Analysis of Cranes Control Processes for Converter Production Based on Simulation

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Abstract. The paper deals with solution of logistic problem for converter production of metallurgical enterprises. A developed multiagent simulation model of converter production is applied to solve the problem. This model allows assessing the different variants of the cranes motion between steelmaking aggregates. Three variants of the cranes motion have been considered during experiments with the model. As a result of experiments, the most effective variant for motion of the cranes has been revealed. The found variant application provides the cranes with high and uniform loading and reduced downtime of the continuous casting machines.

Keywords: Simulation, automated information system, logistic problem, converter production, multiagent simulation

1 Introduction

Converter production is one of the key stage of the technological chain of the steel products manufacturing. Within the converter production, steel is obtained from raw materials with the help of steelmaking aggregates. Steel ladles are delivered to aggregates via ladle cars and cranes. Typical problem of improving the quality of products under the converter production is closely joined with the problem of optimizing the steel smelting technology. Also, a relevant problem is one of optimizing the motion of vehicles, in particular, cranes. Effectively organized cranes motion can reduce downtimes of continuous casting machines (CCM). Downtimes of CCM lead to defects on the melts border, which reduces the total amount of finished slabs.

We consider application of multiagent simulation [1], [2], [3] to solving the logistic problem of the cranes motion within one day. Multiagent simulation model of the cranes motion has been developed with using the simulation module of a metallurgical enterprise information system. The metallurgical enterprise information system is a web-oriented one for tracking, monitoring, modelling, analysis, and improvement processes of the steel products manufacturing [4], [5], [6], [7].

2 Problem formulation

The developed model includes three converters and five CCM. Motion of steel ladles between steelmaking aggregates is carried out by using three cranes and five ladle cars. The cranes perform the following steps: removing the ladle from the ladle car, ladle lifting on CCM, and empty ladle removing after the melt casting ending.

The multiagent simulation model of the cranes motion is intended for evaluating the following variants of the cranes work. The first variant means that a set of serviced CCM is attached to each crane. The second and third variants mean that the crane serves CCM in dependence on the proximity to CCM.

Evaluation of the effectiveness is carried out via comparative analysis of loading the cranes and total downtime of CCM. Based on the proposed evaluation criteria, it is recommended to choose the variant of the cranes motion, which provides uniform and maximum loading of cranes and decreases the total downtime of CCM.

3 Development of the simulation model of converter production

The cranes motion model has been developed using a notation of multiagent resource conversion processes [4], [5]. Agents in the model are used to implement the logic to process the orders (steel ladles), ladles cars, and cranes motion description. Operations in the model are used to visualize duration of the work of steel making aggregates and vehicles. In the model developed, three orders are described for determination of the melt, cranes, and ladle cars motion. Order *z1* passes through the model according to the plan for melt processing. Orders *z2* and *z3* "Order for ladle car" and "Order for crane" are used to describe the motion logic of cranes.

The model structure can be divided into five work units: 1) description of the converters work; 2) description of the ladle cars work; 3) description of the cranes work; 4) description of the ladles overload; 5) description of the two streams elements for each CCM: mold, secondary cooling zone, and gas cutting. A fragment of the model structure with description of two CCM streams is shown in Fig. 1.

Converters work consists of the following stages: preparation, purging (this operation may be performed simultaneously on only two converters), operation after purging, and draining steel operation. After completion of the converter work, the ladle car delivers a steel ladle into the shop of the converter steel spill. There, the steel ladle is transferred to the crane. At the end of transferring, the empty ladle is sent back to the converter, and the crane with the melt is moved towards the continuous casting machine for steel casting. The number of CCM for casting depends on the used cranes motion variant. Cranes motion variants are described in the model via the knowledge base of the agent "Melt's distribution on CCM".

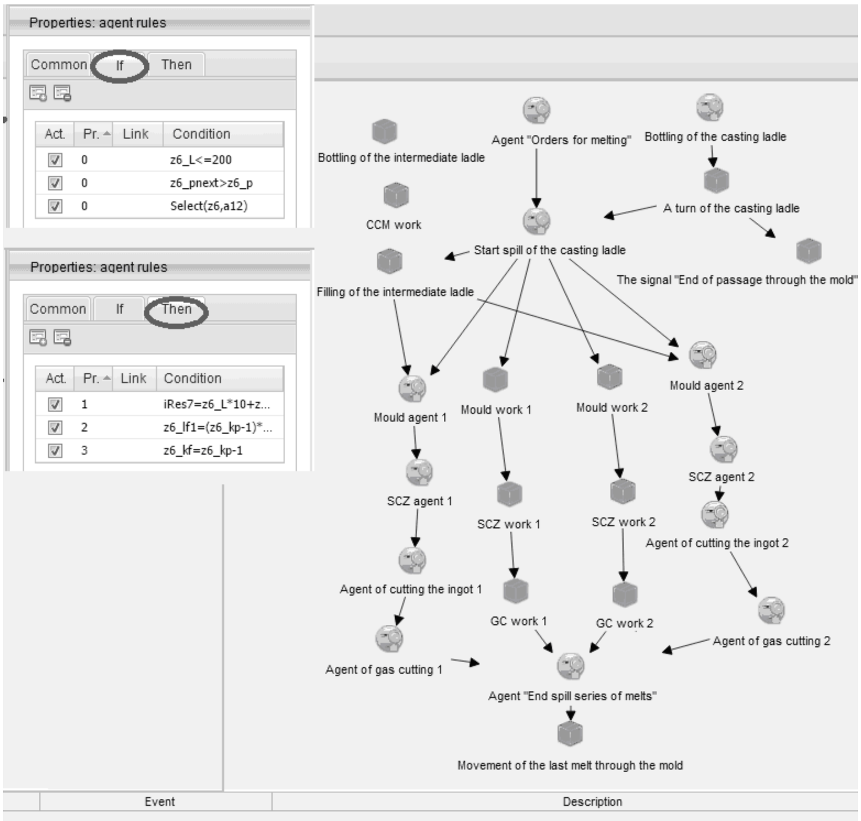

Fig. 1. Fragment of the model structure with description of two CCM streams.

The knowledge base of the agent “Melt’s distribution on CCM” has been described using If-Then rules with system variables. During simulation, each rule with performed initial conditions is stored in a calendar. The calendar is a queue that contains an ordered list of the rules. According to the rule, one of the following actions should perform at a certain time: check the condition of operation or agent launch, perform operation input steps, perform operation output steps, and perform agent steps.

4 Analysis of experiments results

The first variant of the cranes motion (**variant A**) assumes that each crane serves strictly assigned CCM: crane No1 serves CCM No1 and No5, crane No2 serves CCM No2 and No3, crane No3 serves CCM No1. In this case, there is no intersection between the cranes motion.

The second variant of the cranes motion (**variant B**) assumes that the crane serves CCM depending on crane’s current location and proximity to CCM that requires service: crane No1 serves CCM No1 and No2, crane No2 serves CCM No2, No3 and No4, crane No3 serves CCM No4 and No5. The third variant of the cranes motion (**variant C**) assumes that the crane serves CCM depending on crane's current location and proximity to CCM that requires service: crane No1 serves CCM No1, No2 and No3, crane No2 serves CCM No3, No4 and No5, crane No3 serves CCM No4 and No5. In these cases, there is an intersection between the cranes motion. The final selection of CCM is carried out based on the current location of crane.

We consider experiments with the developed model in the optimization module of the metallurgical enterprise information system. A series of the experiments was implemented, in which three cranes motion variants have been conducted and analyzed. As a result of experiments, the following output characteristics have been evaluated: the loading of cranes and the total CCM downtime. In Figure 2, the loading of cranes for variant A of the cranes motion is shown.

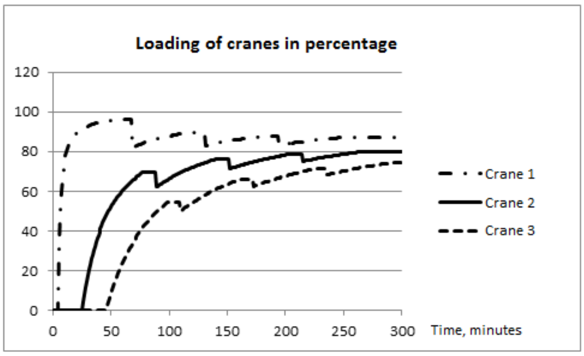

Fig. 2. The loading of cranes for variant A cranes motion, percentage.

In Figure 3, the loading of cranes for variant B of the cranes motion is shown.

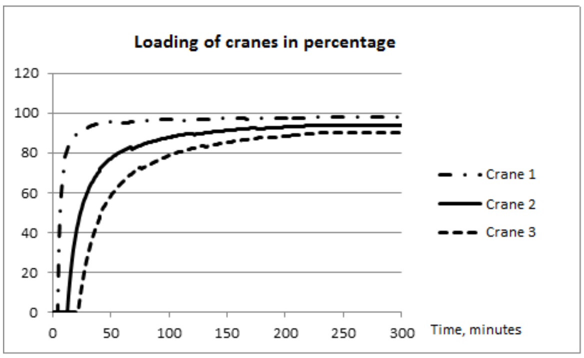

Fig. 3. The loading of cranes for variant B cranes motion, percentage.

In Figure 4, the loading of cranes for variant C of the cranes motion is shown.

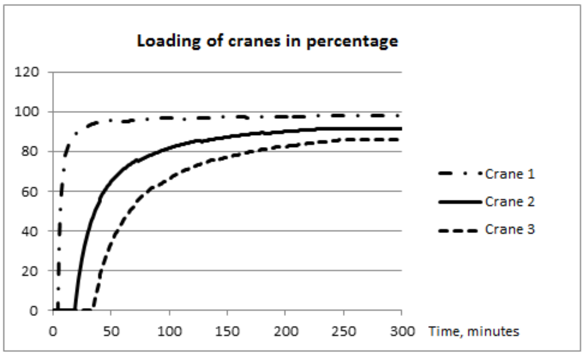

Fig. 4. The loading of cranes for variant C cranes motion, percentage.

As figures show, all variants of the cranes motion provide the high and uniform cranes loading, but the variant B ensures the maximum cranes loading.

The total CCM downtime is one of the output model characteristics. For each variant of the cranes motion, four expeiments with the simulation model have been conducted with the same initial conditions. Experimental results are presented using the diagram, which enables to see the average downtime and the range of values of this variable for each experiment.

In Figure 5, the total CCM downtime for variant A of the cranes motion is shown.

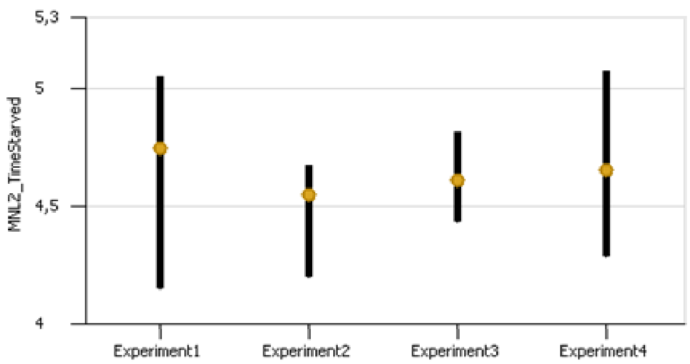

Fig. 5. The total CCM downtime for variant A cranes motion, minutes.

In Figure 6, the total CCM downtime for variant B of the cranes motion is shown.

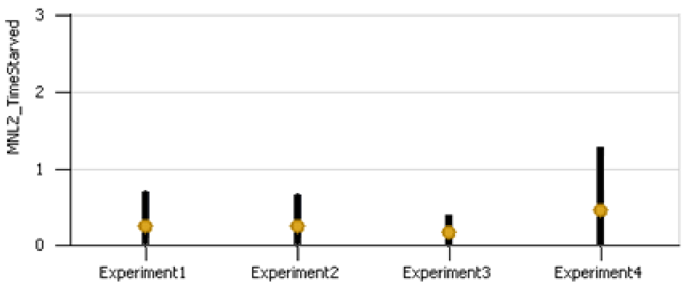

Fig. 6. The total CCM downtime for variant B cranes motion, minutes.

In Figure 7, the total CCM downtime for variant C of the cranes motion is shown.

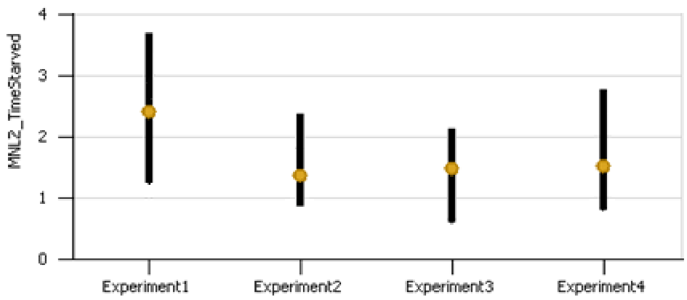

Fig. 7. The total CCM downtime for variant C cranes motion, minutes.

As figures show, all variants of the cranes motion provide the low total CCM downtime, but the variant B ensures the lowest total CCM downtime. Fluctuations in average values of the CCM downtime and changes in the downtime ranges are associated with presence in the simulation model stochastic variables, namely, the processing time of melts on steelmaking aggregates.

5 Conclusion and future work

As a result of analysis of the logistic processes for converter production, a simulation model of the converter production has been developed with the use of the simulation module of the metallurgical enterprise information system. Evaluation of three variants of the cranes motion has been carried out in the model using the agent knowledge base containing algorithms of the cranes motion from the ladle car to CCM. The use of agent-based modeling technology provides the flexibility of the developed model in terms of changes in algorithms of the cranes motion.

As a result of the experiments, the following recommendations have been obtained. More effective crane motion is one, in which, first, the crane serves CCM depending on crane's current location and proximity to CCM that requires service and, second, the following relationship between the cranes and CCM is observed: crane No1 serves CCM No1 and No2, crane No2 serves CCM No2, No3, and No4, crane No3 serves CCM No4 and No5. The use of this variant ensures high and uniform cranes loading and low total downtime of CCM.

The aim of future research is to apply the query builder and the data preparation modules of the metallurgical enterprise information system on the stage of receiving input modelling data from real production.

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