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ORGANIZATION OF MANAGEMENT PROCESSES AND PRINCIPLES OF VIRTUAL PRODUCTION

Abstract. *Introduction.* Quality of products or services is one of the key factors in generating the demand for product. The importance of this factor in development of an efficient competitive strategy of the enterprise, as well as in accomplishment of new competitive advantages in the industry is a criterion of primary significance for quality management system implementation. *Purpose:* to research organization of management processes and analyze principles of virtual production. *Results.* Methods of management processes organization and implementation of virtual technologies principles are reviewed. It is proven that transition to organization of technological processes on the basis of flexible automated production creates new opportunities to enhance efficiency of industrial production. Analysis of CALS-Technologies is provided. *Conclusions.* The outcomes of the study enabled the authors to formulate specific recommendations for: 1. effective application of different types of industrial automation, depending on the batch size and diversity of similar parts and mix of products; 2. successful implementation of the proposed technology of 3D-modeling as a basis for creating objects in CAD-systems; 3. justification the virtual CALS-technologies application.

Keywords: Production Management; Virtual Production; Process-based Approach; CALS-Technologies; Quality Management System; Competitive Advantage.
JEL Classification: M11

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ОРГАНИЗАЦИЯ ПРОЦЕССОВ ПРОИЗВОДСТВЕННОГО МЕНЕДЖМЕНТА И ПРИНЦИПЫ ВИРТУАЛЬНЫХ ПРОИЗВОДСТВ

Аннотация. В статье анализируются процессы управления виртуальным производством и принципы, на которых оно базируется. Доказано, что переход к организации технологических процессов на основе гибкого автоматизированного производства создает новые возможности для повышения эффективности промышленного производства. Результаты проведенного исследования позволили авторам сформулировать конкретные рекомендации относительно: 1) эффективного применения разных видов автоматизации производства в зависимости от размеров партий однотипных деталей и разнообразия номенклатуры производимой продукции, 2) использования предложенных технологий 3D-моделирования как основы для создания объектов в CAD-системах, 3) обоснования применимости виртуальных CALS-технологий.

Ключевые слова: производственный менеджмент; виртуальное производство; технологический процесс; CALS-технологии; системы управления качеством; конкурентное преимущество.

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ОРГАНІЗАЦІЯ ПРОЦЕСІВ ВИРОБНИЧОГО МЕНЕДЖМЕНТУ ТА ПРИНЦИПИ ВІРТУАЛЬНИХ ВИРОБНИЦТВ

Анотація. У статті аналізуються процеси управління віртуальним виробництвом та принципи, на яких воно базується. Доведено, що перехід до організації технологічних процесів на основі гнучкого автоматизованого виробництва створює нові можливості для підвищення ефективності промислового виробництва. Результати проведеного дослідження дозволили авторам сформулювати конкретні рекомендації стосовно: 1) ефективного застосування різних видів автоматизації виробництва залежно від розмірів партій однотипних деталей і розмаїтості номенклатури виробленої продукції, 2) результативного застосування запропонованих технологій 3D-моделювання як основи для створення об'єктів у CAD-системах, 3) обґрунтування можливості застосування віртуальних CALS-технологій.

Ключові слова: виробничий менеджмент; віртуальне виробництво; технологічний процес; CALS-технології; системи управління якістю; конкурентна перевага.

1. Introduction

The ever-growing level of competition motivates the search for new strategies of development targeted to create a long-term stable strategy of enterprise and build the quality policy on its basis. The implemented quality system is the integral part of production process. Quality control across the entire life cycle has become a necessary element of competitive strategy for any contemporary enterprise.

The level of product quality and its cost determine the level of economic efficiency of the enterprise. It will be highly probable to expect that reduction of the product price through loss of quality will promote growth of the volume of sales over a very limited period of time. Product quality assurance is, in many respects, determined by the quality of the production process itself, including the quality of automated production.

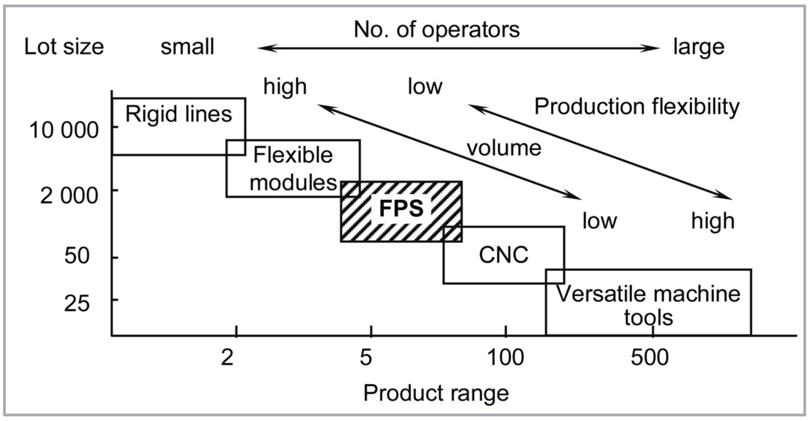

Figure: **Areas of efficient application of various types of production automation**

Source: Own research

2. Brief Literature Review.

Issues of management processes, different aspects of virtual production were discussed in publications of Russian and foreign researchers, such as: Azarov V. N., LaokhinYu. L. et al. (2006), Weiss S. D. (2000), Lontsikh P. A. (2003), Nechaev A. S. (2013, 2014, 2015), Hassi D. (2001), Fakhfakh T., Bartelmus W., Chaari F., and Zimroz R. (2012), Buyukuzturk O. (2011), Adams M. L. (2010), Mark W. D. (2013).

Authors Fakhfakh T., Bartelmus W., Chaari F., and Zimroz R. (2012) in a book that was published lately investigate the vibration diagnostics and monitoring of machines in an unsteady state. The results allows us assessing the ability of forecasting and modeling of resources, machinery and equipment, as well as identify areas of existence CAD-modeling and application of virtual CALS-technologies.

The monograph of Adams M. L. (2010) includes methods for 3D-modeling of kinematic pairs and rotating parts of the machine. It also includes productive methods of analysis to eliminate defects and malfunctions.

In the monograph of Mark W. D. (2013) a series of studies to assess the quality criteria of the kinematic transmission, such as the engine, gearbox, and reducer have been proposed. The author reviewed the range of applicability for virtual production.

3. Results

Flexible automated production is a breakthrough superior stage in integrated production automation. Thanks to rapid scientific and technical progress in such areas as production automation, electronic engineering, computer equipment, information science, it has become possible to consider integrated automation of production processes in a new sense – as a system of automation, which encompasses the entire production, from design of products and technologies to complete manufacture of products and delivery to consumer. This trends leads to development of highly automated shops and automatic production plants, whose key feature is wide application of computer equipment in virtually all steps of production, high level of process equipment automation on the basis of computer numerical control, broad-scale elimination of manual labor through extensive use of robotic equipment [1].

Before introduction flexible systems, automation of production processes was limited to mass production. However, as the lifecycle of products shortens resulting from rapid scientific and technical progress with associated growth of the number of product items range, the need arises to create such production facilities, which would enable to produce parts in small lots while still preserving their overall production capacity, quality and production cost typical of a large-scale production facility.

It should be noted that flexible automated production facilities will still be unable to replace all traditional types of production. Their area of application is broad, yet limited.

Figure indicates the zones of the most efficient use of various types of production automation depending on the lot size of similar parts and diversity of product items range.

In conditions of individual production of individual parts, it appears feasible to use versatile or unique equipment, which is maintained by highly qualified staff. Flexible automated production facilities occupy the intermediate position between these two production types. Their use appears to be the most feasible of the lot size is several hundred items, while product items range is within single digits to several hundred of different parts. Prospects of development are related to ever-growing integration of various production functions within one system and complete handover of these functions into computer-controlled prouction. Accurate forecast for development of flexible automated production facilities is completed due to the fact that systems of different size are often included into this notion.

Revolutionary new opportunities to improve efficiency of industrial production in all of its areas become available in transition to organization of production processes based at principles of flexible automated production in creating flexible production systems [2].

The principles are based on the following:

- use of control methods, which enable flexibility, i.e. prompt changeover of production facility;
- use of automated production control units for equipment, production lines, production bays etc, as a set of program control complexes deployed in computer equipment of different classes;
- creation and implementation of new methods and means for rapid improvement of functional reliability of flexible production systems in general, and core technology areas in the first place.

Technological flexibility determines the ability to perform several process tasks with the existing set of equipment. This allows using process modules with a wide range of production operations (use of multitool and multipurpose machines).

Organizational flexibility determines the structure of flexible production system to a considerable extent. There will always be a certain contradiction between the strive to operate the equipment at maximum load and the strive to provide the minimum production cycle. Efforts for reduction of production cycle are associated with targeting the flexible production system «at a product», which will inevitably lead to non-rational (in terms of operational load) use of equipment and labor resources.

An alternative can be found in targeting the production structure at the technology principle. This allows for a more efficient use of equipment, reduction of the number of staff, however may cause longer production cycle and larger volume of production-in-progress. A flexible system of calendar planning and operative dispatcher control with centralized distribution of work scope will be required for efficient use of the technology principle.

The modern development of flexible production system is the Computer-integrated Production (CIP).

The leading countries of the world currently experience of the transition from industrial economy based on rigid division of labor, mass production and exchange of material products, to postindustrial (information) economy, with ever-growing role of computer means of generation and exchange of knowledge, telecommunications and management. This process should be expected to accelerate during the following decades [1].

Development of postindustrial economy appears to be one of the necessary conditions to escape from the global ecological crisis, into which the contemporary industrial civilization typical of uncontrolled growth of production and consumption is gradually become more and more involved. In connection with this crisis, the feasibility of traditional production is questioned due to a number of negative effects of global nature, such as pollution, depletion of natural resources, contamination of environment with hazardous waste. Long known, generally used and little coordinated methods to resolve these problems, which are currently used, bring only short-term and partial results.

In this situation, development of new strategies for organization, computer integration, and introduction of smart technologies based on new information and communication technologies into production acquires special significance, due to apparent limitations of natural resources, impossibility to further increase environmental load. Some examples of this type of solutions include: strategy of ecologically permissible or acceptable production (Sustainable Manufacturing), which is targeted at implementation of the principle of joint evolution of nature and society, which becomes the basic principle at the present stage of development of mankind, or the strategy of post-mass production based on intensive technologies of processing corporate knowledge and «Soft Machines». Similar strategies also include the strategy of expansion of traditional representation of computer-integrated production.

The term «computer-integrated production» indicates at «partially automated industrial enterprise, where all processes related to manufacture of products are consolidated and controlled by computers».

Originally, the notion of CIP consolidated the systems of computer-aided design (CAD), automated systems of technological production preparation (CAPP) and computer-aided manufacturing (CAM). At a later point, it began to include computer-aided engineering (CAE), systems of computer-aided quality control (CAQ), computer-aided systems of production control (CAPM), computer-aided systems of operative control. Generally speaking, CIP must encompass all stages of the production cycle, from the marketing stage to the finished product release stage. The remaining stages of the product life cycle are viewed as external to CIP and remain in constant interaction with the latter.

However, a recent trend has developed to view CIP as the concept encompassing all stages of the product life cycle. This view received the name of «quality loop» in international practice (ISO 9004). At present, CIP also begins to include the stages of distribution and sales, use and even disposal of products.

The notion of CIP is closely related to CALS-Technologies. At this point, CALS (Continuous Acquisition and Life Cycle Support) is understood as a continuous support of the product or item life cycle. In its essence, CALS is the global strategy of improving efficiency of business processes implemented over the course of the product's life cycle through informative integration and succession of information generated at all stages of the life cycle. This strategy is implemented through CALS-Technologies, which are based on a set of integrated information models – the life cycle itself and business processes implemented in the duration of the cycle, products (good), production and operation environments etc. Opportunity of shared use of information is provided through application of computer networks and standardization of data formats, which secure correct data interpretation.

The ideal basis to solve tasks faced by design engineers is the use of product life cycle and its sole integrated model, which describes the object so completely, that is appears as the single source of information for any processes performed in the course of the product life cycle. The concept of CALS encompasses not only production but all other stages of the product life cycle. The object of CALS-Technologies is the format of digital representation of generated solutions for applied tasks, regardless of the source of origin, security of this electronic information and legal issues of its shared use.

Implementation of CALS-Technologies into design and optimization of production processes will enable to provide support of all product life cycle stages on the basis of computer-aided design system (CAD) in accordance with international CALS-standards ISO and STEP, to reduce the duration of design by 5-10 times through deployment of parallel development technology [4].

CALS-Technology of automated design and optimization provides the full cycle of goods manufacturing («conceptual product design – engineering and assembly – finite elements analysis and optimization – development of machining process for CNC machines») on the basis of unified parametric object-oriented technology of solid-state modeling and is used in integrated CAD/CAM/CAE-systems [1]. These systems are built on modular basis, according to which each stage of design is implemented in a separate, relatively independent module provided with a special interface (link between the computer and user, or computer systems) and a set of functions. All modules are integrated by a core, which contains a geometric processor, and functions and operations common for all modules. The core supports the module-based project creation process hierarchy, while providing parametrization and bidirectional associativity feature.

Computer-integrated production is a modern development of flexible computer-aided production, which consolidates information processing automation systems and means of production technology automation [3]. A considerable contribution into development of CIP was made by developments related to creation of computer-aided systems of design and production preparation, procurement, process control, operative dispatching and control, technical vision, robot control, transportation and warehousing operations and many others. Each of these systems provided CIP with new capacities of functioning as the source of data and generate more considerable involvement of special means of new computer-aided production systems into the design process.

Development of CIP is related with integration of information and communication technologies around the product life cycle, as well as building of generalized model of product, including various local models. In the current conditions of ecological crisis, the «unidimensional» strategies of maintaining economic feasibility of enterprises by increasing profit through growth of production, quality and sales of product appear to be insufficient. At present, total competitive edge increasingly stronger depends on efficiency of production and non-production processes of the enterprise, as well as its own organizational structure, type of management, evolution and age [5].

This is why in relation to contemporary dynamic market environment of enterprises, the «purely production» strategy of computer integration of product life cycle should be supplemented with new organizational and managerial strategies related to support of the enterprise operations, provision of more efficient communication among its departments and services, close cooperation with partners, operative interaction with customer, adaptation to market environment [6]. This «multidimensional» computer integration of production suggests convergence of targets and increase of the level of mutual trust between suppliers and consumers, sharing of resources and experience among partner enterprises, which is accomplished through organization of networking postindustrial enterprises. In this case, the creation of virtually linked workplaces will result is dilution of enterprise boundaries, disappearing of differences between customers and contractor, internal and external factors of organization, i.e. development of radically new forms of coordination of collective labor. Meanwhile, open, highly integrated and developing network-based organizational structures on the basis of Intranet/ Internet technologies and artificial intelligence systems serve as instrumental means of building CIP [7].

Integration of all stages of product development appears to be the most revolutionary breakthrough in CAD technologies, which allows a considerable reduction of the time required for development, while simultaneously improving quality of production. What such integration can be based on?

Discussions on the usage of integration have been popular for a long time; however, their practical implementation began only after appearance of object-centered approach based on spatial (3D) and a predominantly solid state product model. This model provides the most accurate and visible representation of the designed product, and it may incorporate all valuable information. Advantages of using 3D models are apparent [8]:

- 3D models allow presenting to customer a conceptualized design of his product at the very early stage of design, through means of realistic rendering and virtual reality.

- 3D model can be used to plot drawings – automated generation of views, sections of assemblies and parts, including generation of sections and shading.

- 3D models are used to generate STL files supplied at inputs to fast prototyping systems. These files allow manufacturing real-size models (prototypes) of goods for their subsequent assessment or use.

- 3D models provide unique opportunities for production preparation: a fivefold improvement of surface machining has been accomplished and the duration of CNC machines programming was reduced by four to five times. Improvement of the quality of product requires creation of high-precision tool trajectories. This process is associated with very large data volumes, since the cutting tool needs to make a lot more passages in each trajectory.(For instance, development of a program for CNC machine to manufacture a typical cylinder head requires work of 3-4 specialists for approximately five months. Approximately one million points will be generated in the process. Automatic generation from solid state model using, for instance, CV Toolmaker, can be performed in half an hour, taking into consideration two and a half million points and with resulting crest height less than 0.0001 inch given the industrial standard of 0.0005 inch).

The notion «virtual» originates from the Latin word «virtus» (strength, capacity, and valor). This word is used to describe the object, which, being unreal, «apparent» exists in the sense of action generated by this object. In the domain of industrial production, the term «virtual» is increasingly often used to designate computer models of designed products, technological models and production processes [9].

Use of this term appears to be justified. In fact, a computer model of the product does not exist as a physical object, but it is rather perceived by design engineers, process engineers and other specialists as something real. Existence of the model of product is the necessary precondition to deploy the processes of production preparation, i.e. it generates impact onto actions taking place in reality. This is why the model of product or part is often referred to as virtual object [3].

The same holds true for technological processes. For instance, computer modeling of die forging, plastic molding etc, and their research with use of CAE-systems, realistic imitation (modeling) of part machining processes on CNC machines and modeling of their operation. Analysis of virtual technological process allows a process engineer to make real optimal solutions. Production processes of control may also exist in the form of models, e.g. computer models of operation assignment flow [10].

4. Conclusion

Therefore, large-scale use of computer technologies enable the situation, where all design and organization-related decisions at the enterprise are first made at the level of models. Meanwhile, real objects and processes become a type of projection of «virtual» objects and processes into external environment. This indicates at the actual virtualization of contemporary industrial production.

The concept of multidimensional integration of enterprise as the result of consolidation of network and intellectual technologies is currently developing at an ever-growing pace. Main problems in development of this concept include intellectualization of production facilities and building virtual enterprises (VE) on the basis of virtual technological machines.

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