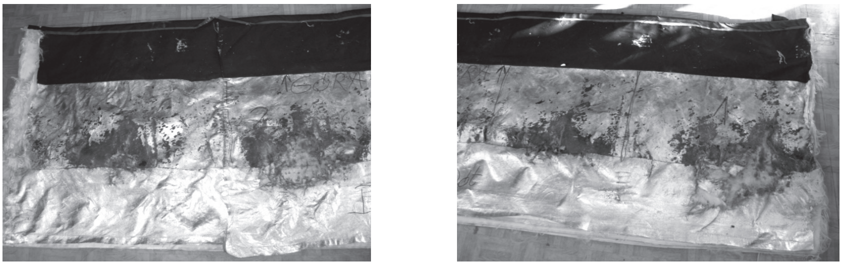


Figure 14. A view of sample of destructed surface of cylinder cover version II.

Figure 15. A view of destruction of cushion layer of cylinder cover version II.

Figure 16. A view of deformed, standard fragments.

Behavior of samples of the cover version II during explosion of the charge recorded by high-speed camera is shown in Figures 17 and 18.

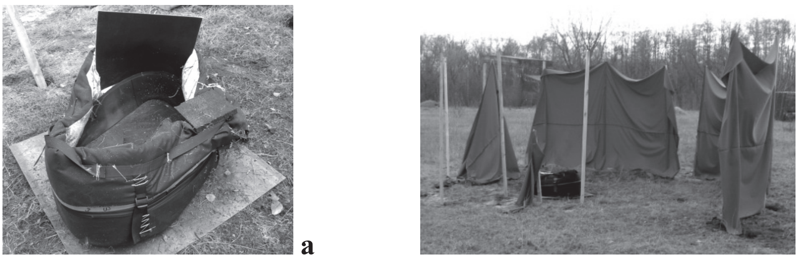
Figure 17. Cylinder after charge explosion, t = 0.32 s.

Figure 18. 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 the starting point. Fabric screens were partially perforated (Table 1), and the cardboard shields remain intact.

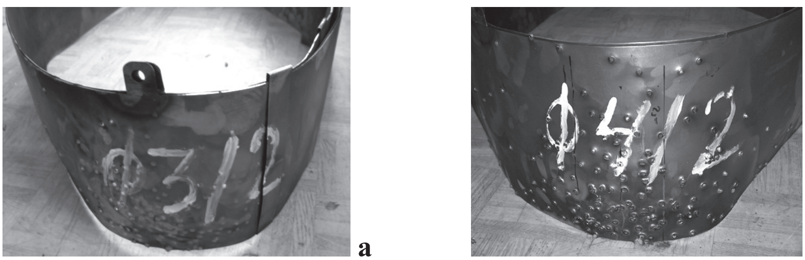
Cylinder fibrous cover - version III

Views of the cylinder cover version III after tests are shown in Figure 19, while the cylinder components destruction samples after the tests are shown in Figures 20-22.



a **b**

Figure 19. Post-explosion view of destruction of cylinder fibrous cover version III and screens after the explosion: a – cylinder fibrous cover version III; b – fabric screens.

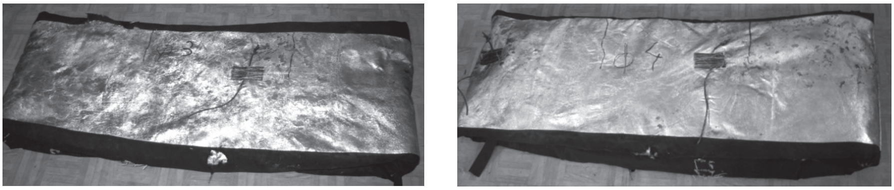


a **b**

Figure 20. View no. 2 of outer side of metal sheet after (a) 3 mm and (b) 4 mm fragments hits.

a **b**

Figure 21. View of outer side of cylinder where the (a) 3 mm and (b) 4 mm bearing balls operated.



a **b**

Figure 22. View of 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 remained 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 remained intact (Table 1).

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

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