АСПАПТАР МЕН ЭКСПЕРИМЕНТ ТЕХНИКАСЫ
ПРИБОРЫ И ТЕХНИКА ЭКСПЕРИМЕНТА
INSTRUMENTS AND EXPERIMENTAL TECHNIQUES

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Automated control system for casting process

This article is dedicated to technologies research that require development and implementation in Kazakhstan, able to provide energy sources economy, as well as improvement of sanitary-hygiene and economical indexes of production. But it's hard to achieve it, if there is no special equipment at enterprises for achieving of this aim. Therefore, the main aim is to design schemes for automated control system and management for technological process for providing of safety and effective functioning of enterprise. To accomplish this goal, we will describe the mathematical model of the regulatory object, as well as investigate the system of automatic regulation for stability. To analyze the relationship between the defining parameters of the cupola process using advanced experience in operating cupola, the latest achievements in the field of mathematical modeling of technical systems and modern computer technology, considering the process as a cybernetic system.The structure of the management system is developed in accordance with the main trends in automation identified during the analytical review.

Keywords: mathematical description, stability research, automated system, casting manufacture.

Introduction

Today, casting manufacture and metallurgy are the main suppliers of raw materials, blanks and final products for other branches of national economics, which together with electric energy industry and chemical industry provide development of Kazakhstan economics.

At each technological operation one strived to replace manual work by machine one: there were improved equipment for making of forma and rods, shake-out and finishing of casing, mechanized transportation of materials and finished castings, implemented conveyors, developed methods of flow-line production. Further growth of mechanization of casing production is expressed in creation of new improved machines, automatic casting machines and automated casting lines, in organization of complex-automated plots and shops. The most labor-consuming operations during casting are moulding, rods manufacture and finishing of final castings. At this plots of casting shops technological operations are most mechanized and partially automated. Especially effective is implementation of complex mechanization and automation to casting production. Most advanced are automated moulding lines, assembling and casting of forms with cooling casting alloy and their shake-outs [1].

Implementation of automated control systems permits to carry out systematic approach to the problem of complex automation of technological process of cast-iron melting in cupola installations on the basis of ECM use. Transition from certain local ACS to ACS TP makes it possible not only quickly establish connections between particular tasks when solving general tasks of complex automation of cupola process, but also to carry out an optimal control for the last as a whole, taking into account technical, organizational and economic factors [2].

Automation allows reducing emergency situations, size of work force, as well as expenses for raw material production, and as a whole providing of new requirements to the quality of cupola heat.

Mathematical descriptions of controlled unit

Before formulating of the task of automatic control for one of the parameters of technological process, the example of mathematical descriptions of controlled unit is considered.

Let's consider a simple mathematical model of controlled unit–cupola. To do this, we'll make the heat balance equation

$$Q_{heating} = Q_{cooling} + Q_{evaporation},$$

where

$$Q_{heating} = CM\left[T(t) - T(t-\Delta t)\right]$$

$Q_{heating}$ — heat amount, required for heating to temperature $T(t) - T(t-\Delta t)$ object with the *M* weight and C specific heat capacity for the time Δ*t*;

$$Q_{cooling} = -\lambda_{oc}\left[T(t) - T_{cp}(t)\right]\Delta t$$

$Q_{heating}$ — hat losses for the time Δt due to heat transmission to environment with the temperature $T_{cp}(t)$ and with heat transmission coefficient «object-environment» λ_{oc};

$$Q_{ucm} = \lambda_{он}\left[T_{н}(t) - T(t)\right]\Delta t$$

$Q_{evaporation}$ — heat amount, supplied for the time Δt from heating with surface temperature $T_{н}(t)$ and heat transmission coefficient «object-heating device» $\lambda_{он}$.

In the result, temperature in the object shall be described as follows:

$$\frac{dT}{dt} + \frac{T}{\tau_0} = \frac{1}{\tau_0}\left[\frac{T_{cp}(t)}{1+\mu} + \frac{T_{н}(t)\mu}{1+\mu}\right],$$

where

$$\tau_0 = \frac{CM}{\lambda_{oc} + \lambda_{он}},$$

τ_0 — object time constant taking into account the at transmission effects with environment and heat device.

$$\mu = \frac{\lambda_{oc}}{\lambda_{он}},$$

μ — coefficient, that indicates how effective is heat transmission «object-heating device» in comparison with heat transmission «object-environment».

Obtained simple model permits to construct graph for cupola temperature curve (Fig. 1) [3]

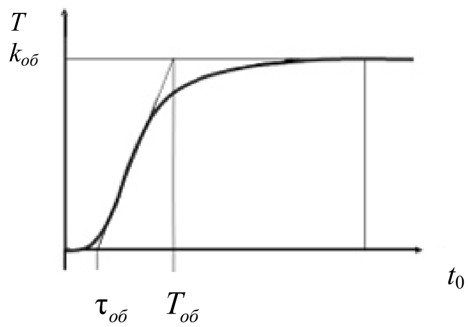

Figure 1. Acceleration characteristic of cupola temperature

According to received acceleration characteristic by graphic method, there are defined parameters of controlled unit:

a) $T_{об} = 150\ c$ — acceleration time of controlled unit;

b) $\tau_{об} = 50\ c$ — time delay of controlled unit;

c) $k_{об} = 150\ ^{o}C$ — transfer factor of controlled unit.

By characteristic appearance we determine that the object belongs to multivalent objects with self-adjusting, respectively, the formula of object transfer function has the following formula:

$$W = \frac{150}{1+150s}e^{-50s}.$$

Research of automatic control system stability

To evaluate stability of automatic control system we have to make a scheme, consisting of controlled object and regulator, interacting to each otherina closed cycle (Fig. 2).

Line arising the model using Line arise Model function and transferring data to working space with the name of w02

>>w=tf(w02);

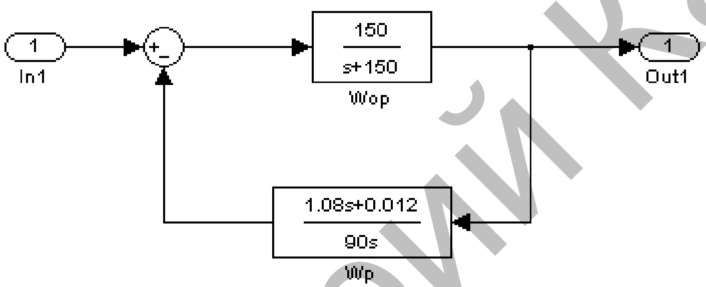

Figure 2. Scheme of typical ACS

According to found function in the Matlabc program using Nyquist function, we make Nyquist hodograph (Fig. 3)

>>Nyquist (w(1,1))

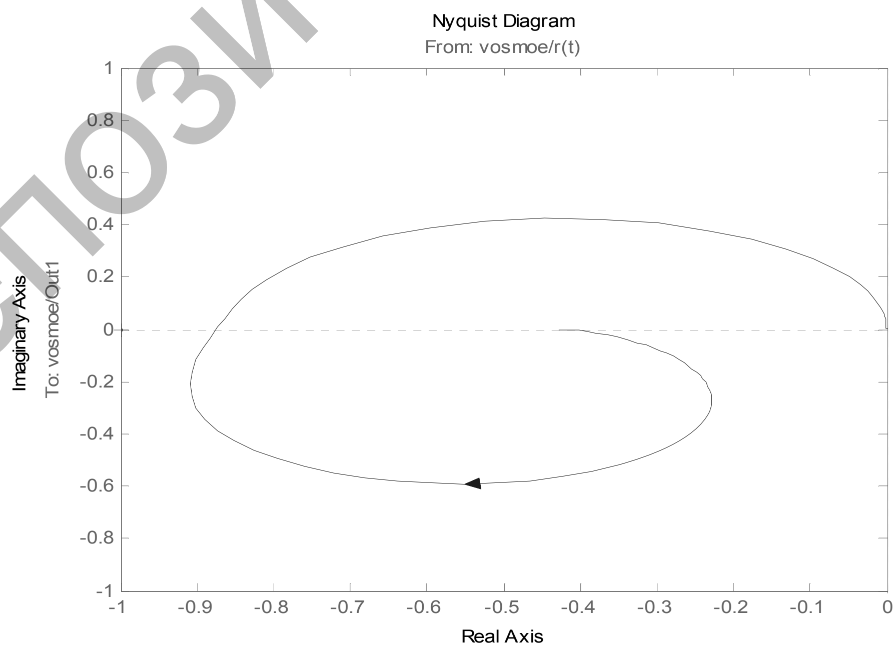

Figure 3. Nyquist hodograph

According to this hodograph we find stability margin in amplitude and phase.

Stability margin by amplitude is equal to

$$A_m = \frac{|A_m|}{1} * 100\ \%,$$

$$A_m = \frac{|-1-(-0,875)|}{1} * 100\ \% = 12,5\ \%.$$

Stability margin in phase 180 degree or 100 %. Margins in amplitude and phase are within normal limits [4].

Research of transition processes

We draw units tepresponse (Fig. 4) relatively to output: Out(1) conforms withy(t) value at output of controlled unit.

>>step(w02)

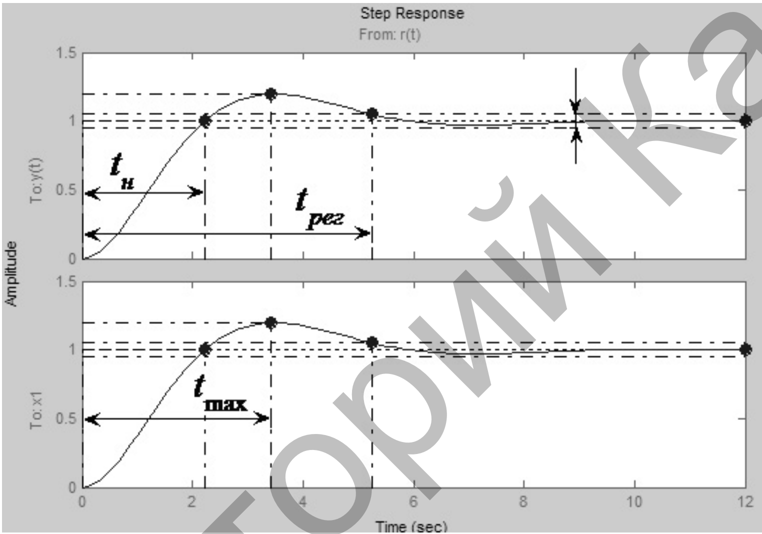

Figure 4. Transient curve

We define regulator performance indexes.

By taking $\Delta = 5\ \%,$ we calculate band-edge $2\,\Delta$

$$\Delta = 0,05,$$

$$y(\infty) + \Delta = 1,05,$$

$$\mathrm{y}(\infty) - \Delta = 0,95.$$

Over regulation is determined by the formula

$$\sigma = \frac{y_{\max 1} - y(\infty)}{y(\infty)},$$

where $y_{\max 1}$ — first maximal value of transient characteristic; $y(\infty)$ — steady-state response.

Over regulation

$$\sigma = \frac{y_{\max 1} - y(\infty)}{y(\infty)} = \frac{1,2-1}{1} \times 100\ \% = 20\ \%.$$

Regulation time $t_{рег} = 5,25\ c.$ this parameter confirms with selected one [3].

Rise time $t_н = 2,23\ c.$ Rise time is determined using stated determination method from 0 to 100%.

Maximum time $t_{\max} = 3,42\ c.$

Variability $N = 1$.

Stationary value of output value ($y(\infty)=1$) coincides with set point (unit step), therefore a stationary error $\varepsilon(\infty)=0,$ which means that the system is astatic relatively to unit step in output [5].

Conclusions

Implementation of automatic control system by technological process in the work of pump plants of heat supply system has made it possible:

– To expand the functions of automatic and automated control and management;

– To increase safety of emergency shut-down system functioning;

– To increase the quality of industrial process control;

– To reduce time and number of localizations of emergency and equipment failure.

В расчетной части была произведена настройка оптимального контура регулирования температуры, время регулирования и экономическая эффективность. In calculation part there has been made setting of optimal temperature control circuit, regulation time and economic efficiency.

With the results:

– overregulation 20 %;

– regulation time 5,25 seconds;

– stability margin in phase 180°.

Review of automatic control system examples shows that modern control systems are decentralized, providing:

– flexibility;

– high productivity due to functions separation between control devices;

– in comparison with centralized control systems, possibility of significant increase of resources.

Use of automated control system will allow automating the process, increasing the level of productivity, improving the quality of produced energy products, preventing emergency situations, reducing the psychological stress to operator, and in general ensuring failure-free and reliable operation. Due to that a performance specification was developed.

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Құйма үрдісінің автоматтандырылған басқару жүйесі

Мақала Қазақстанда дамытуды және іске асыруды талап ететін, энергия қорларды үнемдеуді, өндірістің санитарлы-гигиеналық және экономикалық көрсеткіштерін жақсаруын қамтамасыз етуге қабілетті технологияларды зерттеуге арналған. Егер кәсіпорындарда осы мақсатқа қолжеткізу үшін арнайы жабдықтар болмаса, жұмыста қиындықтар туындайды. Сол себепті негізгі мақсат кәсіпорынның сенімді және тиімді жұмыс істеуін қамтамасыз ету үшін технологиялық үрдістерді басқару және қадағалаудың автоматтандырылған жүйелерінің сұлбасын жобалау болып табылады. Осы мақсатты жүзеге асыру үшін біз басқару объектісінің математикалық моделін сипаттаймыз, сондай-ақ автоматты басқару жүйесінің тұрақтылығын зерттейміз. Шойын балқытатын пешті пайдаланудағы озық тәжірибені, заманауи компьютерлік техниканы және техникалық жүйелерді математикалық модельдеу саласындағы соңғы жетістіктерді пайдалана отырып, шойын балқытатын пеш процесін кибернетикалық жүйе ретінде қарастыра отырып, шойын балқытатын пеш процесінің анықтаушы параметрлері арасындағы қатынастарды талдауды орындау қажет. Басқару жүйесінің құрылымы аналитикалық шолу барысында анықталған автоматтандыру саласындағы негізгі үрдістерге сәйкес жобаланған.

Кілт сөздер: математикалық сипаттама, тұрақтылықты зерттеу, автоматтандырылған жүйе, құйма, кибернетикалық жүйе.

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Автоматизированная система управления процессом литья

Статья посвящена исследованию технологий, требующих развития и внедрения в Казахстане, способных обеспечить экономию энергоресурсов, улучшение санитарно-гигиенических и экономических показателей производства. Но этого очень тяжело добиться, если на предприятиях нет специального оборудования. Поэтому главной целью является спроектировать схемы автоматизированной системы контроля и управления технологическим процессом для обеспечения надежного и эффективного функционирования предприятия. В статье описана математическая модель объекта регулирования, а также исследована система автоматического регулирования на устойчивость. Выполнен анализ взаимосвязей между определяющими параметрами ваграночного процесса с использованием передового опыта эксплуатации вагранок, новейших достижений в области математического моделирования технических систем и современной компьютерной техники, рассматривая ваграночный процесс как кибернетическую систему. Структура системы управления разработана в соответствии с основными тенденциями в области автоматизации, выявленными в ходе аналитического обзора.

Ключевые слова: математическое описание, исследование устойчивости, автоматизированная система, литейное производство, кибернетическая система.

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