LEAN ORGANIZATION OF ADDITIVE MANUFACTURING OF AIRCRAFT PURPOSE PRODUCTS

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Abstract: This study considers the question of creation of a modern small aircraft purpose parts manufacturing company which will use additive technologies according to the principles of "smart" production and the concept of «lean» management. In order to reduce time and cost of current production, conform to world technologies and competitive ability optimization of key business processes of the foundry was carried out with adoption of a model of additive manufacturing.

Keywords: business process, additive technology, product life cycle, optimization, "smart" production, lean management

1. Introduction

The early 21th century is characterized by the third industrial revolution. This, of course, affected performance of manufacturing facilities. A behavior of demand both for industrial goods and for strategically important products, such as aircraft units, is changed, customers want to quickly get unique items made of new materials equivalent to international competitors. Traditional manufacturing techniques passes into the background, manufacturing systems require using of additive technologies for rapid adaptation to current demand and reduction of production cycle duration.

Today the following basic concepts of enterprise activities development are formed: industrial use of additive technologies (3D printers), creation and application of new materials, manufacturing automation, energy efficiency. All this implies dynamism of production systems functioning - speed of passing of products from a concept to the market, flexibility to demand changes in order to increase competitive ability of the Russian engineering industry [1]. And this, in turn, will lead to a change in business models of enterprises, corresponding to production systems of international standard.

A change of production system of an enterprise business model requires its operational optimization. The main tools of optimization are: supply chain management (product lifecycle management), capacity optimization, adoption of “new” technologies and outsourcing. “Smart” production is the production, where a system solution is used for enterprise management based on an integration of IT technologies, constructing the following chain of CAD/CAE/CAM/PDM/FRP/MRP/MES/PLM/ERP systems [2].

When constructing such production it is necessary to have an electronic model not only of products, but also a model of the whole production system. That means the organization of a single information space of design and production of products based on their electronic models and optimization at all stages of the life cycle. In addition, determination of the efficiency of production requires regular condition monitoring and operational planning using modern simulation techniques. The defining purpose of “smart production” organization is improvement of efficiency of pre-production and production itself. The basis of “smart production” is “lean” manufacturing management. Production systems management using this principle will lead to reduction of production lead time by getting rid of losses.

Modification and optimization of existing business processes is performed at the expense of re-engineering. An organizational and management system of an industrial enterprise in the concept of re-engineering was founded by Adam Smith. When constructing the system some theoretical and practical problems should be solved, the main of which is system management and organization, and implementation of information technologies.

Another direction of pre-production optimization is Lean Production. This is the Japanese concept of production organization, which allows to reduce labor, time and space expenditures, with an increase of efficiency and minimization of manufacturing defects using supply chain management, the Japanese Kanban, Kaizen, Poka-Yoke principles the purpose of which is to remove actions which do not have any incremental benefit for the enterprise [3].

The aim of this work is to develop a configuration of a new production system of a small innovative engineering enterprise for the production of aviation products in order to increase operational efficiency and eliminate "bottlenecks" through the introduction of lean principles and modern methods of manufacturing systems modeling.

2. Methods

For the organization of an innovative engineering enterprise, we use a concept of e-Manufacturing. This is a combination of additive and modern technologies of product lifecycle management (PLM-systems). Primarily this means the possibility of production of products with a high degree of complexity which cannot be obtained by conventional serial products production methods. The process is fully automated and implements new production models, such as decentralized production. Many large mechanic and aircraft engineering companies have already adopted the e-Manufacturing technology in their future production strategy. The general concept of “smart production” on the basis of the principles of e-Manufacturing is aimed at integration of computer models of physical objects and processes.

The first step of creation of the like enterprise is a phase of transition from traditional technologies to additive. Let us consider the role of additive technologies in the model of “smart production” in more detail. There are a lot of products with complex geometry, made of special materials in the aeronautical engineering, aerospace industry, power engineering and other industries. It is here where there is a need of “direct cultivation” of products as an alternative to traditional manufacturing methods. Often, the motivation here is not an opportunity to create something unique, with unusual properties, but economic feasibility. In some cases, objective calculation of the real cost shows that additive technologies are less expensive than the traditional ones.

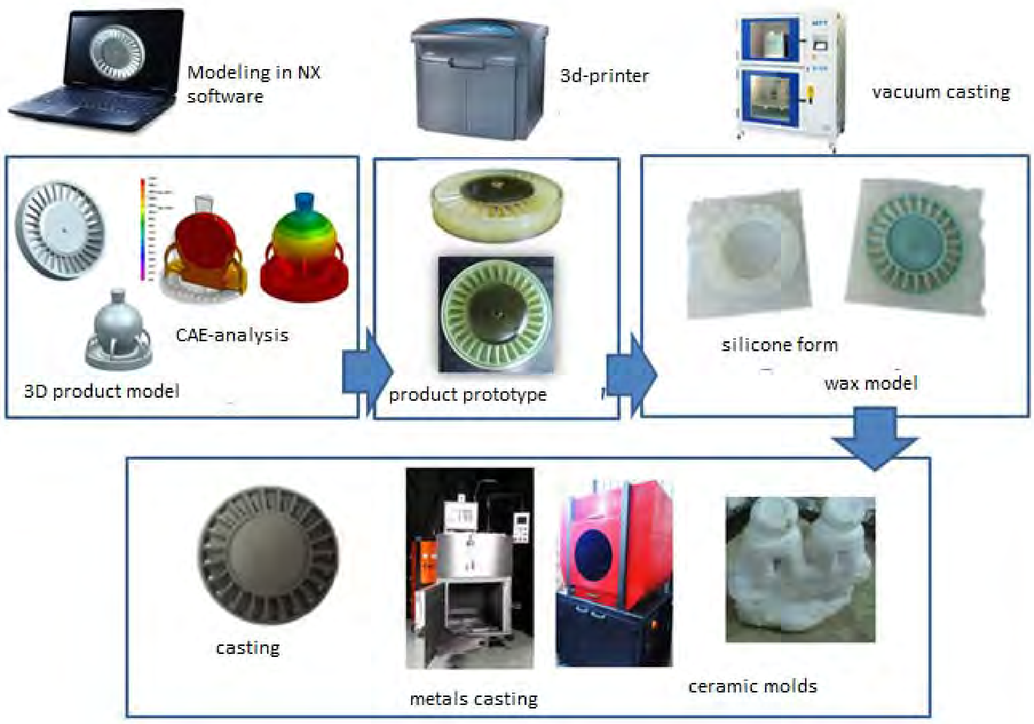

Fig. 1. Turbine wheel of manufacturing technology

In the laboratory of additive technologies of SSAU we carried out an experiment of replacement of the traditional turbine wheel (BLISK) of mini GTE manufacturing technology by a technology using rapid prototyping, the production procedure is shown in Figure 1.

As a result defect ratio was significantly reduced; product weight was reduced by 21%. This technology has an absolute advantage over the traditional one because of reduction of the time and cost of research and development work. Multivariate researches and rapid prototyping promoted faster release of new products, products of various modifications. Savings in production time was 24 days. With the adoption of rapid prototyping, we have eliminated “bottlenecks” in the technology of BLIC production, reduced WIP, increased productivity and capacity.

After this technological modernization we carried out a study of business systems of the production system based on the method of valuestream map construction (“value stream”) in order to optimize, reduce costs, and organize the production, working on the principle of “just-in time”. The “just in time” principle implies a greater production flexibility, which is achieved by reduction of time of new production launching and inventory, efficient capacity utilization, which is provided through labor costs reduction, delivery of materials calculation depending on the needs, special arrangement of production facilities, etc. [4-6]. Thus, the production system flexibly responds to demand (order) signals and produces only the amount of products to ensure distribution.

Today economic benefits of "smart" production are not entirely clear. Under certain conditions, the traditional approach of production organization may be cheaper than high-tech solutions. Therefore, to construct a similar enterprise SWOT-analysis was conducted (Figure 2).

Strengths	Weaknesses
Automation of production and product lifecycle management;	Electronics dependence;
More efficient use of production capacities;	System reliability and safety
Adaptability of production systems;	Dependence on information technologies and their manufacturers;
Work in integrated information space;	
Introduction of new technologies	
Opportunities	Threats
Downtime, losses, costs reduction;	Risk of disabling of large areas of infrastructure due to hardware malfunction;
Transfer to new production process planning and monitoring standards;	Return on investments in new equipment;
Production flows management	Commercialization of operating results

Fig.2. SWOT-analysis of "smart" production usage

3. Results

At the stage of analysis of business processes of traditional production of aircraft purpose products in the foundry a Sankey chart was built; this diagram allowed to visualize physical movement and distance in a business process, Figure 2, within a short period of time, analyzing a considerable amount of engineering information. It can be seen that monthly production was 84 castings. Design-engineering preparation is ignored in this chart.

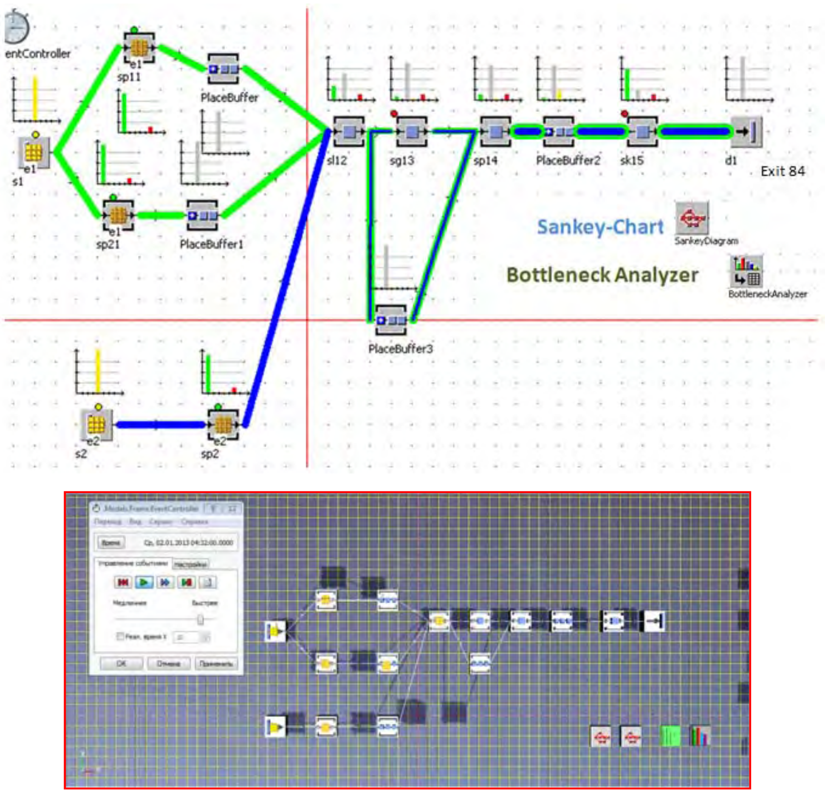

Fig.2. Sankey chart, sp - areas of technological operations: s1 - stock collection, sp1 - model compartment, sl12 - form cover production, sg13 – calcining-charging area, sp14 – heat treatment and fettling area, sk15 - defect correction and control, d1 - warehouse , placebuffer – areas for blanks stockpiling.

When constructing new business processes of additive production a value stream map was compiled. This map showed each stage of materials and information flows movement according to a selected order (work on a “BLIK” workpiece - casting) in Tecnomatix Plant Simulation by simulation modeling, showed the production cycle for very operation in order to identify "bottlenecks" of the production process (Figure 3). We should note the places of the map, where there are "kaizen" and "expectation" sign, these subsystems should be optimized [7].

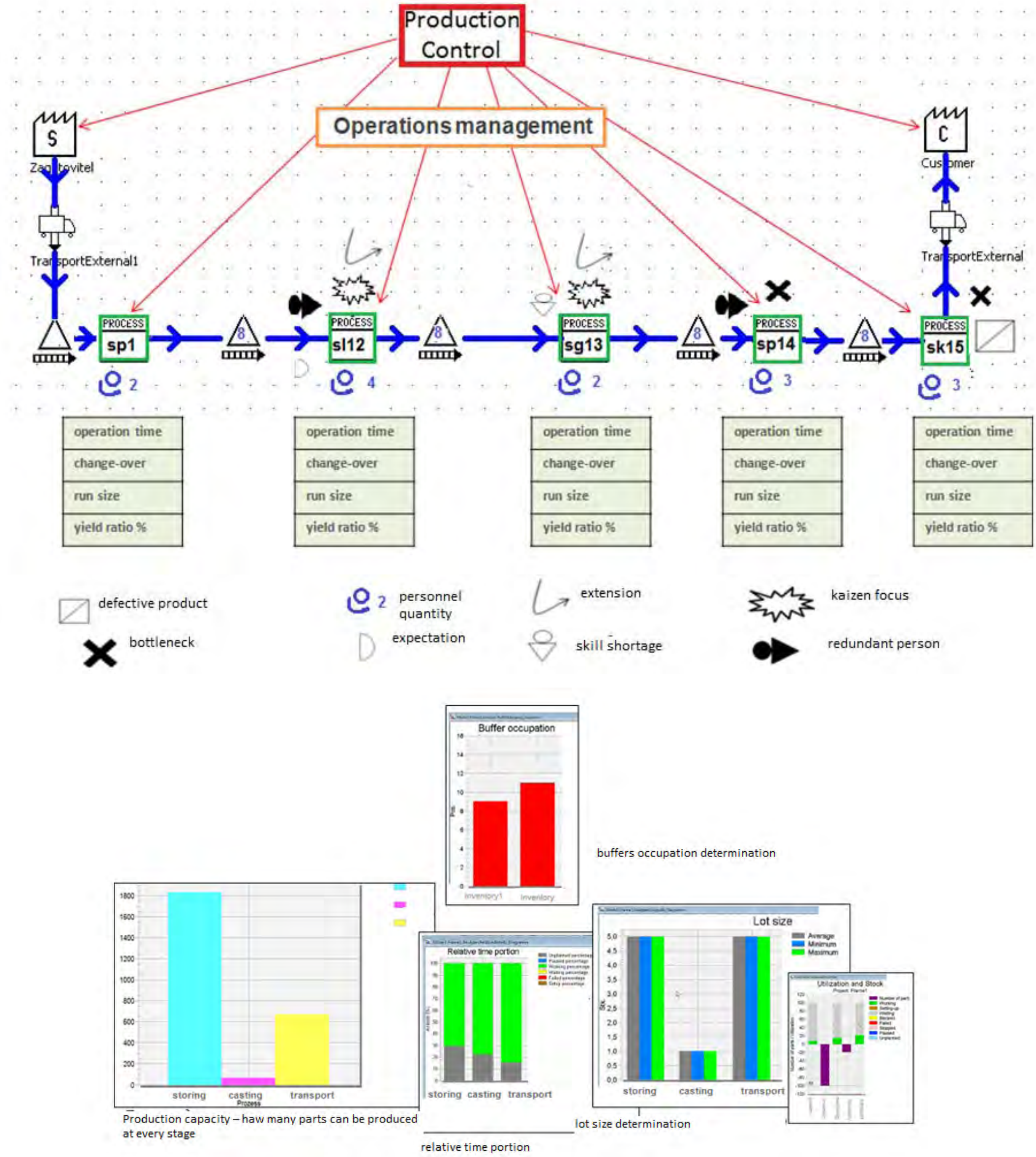

Fig. 3. Analysis of current business processes

According to the obtained data the total duration of the traditional production process of part processing is 695 minutes. Moreover, the cycle time, i.e. the time of value adding is 115 minutes, only 16.5%. This means that the manufacturing process has a large part of losses. Production losses are so large that the process under study requires optimization in time and space. The most significant amount of time is spent for storage operation - 210 minutes 30.2% of the total time. We created a value stream map of a future state of the parts production process, in order to reduce the identified losses. Key indicators of future state map - table 1.

Table 1 – Value adding map

Indicator	Current state	Planned state
Time of value adding	695 min	420 min
Total time of operation	115 min	360 min
Transportation	50 min	15 min
Readjustment	320 min	35 min
Storage	210 min	10 min
Stock	965 pcs	10 pcs
WIP	250 pcs	5 pcs
Number of operators	14 persons	5 persons

The production time portion increased to 86%. Thus, the flow value increased by a factor of 5.2. Among overheads storage time was reduced to 2.4%, the time of readjustment - to 8.3%.

In lean management an information flow is considered to be as important as the material one. The information flow should be organized in such a way that every process executed only what is necessary for the following process [8]. Figure 4 offers an information model of a small innovative enterprise realizing rapid prototyping technologies for production of aeronautical products (mini GTD, BLISK detail). All stages of development and production of the product were carried out in a single information space on the basis of CAD /CAE/CAM/PDM/PLM-systems.

In addition to the technological reorganization computer engineering was carried out, since the development of high-end technologies and the organization of a processing chain involves creation of a "digital / smart" production. And this is basically an integrated solution of problems of design and technological engineering considering the collaboration with engineering data (PDM-systems). On the platform of Siemens Teamcenter PLM system we managed to combine single management of products data of the designed enterprise, including visualization, data exchange, quality management, strategic planning, and projects execution control. For workflows modeling, documents routing, implementation of changes schemes and approval of documents of Teamcenter "Designer processes" usage. The main application was the "Parts production process planner", where interplant routes were indicated, technological processes of engine basic units production were developed (machine processing, die forming, casting). By the integration with NX CAM, we provided a two-way communication between Teamcenter engineering process operations and NX CAM processing operations (equipment, tools, jigs and fixtures, machining conditions, tool application geometry, setup sheets, etc.).

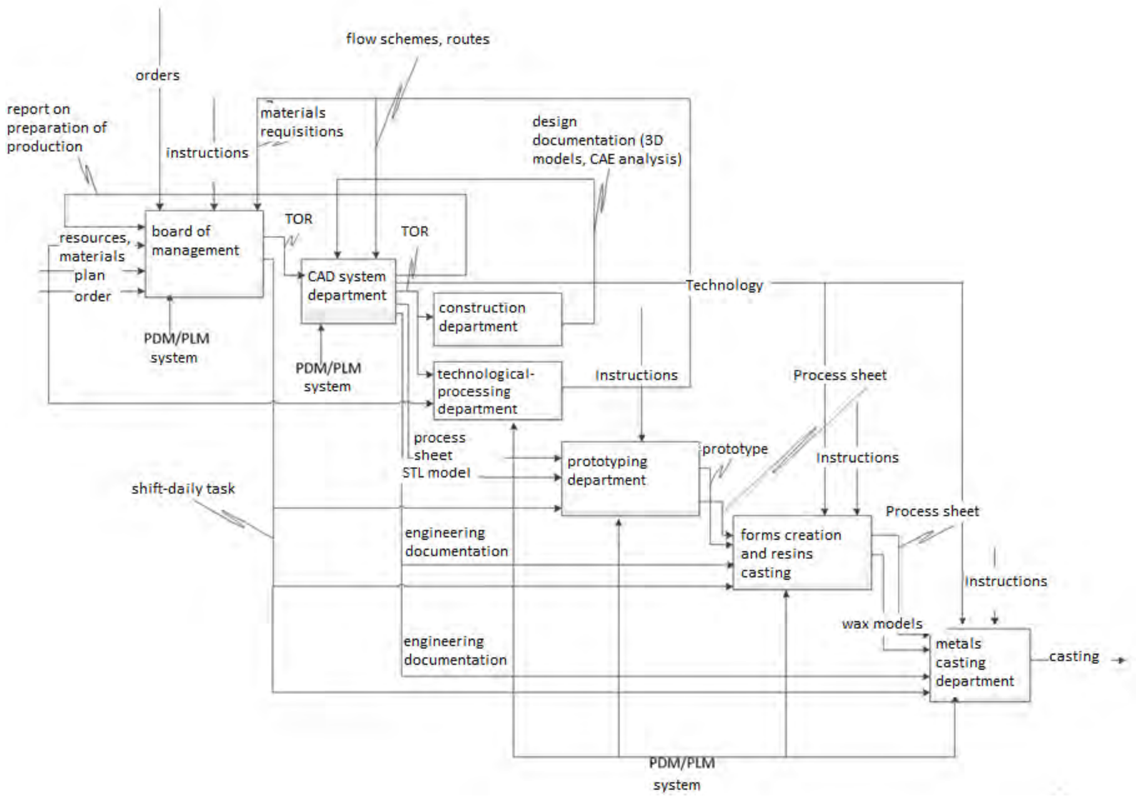

Fig.3. Information models

5. Conclusion

Thus, the main advantages of the constructed system of a small innovative enterprises are in the high-speed and cost-effectiveness of production of fully functional components / prototypes with complex geometry for the aircraft industry. Furthermore, there is a possibility of material consumption and weight reduction, manufacturing of a small lot of details of specific modifications. Analyzing and optimizing business processes of the traditional production method of a selected part we have built the system of its "smart" production using the concept of e-Manufacturing and visualization of product life cycle.

6. Thanks

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