

## Application of a Models Integration Module to the Cutting Slabs Problem in a Continuous Casting Machine

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**Abstract**—This paper considers an application of a model integration module to the cutting slabs problem in a continuous casting machine. The model integration module is a part of the modeling subsystem of the metallurgical enterprise information system being developed. Developed information system is intended to decide the topical production problem: analysis and improvement the technological, logistical and organizational processes. This paper focuses on the interaction of the system modules and dives into the principles that the integration module is based on. Also, the development of a simulation model of cutting slabs in a continuous casting machine is considered with the use of the integration module. Simulation modeling is used to optimize the sequence of the melts supplied to the continuous casting machine. The goal of optimization is to reduce the deviation between the estimated and actual numbers of slabs, because such deviations can lead to missed deadlines. The integration module supports a multi agent simulation. Agents in the developed model are intended to describe the cutting slabs algorithm used by technologists in the metallurgical production. As a result of experiments with the model a solution has been found. The following sequence of melts should be supplied to the continuous casting machine: initially, the melts from the usual quality steel, followed by the melts from the high quality steel.

**Keywords**—*model integration; simulation; agent-based modeling; continuous casting machine; automated system.*

### I. INTRODUCTION

Effectiveness of metallurgical production is tightly interconnected with perfection of technological, as well as logistical and business processes. The problems that can benefit from modeling are the following.

1. Industrial: a) irregularity of production load over a monthly period and other scheduling intervals; b) suboptimal load of production units of main technological process; c) as a result of the previous, suboptimal load of auxiliary and transportation equipment; d) unavailability of operative modification of the schedules and production graphs on technological reasons, related to the downtime of equipment on various reasons, interruption of stock supply.

2. Predictive modeling: a) analysis of effectiveness of suggested actions on new technological decisions; b) analysis of effectiveness of the innovative events on energy and resource saving; c) analysis of suggested actions on new business decisions at the level of processing facilities

control, shop and inter-shop control and interaction; d) analysis of results of possible operative re-planning in case of unexpected failures, accidents and other emergencies.

Thus, creation and interaction of technological, logistical and business models is an important aspect for improvement of effectiveness of a metallurgical enterprise as a whole.

In addition, a feature of the problem of production processes execution analysis is the need to work with the processes model in real time. The processes model execution in real time means delivering the parameters from automated process control system (APCS) sensors to the model input and producing at the model output a set of control parameters transmitted in manufacturing execution system (MES-system). Real time is connected with the application of the control models for tracking and monitoring the current state of the processes. For example, in the cutting slabs problem there is a need to track in real time the signal supply for gas cutting for cutting the slab to withstand the specified dimensions of the slabs.

This paper focuses on the issue of the integration of enterprise information systems and intelligent automated system for tracking and monitoring the current state of the production process. We propose an approach for the integration of collection, storage and analysis of production processes, simulation of production processes in real time, and formation a recommendation for change in production processes. This approach is implemented in the models integration module of the metallurgical enterprise information system.

The remainder of the paper is organized as follows: Section 2 provides an overview of current state of the modeling tools. Section 3 presents a metallurgical enterprise information system architecture including systems modules interaction description. Section 4 introduces the application of the integration module to the decision of the cutting slabs problem in a continuous casting machine. Section 5 concludes this paper and explores future work.

### II. CURRENT STATE OF TOOLS

In modern production enterprises, there is a problem of integration of heterogeneous information systems into a single information space. Such an integration requires a decision to be made for the following tasks:

- Synchronization of identifiers of the entities (processes, production units, etc.).

- Converting forms of information transfer. One accounting system can only work with the files, the other system allows communication via TCP/IP, the third system is a WEB-service.
- Converting formats of information transmitted. Attributes of the same production units are different in different information systems. Some attributes overlap (but have different names) and other attributes are specific to the information layer.
- Synchronization in time of incoming messages. Because the information systems are different (some records are maintained automatically, other involve human subjects), then, for example, we can have a message about creating a production unit arrive sooner than the message about the beginning of the process to create the production unit.

Today, there are several approaches to integrate heterogeneous information systems. The approach in which the information exchange takes place with the participation of the Enterprise Service Bus (ESB) [1] now. The basic idea of ESB is the message exchange between different IPs through a single point. But ESB is nothing more than a framework, based on which the mentioned problems will have to be solved. Not all information systems have ESB-adapters, so the transition from the form of data presentation in one system in the form of data representation in the other system usually has to be implemented within the ESB. In this paper, we propose an approach to the problem of integration of heterogeneous information systems aimed at solving the above mentioned problems, rather than to cover various protocols. The approach is implemented in the models integration module. This module allows using the integrated data from the different information systems in the real-time simulation.

The proposed approach has been verified on the data of metallurgical enterprise which has the following features: 1) the number of parameters of the life cycle of product unit is about 6-7 thousand units; 2) information on the parameters is stored in various information systems; 3) there are no adequate mathematical models of the processes. The modeling system in the proposed approach is used to describe and track in the real-time the dynamics of changes in the parameters of the production processes, optimization of production processes, and formation of recommendations for changes in the processes. Multi-agent simulation is used to formalize the expert knowledge of technologists about management of production processes.

The development trend of enterprise information systems focuses on wide application of Internet technologies. Currently the commercial modeling systems available on the market, including Plant Simulation [2], Simio [3], AnyLogic [4] are all desktop applications. Additional requirements for simulation modeling tools for team development of comprehensive simulation models include support for multi-user environment, and running simulation on the Internet. Comparison of Plant Simulation (PS), Simio (Sm), AnyLogic (AL) systems and modeling subsystem (MS) of the metallurgical enterprise information system is shown in Table 1.

TABLE I. ANALYSIS OF THE MODELING TOOLS

| Comparison criteria   | PS  | Sm  | AL  | MS  |
|---|-----|-----|-----|-----|
| <i>Creation an enterprise processes model</i>   |     |     |     |     |
| Description language of the technological, logistical and business processes              | •   | •   | •   | •   |
| Creation of a multi agent model   | ○   | •   | •   | •   |
| Description of an agent knowledge base  | ○   | ○   | ○   | •   |
| Expert modeling   | ○   | ○   | ○   | •   |
| <i>Optimization of enterprise processes</i>   |     |     |     |     |
| Creation of an experiments plan   | •   | •   | •   | •   |
| Changing the model parameters during the experiment                                       | ○   | ○   | •   | •   |
| Use of heuristic methods to automatically search an optimal solution                      | •   | •   | •   | •   |
| Ability to use 2D / 3D animation  | •   | •   | •   | •   |
| Formation recommendations on the elimination of bottlenecks                               | ○   | ○   | ○   | •   |
| Execution model in real time  | ○   | ○   | ○   | •   |
| <i>Convenient interface</i>   |     |     |     |     |
| User interface (GUI / WEB)  | GUI | GUI | GUI | WEB |
| Interface of a specialist in the subject area for model creation and process optimization | ○   | •   | ○   | •   |

A metallurgical enterprise information system is developed in the Ural Federal University for the purpose of integrated application of the simulation and statistical analysis of production data for the problem of continuous improvement of the production process. The metallurgical enterprise information system is a web-oriented system for tracking, monitoring, modeling, analyzing and improving processes of steel products manufacturing [5]-[7].

Comparison of modeling tools showed that the most functionality is included in the modeling subsystem of the metallurgical enterprise information system and AnyLogic. Only modeling subsystem of the developed information system is focusing on the execution model in real time via web-oriented interface.

At the moment, the software-as-a-service (SaaS) technology is the most convenient in use, optimal in performance and client software requirements. The end user in this case is the analyst or decision making person. The modeling subsystem of the metallurgical enterprise information system includes a model integration module. This module uses a service oriented approach [5].

All of the analyzed modeling tools except MS cannot be included into the metallurgical enterprise information system because they do not support the real-time simulation and parameters exchange with the corporate information systems of the metallurgical enterprise.

### III. METALLURGICAL ENTERPRISE INFORMATION SYSTEM ARCHITECTURE

The metallurgical enterprise information system consists of the following subsystems: subsystem of the data collection and analysis of production and modeling subsystem. The architecture of the metallurgical enterprise information system is shown in Figure 1.

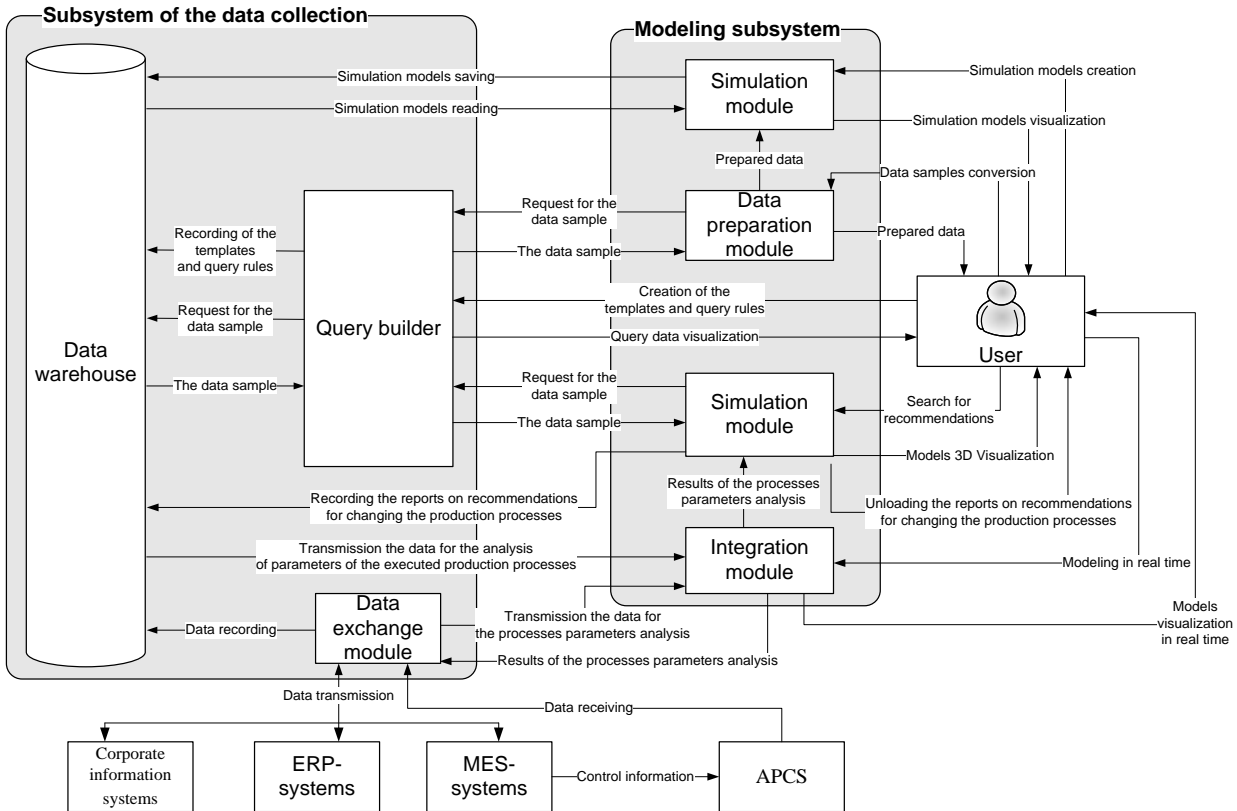


Figure 1. Architecture of the metallurgical enterprise information system

The subsystem of the data collection consists of the following modules: data exchange module, query builder [7], and data warehouse. The modeling subsystem consists of the following modules: data preparation module, simulation module, and integration module.

The data exchange module is intended for two-way communication between the modules of the developed system and enterprise information systems. The query builder module is intended to construct of requests for issuance of data on production processes without the involvement of information technology (IT) professionals.

The data warehouse module is intended to accumulate and store the information about production processes from the following data sources: corporate information systems, MES-systems, and APCS. The data preparation module is intended to transform and analyze the data from the data warehouse. The prepared data is used in the simulation module. The simulation module is intended to: 1) create and execute simulation models of the production processes with the use of 2D/3D animation, 2) receive data from the data preparation module, query builder, and integration module, 3) optimize the production processes, and 4) form recommendations on the elimination of bottlenecks.

A. Interaction of the Integration Module with the Data Exchange Module

The first option of interaction between the integration module and the module for data exchange with the enterprise

automated system suggested the use of “Publisher – Subscriber” mechanism [8]. In this case, the integration module subscribed for a specific subject, and the data exchange module published all occurring events, distinguishing these by the subject. Thus, the integration module obtained only the required events. A significant disadvantage of this option is that the integration module has to reserve its own resources for the channel listening and awaiting the new information.

The main ideology of the system under discussion is the asynchrony of operation and the use of non-blocking operations of input-output. At this moment, the integration module uses the events mechanism, which is identical for all parts of the system. The event exchange is based on the Socket.IO protocol, on top of which the Java framework netty.io is implemented. Netty.io is the event oriented library for the implementation of network exchange using various protocols, including UDP, HTTP/HTTPS.

The data exchange module receives the emerging events on any of the listed protocols, providing the maximum versatility of its operation. At the same time, all events are produced using the only protocol, which is Socket.IO. Such approach allows maximum unification of event exchange, providing the feature of receiving messages both from Java based modules and from in-browser clients, written in JavaScript. Work through Socket.IO requires registration of callback procedures. Any waits in this case are eliminated.

Apart from this, the use of event mechanism conforms to the Model-View-Controller (MVC) concept [9], since the processes of receiving, possible data pre-processing, model execution and display of results are fully isolated. This allows multiple views of the same working model at the same time, e.g., the work may be represented in 2D and 3D, or the specific user may have the aggregated information on the shop or the full detail on a certain mechanism [5].

**B. Data Exchange Mechanism Between the Modules**

If model operation permits the real-time mode, the integration module subscribes for the necessary parameters. Subscription checks previously loaded models, which avoids double subscription for the same parameter (see Figure 2).

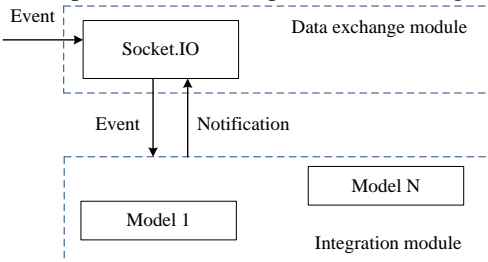


Figure 2. Receiving data from the data exchange module

The integration module launches the models and transfers the results of their operation into the data exchange module. In the first step, the fully loaded and executed test model modifies the state of its inputs. Next, the parameter is searched in the database. When the data exchange module receives the «Event\_ParamValue\_Got» event, it runs a number of checks. The received value must be of expected type (string, integer, etc.). The values themselves are written in the pre-defined form, depending on parameter kind (vector, scalar, linked list, synthetic).

Thus, before the «parameter value changed» event is received, the parameter itself needs to be stored in the database as an object with certain features. If this is not done, the processing of received value will cause an error.

The integration module interacts with the database in two cases: 1) when loading the model, since all information is stored in the database, 2) when model operation requires processing of statistical data, since this data is obtained beforehand and stored in the database. In the first case, the integration module receives a “Start” signal, which has the unique model identifier. Knowing it, the integration module accesses the database and selects the corresponding model. In the second case, the integration module receives the required parameter identifiers from the model as well as the desired time interval. Next, it selects the values of parameters from the database and forwards them to the model.

**C. Multi-agent Architecture of the Integration Module**

The multi-agent architecture of the integration module includes the following agents.

- Data exchange agent (used to update the model parameters and transfer the results of the experiment in the corporate information systems).

- Simulation agent (used to solve the process management problems in real time based on real-time models).

- Messaging agent (used for interaction between the data exchange agent and simulation agent).

The simulation agent allows to build models with the use of the notation of multi-agent resource conversion processes (MRCP) [6][10]. According to the MRCP notation, model's nodes are either agents or operations.

The simulation agent is based on the InteRRaP architecture [11] as the most appropriate for problem domain. In accordance with InteRRaP architecture common concept, a simulation agent model is represented in four levels (Figure 3).

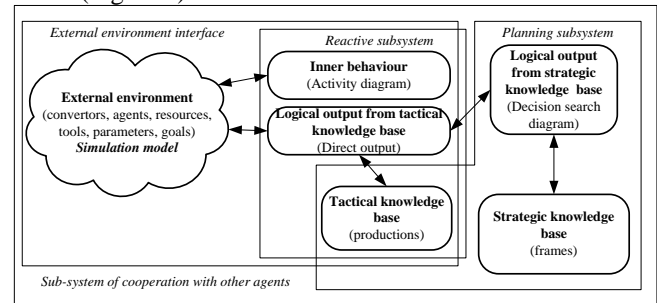


Figure 3. BPsim agent hybrid architecture

1. Sub-system of cooperation with other agents corresponds to the following MRCP elements: converters, resources, tools, parameters, goals.

2. External environment interface and reactive behavior components are implemented in form of agent rule's base and inference machine (simulation algorithm).

3. Reactive subsystem performs the following actions: receives tasks from the external environment, places tasks in a goal stack, collates the goal stack in accordance with the adopted goal ranging strategy, selects a top goal from the stack, and searches on the knowledge base.

4. Local planning subsystem purpose is effective search for decisions in complex situations (e.g., when goal achievement requires several steps or several ways for goal achievement are available). Local planning component is based on a frame expert system. The frame-concept and conceptual-graph based approach are utilized for knowledge formalization.

**IV. APPLICATION A MODELS INTEGRATION MODULE TO THE CUTTING SLABS PROBLEM**

**A. Statement of the Problem**

In metallurgical production, special attention is paid to the improvement of the continuous casting process in order to increase the share of steel produced at continuous casting machine (CCM). The effectiveness of the CCM has a direct impact on the quality and cost of the production manufactured in the subsequent process stages. In the study of the physical and mechanical processes of continuous casting affecting the quality of the finished product, a method of mathematical modeling is widely spread [12]. In

the study of the logistics and organizational (business) processes of continuous casting, a simulation method shows good results as applied to the optimization of production planning [13]. Development of simulation models of CCM technological processes affecting the quality of the finished product is topical.

We consider the development of a cutting slabs model with the use of the simulation module of the metallurgical enterprise information system. The developed model is run in the integration module, and the series of the melts are fed to the model input in real time (baseline experiment).

A casting ladle with melt goes to the CCM, where the liquid steel is cast; the ingot is cooled and cut into slabs. A CCM intermediate ladle distributes steel on the streams and allows continuous casting when replacing an empty casting ladle by full ladle. Metal is cooled in the water-cooled mould; the metal ingot is pulled in a secondary cooling zone (SCZ). For gas cutting (GC) work in automatic mode, technologists use an algorithm for cutting the ingot into slabs on the melts border.

When the signal "Start pouring of the melt from the casting ladle" is generated, the estimated length of the melt  $L_{est}^i$  is determined by the formula:

$$L_{est}^i = \frac{M^i}{2 \cdot \rho^i \cdot F} \quad (1)$$

Formula (1) shows that the melt length is proportional to the steel mass with a coefficient depending on the steel density and cross-section of the finished slabs.

We consider the work of two-strand CCM with the following characteristics: the pulling speed of the ingot from the mold  $v$  is 0.8 meters per minute; the mold length is 1 meter, the SCZ length is 50 meters. A diagram of cutting the ingot of the melt ( $i-1$ ) based on the desired slab length  $DSL^{i-1}$  and new melt start signal is shown in Figure 4. The parameter  $P$  is determined by measuring as shown in Figure 4.

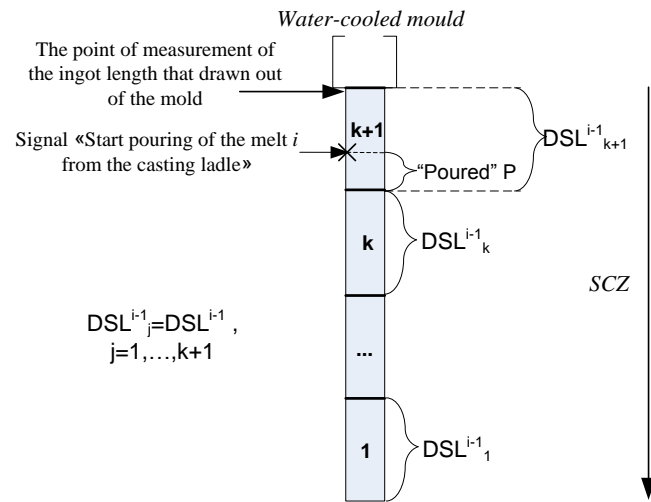


Figure 4. Diagram of cutting the ingot of the melt ( $i-1$ )

We analyze the CCM work on bottling series of 10 melts. Each melt  $i$  is characterized by the following parameters: steel weight in the casting ladle  $M^i$  (kg); steel grade (usual quality steel 'A' with density  $\rho^i$  equal to 7280 kg/m<sup>3</sup> and high quality steel 'B' with  $\rho^i$  equal to 7850 kg/m<sup>3</sup>); desired slab length  $DSL^i$  (m); slab sectional area  $F$  equal to 0.225 m<sup>2</sup>.

Table 2 shows the algorithm for cutting the ingot into slabs on the melts border. This algorithm is used by technologists in order to determine the actual number of slabs  $K_{act}^i$ . The estimated number of slabs  $K_{est}^i$  is defined as the ratio of the estimated melt length  $L_{est}^i$  to the desired slab length  $DSL^i$ .

We minimize the total number of positive and negative deviations in the slabs quantity  $S$  by changing the sequence of the supply of melts on the CCM. The total number of positive and negative deviations in the slabs quantity was determined by the formula:

$$S = 2 \cdot \sum_i |\Delta_{negative}^i| + \sum_i \Delta_{positive}^i, \quad (2)$$

where  $\Delta_{negative}^i$  – negative deviation in the slabs quantity of the melt  $i$ :  $\Delta_{negative}^i = K_{act}^i - K_{est}^i < 0$ ,

$\Delta_{positive}^i$  – positive deviation in the slabs quantity of the melt  $i$ :  $\Delta_{positive}^i = K_{act}^i - K_{est}^i \geq 0$ .

Formula (2) shows that the total number of deviations in the slabs quantity is growing faster when the growth in the number of negative deviations is observed.

TABLE II. THE ALGORITHM FOR CUTTING THE INGOT INTO SLABS ON THE MELTS BORDER

| Transition type on the melts border  | The condition on the parameter $P$ "Poured" | Decision  |
|--|---|---|
| The melt "the worst for the best" (steel grade of the melt $i-1$ is worse than steel grade of the melt $i$ ) | $P \leq 200cm$                              | In the melt ( $i-1$ ) there are ( $k-1$ ) slabs with a slab length $DSL^{i-1}$ . Slab $k$ with a new desired length $DSL^i$ will be the first in the melt $i$ .       |
|  | $P > 200cm$                                 | In the melt ( $i-1$ ) there are $k$ slabs with a slab length $DSL^{i-1}$ . Slab ( $k+1$ ) with a new desired length $DSL^i$ will be the first in the melt $i$ .       |
| The melt "equivalent" (steel grades of the melts $i-1$ and $i$ are equal in quality)                         | $P = 0cm$                                   | In the melt ( $i-1$ ) there are ( $k-1$ ) slabs with a slab length $DSL^{i-1}$ . Slab $k$ with a new desired length $DSL^i$ will be the first in the melt $i$ .       |
|  | $P > 0cm$                                   | In the melt ( $i-1$ ) there are $k$ slabs with a slab length $DSL^{i-1}$ . Slab ( $k+1$ ) with a new desired length $DSL^i$ will be the first in the melt $i$ .       |
| The melt "the best to the worst" (steel grade of the melt $i$ is best than steel grade of the melt $i-1$ )   | $(DSL_{k+1}^{i-1} - P) \leq 600cm$          | In the melt ( $i-1$ ) there are ( $k+2$ ) slabs with a slab length $DSL^{i-1}$ . Slab ( $k+3$ ) with a new desired length $DSL^i$ will be the first in the melt $i$ . |
|  | $(DSL_{k+1}^{i-1} - P) > 600cm$             | In the melt ( $i-1$ ) there are ( $k+1$ ) slabs with a slab length $DSL^{i-1}$ . Slab ( $k+2$ ) with a new desired length $DSL^i$ will be the first in the melt $i$ . |

The negative deviation is such deviation, where the actual number of slabs is less than the estimated (expected) number of slabs. This situation is bad, because the order will not be satisfied. The number of positive deviations also affects the total number of deviations in the slabs quantity. The positive deviation is such deviation, where the actual number of slabs is more than the estimated (expected) number of slabs. This situation is not so good, because the additional slabs will not be paid.

**B. Development of the Simulation Model of Cutting Slabs**

The structure of the simulation model developed via the simulation module of the metallurgical enterprise information system is shown in Figure 5 (right side). Agents in the model of cutting slabs are used to implement the logic to process the orders and to manage the order's attributes. Operations in the model are used to visualize the duration of the work of CCM elements for each stream: mold, secondary cooling zone and gas cutting. The model structure can be divided into three work units: 1) description of the casting ladle (intermediate ladle) state; 2) description of the CCM elements work; 3) description of the generation and removal of the orders. Seven orders have been described in the model. The order *z1* "Melt order" is the main order that collects data from all orders about temporal characteristics of the CCM elements work and the number of slabs for each melt. Orders *z2* and *z3* «Melting through the water-cooled mould 1" and "Melting through the water-cooled mould 2" are used to describe the logic of two streams of water-cooled moulds and then removed. Orders *z4* and *z5* «Melting through SCZ 1" and "Melting through SCZ 2" are used to describe the logic of two streams of the CCM secondary cooling and then removed. Orders *z6* and *z7* «Melting through GC 1" and

"Melting through GC 2" are used to describe the logic of two streams of the gas cutting and then removed. Each order has its own attributes, for example, attribute *z6\_pnext* contains the steel density for the next melt.

The algorithm for cutting the ingot into slabs on the melts border is described using agents of cutting the ingot for each CCM stream. A knowledge base of agent of cutting the ingot 1 (for stream 1) is shown in Figure 5 (in elements tree on left side). The agent knowledge base comprises situations described in Table 2. Separate situation is a rule of the form "If - Then" built using model variables (resources and orders *z6* attributes). The water-cooled mould agent knowledge base contains "If - Then" rules to ensure the work with the orders *z2/z3* attributes and generation of the orders *z4/z5*, which is transferred to the SCZ agent. The SCZ agent knowledge base contains "If - Then" rules to ensure the work with the orders *z4/z5* attributes and generation of the orders *z6/z7*, which is transferred to the ingot cutting agent.

**C. Experiments Results Analysis**

We consider the experiments with the developed model in the integration module of the modeling subsystem. Table 3 shows the simulation results for the initial input data. The following value of the output characteristic has been obtained: total number of positive and negative deviations in the slabs quantity *S*=4.

We conducted and analyzed a series of seven experiments on the supply chains of the melts with different interleaving DSL parameters and steel grade. The results of the experiments are shown in Figure 6 as a distribution of the total number of deviations in the slabs quantity *S* depending on the experiment.

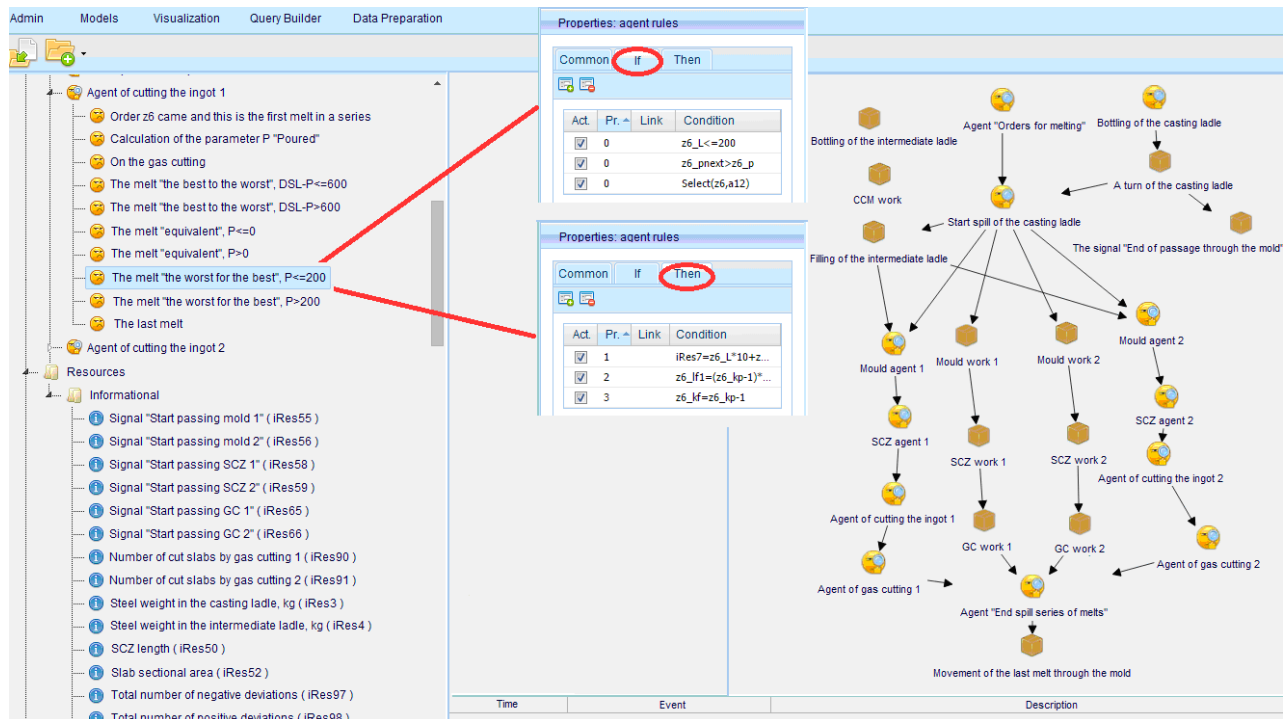


Figure 5. Structure of the simulation model developed in the modeling subsystem of the metallurgical enterprise information system



TABLE III. BASELINE EXPERIMENT RESULTS

| Input model parameters   |                  |                              | Output model parameters   |   |  |  |
|--|------------------|------------------------------|---|---|--|--|
| <i>N</i> <sub>o</sub> of the melt, <i>i</i>                                      | Steel grade type | DSL <sup><i>i</i></sup> (mm) | Actual length of the melt, <i>L</i> <sup><i>i</i></sup> <sub>act</sub> (mm) | Actual number of slabs, <i>K</i> <sup><i>i</i></sup> <sub>act</sub> | Estimated number of slabs, <i>K</i> <sup><i>i</i></sup> <sub>est</sub> | Number of deviations in the slabs quantity, <i>A</i> <sup><i>i</i></sup> |
| 1  | B                | 5500                         | 39039   | 7   | 7  | 0  |
| 2  | B                | 7900                         | 48066   | 6   | 5  | 1  |
| 3  | A                | 12000                        | 36504   | 3   | 3  | 0  |
| 4  | A                | 9100                         | 46135   | 5   | 6  | -1   |
| 5  | B                | 6000                         | 48672   | 9   | 9  | 0  |
| 6  | B                | 8800                         | 53538   | 6   | 5  | 1  |
| 7  | A                | 6700                         | 40764   | 5   | 5  | 0  |
| 8  | A                | 7300                         | 44412   | 6   | 6  | 0  |
| 9  | B                | 10100                        | 51205   | 5   | 5  | 0  |
| 10   | B                | 11600                        | 35286   | 3   | 3  | 0  |
| Total number of positive and negative deviations in the slabs quantity, <i>S</i> |                  |                              |   |   |  | 4  |

As Figure 6 shows, experiments with the best results are experiments №2 and №5: they are characterized by the absence of negative deviations in the number of slabs. In these experiments, the following sequence of the melts has been supplied on the CCM: initially, the melts from the usual quality steel, followed the melts from the high quality steel.

The impact of ascending / descending DSL on the number of deviations in the slabs quantity has not been identified.

In this section, a simulation model of cutting slabs in the continuous casting machine has been described using a

modeling subsystem of the metallurgical enterprise information system. The developed model uses agent-based modeling in order to represent the knowledge of technologists.

The model of cutting slabs has been used in the integration module to solve the problem of optimization the CCM melts sequence.

V. CONCLUSION AND FUTURE WORK

This paper introduces the perspectives of simulation modeling in metallurgical production. The architecture of the developed metallurgical enterprise information system has been described. Among all of the system modules the integration module has been highlighted as a module that launches the simulation models in real time. During real-time modeling, the input parameters are fed to the model from the corporate information systems, MES-systems, or APCS, and the output parameters formed by the model are translated to the data exchange module. This paper focuses on the description of the systems modules interaction and describes the integration module work principles.

The integration module has been applied to the decision of the cutting slabs problem in the continuous casting machine. As a result of the experiments, the following recommendations have been obtained to optimize the CCM processes: it is necessary to supply the melts to CCM in the following sequence – initially, the melts from the usual quality steel, followed the melts from the high quality steel. These results are consistent with those obtained on the production. Use of simulation modeling for analysis of technological, logistical and business problems of an enterprise is a perspective direction. The method of simulation models integration that has been implemented in the developed system has successfully passed the test.

The aim of future research is to apply the query builder and the data preparation modules on the stage of receiving input modeling data from real production.

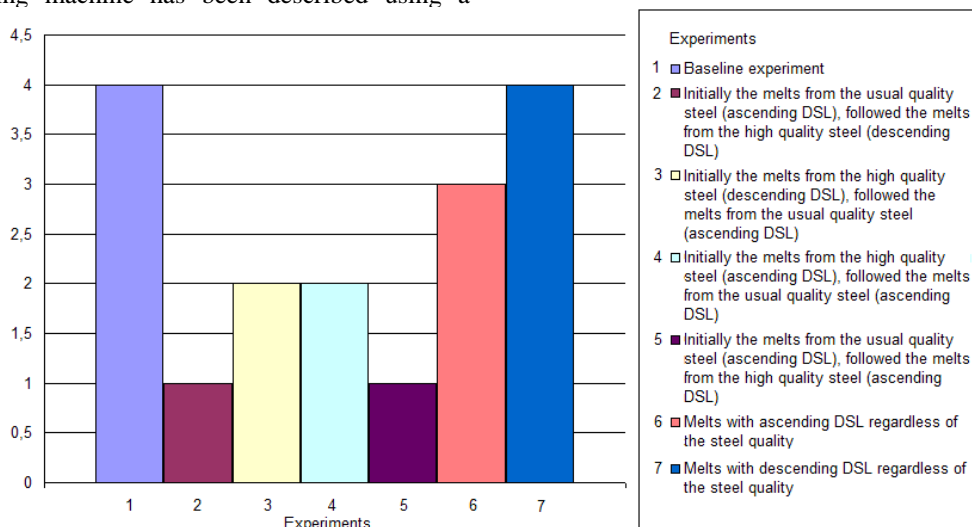


Figure 6. Distribution of the total number of deviations in the slabs quantity S depending on the experiment

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