ISSN 1392 - 1207. MECHANIKA. 2007. Nr.1(63)

Experimental study of paperboard package resistance to compression

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1. Introduction

In terms of consumed quantity, paper and paperboard have long been the main packing materials for different products and goods. The amount of this packaging makes up about 48.8% of the whole packaging used in the European Union (from 41.7% in France to 59.6% in Sweden), while glass packaging accounts for 22.8%, plastic – 20.3% and metal – 7.8%. Although plastic industry is developing rapidly, the usage of paperboard as a cheap and ecological packing material is not decreasing. Paperboard is made from renewable resources and the paperboard-based materials decompose relatively easily under the effect of humidity and usual atmospheric conditions [1-3].

Packaging construction and design is being constantly improved. Complex problems have to be solved for ensuring package reliability during distribution and transportation of packed goods, since the packed products may be damaged by the developing static and dynamic forces. Static load of the packaging is usually caused by internal pressure of the product and the impact of other packed goods lying above. Dynamic loads usually arise during transportation because of rough roads, sharp braking of the vehicle, shocks during loading-unloading operations, etc. [3, 4]. Reliability of packaging is extremely important in food industry, where packaging takes a continuously increasing part [5]. The most popular paperboard packages are boxes in the shape of parallelepiped rectangles.

Following the requirements of European Union directives, the goal in further development of packaging is manufacturing durable packaging and minimizing the amount of materials needed for that [6, 7]. One of the essential requirements related to amount minimizing of packaging materials in Directive 94/62/EB is formulated as follows: „Packaging shall be so manufactured that the packaging volume and weight be limited to the minimum adequate amount to maintain the necessary level of safety, hygiene and acceptance for the packed product and for the consumer“.

The methodology of checking how packaging corresponds to the requirement is specified in European Standard EN 13428:2004, which has been followed by the Lithuanian Standard [8]. Its aim is to ensure that all the possibilities of 'preventing the impact on the environment and minimizing the usage of raw materials' for achieving the lowest possible packaging weight and/or volume have been determined and considered. It has been agreed that in designing certain packages, some particular requirements define practical limits of further reduction of packaging weight and/or volume. The second evaluation stage enumerates maintenance criteria that limit the possibilities of reducing packaging weight and/or volume. Each of the enumerated criteria in the Standard is accompanied by the list of typical requirements that could help every user of the Standard to determine significant and crucial requirements when identifying the so-called 'critical area', which plays a decisive role in minimizing the package weight or volume. This identification should be based on tests or research. Further testing of adequacy of the package with the essential requirement is carried out only in the "critical area".

One of the main characteristics of packaging is its resistance to vertical load which increases significantly, for instance, by stacking packed goods on pallets and storing thus formed units side by side. In this case, the highest loads act upon the goods lying below, and the acting forces are directed vertically downwards. The packed product can take a part of the loads and thus reduce the danger of damaging the package, however, it is not always efficient. For example, it has been determined that boxes filled with peas, beans or similar products are only 10% more resistant to shape changes than empty boxes [4].

An important step in designing the boxes most suitable for packaging is understanding how static forces affect the paperboard package. Early work, performed by H. Grångard [8, 9], was based on empirical dependencies in predicting the cardboard packaging resistance to compression. In more recent studies, T. Wågsater and A. Palenryd focused on studying static loads of packaging by applying the method of finite elements [10, 11]. However, it resulted in some uncertainties, compared with more precise deformation control methods. L. Beldie, G. Sandberg and L. Sandberg analyzed the resistance of paperboard packaging side planes, the whole package and its parts to compression (the whole box was divided into three parts) [12]. The resistance of a paperboard as printing material to compression, depending on the direction, was studied in [13]. The papers mentioned above lack studies concerning the packaging resistance to compression, with regard to the paperboard direction.

The aim of the present work is to study the resistance of paperboard packaging in the shape of a rectangular box to compression when subjected to a vertical load, with regard to the paperboard direction (when the paperboard direction of the side walls is parallel to the packaging vertical axis and when the paperboard direction of the mentioned walls is perpendicular to the axis).

2. Equipment and methodology of the study

A tension-compression stand was used for the tests, and special computer programme was used for processing and visualizing the measurement data (Fig. 1).

Experimental tests were carried out by using three specimens (packages) of different sizes; their external view is presented in Fig. 2. Boxes of these sizes are widely used in Lithuania, for example, for packing grain products (rice, buckwheat, etc.), prepacked in separate bags for cooking. The choice of this type of packaging specimens was determined by their wide usage for packing food products. The dependences of deformations upon the compression force were determined during compression tests of empty boxes.

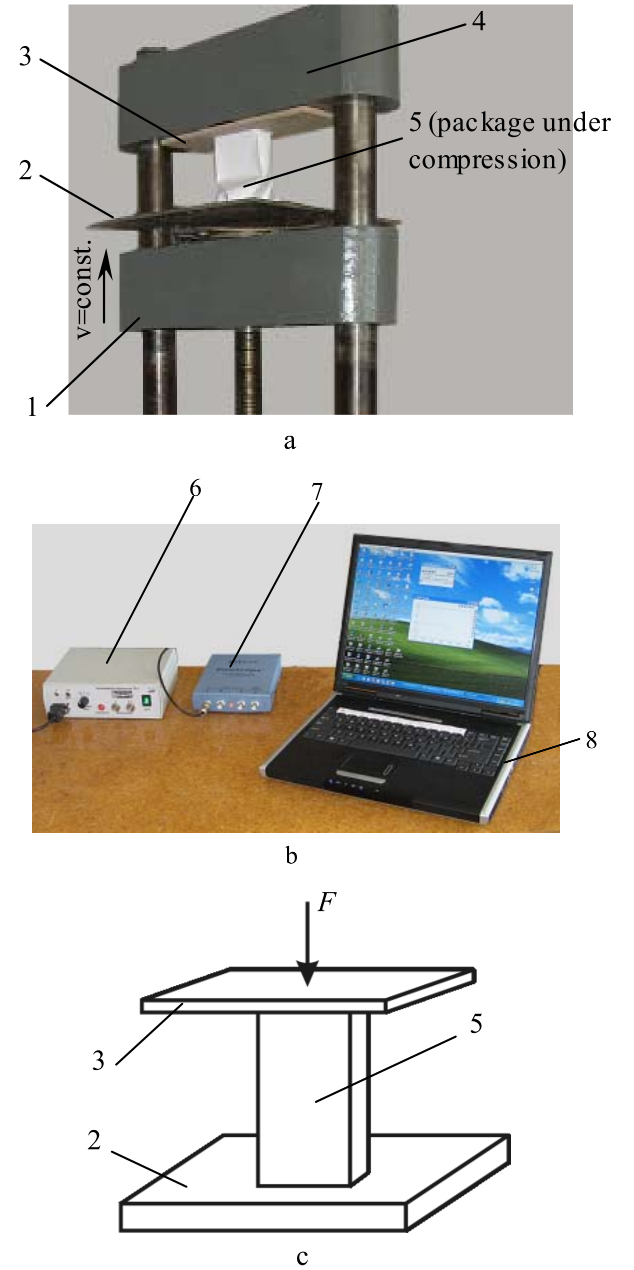

Fig. 1 General view of the equipment used for studying the compression process of paperboard packages: a - box compression stand, b - equipment for processing measuring data, c - compression test scheme of a package under the action of vertical load *F*, N: *1* - moving base support, *2* - bottom base slab, *3* - top base slab, *4* - fixed base support, *5* - package under compression, *6* - tensometric amplifier TS-3, *7* - oscilloscope PicoScope 3424, *8* - computer

Samples for the package tests were made of paperboard of five different types of grammage. The term 'machine direction', used in this paper, means that the paperboard direction in the side walls is parallel to the vertical axis of the package, and the term 'cross-machine direction' means that the paperboard direction in the side walls is perpendicular to the vertical axis of the package. Considering potential conditions of package storing, transporting and maintenance, the packages used for testing were made of different paperboard types: soft MC Mirabell cardboard, medium soft Kromopak cardboard and tough paperboard FRÖVI Carry. Table 1 presents technical characteristics of the chosen paperboards, as defined by the manufacturers.

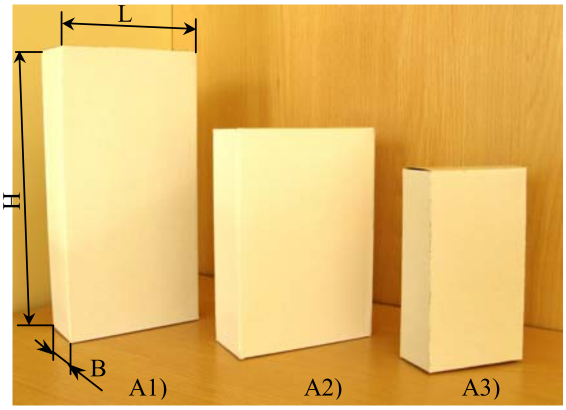

Fig. 2 Specimens (packages): A1) box size I (*H*=230 mm, *L*=118 mm, *B*=48 mm), A2) box size II (*H*=165 mm, *L*=118 mm, *B*=48 mm), A3) box size III (*H*=137 mm, *L*=77 mm, *B*=37 mm)

During the tests, the packages under investigation were placed on the bottom base slab *2* which is part of the unit measuring the compression load acting on the package (Fig. 1, a), mounted on bottom base *1* of the stand. The bottom and the top base slabs are parallel and absolutely rigid. The mentioned slab *2* is connected with the tensoresistor measuring unit, which contains four wire tensosensors, connected by a bridge circuit. During the package compression the sensor system signal is amplified by a tensometric amplifier TS-3 *6*. The obtained analogical signal was transmitted to oscilloscope PicoScope 3424 *7* for converting it into a digital one. The dependence of the compression force and deformations was observed on PC monitor *8*. A PC with PicoLog Recorder oscilloscope software was used for processing the obtained results and visualizing the dependences. During the test, when the bottom base slab was moving upwards vertically at a constant speed 3.5×10^{-4} m/s, the upper part of the package would touch the fixed top base slab, and then the compression process would start. The concrete test data, describing the dependence of compression force upon time, when received by the computer, would be processed to determine the dependence of the compression force upon the value of the vertical package deformation.

The tests were carried out at the temperature of 20±2°C and air humidity 65± 2%.

Before measuring, the stand was calibrated. During the calibration process it was determined that within the range of load values occurring during the tests, the dependence of computer input signal measuring the force upon the mentioned force is close to linear, and the measuring errors do not exceed ±3%.

Table 1

Comparison of paperboard technical characteristics [14-16]

No.	Type of paper-board	Grammage, g/m^2	Thickness, µm	Rigidity					
				L&W[1], Nm (5°)			TABER[2], Nm (15°)		
				MD[3]	*CD*[4]	$\sqrt{MD \times CD}$	*MD*	*CD*	$\sqrt{MD \times CD}$
1	MC Mirabell	400	580	60.9	24.4	38.5	28.9	10.9	17.8
2	MC Mirabell	320	435	31.8	13.3	20.6	16.2	6.4	10.2
3	Kromopak	300	395	34.3	14.3	22.2	18.0	7.5	11.6
4	Kromopak	275	430	29.0	12.0	18.7	15.6	6.5	10.1
5	FRÖVI Carry	400	585	113.0	55.3	79.0	56.2	27.5	39.3

[1]L&W device-measured moment needed for bending the sample material to an angle of 50°
[2]TABER device-measured moment needed for banding the sample material to an angle of 150°
[3]-MD - machine direction
[4]-CD - cross machine direction

3. Experimental results and their analysis

Fig. 3 shows the dependences of axial deformation and compression load of size A1 boxes made of different grammage MC Mirabell paperboard. During package compression process it can be noticed that when compression load is gradually increased by means of a worm-gear, deformation starts at the joints of the package walls, bottom and lid. When certain compression power is reached, these parts lose resistance, and later only the package walls continue deforming. However, because of manufacturing inaccuracies, the walls are unevenly loaded, and in further compression process the more loaded walls are primarily deformed. Most frequently, a package wall gets deformed either at top or bottom part. When the walls deformation gradually develops, they lose their strength and the resistance to deformation starts decreasing significantly.

The obtained results of the study are presented in Fig. 3-9 and Tables 2, 3.

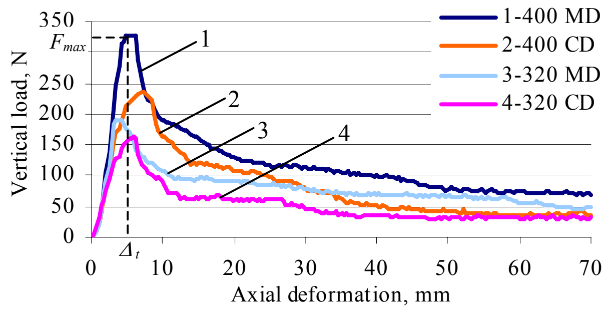

Fig. 3 Graph of resistance to compression of Size A1 boxes made of MC Mirabell paperboard: *1* - 400 g/m^2 paperboard (machine direction); *2* - 400 g/m^2 paperboard (cross-machine direction); *3* - 320 g/m^2 paperboard (machine direction); *4* - 320 g/m^2 paperboard (cross-machine direction); F_{max}–maximum compression load (vertical load), Δ_t–deformation at maximum compression load, mm

The graphs in Fig. 3 show that the boxes made of 400 g/m^2 paperboard, machine-direction, can carry the largest load up to 328.6 N (at axial deformation 5.6 mm), see curve *1*. Identical boxes made of 320 g/m^2 paperboard, machine direction, at 3.2 mm deformation can withstand up to 42% smaller maximum load (190.96 N), see curve *2*.

The box resistance is also influenced by the paperboard direction. 400 g/m^2 cross-machine direction paperboard boxes can withstand 30% smaller load (up to 235.47 N) at axial deformation 7 mm. (see curve *3*). A similar tendency is observed with boxes made of 320 g/m^2 cross-machine direction paperboard. These boxes, at 5.95 mm deformation, withstand 164.34 N compression load (see curve *4*).

The rest package tests were carried out by deforming boxes along the axis up to 20 mm, assuming that larger deformation of packages filled with grain products would make them unsuitable for consumption (Fig. 4-9).

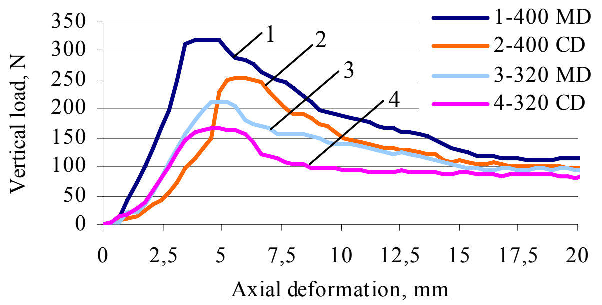

Fig. 4 Resistance to compression of A2 size boxes made of MC Mirabell paperboard: *1* - 400 g/m^2 paperboard (machine direction); *2* - 400 g/m^2 paperboard (cross-machine direction); *3* - 320 g/m^2 paperboard (machine direction); *4* - 320 g/m^2 paperboard (cross-machine direction)

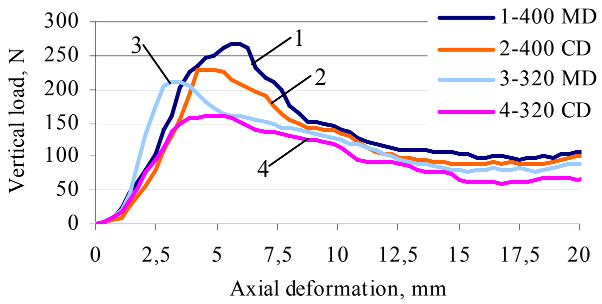

Fig. 5 Resistance to compression of A3 size boxes made of MC Mirabell paperboard: *1* - 400 g/m^2 paperboard (machine direction); *2* - 400 g/m^2 paperboard (cross-machine direction); *3* - 320 g/m^2 paperboard (machine direction); *4* - 320 g/m^2 paperboard (cross-machine direction)

Table 2

Test results of package resistance to compression

No.	Package material, paperboard grammage and direction	Package dimensions, mm	Maximum compression (vertical) load F_{max}, N	Deformation at maximum compression load, Δ_t, mm
1.	MC Mirabell paperboard, 400 g/m^2, machine-direction	A1 size: H=230 mm, L=118 mm, B=48 mm	328.58	5.60
2.	MC Mirabell paperboard, 400 g/m^2, cross-machine direction		235.47	7.00
3.	MC Mirabell paperboard, 320 g/m^2, machine-direction		190.96	3.50
4.	MC Mirabell paperboard, 320 g/m^2, cross-machine direction		164.34	5.95
5.	MC Mirabell paperboard, 400 g/m^2, machine-direction	A2 size: H=165 mm, L=118 mm, B=48 mm	320.18	4.20
6.	MC Mirabell paperboard, 400 g/m^2, cross-machine direction		252.64	5.60
7.	MC Mirabell paperboard, 320 g/m^2, machine-direction		210.99	4.90
8.	MC Mirabell paperboard, 320 g/m^2, cross-machine direction		166.79	4.55
9.	MC Mirabell paperboard, 400 g/m^2, machine-direction	A3 size: H=137 mm, L=77 mm, B=37 mm	267.35	5.60
10.	MC Mirabell paperboard, 400 g/m^2, cross-machine direction		230.18	4.55
11.	Multicolor Mirabell paperboard, 320 g/m^2, machine-direction		210.04	3.15
12.	MC Mirabell paperboard, 320 g/m^2, cross-machine direction		160.98	4.90
13.	Kromopak paperboard, 300 g/m^2, machine-direction	A1 size: H=230 mm, L=118 mm, B=48 mm	183.96	4.20
14.	Kromopak paperboard, 300 g/m^2, cross-machine direction		164.88	5.25
15.	Kromopak paperboard, 275 g/m^2, machine-direction		161.88	3.85
16.	Kromopak paperboard, 275 g/m^2, cross-machine direction		132.45	4.20
17.	Kromopak paperboard, 300 g/m^2, machine-direction	A2 size: H=165 mm, L=118 mm, B=48 mm	196.22	3.15
18.	Kromopak paperboard, 300 g/m^2, cross-machine direction		183.96	4.90
19.	Kromopak paperboard, 275 g/m^2, machine-direction		176.6	2.80
20.	Kromopak paperboard, 275 g/m^2, cross-machine direction		149.62	3.50
21.	Kromopak paperboard, 300 g/m^2, machine-direction	A3 size: H=137 mm, L=77 mm, B=37 mm	196.22	3.85
22.	Kromopak paperboard, 300 g/m^2, cross-machine direction		166.79	3.15
23.	Kromopak paperboard, 275 g/m^2, machine-direction		186.41	3.15
24.	Kromopak paperboard, 275 g/m^2, cross-machine direction		142.36	3.50
25.	Frövi Carry paperboard, 400 g/m^2, machine-direction	A1 size: H=230 mm, L=118 mm, B=48 mm	446.88	5.95
26.	Frövi Carry paperboard, 400 g/m^2, cross-machine direction		365.75	5.25
27.	Frövi Carry paperboard, 400 g/m^2, machine-direction	A2 size: H=165 mm, L=118 mm, B=48 mm	456.22	5.25
28.	Frövi Carry paperboard, 400 g/m^2, cross-machine direction		370.9	5.60
29.	Frövi Carry paperboard, 400 g/m^2, machine-direction	A3 size: H=137 mm, L=77 mm, B=37 mm	394.90	5.25
30.	Frövi Carry paperboard, 400 g/m^2, cross-machine direction		360.01	5.60

Table 3

Characteristics and general view before and after compression of some paperboard packages (boxes) used for testing

Technical characteristics of packaging materials and testing conditions	General view of the paperboard package before compression load	View of the deformed package after compression load	
Paperboard type: MC Mirabell Grammage, g/m^2: 400 Surrounding temperature, C°: 20±2° Surrounding humidity, %: 65± 2 Machine direction: F_{max}=334 N, Δ_t=6.65 mm Cross-machine direction: F_{max}=235 N, Δ_t=8.05 mm	 Package view before deformation. Package type A1 (230×118×48 mm)	 Machine direction paperboard	 Cross-machine direction paperboard
Paperboard type: MC Mirabell Grammage, g/m^2: 320 Surrounding temperature, C°: 20±2° Surrounding humidity, %: 65± 2 Machine direction: F_{max}=210 N, Δ_t=5.95 mm Cross-machine direction: F_{max}=168 N, Δ_t=5.6 mm	 Package view before deformation. Package type A2 (230×118×48 mm)	 Machine direction paperboard	 Cross-machine direction paperboard
Paperboard type: Frövi Carry Grammage, g/m^2: 400 Surrounding temperature, C°: 20±2° Surrounding humidity, %: 65± 2 Machine direction: F_{max}=456 N, Δ_t=6.3 mm Cross-machine direction F_{max}=353 N, Δ_t=7.7 mm		 Machine direction paperboard	 Cross-machine direction paperboard
Paperboard type: MC Mirabell Grammage, g/m^2: 400 Surrounding temperature, C°: 20±2° Surrounding humidity, %: 65± 2 Machine direction: F_{max}=267 N, Δ_t=7,0 mm Cross-machine direction: F_{max}=230 N, Δ_t=5.6 mm	 Package view before deformation. Package type A3 (230×118×48 mm)	 Machine direction paperboard	 Cross-machine direction paperboard
Paperboard type: Kromopak Grammage, g/m^2: 275 Surrounding temperature, C°: 20±2° Surrounding humidity, %: 65± 2 Machine direction: F_{max}=186 N, Δ_t=4,2 mm Cross-machine direction: F_{max}=142 N, Δ_t=4.2 mm		 Machine direction paperboard	 Cross-machine direction paperboard

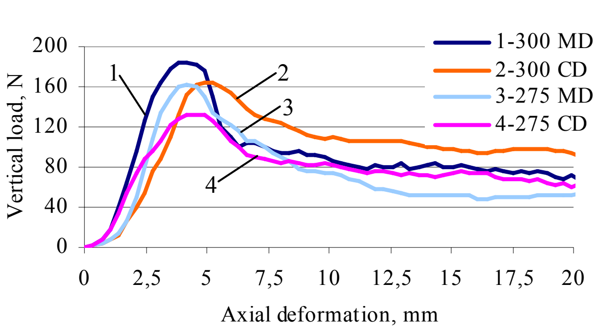

Fig. 6 Resistance to compression of A1 size boxes made of Kromopak paperboard: *1* - 300 g/m^2 paperboard (machine direction); *2* - 300 g/m^2 paperboard (cross-machine direction); *3* - 275 g/m^2 paperboard (machine direction); *4* - 275 g/m^2 paperboard (cross-machine direction)

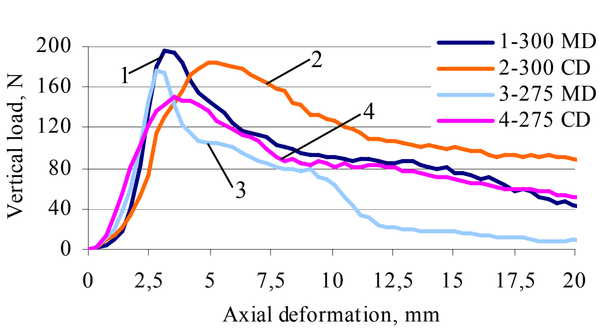

Fig. 7 Resistance to compression of A2 size boxes made of Kromopak paperboard: *1* - 300 g/m^2 paperboard (machine direction); *2* - 300 g/m^2 paperboard (cross-machine direction); *3* - 275 g/m^2 paperboard (machine direction); *4* - 275 g/m^2 paperboard (cross-machine direction

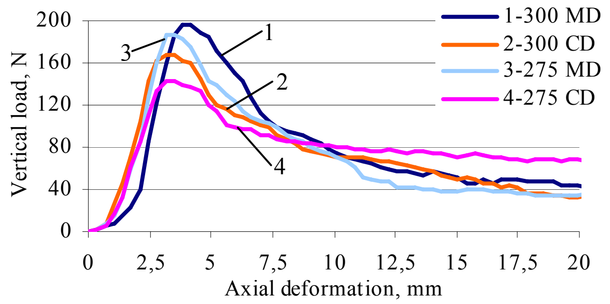

Fig. 8 Resistance to compression of A3 size boxes made of Kromopak paperboard: *1* - 300 g/m^2 cardboard (machine direction); *2* - 300 g/m^2 paperboard (cross-machine direction); *3* - 275 g/m^2 paperboard (machine direction); *4* - 275 g/m^2 paperboard (cross-machine direction)

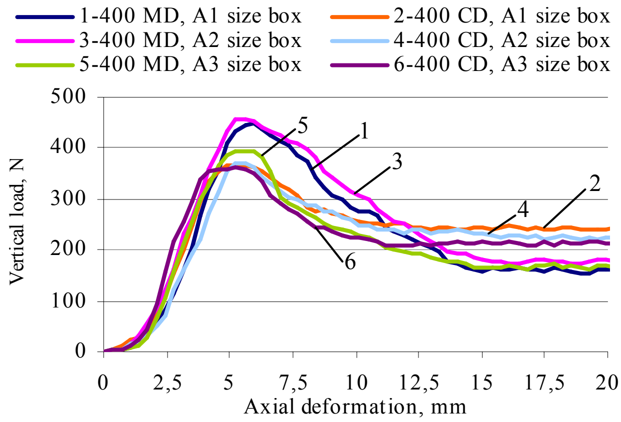

Fig. 9 Resistance to compression of boxes made of Frövi Carry paperboard: *1* - A1 size box, 400 g/m^2 paperboard (machine direction); *2* - A1 size box, 400 g/m^2 paperboard (cross-machine direction); *3* - A2 size box, 400 g/m^2 paperboard (machine direction); *4* - A2 size box, 400 g/m^2 paperboard (cross-machine direction); *5* - A3 size box, 400 g/m^2 paperboard (machine direction); *6* - A3 size box, 400 g/m^2 paperboard (cross-machine direction)

Tests results presented in Figs. 3-9 show that the changes in the deformation-compression load dependences take place in a similar way in all the three types of packages (made of both machine direction and cross-machine direction paperboard). Packages made of machine direction paperboard carry 10-33% larger compression loads than those made of cross-machine direction paperboard. Judging by the test results, A2 size packages (made of both machine direction and cross-machine direction paperboard) carry larger loads than A1 and A3 size packages.

While compressing the boxes made of Kromopak paperboard, it was noticed that all the boxes made of machine direction paperboard tore along the vertical wall bending line. The tearing could have been caused score, since the paper rigidity decreases in the vertical scoring line.

When analyzing nature of the changes of these curves, two zones could be singled out: zone 1, where the deformation – compression load dependence can be considered close to linear, and zone 2, where this dependence is nonlinear.

General view of the deformed packages after compression load is presented in Table 3. Pictures show that external view of the boxes does not allow us to define what direction (machine or cross-machine) paperboard the boxes are made of, since the outer view of all the deformed packages is similar.

The analysis of the results obtained during the testing leads us to the conclusions presented below.

5. Conclusions

1. The highest compression load above which significant package deformations start has been determined.
2. Nature of the changes of deformation-compression load dependences is similar for all the three types of packages. Two zones should be singled out: Zone 1, where the deformation-compression load dependence can be considered to be close to linear, and Zone 2, where the dependence is non-linear.
3. Any size packages made of paperboard whose side wall direction is perpendicular to the package vertical axis carry lower compression load than the packages whose side wall direction is parallel to the package vertical axis; however, the deformation of the former packages is larger.
4. When comparing resistance to compression of the boxes of different grammage, made of MC Mirabell machine-direction paperboard, it was determined that A1 size package made of 400 g/m^2 paperboard carries 42% higher compression load, A2 size - 35%, and size 3 - 21% higher compression load than the boxes made of 320 g/m^2 paperboard.
5. The analysis data showed that all the three types of packages made of Frövi Carry 400 g/m^2 paperboard, both machine-direction and cross-machine direction, can carry about 30% higher compression load than MC Mirabell 400 g/m^2 paperboard packages.
6. When comparing resistance to compression of all the three types of boxes made of Kromopak paperboard, it was determined that the boxes made of 275 g/m^2 machine-direction paperboard can carry some 12% lower compression load than 300 g/m^2 paperboard boxes. Boxes made of 275 g/m^2 cross-machine paperboard can carry about 21% lower compression load than 300 g/m^2 paperboard boxes made in the same paperboard direction.
7. Since packages made of Kromopak paperboard used to tear during compression, this paperboard is recommended for boxes that are subjected only to minimum loads.
8. The obtained study results can be applied in designing packages, for the expected package compression loads, enabling the designers to choose paperboard of smaller grammage, this leading to minimizing packaging mass. When package compression loads are minimal, the paperboard direction can be ignored, as it does not have any noticable effect on the package resistance.

References

1. Evaluation of costs and benefits for the achievement of reuse and recycling targets for the different packaging materials in the frame of the packaging and packaging waste directive 94/62/EC: Final Consolidated Report. RDC, PIRA, March 2003.- 131 p. Annexes 1 – 13, 211 p.+ 59 pages of tables and diagrams.
2. **Danys, J., Lebedys, A., Milašiūnas, A., Motiejūnas, J., Rudgalvytė, E., Rudagalvis, B., Uselytė, R.** The

Solution of Problems of Effective Packaging Waste Management and Functioning of Packaging Waste Information Databases in Lithuania in the Context of the Requirements of the EU: proect of 2000 PHARE ACCESS programme.-Kaunas: Technologija, 2003. -56p. ISBN 9955-09-502-4 (in Lithuanian).
3. **Soroka, W.** Fundamentals of Packaging. Institute of Packaging Professionals. Second Edition. ISBN 1-930268-06-08. Herndorn, Virginija, 1999.- 589 p.
4. Lexikon der Warenschäden. Zweite neu bearbeitete und erweiterte Auflage, herausgegeben von Günter Grundke. ISBN 3-87706-792-1. Hannover: Schlütersche, 1997.-350p.
5. **Danys, J., Lebedys, A.,** Trends of food packaging development in Europe //Food Chemistry and technology: studies / Food Institute of Lithuania, Kaunas University of Technology. ISSN 1392-0227. 2004, T. 38, nr. 1, p. 15-26 (in Lithuanian).
6. European Parliament and Council Directive 94/62/EC on packaging and packaging waste // Official Journal of the European Communities. No. L 365. Brussels, 31 December 1994, p.10-23.
7. Directive 2004/12/EC of the European Parliament and of the Council of 11 February 2004 amending Directive 94/62/EC on packaging and packaging waste // Official Journal of the European Union. No. L 47. Brussels, 18.2.2004, p.26-31.
8. EN 13428:2004. Packaging. Requirements Specific to Manufacturing and Composition. Prevention by Source Reduction. 2004.-25p.
9. **Grångard, H**. Some Aspects of the Compressive Strength of Cartons. Svensk papperstidning: 1972. -473p.
10. **Grångard, H., Kubat, J.** Compression of Board Cartons. Svensk papperstidning, 1973.-462p.
11. **Wågsater, T., Palenryd, A.** FE-simuleringar och experimentella forsok pa karton for packningar. Department of Structural Mechanics, Lund University: Lund, Sweden, 1998.-382p.
12. **Beldie, L., Sandberg, G., Sandberg, L.** Paperboard packages exposed to static loads-finite element modeling and experiments / Packaging Technology and Science. - John Wiley & Sons, 2001 Vol. 13, Issue 5, p.171-178.
13. **Kibirkštis, E., Kabelkaitė, A**. Research of paper/paperboard mechanical characteristics.- Mechanika.- Kaunas: Technologija, 2006, Nr.3(59), p.34-41.
14. http://www.schneidersoehne.lt/MCMTech.shtml (visited 5th September 2006).
15. http://www.schneidersoehne.lt/KromopakTech.shtml (visited 5th September 2006).
16. http://www.schneidersoehne.lt/FroviCarryTech.shtml (visited 5th September 2006).

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EKSPERIMENTINIS KARTONO PAKUOČIŲ ATSPARUMO GNIUŽDYMUI TYRIMAS

R e z i u m ė

Atlikti eksperimentiniai tyrimai, nustatytas skirtingos gramatūros kartoninių pakuočių atsparumas deformacijai gniuždymo metu. Tyrimams buvo naudoti iš kartono pagaminti stačiakampės dėžutės formos bandiniai, kurių šoninių sienelių kartono liejimo kryptis eina išilgai pakuotės vertikaliosios ašies arba statmenai jai. Nustatyta maksimali gniuždymo apkrova, kurią gali atlaikyti pakuotė, esant minimaliai deformacijai. Ištirta kartono liejimo krypties įtaka pakuotės atsparumui gniuždant. Nustatytos tirtų pakuočių deformacijų ir gniuždymo apkrovų priklausomybių zonos, kuriose galima išskirti artimą tiesiniam arba netiesinį parametrų kitimo pobūdį.

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EXPERIMENTAL STUDY OF PAPERBOARD PACKAGE RESISTANCE TO COMPRESSION

S u m m a r y

Experimental tests have been carried out and resistance to deformation during compression has been determined for different grammage paperboard boxes. For testing, specimens of rectangular paperboard boxes, whose side wall paperboard direction was either parallel or perpendicular to the vertical axis of the package ware used. The maximum compression load that the package can carry with minimum deformation was determined. The effect of paperboard direction on package resistance to compression was analyzed. The zones of deformation-compression load dependences of the studied packages, in which the parameter changes are either of close to linear or of nonlinear character were, singled out.

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ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ КАРТОННЫХ УПАКОВОК НА СОПРОТИВЛЕНИЕ СЖАТИЮ

Р е з ю м е

Проведены экспериментальные исследования, установлена деформационная прочность при сжатии картонных упаковок разной грамматуры. Для исследований были использованы образцы в виде прямоугольных коробок, у которых машинное направление картона для изготовления боковых стенок является параллельным или перпендикулярным к вертикальной оси упаковки. Установлена максимальная нагрузка при сжатии, которую может выдержать упаковка при минимальной деформации. Исследовано влияние машинного направления картона на прочность упаковки при сжатии. Для исследованных упаковок установлены зоны зависимостей деформаций и нагрузок при сжатии, в которых можно выделить близкий к линейному или нелинейный характер изменения параметров.

Received December 27, 2006