ANALYSIS OF COMBINED METAL CASTING THERMAL CONDITIONS: THE PRESSING PROCESS DURING CONFORM INSTALLATION

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ABSTRACT

The outlet temperature of the profiles is determined by the thermal conditions of the combined Conform process and exerts a decisive influence of this process' effectiveness. Therefore, designating the thermal conditions for continuous pressing via the Conform method is an important task instrumental in rationally devising a manufacturing technology for profiles. The temperature conditions for the pressing process may be calculated via numerical methods since an augmentation in the task's rhythm and factors would only result in an increased quantity of calculations and the need to utilize computers with the corresponding storage spaces and speed. At the same time, the application of engineering calculation methods, especially when analytical dependence is obtained with a reasonable degree of accuracy, is still important and useful. This article presents engineering methods designed for determining thermal conditions based on a heat balance equation that are easily realized in the Microsoft Excel program and allow us to determine temperature conditions in the course of pressing in the case of discrete initial data input. The practical application of this obtained solution does not require the special skills that engineers and technicians possess and provides a means to analyze the influence of the process's key parameters in the event of a change in temperature conditions during the course of pressing for the purpose of developing an optimum manufacturing technology for profiles.

Keywords: conform installation, continuous pressing of metals, thermal conditions, heat balance equation.

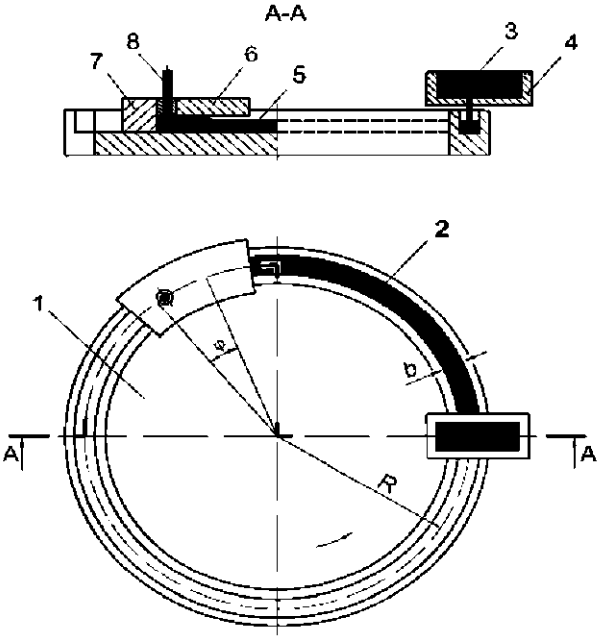
INTRODUCTION

In the second half of the 19th century, as a result of the technological revolution, a sharp growth in the consumption of metal structures occurred that led to a number of semi-continuous and continuous metal casting methods being developed [1, 2]. Semi-finished products manufactured in this way were generally subject to subsequent pressure treatment, which gave rise to the idea of combining these operations in order to maintain one continuous technological process through creating main metallurgical conversion technologies combined into one unit for the purpose of manufacturing the products that were needed. Today, there are high-performance casting and rolling units (CRU) lines designed for manufacturing long ferrous and non-ferrous metal products and alloys used under mass production conditions. Pressing is most often used for manufacturing light products.

SUMMARY OF RESULTS

The latest achievements concerning the continuous metal and alloy pressing processes have confirmed the effectiveness of replacing the rolling mills in CRU with more universal continuous pressing installations. According to this principle, the firms leading this field manufacture and replicate continuous non-ferrous metal pressing lines [3, 4] with the use of the Conform method.

Nowadays, an emphasis is placed not only by foreign, but also by domestic metallurgists on the combination of casting and continuous pressing operations into one unit, which will allow them to considerably decrease the production lines' metal consumption and increase their flexibility and automation [5-7]. Continuous casting-pressing Castex (when a liquid metal is poured directly into the Conform installation's container) is a more economic method of manufacturing wires and profiles in comparison with methods in which they are made of monolithic billets [8]. However, there is not currently sufficient information on designing this innovative process for the purpose of carrying out a stable, continuous liquid metal crystallization process in a two-part container. It is known [9] that the attempts to use the basic Conform installation with a vertical wheel have caused difficulties in regard to observing the stabilization of a metal feed into a tool, as a result of "freezing out" the liquid phase of a melt during solidification in regard to the container's fixed part. This shortcoming can be eliminated if the continuous casting-pressing process on the Conform's installation is carried out with a carousel-type wheel [10-12] according to the chart presented in Figure-1 (Figure-1).



1 - wheel crystallizer; 2 - ring groove; 3 - metal melt; 4 - dispenser; 5 - solidified ingot; 6 - fixed segment; 7 - die stop; 8 - pressed article

Figure-1. Continuous casting-pressing installation with a carousel-type wheel.

The process is carried out in the following sequence: the melted metal 3 is poured through dispenser 4 into pass 2 of the rotating wheel crystallizer 1 and is crystallized before its ingress into a container formed on the interface between the pass and fixed insert 6. Ingot 5 reaches the die stop 7 and is pressed in a container for a length determined by the central corner ф and is forced out into the die hole in the form of pressed article 8.

The obvious potential of this process requires its fastest possible introduction into the domestic industry and is connected, first of all, with research and development activities aimed primarily toward determining the temperature and speed conditions of the process' implementation.

The temperature of a metal and the speed during pressing are the main technological factors of the process' rational technology. Pressing temperature and speed are critical in creating optimum conditions for a deformation process that ensure a maximum pressing speed and the required quality of the pressed articles [13].

A thermal continuous casting-pressing process mode depends on a gradient of temperatures pouring a melt into a wheel groove and pressing the metal into a die hole. When the wheel rotation speed increases, the metal pressing temperature intensively grows and when the precisely specified "critical" temperatures for each alloy are reached, the alloy is broken, i.e. the thermal pressing conditions have a decisive impact on the effectiveness of the manufacture of pressed articles. Therefore, analyzing the thermal mode and calculating a pressing temperature as a rule lead to a rough assessment of a metal-tool-environment system in a deformation center on the basis of a heat balance equation.

Let us set up a heat balance equation in time unit of a plastic deformation center in the course of continuous pressing under the condition that the temperature 70 of the metal that is in contact with the shoe is less than its solidus point:

where

	represents the heat flowing into a plastic zone with a billet with an initial temperature 70;
	denotes the heat emission from the plastic deformation;
	is the heat from overcoming the friction with a fixed tool;
	means the heat carried away by a pressed article (profile) from a plastic zone;
Qz-л	represents heat moving to the environment through a tool.

It should be noted that this method holds for stationary temperature conditions that have been specified in the course of continuous casting-pressing or in a natural way as a result of the convective heat transfer of a tool and the environment, or by means of the forced cooling of a tool, a billet, and a pressed article. Therefore, when we set up the heat balance equation, the following assumptions have been accepted:

a) the materials of bodies in contact with each other are homogenous and isotropic during the course of deformation of a solidified metal;

b) the interface of a metal being pressed and a tool has no third body, for example, such as a lubricant;

c) the continuous pressing process is carried out under isothermal conditions with a fixed metal speed flow;

d) deformation and friction forces are completely converted into heat;

e) the square cross section of the container $h = b$ and friction equality indicators are accepted; in regard to all its contact surfaces with a deforming metal;

f) according to the von Mises criterion and the Siebel's theory, the average value of the plastic shear stress of a metal being pressed (shear stress intensity) and the contact friction stress of a billet's material on the surface of a pressing tool is: $T_{\tau} = \mu\sigma_s/\sqrt{3}$, where is plastic resistance; и represents the friction index.

$$Q_z = T_0 b^2 \rho \cdot c \cdot v_0, (Вт). \quad (2)$$

where p и c are the density (g/cm³) and specific heat of the billet's material (J/g-°C), respectively;

v_0 is the feed speed of a billet into a container (m/sec);

T_0 is the initial temperature of a billet, °C.

In order to calculate, Q_d tone can use the formula [14] for pressing with a metal side flow:

$$Q = a_s\{T, s, g) (1\ 45л + 0,8)\ IfA - v_{0i}\ (Bm), \quad (3)$$

where X is the elongation ratio;

b is the wheel groove width;

C_s $(T,$ S, E) is the deformation resistance of a billet's material, the value of which may be presented in the form of an empirical dependence as a regression equation [15] for a deformation speed interval, for example, for aluminum alloy AD 1 at $E = 3 \div 20$ c⁻¹:

$$c_s = 0{,}000538 \cdot E \cdot s \cdot T + 0{,}02658 \cdot s \cdot T + 0{,}0001324T^2 - 0{,}2525T \quad (4)$$
$$0{,}3482Es - 7{,}528s^2 - 6{,}1668s + 105{,}832 + 5{,}136E - 0{,}201E^2,$$

where s, E и T are the deformation degree and speed, respectively:

$$E = 4{,}8v_{пр} \ln X/b(1 + Л + \quad (5)$$

The heat resulting from overcoming the friction with a fixed tool is determined by the following expression:

$$Q_{FR} = 4 \cdot b \cdot c_s(T, s, E) \cdot M \cdot R \cdot v_0 \quad (6)$$

where R is the average radius across the width of a wheel groove;

$QCOOL$ is the heat moving to the environment via a tool.

Heat carried away via a pressed article from a plastic zone:

$$Q_{PR} = F_{пр} T_{пр} p c v_n \quad (7)$$

where $T_{пр}$ is the temperature of a profile as it exits out of a die channel

$F_{пр}$ - is the cross section area of a profile.

A share of heat escaping the deformation zone through a tool into the environment is determined by the expression [16]:

$$QCOOL = T - T_c) \cdot R \cdot \varphi \cdot 4 \cdot b / (S_к / Л + 1/a_к), \quad (8)$$

where Л и a_c are the heat conductivity of a tool's material and the heat transfer coefficient, respectively; $S_к$ is the thickness of a container's walls; $T_к$ and T_c are the temperature of a container, die stop, and the environment. For stationary temperature conditions specified in the course of continuous metal casting-pressing - $T_к = T_c = T$. φ is the central corner of a container's arc with an ingot pressed along its section (rad.).

It should be noted that when forced cooling is used in relation to a tool, this formula will feature an absolutely different look and will considerably depend on the cooling device and a cooling method. After inserting the resulting components into an equation (1), one can measure a profile's outlet temperature $T_{пр}$ as a first approximation.

The use of this calculation method for the purpose of choosing the continuous metal pressing temperature and speed modes with due regard to deformation resistance from the temperature, degree, and speed will allow us to specify a rational mode and understand how to improve it with a reasonable degree of accuracy.

A necessary condition for the stable, continuous casting-pressing process is the forced cooling of a tool that includes a wheel crystallizer, a shoe with a stop, and a die. The calculation results on the above formulas allowed us to patent a non-ferrous metal casting-pressing device with tube vertical rotation axis of a carousel-type wheel crystallizer [17-23], the chart of which is provided in Figure-2 (Figure-2).

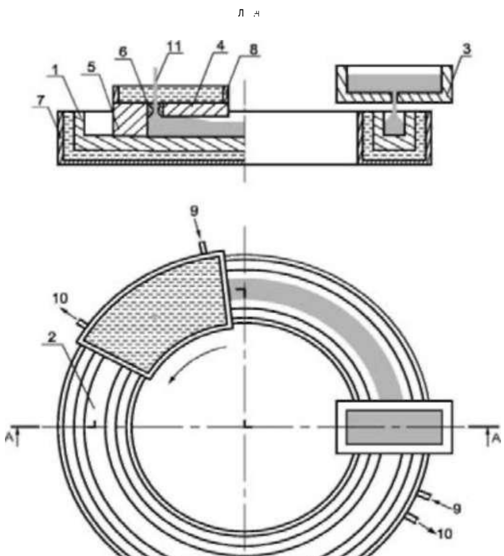


Figure-2. Device for cooling a continuous metal casting-pressing installation tool [17]:
1 - wheel crystallizer; 2 - pass; 3 - dispenser; 4 - shoe; 5 - stop; 6 - die; 7, 8 - manifold; 9, 10 - pipe branches

A molten metal comes from the feeder (not shown in the drawing) into dispenser 3 and is further poured into the ring groove 2 made on the upper part of a disk of the crystallizer 3. Meanwhile, the speed of feed of the molten metal into the ring groove must be connected to the rotating speed of the crystallizer. As the crystallizer rotates, the metal crystallized in the ring groove reaches a protuberance 5 in a fixed arc-shaped segment 4 where it is extruded into a pressed article 11 through the working channel of vertical die 6 under the contact friction forces between the ring groove walls and the crystallized metal. The tool is forcedly cooled by feeding a coolant through the branch pipes 9 and 10 into the tanks.

This device has been implemented in a laboratory installation, the design and operation of which are described in the work [14] (no forced cooling system included).

By using this installation in the laboratory of the SibFU Pressure Metal Treatment Department, it is planned to conduct a set of theoretical and experimental studies. Based on the quasi-equilibrium two-phase condition theory, it is possible to estimate the distribution of the temperature fields in the transition zone of a solid-liquid metal melt into the groove of the carousel-type crystallizer that determines the intensity and time of an ingot cooling up to a set pressing temperature. In order to calculate the power parameters, it is reasonable to use an energy balance method (energies brought to a deformation zone and consumed in it). The functional dependence between the mechanical properties of pressed continuous casting-pressing process articles and parameters is planned to be carried out using elements of experiments' mathematical planning. Conducting a planned set of scientific studies will allow us to determine such important technological and constructive parameters as the length of the shoe (container) that is sufficient for the continuous pressing of a solidified ingot part, crystallization time of a metal melt fed into the groove of a moving wheel and the length of this area, the location of a melt feed into a wheel groove depending on set temperature and pressing speed values, the intensity of cooling a working tool, as well as the power parameters of the installation.

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