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Injection Moulded Polycarbonate Covers of Rocket Launcher Tubes

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The results of an investigation of thermoplastic rocket launcher tube covers are presented. Rocket launcher tube covers are first obtained by injection moulding of polycarbonate in appropriate molds (two types), and by subsequent machining (another two types). The specimens of all four cover types were exposed to the influence of compression force in static conditions. The results of the breakthrough force of the specimen covers were thus obtained. The dependence of the breakthrough force on the investigated cover types was established.

Key words: **rocket launcher, launcher tube, cover, polycarbonates, injection moulding breakthrough force, static testing.**

Introduction

THE military area in the last more than a half of century can be defined as a period of intensive development of rocket armament. This armament has exsisted in almost all army segments. Rocket armament is used more and more and it is more sophisticated in newly developed systems. In a physical sense, system efficiency denotes a quality of functioning of all elements of the system directed to realising a unique task for which the system is designed [1].

Launcher tube covers

One of rocket system elements about which only a few parameters can be found in literature is the cover of the rocket launcher tube. This construction element is mostly of a spherical shape.

The basic goal of investigating cover specimens of a rocket launcher tube is to determine force which causesits breaking in static conditions.

Four cover types are selected for investigation:

- covers type 1 are obtained solely by injection moulding of thermoplastic material in the basic mould,
- covers type 2 are obtained solely by injection moulding of thermoplastic material in the adapted basic mould,
- covers type 3 are obtained by injection moulding of thermoplastic material in the basic mould and later on by machining,
- covers type 4 are obtained by injection moulding of thermoplastic material in the adapted basic mould and later on by machining.

The scheme of cover type 1 mark T1 and the scheme of cover type 2 mark T2, tested in this examination, are presented in Schemes 1 and 2.

The figure of cover type 3 general mark T3/Nnumber and the figure of cover type 4 general mark T4/Nnumber, also tested in this investigation, are presented in Figures 3 and 4.

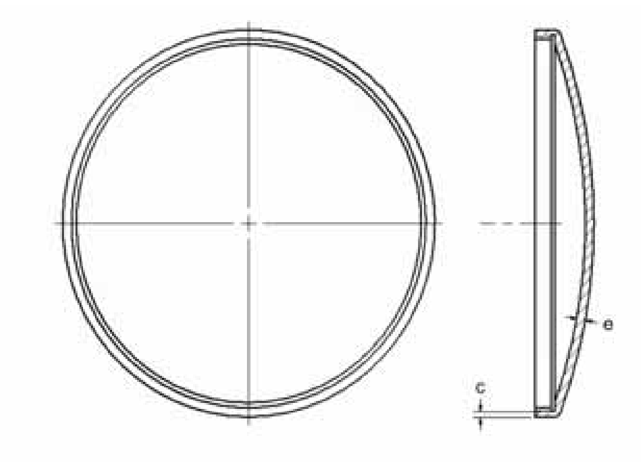

Figure 1. Cover type 1 (T1)

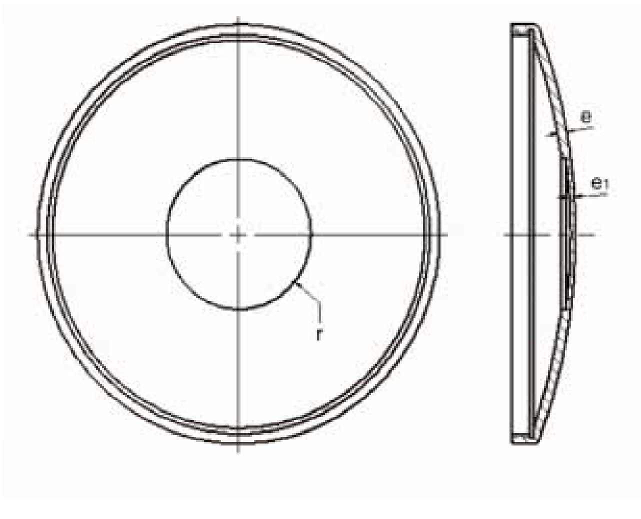

Figure 2. Cover type 2 (T2)

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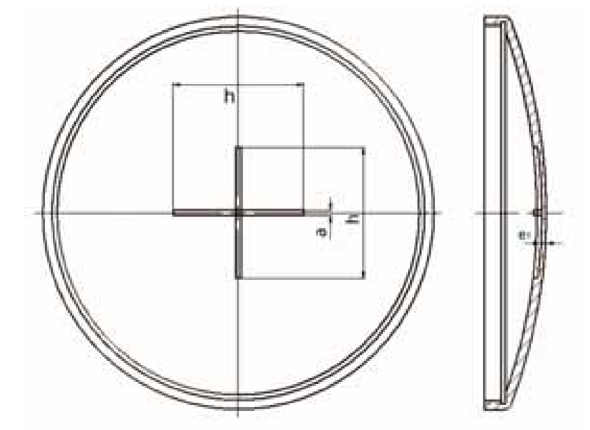

Figure 3. Cover type 3 (T3/Nnumber)

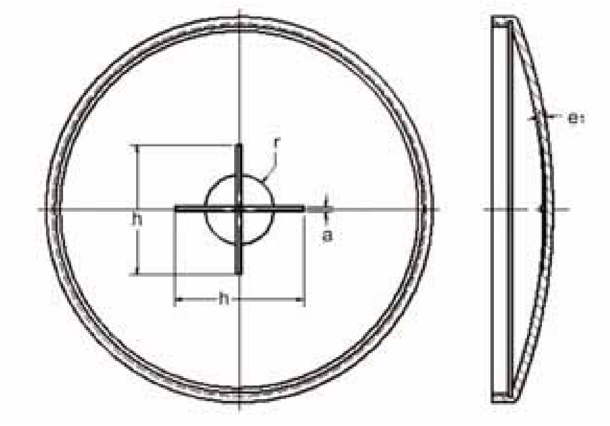

Figure 4. Cover type 4 (T4/Nnumber)

Cover specimen production

Injection moulding

Cover specimens are produced by injection moulding technology. A chosen thermoplastic material, an injection moulding machine type BKSMT 250/400, produced by a manufacturer of equipment for moulding of plastics material Battenfeld, Germany, and appropriate moulds were used for the cover specimen production.

Injection moulding consists of a process of warming polymeric material to the melt state in the machine cylinder and of a process of injecting molten thermoplast into a mold. Thermoplastic material is injected into a relatively cold mold, where a solidification process occurs and, in that way, a final shape of the product is formed [2].

The figure of the injection moulding machine, in a simple form, is presented in Fig.5 [3].

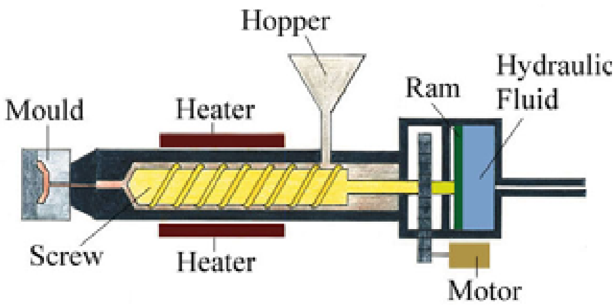

Figure 5. Injection moulding machine

In 1946, James Watson Hendry built the first screw injection machine, which allowed much more precise control over the speed of injection and the quality of articles produced. This machine allowed adding of colored or recycled plastic to virgin material and thoroughly mixing before being injected. It is considered that injection moulding is the most important plastics manufacturing process [4, 5].

Cover specimens are produced by injection moulding technology using polycarbonate thermoplastic material trade name Makrolon 6267, fabricated by Bayer, Germany.

Thermoplastic material trade name Makrolon 6267 (formerly developmental product Makrolon ® DP1-1872) is low viscosity polycarbonate (MVR 19 cm^3/10 min), which contains flame retardant agens (burning behaviour V-0/1.5 mm class, according to UL 94 method). This material is UV stabilised and contains an easy release agent, which allows easier product removing from a mold.

Polycarbonates, as well as polyamides, polyacetals, polyphenylene oxides, polysulfones and thermoplastic polyesters, are known as thermoplastic engineering polymers because they are used for the production of stressed parts and often used as alternatives or replacements for metals in load-bearing applications [6].

Thermoplastic material known shortly as ABS is used for the production of wheel covers, protective head gears, and similar parts [7]. The material ABS (Acrylonitrile Butadiene Styrene) combines the strength and rigidity of acrylonitrile and styrene polymers with the toughness of polybutadiene. Although ABS is considered the best of the styrenic polymer family, its set of mechanical and thermal properties is weaker than the characteristics of the polycarbonate named Makrolon.

The mentioned polycarbonate of the trade name Makrolon 6267 has a better set of characteristics than the other polycarbonates with the trade name Makrolon:

- material 6457 has similar mechanical, but weaker reological and thermal properties,
- material 2407 has similar reological, but weaker mechanical and thermal properties.

The structure of the polycarbonate basic repeating unit is shown in Figure 6 [8].

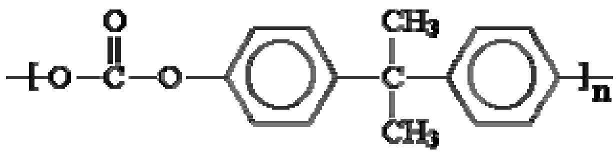

Figure 6. Structure of the polycarbonate basic repeating unit

Polycarbonate gets its name from the carbonate groups in „backbone“ macromolecule chain of this polymer. Owing to strong bonds between carbon and oxygen atoms in the basic polymer chain and the presence of aromatic nucleus, polycarbonate is characterised by high mechanical and thermal properties, important for cover functioning.

Cover machining

Covers consist of the central partially spherical part and the side radial part.

Cover type 1 mark T1 has the nonchangeable wall thickness (e=3.5 mm) all along the central part.

Cover type 2 mark T2 has the changeable wall thickness i.e. the central part with a diameter of 26 mm has the wall thickness e1=2.4 mm, and the rest part has the wall thickness e=3.5 mm.

The wall thickness of the side radial part of cover type 1 and cover type 2 is the same (*c*=2 mm).

The weakening on the central and the side part of cover type 1 and cover type 2 was done by machining.

It was decided that the weakening on the central part was to be done from that side of a cover, which is first exposed to the action of puncture force of the construction element during its function. In other words, the weakening of the cross shape is located on the concave side of the central part of the cover specimen.

The weakening of the cross shape on the central side of the cover were done by a CNC milling machine type TM1, produced by the tool machine manufacturer Haas, USA.

The weakening on the side part cover specimen was done by a lathe type TVP 300, produced by the tool machine manufacturer "Prvomajska", SFRJ.

The details of the cross shape weakening on the concave area of the central part and the weakening details on the side radial part of the cover specimen are presented in Table 1.

These weakenings reffer to cover specimens type 3 general mark T3/Nnumber, obtained by machining of cover specimens type 1 mark T1.

Table 1. Weakenings of covers type 3 general mark T3/Nnumber

Specimen mark	„Cross“ dimension (mm)	Remaining wall thickness of the central part (mm)	Width groove (mm)	Side wall thickness (mm)
T3/N1	40 x 40	2.4	1.0	2.0
T3/N2	80 x 80	2.4	1.0	2.0
T3/N3	80 x 80	1.1	2.0	1.0
	80 x 80	1.1	2.0	1.0
	80 x 80	1.1	2.0	1.0
T3/N4	150 x 150	1.1	2.0	1.0
	150 x 150	1.1	2.0	1.0
T3/N5	80 x 80	1.1	2.0	2.0
	80 x 80	1.1	2.0	2.0
T3/N6	150 x 150	1.1	2.0	2.0
	150 x 150	1.1	2.0	2.0
	150 x 150	1.1	2.0	2.0

Table 2 consists of the details about the weakenings on the concave area of the central part („cross“ shape) and on the side radial part of the covers. The defined weakenings are presented for cover specimens type T4 general mark T4/Nnumber, obtained by machining cover specimens type 2 mark T2.

Table 2. Weakenings of covers type 4 general mark T4/Nnumber

Specimen mark	„Cross“ dimension (mm)	Remaining wall thickness of the central part (mm)	Width groove (mm)	Side wall thickness (mm)
T4/N1	40 x 40	2.4	1.0	2.0
T4/N2	80 x 80	2.4	1.0	2.0
T4/N3	80 x 80	1.1	2.0	2.0
	80 x 80	1.1	2.0	2.0
T4/N4	150 x 150	1.1	2.0	2.0
	150 x 150	1.1	2.0	2.0
T4/N5	150 x 150	1.1	2.0	1.0
	150 x 150	1.1	2.0	1.0

Experimental part

Four types of cover specimens were investigated:

- covers type 1 solely injection moulded in the basic mould,
- covers type 2 solely injection moulded in the adapted basic mould,
- covers type 3 are obtained by machining of covers type 1,
- covers type 4 are obtained by machining of covers type 2.

The figure of the equipment used for the determination of cover specimen resistance to the action of impact force in static conditions i.e. the breakthrough force is presented in Fig.7.

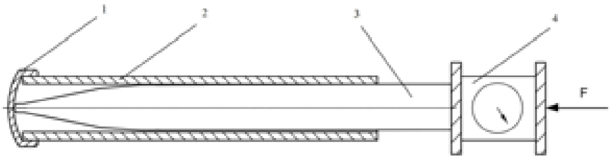

Figure 7. Figure of the equipment used for the determination of the breakthrough force of the cover specimens, where : 1-cover specimen, 2-launcher tube, 3-rocket specimen, 4-dynamometer

For measuring the force applied to the cover specimens by the action of rocket specimens, a dynamometer type FA5k, produced by the measuring and testing equipment of the manufacturer Axis, Poland, was used. This dynamometer, with a range to 5.000 N (500 daN), can be used for measuring tensile and compressive force.

Experimental results and analysis

The results obtained by the inside stressing of cover specimens mark T1 and T2 are presented in Table 3 [9].

Table 3. Testing results obtained by stressing cover specimens mark T1 and mark T2

Specimen mark	Testing results (daN)	Remark
T1	>470	Specimen did not break, but stressing was stopped because of the measuring range of the applied dynamometer
T2	>476	Specimen did not break, but stressing was stopped because of the measuring range of the applied dynamometer

Based on the data presented in Table 3, it can be pointed out that none of cover specimens type 1 and type 2 break i.e. the breakthrough force of these two kinds of specimens is higher than about 470 daN.

The results obtained by the inside stressing of cover specimens general mark T3/Nnumber are presented in Table 4 [9].

Table 4. Testing results obtained by stressing cover specimens general mark T3/Nnumber

Specimen mark	Testing results (daN)		Remark
	Single values	Aritmethic mean values	
T3/N1	>452	>452	Specimen did not break, but stressing was stopped because of the measuring range of the applied dynamometer
T3/N2	>457	>457	Specimen did not break, but stressing was stopped because of the measuring range of the applied dynamometer
T3/N3	404	434	Cover specimens are broken
	450		
	420		
T3/N4	240	246	Cover specimens are broken
	252		
T3/N5	403	425	Cover specimens are broken
	446		
T3/N6	297	337	Cover specimens are broken
	415		
	300		

Fig.8 presents a view of cover specimen mark T3/N1 after the action of force of 452 MPa, and it is clearly seen that the specimen was not broken.

Figure 8. View of cover specimen mark T3/N1 after the action of force of 452 MPa

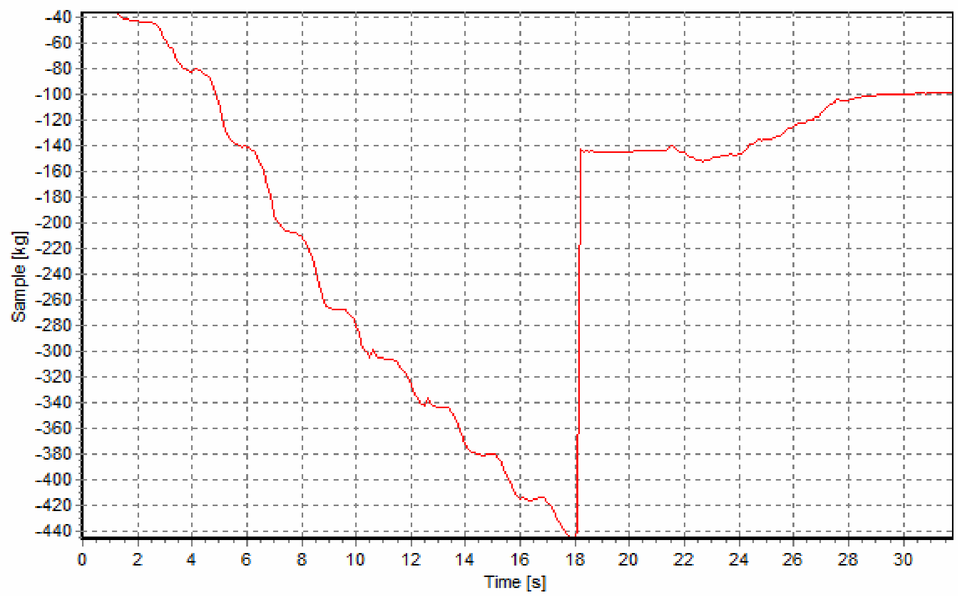

Diagram 1. Change of a force value from the start moment of stressing till the stop of the force action, without breaking cover specimen mark T3/N1

Figure 9. View of cover specimen mark T3/N3 after determining the breakthrough force (420 MPa)

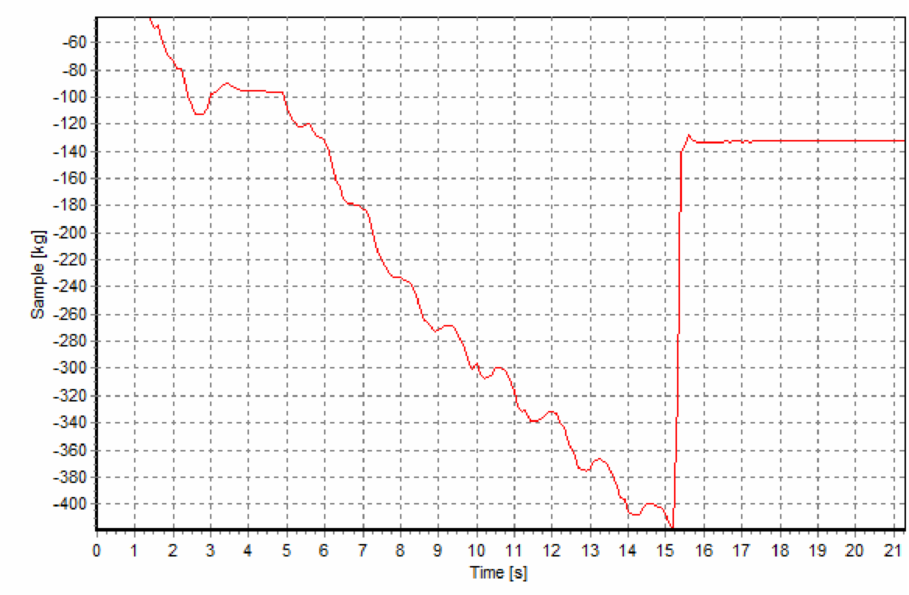

Diagram 2. Change of a force value from the start moment of stressing till the moment of breakthrough of cover specimen mark T3/N3

Diagram 1 presents a change of a force value from the start moment of stressing till the stop of the force action,without braking cover specimen mark T3/N1.

Fig.9 presented a view of cover specimen mark T3/N3 after determining the breakthrough force (420 MPa), i.e. a mode of breaking the cover specimen is clearly seen.

Diagram 2 presents a change of a force value from the start moment of stressing till the moment of breakthrough of cover specimen mark T3/N3.

Based on the data presented in Table 4, it is obvious that the smallest mean value of the breakthrough force (246 daN) is found in cover specimen mark T3/N4, while cover specimen mark T3/N3 was broken at the highest force of 434 daN.

The results obtained by the inside stressing of cover specimens general mark T4/Nnumber are presented in Table 5 [9].

Table 5. Testing results obtained by stressing cover specimens general mark T4/Nnumber

Specimen mark	Testing results (daN)		Remark
	Single values	Aritmethic mean values	
T4/N1	>459	>459	Specimen did not break, but stressing was stopped because of the measuring range of the applied dynamometer
T4/N2	>447	>447	Specimen did not break, but stressing was stopped because of the measuring range of the applied dynamometer
T4/N3	416 372	394	Cover specimens are broken
T4/N4	404 420	412	Cover specimens are broken
T4/N5	408 417	413	Cover specimens are broken

The stressing force increase, applied to cover specimen mark T4/N3 from the beginning of the process till the break of the tested specimen, is presented in Diagram 3.

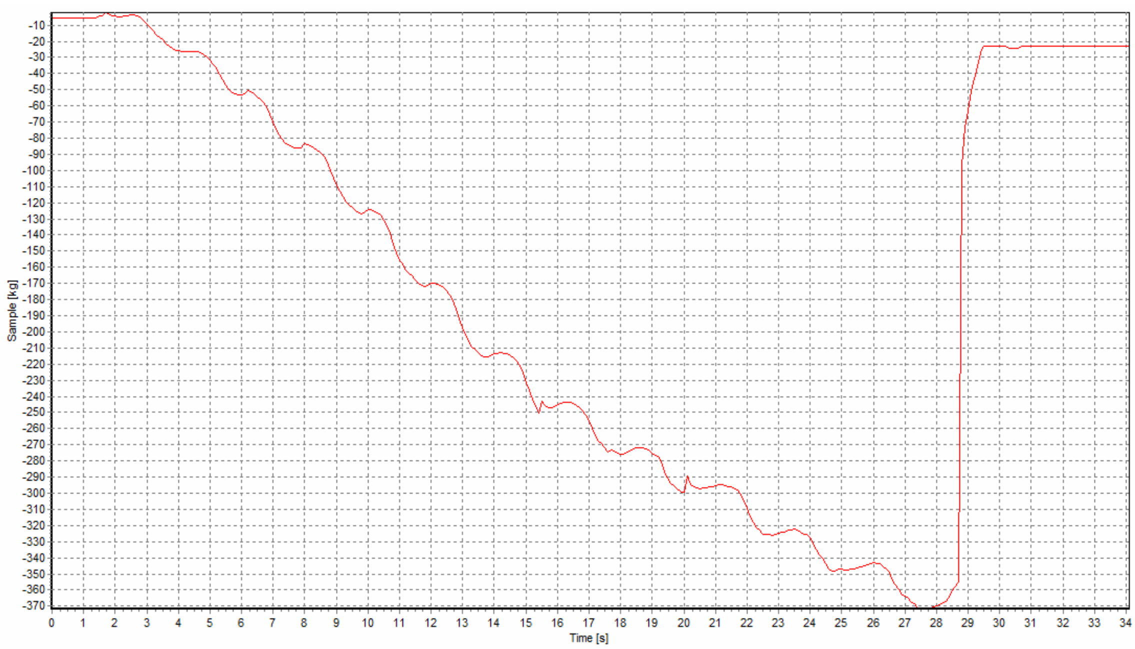

Diagram 3: Change of a force value from the start moment of stressing till the moment of breakthrough of cover specimen mark T4/N3

In cover specimens general mark T4/N number, the smallest breakthrough force of 394 daN was found in specimen mark T4/N3, while the highest breakthrough force (413 daN) was recorded while testing cover specimen mark T4/N5.

Conclusions

Based on all presented data, it can be concluded:

1. Two cover types are obtained solely by injection moulding of polycarbonate material in appropriate moulds, and other two cover types with additional machining.
2. Breakthrough force of four thermoplastic polycarbonate cover types of a rocket system launcher tube was determined.
3. The smallest breakthrough force of cover specimens general mark T3/N number was found in specimen mark T3/N4 (246 daN).

These specimens have the „cross" shape weakening on the cental part, 150 mm long, 2 mm wide groove, 1.1 mm residual wall thickness, while the wall thickness on the side part is 1.0 mm.

4. In cover specimens general mark T4/N number, the smallest value of breakthrough force (394 daN) was registered while testing cover specimen mark T4/N3.

These specimens have the „cross" shape weakening on the cental part, 80 mm long, 2 mm wide groove, 1.1 mm residual wall thickness, while the wall thickness on the side part is 2.0 mm.

5. Breakthrough force of cover specimens mark T1 and T2 is higher than 480 daN.
6. Cover specimen are broken on the central part.
7. The obtained results will be used for the production of covers in the next developing phase.

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Injekciono presovani polikarbonatni poklopci cevi lansera raketa

U ovom radu prikazani su rezultati ispitivanja termoplastičnih poklopaca cevi lansera raketa u statičkim uslovima. Poklopci cevi lansera raketa dobijeni su, prvo, postupkom injekcionog presovanja polikarbonata u odgovarajućim alatima (dva tipa), a zatim naknadnom mašinskom obradom (još dva tipa). Uzorci sva četiri tipa poklopaca bili su izloženo dejstvu pritisne sile u statičkim uslovima. Na ovaj način dobijeni su rezultati sile probijanja uzoraka poklopaca. Utvrđena je zavisnost sile probijanja od tipa ispitivanih poklopaca.

Ključne reči: **lanser rakete, lansirna cev, poklopac, polikarbonati, injekciono presovanje, probojna sila, statičko ispitivanje.**

Поликарбонатные крышки трубок ракетных пусковых устройств, получены литьём под давлением

В данной работе представлены результаты испытаний термопластичных крышек труб ракетных пусковых установок в статических условиях. Крышки трубок ракетных пусковых установок получаются, во-первых, методом литья под давлением поликарбоната с соответствующими инструментами и приборами (два типа), и последующей механической обработкой (ещё два типа). Образцы всех четырёх типов крышек подвергались воздействию сил давления в статических условиях. Таким образом были получены результаты путём силы штамповки образцов крышек. Установлена и корреляция между силой нарушения и типом исследованных крышек.

Ключевые слова: **ракетные пусковые установки, запускная трубка, крышка, поликарбонаты, литьё под давлением, диэлектрическая прочность, статические испытания.**

Les couvercles en polycarbonate des lance-fusées obtenus par la presse d'injection

Dans ce papier on présente les résultats des essais dans les conditions statiques pour les couvercles thermoplastiques des tubes du lance-fusées. Les couvercles des tubes examinées ont été produits par le processus de la presse d'injection des polycarbonates à l'aide des outils correspondants (deux types) et ensuite par l'usinage (deux types encore). Les échantillons de tous les quatre types de couvercles ont été exposés à l'action de la force de pression dans les conditions statiques. De cette façon on a obtenu les résultats pour la force de pénétration chez les échantillons des couvercles. On a constaté que la force de pénétration était dépendante du type des couvercles examinés.

Mots clés: **lance-fusées, tube lance-fusées, couvercle, polycarbonates, presse d'injection, force de pénétration, examen statique.**