Interactive environment for simulation manufacturing system in machine building and coal processing

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Abstract—**While creating new or upgrading already functioning production, problems of analysis of multiple technical and organizational options and the choice of optimal solutions arise. Currently, equipment is designed based on past experience and intuition, and technology parameters are calculated by taking serious assumptions. Also options calculated in statics can give quite different results in dynamics, and the neglect of random factors may in fact give substantial deviations from planned performance. Application of the developed software will speed up and improve the quality of engineering design of the machine-building process and coal processing plants, as well as exclude expensive technological risks. The main result is a new specialized software product that allows one to interactively simulate various options for engineering and coal processing plants in the dynamics with the possibility of taking into account the random factors and automatically select the optimal variant of technical and organizational solutions. The originality of the proposed solutions is to develop simulation models that display a variety of options of production and different mapping associated equipment in time and space, as well as the development of a unique specialized software product that allows one to interactively simulate various production options, with the ability to automatically select the optimal variant of technical and organizational solutions.**

Keywords— Machine-building and coal processing, interactive environment, simulation

I. INTRODUCTION

In today's market conditions, there is a need to create new, highly automated production systems in mechanical engineering (APS) [1] and energy technology systems for deep processing of coal in the energy sector (ETS) [2,3,4]. This will allow one to ensure the manufacture of products in small batches while maintaining the productivity, quality and cost, as in the large-scale production.

Research of scientific developments showed that to date there is no product or method that allow high speed and reasonable accuracy to develop a complex production system with the specified or best parameters.

Suggested analytical and numerical methods [5, 6] often do not allow one to describe the parts of the system and the interaction between them. We have to apply serious simplifying and allowance to display the dynamics of the modeled system. Out-of-cyclic losses, i.e. losses of time, caused by process equipment downtime, play a greater role in the system. Available methods of calculation take into account a static coefficient of out-of-cyclic losses, which are defined approximately only for typical existing production. Often this coefficient is taken intuitively, based on the experience of designers. Meanwhile, out-of-cyclic losses significantly affect the performance of the system and can be up to 40% of process time [1].

The most effective is simulation, in which the dynamics of the system is displayed in some computer algorithm simulating its behavior [8, 9]. Modern simulation software allows one to display the dynamics of the production system and has specialized tools that provide additional opportunities for the organization and conduction of experiments on a computer.

Simulation modeling shows the dynamics of the interaction of system elements in time and space. Moreover it is effective when it is necessary to trace the dynamics of the development process in non-standard and emergency situations, as well as very short and very long periods of time [10-15]. Most of these tasks are not amenable to analytical solution.

The most common specialized language is GPSS (General Purpose Simulation System) [16].

To develop models of automated manufacturing and simulation experiments, classifications of layouts APS and ETS were designed. Classification is based on the automated storage and retrieval systems (ASRS): roller, automated truck,

crane stockpilers, bridge crane and overhead crane, industrial robot, conveyor system for the APS and conveyors, cranes, warehouses, mills and coal charging machines for ETS.

Automated production is represented as a queuing system (QS) [17]. Operation of the workplace (i.e., technological units and industrial robots) is displayed by multichannel single-phase or multi-phase QS, where parallel operating devices will serve the application and simulate the performance of joint operations. Such QS has standard definable mathematical description.

Several workplaces using the transport and storage systems are combined into APS or ETS. It is shown that any automated production system displayed by the network of a multiphase single-and / or multi-channel queuing system without failure with a simple discipline of FIFO service and limited input stream of applications, which corresponds to the production plan. Applications are workpieces or parties of coal. Servicing applications consists in delaying them for the time of milling, drilling, turning, gasification and other operations in devices, simulating equipment APS or ETS. The output stream represents finished products or medium temperature coke (Fig. 1).
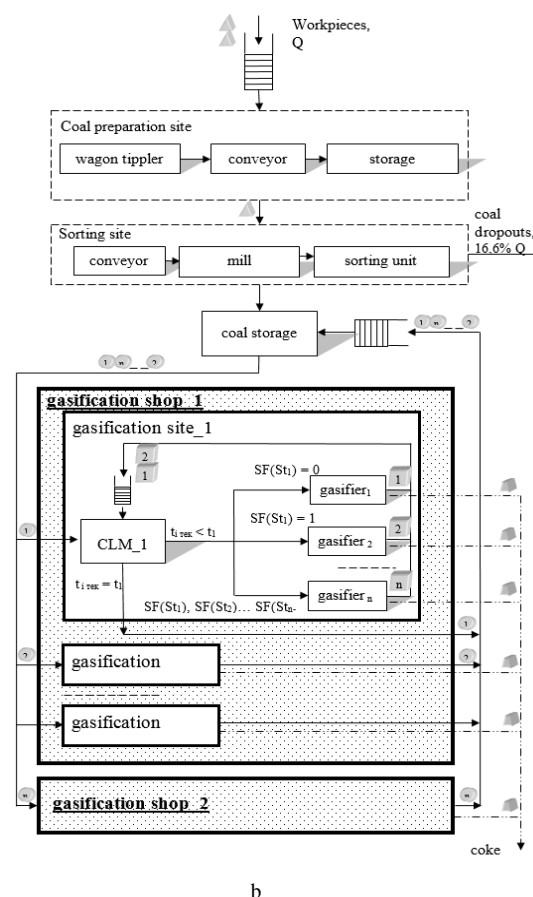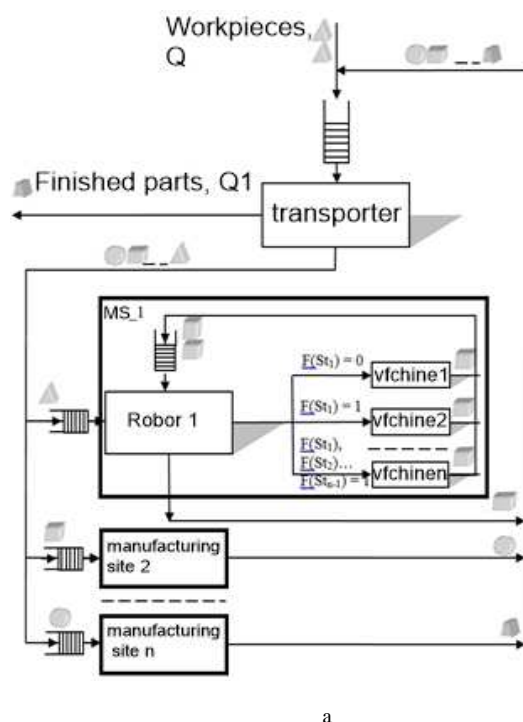

a

b

Fig. 1. APS (a) and ETS (b) as a network of a multi-phase multichannel queuing system without failure

The problem of this approach is the complexity of the mathematical description of the QS network. At the moment, there are various methods of solving such networks. Some authors propose dividing the network into smaller queuing systems, reducing them to a standard classification, for example, to the symbolism of Kendall (general view: G1/G2/m/N/r/f ...) [17]. However, in this case, to obtain the actual characteristics of the system is not possible. American scientist Leonard Kleinrock [6] proposed a method for calculating the QS of almost any complexity, but this technique is only applicable for QS with the exponential distribution law. Scientists from New Jersey, Edward D. Lazowska, John Zahorjan, G. Scott Graham, and Kenneth C. Sevcik, suggested a method of bringing the network gradually to an elementary QS system. This method allows obtaining the characteristics the whole system. However, it is applicable for the case where each maintenance device has less service time than the previous one does. Moreover, the device is considered as a "black box", the characteristics of which can not be received.

Based on the above-stated facts, to solve the problem of obtaining the characteristics of elements of QS and the whole network, a simulation approach was applied.

Based on the obtained queuing system of APS with different types of transport systems, represented in the block diagram form and using the GPSS language, simulation

models were created. For example, Fig. 2 represents a fragment of the block diagram of the simulation APS model with a stacker crane and ETS with coal boot machines.
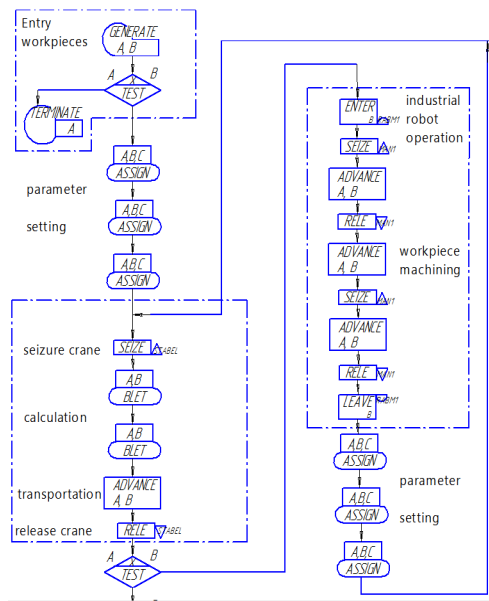
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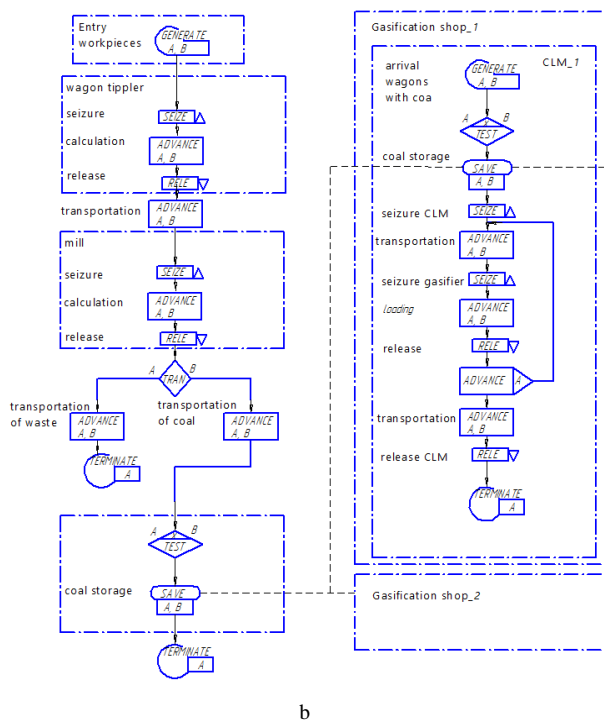
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Fig. 2. Fragment of block diagram of GPSS-model of APS (a) and ETS (b)

On the basis of constructed block diagrams, using a specialized simulation GPSS language [4], APS and ETS models with different types of ASRS used were developed.

Simulation models are built on time data operations.

```
MAR MATRIX          MX,2,10
INITI MX$MAR(1,8),&ST7/MX$MAR(1,9),&ST8
INITI  MX$MAR(2,1),&XSZ/MX$MAR(2,2),
&XST1/MX$MAR(2,3),&XST2/MX$MAR(2,4),&X
ST3/MX$MAR(2,5),&XST4/MX$MAR(2,6),&XST5
/MX$MAR(2,7),&XST6
INITI MX$MAR(2,8),&XST7/MX$MAR(2,9),
&XST8
          GENE      &TOBR1,,,100,,4PL
          ASSIGN    1,MX$MAR(2,1),PL
          ASSIGN    3,MX$MAR(1,2),PL
          ASSIGN    2,MX$MAR(2,2),PL
          ASSIGN    4,2,PL
KRAN      SEIZE     KRANSHT
          BLET      &A=ABS(&TEK-PL1)
          BLET      &B=ABS(PL2-PL1)
          ADVA      (&A+&B)/(&V)
          RELE      KRANSHT
          BLET      &TEK=PL2
          TEST NE PL3,0,YSE
          TEST NE   PL3,1,RABM1
          TEST NE   PL3,2,RABM2
          STORAGE   S(SST1),&NST1
RABM1     ENTER     SST1
          SEIZE     MAN1
          ADVA      2*&TPOW1
          RELE      MAN1
          ADVA      &TOBR1
          LEAVE     SST1
          BLET      &KUD1=PL4+1
          ASSIGN 1,MX$MAR(2,&KUD1-
1),PL     ASSIGN
          3,MX$MAR(1,&KUD1),PL
          ASSIGN
          2,MX$MAR(2,&KUD1),PL
          ASSIGN    4,&KUD1,PL
          TRAN      ,KRAN
                    a
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```
* coal mill
ADVANCE 0.3,0.01
QUEUE Drob1
SEIZE Drob
DEPART Drob1
ADVANCE 0.0126,0.0007
RELEASE Drob
*******************************
coal sorting
TRANSFER 0.74,,Dal
ADVANCE 0.3,0.01
TERMINATE
*******************************
transportation on the conveyor
Dal TEST L X$Tower,1500
*ADVANCE 0.3,0.01
*******************************
coal tower
SAVEVALUE Tower+,1
TERMINATE
*******************************
gasification unit_1
GENERATE ,,,1
Ryd_1               TEST G
X$Tower,180
SAVEVALUE Tower-,180
ASSIGN KolGaz_Ryd_1,10
SEIZE MUZ_1
Up_1 ADVANCE 0.025,0.0007
SEIZE gaz_1
ADVANCE 0.25,0.001
RELEASE gaz_1
ADVANCE 0.025,0.0007
LOOP KolGaz_Ryd_1,Up_1
ADVANCE 21.25,0.0007
RELEASE MUZ_1
TRANSFER ,Ryd_1
                    b
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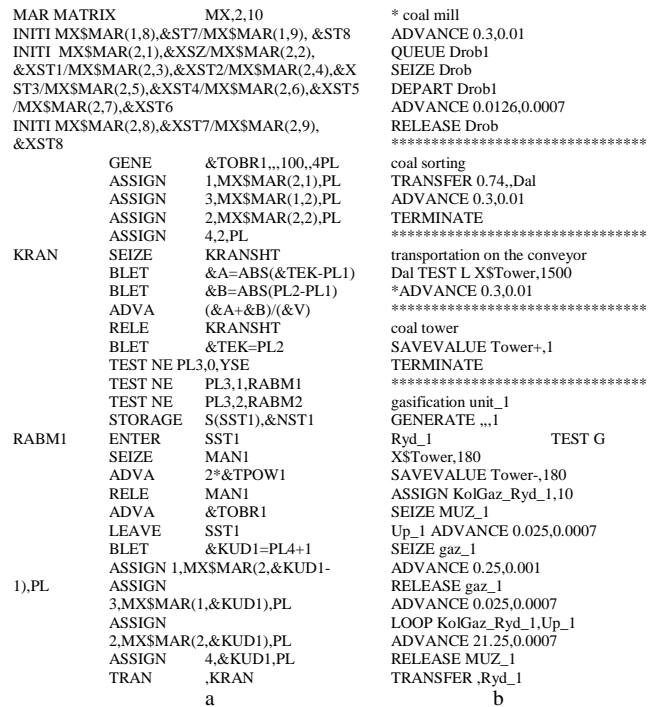
Fig. 3. Fragment of GPSS- mode of APS (a) and ETS (b)

For verification and validation of the entering conceptual models in the computer, the authors used the method of constructing a logical block diagram and interactive control over the simulation, using the debug mode, as well as the analytical calculation of characteristics and their comparison with model results (Fig. 4). The decomposition of the model was carried out and all subsystems were tested. Table. 1 shows a comparison of the results of simulations and analytical calculations for the model of APS stacker crane and one workplace in the form of QS classification Kendall-Basharina - 2*M/M/1. Similarly, for the same classification, Table 2 shows a comparison of the results of simulations and analytical calculations for the model of ETS with coal loading machine and one gasifier.
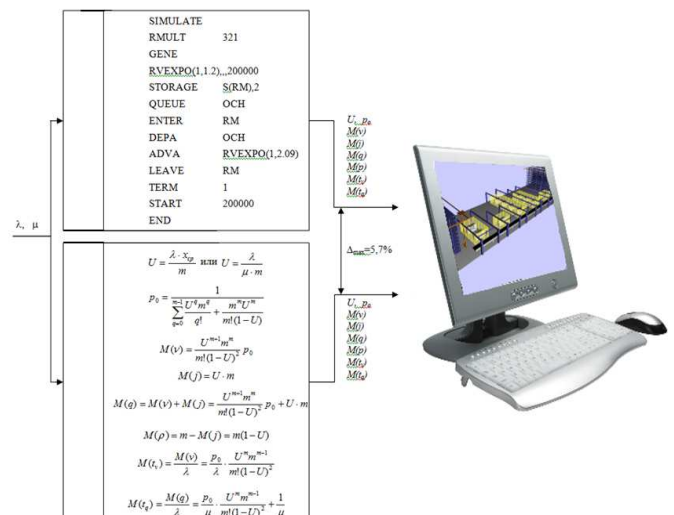

Fig. 4. Concept diagram of validation of models APS and ETS.

where λ - arrival rate requirements;

μ - intensity of service requirements;

a - the average time interval between the receipt of the request;

x_{cp} - average service time requirements.

TABLE I. COMPARISON OF THE RESULTS OF SIMULATION EXPERIMENTS AND ANALYTICAL CALCULATIONS FOR APS MODEL (QS - 2 * M/M/1)

Characteristic	First QS			Second QS		
	Analytical calculations	The results of simulation experiments	Deviation,%	Analytical calculations	The results of simulation experiments	Deviation,%
Coefficient of loading	0,276	0,275	0,36	0,381	0,381	0,0
The probability that the system is free	0,724	0,725	0,14	0,619	0,618	0,16
AVG. number of requests in the system, pcs.	0,381	0,379	0,79	0,616	0,618	0,32
AVG. number of requests in the queue, pcs.	0,105	0,104	0,96	0,235	0,237	0,8
AVG. processing time for requirements in the system, h.	0,400	0.399	0,25	0,648	0,654	0,92

TABLE II. COMPARISON OF THE RESULTS OF SIMULATION EXPERIMENTS AND ANALYTICAL CALCULATIONS FOR THE ETS MODEL (QS - 2 * M/M/1)

Characteristic	First QS			Second QS		
	Analytical calculations	The results of simulation experiments	Deviation,%	Analytical calculations	The results of simulation experiments	Deviation,%
Coefficient of loading	0,833	0,832	0,16	0,820	0,818	0,24
The probability that the system is free	0,167	0,168	0,79	0,180	0,172	1,10
AVG. number of requests in the system, pcs.	5,000	4,996	0,08	4,556	4,551	0,10
AVG. number of requests in the queue, pcs.	4,167	4,110	1,38	3,736	3,730	0,15
AVG. processing time for requirements in the system, h.	30,00	29,90	0,33	22,77	22,80	0,10

The maximum deviation of the results of simulation experiments from analytical calculations was less than 1.5%. Simulation models of other subsystems ETS were similarly verified; the maximum deviation was 7%.

The general form of a block diagram of interactive environment production systems is shown in Fig. 5.

3D-module was created in C + + [18] using DirectX. DirectX in 3D module is responsible for the low-level output of computer graphics. APS objects in 3D-module are represented by classes of C + +. Each class of 3D-module is either an abstraction or object APS or ETS (machine, industrial robot, gasifier) or process (the processing route, simulated data). Classes allow creating specific instances of objects or processes in 3D-module in the simulation. Instance of a class contains information about the created technological object (its location in space, processing time), and provides information about the state of class to other objects of 3D-

module. This object-oriented approach allows encapsulating the data of each process object in the corresponding object, and, if necessary, making changes in the representation of the technological object in 3D-module; one will need to introduce a change only in the appropriate class, without remaking entire software.
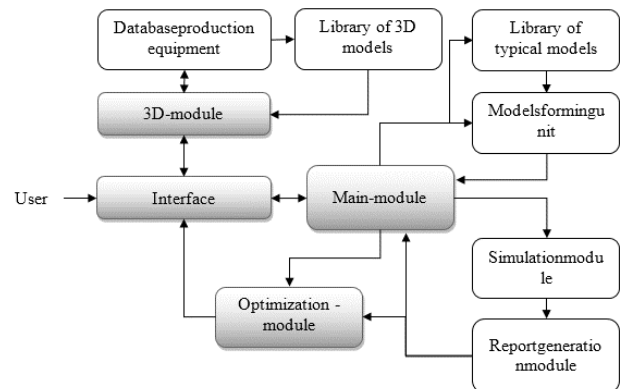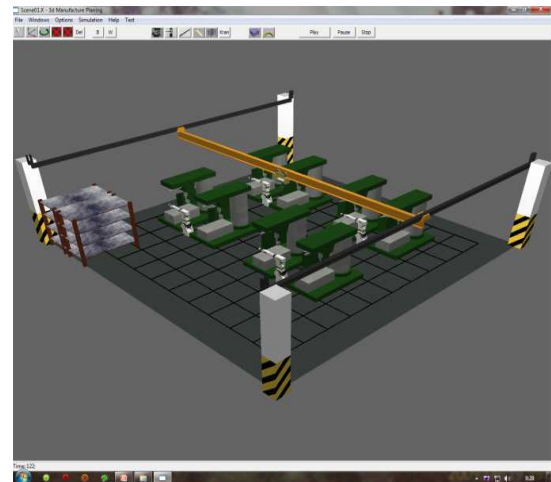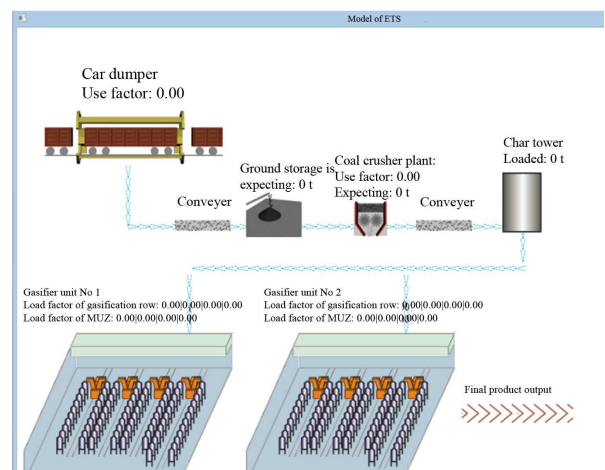

Fig. 5. Block diagram of interactive environment production systems

a

b

Fig. 6. Screenshot of interactive environment of APS (a) and ETS (b)

Fig. 6. Sscreen forms of interactive environment of APS [19] and ETS [20], built according to the proposed approach.

Analysis of the data reveals effective ways to improve the performance and utilization of equipment options for automated production. An example of such analysis of the obtained simulation data sets is shown in Fig. 7.
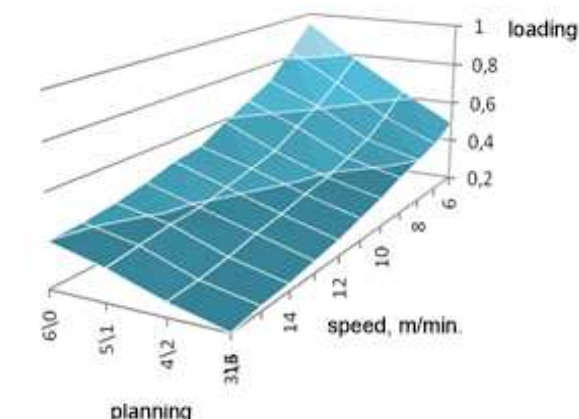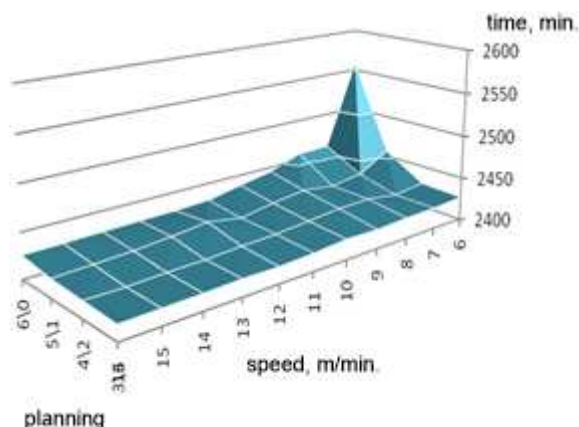
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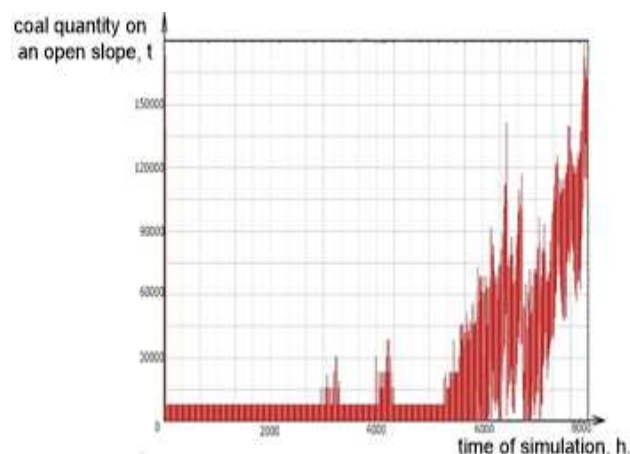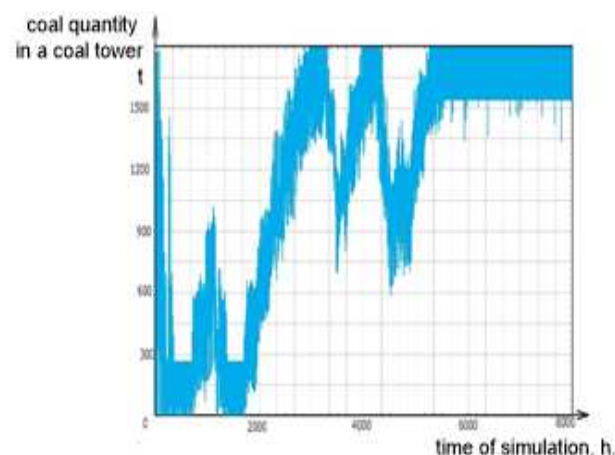
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Fig. 7. Example of processing of experimental results for APS (a) and ETS (b)

The proposed approach allows us to solve a wide range of tasks of the study of systems and equipment layout when designing new automated production engineering and energy technology systems for deep processing of coal. Realization of this approach allows one at the pre-design stage to find effective ways to increase productivity and the degree of utilization of equipment, identify and eliminate "bottlenecks" in the system.

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