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HEATING PROCESS MODELING FOR DIE-CASTING JETS ON THE MACHINES WITH HOT CHAMBER

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ABSTRACT: *In general the application of die-casting technology in foundries that are focused on non ferrous metals allows producing cast parts with specific properties. Another advantage of pressure die-casting technology with hot chamber is the possibility of production of precision cast parts in low dimensional tolerances, often without further machining. Castings have got smooth surface, good mechanical properties, and they also may have complex construction workability. Required qualitative properties of castings produced with the pressure die-casting technology with hot chamber are dependent on several parameters, which include holding stable temperature of the die-casting nozzle. Therefore in this paper we proposed the mathematical model as one of the method how to control heating die-casting nozzle of the hot chamber pressure die-casting machine using a gas torch.*
KEYWORDS: *Pressure die-casting, die-casting nozzle, hot chamber pressure die-casting machine*

INTRODUCTION

High pressure die-casting technology in foundries processing non-ferrous molten metal metals allows producing casting of various shapes with specific properties. The advantages of applying the technology of high pressure die casting using hot chamber is the possibility of precision castings in low dimensional tolerance [1,2] .

These castings have a smooth surface often without any further machining, and they also have good mechanical properties [3]. This technology may produce castings with complex construction. The quality of the castings depends on several parameters. One of the important parameter is control and regulation of temperature stability of nozzle [4,5].

During the operation of pressure die-casting machines with hot chamber dynamic changes occur mainly in temperature time casting nozzle according to the casting machine cycle. It is needed to hold the temperature of casting nozzle at optimum value therefore it is necessary to eliminate dynamic changes. Given the operation consuming conditions during the die-casting process the nozzle is regulated by controlled gas torch. For regulation of nozzle temperature, there are several types of regulation [2,6].

In this paper we focus on the compilation of model with simple control loop with a mathematical description of the regulated system, and also on the creation of transitional characteristic with regulatory design. Simple control-loop that is formed by the torch that heats the nozzle of pressure die-casting machine uses the proposed proportional regulatory.

EQUATION MODEL DEFINITION OF REGULATORY SYSTEM

For appropriateness of the solutions it is firstly necessary to derive an equation describing the dependence of torch gas flow on temperature of casting nozzle as the equation of the regulatory system. In the regulatory system the gas flow of the gas torch is referred as input value q and the temperature difference of the nozzle expressed as $T-T_0$ and surroundings temperature is an output variable [4].

For the casting nozzle we can determine equation for thermal balance:

$$nQ_1 = Q_2 + Q_3 \qquad (1)$$

where: Q_1 - amount of the heat per time unit generated by burning gas in torch, nQ_1 - amount of the heat per time unit generated by burning gas in torch that crossed into nozzle, Q_2 - amount of the heat per time unit generated by burning gas in torch that heats nozzle, Q_3 - heat loss per time unit.

Variable Q_1 can be expressed as:

$$Q_1 = ql \qquad (2)$$

where: q - gas flow of the torch, l - calorific value of the gas.

Variable Q_2 is expressed as:

$$Q_2 = cm\frac{dT}{dt} \qquad (3)$$

where: c - specific heat of the nozzle, m - weight of the nozzle, T - nozzle temperature, t - time.

$$Q = kS_p(T - T_0) \qquad (4)$$

where: k - heat transfer coefficient from the nozzle into the surroundings, S_p - surface area of the nozzle, T_0 - surroundings temperature.

Substituting equations (2), (3), (4) into equation (1) with subsequent adjustment we determine equation of regulatory system:

$$q=\frac{mc}{nl}\cdot\frac{d(T-T_o)}{dt}+\frac{kS_p(T-T_o)}{nl} \qquad (1.1)$$

The input quantity of the regulatory system is the gas flow q and output is the temperature difference of the nozzle T-T$_o$ together with the temperature of surroundings.

In operator's shape:

$$q=\left(\frac{mcp+kS_p}{nl}\right)(T-T_o) \qquad (1.2)$$

The transmission of the system S is represented by ratio of output to input quantity.

$$S=\frac{T-T_o}{q}=\frac{nl}{mcp+kS_p} \qquad (5)$$

TRANISTIONAL CHARACTERISTIC

Based on the establishment of the transmission of the system we described transitional characteristics for step unit change of input variable and also for particular value q.

Transitional characteristic of the system can be expressed as follows (see figure. 1a):

$$T-T_o=\frac{nl}{kS_p}\left(1-e^{-\frac{kS_p}{mc}t}\right) \qquad (6)$$

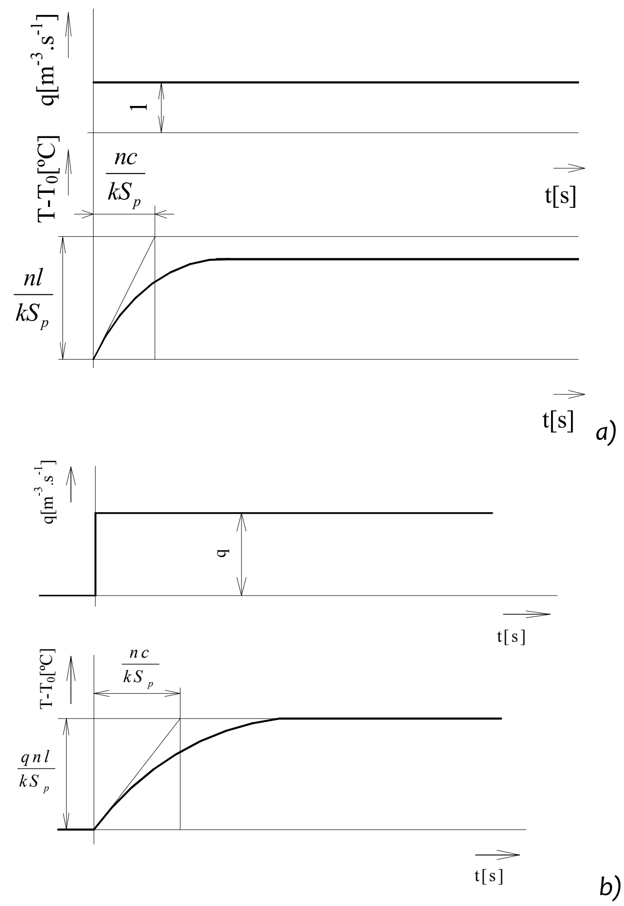

Figure 1. Transitional characteristic, a) with step b) with step q

If the step of the input variable is not unity, but enters particuler value q the course of the temperature difference of the nozzle and surroundings is described by the equation (figure. 1b):

$$T-T_o=\frac{nlq}{kS_p}\left(1-e^{-\frac{kS_p}{mc}t}\right) \qquad (6.1)$$

MODEL OF REGULATORY SYSTEM

The initiation of the temperature change of the nozzle towards surroundings can be realized by regulating of the gas flow q that enters the torch. To control the gas flow a proportional regulator can be selected.

Transfer of a proportional regulator is formulated as follows:

$$R=KP \qquad (7)$$

Regulatory circuit can be depicted by block diagram as in figure 2.

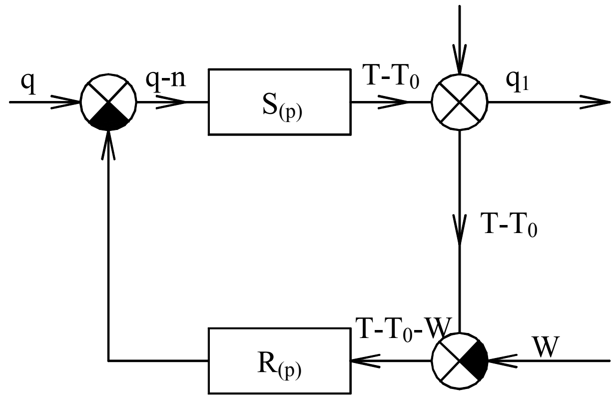

Figure 2. Block scheme of regulatory circuit

Transmission of the action variable is expressed by following equation:

$$F_a=\frac{S}{1+RS}=\frac{\frac{nl}{mcp+kS_p}}{1+\frac{KnlP}{mcp+kS_p}}=\frac{nl}{mcp+kS_p+KPnl} \qquad (8)$$

Figure 3 depicts amplitude and phase characteristics and figure 4 depicts transitional characteristic for K=1 and P=1. Circuit is characterized by stability and irregularity.

The transmission of the disturbance:

$$F_{Por}=\frac{1}{1+RS}=\frac{1}{1+\frac{KnlP}{mcp+kS_p}}=\frac{mcp+kS_p}{mcp+kS_p+KPnl} \qquad (9)$$

Amplitude and phase characteristic is depicted in figure 5 and figure 6 depicts transitional characteristic for K=1 and P=1.

The transmission of the control is:

$$F_r=\frac{RS}{1+RS}=\frac{\frac{knlP}{mcp+kS_p}}{1+\frac{KnlP}{mcp+kS_p}}=\frac{KnlP}{mcp+kS_p+KPnl} \qquad (10)$$

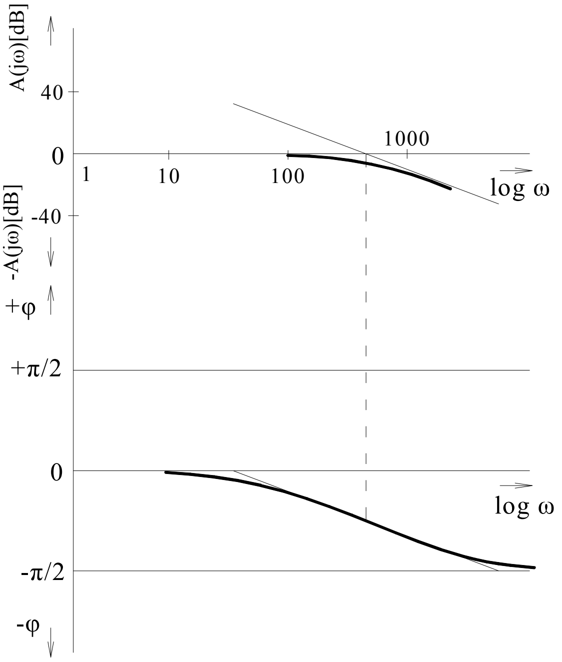

Figure 3. Amplitude and phase characteristics

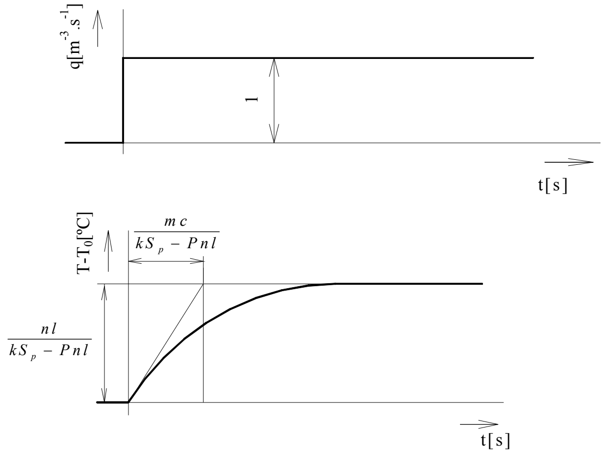

Figure 4. Transitional characteristic

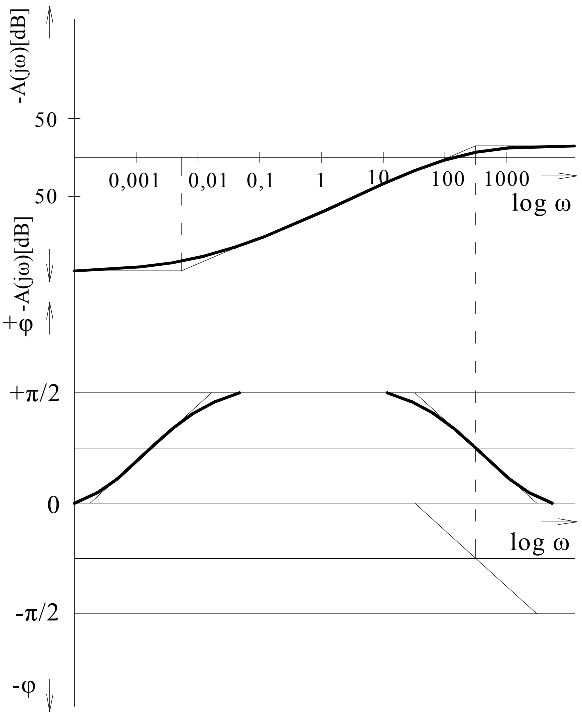

Figure 5. Amplitude and phase characteristics

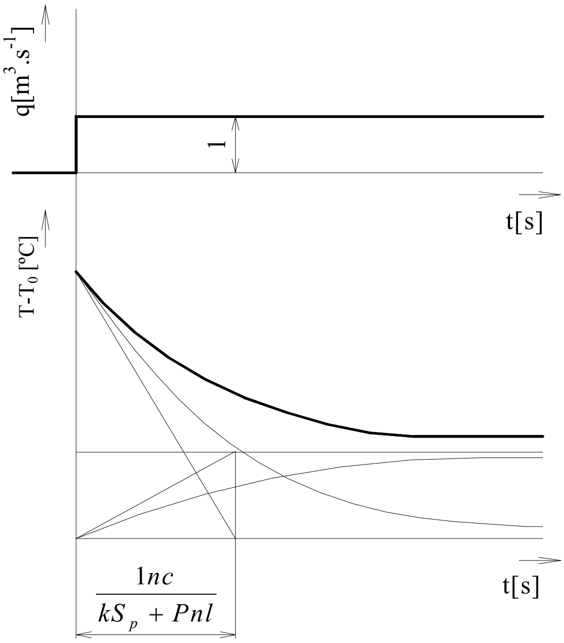

Figure 6. Transitional characteristic

CONCLUSIONS AND DISCUSION

For simple regulatory circuit formed by the torch that heats the nozzle the proportional regulator was used. On the basis of the proposed model of regulatory system the amplitude, phase and transitional characteristics of the action variable were determined (Figure 4 - 6). The control of the regulatory circuit was designed by equation of the transmission (10). From these characteristics, it is known that the regulatory circuit is stable and irregular. From transmission equation of disturbance (9) and based on the amplitude, phase and transitional characteristics for the failure of the circuit it is evident that the defect in the regulatory circuit is quickly diminishing. It can be concluded that heating the nozzle by gas torch in pressure die-casting machines with hot chamber together with proportional regulator is easy to control and it has relatively good regulatory characteristics.

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