PLM as a sequential round of the technological revolution

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Abstract. The fourth industrial revolution is actively developing in the world. Since 2011 it has become widespread. Affecting all areas of life activity, economy, which manifests itself in the qualitative reorganization of its mechanisms, creates new adapted management models, changes the nature of production processes. The digital revolution opens up new opportunities for using digital networks, agile production systems, and new business models for all stages of production. The faster the company makes this transition, the better its chances of succeeding and outperforming its competitors. Product lifecycle management (PLM) refers to the management of data and processes used in the design, engineering, manufacturing, sales, and service of a product across its entire lifecycle. The introduction of digital technologies occurs at all stages of the product lifecycle: product development, technology development, preparation and launch of production, product production, its operation and maintenance. PLM affects the ideology of creating a new product: to reduce the time to market and save resources, the system pushes to shift the labor intensity from the "production" stage to the "design" stage. The purpose of this study is to analyze product lifecycle management in agile management and to relate it to the current state of the Russian industrial development. Theoretical and practical aspects of this concept are given. The example of PLM implementation in the Russian industrial sector is presented. The Kalashnikov concern has built a product lifecycle management system. Today, the development of production of an industrial enterprise is impossible without a clear understanding of all stages of life cycle management of the product that it produces. Summarizing, PLM is offered as a promising concept for Russian economy.

1. Introduction

Industry 4.0 is not the near future, but a reality that introduces fundamental changes, especially evident in the development of the economy. The creation of a digital economy is a preference for the modern level of Russian industrial development. Industry 4.0 is making its own adjustments to the balance of power in the world market, and even the flagships of Russian engineering will not be able to ignore them. The old approaches to management and organization of production do not work, only digital technologies are able to ensure stable growth of efficiency and solution of strategic tasks, namely:

1. Fast product introduction to the market. Product innovation and the speed of its introduction to the market are the most important factors of competitiveness. At the same time, it is very difficult to provide them to manufacturers: the complexity and manufacturability of products is growing, the production chain is becoming more complex, and there is a need to process large amounts of data. Modern it solutions make it possible to solve these problems, providing the necessary level of interaction between the product and production.

2. Quality improvement. Without full compliance of the product with the consumer's expectations, the company cannot expect to be competitive. The key to quality is the ability to detect the root causes...
of defects, rather than fighting their consequences, which in turn depends on the transparency of processes. Modern technologies of process monitoring and production management successfully solve this problem.

3. Improving efficiency. Production efficiency ensures the company's resource intensity – rational use of material, labor, and time resources and the ability to offer more competitive prices by reducing the cost of production. Optimization of production resources is also one of the consequences of effective implementation of digital technologies.

4. Increased agility. The need to increase the agility of production is caused by the variety of individual consumer requirements for the product, the instability of markets and the task of increasing labor productivity. Digitalization can provide production agility and product customization.

It is Industry 4.0 that opens up new opportunities for manufacturers to use digital networks, agile production systems and new business models for all stages of production. Development of industrial enterprise production is becoming impossible without a clear understanding of all stages of the product management life cycle. And the faster the company makes this transition, the better its chances of succeeding and beating the competition. So, product lifecycle management in agile management comes to the fore.

The theoretical and practical aspects of the modern management concepts are studied by many scholars. Focusing on agile management [1-8], it is important to select the following: P.T. Kidd (1994), S.L. Goldman, R.N. Nagel and K. Preiss (1995), A. Gunasekaran (1998, 2014, 2017), J. Sharp, Z. Irani, and S. Desai (1999), C. Larman (2004), J. Sutherland (2014). Noteworthy that Russian sector of economy has traditionally been conservative. So, the purpose of this research is to analyze PLM in agile management and to relate it to the current state of the Russian industrial development.

2. Materials and Methods

Product lifecycle management (PLM) [9] is the process of managing the entire lifecycle of a product from inception, through engineering design and manufacture, to service and disposal of manufactured products. PLM integrates people, data, processes and business systems and provides a product information backbone for companies and their extended enterprise. PLM is a completely consistent round of the technological revolution.

PLM influences the ideology of creating a new product: in order to reduce the time to market and save resources, the system pushes to shift the labor intensity from the "Production" stage to the "Design" stage. So, Professor G. Taguchi [10] believes that approximately 85% of the future success of products is laid before the start of production, and only 15% is accounted for directly by production. Figure 1 shows this schematically, and also shows the advantage of implementing digital design. Digital technologies are implemented at all stages of the product lifecycle: product development, technology development, preparation and launch of production, product production, operation and maintenance. Universal digitalization provides for the creation of a "digital product double", a "digital production process double", and a "digital equipment double".
The requirements for the technical task for products, registration of documents, and design development are increased. To meet these requirements, it is necessary to move from an ascending to a descending design method.

In the ascending development method, designers design individual small parts independently of each other, then combine them in the program. The first node of the product is obtained. The rest of the components are also designed, and at the end, all the parts are finally assembled. This approach is not ideal because unnecessary intersections of parts may appear in the final assembly, or, conversely, the gaps between them. Since the parts were designed by different people in different programs, there are no connections between the design elements. You need to manually change the parameters of the component that entered the assembly incorrectly, and all the surrounding parts. The disadvantage of the ascending method is that you may not notice an extra intersection. Due to the lack of connections between parts of the product, the program does not recognize where the intersection is really needed and where it is not. If the designer didn't see the error, the incorrect layout will be sent to production. Hence, there are defects, time to recheck the layout, and resources to restart production.

In descending design, the chief designer of the project creates a sketch of the product – a "skeleton", then splits it into nodes and distributes these nodes among the designers. It is important that all project designers work in the same program and see the same "desktop": the model frame, main surfaces, and axes. When a part or node is ready, you don't need to move it from program to program. They are already where they should be. If the design components overlap or do not fit together, the program will show this: the entire product was originally designed within the same it system, so it can recognize the connections between the design details. In descending design, the probability of transferring an incorrect layout to production is lower, which means that the risk of defects is lower.

Transferring a product to a virtual environment allows you to check its performance even before it appears in reality. Understand what will happen to each cog of the rocket during its launch and entry into orbit, conduct a crash test of a new car model, or calculate the strength of the bolt when fired from a machine gun—all this can be calculated thanks to PLM in a couple of days. The system includes

Figure 1. Comparison of the traditional design process and the design process with digital technologies, based on the [11].
integrated systems for modeling the operation of products. In terms of time and cost, virtual tests are more efficient than real ones.

A promising area of PLM development is interaction with customers. Instead of showing customers "live" samples, in theory it is possible to provide them with an electronic product layout. If customers want to upgrade something in the design or purchase a product with an individual configuration, the company will make changes to the digital design of the product. Production of the model will start only after the client approves its design and all technical characteristics. If the sample does not meet expectations, you can replace it with another one, without wasting months of work of all the plant's services.

3. Results and Discussion

Modern organizational concepts in production including agile manufacturing have been implemented sporadically in Russian industrial sector of economy [12-18].

JSC Kalashnikov Concern is the largest Russian manufacturer of a wide range of precision weapons. A large segment of civilian products includes hunting rifles, sporting rifles, machine tools and tools. 51% of the concern's shares belong to the State Corporation Rostec, 49% - to private investors. Kalashnikov concern products are delivered to more than 27 countries. The concern includes three product brands: Kalashnikov-military weapons, Baikal-hunting and civilian weapons, and Izhmash-sports weapons. Today, the group of companies is implementing a development strategy until 2020, the main priorities of which are to produce a wide range of products that are competitive on the world market, improve the efficiency of production processes, build an effective management structure and create comfortable working conditions for all employees of the enterprise.

Kalashnikov Concern took part in the First all-Russian conference "Digital industry of industrial Russia" (CIPR), which takes place from 7 to 10 June 2016 in Tatarstan [19]. The group's specialists shared their experience in building and developing smart manufacturing, as well as supply chain management (SCM), warehouse management (WMS), and product lifecycle management (PLM) systems. Today, the development of production of an industrial enterprise is impossible without a clear understanding of all stages of life cycle management of the product that it produces. Even the traditionally conservative arms industry can't do without dramatically speeding up the process of developing and bringing a product to market. This acceleration can be achieved through the use of a agile development methodology and an emphasis on quality control of the development process, as well as the introduction of a unified product lifecycle management environment for the designer, technologist and customer.

PLM combines all the enterprise it platforms used to create products. It all starts with a computer-aided design system, in which designers create an electronic 3D model of the product. Based on the ready-made layout, technologists develop control programs for processing parts on CNC machines (numerical control). Information about what tools and materials are needed for the production of each part of the product, production standards and deadlines, as well as other data is sent to KSAUP QC and MES&SCADA QC: systems for production planning. The first one plans globally - in the period from a month to a year, the second one is intended for forming a shift-daily task and monitoring its implementation at the level of production, shop, site and each employee. Every PLM project is unique because every enterprise is unique. All have their own internal regulations, project management methods, organization of processes, interaction between services, and a different it landscape.

The implementation process is very extensive: there are many information systems in the enterprise, and they are all different. According to the head of the Department for technological preparation of production and technological design of the Department of development and support of PLM A. Pleshkova: "Since the start of the project, the format of work has changed several times, and priorities in tasks have changed." As a result, the company switched to scrum and divided the team into two parts: design and technological preparation of production. This distinction is mandatory. If you consistently transfer designers to the system first, and then technologists, the latter will sooner or later find themselves in an information vacuum.
The first product that was developed in the electronic layout format was the new AK-12 assault rifle. It was a complex and lengthy project: the equipment was updated to meet the requirements of the system, the format of interaction between services was changed, people were trained to work in the program, and a new approach to design was tested. In the course of digitizing the product, many problems arose. The development and support team changed the system architecture several times based on feedback. Despite the fact that many employees were involved in the project, including specialists from the design and technology center, digitizing the product took quite a long time. And this is absolutely justified: together with the introduction of a new computer-aided design system, the process of creating a new product was completely rethought.

Before the introduction of PLM, it was only possible to mark and control the product path based on reports on paper and uploads from different programs. In an industrial environment, PLM combines all information about a product from the beginning of work on it, and provides data integration between engineering programs, planning systems, and production management. The relationship between multiple it platforms will help to avoid defects and to improve the quality of the product. Since all this happens in the same ecosystem, everyone who has access to the project will see any change that a colleague has made. No matter what distance the participants are from each other. PLM eliminates errors: designers, technologists, purchasing, and related departments are all located in the same information field.

Another factor that affects the speed of product creation is the complex geometry of product parts. When it is justified by the requirements for the technical characteristics of the product or its appearance, technologists look for production methods and methods of processing materials. It happens that the geometry can be simplified without losing the quality of the product, then technologists and designers discuss how to do it better. PLM includes a set of programs for calculating the parameters of design solutions. For example, the strength calculation system will show that the geometry of some part of the part does not meet the requirements. Because of this, the element may fail during operation of the product. After seeing this, the designer can change the geometry before passing the finished layout to the technologists.

4. Conclusions
According to the results of the study, the following conclusions can be drawn:

1) Industry 4.0 initiates a change in the strategic guidelines of industrial enterprises. Transformation of operational models into new digital models entails an identification of new effective models for the industrial development in new reality. Agile management is one of them, which basic idea is to adapt and rapid response to changes in the external environment, using their advantages as market opportunities;

2) currently, the development of industrial enterprise production is impossible without a clear understanding of all stages of the product management life cycle. So, PLM comes to the fore. PLM affects the ideology of creating a new product: to reduce the time to market and save resources, the system pushes to shift the labor intensity from the "production" stage to the "design" stage;

3) successful existing example of JSC Kalashnikov Concern of PLM implementation in the context of agile approach indicates the possibility of improving the state of the Russian industrial sector and, in general, the prospects of this concept in Russian economy. JSC Kalashnikov Concern can be competitive in the global industry;

4) when all stages of the product lifecycle are automated, engineers will be able to devote more time to the question "what do you need from the model?". The question "how to achieve this?" will take a back seat and will be provided with PLM. The lack of a framework in the thinking of inventors brings us closer to the era of the smartest and most complex machines in the history of mankind.
A special value of the work is the described aspects of JSC Kalashnikov Concern’s case study. This example is significant in the context of the author’s research of enterprises in the industrial sector of Russia. It makes possible to highlight the distinctive features of the development of Industry 4.0 in Russia. The study is a value for researchers in the field of digital transformation of industrial enterprises due to requirements of Industry 4.0 across the globe.

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