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OPTIMIZATION DESIGN DATA OF MOLDS FOR THE MANUFACTURE OF PLASTICS AND AUTOMATION OF ITS DESIGNING

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INTRODUCTION

Now special attention of producers is paid on products from polymeric and composite materials. Thanks to a unique combination of their physical-mechanical and operational properties they have primary differences from the details and knots received by traditional metallurgical conversion. Products from PCM have the increased specific durability, the elasticity module, the fatigue (cyclic) durability, high wear resistance, an opportunity to work in the conditions of low temperatures (to minus 200 °C), the high impact strength, ultralow coefficient of friction, resistance to hostile environment, atmospheric and radiative effects. However, despite the obvious advantages of PCM, up to the present time there are no recommendations for the calculation and design of technological processes for the production of products based on them, especially at the stage of consolidation during pressing, the formation of structures and properties with a homogeneous distribution of the phase components of the PCM. Local gradients on density and high internal residual tension, great values of an elastic after-effect, unevenness of size of shrinkage when cooling and as result a buckling, cracking, or even destruction of products. Therefore, the analysis and calculation of tension in a zone formation of polymeric and ceramic materials, optimization of a form and the sizes of the tool for extruding, development of methods and recommendations about the choice and calculation of the technological modes consolidation for PKM of various structure is urgent scientifically technical task.

The aim of the work is to optimize the structural heterogeneity of the composite material for pressing ceramic powders of nano- and micron fractions, with an increase in the structural homogeneity in the volume of the compact resulting in an increase in the strength properties of the sintered ceramic due to a change in the geometric parameters of the die extruder.

To achieve the goal in work the following tasks were solved:

1) Literary-patent analysis results of the internet search processes extrusion of plastics, design of molding equipment for injection molding;

2) Development and verification mathematical model of process material flow in the forming products;

3) Analysis and calculation of stress fields in the zone of molding considering design elements;

4) Optimization of the compaction process due to configuration changes and local changes of the envelope surface and cross-sectional area of the forming channels;

5) Development of recommendations on modernization of the design the forming tooling of the extruder;

Scientific novelty

Determined by the rational form of the envelope surface of the forming extruder head, which allows to increase the structural homogeneity of the pressed composite material. Processes for the extrusion of cylindrical billets with screw feed solved the problem of the flow of materials through the snap with a decrease in cross-sectional area for the tapered and rounded surfaces of the forming channel, allowing to reduce residual stresses in polymer composite material.

Practical significance

The proposed approach of the process of pressing powders in rigid matrices allows extruding long-length blanks from polymer-composite materials, with low residual stresses and minimizing the destruction of the material during extrusion.

Reliability

Reliability of the received results are confirmed by good convergence of fields of tension, with a picture of fields of tension the received other authors during their analytical calculations and production experiments, however numerical values differ from results which received in articles.

The author's contribution

Conducted literature and patent analysis of polymeric materials, processes extrusion of plastics, design of moulding equipment for injection molding.

The tasks the study conducted by analytical calculation of the shear stress, resistance in the channel, the maximum pressure in the extruder, the pressure loss in the forming head and the thermal design of the extruder.

Conducted finite element analysis of extrusion composite materials through the forming head of the extruder.

Criteria for the efficiency various variants of the geometric parameters of the transition surfaces in the areas reduction of the cross-sectional area of the shaping channels have been determined, and an optimal configuration of such equipment has been proposed.

Place of the thesis and passing of international internships

The place of fulfilment of the thesis – Work was completed at the Department "Design and technological ensuring of engineering industries" Polytechnic Institute of Federal State Autonomous educational institution of higher education "Siberian Federal University"

The course of international internships – the Company "CADFEM" inc, Germany: Munich (Grafing), Stuttgart, Hannover.

2 MAIN CONTENT OF THESIS

The total characteristic of work is given in introduction, justification and relevance of the chosen subject is given, the purposes and research problems are formulated, original positions, and also the main practical and scientific results of the conducted research are explained.

In the first chapter, a classification of polymer materials is given for a number of characteristics: chemical, technological, in the field of application and in the aggregate of operational properties. The properties of several polyethylene materials PE-UHMWPE 1000, PE-HMWPE 500, PE-HDPE 300 are considered, and their properties are compared. The process of molding thermoplastics under pressure is described.

From the analysis of a significant number patents, experimental and theoretical studies, and publications on the technological process of pressing, the conclusion is made: The problems and disadvantages present in modern plastic processing with pressure. The problem of compacting homogeneous, dense compacts with a uniform distribution of phase components in volume has not yet been solved, and also the problem of the appearance interparticle adhesion bonds, interparticle friction and boundary friction along the channel surfaces.

An analysis was conducted of patent documents materials for cylindrical workpieces. It is noted, that the compaction of nano - and fine powders regardless of the properties material powder particles have a relative density of such products even at high pressing pressures seldom reaches 50%, and the inefficiency of the traditional schemes of compression allows to put the problem of the research on search and study of promising or alternative processes for forming workpieces from powders in this class.

Of the works, which dealt with the processes of extrusion billets of powder porous and composite materials, it follows that the processes of extrusion, cold and warm pressing are fundamentally different from processes of hot extrusion material in screw presses, as the nature of the flow material by forming the channels of the tooling, and the type of defects that develop in the molded workpieces during their thermal processing.

From the analysis of references, it is possible to conclude that new quality of model operation processes of a molding and extrusion composition and powder materials can solve a problem of structural inhomogeneous media on the boundaries of the structural elements of which the particles suffer destruction.

In the second chapter

A mathematical model of the process of deformation of composite materials in forming equipment of an extruder with step transitions in the zone of reduction of the cross-sectional area of the working channel is presented, and a mathematical model of the process pressing cylindrical blanks from various polymer powders is studied. The study of this and calculations stress distribution in compacts from nanodispersed powders.

The methods of determining the stress-strain state of pressing of powder materials, presented in the literature, are considered in detail. It is shown that in determining the flow of a material, a system of equations is performed that includes equilibrium equations, kinematic relationships, the equations of the relation between the strain rates and stresses, and the continuity equation.

Relatively simple, and at the same time, giving fairly accurate results, is a power-law analytic expression describing the dependence of the velocity gradient on the shear stress and rheological constants, the Oswald and de Ville equation:

$$\eta = \mathrm{B}|\dot{y}|^{n-1} \tag{1}$$

where η – viscosity of liquid;

B – the coefficient characterizing viscosity of system, γ – shearing rate,

n – a deviation of properties the used liquid from properties of the Newtonian liquid.

The current of composite occurs at the expense of the appendix on an entrance to a pressure channel of P_0 operating on an entrance to a molding channel. As the rheological equation we use Balkli's equation - Gershelya for non-linear visco-plastic liquid.

$$\tau = \tau_0 \cdot sing(\dot{\gamma}) + B|\dot{\gamma}|^{n-1} \cdot \dot{\gamma} \tag{2}$$

where τ – shear stress;

τ_0 is the initial yield stress (when $\tau<\tau_0$, the liquid begins to flow);

B – coefficient, which characterizes the viscosity of the system (determined experimentally);

n – deviation properties the fluid properties of a Newtonian fluid (determined empirically).

Taking into account the accepted notation and assumptions, equation (1) takes the form

$$\tau = B\left|\frac{\partial V}{\partial z}\right|^{n-1}\frac{\partial V}{\partial z} \tag{3}$$

The boundary conditions at the walls, taking into account the factor of wall sliding, described by the expression:

$$V_s = \begin{cases} 0, \text{ при } \tau \le \tau_{ss} \\ \frac{\beta_s \cdot (\tau_{ss}) \cdot |\tau_{ss}|}{(k_0 H)^{m_0}}, in\ case\ \tau > \tau_{ss} \end{cases} \tag{4}$$

where β_s is the "true" coefficient of friction;

τ_{ss} – shear stress on the wall;

k_0 – coefficient of transition from viscometric measurements in the capillary on the flow between the plates;

H – height of the forming die;

m_0 – factor determined experimentally.

The Chapter also presents the method calculation of the coefficient resistance in the flow channel material.

The main geometrical characteristics of the forming channel is its total resistance coefficient K_g is defined as the sum of the coefficients resistance simple geometry plots k_1, k_2...k_i using the equation:

$$K_{\Gamma} = \frac{1}{\frac{1}{k_1}+\frac{1}{k_2}+\dots+\frac{1}{k_i}} \quad (5)$$

where k1, k2...ki – private resistance coefficients of sections channel with simple geometry. When calculating Kg, the head is arbitrarily divided into sections of different configuration, and for each area determine the private coefficient resistance.

Injection rate is a critical parameter to obtain high-quality products in plastics injection molding. In this regard, the injection rate must be such that:

1) shaped structure of the polymer material, which provides satisfactory indicators of quality;

2) there were no significant mechanical degradation of the polymer.

On these grounds were considered methods calculation of pressure loss calculation procedure of maximum pressure, thermal calculations of the extruder, the stress distribution in the cross section of the channel. Calculation pressure loss in the head is carried out according to the following algorithm:

1) calculate the shear rate γ, s^{-1}, in simple sections.

2) according to the logarithmic dependence

$$lg\eta = -Alg\dot{\gamma} + B \quad (6)$$

3) the formula calculates the pressure loss in the elementary parts of the head;

$$\Delta P_i = \frac{Q\eta_i}{K_i} \quad (7)$$

4) sum up the ΔP.

The basis of processing polymeric materials into products are complex thermal processes. A correct understanding about the heat balance of the refining process, i.e. the equality of the input and exhaust heat, allows you to set the optimal modes of processing, provides an opportunity to understand the influence of technological parameters on the performance of the equipment and the quality of the finished product, to obtain data for the economic calculations.

To conduct a thermal calculation requires knowledge of the thermo-physical properties of polymers.

These include:

1) the thermal diffusivity a, m^2/s;

2) coefficient of thermal conductivity λ, kJ/m·h·K;

3) heat capacity, kJ/kg·K;

4) melt density of polymer ρ, kg/m^3.

Thermal balance of the extruder is determined by the equation:

$$E_N + E_m = E_{at} + E_O + E_P \quad (8)$$

where E_N – the heat coming from the outside of the heaters, kW;

E_m – the heat released when operating the auger (so-called dissipative heating – internal frictional heat), kW;

E_{at} – the warmth that goes with the heated material, kW;

E_O – the heat carried away by the cooling system (water, air, etc.), kW;

E_P – heat loss to the environment through the casing of the extruder, kW.

The stress distribution in the cross section of the material in the channel of a device for continuous extrusion.

Solving this problem will allow, in particular, to carry out the calculation and optimization of the profiles channels for forming various materials.

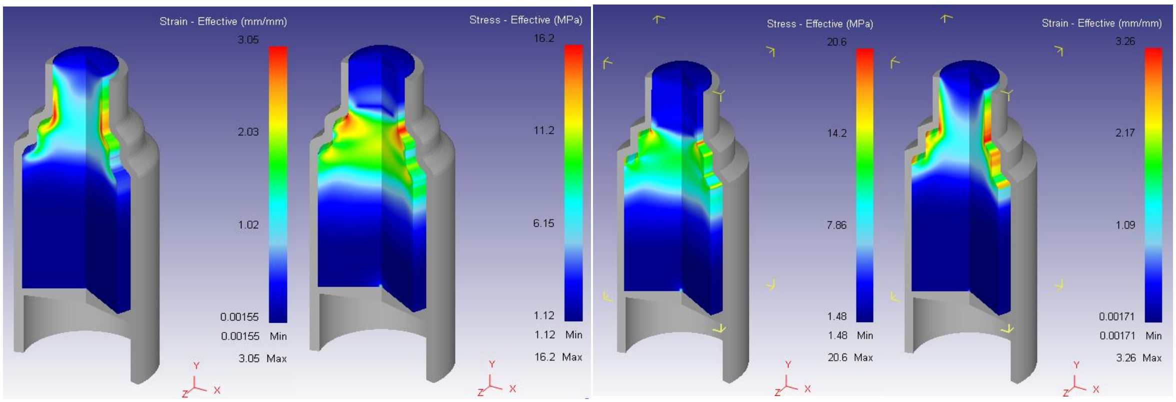
In the finite element analysis, there is also the possibility of calculating the destruction of the material. Based on the recommendation for modeling the pressing process, a model for the destruction of Cockcroft-Latam was adopted.

According to the model the destruction of the Cockcroft-Latham condition is not the destruction of the material point check the inequality:

$$\int_0^{\varepsilon_i} \frac{\sigma_1}{\sigma_i} \cdot d\varepsilon_i < c_{\text{пр}} \qquad (9)$$

Where σ_1 is the main positive normal stress, σ_i is the stress intensity, ε_i is the strain rate, c_{pr} is the Cockcroft-Latam limit value.

The third chapter presents the results a mathematical model of the process deformation composite materials in the extruder's shaping head with stepwise transitions to a section of a smaller diameter in the zone mold channel, and a mathematical model of the process pressing cylindrical blanks from various polymer powders is considered.



A B C D

Figure 1 - Stresses and deformations of material with a cone-shaped transition and optimized: A - stress field in an optimized channel with an angle of inclination of 45; B - deformations in an optimized channel with an inclination angle of 45; C is the stress field in a cone-shaped channel with a slope angle of 45; D - deformations in a cone-shaped channel with a slope angle of 45

The entrance of finite element analysis was analyzed deformation parameters and stress of the polymer-ceramic material (figure 1). In addition, the reduction of tension in the extruded material, the geometry of the channel needs to provide a complete study of the deformation of the material over the entire cross-sectional area of the extruded material. The test results are shown in table 1, where it is possible to trace the dependence of the material fracture from the strain. Table 1 presents the results of materials with a conical profile cross-section, and in table 2 with the optimized cross section.

Since the destruction of the material depends on the stress, graphs of the relationship between the angle of inclination of the forming surface and the stress

(Fig. 2 - A), as well as between the angle of inclination and the material destruction (Fig. 2 - B) were plotted.

Based on the complex of carried out exploratory experimental works on optimizing the structural homogeneity of PCM, technological regulations for the pilot production of PCM products were developed.

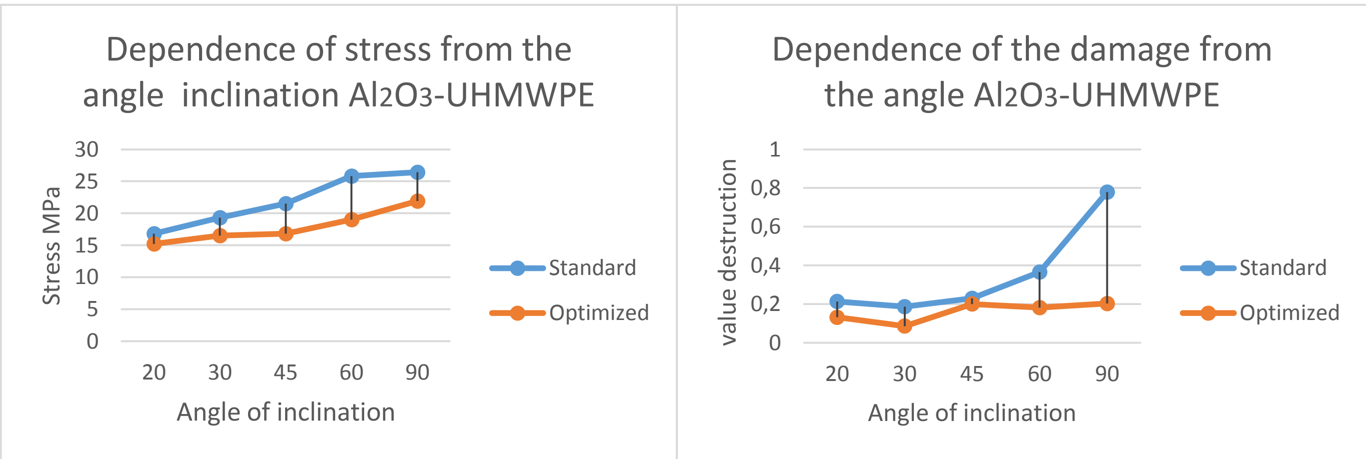
Based on the complex of carried out exploratory experimental works on optimizing the composition and production modes of PCM, technological regulations were developed for the pilot production of PCM products for various purposes. The following technological scheme for obtaining PCM (UHMWPE - Al_2O_3) is proposed.

Table 1 - Table 1 - Parameters fracture the compacted composite materials depending on the inclination angle of a tapered transition forming a channel surface

	Angle of inclination	20	30	45	60	90
Al_2O_3	$c_{пр}$,	0,229	0,311	0,348	0,372	0,496
	σ_1, MPa	15,5	17,1	18,6	20,6	22,3
Al_2O_3/ UHMW-PE	$c_{пр}$,	0,214	0,187	0,230	0,366	0,514
	σ_1, MPa	16,8	19,3	21,5	25,8	26,9

Table 2 - Parameters fracture of compressed composites, depending on the angle with rounded transition surface forming a channel

	Angle of inclination	20	30	45	60	90
Al_2O_3	$c_{пр}$,	0,193	0,177	0,320	0,264	0,229
	σ_1, MPa	13,1	14,2	15,2	17,2	18,5
Al_2O_3/ UHMW-PE	$c_{пр}$,	0,132	0,087	0,201	0,182	0,203
	σ_1, MPa	15,2	16,5	16,8	19	21,9



A B

Figure 2 – A - Graph of the dependence of the workpiece fracture on the angle of inclination; B - Graph of the destruction workpiece from the inclination angle

CONCLUSIONS

1. Modeling of powder pressing processes made it possible to determine that the distribution of compressive stresses in a composite material is not uniform. The mathematical model of the process extrusion of powder and composite materials through the die extruder head with a reduction in the cross-sectional area based on the theory of plastic extruder it makes it possible to obtain sufficiently complete information on the effect of material stresses, that is: the ultimate properties of the material; The conditions of its friction along the surface channel; Forms of working surfaces equipment; The ratio of the dimensions the rigging elements, and also to determine the optimal combinations of these factors.

2. The study of determining the optimal angles the forming surfaces of the rigging and parameters of the function plasticity composite materials based on a combination of calculated data obtained directly in the process pressing powders of UHMWPE and alumina in the processes extrusion of composite materials based on UHMWPE.

3. Defined a criterion to determine the shape of the geometry transition surface of the channel, which should not be made, since they are not subjected to the full material deformation and thereby the depth of the material over the entire cross-sectional area in the extrusion process of cylindrical workpieces.

4. Analysis of the calculated and obtained in the course of finite element analysis data on the distribution of material properties over the cross section of workpieces, molded in equipment of various configurations, allows to conclude that the mathematical model of the extrusion process, the core sheets through the tooling transitions to the smaller diameter section is effective for the development optimal configurations of complex rigging screw presses.

The main results of dissertation work are presented in publications:

1. A. S. Demyanenko Automative calculations and simulation die//Electronic collection of materials of the international conference of students, graduate students and young scientists "The free prospectus" 2016.

2. A. S. Demyanenko The automated modeling of a compression mold//the Electronic collection of materials of the international conference of students, graduate students and young scientists "The free prospectus" 2016.