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USE OF AUTOMATIC CONTROL METHOD FOR MOULD CAVITY FILLING

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Abstract:
The method of the automatic control is created for the determination of the dynamics of mould cavity durig gravity die casting. The search version of the method assumes the application for the process.The paper deals with the step when the .-...
The given results demonstrate that some modification of the mathematical means is very usefull.
KEY WORDS:
control unit, gravity die casting, transfer system, output variable

1. INTRODUCTION

The process of gravity die casting with a knife-edge gate is a relatively standard process, nevertheless the theory of regulation the process of pouring and filling of the mould is considered to be a regulated by system.

2. THEORETICAL ANALYSIS OF PROBLEM NAD MATHEMATICAL MODEL

2.1. Gravity die casting process

The pouring process takes place owing to the height of liquid metal h in the inlet channel, called the manipulated variable of a controlles system S. In this case this results in filling the mould up to a level of x_2 called the output and/or the regulated variable of the contolled system S.

By this way there is not described the full obtain of the temporal course of the manipulated variable $h=h(t)$ and of the output variable $x_2=x_2(t)$. The simplest case is when the manipulated variable takes place in the time $t=0$ by a jump from $h=h_0$ up to $h=h_\infty$ and remains constant, while the output variable x_2 varies with time from $x_2=x_{20}$ in the time $t=0$ till it attains a certain constant value, is $x_{2\infty}$. This processig is identical with one of the case of mould casting with a knife-edge gate. If the jump of the manipulated variable is equal to one unit, the temporal course of the output variable is called the transient curve.[1,2] The temporal course of the output variable can be theoretically derived in the form of a linear differential equation with constant coefficients, in our case in the terms of the following equation:

$$x_2 + a_1 \frac{dx_2}{dt} + a_2 \frac{d^2x_2}{dt_2} = zh \qquad (1)$$

where: a_1... coefficient with term of the first derivation x_2, $1/s^2$
a_2 ... coefficient with term of the second derivation x_2 , $1/s^2$
z ... coefficient with the manipulate variable h, amplification of the system.

The second mode consists in meassurement of the temporal course of the manipulated variable h and the output variable x_2 and in processing it by the method of gradual integration according to the following equations:

$$Q_{1t} = \int_0^t (h - h_\infty) dt \qquad (2)$$

After the substituting the individual values into equations for a_1,a_2,z is possible calculate, in this case, the coefficient a_1, a_2, and z we obtain the well-known formula (1). On the basis of the Laplace-Wagner transformation of the differential Eq.(1) with zero initial conditions we obtain:

$$x_2 + a_1 p x_2 + a_2 p^2 x_2 = ZH \tag{3}$$

By using of the ratio of the output magnitude and manipulated variable s_{x2} is possible to define transfer of system:

$$S_{x2} = \frac{x_2(p)}{H(p)} = \frac{z}{1 + a_1 p + a_2 p^2} \tag{4}$$

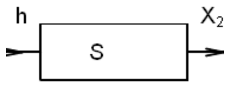

Figure 1. Block of gravity casting with knife-edge gating [3]

The orginal of the transfer is the transient curve, being the temporal course of the output variable x_2 (t) for one unit step of the manipulated variable.

The process control represent to develop an automatic control system. The simplest automatic control uses the in our case with transmision s_{x2} , and of a regulator with transmission R. The block diagram is illustrated in Figure 1. At the outlet from the control system we have the output variable x_2 and we assume here an input of the disturbance x^2 involving, for the sake of simplicity, all the disturbances. This disturbance is influencing the controlled variable so that it is added to the variable.[4,5,6] This sum x_2 is compared with the required value of with control unit w and the control deviation $\Delta x_{2_2} = x_2 - w$ should be introduced into the regulator. The output variable of regulator m is acting on the manipulated variable h so that the deviation would diminish and, as a rule, it is substracted. In this way a closed automatic control system is produced in which the variations, i.e. the signals, are propagating in a single sense only. For the image of the controlled variable x_2 (p) we may write:

$$x_2(p) = \frac{s_{x2(p)}}{1 + s_{x2(p)} R_{(p)}} H(p) + \frac{s_{x2(p)} R_{(p)}}{1 + s_{x2(p)} R_{(p)}} W(p) + \frac{1}{1 + s_{x2(p)} R_{(p)}} x^2(p) \tag{5}$$

Where are the partial transmissions F_H and we call them the transfer of the manipulated variable, control and disturbances. These transfer influence above all the stability of the automatic control system being the indispensable conditions for reasonable control of the process.

2. 2. METHOD OF THE CONTROLLING THE PROCES

The method is based upon the derivation of the equation of motion of the process.Usually feeding of metal Q is by the inlet channel and is devided into supply of metal Q_1 resulting in raising the metal level in the skimmer 1 and into a supply of metal, where Q_2 resulting in raising the metal level in the mould 2. That is defined by the equation:

$$Q = Q_1 + Q_2 \tag{6}$$

Calculation by applying the equation of continuity is possible to define:

$$fv = F_1 \frac{dx_1}{dt} + F_2 \frac{dx_2}{dt} \tag{7}$$

where:

f... inlet sectional area of the inlet channel int the skimmer 1, (mm^2) ,
F_1 ... sectional area of the skimmer 1, mm^2
F_2 ... sectional area of the skimmer 2, mm^2
x_1 ... instantaenous height of the metal level in skimmer 1, mm
x_2 ... instantaneous height of metal level in the mould 2, mm
$\frac{dx_1}{dt}$ ... instantaneous rate of rise of the metal level in the skimmer 1, mm/s
$\frac{dx_2}{dt}$ ... instantaneous rate of rise of metal level in the mould 2, mm/s
v ... instantanenous streaming rate through the cross-section f, mm/s

The instantaneous pressure head (h-x_1) is changing into the velocity head and the coefficient λ dependent on the surface roughness of the inlet channel. When considering the deviation Δh to be no higher than–10%, it is not cause an error greater than 1,5%.The supply from the skimmer 1 through the knife-edge gating must be identical it with the supply resulting in raising the metal level in the mould.

3. RESULTS FOR THE MODEL OF PERSPEX

The prepared a transparent model of Perspex was elaborated. The example of the sample according Fig. 2 and the related values were taken as follows: F_1 = 500 mm², F_2 = 600 mm², f = 78,5 mm², h = 70 mm, s = 5 mm, d = 10 mm, ξ = 1,3 λ = 0,04.

In view of the similar values of the kinematic viscosity of molten aluminium and of water, it was osscible in simulation of the filling process to use coloured water. A picture of the filling of the model with coloured water was prepared by means of a camera. The temporal course of the height of the metal level in a casting x_2 and it is completed by a dashed line up to the full value h. The variation in the height h in the inlet channel owing to its qiuck filling within 0,04 s is considered to be an instantaneous variation in comparison with x_2 which is slower by about 100 times.

The mentioned, we have measured the temporal course of the manipulated variable h and the output signal x_2 of the control system and by means of the method of stepwise integration we obtain the coefficients a_1, a_2 and z for the case in question. By applying method of gradual integration, coefficient a_1, by graphical integration of course of P_{1t}, after calculation of the coefficients a_1, a_2 and z we also obtain Eq.(1) for this case. The decisive coefficient a_1 and strengthening z are close to one another in both ways of calculation. The coefficient a_2 can actually differ less than that calculatd, when the method of stepwise integration applied in the derivation with higher orders has less accuracy. The theoretically derived form of the kinetic differential equation approches reasonably to the actual form (Eq.1) determined by the method of stepwise integration from the measured course.

The results for the controlling of the process are more interesting after transfer of system.

The majority is the control according automatic control system of Fig.2 for transfer of the manipulated variable there and we consider here transfer of a control system s_{x2} according to Eq.8 as follows:

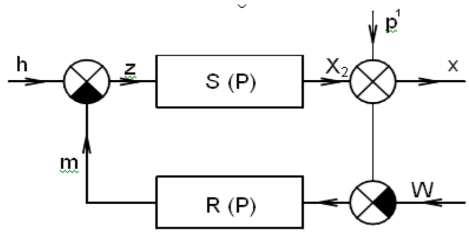

Figure 2. Temporal course of the manipulated variable h and of the output variable x_2 of the process

$$s_{x2}=\frac{\frac{1}{0,13k}}{\frac{F_1+F_2\left(1+0,078\frac{f}{s}\sqrt{\frac{1+\xi_1}{1+\sum\xi+\lambda h\frac{k}{d}}}\right)}{0,13f\sqrt{\frac{2g}{1+\sum\xi+\lambda h\frac{k}{d}}}}p+\ldots+\frac{1,925F_1 * F_2}{gsf}\sqrt{\left(1+\xi_1\right)*\left(1+\Sigma\xi+h\frac{k}{d}\right)}p^2} \tag{8}$$

For described application we take control unit PD with transfer

$$R(p)=P\left(1+pT_d\right) \tag{9}$$

where: p ... proportional constant of the control unit,

T_d ... time derivation constant of the control unit, s.

For the computation transfer of the control unit we can investigate the condition of stability by analyzing the transfer of the manipulated variable by setting for s_{x2} of Eq. (8) and for R(p).

The remaining Hurwitz criterion of stability of a closed automatic control system, i tis necessary for the coefficients to have the same sign. In our case all the coeficients are positive and thus the circuit is stable and controllable. In order words, when applying a control unit with transfer expressed to the regulation of the metal level x_2 in mould with knife-edge gating, this process can be controlle. By calculating the roots of the characteristic equation, by plotting the logarithms to the horizontal coordinate and by plotting the relevant inclinations of the amplitudes we can readily plot the amplitude and phase characteristic required for determination of the transient curve. When the logarithmic amplitude characteristic intersects the horizontal coordinate log ω sooner than the phase characteristic attains the phase π, the process is stable even according to the Nyquistov criterion. From the coefficients of the characteristic equation, it is possible to determine, by means of the Mejer criterion, whether the stable automatic control system has an aperiodic course or a damped oscillation. When cutting down the number of terms down to 3, we obtain all the new coefficients higher than zero or zero. The described effect the process aperiodic, while in the opposite case, the process reveals damped oscillations.

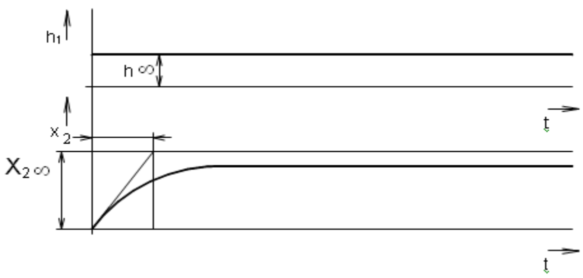

Figure 3. Transient curve of process as a controlled system S referring to its transition s_{x2}

The proposed method create a sequense of the coefficients of the characteristic equation and of its derivive by p, we underline the memebers of the sequence, divide them by the negative proportion of the second and of the first member by the underlined members and write the products below the previous members.

This projection sum up the members vertically and after repeat procedure in the reduced sequence till it reduces to 3 members. Because of the fact that a negative member appeared after the second reduction, the controlling process is oscillating.

4. CONCLUSIONS AND PROPOSITION

When assumption about the process of gravity casting with knife-edge gating it is considered to be a control system with manipulated variable represented by the column of metal in the inlet channel h and with the output variable represented by the height of level x_2 of the liquid in the mould.

Transfer of the system s_{x2} is expressed by Eq. (8) as a system of the second order with an aperiodic time course of the output variable x_2. The measured results are in reasonable agreement with the calculated course as folows from the comparison of the coefficient a_1, a_2 and z determined from the derived kinetic equation and from the measured course evaluated by the method of stepwise integration. The results of the automatic control system including regulation of a system with a PD control unit, which is stable and oscilating. For this reason the proces of gravity casting with a knife-edge gating is a controllable connection with a PD control unit.

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