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Theoretical background when closing a package with metal clips

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1. Introduction

A problem of avoiding food product losses that appear because of the long distance the products travel from producer to end user and maintaining good quality is a social concern, not only the economical one. The problem can be solved and food products protected from environmental factors, including the influence of harmful substances, by a rational use of polymer and protein substances preventing the products from loosing their beneficial properties and components, which define the nutrition value of a product [1, 2, 3].

Packaging materials, which directly contact food products must have chemical resistivity and certain physical, chemical, mechanical and technological properties, meet hygiene requirements and assure high automatization level of packaging process [4, 5].

When packaging products into bar-type packages, internal surfaces of packaging material contact the product and that disturbs or totally prevents the proper tight joining of the package ends using traditional methods like welding, gluing etc. In such case the best solution is closing the package ends with metal clips [6].

Summarizing the carried out research of on the application of new packages, packaging materials and technologies it can be stated that:

- a proper package, new packaging materials and new package development is a global problem of food preservation.
- development of packaging system for product packing into film packages closing their ends by metal clips requires comprehensive investigations, new technologies, new principal design solutions, new calculation methods, improvement of theoretical design basics, new structure design, analysis of their testing in industrial environment and extensive implementation in a batch production.

2. Theoretical investigations

Fig. 1 shows the clip shaping technology. Usually for clip production aluminium or magnesium alloys of medium or high plasticity are used. The limiting value of clip bending moment M_{rb} is determined according to the condition that normal stresses in all the sections must be equal to the yield point σ_y. In the presence of plastic strain of a clip the limiting bending moment is the best expressed in terms of yield strength

$$M_{rb} = W\sigma_y \tag{1}$$

In the beginning of clip bending (Fig. 1) the bending moment can be expressed by the following equation:

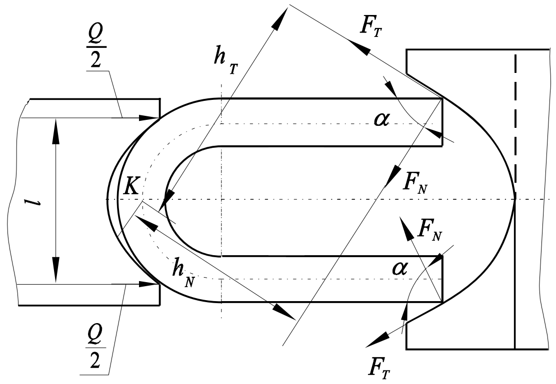
$$M_{rb} = \frac{Ql}{4} + F_N h_N - F_T h_T = \frac{Ql}{4} + F_N\left(h_N - \mu h_T\right) \tag{2}$$

The value of force Q necessary for acting upon a punch can be expressed by matrix reaction and friction coefficient the clip and matrix surface

$$Q = 2F_N\left(cos\alpha + \mu sin\alpha\right) \tag{3}$$

Reorganizing the equation (2) we get

$$M_{rb} = F_N\left[h_N - fh_T + 0.5l\left(cos\alpha + \mu sin\alpha\right)\right] \tag{4}$$



a

b

Fig. 1 The clip shaping technology: a - brace in the beginning of bending; b - the punch

From Eqs. (3) and (4)

$$F_N = \frac{M_{rb}}{h_N - \mu\, h_T + 0.5l\left(cos\alpha + \mu\, sin\alpha\right)} \tag{5}$$

$$Q = \frac{2M_{rb}\left(cos\,\alpha + \mu\, sin\,\alpha\right)}{h_N - \mu h_T + 0.5l\left(cos\,\alpha + \mu\, sin\,\alpha\right)} \tag{6}$$

The parameters α, h_N, h_T used in the equations are variable.

When the clip position changes (Fig. 2, cases a and b), force Q distributes over all working surface of the punch as bending increases. In the final clip bending stage the force necessary to act upon the punch is

$$Q = \frac{2M_{rb}\,cos\,\alpha}{0.25l\,cos\,\alpha + h_N} \tag{7}$$

Assuming that $Q = lq$, the distributed load acting upon the clip has the following expression

$$q = \frac{2M_{rb}\cos\alpha}{l(0.25l\cos\alpha + h_N)} \quad (8)$$

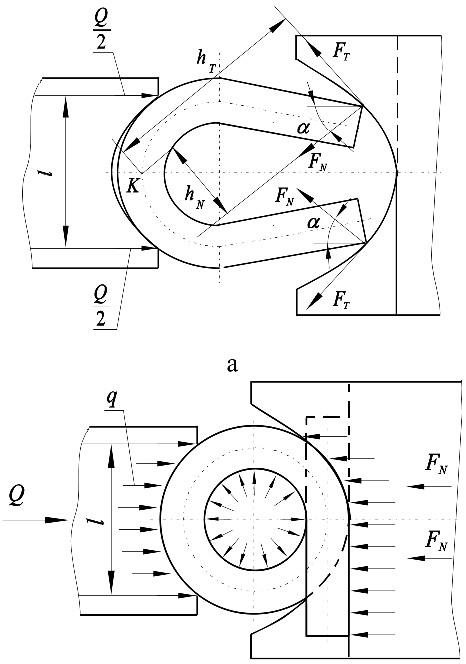


Fig. 2 Distribution of force Q over operational surface of the punch in the case of: a – intermediate brace bending position; b – bended brace

Let us say that relative pressure in the wrinkles is uniformly distributed in the contact surface with respect to width. Relative pressure p can be expressed in terms of the force Q acting upon the punch. For this purpose an equilibrium equation of forces acting upon the wrinkle with respect to the horizontal axis is constructed (Fig. 3.)

$$Q - \int_S \cos\gamma dN = 0 \quad (9)$$

where dN is $prbd\gamma$; b is clip width; r is radius of a wrinkle.

Integrating in the range of angle γ from $\gamma = -\frac{\pi}{2}$ to $\gamma = \frac{\pi}{2}$, we obtain

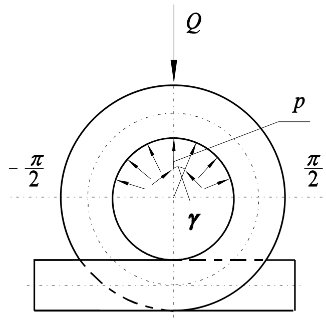


Fig. 3 The scheme of pressure determination when putting on the brace

$$p = \frac{Q}{2rb} \quad (10)$$

Limiting clip bending moment, when the punch contacts the clip by its total surface, in the section n–n (Fig. 4), is expressed as follows

$$M_{rb} = F_N h\left[\sin(\alpha+\beta) - \mu\cos(\alpha+\beta)\right] \quad (11)$$

from here

$$F_N = \frac{M_{rb}}{h\left[\sin(\alpha+\beta) - \mu\cos(\alpha+\beta)\right]} \quad (12)$$

The force Q, acting upon the punch is

$$Q = \frac{2M_{rb}(\cos\alpha + \mu\sin\alpha)}{h\left[\sin(\alpha+\beta) - \mu\cos(\alpha+\beta)\right]} \quad (13)$$

The force acting upon the punch during bending, when the variable parameters are e, ρ and c, is determined from the equation (13).

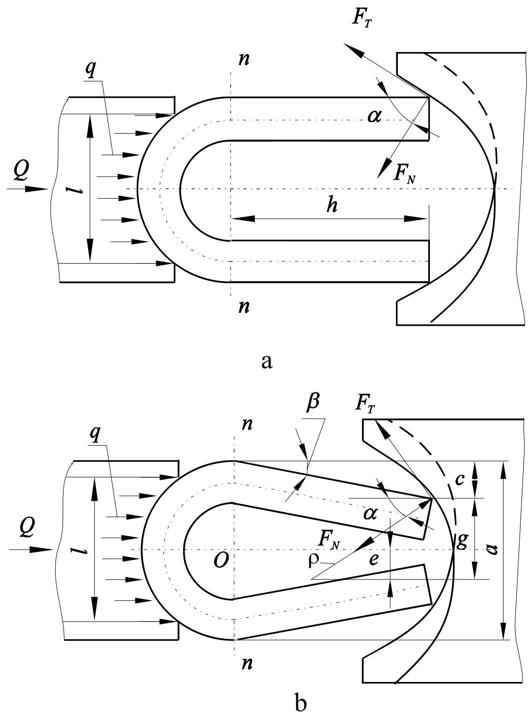
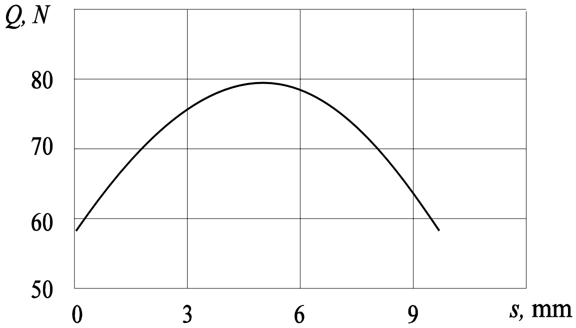


Fig. 4 Determination scheme of forces and moments, acting in clip bending when the punch contacts the clip by its total surface in the cases: a – beginning of clip bending; b – intermediate clip position in bending

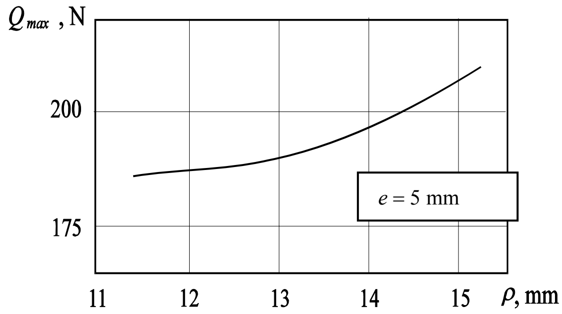
When $\alpha \to 0$ and $\beta = 90^0$, the force acting upon the punch and delivered to the wrinkle at the end of clip formation has the following expression

$$Q = \frac{2M_{rb}}{h} \quad (14)$$

As it can be seen from the equation (14), force Q is inversely proportional to the clip height h.



a



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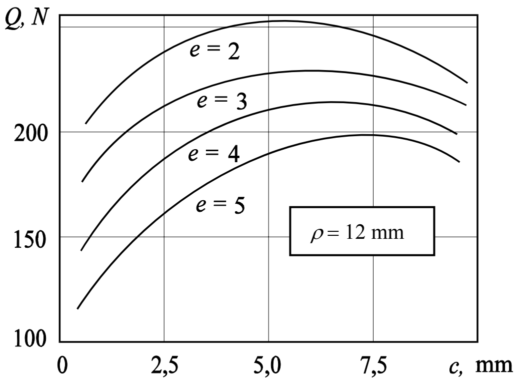
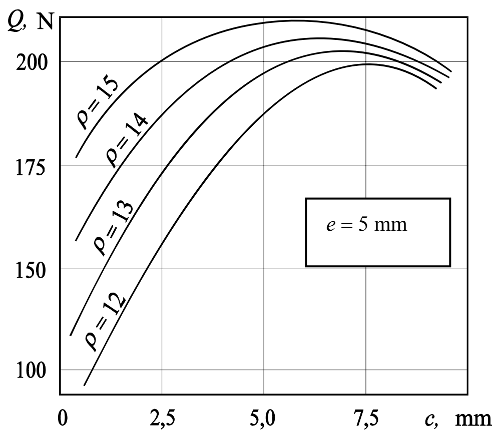


c



d

Fig. 5 Dependency of force Q, upon: a – punch motion s; b – radius of curvature ρ; c – magnitude of clip bend c; d – magnitude of clip bend c; when d = 3 mm, h=12 mm, l=10 mm, σ_u=200 MPa

The dependency of a force Q, acting upon the punch on punch motion s, the magnitude of clip bend c, curvature radius ρ and eccentricity e is presented in the Fig. 5, cases a, b, c and d.

The clip can be produced from a rolled aluminum wire of different cross-sections. The wire can have round, flat or other type cross-sectional shape. When forming the clip on a film bar it is very important that the film would not be harmed or pressed through in the clip shaping position.

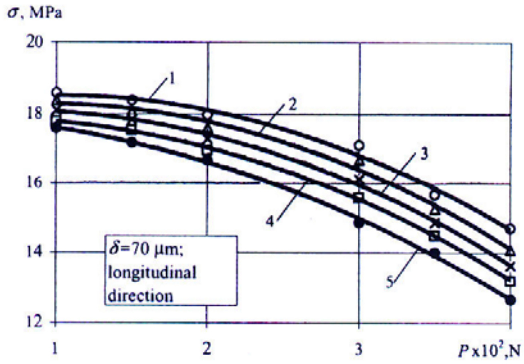


Fig. 6 Dependency of strength change on the pressing force in tension, pressing through the samples of the different thickness δ cut in the transverse direction with the clip of different diameter d: 1 – d = 3 mm; 2 – d = 2.5 mm; 3 – d = 2.25 mm; 4 – d = 1.75 mm; 5 – d = 1.0 mm

One of the diagrams of the change of film pressing through force is presented in Fig. 6.

The experiments showed that employing flat clips the samples could be pressed through by a 4 - 5 times higher force.

On the basis of the investigated technologies of aluminium wire clip shaping and putting on the package wrinkle, process research, calculation and optimization data there were made several characteristic design solutions, which were implemented in packaging machines and they were produced in batches [7, 8].

3. Conclusions

1. Theoretical basics of package closing with metal clips were created, new technologies, new design solutions and their calculation and optimization methods and structures were developed. The equations for calculations of a force necessary to act upon the punch and the value of normal reaction force between the clip and matrix were presented. It was determined that matrix parameters, i.e. eccentricity of matrix curvature centre e and radius of curvature ρ, have on influence on the force necessary to act upon the punch and on normal reaction force appearing between the clip and matrix.

2. It was determined that cross-section shape of the clip wire has essential influence in pressing through the samples. When employing flat clips, samples could be pressed through by a 4.5 times greater force.

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TEORINIAI PAKUOČIŲ UŽDARYMO METALINĖMIS SĄVARŽOMIS PAGRINDAI

R e z i u m ė

Straipsnyje pateikti pakavimo automatų produktams fasuoti į plėveles, užspaudžiant pakuočių galus metalinėmis sąvaržomis, teoriniai pagrindai. Gautos priklausomybės pateiktos parametrine forma bei leidžia parinkti reikiamus parametrus, optimizuoti konstrukcijas, praplėsti tokių pakavimo automatų automatizuotojo modulinio projektavimo duomenų banką.

L. Paulauskas

THEORETICAL BACKGROUND WHEN CLOSING A PACKAGE WITH METAL CLIPS

S u m m a r y

Technology and calculation of automatic formation of clips in automatic machines for food products packing into film packages is presented. Relationships obtained are presented in parametrical form and form of diagrams for the selection of necessary parameters, structure optimization and extend the data bank for automated modules of packing machines designing.

Л. Паулаускас

ТЕОРЕТИЧЕСКИЕ ОСНОВЫ ЗАКРЫТИЯ УПАКОВОК МЕТАЛЛИЧЕСКИМИ СКРЕПКАМИ

Р е з ю м е

Представлены теоретические основы закрытия упаковок металлическими скрепками в фасовочно – упаковочных автоматах для упаковки пищевых продуктов в пленочную тару. Полученные зависимости, представлены в параметрической форме и в графиках дают возможность подобрать необходимые параметры, оптимизировать конструкции и расширить банк данных модульного автоматизированного проектирования упаковочных автоматов.

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