Investigation of three-layered rectangular corrugated cardboard package resistance to dynamic loads

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Abstract. This paper presents the values of dynamics loads determined during experimental investigations as multi-layered corrugated cardboard packages were subjected to loading mass m and underwent shock loads. Existence of such loadings cause undesirable mechanical and exploitation damage to packages.

Keywords: rectangular package, corrugated cardboard, dynamic loading.

1. Introduction

A package has a number of functions. One the most important of them is protection. It has dual purpose – to protect the product during transportation and against the effect of environmental factors. A suitable package is one of the conditions of product protection that significantly reduces the losses occurring due the damage during loading and transporting [1, 2]. Great attention is focused on exploitation criteria by designing the packages because packages are subjected to various loading during their life cycle [3]. Not only static, but also and dynamic loading as the package could fall or be affected by vibrations during transportation [4-6].

The authors of works [7-9] analyzed the effect of the geometrical shape of corrugated cardboard boxes during shock loadings. In some cases the damage to packed products was determined, or deformations were measured, or visual assessment was performed based on relevant criteria.

This work differs from the previously mentioned ones by the fact that it analyses dangerous shock load values that have the greatest effect on deformations of a rectangle package. The aim of this work is to evaluate the resistance to dynamic loads of a rectangle corrugated cardboard package loaded by mass m.
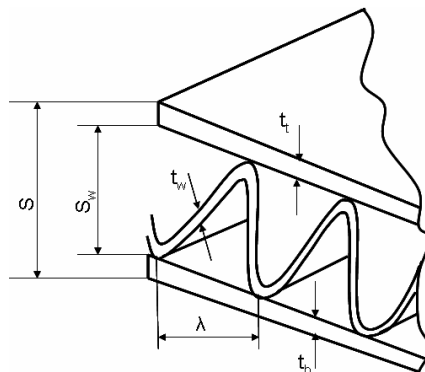

Fig. 1. General view of a three-layered, B type corrugated paperboard used for experimental testing: height of corrugated paperboard: $S = 3$ mm; corrugated medium height: $S_w = 2.14$ mm; thickness of upper and lower layers: $t_t = 0.43$ mm and $t_b = 0.43$ mm; corrugated layer: $t_w = 0.45$ mm; corrugated medium step: $\lambda = 6.5$ mm

2. Methods and equipment used for the tests

Methods and equipment of deformation dependences of packages on mass m and shock load.

18 rectangle corrugated cardboard packages were made for the tests with the following parameters: $H = 140$ mm; $L = 250$ mm; $B = 160$ mm (see Fig. 2). The tests were carried out at the ambient temperature 20±2 °C and air humidity 50±5 °C. The shock load testing stand, whose structural scheme and parameters are shown in Fig. 4 and Table 1, was used.

A study of a corrugated cardboard package (its geometrical parameters and the cross section of the corrugated cardboard are shown in Figs. 1 and 2) was carried out in order to determine the resistance to compression of packages under 15 kg mass and shock loads [10].
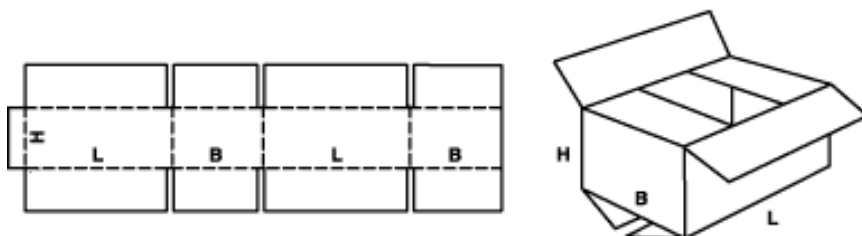

Fig. 2. Tile of a three-layered corrugated paperboard package

A stand was used for testing (see Fig. 3), where the corrugated cardboard package 3 was placed on steel plate 2 that is attached to shock generator 1 whose more detailed characteristics are listed in Table 1. On the package 3 15 kg mass was placed that could move in h direction. The deformations of the package were recorded using sensors 5, 6. The obtained testing data were sent to personal computer 8.

Fig. 3. General view of the shock load testing stand: 1 – shock generator; 2 – steel plate; 3 – sample; 4 – loading mass m; 5 – shock sensors; 6 – ultrasound distance sensor; 7 – oscilloscope; 8 – personal computer, h – move direction of mass m
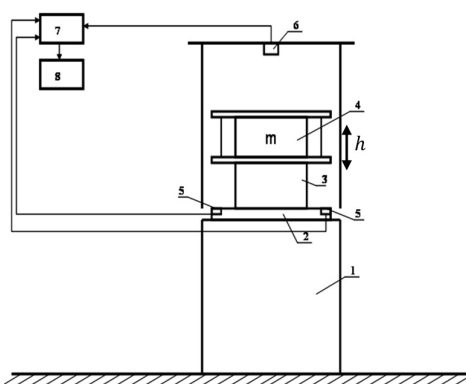

Fig. 4. Structural scheme of the stand: 1 – shock generator; 2 – steel plate; 3 – sample; 4 – loading mass m; 5 – shock sensors; 6 – ultrasound distance sensor; 7 – oscilloscope; 8 – personal computer, h – move direction of mass m

Table 1. Parameters of shock impulse

Loading mass	Up to 5 kg	Up to 50 kg	Up to 100 kg
Impulse duration	1, 5,…, 20 ms	2,..., 18 ms	2,..., 15 ms
Impulse acceleration	100 m/s², ..., 4000 m/s²	100 m/s²,…, 1600 m/s²	100 m/s²,…, 500 m/s²

The parameters of the shock impulse presented in Table 1 were formed using the shock load testing stand. During the testing, the corrugated cardboard package is attached to a moving table raised to a particular height and dropped on a solid surface.

3. Research of package deformation dependences under dynamic loading

All the tested packages during the experiment were loaded with the same mass $m = 15$ kg. During the test, the acceleration of shock mass changes from 360 m/s² to 140 m/s². The aim of this research was to determine the effect of shock frequency and loading on the package deformation.
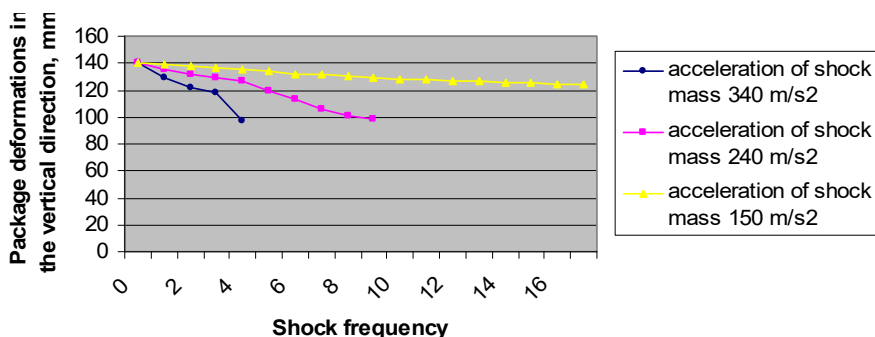
The test findings are given in Fig. 5.

Fig. 5. Dependences of deformations of rectangle three-layered corrugated cardboard packages under dynamic effect when the load mass $m = 15$ kg

Carrying out the research in 340 m/s² mode, it was determined that up to 5 shocks of the package on the solid surface, the package height in the vertical direction decreases by up to 40 mm. Besides, the edges of the package fold and the longest sidewall of the package buckles to the outer side (see Fig. 6).
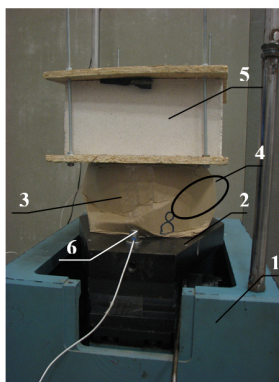

Fig. 6. General view of rectangle three-layered corrugated cardboard package after the experiment at shock acceleration 340 m/s² and vertical load mass: 1 – shock generator; 2 – steel plate; 3 – sample; 4 – buckling of package longest sidewall into outer side; 5 – load mass $m = 15$ kg; 6 – shock sensors

The other study carried out in 230 m/s² mode has shown that a corrugated cardboard package is able to withstand almost a double number of shocks (9) as the package deforms in the same way after 5 shocks in 340 m/s² mode under the same load mass $m = 15$ kg (see Fig. 5). In this case the height of the package after 5 shocks to a solid surface decreased only by 13 mm, meanwhile at 340 m/s² shock the package decreased by 40 mm.

Carrying out the test in 150 m/s² mode under the same conditions as in previous tests, the height of the package after 5 shocks to a solid surface decreased by only 5 mm. Such deformation is not clearly seen visually. As can be seen from the graph (see Fig. 5), at shock acceleration 150 m/s² and mass $m = 15$ kg, the height of the package changes in 0.2÷1 mm range, depending

on the number of shocks to a solid surface.

4. Conclusions

1) It was determined that dynamic loads with shock acceleration 340 m/s^2 and load mass $m = 15$ kg are most dangerous to package deformations.

2) At the 210 m/s^2-240 m/s^2 range of 15 kg mass acceleration, the package can withstand two times more shocks to a solid surface than at the same 15 mass 340 m/s^2 acceleration.

3) It was determined that the corrugated cardboard package loaded by mass $m = 15$ kg and at 150 m/s^2 shock mass acceleration deforms very marginally after 4-5 shocks to a solid surface. At this shock mode, the deformation of the package in the vertical direction after 5 shocks is 5 mm.

4) It was determined that during package transportation, the most dangerous regime for their deformations is at 340 m/s^2 shock mass acceleration.

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