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Various production planning models for manufacturing execution systems

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Abstract. Presently, many enterprises are automating all processes in their production, and the metallurgical industry is no exception. There are many software products for industrial automation on the market today. Such products allow bringing certain processes to a single management process, displaying all processes and automatically monitoring performance indicators, thereby assessing the effectiveness of the models implemented in the enterprise and the operation of the entire enterprise in general. The purpose of this study is to consider which production planning models are currently used for manufacturing execution system (MES) and highlight their features, specifically when implemented at metallurgical enterprises. The study employed the following methods: analysis, synthesis, comparison, graphical presentation of data. The information basis of this paper included the studies of Russian, European, American, Asian specialists investigating the implementation of an integrated management system (MES) in the metallurgical industry. The results of this study allowed highlighting the features of existing production planning models for manufacturing execution systems (MES) in the metallurgical industry. This study is of practical importance because it allows highlighting the major features of various production planning models for manufacturing execution systems (MES) in the metallurgical industry and based on a comparative analysis, choosing the best one to implement at the enterprise. The results of a comparative analysis of production planning models for manufacturing execution systems (MES) in the metallurgical industry can also lead to the fact that an enterprise may abandon one model that is already operating in the enterprise and switch to a new, more progressive model that meets all the requirements and development trends market in the steel industry

Keywords: metallurgical enterprise; digital transformation; IT infrastructure; big data analysis; business processes

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INTRODUCTION

The purposes of digitalisation and the introduction of information technology (IT) solutions at mining and metallurgical enterprises are aimed at reducing production costs, accelerating the introduction of new products and services to the market, simplifying and optimising interaction with participants in the value chain and, consequently, increasing business profitability. The purpose of automation is the need to set up the continuous functioning of production processes. According to researchers (Yang *et al.*, 2021), the level of digital maturity and activity of enterprises in the mining and metallurgical sector is growing every year.

Currently, due to the automation of production, it is possible to solve several problems at once: to set up and configure the optimal modes of operation of technological processes; to support the smooth functioning of the enterprise; to carry out activities aimed at improving the quality of products, etc. As a rule, automation of production is based on a systematic approach to all processes: heat engineering, environmental, metallurgical, and managerial. The introduction of integrated automation at enterprises running in the metallurgical industry allows subordinating all components of the enterprise's activities to the main management centre. According to Chehri *et al.* (2021), Gong *et al.* (2021), the problem of the performance of an enterprise related to the metallurgical industry is directly dependent on ensuring environmental safety for the environment.

To increase the service life of capacities and mechanisms, it is better to build them considering the possibility of collecting data on their state. In this regard, solutions using Big Data and IoT technologies are applied, with the later integration of data with ERP (Enterprise Resource Planning) or MES systems (Manufacturing Execution System) (Armellini *et al.*, 2018). The use of simulation modelling and end-to-end tracking allows controlling the technological process to maintain the specified product quality parameters and reduce costs. The study by Shinkevich & Malysheva (2020) suggests that online analysis of a large amount of data at each stage, the development of a dynamic management of reference information (RI) and mathematical modelling provides a synergistic effect, which reduces operating and technological costs. The level of automation of the largest metallurgical enterprises today can be described as quite high, although it cannot be said that it corresponds to the latest technological trends. For instance, MES, which links production resource planning, logistics processes, downtime monitoring, product quality management, and other links in the value chain in a single information space, is often built to satisfy the interests of one side of the technological process and does not consider the possibility of further integration and modernisation of systems.

When discussing the current demand for IT from steel companies, Li *et al.* (2018), Xiaoa *et al.* (2021) are oriented towards digital solutions and services. But digitalisation is impossible to implement without ensuring the proper level of automation. Thus, the introduction or modernisation of MES is one of the necessary and obvious requests. Steady demand for software solutions aimed at increasing the effectiveness of managing logistics processes, as well as the sales and purchases unit, is dictated by economic feasibility and industry specifics.

Liu *et al.* (2021) suggest that digital technologies allow the largest metallurgical producers to form their ecosystems, unite the client network and contractors. Metallurgical companies, traditionally considered B2B, currently can reach their end customers directly and, thereby, expand their business by entering new sales markets, where they were previously represented through intermediaries.

The studies by Verevka *et al.* (2021), Yanzhao *et al.* (2020) indicate that digitalisation enables an accelerated exchange of information and ensures the mutual enrichment of companies with ideas, technologies, and successful experience. In addition, they are multifaceted in their operation and can reduce costs in the production of products. Furthermore, when carrying out the digital transformation of an enterprise, it is important that all its tools, including artificial intelligence, predictive analytics, etc., can be distinguished, combined into a single information system. One should not forget about the security of network technologies during their installation.

Thus, the purpose of this study is to consider which production planning models are used today for manufacturing execution systems (MES) and highlight their features, specifically when implemented at metallurgical enterprises. Research goals: to investigate all the MES models available on the market and identify those that are used for the metallurgical industry; to characterise the selected MES models for the metallurgical industry; to offer recommendations for improving work related to production automation.

MATERIALS AND METHODS

The main approaches used in this study were theoretical (analysis, synthesis, comparison) and graphical methods of presenting data. The basis for this study was formed by the studies of European, American, and Asian researchers investigating the issues related to the digitalisation of industrial enterprises, namely in the metallurgical industry.

The first stage characterised the MES system, identified the number of customers, contractors, and projects currently available within the framework of the implementation of MES. Using the example of Interpipe, the practices of implementing major projects within the framework of the digitalisation of production was considered. Then the author of this study investigated the products available on the market, which are being intro-

duced at industrial enterprises to automate production, namely, at the enterprises of the metallurgical industry. At the second stage of the study, several MES models were selected for a comprehensive characterisation and evaluation. The following models were chosen: A'MES metal, K.U.P.O.L., Atlas MES, Symphony MES, 1C: MES, MES PHARIS, Zenith SPPS (Special Payroll Processing System).

The second stage of the study was to provide a complete description of each model: A'MES metal, K.U.P.O.L., Atlas MES, Symphony MES, 1C: MES, MES PHARIS, Zenith SPPS. For instance, Ausferr offers the implementation of the A'MES metal model in different workshops of a metallurgical enterprise, considering the specific features of each of them. When examining the A'MES metal model, the study considered its characteristics, the objectives of the task, the functions, principles, and advantages of working in an enterprise. The effectiveness of the implementation of this model and the platform on which it runs were also assessed. When describing the K.U.P.O.L. MES model, its characteristics were given, the possibilities, main components, and advantages were highlighted. The third model considered in this study was Atlas MES. When examining this model, its characteristics, elements, purpose, tasks, and opportunities were analysed. The next MES model under study was Symphony MES. When examining it, the author considered its features, capabilities, and advantages.

Next, the author singled out another model that is often implemented at metallurgical enterprises – 1C: MES. Its features of operation and the possibility of integration with different components were identified. Another model that was considered is MES PHARIS. Its features, functions, capabilities, structure, advantages, and sources of information and data were highlighted. The last model considered was the Zenith SPPS MES system for the metallurgical industry. The features of its functioning were highlighted, along with the reasons for choosing it and its possibilities. Based on the characteristics of these models, conclusions were drawn on how each model functions in production, with what processes it is associated.

At the third stage, recommendations were proposed aimed at improving the automation of production planning for production control systems (MES). These proposals can be implemented not only at metallurgical enterprises, but also at enterprises operating in other industries. Whatever model of production automation is chosen by the management of the enterprise, it allows reducing costs, ensuring an increase in labour productivity, and reducing the amount of manual labour, both when performing any operations in the production department and related to document flow.

RESULTS AND DISCUSSION

MES is an information and communication system of the enterprise environment where production processes take place (Clemons, 2021). MES, which is being implemented at the enterprises of the metallurgical industry, can be described as a system capable of supporting the implementation of the main ones in the production process and enabling the maximum economic effect; their functionality is related to the shop floor delivery process (Zheng *et al.*, 2021; Chen *et al.*, 2021).

According to official data, there are currently 298 customers ready to implement MES systems, 196 contractors, and 345 projects ("Interpipe", 2021). The study considers various production planning models for manufacturing execution systems (MES) and the practices of their implementation in enterprises. Using the example of Interpipe, the practices of implementing major projects within the framework of the digitalisation of production were considered. The main projects of Interpipe as part of the digitalisation of production are presented in Figure 1. The company is striving to move towards the digitalisation of delivery methods and routes and enable its customers to track the production of orders online ("Interpipe", 2021). Next, the study highlights several MES models for metallurgical enterprises.

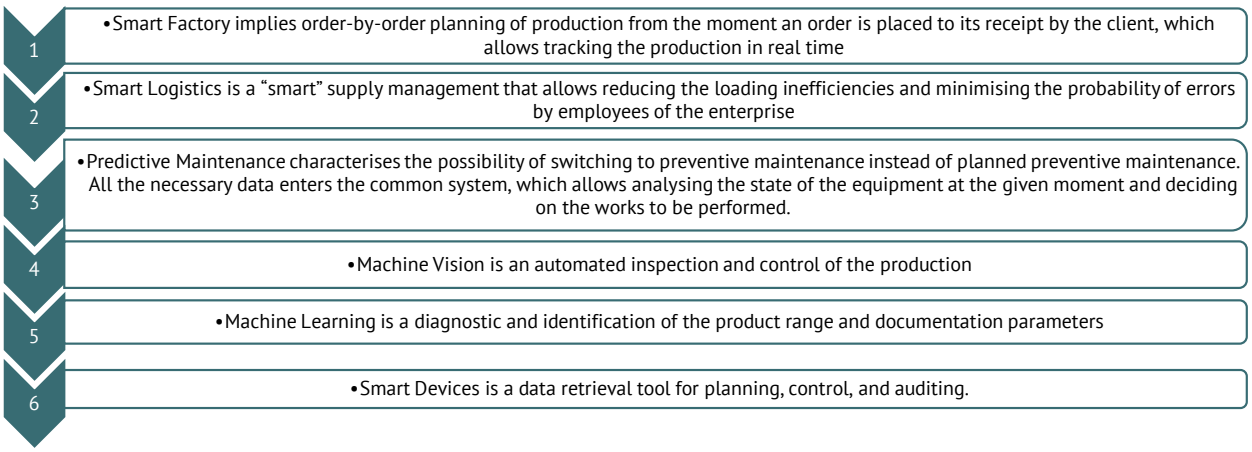

Figure 1. *The main projects of Interpipe as part of the digitalisation of production (Interpipe, 2021)*

A'MES metal is a full-featured production time management system that has been designed for use in enterprises running in the metallurgy industry. This model considers the specifics of all production business processes that occur at enterprises engaged in the metallurgical industry. Apart from the main tasks of production management, the system supports many other functions that can expand its use in the enterprise (Ausferr, 2021).

The composition and principles of the functioning of the system include: the implementation of enterprise resource planning (ERP), the implementation of business process management (Enterprise Asset Management: EAM; Customer Relationship Management: CRM; Supply Chain Management: SCM; Engine Control Module: ECM), the implementation of management technological processes (Distributed Control System: DCS; Supervisory Control and Data Acquisition: SCADA), monitoring the state of resources (Resource-aware Adaptive Scheduler: RAS), implementing production dispatching (Dispatching Production Units: DPU), collecting and storing data (Data Collection Agent: DCA), Implementation of Human Resource Management (HRM), Implementation of Quality Management (QM), Implementation of Process Management (PM), Implementation of Product Tracking and Genealogy (PTG), analysis and evaluation of effectiveness (Performance Appraisal: PA), implementation of the preparation of production orders (OpenDocument Spreadsheet: ODS), implementation of document management (DOC), and the implementation of information management of laboratories (Laboratory Information Management System: LIMS); people who work with these processes: administrators, staff, managers (Ausferr, 2021). The features of A'MES metal are presented in Figure 2.

1. •ensure the planning of manufacturing products at the enterprise with the implementation of the most effective programmes within the production cycle
2. •control the available flows of raw materials and components, from a material standpoint
3. •manage warehouses where the necessary materials and finished products are stored
4. •manage all processes directly related to production, operational accounting of production
5. •ensure the generation and transmission of tasks for automated process control systems of units
6. • ensure the implementation of the process aimed at collecting and storing information, processing this information, and transferring it to information systems
7. •ensure online production dispatching and timely detection of emergency situations
8. •provide product quality management, which would include the maintenance of protocols and data sheets of processes associated with technological operations, control to determine product quality
9. •implementat the automation of research centres by means of applying the methods of analysis of measurement system analysis (MSA) in the work
10. •monitor the production process, exercise control, which is aimed at determining the status of orders, and manage the processes associated with certification and shipment
11. •manage documentation, ensure its safety and the ability to quickly search for the necessary data
12. •analyse the level of production efficiency, create reports to determine its effectiveness, and find options for optimisation
13. •manage employees, ensure a high level of personnel involvement in the decision-making process and their personal responsibility
14. •provide the possibility of forming data samples for processing the relevant technological information to assess the state of the enterprise, technological processes, etc.
15. •manage the information that accompanies the processes associated with production
16. •ensure the monitoring of the condition and wear of equipment, manage its maintenance and repair work

***Figure 2**. A'MES metal features*

The main advantages of the A'MES metal system for enterprises in the metallurgical industry include the content of such components, tested in real production, which allow quickly and correctly adapting the solution to the conditions of a particular object (Ausferr, 2021).

Next, the study highlights the effectiveness of the use of A'MES metal. Its most clear components are as follows: the growth of productivity, the improvement of logistics processes, the optimisation of stocks, the reduction of work in progress. All this leads to an improvement in economic indicators and allows forming a positive image of the enterprise. This system allows reducing the number of deliveries that do not meet the requirements in terms of quality, by conducting a complete quality control using modern statistical methods in the work.

A'MES metal works with several platforms that ensure its productive functioning in the enterprise. The

A'Info system enables productive management of regulatory and reference information. A'Info holds guides and dictionaries specifically designed to help the industry function more efficiently, allowing for significant productivity. In turn, A'UniPlat (Universal Platform) ensures the development of a modern and efficient integration structure. A'Q cube represents an opportunity to ensure the implementation of additional capabilities in the management of the technological process of production and product quality that would correspond to the needs of a particular production. A'Material also provides similar opportunities. The systems described above have a lot of practical use and the best equipment for the quality management of certain projects (Ausferr, 2021).

The next MES model proposed for consideration is called K.U.P.O.L. (complex of production management and organisation of logistics). K.U.P.O.L. is a software environment that integrates engineering departments, supply, warehouse, workplaces, and technological equipment through the local area network of the enterprise and allows effectively managing the production cycle of product development (MES production management system, 2021). Capabilities of the K.U.P.O.L. system are presented in Figure 3. Its prominent level of integration is focused on ensuring seamless database maintenance. In addition, it allows efficiently managing production processes. The implemented technical support functionality allows sending reports online, and the availability of API (Application Programming Interface) allows interacting with external software environments. One of the many advantages of the system under study is its multifunctionality, which allows using only the currently required functionality, and using other features only as needed (Production process control..., 2021).

1. •ability to keep catalogues related to documentation on products, tools and equipment, in such areas as design and technological
2. •possibility of conducting preparation for the production of products for the electronic radio industry
3. •carry out the development of production routes between the constituent links of the production chain
4. •regulate access to work in the system, according to the roles and qualifications of the enterprise personnel
5. •ensure adherence to manufacturing routes and observe technological discipline at the enterprise
6. •approval of the calendar schedule for the product before its placement in production
7. •ensure the safety of data on each stage of production of products, as well as on the details and components created as part of this process, to be able to analyse the probable causes of failures
8. •maintaining inventory records of parts, components and finished products at the stages of manufacturing and preparing products
9. •keeping records of the number of substitutes used in the production of components, ensuring the preservation of contacts of their suppliers
10. •carry out the interaction of various types of technological equipment directly
11. •carry out integration with currently existing software environments

***Figure 3**. Abilities of the K.U.P.O.L. system*

The components that the K.U.P.O.L. system works with include production preparation, production management, and warehouse management. The ten key capabilities of this system (Fig. 4) make production more flexible and improve process control. The advantages that the system has are in its user-friendly interface, which allows increasing the possibilities in terms of penetration into the processes of enterprise operation even without subject knowledge. Furthermore, Dipol support allows customising the system to the needs of the buyer at any time of its use (Production process control ..., 2021).

1. •ability to draw up and comply with the technological route
2. •ability to provide traceability of processes, products, and suppliers
3. •ability to ensure the safe storage of products
4. •ability to carry out high-quality planning of future processes at the enterprise
5. •ability to provide data on production processes
6. •ability to keep track of the amount of inventory in warehouses
7. •ability to manage processes
8. •ability to automate workplaces and technological support
9. •ability to provide direct integration with process equipment
10. •ability to integrate with the software environment of production

***Figure 4**. Ten key abilities of the K.U.P.O.L. system*

The next model is Atlas MES, which characterises a system for automating production management (Atlas MES, 2017). Atlas MES can be used not only in large enterprises but is also focused on work in small and medium-sized enterprises, where a product, as a rule, goes through several units during its production. Thus, for example, if a product is manufactured on a single machine, then such a complex system is not required. However, if the products pass 10-15 units, along with different routes, then such a system can bring a tangible effect, both economic, social, and other types of effects. One of the key tasks of any production is to increase productivity and improve product quality without increasing the level of costs. Manual management of processes related to production and orders reduces quality, and therefore, it needs to be automated as much as possible. For instance, MES-systems can measure indicators, carry out planning, issuance, and distribution of tasks, analyse the received data, prepare reports, etc. Atlas MES includes five elements related to providing technology guidance, carrying out work on modelling technological processes, carrying out production planning, performing work with tasks from the contractor's perspective, performing work on collecting analytics related to production processes (Atlas MES, 2017).

As of the technical aspects of the model under consideration, Atlas MES is a cloud-based system, which makes it easy to deploy work and organise access to the system in factories of any size. Furthermore, it is possible to provide flexibility: any computer or Android-based device can act as a worker's terminal, due to which the system is cheaper and easier to implement, and therefore, the enterprise does not need to purchase an expensive boxed solution and immediately invest a lot of money in its implementation. The effect of the introduction of Atlas MES, from an economic standpoint, from the use of all the capabilities of this system is several times higher than its cost. As for the future of this system, the top priority for Atlas MES is, firstly, conducting analytics in terms of automating this process. Today, this system collects data, but the analysis of the received data is carried out by people who then decide based on their subjective assessment. The developers of this model strive to ensure that Atlas MES not only systematises information, but also can independently analyse it, signal problems, and offer ready-made solutions itself. In addition, the purpose of Atlas MES is to implement an increase in the level of planning, in terms of automating this process (Atlas MES, 2017).

The next model of the MES system is called Symphony MES (MES production management system, 2021). It is an enterprise process management system that can solve emerging problems related to synchronisation, coordination, analysis, and optimisation of output in real time. The system is very well-developed in its essence and is one of the most competitive among MES systems. The reason for this is its accounting features, the essence of which is to track each production element on the line online. In addition, it allows performing the necessary calculations to understand the process of manufacturing products at the moment. Its principle of operation is to provide capacity planning and continuous production support based on the received information about the processes on the line, the state of the equipment, the amount of remaining resources, etc. Symphony MES allows working more efficiently with scheduling and combining it with supervisory control (MES production management system, 2021). Furthermore, Symphony MES is a very versatile system in its own way, as it allows it to be adapted to different production capabilities and business processes.

Next, the study considers the 1C: MES model (1C: MES, 2021). The capabilities of this product are as follows: the implementation of production planning, production dispatching, volume-scheduling, data synchronisation, management of RI, factory orders, inventory management. The RI about the product is an initially available set of data that allows better planning the process of manufacturing future products. It consists of two main components: planning of material costs (a list of resources, materials, etc., used to manufacture a product) and the production process itself. All the necessary data is entered into the database and stored there, simplifying the process of managing and controlling production (1C: MES, 2021). One of the components of this database is resource specifications, which contain data, firstly, about the stages of production. In the description of this process, route maps are actively used, which is quite convenient both for understanding the data and their subsequent use. The product description methodology is identical to that used in 1C: ERP; therefore, when using it with 1C: MES, data systems are synchronised. It is possible to create RI and product compositions both using the interaction of Product Data Management (PDM) / Product Lifecycle Management (PLM) – systems with 1C: MES and using built-in products. The technological advantages of this model lie in the fact that it was developed on the latest version of the 1C:Enterprise 8.3 platform, which allows it to achieve a prominent level of security and efficiency both in terms of model generation and management, and when working in the system via the Internet (1C: MES, 2021).

The blocks that the 1C: MES system includes are provided below, in Figure 5.

One more model should be singled out – MES PHARIS (MES PHARIS, 2021). This MES PHARIS (C) model is a modular production process control system capable of solving all kinds of tasks that may face employees of production, workshops, and production sites, and can create and track the implementation of production orders. In this regard, it is important to determine some variables before the direct implementation of production, namely: who will be engaged in

its development, on what equipment and from what materials. This system is one of the most used in various industries, including metallurgy. The main functions of MES PHARIS are shown in Figure 6. MES PHARIS provides the implementation of all functions of the MESA MES model (MES PHARIS, 2021).

The modules that the MES PHARIS structure includes are shown in Figure 7 (MES PHARIS, 2021).

1. •production order portfolio management
2. •operational planning of production
3. •transportation matrix
4. •production schedule calculation
5. •production scheduling
6. •rescheduling of the production schedule
7. •production dispatching
8. •creation of production orders
9. •reflection of the fact of execution of the operation
10. •work with production terminals
11. •shift production report
12. •shift composition report
13. •generation of piecework orders
14. •quality assurance
15. •transfer of items to the warehouse
16. •role-based approach to workplace organisation

***Figure 5**. Blocks included in 1C: MES*

1. •ensuring production order management
2. •ensuring the nomenclature management
3. •providing equipment and tooling management
4. •ensuring the management of technical documentation and control programs
5. •ensuring personnel management
6. •implementation of production planning
7. •production visualisation
8. •implementation of maintenance and tracking of production
9. •information exchange with equipment that does not have built-in communication capabilities
10. •monitoring the properties of manufactured goods
11. •equipment health management
12. •analysis of the level of personnel training, as well as the serviceability of equipment
13. •accounting for the amount of energy used

***Figure 6**. Main functions of MES PHARIS*

1. •data collection
2. •control over orders
3. •control over production processes
4. •control over the keeping of documentation
5. •control of management programmes
6. •personnel control
7. •monitoring the maintenance of production facilities
8. •design assurance
9. •image provision

***Figure 7**. Main functions of MES PHARIS*

In practice, most often they start with the implementation of a basic system that can provide timely information, and conduct production visualisation with subsequent expansion to a full-fledged MES. MES PHARIS is focused on ensuring the creation and maintenance of a single base of reference data, which contains all the information necessary for the release of a product: product characteristics; operations within the technological process and their sequence; about materials for production, as well as the regulatory need for them; about the equipment that is used directly during production; about the time of equipment reconfiguration when creating a product; about the requirements for operators, etc. MES PHARIS can organise concentrated storage of programmes, which allows creating their new versions in the future, or return to the old ones, if necessary, at any time. MES PHARIS provides access for users from any place to the data they require from the documentation. MES PHARIS includes the creation of client process screens, which makes this system even more versatile and easy to use. These client process screens have all the capabilities to be displayed on almost any type of screen, even on ordinary personal computers or terminals (MES PHARIS, 2021).

Among the tasks of MES PHARIS, assistance to the operator at all stages of production also stands out. Assistance in this case will be in the form of issuing instructions on the implementation of the current stage of work, displaying data on the operation of a particular machine, and the above-mentioned submission of the necessary documents that are required at this stage of production. This is especially important given that the more information the operator receives, the fewer mistakes they will eventually make, and the less time they will spend on its implementation. One of the best ways to organise data exchange is to use the specialised EUROMAP63 protocol, which allows automatically obtaining the necessary information about the necessary parameters of the machine operation process (MES PHARIS, 2021).

Next, the study considers the Zenith SPPS MES system for the metallurgical industry (MES-system Zenith SPPS, 2021). The system provides guarantees regarding the continuity of the flow of information about all technological processes, while maintaining a constant high level of staff awareness. The key reasons to choose the Zenith SPPS MES system are the following: the need to optimise the use of enterprise capacities; the importance of maintaining consistent product quality; the need to ensure transparency of processes related to production; rapid implementation of the system into operation; the need to ensure the growth of the stability of the production process as a whole. The results of the operation of this system can be saved in several types of formats, as well as to be source codes for further analysis in other applications (MES-system Zenith SPPS, 2021). The features of the Zenith SPPS MES system are as follows: the presence of a high-performance core, the presence of an ergonomic user interface, networking (automation of the workplace of the shop manager, supervisor of the production site, technologist), ensuring openness and flexibility, accessibility to a wide range of enterprises. The use of the Zenith SPPS system at the enterprise allows significantly increasing the performance of the enterprise, namely, ensure the growth of labour productivity; ensure an increase in the equipment load factor; ensure a reduction in the volume of work in progress; ensure an increase in the level of "transparency"; improve the ability to control production processes; ensure an increase in the percentage of deliveries made on time (MES-system Zenith SPPS, 2021).

All the models considered in this study suggest that any software product related to production automation must consider the specifics of production, the quality of resources, the age of equipment, the readiness of personnel to switch to modern technologies, etc. Each of the models of production automation and individual production processes considered in this study has its specific features, its functions, advantages, relative to similar models. The market is constantly replenished with new companies that are developing IT solutions for automating production in a particular industry, considering the specifics of production, but also offering added support when implementing their product in an enterprise. As suggestions aimed at improving the automation of production planning for manufacturing execution systems (MES), the following can be proposed:

— before the implementation of automation in production, it is necessary to train all personnel to work within the framework of new technologies;

– introduce new equipment that allows implementing all the tasks in the framework of production automation;

– carry out constant monitoring and control of all electronic systems that transmit and process information;

– based on a comparative analysis of the characteristics of MES models, choose the one that is most suitable for the enterprise and considers the specifics of not only the industry where it operates, but also the production itself, its processes, and products manufactured by this enterprise;

– conduct a continuous audit of the effectiveness of the implemented model and, if efficiency decreases, be able to switch to another, more progressive model.

These proposals can be implemented not only at metallurgical enterprises, but also at enterprises operating in other industries. In any case, whatever model of production automation is chosen by the management of the enterprise, it allows reducing costs, increasing labour productivity, reducing the amount of manual labour, both when performing any operations in the shops and related to document flow. The introduction of MES systems is considered as a steppingstone towards the

creation of a high-tech manufacturing process. Due to the uniqueness, individuality, and diversity of MES-level systems, most companies developing software products for industrial automation offer various solutions, considering the characteristics of the production of an enterprise in a particular industry. As of the cases, when the MES system is indispensable in production, the following positions can be distinguished: synchronisation, analysis, and optimisation during production are required; it is required to obtain reliable information promptly about production; if the enterprise carries out many types of products, then, in this case, the processing of large amounts of data is required.

CONCLUSIONS

The study analysed many MES systems. In general, modern enterprises work with a large amount of data at various levels of management, and therefore, the introduction of automated systems is required. The efficiency of production in such a case is directly dependent on the well-coordinated work of many employees: personnel performing management functions, specialists who work in the laboratory, operators, as well as on the level of efficiency of the functioning of all means that carry out the production process. MES provide an opportunity not only to speed up the process of coordinating data flows between ERP levels and automated process control systems, but to help line operators optimise the production process and reduce the number of errors.

The integration of the MES system, as a rule, does not require large expenditures, and therefore, there are plenty of positive aspects from the introduction of the MES system, which include the acceleration of production activities by optimising various processes, the ability to improve product quality due to the possibility of introducing necessary amendments to the planning of the production process based on detailed information about the production load and what raw materials were used; increasing the productivity of technological equipment, personnel, materials; increase in data processing speed and many other indicators. As for what determines the choice of MES, it is not so much the choice of the system that plays a role, but the choice of functions used in it. The main criterion for choosing an MES model should be the focus on choosing a process with the most problems (or vice versa – with the greatest opportunities for improvement). Thereafter, it is worth selecting such functions within the framework of the system that allow influencing this particular process. Promising in subsequent research is to investigate the possibilities of increasing the efficiency of one or more MES systems, based on the disadvantages existing in them.

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CONFLICT OF INTEREST

The authors report no conflict of interest.

REFERENCES

[1] Armellini, D., Borzone, P., Ceschia, S., Di Gaspero, L., & Schaerf, A. (2018). Modeling and solving the steelmaking and casting scheduling problem. *International Transactions in Operational Research*, 27(1), 57-90. doi: 10.1111/itor.12595.
[2] Atlas MES – an innovative system for automating production management (2017). Retrieved from https://controleng.ru/mes-sistema/atlas-mes/.
[3] Ausferr. (2021). Retrieved from https://ausferr.ru/infosystems/mes/.
[4] Chehri, A., Zimmermann, A., Schmidt, R., & Masudad, Y. (2021). Theory and practice of implementing a successful Enterprise IoT Strategy in the Industry 4.0 Era. *Procedia Computer Science*, 192, 4609-4618. doi: 10.1016/j.procs.2021.09.239.
[5] Chen, B., Chen, H., & Li, M. (2021). Automatic quality inspection system for discrete manufacturing based on the Internet of Things. *Computers & Electrical Engineering*, 95, article number 107435. doi: 10.1016/j.compeleceng.2021.107435.
[6] Clemons, J. (2021). How to correctly build a model of intelligent production. *Control Engineering russia*, 3(93), 19-21.
[7] Gong, Z.-X., Zhang, W.-X., Li, T.-K., & Wang, B.-L. (2021). Product life cycle-based digital plant modelling method for process industry. *IOP Conference Series: Materials Science and Engineering*, 1043(2), article number 022049. doi: 10.1088/1757-899X/1043/2/022049.
[8] "Interpipe". (2021). Retrieved from https://interpipe.biz/.
[9] Li, J., Duan, P., Sang, H., Liu, Z., & Duan, P. (2018). An efficient optimisation algorithm for resource-constrained steelmaking scheduling problems. *IEEE Access*, 6, 33883-33894. doi: 10.1109/ACCESS.2018.2840512.
[10] Liu, S., Xie, S., & Zhang, Q. (2021). Multi-energy synergistic optimisation in steelmaking process based on energy hub concept. *International Journal of Minerals, Metallurgy and Materials*, 28(8), 1378-1386. doi: 10.1007/s12613-021-2281-7.
[11] MES PHARIS. (2021). Retrieved from http://www.tersys.ru/index.php/MES_PHARIS.
[12] MES-system Zenith SPPS in metallurgy. (2021). Retrieved from http://www.zspps.ru/index_option_com_content_view_article_id_191.html.
[13] MES production management system. (2021). Retrieved from https://italliance.kz/produkty/erp-symphony/-mes.

[14] Production process control system DIPOL K.U.P.O.L. opens doors to the industry 4.0. (2021). Retrieved from https://sapr.ru/article/26120.
[15] Shinkevich, A.I., & Malysheva, T.V. (2020). Waste management for production of steel electric welding pipes using data mining technologies and MES systems. *CIS Iron and Steel Review*, 20, 70-75. doi: 10.17580/cisisr.2020.02.15.
[16] Verevka, T., Mirolyubov, A., & Makio, J. (2021). Opportunities and barriers to using big data technologies in the metallurgical industry. In D. Rodionov, T. Kudryavtseva, A. Skhvediani, & M.A. Berawi (Eds.), *Innovations in digital economy. SPBPU IDE 2020. Communications in Computer and Information Science*. Cham: Springer. doi: 10.1007/978-3-030-84845-3_6.
[17] Xiaoa, X., Xiaoa, Y., Zhanga, Y., Qiub, J., Zhangb, J., & Yildirimc, T. (2021). A fusion data preprocessing method and its application in complex industrial power consumption prediction. *Mechatronics*, 77, article number 102520. doi: 10.1016/j.mechatronics.2021.102520.
[18] Yang, T., Yi, X., Lu, Sh., Johansson, K.H., & Chaia, T. (2021). Intelligent manufacturing for the process industry driven by industrial artificial intelligence. *Engineering*, 7(9), 1224-1230. doi: 10.1016/j.eng.2021.04.023.
[19] Yanzhao, L., Panfilova, E.S., & Lvova, M.I. (2020). Formation of the capital structure of metallurgical industry companies in conditions of sustainable industry development 4.0. *E3S Web of Conferences*, 208, article number 07006. doi: 10.1051/e3sconf/202020807006.
[20] Zheng, Z., Zhang, K., & Gao, X. (2021). Human-cyber-physical system for production and operation decision optimisation in smart steel plants. *Science China Technological Sciences*, 65, 247-260. doi: 10.1007/s11431-020-1838-6.
[21] 1C:MES Operational production management. (2021). Retrieved from http://surl.li/fmkkp.

Різні моделі планування для систем управління виробництвом

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Анотація. В даний час багато підприємств автоматизують всі процеси на своєму виробництві, металургійна галузь не є винятком. Сьогодні на ринку існує безліч програмних продуктів для автоматизації виробництва. Такі продукти дозволяють звести окремі процеси до єдиного процесу управління, відображати всі процеси та автоматично контролювати показники ефективності, тим самим оцінюючи ефективність впроваджених на підприємстві моделей та роботу всього підприємства в цілому. Метою даного дослідження є розгляд того, які моделі виробничого планування використовуються в даний час для систем управління виробництвом Manufacturing Execution System (MES) та висвітлення їх особливостей, зокрема при впровадженні на металургійних підприємствах. В ході дослідження були використані наступні методи: аналіз, синтез, порівняння, графічне представлення даних. Інформаційною базою даної роботи стали дослідження європейських, американських, азіатських фахівців, що досліджують питання впровадження інтегрованої системи менеджменту (ІСМ) в металургійній галузі. Результати даного дослідження дозволили виділити особливості існуючих моделей планування виробництва для систем управління виробництвом (MES) в металургійній галузі. Дане дослідження має практичне значення, оскільки дозволяє виділити основні особливості різних моделей виробничого планування для систем управління виробництвом (СУВ) в металургійній галузі та на основі порівняльного аналізу вибрати найкращу з них для впровадження на підприємстві. Результати порівняльного аналізу моделей виробничого планування для систем управління виробництвом (MES) в металургійній галузі також можуть призвести до того, що підприємство може відмовитися від однієї моделі, яка вже працює на підприємстві та перейти на нову, більш прогресивну модель, яка відповідає всім вимогам та тенденціям розвитку ринку в металургійній галузі

Ключові слова: металургійне підприємство; цифрова трансформація; IT-інфраструктура; аналіз великих даних; бізнес-процеси