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DEVELOPMENT OF AUTOMATED CONTROL SYSTEM FOR CONTINUOUS CASTING

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ABSTRACT

Context. Today, automated continuous casting control systems are developing rapidly, as process of manufacturing billets (products) of same size from metal in casting mold in mass production has long been outdated and "continuous casting stage" is coming. This process is suitable for non-ferrous metals and steel. However, each time during development, task of improving quality of resulting billet arises, which directly depends on optimizing efficiency and reliability of automated systems themselves. Optimization is key stage in development process, as it is aimed at ensuring accuracy and stability of casting process, which includes development of parametric model and accurate algorithms that ensure optimal temperature, metal pouring rate, oscillation frequency, oscillation amplitude, metal level in crystallizer, and position of position of industrial bucket stopper for each casting stage. In particular, this problem has not yet been fully solved in literature known to authors, so it is necessary to formulate problem and develop algorithm for system operation for specific safety casting unit.

Objective. The aim of study is to develop automated control system to ensure accuracy and stability of casting process.

Method. The developed control system for continuous casting plant is based on proposed parametric model, which is formalized on basis of set theory. The model takes into account key parameters for particular casting process: metal pouring rate, oscillation frequency, oscillation amplitude, metal level in crystallizer, and position of industrial bucket stopper.

Results. The problem was formulated and key parameters were determined, which are taken into account in system's algorithm, which made it possible to develop control system for continuous casting plant to solve problem of improving quality of resulting billet.

Conclusions. A parametric model and generalized black box model representation were created, which are necessary for both new continuous casting projects and existing units to optimize metal casting process. To set up continuous casting system, controlled parameters such as pouring speed, oscillation frequency and amplitude, metal level in crystallizer, and position of industrial bucket stopper were determined. The algorithm of control system for continuous casting plant was developed, on basis of which system was developed that allows monitoring, regulation and control of obtaining steel process or non-ferrous billets. The developed user interface of control system is simple and easy to use.

KEYWORDS: process, continuous casting, automation, system, control.

ABBREVIATIONS

CC is a continuous casting;

CCM is a continuous casting machines.

NOMENCLATURE

A_{rc} is a vibration amplitude of crystallizer;

D_c is a distance between opposite walls of crystallizer;

F_{cc} is a cross-sectional area of crystallizer cavity;

F_{rc} is a frequency of crystallizer oscillation;

G_{cc} is a geometric parameters of crystallizer;

H_c is a height of crystallizer;

H_{Tecp} is a temperature at end of curing process;

I is a number of mold types, for example, parallel-walled molds or straight or reverse tapers for metal casting;

M_{lv} is a metal level in crystallizer;

P is a set of casting parameters;

P_{ib} is a stopper position industrial bucket;

SH^i_{cr} is a shape of crystallizer;

T is a logically ordered set of parameters required for casting;

T_{cc} is a temperature conditions;

T_{lq} is a liquidus temperature (at which first crystal falls out under equilibrium conditions);

T^s_{il} is a metal temperature in intermediate ladle;

T^s_{sl} is a metal temperature in steel ladle;

u_o is a speed of liquid metal with which it meets melt surface;

V_p is a speed of metal pouring;

W_o is a metal velocity at outlet of pouring hole;

Π is a set of all possible options for casting parameters.

INTRODUCTION

Today, problem of controlling continuous casting is relevant and key to improving production processes. The main scientific task is to develop efficient automated control system that will ensure accuracy, stability and optimal conditions during metal casting. Automation requires solving technical, engineering, and algorithmic challenges associated with complexity of process and its interaction with variable conditions.

This issue is important because it determines quality and productivity of casting process, which in turn affects quality of resulting billet. Automation of control in molding can lead to significant increase in production efficiency, resource savings, and cost reduction.

The scientific tasks include development of parametric model of CC installation and system operation algorithm, which together will ensure optimal casting conditions. Practical tasks include creation of functional and reliable system that can be implemented in industrial production.

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The development of topic is based on analysis of current state of continuous casting production, existing problems and shortcomings in control systems. The initial data include results of preliminary research, technical requirements and specifications for creation of automated control system [1–3].

The research is critical to solving problems and achieving new levels of efficiency in field of CC. The development of automated control system not only optimizes production process, but also makes significant contribution to development of industry, improving product quality and rational use of resources.

The object of research is control process of plant for continuous casting of steel or non-ferrous metal billets.

The subject of research is continuous casting machines.

The purpose of the research is development of automated control system to ensure accuracy and stability of casting process.

1 PROBLEM STATEMENT

This paper solves problem of optimizing continuous casting process by developing automated control system. The mathematical formulation includes creation of parametric model that takes into account peculiarity of crystallizer to improve quality of produced slabs.

The input data for system includes parameters of casting process, as well as configuration of new or existing plants.

It is planned to obtain optimal values of parameter values, which will ensure high quality of manufactured billets.

Let's assume that proposed parametric model is necessary to determine key parameters for particular casting process and formalize them, which is necessary both when designing new CCMs and for already operating units to optimize casting process.

The input parameters in development of automated control system for CC plant are represented by model: V_p=<W_o, u_o>, G_{cc}=<SH^i_{cr}, H_c, F_{cc}, D_c>, i = 1, 2, ..., I. T_{cc}=<T^s_{il}, T^s_{sl}, H_{Tecp}, T_{lq}>.

As result, it is planned to take into account key elements of parametric model during development of automated system, which will further improve product quality through accurate and stable control of these casting parameters.

2 REVIEW OF THE LITERATURE

The process of producing products by casting is focus of many scientific papers [4–6], and continuous casting of metals is described in detail in [7, 8]. Continuous casting is main process of steel production today [6].

In recent years, growing complexity and global competition to improve quality of metal products have led to need to introduce new approaches to monitoring and controlling continuous steel casting process, as evidenced by work of authors [9–11].

A scheme for coordinating process of steelmaking and continuous casting is presented in [8]. The authors reviewed methods for studying planning of iron and steel production. The correlation between productivity of continuous casting process and its equipment is considered.

The integrated application of several algorithms based on operations research, heuristic algorithms, and artificial intelligence methods is effective means of solving such complex production planning problems. However, work [8] does not identify specific technological parameters, challenges, or limitations that iron and steel producers may face when implementing proposed methods.

In [9], authors present online monitoring system based on Internet of Things for continuous steel casting, which consists of four layers: sensing, network, service resources, and application layers. It integrates various data processing techniques, including protocol conversion, data filtering, and data transformation. Although authors describe how proposed system was implemented and demonstrated on real continuous casting line, paper would be more informative if mathematical framework on basis of which implementation was realized was provided.

Online monitoring of steel casting processes using multivariate statistics technologies is presented in [10]. The authors paid special attention to development of new scheme for synchronizing technological trajectories to monitor specific transient operations, such as equipment replacement or steel grade change, i.e., work is aimed at increasing productivity and reducing maintenance costs, and problem of improving quality of resulting products is not particularly addressed in paper.

Paper [11] investigates unsteady states of continuous steel casting process using industrial diagnostic systems process diagnostic system, special measuring devices, and thermal numerical model. The authors present mathematical component: thermal model based on Fourier-Kirchhoff equation. The authors graphically present study of vertical temperature profiles in mold and analyze measured dependencies of heat transfer coefficient on surface temperature, but more information about system hardware itself: sensors, devices, and data analysis methods could be provided, which could improve understanding of work.

The control and design of continuous steel casting process based on modern numerical models is described in detail in [12]. The authors described method of determining boundary conditions, initial conditions, and material parameters as most important components that provide numerical calculations based on them in finite element method, which is used most often and is important element of work. However, work does not take into account design features of foundry.

In source [13] describes modern automated system for monitoring crystallizer, which aims to improve product quality, increase process stability and increase casting speed. The source presents main functions of system and provides data that is constantly monitored and recorded.

Overall, these works make important contribution to field of continuous casting.

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The general trend of these scientific papers is great interest in development and improvement of monitoring and control systems for continuous casting processes. They highlight important aspects such as impact of complexity and global competition on need for new control and management methods, integration of IoT technologies, and use of multivariate statistical technologies and numerical models.

Thus, this paper emphasizes regulation and control of most important parameters of CC installation, which are formalized using parametric model, which will undoubtedly be key to improving quality of products.

3 MATERIALS AND METHODS

3.1 Selection of key parameters of CC

In this study, we will not discuss all parameters, but will focus on CC installation.

In this paper, crystallizer will be considered as moulding unit, since it is one of most important functional units that determine rational operation of CCM.

In order to select CCM, it is necessary to determine type of cast billet:

1) machine for producing rectangular billets (slabs) used in production of rolled steel sheets and strips – slab machine [14];

2) machine for producing square billets (blooms) used in production of rolled plates and strips – sizing machine [15, 16].

Thus, slab continuous caster was chosen because company plans to produce slabs. A curved strip mill was chosen because they have high unit capacity and relatively low installation height.

Fig. 1 summarizes scheme of slab continuous caster, which consists of: 1 – intermediate ladle, 2 – turntable, 3 – copper liner, 4 – crystallizer (first cooling level), 5 – spray cooling with water (second cooling level), 6 – pulling and straightening unit, 7 – roller conveyor, 8 – gas cutter [1].

We'll focus on crystallizer because it's where workpiece is directly shaped.

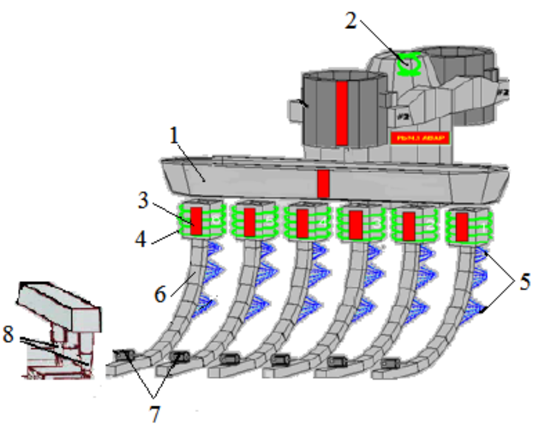

Figure 1 – Slab continuous casting machine

To determine key plant parameters that have greatest impact on quality of workpiece during continuous casting, it is necessary to analyze possible emergencies and their causes (Table 1).

Table 1 – Main emergencies in CC

Type Type of emergency / Location of emergency	Reason	Method of elimination
Slab breaker / Crystallizer	High speed pulling of workpiece	Setting speed according to pouring speed and acceleration chart
Crust thickness deformation / Crystallizer	Metal level	The required metal pouring rate, which depends on cross-section of crystallizer and flow-through section of slag dosing unit
Slab deformation / Crystallizer	Excessive wobbling of crystallizer	Distance between rollers according to thickness of workpiece or design features of rolling mechanism
Pouring steel over edges of crystallizer / Crystallizer	Improper adjustment of industrial bucket stopper position	Adjusting the position of stopper industrial bucket
Workpiece deformation / Pulling and straightening unit	High ingot drawing speed	Setting speed according to pouring speed and acceleration chart

After analyzing reasons, it was determined that following parameters should be selected for management:

1) metal pouring rate because this parameter affects frequency and amplitude of oscillations and shape of oscillations;

2) metal level in crystallizer because when controlling metal level in crystallizer, it is necessary to observe movement of industrial bucket stopper (it must be minimal) and prevent pulsation of metal jet entering crystallizer during casting process, in addition, to maintain continuous flow (jet) of metal during casting and stable metal level in crystallizer;

3) stopper position industrial bucket.

All these parameters affect required thickness of crust, which is shell of future billet.

Since key parameters of CC unit were defined above, they are written in form of parametric model as follows:

$$b=<V_p, G_{cc}, P_{ib}, T_{cc}, M_{lv}>.$$

Fig. 2 shows generalized representation of parameters in form of black box model.

The input data to "gray box" is set represented by expression above), which describes all parameters necessary and sufficient for complete selection of continuous casting parameters.

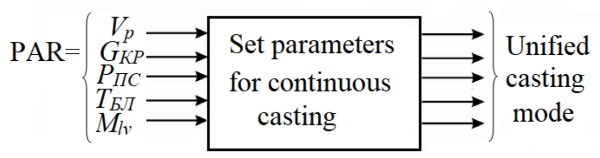

Figure 2 – Black box model

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Inside "black box" there is set Π of all possible variants of casting parameters P, which has following properties:

1) possibility of existence $\Pi \in P$, provided that $P \to \max$;

2) set Π contains subset of $(T_1, T_2, ..., T_r) \in T$, as logically ordered set of parameters required for casting.

The output is partially unified sequence of casting mode parameters.

3.2 Technical means for controlling casting parameters

Effective control of casting parameters is crucial to ensure quality and safety of production process. In this context, use of technical means becomes necessity, and key element of such means is sensors that allow us to accurately measure and control various casting parameters, ensuring effective process control.

To begin with, metal level in crystallizer will be monitored using special sensor – XLEV eddy current level sensor, which detects level of molten metal. We chose XLEV because it has several key advantages that make it optimal choice for monitoring metal level in crystallizer:

1) it uses principle of eddy currents, which allows for non-contact measurement of level of molten metal without direct contact with it. This is important to avoid possible deformation or contamination of sensor, which can affect its accuracy;

2) XLEV has high sensitivity and measurement accuracy, which allows it to detect even slightest changes in metal levels. This ensures reliable control and response to any changes in production process [17].

Accurate speed measurements are crucial for control in continuous casting, so LSV-2100 optical speed measuring device was chosen because it also offers following advantages:

1) non-contact measurement principle with laser precision and no need for recalibration;

2) direct feedback via touchscreen display.

Digital frequency meter 10-199.9 Hz was chosen to measure oscillation frequency because it provides high measurement accuracy. Its digital nature allows for clear and stable results without distortion that can occur with analog measurements. In addition, this frequency meter has wide measuring range from 10 to 199.9 Hz, making it versatile and suitable for measurements in various crystallizer operating conditions. It is able to effectively detect even high-frequency vibrations that can occur as result of changes in metal crystallization process.

Vibrations will be measured with 640B01 sensor – industrial speed converter because it:

1) it is specifically designed for measuring vibrations in industrial environments. It has high sensitivity and measurement accuracy, which allows it to effectively detect various vibrations and vibrations that may occur during operation of crystallizer;

2) 640B01 sensor, equipped with communication interfaces that allow it to be effectively integrated into monitoring and control system [18]. This makes it convenient tool for continuous vibration monitoring and responding to any unforeseen situations.

LTR series linear encoder is linear encoder for measuring short displacements with return spring. Important feature of LTR series position sensors is presence of return spring.

3.3 Development of control system operation algorithm for continuous casting plant

Fig. 3. The developed algorithm of control system operation for continuous casting machine is shown.

First, power supply is switched on and molten metal from industrial bucket is poured into water-cooled crystallizer, where it is formed into slabs and cooled in copper sleeve.

Next, pouring speed is checked, if value is 2 (is value obtained in calculations that will be presented in further works), slab is gradually poured into the crystallizer. If the speed is less than or greater than 2, then this speed can lead to slab rupture, which means that pouring speed must be controlled via PID controller.

The next step is to check shape of oscillation, if it is sin-shaped, then oscillation frequency should be equal to 164, if this condition is met, then amplitude of oscillation should be checked.

If oscillation frequency is not 164 (is value obtained in calculations), then we need to determine whether it is equal to 426 (is value obtained in calculations).

Checking condition and, if «Yes», whether waveform is non-sinusoidal.

If oscillation frequency is generally either higher or lower than 426, then you need to control value of this parameter.

After that, amplitude of oscillations is checked, it should be 242 (is value obtained in calculations), if condition is met, then hydraulic cylinders are turned on.

The slab crystallizer of continuous casting machine is driven by two hydraulic cylinders located on both sides of movable frame.

If «No», then you need to adjust oscillation frequency.

Important task when pouring metal is to maintain given metal level in crystallizer. Therefore, it is necessary to determine level of metal in crystallizer. According to calculation results, metal level should be 0.85 (is value obtained in calculations that will be presented in further works).

If this condition is met, stopcock should turn off.

If this condition is not met, hydraulic cylinders must be switched on again.

It may happen that stopcock does not turn off, in which case you need to turn it off.

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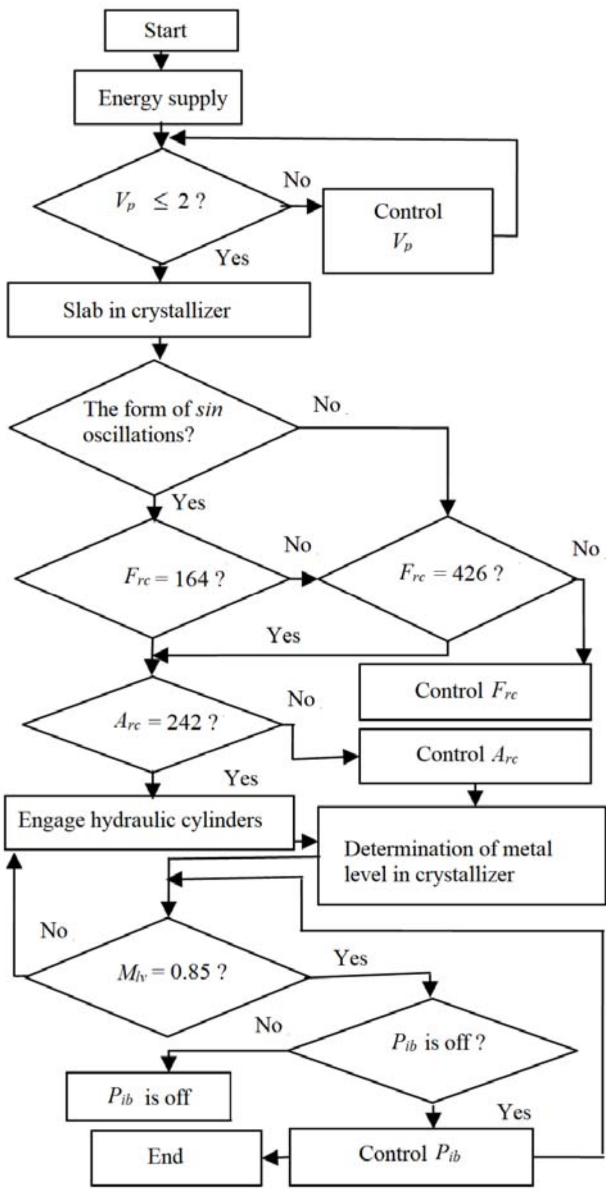

Figure 3 – Algorithm of the control system operation

Therefore, let developed system conventionally consist of two circuits: internal circuit for controlling position of stopper and circuit for controlling metal level in crystallizer.

4 EXPERIMENTS

The system is created with help of functional blocks in TraceMode system.

To begin with, you need to create project that will include operator station node and PID controller OVEN TRM 210 with RS-485 interface. Communication between operator station and device is carried out using OVEN protocol. Automatic converter from RS-485 to RS-232 interface is used as converter.

Using context menu, PLC_1 group is created in this group, and Owen RS485_group is created in this group (Figure 4).

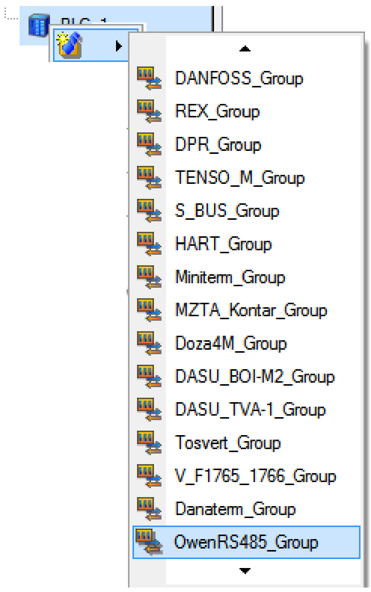

Figure 4 – The process of creating new group in Trace Mode

Fig. 5 shows window with created «Arguments» – necessary for communication with screen (interface) elements.

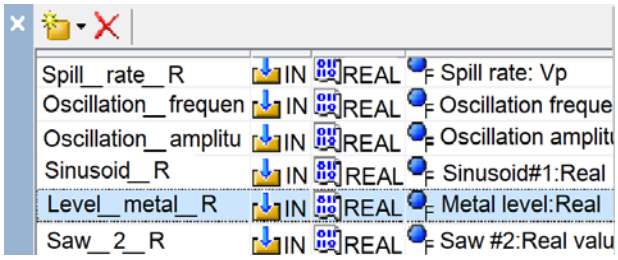

Figure 5 – The window with created «Arguments»

Another screen was also created in order to implement control of locking mechanism of CCM.

To connect elements of second screen, MODBUS_3 group and corresponding groups with names were created in «Sources/Receivers» layer:

– Read_state_Coil – reading states of discrete outputs;

– Read_State_Inp – reading states of discrete inputs;

– Write_Singl_Coil – control of discrete outputs.

In each group, components are created (Figure 6), which are connected to elements on screen through appropriate arguments:

– ARG_000 – reading status of discrete inputs;

– ARG_001 – reading status of discrete outputs;

– ARG_002 – means of controlling discrete output.

Fig. 6 shows fragment of project navigator tree with created components in «Sources/ Receivers» layer.

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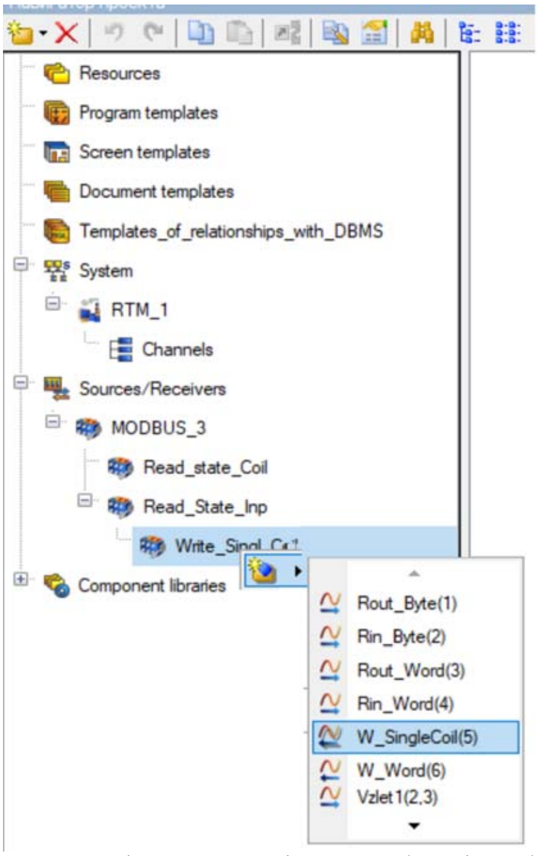

Figure 6 – Creating components in «Sources / Receivers» layer

The «Resources» layer can be used to centrally manage and monitor various resources required for effective operation of automated control system.

In «System» layer, RTM_1 project node is created, and then three groups and channels with same names are created in node: Read_state_Coil, Read_State_Inp, and Write_Singl_Coil.

Visualization of controlling process of key parameter values will be provided by graphical element «Slider».

Fig. 7 shows graphical interface (Display 1) for presenting data on frequency and amplitude of oscillation on operator's monitor.

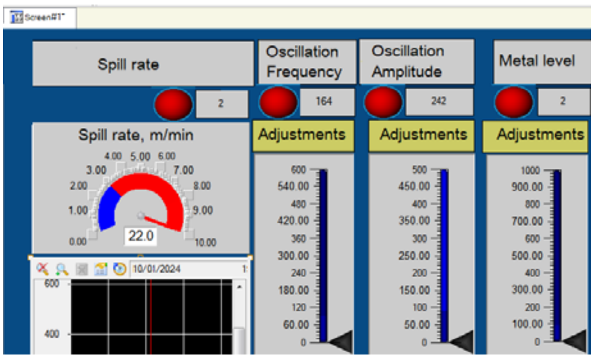

Figure 7 – Control system user interface (Display 1)

All elements: «Arrow device», «Trend», «Slider», «Text» were added to screen by drag-and-drop.

5 RESULTS

Fig. 8 shows developed user interface of control system.

To check whether binding of graphic elements to screen arguments is set correctly, you can use emulation mode. To switch to emulation mode, use special icon on toolbar. When you click on screen of graphic editor, window for setting value of argument in corresponding field is displayed (Figure 8).

Below is list of controls that are included on screen of developed system:

Process parameters: metal level in crystallizer, metal pouring rate, position of stopcock.

On screens 1 and 2, there are elements such as «Trend» graph and «Arrow device» for better perception of process dynamics, and history of changes in key parameters over time will be archived every 4 hours, while minimizing excessive amount of stored data.

The metal pour rate indicator shows current speed of molten metal. It is important to monitor this parameter because it can affect quality of casting and shape of product.

Oscillation frequency and amplitude indicators to monitor these parameters to avoid process instability and improve product quality.

If it is necessary to turn off locking valve, button changes from «ON» to «OFF», which allows operator to intervene quickly and easily if necessary.

As result, when formulating context of this work, its main goal was determined – development of automated control system to ensure accuracy and stability of casting process. As result of this work, this goal has been achieved because:

– analysis of current state of continuous casting production;

– analysis of molding machine;

– nature of cast billet was determined and required CCM was selected;

– analyzed main emergency situations in casting process;

– key parameters of continuous casting were selected with emphasis on casting machine;

– parametric model of CC is proposed;

– technical means for controlling casting parameters were selected and substantiated;

– developed algorithm for control system for continuous casting machine;

– operator interface was developed and virtual devices were connected;

– comparison with analog was made.

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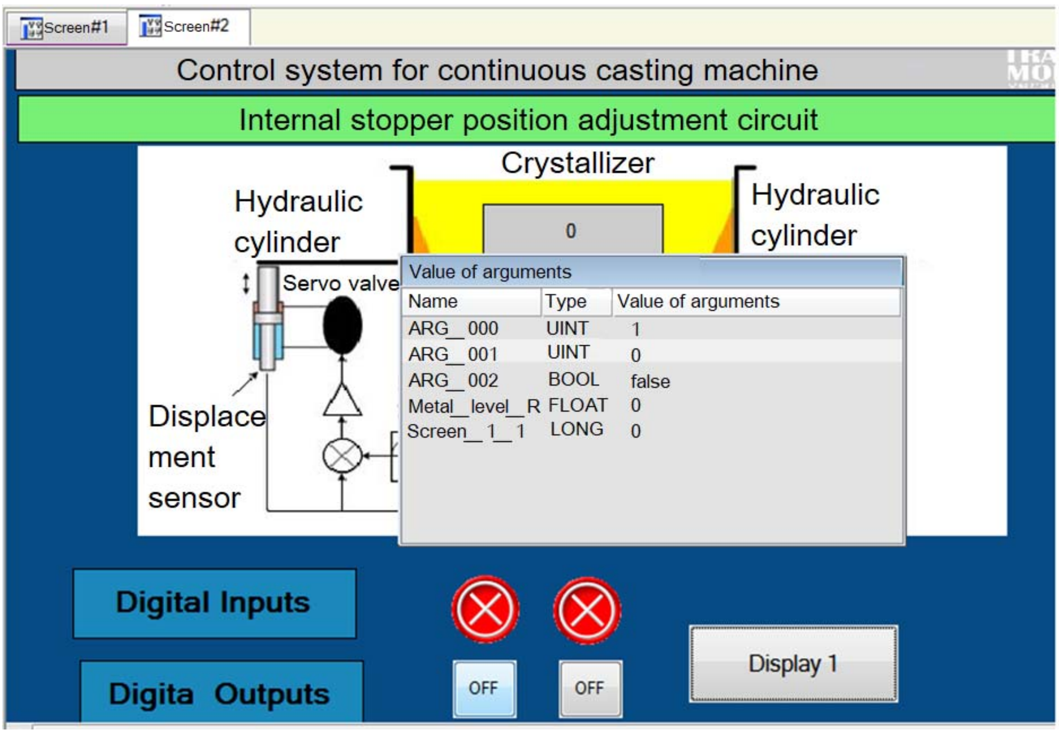

Figure 8 – Interface of developed system in process of emulation (Display 2)

6 DISCUSSION

The developed automated control system for continuous casting is represented by two screens with elements for monitoring, adjusting and controlling key parameters of mold.

A common visual representation provides clarity and intuitive navigation for operator, which is important when working with automated control systems.

To compare development with analogues, we selected program that is used to control continuous casting machine.

The software for controlling molds is classified, but there are modules for modeling metal casting.

ABAX TubeStar, automated crystallizer tracking system, is special function of standard automated control system for continuous casting machines [13].

The main functional aspects are: safe system operation, high stability of meniscus level, high operational reliability, simple operation, low investment and maintenance [13].

In ABAX TubeStar, user enters input data required for crystallizer monitoring step by step.

Project data is stored and can be displayed in reports.

The following information is monitored and recorded continuously:

– number of melts and weight of ingots cast in tons;

– steel grades of steel to be poured and ingots already poured;

– casting speed;

– heat removal;

– temperature difference in primary cooling;

– location of stream;

– current internal geometry of sleeves as measured by system.

Table 2 shows input data for steel casting process monitoring experiment.

Whole experiment is divided into two stages for comparison:

1) data entry;

2) monitoring process of forming slab product.

As comparison criterion, we will count number of module failures over certain period of time, namely two days.

As result, one system was chosen for comparison, because others are paid, and these programs are highly specialized and developed for specific size of CCM.

It was found that during two days of using these programs, developed system «worked without failures» longer than ABAX TubeStar.

Fig. 9 shows results of research in form of diagram for clarity.

Table 2 – Input data of experimental study

	Characteristics			
	Filling speed, m/ min	Oscillation frequency, min $^{-1}$	Oscillation amplitude, mm	Metal level, m
	1	2	3	4
Value	1	164	242	0.85
	2	164	242	0.85
	3	164	242	0.85
	4	165	243	0.86
	5	165	243	0.86
	6	165	243	0.86
	7	166	244	0.87
	8	164	244	0.87
	9	166	244	0.87
	10	166	244	0.87

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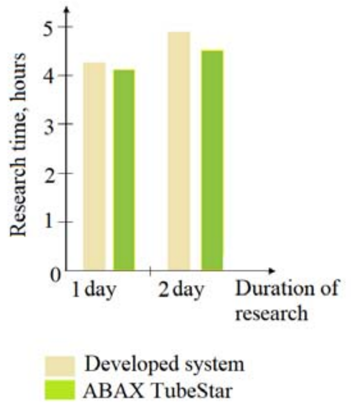

Figure 9 – Failure diagram of developed system and ABAX TubeStar module

During two-day experiment, developed system showed greater stability and efficiency, with fewer failures compared to ABAX TubeStar. The developed system allows user to enter data step by step to monitor crystallizer, ensuring high stability of meniscus level, safe operation and easy operation. Low investment and maintenance make it cost-effective option for controlling continuous metal casting plant. The experimental results show advantages of development compared to ABAX TubeStar in controlled monitoring of steel casting.

CONCLUSIONS

The urgent problem of developing automated control system for continuous casting is solved.

The scientific novelty of results obtained is that for first time parametric model for optimizing casting process has been proposed, which can be used both in design of new plants and to optimize operation of existing ones. This allows to reduce production time and costs and ensure higher quality of manufactured blanks. This model differs from existing ones in that it takes into account position of industrial bucket stopper, which leads to increase in quality of slabs produced.

Based on parametric model, Trace Mode system was used to implement automated control system for continuous casting, which is user-friendly because it consists of two screens for monitoring, regulation and control. The system is easy to use. Advantage is built-in function of auto-automated control of slab CCM, which contributes to safety and stability of casting process.

The practical value of results obtained is that software has been developed that implements control of plant during continuous casting, and experiments have been conducted to study stability of developed system. The results of experiment allow us to recommend proposed system for use in practice.

Thus, results obtained reflect important step in development of methods for controlling and monitoring continuous casting, ensuring improved product quality and optimization of production processes.

Prospects for further research are to expand functionality of system and adapt it to various production conditions. Namely, to add to proposed screens (Display 1 and 2) screen with two basic parameters of casting process temperature and pressure to expand class of practical tasks.

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РОЗРОБКА АВТОМАТИЗОВАНОЇ СИСТЕМИ УПРАВЛІННЯ ПРИ БЕЗПЕРЕРВНОМУ ЛИТТІ

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АНОТАЦІЯ

Актуальність. На сьогодні автоматизовані системи управління безперервним литтям стрімким чином розвиваються, оскільки процес виготовлення заготовки (виробів) одного розміру з металу у виливниці при масовому виробництві давно застарів і настає «етап безперервного лиття». Такий процес виготовлення виробів підходить для кольорових металів та сталі. Однак, при розробці кожен раз виникає задача підвищення якості отриманої заготовки, яка безпосередньо залежить від оптимізації ефективності та надійності самих автоматизованих систем.

Оптимізація є ключовим етапом в процесі розробки, оскільки вона спрямована на забезпечення точності та стабільності процесу лиття, що включає в себе розробку параметричної моделі та точних алгоритмів, які забезпечують оптимальну температуру, швидкість розливу металу, частота коливань, амплітуда коливань, рівень металу в кристалізаторі та положення стопора промковша для кожного етапу лиття. Зокрема, у відомій авторам літературі ця задача досі не вирішена у повному обсязі, тому, необхідно провести постановку задачі та розробити алгоритм роботи системи для конкретної установки безперервного лиття.

Мета. Метою дослідження є розробка автоматизованої системи управління для забезпечення точності та стабільності процесу лиття.

Метод. Розроблена система управління установкою безперервного лиття спирається на запропоновану параметричну модель, яка формалізована на базі теорії множин. Модель враховує ключові параметри для конкретного процесу лиття: швидкість розливу металу, частота коливань, амплітуда коливань, рівень металу в кристалізаторі та положення стопора промковша.

Результати. Здійснена постановка задачі та визначені ключові параметри, які враховані в алгоритмі роботи системи, а це дало можливість розробити систему управління установкою безперервного лиття для вирішення задачі підвищення якості отриманої заготовки.

Висновки. Створено параметричну модель та узагальнене представлення у вигляді моделі чорного ящика, які є необхідними як для нових проектів безперервного лиття, так і для вже існуючих агрегатів з метою оптимізації процесу лиття металу. Для налаштування системи безперервного лиття були визначені контрольовані параметри, такі як швидкість розливу, частота та амплітуда коливань, рівень металу у кристалізаторі та положення стопора промковша. Розроблено алгоритм системи управління для установки безперервного розливу на основі якого розроблено система, яка дозволяє реалізувати моніторинг, регулювання та управляння процесом отримання заготовок зі сталі або кольорових металів. Розроблено інтерфейс користувача системи управління є простим та зручним для користування.

КЛЮЧОВІ СЛОВА: процес, безперервне лиття, автоматизація, система, управляння.

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