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INVESTIGATION OF THE INFLUENCE OF THE DEGREE OF FATIGUE OF THE PAPERBOARD IN THE FOLD LINES ON THE OPENING FORCE OF THE CARTONS

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Abstract: *There were a series of experiments to establish a change of opening force of cardboard boxes as a function of fatigue cardboard in the line of folding. Were investigated cases of a single opening and closing of the carton and prior two- and three-fold opening the box. Conclusions are made with respect to the single pre-opening and was made a full factorial experiment for this case.*

Key words: *force of opening, creasing, folding boxes, paperboard, experiment, packaging, crease stiffness*

1. Introduction

Nowadays there out the cartons from the shops, where they are kept in different conditions and their opening for featuring operations with them.

The behavior of cartons during their withdrawal from the shops and the opening of the mechanisms of modern packaging machines is largely unpredictable [6, 8]. This is mainly due to the encountered in storage cartons deformation and insufficient are a lot of methods for analyzing the process of opening the cartons of the packaging machines. They allow to simulate different loads into the package and the opportunities, which the mechanisms have for drawing fatigue in the fold lines. Manufacturers cannot rely on existing empirical relationships established through experiments and experiments based on the method of "trial and error".

Dai and Cannella examine closely the characteristics and the lassitude of the material in the folding line and reveal for the first time the motion of folding and show the process through a passing graphic of the position. Three stages show the process of unfolding and the power, needed for opening the packages in each stage is with different value through the time of the package opening.

Sirkett and others examine the process of folding and closing the cartons like sequence of folding in exact position and orientating after that from one configuration to another. The possibility the cartoon groans to be folded in particular configuration is defined through cinematic geometry. By the kinematical analysis of the cartoon in time of folding the cartoon they are investigated the linear vectors and the screw theory connected with the graphical theory.

The well interaction between the packaging machines and the materials is defined through complex of interactions between the characteristic of the materials, the characteristics of the packaging as a hole, the conditions of the area, the setting of the packaging machine and the production speed. Unfortunately, there are only a few quantity defined interactions by the packaging machines and it can't be foreseen what would happen by the time of unfolding the folded cartoons. As a result of that the packaging machines are usually set through the principle of the collected into the time attempt

In the lines for the production of folding boxes to improve their characteristics, it is provided to bond with them to create compelling deformations in the folding lines. In this way it is achieved a pre-fatigue, which has a positive influence on the behavior of the packaging machine. Beldie and others [3] study and analyze the mechanical behavior of packaging paperboard subjected to static loads. The pack is cut into parts and each part has been subjected to pressure in order to determine the behavior of the different parts of the container on the overall behavior of the packaging, and then the whole package.

The results of the studies of some researchers have shown that the middle segment of the package has a higher hardness than that of the upper and lower segments and that of the entire package, which leads to the conclusion that the lower the initial hardness of the package is the result of the low rigidity of upper and lower segments. Barbier [2] and others say that it is difficult to create an accurate model for materials subjected to multiple deformations. They use FEM (Finite Elements Method) for reporting high anisotropy in the direction ZD folding of coated paper.

Numerical results show that high elastic anisotropy leads to lower levels of tensile stress in bending. The high plastic anisotropy on the other hand would be contrary to this result. Numerical methods must be used to achieve the full study of the folding process, as some of the features such as stratification, can be explained only on the basis of experimental results.

2. Materials and methods

With the help of specially made stent [1] for defining the strength of opening the cartoons are made a lot of trials. There are made trials by single and by foretime twice and three times opened cartons. The methodic for making the experiments is shown in the literature [1].

3. Results

In Figures 1, 2, 3 are shown the results of changing the power , depending on the lassitude of the cartoon in the folding line through the opening and closing in several times.

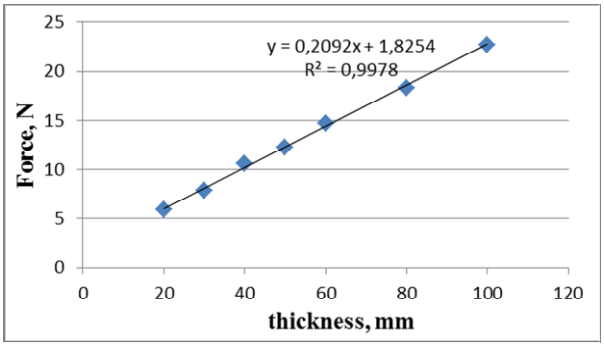

Fig. 1. *Strength of opening in a single opening and closing the cartons*

Figures 2, 3 present the results of tests of individual segments of the packaging in double and triple opening of the test model. It is obtained dependence on the strength and they were derive equations of the dependence. The values are in the range 5 ÷ 20 N, about opening twice and 4,8 ÷ 19 N opening three times the carton.

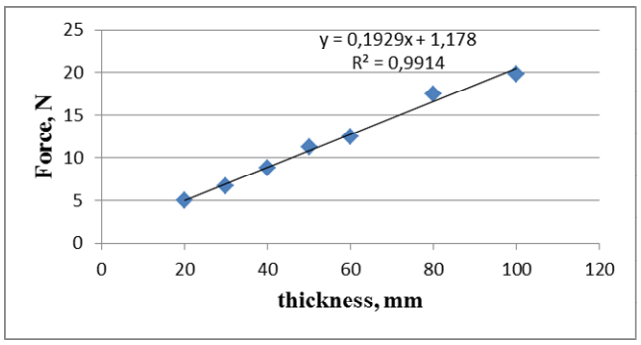

Fig. 2. *Alteration of the power at twice the opening of the samples*

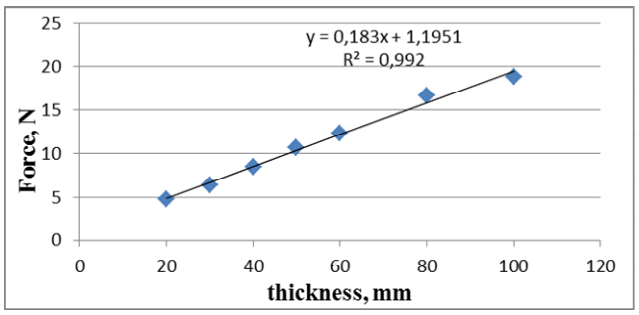

Fig. 3*. Alteration of power by opening the samples three times*

Force needed to open the carton at a preliminary fatigue by once opening and closing of the boxes. When performing a full factorial experiment for each experience it is measured also the power by opening the carton two times (F1, N). Table 1 presents the values of the force needed to open the carton at a preliminary fatigue at any attempt by FFE, as $Y_1 \div Y_3$ are measured values for each of the repetitions and $\bar{Y}$ is the average of three repetitions.

Table 1.
Matrix FFE at once opening and closing the cardboard box

№	X_1	X_2	X_3	Y_1	Y_2	Y_3	$\bar{Y}$
1	-	+	+	23,20	23,74	24,5	23,81
2	-	-	-	19,33	18,81	14,83	17,65
3	-	-	+	22,8	24,99	25,89	24,56
4	+	-	+	52,9	53,0	56,72	54,20
5	-	+	-	12,95	14,13	16,27	14,45
6	+	+	-	55,3	54,56	56,37	55,41
7	+	-	-	58,73	60,79	61,73	60,42
8	+	+	+	47,35	51,35	49,32	49,34

They is made check for uniformity of dispersion and checking of the adequacy of the

resulting regression equation. Check of the homogeneity of variances. Calculation criteria of Cochrane:

$$G = \frac{S^2_{max}}{\sum_{i=1}^{N} S_i^2} = \frac{6,06}{23,59} = 0,257 \quad (1)$$

By significance level α = 0,05 and degrees of freedom k_1 = m-1 = 3-1 = 2 and k_2 = N = 8 the value of the critical value of the criterion of Cochrane is 0,516. In the case G <G_T, which can draw a conlusion that the dispersions are homogeneous. This means that all measurements are conducted with approximately the same accuracy guaranteed by the probability γ = 1- α = 1-0,05 = 0,95.

Determining coefficients of the regression equation

The coefficients of the regression equation are determined by using the software Statgraphics. The resulted equation is as follows (with a coefficient of determination R^2 = 99,4894%):

Y = 37,4817 + 17,3617*X1 - 1,72833*X2 + +0,498333*X3 - 0,74*X1*X2 - 3,56833*X1*X3 + +0,325*X2*X3. (2)

In the equation the numbers are the coefficients of the regression where X_1, X_2 and X_3 are independent factors: the mass of the carton, the folding channel depth and the degree of deformation which influence the process. Y is a function of response - by double force opening the box F1, N. sign before each member indicates the direction of impact. Linear coefficients in the equation characterize fully the influence of the factor on the target function.

Figure 4 presents a Pareto diagram that illustrates the importance of each of the coefficients of the obtained regression equation.

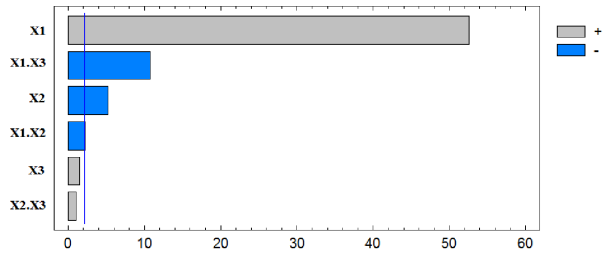

Fig. 4. *Pareto diagram*

From the resulted diagram it is clear that in this case the first three coefficients are statistically significant. After removal of the coefficients which have an insignificant effect on the output value, equation (2) takes the form:

Y = 37,4817 + 17,3617*X1 – -1,72833*X2 - 3,56833*X1*X3. (3)

Figure 5 shows the individual effects of each factor on the target function. The value of each of the lower ranges (-1) to the upper level (+1), while the other factors are fixed at their zero level.

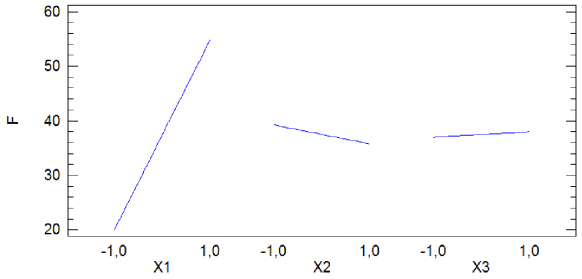

Fig. 5 *Self-influence of factors on the strength which is necessary for double opening of cardboard boxes*

Figures 6 and 7 present the surfaces of reflection and contours of the amending power needed for pre-fatigue, according to the joint influence of couples factors - mass per unit area of the board (X_1) and the depth of creases line (X_2) - Fig. 6. In Fig. 7 presents the reflection surface and contour describing the change in the force necessary to open the box with pre-fatigue depending on factors mass per unit area of the board (X_1) and the depth of creases line (X_2).

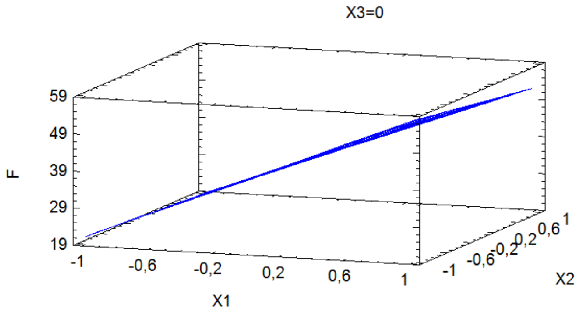

Fig. 6. *Surface reflection and contours describing the change in the force necessary to open the box with pre-fatigue depending on factors mass per unit area of the board (X1) and the depth of creases line (X2)*

4. Analisys of results and conclusions

In Figure 1 the dependence is linear with high enough accuracy. It is worked out an equation of the dependence y = 0,2092x + 1,8254, with a

coefficient of determination R^2 = 0,9978. Power is from 6 ÷ 23 N, per separate segment at the first opening of the samples. The validity of the obtained regression equations, the analyzes and conclusions are limited in the experimental plan and the specific type of carton with different mass per unit area.

The force required at a preliminary fatigue by opening of carton packages are most impacted by factors X_1- mass per unit area of the carton. The least influential factor X_2 - depth of creases line.

The analysis of temperature and humidity in the production rooms and warehouse storage shows that the critical values of temperature and humidity during the summer when the temperature and the relative humidity RH 60 ÷ 70% and winter, when the temperature and the relative humidity RH 5 ÷ 8% are. During these periods there are the most variations and manufacturers of cartons have to change production environment to produce high quality packaging.

By single foretime opening of the package from the packaging equipment, the force needed to open the carton is reduced by 10% because modulus in creases reduced due to fatigue.

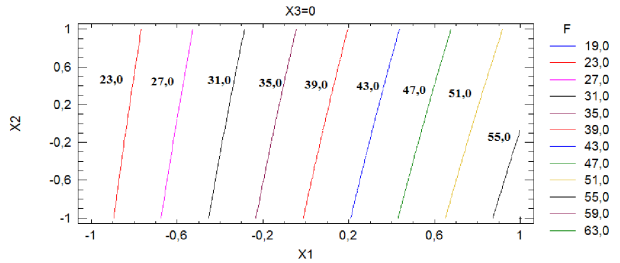

Fig. 7. *Surface reflection and contours describing the change in the force necessary to open the box with pre-fatigue depending on factors mass per unit area of the board (X_1) and the depth of creases line (X_2)*

5. Conclusion

The expected influence of the folding canal's lassitude over the power of carton's opening.

It is conducted a comparative analysis by one, two and three times foretime opening of the carton over the power size of the opening. It is presented the combined influence of the three Factors over the opening power and their separate influence. A regression analysis of the dependence is made between the opening power by foretime single opening of the carton which represents practical interest.

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