

Investigation of mechanical characteristics of polymer films for packaging production

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1. Introduction

Recently an increasing amount of polymeric materials has been used for packing and prepacking products. Besides, special effort is put into making packaging more colourful and more attractive to the buyer. This branch of industry is expanding and developing as more and more production is being exported both to the East and West. The growth of this industry segment is preconditioned by the total growth of goods turnover and advertising, as well as the development of technologies for printing graphic images on different surfaces.

There is a substantial number of studies related to mechanical properties of polymeric materials [1-6]. Quite a number of the studies have been carried out in the area of packaging technologies, medicine or pharmacy [e.g., 7]. Most of those studies focus on tension tests, and the obtained tensile characteristics help to determine the mechanical characteristics of polymers. Such studies are presented in [8, 9]. However, there are very few studies in which the mechanical characteristics of welding seams of polymeric materials are investigated [10]. There is also a shortage of studies, which would analyse mechanical characteristics of polymeric materials with formed graphic images. Therefore, the present research is of prime importance.

The growing competitiveness among manufacturers of polymeric packaging has given rise to higher requirements for its mechanical, electro-optical, qualitative and other parameters. The quality of the package manufacturing processes depend to a great extent on the quality parameters of printing materials (polymeric films), therefore the aim of this study is to determine the mechanical properties of polymeric films used in producing packaging and their seams.

2. Testing procedures

For the research purposes, two types of LDPE polymers were used, one type of them being made of 100% Tipolen granules, the other combining 50% Tipolen and 50% Pollock granules. The strength of the welding seam joints of the polymeric films and the polymer resistance to longitudinal and transversal tension was tested.

Before the tension test started, the specimens were kept under constant temperature (21°C) and humidity (52%) for a week. During the test the same temperature and humidity were maintained. The findings presented are the mean values of 10 specimens under tension test. Fig.1 shows the scheme of specimens used for testing tensile strength of LDPE polymeric bag welding seams.

For testing welding seams, 20 specimens of one polymer bag were used: 10 separate segments, obtained by

cutting them into halves (see the cutting line 1, Fig. 1) and by numbering them from 1 to 10. In order to compare and evaluate the strength of the different bag sides the two sides were marked by letters L (left) and R (right).

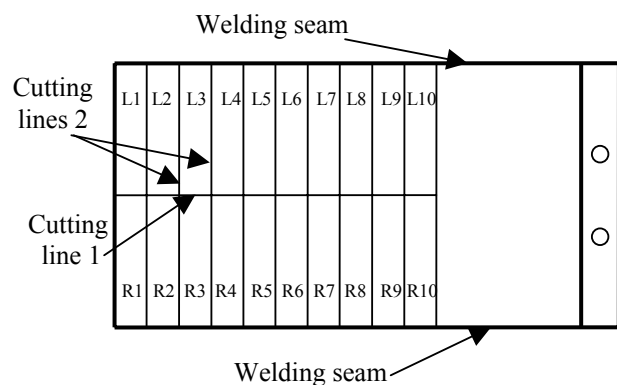


Fig. 1 Polymeric bag divided into separate segments (L1,...,L10 ir R1,...,R10) for testing the strength of the welding seams.

Tension machine Heckert FP 10/1, the technical characteristics of which are presented in Table 1, was used for carrying out the tests.

Table 1
Technical characteristics of VEB Werkzeugmaschinen tension machine "Fritz Heckert"

Tension machine number	36/85
Mass, kg	1200
Temperature interval, °C	18 – 25
Force scales, N	0-40; 0-400; 0-10000
Relative speed interval, mm/min	40-140
Elongation scales	1:4; 1:1; 4:1; 10:1
Power, k VA	2.7

The samples of the polymeric films under test were fixed in the clamps of the tension machine. For testing the welding seam strength, the specimens were placed so that the welding seam would be as close to the assumed centre between the clamps as possible, and the film itself would be least strained.

While testing the polymeric films, tension was applied at the relative speed of 100 mm/min, with the force scale 0 – 40 and the interval up to 10 N and the elongation scale 1:1. The initial width b of the specimens was 15 mm, length l was 150 mm, and the length between the tension machine clamps (operation length) l_0 was 100 mm (Fig. 2).

Thickness of the films was measured with the horizontal optimeter IKG; each polymer type was measured 10 times, and the Tables below present arithmetical mean value of the measured thicknesses.

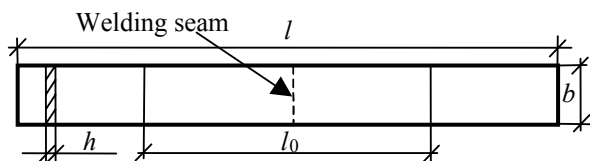


Fig. 2 Scheme for tensile test of experimental specimen: l is the initial specimen length, l_0 is length between the tension machine clamps (operation length), h is specimen thickness, b is specimen width

During test the tension machine draws the dependence of tensile strength upon the specimen elongations. In order to replace tensile strength dependence on specimen elongation by stress dependence on deformation, cross section of the specimen has to be evaluated. The stress is calculated as the ratio of strength and cross-section area:

$\sigma = \frac{F}{A}$, where σ is stress, MPa; F is tensile strength, N; A is cross section area, mm^2 . $A = b \cdot h$, where h is thickness of the specimen, mm; b is width of the specimen, mm.

The strain is calculated as the ratio of elongation and initial length: $\varepsilon = \left(\frac{\Delta l_0}{l_0}\right) \cdot 100\%$, where ε is strain, %; Δl_0 is polymer elongation before it breaks, mm; l_0 is length between the tension machine clamps (operation length), mm.

3. Analysis of the obtained testing data

LDPE films were subjected to longitudinal and transversal tensile tests to study the strength of welding seams. The characteristics obtained during the tension test are presented in Table 2 and Fig. 3.

In column one of Fig. 2, the given names mean: "Tipolen" – LDPE polymer made from 100% "Tipolen" type granules, "50/50" – LDPE polymer made from 50% "Tipolen" and 50% "Polock" granules.

Table 2

Results of LDPE film longitudinal tension tests

Polymer film type	Thickness h , mm	Width b , mm	Cross section area A , mm^2	Length l_0 , mm	Elongation Δl_0 , mm	Yield force F_y , N	Yield stress σ_y , MPa	Fracture force F_f , N	Fracture stress σ_f , MPa	Fracture strain ε_f , %
Tipolen	0.03	15	0.45	100	283.7	4.85	10.78	4.65	10.33	283.7
50/50	0.029	15	0.435	100	197.6	4.31	9.91	4.19	9.63	197.6

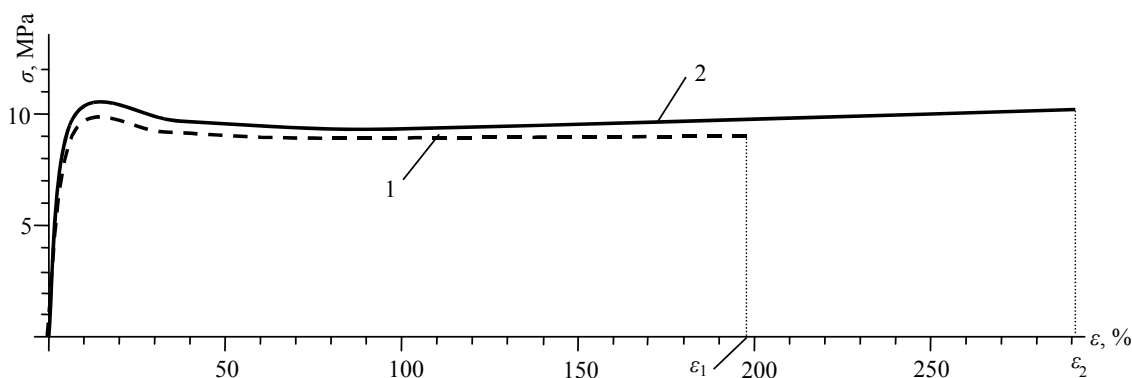


Fig. 3 Stress dependence on strain during longitudinal tension of LDPE polymers: 1 – polymer made from 50% "Tipolen" and 50% "Polock" granules; 2 – polymer made from "Tipolen" type granules

Table 3

Results of welding seam strength test of polymer bags made from LDPE polymers

Polymer film type	Thickness a_0 , mm	Width b_1 , mm	Cross section area A , mm^2	Length l_0 , mm	Elongation Δl_0 , mm	Yield force F_y , N	Yield stress σ_y , MPa	Fracture force F_f , N	Fracture stress σ_f , MPa	Fracture strain ε_f , %
Tipolen L	0.03	15	0.45	100	78.3	4.66	10.36	8.01	17.8	78.3
Tipolen R	0.03	15	0.45	100	76.5	4.7	10.44	7.91	17.58	76.5
50/50 L	0.029	15	0.435	100	70.9	3.47	7.98	7.49	17.22	70.9
50/50 R	0.029	15	0.435	100	70.4	3.79	8.71	7.98	18.34	70.4

Table 2 and Fig. 3 show that the tension characteristics of LDPE polymers made from “Tipolen” type granules and polymers made from 50% “Tipolen” and 50% “Pollock” granules are similar. It may be noted that yield stresses (repectively, $\sigma_y^{Tipolen} = 10.78$ MPa, $\sigma_y^{50/50} = 9.91$ MPa) and fracture stress ($\sigma_f^{Tipolen} = 10.33$ MPa, $\sigma_f^{50/50} = 9.63$ MPa) do not differ much. The results of polymer made from 100% “Tipolen” type granules are higher. During the transversal LDPE polymer tension, the yield stresses are larger than a fracture stresses.

Meanwhile, fracture strains in these different polymers differ. Fracture strains in LDPE polymers made from “Tipolen” type granules are about 1.5 times larger than in polymers made from 50% “Tipolen” and 50% “Pollock” granules ($\epsilon_f^{Tipolen} = 283.7\%$, $\epsilon_f^{50/50} = 197.6\%$, respectively).

Results of LDPE polymer welding seam strength study are presented in Table 2 and Fig. 4.

In Fig. 4 one can see that yield stresses of the left and right seam ($\sigma_y^L = 10.36$ MPa, $\sigma_y^R = 10.44$ MPa, respectively), fracture stresses ($\sigma_f^L = 17.8$ MPa, $\sigma_f^R = 17.58$ MPa) and fracture strain ($\epsilon_f^L = 78.3\%$, $\epsilon_f^R = 76.5\%$) of “Tipolen” type polymer bags do not differ much. Bigger differences can be traced between stresses in polymer made from 50% “Tipolen” and 50% “Pollock” granules (yield stresses $\sigma_y^L = 7.98$ MPa, $\sigma_y^R = 8.71$ MPa and fracture stresses $\sigma_f^L = 17.22$ MPa, $\sigma_f^R = 18.34$ MPa, respectively), while fracture strains differ only slightly ($\epsilon_f^L = 70.9\%$, $\epsilon_f^R = 70.4\%$).

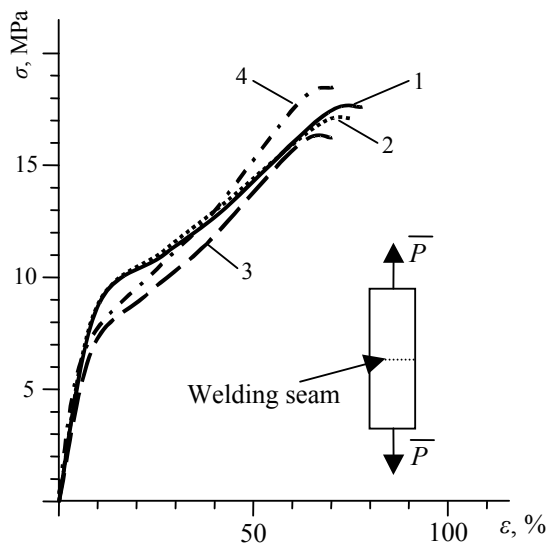


Fig. 4 Tension curves: 1 – polymer made from “Tipolen” type granules, left seam; 2 – polymer made from “Tipolen” type granules, right seam; 3 – polymer made from 50% “Tipolen” and 50% “Pollock” granules, left seam; 4 – polymer made from 50% “Tipolen” and 50% “Pollock” granules, right seam

A more thorough statistical fracture analysis showed that out of 30 “Tipolen” type polymer bag specimens there were 4 cases of fracture through the left seam (see Fig. 1 L1 – L10) and 12 fracture through the right seam. Meanwhile, among the 30 specimens of polymer made from 50% “Tipolen” and 50% “Pollock” granules, 2 cases of fracture occurred both in the left and the right seams. Consequently, it may be stated that the seams of the

polymer made from 50% “Tipolen” and 50% “Pollock” granules are stronger than those of “Tipolen” type polymer.

Tensile tests with different materials showed that the polymer made from “Tipolen” type granules has higher yield stress than the polymer made from 50% “Tipolen” and 50% “Pollock” granules (e.g, left side $\sigma_y^{Tipolen} = 10.36$ MPa and $\sigma_y^{50/50} = 7.98$ MPa). However, the right side fracture stress is bigger in the polymer made from 50% “Tipolen” and 50% “Pollock” granules than in the polymer made from “Tipolen” type granules ($\sigma_f^{Tipolen} = 17.58$ MPa ir $\sigma_f^{50/50} = 18.34$ MPa).

The tests carried out lead to the following conclusions.

4. Conclusions

1. The longitudinal tension tests have shown that mechanical properties of LDPE polymer made from 100 % “Tipolen” type granules are better than those of the polymer made from 50% “Tipolen” and 50% “Pollock”, i.e, higher yield stress σ_y ($\sigma_y^{Tipolen} = 10.78$ MPa, $\sigma_y^{50/50} = 9.91$ MPa), higher fracture stress σ_f ($\sigma_f^{Tipolen} = 10.33$ MPa, $\sigma_f^{50/50} = 9.63$ MPa).

2. Welding seam strength tests of LDPE polymers have shown that there is a little difference between the left and right side yield stresses ($\sigma_y^L = 10.36$ MPa, $\sigma_y^R = 10.44$ MPa, respectively), fracture stresses ($\sigma_f^L = 17.8$ MPa, $\sigma_f^R = 17.58$ MPa) and strains ($\epsilon_f^L = 78.3\%$, $\epsilon_f^R = 76.5\%$). Greater differences were noted between stresses in the polymer made from 50% “Tipolen” and 50% “Pollock” granules (yield stresses $\sigma_y^L = 7.98$ MPa, $\sigma_y^R = 8.71$ MPa and fracture stresses $\sigma_f^L = 17.22$ MPa, $\sigma_f^R = 18.34$ MPa, respectively), while strains do not differ much ($\epsilon_f^L = 70.9\%$, $\epsilon_f^R = 70.4\%$).

3. Comparison of welding seam strength of both LDPE type polymers demonstrated that the yield stress is higher in the polymer made from “Tipolen” type granules than in the polymer made from 50% “Tipolen” and 50% “Pollock” granules (e.g, left side (see Fig.1 L1,...,L10) $\sigma_y^{Tipolen} = 10.36$ MPa, and $\sigma_y^{50/50} = 7.98$ MPa). Meanwhile, the fracture stress of the right side of the polymer made from 50% “Tipolen” ir 50% “Pollock” granules (see Fig. 1 R1,...,R10) is higher than that of the polymer made from 100% “Tipolen” granules ($\sigma_f^{Tipolen} = 17.58$ MPa and $\sigma_f^{50/50} = 18.34$ MPa).

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PAKUOČIŲ GAMYBAI NAUODOJAMŲ
POLIMERINIŲ PLĖVELIŲ MECHANINIŲ
CHARAKTERISTIŲ TYRIMAS

R e z i ū m ė

Straipsnyje pateiktas lanksčioms pakuotėms naudojamų LDPE polimerinių plėvelių išilginio tempimo ir

suvirinimo siūlių atsparumo tempimui, taip pat deformacijų tyrimas. Sudarytos įtempių priklausomybių nuo deformacijų kreivės, nustatyti takumo (σ_y) ir trūkimo (σ_f) įtempiai bei deformacijų (ϵ_f) vertės.

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INVESTIGATION OF MECHANICAL
CHARACTERISTICS OF POLYMER FILMS FOR
PACKAGING PRODUCTION

S u m m a r y

This paper reports on a comparative study of various types of experimental tests of LDPE polymer films. Mechanical and tensile characteristics, also the strength of welding seams of polymer packages are investigated. Fracture (σ_f), yield (σ_y) stress and strain (ϵ_f) are determined.

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ИССЛЕДОВАНИЕ МЕХАНИЧЕСКИХ
ХАРАКТЕРИСТИК ПОЛИМЕРНЫХ ПЛЕНОК,
ИСПОЛЬЗУЕМЫХ ДЛЯ ПРОИЗВОДСТВА
УПАКОВОК

Р е з ю м е

В настоящей работе приведено исследование механических характеристик полимерных пленок LDPE, используемых для производства гибких упаковок. Составлены зависимости и кривые напряжений от деформаций, установлены значения напряжения текучести (σ_y) и разрыва (σ_f), а так же деформации (ϵ_f).

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