ISSN 2347 - 3983
Volume 8. No. 9, September 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter135892020.pdf
https://doi.org/10.30534/ijeter/2020/135892020

The study of approaches for the coordination of product development systems and production systems in the stage of conceptual design

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ABSTRACT

Modern machine building industry is often represented by a set of partially aligned product development systems and original production systems, the activity of which is caused by initially not interconnected structural maintenance and technological support, validation assortment diversity and quality of the produced product, which necessitates the transformation of systems "product-production" in the direction of their coordination and integration. This determines the need to build new logic, principles, and criteria for decision-making.

The purpose of research - to evaluate existing approaches to coordination of product development systems and production systems in the stage of conceptual design in the context of their effectiveness; to form embodiments of practical-application integration systems and processes in the conditions of domestic production.

Materials and methods: systematization and generalization of experience in the joint development of product-production systems, as well as the integration of existing systems and processes using the example of the engineering industry; assessment of the potential for practical application of the selected solutions for the joint design and integration of systems and processes in the Russian Federation.

Results: Methodological recommendations have been developed for the coordination (parallelization) of systems for creating products and production systems at the stage of their conceptual design. Unlike existing ones where either the product model or process model is primary, the comparison is proposed at the system design level based on the similarity of system specifications and commonality components through calculated targeting and “critical points” of–χοορδινατιον parameters, which are the cost of the system a "product-production", quality, flexibility, and efficiency. The approach also involves the formation of original connections between elements of the original systems by systematizing the results of "their best design".

Key words: Product development system, production system, coordination of product-production systems, the practice of systems development, continuous improvement

1. INTRODUCTION

Available results of scientific research in the field of methodology for the formation and development of product creation systems are characterized by the inconsistency in the development of individual design practices for product development; non-systematic and non-adaptive methods and tools for modeling integrated high-tech processes and complex high-tech products to the manufacturer's production systems - the scale of parallel design of production systems and product creation systems varies greatly from project to project; tools and methods are created for single/one-time projects, specific production needs [1,2], which predetermines the impossibility of prolonging the result, systematizing the current practice of coordinating product development systems and production systems.

Set of problems determines the need for a new theoretical-methodological basis for the product formation of a system where the main decisions may be: system design "product-production" in terms of their flexibility, practical-application; product and technology integration systems.

The purpose of research - to identify existing approaches to coordination of product development systems and production systems, implemented in industrial production, also to systematize current practice that exists in terms of domestic production and propose options for their development.

2.METHODOLOGY

The categorical apparatus on the topic of research is considered, the existing relevant practices of coordinating product development systems and production systems, the potential of practical application of the industry leaders experience in the conditions of domestic production is

analyzed using the example of the mechanical engineering industry highlighted in the study.

3.RESULT AND DISCUSSION

Proceeding from the position that the product development system serves as a model in the formation of the development strategy of an industrial enterprise, we determine the content of the methodology for the formation of product systems at the enterprises based on the parallel product design and the planning of corporate systems and production.

Considering the relevant practices of the formation of product systems by manufacturers, we determine that at the methodological level, in this case, strategic decisions on the product are written and only then technical, technological and operational solutions for the design of corporate systems and production such as: process phases, methods and tools; the critical success factors, approaches to their combination are distinguished: parallelizing the processes of product creation systems, production systems, or their joint development initially - at the beginning of the project [3].

Assessment of approaches to complex production and technical systems from a position of joint technology, engineering design, production systems and product creation systems allowed to conclude that:

1. Coordination of product development systems and production systems is possible at stage 4. Figure 1 "Structuring processes" landscape of PD-processes (CSL-system Lehtonena):

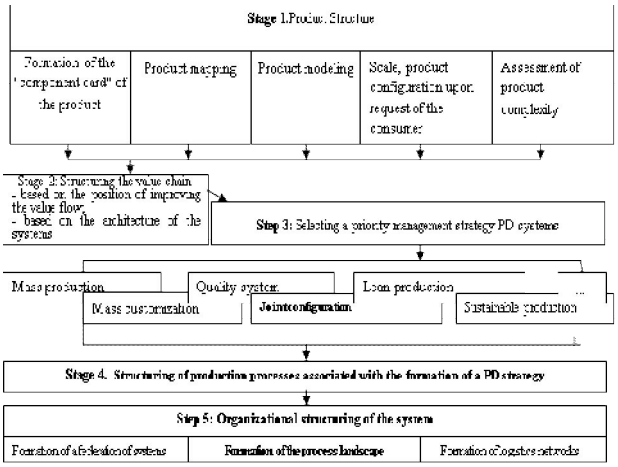

Figure 1: The sequence of the methodological approach implementation for the development of production through the management of product creation systems

2. Ensuring the connection between products and processes is possible through:

2.1. Integration of production systems and product creation systems;

2.2. Joint development of production systems and product creation.

Integration "product-production" system is likely based on:

a) The primacy of the product model; b) primary production model.Integration approaches based on the primacy of the product model are implemented through geometric modeling of products, their functional description, and the formation of relationships between product components that are combined and adapted during the production process. Examples of such product models used in practice are “end product” models (eg technical drawings, specifications) and complex models used to represent a variety of information: product data, product structure: parts, systems, assemblies, individual components and materials brought to the state of specifications and working drawings - containing information on dimensions, deviations, tolerance ranges, and surface finish. Products in these models are modeled in the interconnection of elements already in the early design stages and brought to the state of rendering [4].

Approaches for integration based on the primacy of the production/process model (technological models, process models) - consider projects as systems of goals that can be decomposed into tasks; describe processes; methods, tools, support/improvement options for processes, presenting a set of product development processes (with specifications, cost and completion time) with options for their improvement. They describe relationships and sustainable processes such as production systems or supply chains, repetitive production workflows [4].

Qualification conceptual approaches to the integration of production systems and create products allowed to formulate a conclusion that the model "product-process" implemented mainly by expanding process models. However, process models are generally more ambiguous than product models, and represent individual solutions of varying granularity, often with a high level of abstraction.

Traditionally, systems integration is carried out through:

– Standardization activities in the field of heterogeneous processes, product systems and processes, including through the adoption of international standards;

– Concurrent product and process design within the CE philosophy.

At the same time, there remains a field for the development of integration systems/processes in high-tech domestic industries and the approach can be extended:

1) Comparing the processes of product development and production by phases table 1;

Table 1: Comparison of product development and production processes

Indicators	Product development	Production
Definition	The process of product development - is: 1. The process by which a manufacturer converts the market and technical possibilities for the information to produce a product; 2. The set of steps by which, based on the needs of the market, the manufacturer creates a product, seeking to meet the identified needs	The process of development of production is: 1. Development of new production solutions needed to implement the created product concept; 2. The development of new production technologies and components of production processes, i.e. product innovation, and production systems
Process phases	– Product planning – Project specification – Management requirements – Concept design, system design – Layout, technical project, design specifications. – Systems Integration – Modeling, model analysis – Project implementation	– Planning, equipment layout, – Conceptual planning of the production system, system design (engineering) – Execution planning, design specifications – The actual commissioning – Assembly, commissioning, start-up
frequency	unique/single, usually one process	repeating a plurality of processes in accordance with a frequency change of product models

2) Due to the formation of connections between the elements of the original system. Scientists and experts, comparing different

goals for product modeling and subcategories of process modeling, correlated them with the classification of goals for product models Table 2:

Table 2: Initial elements are recommended for use in integration models

Elements of product models	Elements of process models
Product visualization Components, interfaces Individual elements of the model	Project visualization Actions, interactions and interdependencies Individual elements
Product planning Specifications, alignment of requirements Structuring of the product, and definition of its functionality	Project planning A set of activities, events, works Process structuring
Project execution and control Analysis and product evaluation Product evaluation for compliance with specifications Assessment of the product's functionality	Project execution and control Process assessment and monitoring Assessment of changes in processes or technologies "Refinement" of processes

Joint development of systems "product-production" through parallelizationof project objectives to establish the product and the combination of individual decisions on the level of the production process. The focus is on "connecting" the capabilities of individual products to the capabilities of production systems and machines through the development of work tasks. This level is theoretically justified, but often has no practical use.

To a certain extent, Russian scientists, among whom Sadov's work is of particular interest, have solved this problem. In his opinion, the parallelization of design tasks for the joint development of corporate systems with the subsequent combination of individual solutions at the level of the production process should be carried out in the form of:

1) the formation of the product structure with the subsequent formation of the elements of the production system;

2) formation of the structure of the production system by modifying the parameters of production processes associated with a change in the components or the dispersion of its functionality

In our opinion, the parallelization of project tasks for the joint development of corporate systems can be enhanced by:

1) A description of the capabilities of systems through the provision of "matching points".

Table 3: Matching of system points in their joint development

Parameters	Product development methodology	Methodology of designing production
Production cost	Design cost - a significant limitation on the costs for the NPD-processes within specified performance requirements	The cost of production - development of production innovations that can help reduce production costs without compromising the capacity of
Quality	Quality design - product design with the proposed quality characteristics	Quality Design - development process with a high degree of matching geometric dimensions and tolerances
Flexibility	Product standardization - Product platforms are developed that reuse parts across a product family.	System flexibility - the formation of production flexibility, i.e. the ability of the system to change to produce new products
Risk	Minimization of risk - development characteristics of functionality, ergonomics, safety, reliability,	Minimum design risk - risk management of new technologies to ensure the expected efficiency and quality
Order Execution Time	Reducing the time of product commercialization - forming solutions within the framework of quick response to customer needs	Designing process time - developing flexibility in order to respond quickly to a request while maintaining the required level of cost and quality
Efficiency	Formation of "reliable" design - design of product functions that persist under specified conditions for a specified period	Formation of efficient production - reducing defects/waste in production

2) By systematizing results "best" in terms of their designTable 4:-Saturation component systems their design, configuration [5].

–Selected manufacturing strategy [6].

Table 4: Relevant practices of modeling by industry leaders of a set of systems in the context of ATO / ATS and CPTO strategies

Demand options	Production cost, US dollars				% difference
	ATO *	ATO and ATS (Platform)	CPTO**	The difference in USD	
Option 1					
Option 2					
Option n					
…..					

* ATO - assembly for order from standard components, in which design and technological documentation for various units already available at the enterprise is used, however, slight variability of the product composition is allowed, depending on the customer order (all original components are assumed to be in stock)

** CPTO - Configuration Platform (product/ system) "custom"

** CTO - product customization by changing components/modules, including through their extensions and/or software parameterization to increase the diversity of the product family

–project execution time based on the production strategy table 5.

Table 5: Project lead time data based on the production strategy chosen by individual industry manufacturers

	Production strategy (build policy)/execution time (in seconds.)					
	ATO (without platform)	Hybrid ATS/ATO	CPTO (large platform)			
	Without platform	Same platform	P_1 for D_1	P_2 for D_2	P_3 for D_3	P_4 for D_4
Option 1						
Option 2						
Option n						
…..						
Total execution time						

The proposed solutions allow:

– Reduce inventory and work in progress (WIP). The calculation is based on the timing of inventory and work-in-progress, calculated using DFA - a methodology used to estimate the time required to assemble individual parts to form a complete product and simplify design;

– Reduce the total assembly time of the product (saving engineering hours for the project) table 6:

Table 6: The total assembly time *

Production strategy	Assembly time (in seconds.)
ATO	
ATS/ATO (small platforms)	
CPTO (large platform)	

* calculated by summing the time required to assemble a component in assembly operations and the time to set up a product variant

– Reduce product assembly production costs Table 7:

Table 7:assembly costs

Production strategy	Assembly cost (conventional units)
ATO	1200
ATS/ATO (small platforms)	910
CPTO (large platform)	740

* calculated based on total assembly times for automatic and manual operations

Evaluating the selected production strategies when making a decision, we determine with the least amount of WIP costs, saving engineering hours for the project, and relatively lower costs for assembling a production product.

4.CONCLUSION

The experience of practical application of the integration of systems and processes in Russia indicates that domestic enterprises are not yet ready to replicate the experience of world manufacturers in this area. There are several reasons for this - these are organizational and technical problems [6,7].; this is the unwillingness of domestic producers to switch to "open technologies", etc .; there is a lack of understanding of the nature of interdependencies/interactions between systems of complex products and production systems, as well as the dynamics of their development by domestic manufacturers. Also, when replicating the experience of world manufacturers, Russian manufacturers are faced with the impossibility of adapting and applying modern/classical technologies in domestic production due to the difference in the principles of organizing production, incompatibility of standards, due to the lack of formed business culture, etc. The obvious gap between domestic manufacturers and world leaders in the industry is only growing and reached several decades[8,9].

At the same time, there remains a field for technological/organizational development of integration systems and processes in high-tech engineering industries due to:

1) Product formation in the context of production development strategy.

2) Assessing the product complexity, the quantitative data on which subsequently serve as a starting point for architecture formation of a product, and product families.

3) Formation of solutions for the development of the product due to: the formation of aggregate components unified enterprise systems, modifications of their architectures.

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