Journal for Technology of Plasticity, Vol. 37 (2012), Number 2

PROCESSING OF PLASTICS AND RUBBER MIXTURES ON MILLS AND CALENDERS WITH WEDGE DEVICES

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ABSTRACT

Wedge devices are used to increase the influence of rolls in a roll machines (mills and calenders) in the zone of processed material. These devices not only intensify rolling and calendering, but also promote degassing of the material. The technique of parametrical and thermal calculation of roll machines for processing of power-law materials is presented. Results of numerical simulation of processing of rubber on three-roll calender with the wedge device are presented. It is shown that key parameters of processing in a wedge gap are commensurable with similar parameters of processing in a roll gap the roll machines. Recommendations about an effective utilization of the wedge devices are formulated.
Key words: *Power-law model fluid, roll machine, wedge device, parameters of process, recommendations about using*

1. INTRODUCTION

One of the ways to intensify milling and calendering of plastics and rubber mixes is the use of devices that change hydrodynamics of the processed material on roll machine. Such devices concern, first of all, wedge devices. The wedge devices consist of a wedge which usually has system of thermal stabilization on its working surface and the mechanism for regulation of its position on the rolls. The wedge forms with one or two rolls of the machine additional curvilinear converging (wedge) working gaps, increases a zone of active influence of rolls by a material, improves mixing and plasticizing effect of the equipment, and also promotes degassing of a processed material and raises quality of products or half-finished products [1],[2],[3].
In the literature there are data on mathematical modeling of polymers and rubbers processing both in the wedge gap [4], and in consistently located wedge and roll gaps [5],[6]. In the work [6] the mathematical model of a non-stationary flow of a pseudo-plastic material in a wedge gap is

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considered, and inthe work [5] the similar analysis in isothermal approach is made that essentially simplifies considered process. In the work [4] the isothermal flow of a material in a wedge gap apart from a rolls gap is presented, that is inexpedient , as practical use of wedge devices has shown. Besides, in the work [4] there are no data on boundary conditions on pressure in a wedge gap, and also the assumption about presence of a gradient of pressure across a rolls gap is made but presence of this gradient is not confirmed by experimental researches.
The further intensification of processing of plastics and rubbers on roll machines with use of wedge devices demands working out a design procedure of calendering and milling taking into account presence of one or several wedge devices on a roll machine.
The purpose of this article is working out a design procedure of processing on the calendar and the mills supplied with one or several wedge devices. Materials are thermoplastics which behavior under loading obeys the power rheological law (power law model fluid).

2. MODELING OF PROCESSING OF POWER-LOW MODEL FLUID

During processing the material from the conveyor arrives in a feeding gap (a roll gap or a wedge gap) of the calender. Then the material is distributed lengthways the roll and in the form of preliminary formed sheet leaves the gap. The subsequent movement of the material from one gap to another promotes improvement of quality of a processed material and its physical and mechanical properties. Thus there is a continuous change of temperature of a mixture owing to dissipation of mechanical energy and heat exchange with working bodies and air. Installation of wedges is most expedient in calibrating or intermediate roll gaps of a calender, and also on the beginning of the roll gap of mills (Fig.1).

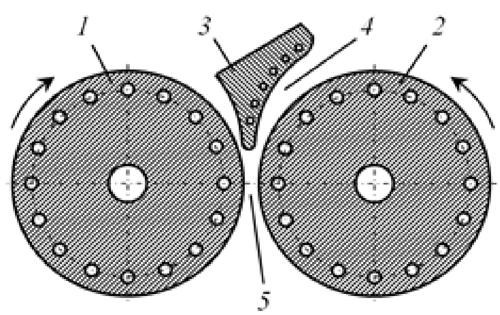

Fig. 1 – The installation scheme of a wedge device on mills:
1, 2 – rolls; 3 – a wedge device; 4, 5 – wedge and roll gaps, respectively

The complex decision of processing of a material on roll machine with use of wedge devices will allow counting correctly material temperature, the capacity spent in wedge and roll gaps, and also a transverse forces operating on each of the rolls from outside wedge and roll gaps (wedge-separating and roll-separating forces, respectively). Thereupon it is necessary to analyze following possible variants of a relative positioning of wedge and roll gaps:

1. Deformation zones of wedge and roll gaps are not crossed and do not adjoin and between zones there is a site of free movement of a material on the roll. Superfluous pressure in the wedge gap changes from zero to maximum and again reduces to zero in wedge top, remains equal to

zero at movement between wedge and roll gaps and then again increases from zero to a maximum in roll gap and reduces to zero on an exit from it.

2. Deformation zones of wedge and roll gaps adjoin. Thus the end of a zone of deformation of the wedge gap in which superfluous pressure is absent coincides with the corresponding coordinate of the beginning of a deformation zone of the roll gap. During processing the mixture contacts to working bodies (rolls and wedge) of roll machine. Superfluous pressure in a material changes from zero to zero, passing thus through two maximum (in the both gaps).

3. Deformation zones of wedge and roll gaps are crossed. Thus the end of the wedge gap deformation zone is located within the deformation zone of the roll gap (Fig.2).

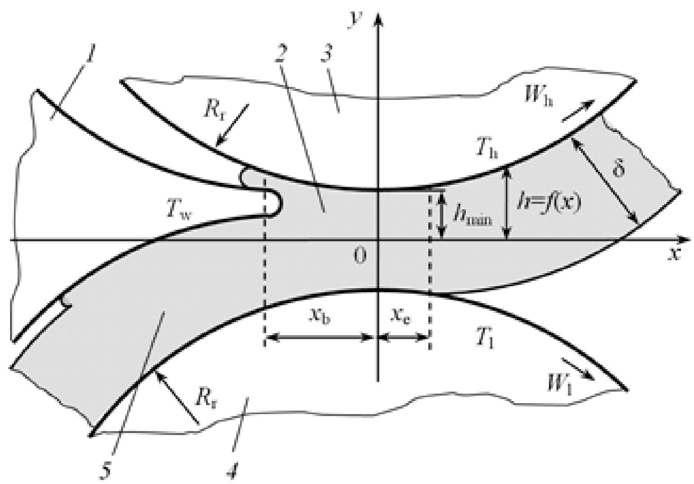

Fig.2 – The scheme of an arrangement of the wedge in the roll gap of calender: 1– the wedge; 2– the roll gap; 3, 4– high-speed roll and low-speed roll, forming the roll gap; 5 – the curvilinear wedge gap; x and y are the coordinates along and across the roll gap, m; x_b and x_e are the coordinates of the beginning and the end of a deformation zone of the roll gap, m; hand h_{min} are half of current and half of minimum sizes of the roll gap, respectively, m;$R_r$is the radius of roll barrel, m;W_h andW_l are linear velocity of the high-speed roll and low-speed roll, respectively, m/s; T_h and T_l are temperature of high-speed roll barrel and low-speed roll barrel, respectively, °C; T_w is temperature of the working surface of the wedge

Pressure in a material changes from zero to maximum, then to boundary value in the wedge gap and from this size to maximum and again to zero in the wedge gap. Depending on depth of immersing of top of the wedge in the deformation zone of the roll gap change the total transverse forces operating on the wedge and the rolls, size of a zone of deformation of the roll gap, and also consumed of the rolls the capacity influencing a temperature field of a material and its quality also. The decision of these problems is extremely important for increase of roll machine throughput with high-quality production.

On the basis of theoretical and current experimental research the technique of definition of key parameters of roll machines with use of wedge devices is developed.

The technique gives the possibility to define:

- A temperature field of a material during processing;
- The wedge separating force operating on the wedge and the roll;

- A torques operating on the rolls, and the capacities necessary for maintenance of the torques;
- Parameters of system of a heat supply of the rolls and the wedge;
- As much as possible admissible speeds of the rolls which provide necessary temperature of a material during processing.

The initial data for calculation are the parameters necessary for definition of power characteristics of calendaring or milling [7],[8] and also size of a wedge gap in the wedge top h_t, an angle α between the wedge and the roll (after a flattening of the curvilinear wedge gap), position of the wedge top x_t in system of coordinates "roll-roll", temperature of the working surface of the wedge T_w and presence of system of thermal stabilization of its.

After definition rheological and thermo physical properties of a material in a working interval of temperatures, thermophysical properties of the heat-carrier and air, district speeds of rolls, and also sizes of roll gaps it is necessary to define borders of the deformation zones of a material in roll [7],[8] and wedge [9] (wedges – in the presence of several devices) gaps.

Coordinate of the beginning of the deformation zone of the roll gap located directly after the wedge gap defines preliminary point [7]. Then count dimensionless analog of the x coordinate positions of the wedge top in system of coordinates "roll-roll":

$$\xi_t = \frac{x_t}{\sqrt{2R_r h_{\min}}}$$

If ξ_t is less than ξ_b the beginning of the deformation zone corresponding of the roll gap the wedge top settles down out of the deformation zone of the roll gap, i.e. deformation zone of wedge and of roll gaps are not crossed. In this case preliminary found coordinate of the beginning of the deformation zone of the roll gap is accepted as coordinate ξ_b the roll gap.

Coordinate ξ_e (the end of the deformation zone of the wedge gap) is defined from expression [6],[7],[9]

$$p = \frac{KW_r^n \cot\text{an}\alpha\,(1+n)^n(1+2n)^n}{n^n h_{wb}^{2n}} \int_0^{\xi} \left|h_{wb}(1-\xi)-2\delta\right|^n \operatorname{sign}\left[h_{wb}(1-\xi)-2\delta\right] \frac{1}{(1-\xi)^{2n+1}}\, d\xi \qquad (1)$$

taking into account that in the beginning and the end (top of the wedge)of the deformation zone of the wedge gap superfluous pressure in a wedge gap is equal zero.

In expression (1) following designations are accepted: W_r is speed of a working surface of roll, forming with the wedge gap, m/s; $K$is consistency index of a material, Pa·s^n; n is power low index (an exponent of the rheological equation); $h_{wb}$is size of the wedge gap in the beginning a of its deformation zone, m; δ is a thickness of a tape of the material removed from the roll gap, m; α is wedging angle of the wedge gap, ….

In a case if value of coordinate of the wedge top ξ_t is less than coordinate the roll gap ξ_b the wedge top settles down within the deformation zone of the roll gap, i.e. zones of roll and wedge gaps is crossing. Thus the pressure developed in a roll gap will be defined by expression

$$\int_{\xi_e}^{\xi_b} \left[\frac{|A|^n \operatorname{sign}(A) - |B|^n \operatorname{sign}(B)}{1+\xi^2}\right] d\xi = 0$$

where: $A = \left(\frac{1+2n}{n}\right)\frac{(1+\psi)(\xi^2-\xi_e^2)}{(1+\xi^2)^2} + \frac{1-\psi}{1+\xi^2}$; $B = -\left(\frac{1+2n}{n}\right)\frac{(1+\psi)(\xi^2-\xi_e^2)}{(1+\xi^2)^2} + \frac{1-\psi}{1+\xi^2}$

ψ – friction factor in the roll gap ($\psi = W_l / W_h$); ξ_e is dimensionless coordinate the end of the deformation zone of the roll gap.

Coordinate ξ_t the end of the zone of deformation of the wedge gap in system of coordinates "wedge-roll" is defined from expression (1) taking into account that at $\xi = \xi_t$ pressure in the wedge gap(in the wedge top) corresponds to the pressure developed in the roll gap at $\xi = \xi_b$ in system of coordinates "roll-roll".

For calculation of a temperature field of processed material on a roll machine and for definition of losses of heat from a surface of the processed material, both free surfaces of the rolls and the wedge, it is necessary to know the angles corresponding to coordinates of an input of the material in the gaps and an exit from them and counted from a plane, passing through longitudinal axes of the rolls, forming the roll gap. Dependences for definition of working zones of the rolls, not co-operating with a wedge, are presented in works [7],[8],[10]. For the roll forming the wedge gap angles depend on a relative positioning of roll and wedge gaps. In a case when between the wedge top the site of contact of the material with environment is available the subsequent by the roll gap, an angle corresponding to a surface of the roll, covered with the material, it is defined on expression [7] and decreases for the size corresponding to the wedge gap.

Otherwise the angle corresponding to a way of the material flow in wedge γ_{wg} and roll γ_{rg} gaps, will be defined as follows

$$\gamma_g = \gamma_{wg} + \gamma_{rg}$$

The temperature field of the material at its movement from the felling gap to a point of removal of a formed sheet or film from a machine is defined according to [7] taking into account that in the wedge gap the temperature field of the material is defined by the equation decision

$$\left[1-\varepsilon-\varepsilon\left(1-\varepsilon^{\frac{1}{n}}\right)(1+2n)\left(1-\frac{2\delta}{h_{\mathrm{wb}}(1-\xi)}\right)\right]\frac{\partial T}{\partial \xi}=\frac{\lambda \operatorname{cotan}\alpha}{\rho\, c_p h_{\mathrm{wb}} W_{\mathrm{r}}(1-\xi)^2}\frac{\partial^2 T}{\partial \varepsilon^2}+$$

$$+\frac{K W_{\mathrm{r}}^n \operatorname{cotan}\alpha}{\rho\, c_p h_{\mathrm{wb}}^n (1-\xi)^{n+1}}\left|-1-(1+2n)\left(1-\frac{2\delta}{h_{\mathrm{wb}}(1-\xi)}\right)\right|\left(1-\frac{1+n}{n}\varepsilon^{\frac{1}{n}}\right)^{n+1} \tag{2}$$

where: ε is dimensionless analog of the y coordinate; T is temperature, °C; λ,ρ, c_p are heat conductivity W/(m·K), density (kg/m^3), mass thermal capacity (J/(kg·K)) of the material as a functions of temperature.

The equation (2) solve taking into account initial and boundary conditions: $T_0 = T(y)$; $T_{|\varepsilon=0} = T_r$; $T_{|\varepsilon=1} = T_w$,where T_r and T_w are temperatures of the roll and the wedge, respectively, °C.

The equation (2) is the nonlinear differential equation of parabolic type which solves one of numerical methods [11].

After definition of a temperature field and average temperatures of the material in the gaps we find the forces operating on the rolls and the wedge. The roll-separating forces operating on are rolls, not co-operating with a wedge, are defined according to a technique [7],[8],[10].

The wedge-separating forces (N) operating on the wedge and the corresponding roll, are defined by expression

$$F_{\mathrm{w}} = \frac{L_{\mathrm{w}} K W_{\mathrm{r}}^{n} \operatorname{cotan}^{2}\alpha (1+n)^{n} (1+2n)^{n}}{n^{n} h_{\mathrm{wb}}^{2n\text{-}1}} \int_{\xi_{\mathrm{wb}}}^{\xi_{\mathrm{we}}} \int_{\xi_{\mathrm{wb}}}^{\xi} \left| h_{\mathrm{wb}}(1-\xi) - 2\delta \right|^{n} \operatorname{sign}\left[h_{\mathrm{wb}}(1-\xi) - 2\delta \right] \frac{1}{(1-\xi)^{2n+1}} d\xi d\xi$$

where:$L_{\mathrm{w}}$is length of a wedge, m; ξ_{wb}, ξ_{we} are dimensionless analog of the x coordinate in a system of coordinates "wedge-roll".
The wedge-separating forces operate on a normal to working surfaces of the wedge and the roll, and points of their appendix define in coordinate the area center of gravity under a pressure curve in the wedge gap [7],[8].
Definition of the forces (N) which are result of tangential stresses action on working surfaces of the wedge P_{w} and the roll P_{r} is similar to definition of the tangential stresses forces operating on the rolls at processing without use wedge device [7],[8]. The specified forces can be defined on dependences

$$P_{\mathrm{w}} = \frac{L K W_{\mathrm{r}}^{n} \operatorname{cotan}\alpha}{h_{\mathrm{wb}}^{n\text{-}1}} \times$$
$$\times \int_{\xi_{\mathrm{wb}}}^{\xi_{we}} \left| -1 - (1+2n)\left(1 - \frac{2\delta}{h_{\mathrm{wb}}(1-\xi)}\right) \right|^{n} \operatorname{sign}\left(-1 - (1+2n)\left(1 - \frac{2\delta}{h_{\mathrm{wb}}(1-\xi)}\right) \right) \frac{1}{(1-\xi)^{n}} d\xi,$$

$$P_{\mathrm{r}} = \frac{L K W_{\mathrm{r}}^{n} \operatorname{cotan}\alpha}{h_{\mathrm{wb}}^{n\text{-}1}} \times$$
$$\times \int_{\xi_{\mathrm{wb}}}^{\xi_{\mathrm{we}}} \left| -1 + \left(\frac{1+2n}{n}\right)\left(1 - \frac{2\delta}{h_{\mathrm{wb}}(1-\xi)}\right) \right|^{n} \operatorname{sign}\left(-1 + \left(\frac{1+2n}{n}\right)\left(1 - \frac{2\delta}{h_{\mathrm{wb}}(1-\xi)}\right) \right) \frac{1}{(1-\xi)^{n}} d\xi.$$

The vector of the total forces operating on the roll (the wedge) is defined as the sum of vectors of weight the roll (the wedge), vectors separating forces and the tangential forces operating from a material deformed in the gaps (the gap).
The torques operating (N·m) on the roll, not co-operating with the wedge, define by a technique [7].
The torques operating from a material on the wedge and roll, define from expressions

$$M_{\mathrm{w}} = P_{\mathrm{w}} R_{\mathrm{w}}\,; \; M_{\mathrm{r}} = P_{\mathrm{r}} R_{\mathrm{r}}\,,$$

Where R_{w} is radius of the wedge work surface..
The general torque operating on the roll, co-operating with the wedge, is defined by the sum of the torques operating on it at deformation of the material in all gaps of this roll.
The capacity spent for deformation of the material in the wedge gap, is defined by torques product for angular speed of the roll. Capacity of a drive of the roll count under the formulas resulted in the work [7],[8].
At wedge installation in the intermediate or calibrating gaps the wedge top can settle down in within a zone of deformation of the roll gap or out of it.
In the first case, definition of power parameters of process similarly considered earlier provided that pressure in wedge top to equally pressure in section of the roll gap, corresponding to an arrangement of the wedge top.For realization of this process it is necessary to support only such volume of the material in the wedge gap that its free surface settled down on distance from the wedge top, it is not less than x_{we}.

In the second case superfluous pressure in the wedge top to equally zero, and material movement through the wedge gap will be defined by uniformity feeding of the wedge gap the initial material which size should correspond strictly to volume flow rate V (m^3/s) provided by the roll gap of roll machine. Thus the free surface of the material in the feeding wedge gap should settle down at section level of the wedge gap in height h_{wb} defined from expression [12] by method consecutive approximations:

$$V = \frac{W_{r1} h_{wb}}{2}\left(\frac{1+n}{n}\right)\left[\left(\frac{h_{wb}}{h_{we}}\right)^{n} - 1\right]\left[\left(\frac{h_{wb}}{h_{we}}\right)^{n+1} - 1\right]^{-1}$$

Thus, knowing size of wedge gap in the wedge top and the volume flow rate of the material (easily defined through productivity of roll machine as a whole), it is easy to define length of the wedge gap deformation zone, and consequently also coordinate of section of the gap on which it is necessary to support material level $x_w = (h_{wb} - h_{we})\,\mathrm{cotan}\,\alpha$.

Energy and power parameters of process are defined under the formulas received above under condition of replacement in them sizes δ by size V/W_{r1}.

Quantity of external energy (heat) Q_{ext}(W) which is necessary for heating or cooling the roll not forming the wedge gap is defined by the technique [7],[8].

For the roll and the wedge forming a wedge gap the equation of power balance will be defined from a condition of presence or absence of system of a heat supply of the wedge.

In case of presence at the wedge of system of a heat supply the quantity of energy Q_m spent for change of a material enthalpy at its contact with roll, will be defined by expression

$$Q_{mr} = \sum_i Gc_p\left(T_{e\,i} - T_{b\,i}\right) + \sum_j G_r c_p\left(T_{e\,j} - T_{b\,j}\right) + \frac{3Gc_p}{4}\left(T_{e\,wr} - T_{b\,wr}\right) \tag{3}$$

where: i is quantity of sites of the roll, covered with the processed material and located out the gaps; $j$is quantity a roll gaps formed by the respective roll; G_r is mass flow rate of the material provided by the roll in the roll gaps and equal flow ates of the material through half of the roll gap from outside the roll, kg/s; G is total mass flow rate provided by the roll machine, kg/s.

Accordingly for a wedge

$$Q_{mw} = \frac{Gc_p}{4}\left(T_{e\,ww} - T_{b\,ww}\right) \tag{4}$$

where:$T_{e\,wr}$, $T_{b\,wr}$, $T_{e\,ww}$, $T_{b\,ww}$ are final and begin average temperatures of the material in the wedge gap from outside the roll and the wedge, °C, respectively.

In expressions (3) and (4)$3G/4$ is the mass flow rate of the material provided by the roll in the wedge gap and equal flow rates of the material through half of the wedge gap from outside the roll, kg/s; $G/4$ is the mass flow rate of the material provided by the wedge, kg/s.

At absence at a wedge of system of a heat supply of heat quantity Q_m for it is roll it will be defined by expression

$$Q_{mr} = \sum_i Gc_p\left(T_{e\,i} - T_{b\,i}\right) + \sum_j G_r c_p\left(T_{e\,j} - T_{b\,j}\right) + Gc_p\left(T_{e\,w} - T_{b\,w}\right)$$

where $T_{e\,w}$, $T_{b\,w}$ are final and begin average temperatures of the material in the wedge gap, °C, respectively.

Energy of dissipation, provided by the wedge, is defined by dependence

$$Q_{\text{diss w}} = \frac{L_w \, KW_{\text{r}}^{n+1} \cot\alpha}{h_{\text{wb}}^{n-1}} \int_{0.5}^{1} \int_{\xi_{\text{wb}}}^{\xi_{\text{we}}} \left| -1-(1+2n)\left(1-\frac{2\delta}{h_{\text{wb}}(1-\xi)}\right)\left(1-\left(\frac{1+n}{n}\right)\varepsilon^{\frac{1}{n}}\right) \right|^{n+1} \frac{1}{(1-\xi)^n} d\xi \, d\varepsilon$$

Energy of dissipation provided that the roll in the wedge gap is defined similarly, but at integration of expression of specific energy dissipation in the range of values of coordinate ξ from 0 to 0.5.
Having defined thermal loading Q_{ext} rolls (and the wedge at presence at it heat supply system) we define speed and temperature of the heat-carrier circulating in the rolls (and the wedge). The technique of definition of the heat-carrier specified parameters is in detail considered in works [7],[8],[11].

3. RESULTS OF NUMERICAL MODELING

Current technique has been used at designing wedge devices for universal three-roll calender 3×500×1250, intended for processing of rubber mixtures at factory "Bolshevik" (Kyiv, Ukraine).
On the basis of multiple calculation of calendering process it has been established that the maximum length of an arch of the deformation zone of the wedge gap does not exceed 0.2m, maximum wedge-separating forces in the wedge gap does not exceed 37t, the maximum capacity consumed in the wedge gap is 40 kW (Fig.3) and local temperature of the processed material in a deformation zone does not exceed its admissible temperature.
Initial data for calculation are given below.
Processed material is tire rubber mixtures.
Rheological properties of rubber mixtures:

-Consistency index, Pa·s^n	80000
- Temperature of definition of consistency index, C	80
-Power low index	0.21
- Thermal coefficient	8.1

Thermo physical properties of rubber mixtures:

- A mass thermal capacity, J/(kg·K)	1850
- Density, kg/m^3	1400
- Thermal conductivity, W/(m·K)	0,175

Distance between restrictive arrows of calender, m	1.1
Linear speed of a working surface of the roll forming the wedge gap, m/s	0.7
Thickness of rubber on an exit from the roll gap, m	0.001 … 0.004
Angle of wedging of the wedge gap, …	4 … 10
Height of the wedge gap in the beginning of the deformation zone, m	0.01 … 0.03
The temperature of the roll working surface, C	80
Temperature of the wedge working surface, C	50
Initial temperature of rubber mixtures, C	70
Admissible temperature of rubber mixtures, C	105

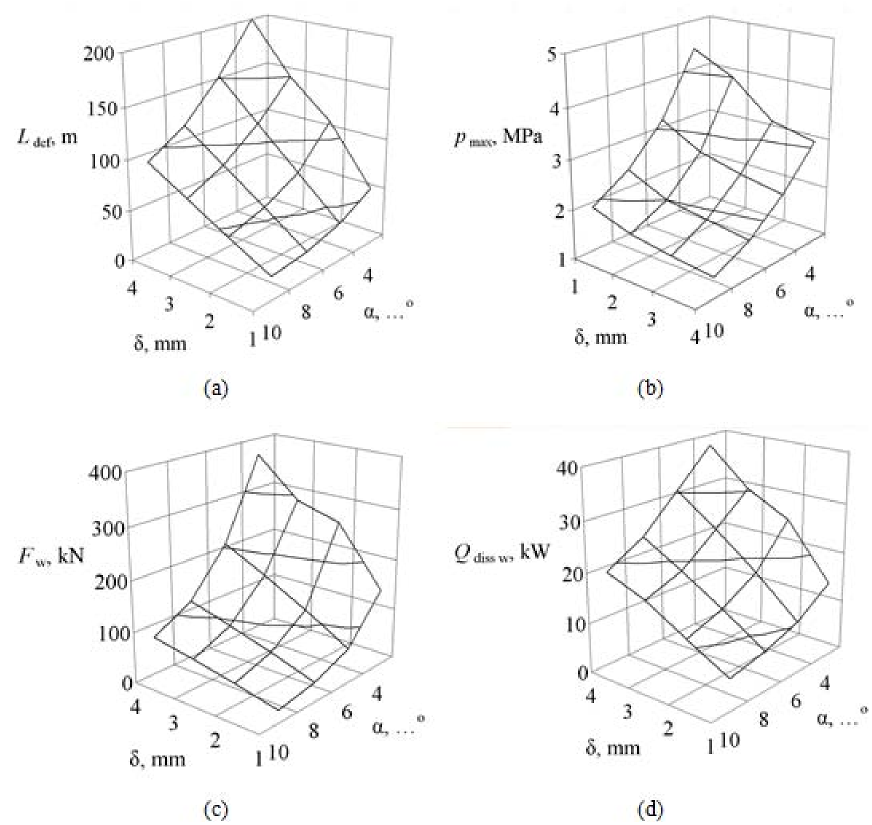

Fig.3 – Dependence of length of a zone of deformation (a), the maximum pressure (b), the wedge-separating force (c) and dissipation capacity (d) in the wedge gap from the angle of wedging of the wedge gap at a various thickness of a material on an exit from the roll gap

4. CONCLUSIONS

The analysis of results of numerical modeling has allowed following recommendations for maintenance of rational modes of calendaring with use of the wedge devices:

1. The temperature of roll forming the wedge gap should be at 5 - 15 ºC above temperature of the wedge working surface and temperature of the roll with which considered roll forms the roll gap located after the wedge gap.
2. Speed of the roll forming the wedge gap for prevention thermal destruction of the processed material should not exceed 0.60 - 0.65 m/s.
3. The angle of the wedge gap should lie within 4 -13º for creation of a sufficient circulating zone and the prevention of formation of stagnant zones of the processed material.
4. The minimum size of the wedge gap (size of the wedge gap in wedge top) should be within 2.01 - 2.36 sizes of the roll gap. At value of the minimum size of the wedge gap less than 2.01

sizes the roll gap considerably increase a zone of active deformation of the material in the wedge gap that leads to growth wedge-separating forces and possibility thermal destruction of the processed material, and at value more than 2.36 sizes of the roll gap use the wedge devices irrational owing to becomes considerable reduction of a zone of active deformation of a material in the wedge gap.

5. Depth of immersing of the wedge gap in the roll gap should correspond to dimensionless longitudinal coordinate ξ in system "roll-roll", equal 1.0 - 1.5. At bigger wedge immersing (reduction of value of coordinate ξ less than 1.0) there is inefficient action in the roll gap, and at bigger wedge extraction (increase in value of coordinate ξ more than 1.5) the mode of an unstable feeding by a processed material the roll gap is observed.

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KALANDRIRANJE PLASTIKE I GUME NA UREĐAJIMA SA KLINASTIM ELEMENTOM

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ABSTRACT

Jedan od načina za poboljšanje procesa kalandriranja plastike i gume je upotreba uređaja sa klinom. Ovi uređaji se sastoje od klina koji poseduje sistem za termalnu stabilizaciju i mehanizam za regulaciju položaja.Uređaji za kalandriranje ne samo da povećavaju valjanje materijala, nego i omogućavaju njihovu degazaciju. Prilikom istraživanja zaključeno je da optimalna temperatura zazora treba da bude za 5-15°C viša od površinske temperature klina. Takođe, brzina obrtanja valjaka treba da bude takva da onemogući termalnu destrukciju materijala, odnosno da ne bude veća od 0.6-0.65 m/s. Ugao zazora treba da bude između 4-13° da bi se omogućila dovoljno velika zona cirkulacije i onemogućilo stvaranje tzv. zona stagnacije. U radu su prikazani i rezulteti numeričke simulacije samog procesa kalandriranja sa klinom.

Ključne reči: m*odel fluida, mašina za kalandriranje, klinasti uređaj, parametri procesa*