Processing of design and manufacturing workflows in a large enterprise

Alexander Afanasyev[1], Maria Ukhanova, Irina Ionova, Nikolay Voit[1][0000-0002-4363-4420]

[1] Ulyanovsk State Technical University, Ulyanovsk, Russia
{a.afanasev, n.voit}@ulstu.ru, mari-u@inbox.ru, epira@mail.ru

Abstract. The paper deals with the problem of design and manufacturing workflows in a large enterprise. As an example of a workflow, we presented the author's model of coordination of design documentation (DD) based on the Petri net. The model was analyzed for possible errors in system designing.

Keywords: Workflow, Process, Manufacturing.

1 Introduction

In the modern world, any large enterprise requires the design and manufacturing production planning to be faster for launching a product to market as soon as possible, for improving product's quality, and reducing production costs. Today, it is impossible to fulfill these requirements without end-to-end design technology, which is based on computer-aided design of technical documentation, project management systems, electronic document management, and a single information space. In order to solve these problems, many software products are developed. These are CAD\CAE, CAM\CAPP, PDM\PLM, and ERP systems. The diagram of the relationship between these systems is shown in Fig.1.

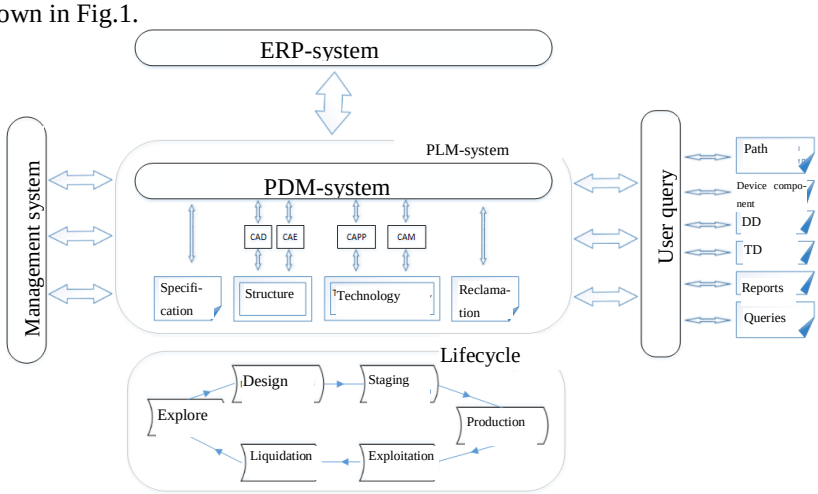

Fig. 1. The diagram of relations between CAD, CAM, PDM and ERP systems.

Modern CAD systems include several interconnected components. First of all, these are Computer Aided Designed (CAD) used for designing documents and Computer Aided Engineering (CAE) used for engineering calculations. In Russia, typical CAD / CAE systems are Kompas-3D, T-Flex CAD, T-FLEX Analysis, Solidworks, Altium Designer, Autodesk Simulation, Unigraphics NX CAE, etc. Several other tools for the design of technological documentation, which include the means of automated development of technical processes CAPP (Computer Aided Production Planning) and means of automated production - CAM (Computer Aided Mechanical). Typical representatives of CAPP systems for the Russian market are Vertical [29], T-FLEX Technology [30], ADEM TDM [31], Sprut TP [32], etc., and CAM systems - Unigraphics NX [33], CAM350 [34], etc. PDM-systems (Product Data Management) act as a single information space in which the developed technical documentation and electronic structure of a product are stored. PDM technology allows managing the product structure and projects and provide multi-user access to documents in real-time. PLM-systems (Product Lifecycle Management) present a technology of managing the entire lifecycle of a product. It is a software solution that controls engineering data and information of a product, and also manages all product-related processes throughout the lifecycle of a product, from its conception, through design and manufacturing, to the end of a product. Today, many such systems have been developed by Russia and other countries: Loodsman-PLM, T-Flex-PLM, Siemens-PLM, Lotsia PLM, etc. Such PLM-systems are very effective for end-to-end design and allow a design development of a 3D model of a product to integrate into manufacturing production planning, which leads to time-reduction in design and manufacturing production planning (DMPP). ERP-systems (Enterprise Resource Planning System) are systems of planning and production management. Such information systems are used to control and plan the resources. They are used by enterprises for procurement and accounting of raw materials, production management of a product, task planning for workshops. Alpha, Lotsia ERP, 1C ERP, SAP can be used as examples of ERP-systems.

Faster coordination process of design and manufacturing documentation is based on the creation of workflows. The introduction of workflow technology in an enterprise allows one to formalize the structure and sequence of documentation passing procedures. Business effects statistics from the introduction of workflow technology are presented in Table 1 [1-14]. However, product lifecycle management systems do not always meet the needs of many large enterprises. The workflow in PLM-systems is often too closely related to the flow of information and with low agility to make alternative decisions in real-time. These factors always lead to excessively long and costly cycles of workflow system implementation, processes' reengineering and systems' reconfiguration. The processes of reengineering are not only slow and expensive, but also often impossible.

Table 1. Statistics of business effects from the introduction of end-to-end workflow technology [28].

Business effects	**% improvement**
Reduction of quantity errors in technical documentation	by 70 **%**

Time-reduction in design and manufacturing production planning (DMPP)	by 20-60 **%**
Cost-reduction in preparing and issuing technical documentation	by 40 **%**
Time-reduction in searching information	by 40 **%**
Time-reduction for documentation coordination	1,5-7
Faster time-to-market	by 25-75 %
Reduction in reject rate	by 40 %

Moreover, most workflow systems allow modeling workflows, but they lack effective methods for verifying the diagrammatical models of workflows and associated semantic components as texts and program modules. These problems will be discussed below.

The purpose of this paper is to develop a model for coordinating design documentation in the form of a workflow and analysis of this model. The design tools of ASCON and RC ASCON-Volga are used as a basis for representation, development and maintenance.

2 Features of design and manufacturing workflows in a large enterprise

Each enterprise has its own characteristics in products' production [15-26]. For large enterprises is typical:

- a large number of nomenclature positions for manufacturing;
- short terms for production planning;
- design documentation of in-house and external developments;
- a long cycle of design documentation coordination and changes;
- production according to 2D drawings;
- a large organizational structure of the enterprise;
- complex interaction between units.

Large industrial enterprises producing mainly special purpose equipment use 2D models mainly. In this case, designers draw a 3D model just to understand the design. Based on the documentation in 2D, production engineers develop their own 3D models in order to describe the technology or develop a control program for CNC machines. It makes the development time longer.

It should be noted that it is necessary to detect errors at the design stage as early as possible. As you know, the later an error is found, the more expensive it is to correct it. The most expensive errors are those introduced at the production stage. But also, at the development of the product manufacturing technology stage, errors in engineering lead to an imminent delay in the design-engineering preproduction, since the designer will have not only to develop a product change, but also to coordinate it, and this takes considerable time.

Therefore, the trend of end-to-end manufacturing solutions based on 3D models and workflow management systems is gaining momentum. Fig. 2 shows a 3D model of the gear's motion (from designing to technology) [14].

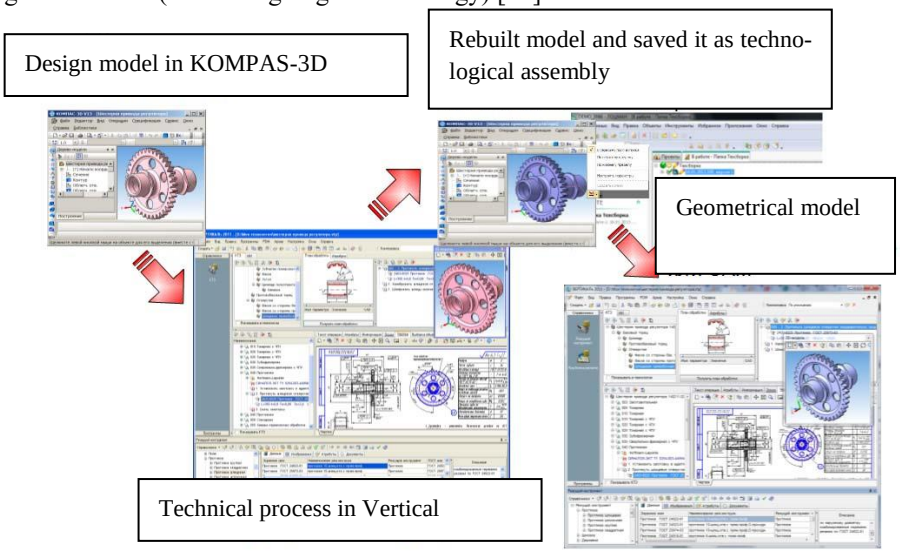

Fig. 2. A diagram of a 3D model of the gear's motion (from designing to technology).

3 Design stages in design and manufacturing workflows

We propose the following design stages in design and manufacturing workflows:

- a formal description of main business processes of design and manufacturing pre-production;
- workflow model building based on a formal description of business processes;
- an analysis of developed model properties of a design and manufacturing workflow;
- a data processing error analysis.

Below, the design stages in design and manufacturing pre-production will be described more detailed.

4 Structural-functional diagram of design and manufacturing workflows

The effective interaction of all enterprise's units and structures makes this enterprise more effective. Data flows displaying the essence of the production process move along the chain.

In order to describe design and manufacturing workflows of any enterprise, we should identify the main processes of design and manufacturing pre-production. Fig. 3

represents a developed processes diagram of design and manufacturing pre-production, which is one of the examples of normative design workflows.

In this diagram, we identify two major workflows, which deal with the design and manufacturing pre-production processes. These processes solve different problems, and the successful mastering of a new product is their goal. Let us consider them more detailed.

The design processes of pre-production workflows include the solution of the following problems:

1. Identify the requirements for a new product.
2. Analyze a new product nomenclature.
3. Schedule the works on mastering or developing a new product.
4. Analyze customer claims.
5. Identify the requirements for a malfunction repair.
6. Develop and coordinate technical specifications for work.
7. Develop and coordinate design documentation (DD).
8. Develop and coordinate DD correction.

The manufacturing pre-production succeeds after the design pre-production. Manufacturing pre-production workflows have to solve the following problems.

1. Analyze the possibility of manufacturing a new product.
2. Analyze the equipment for manufacturing a new product.
3. Make a decision of the equipment procurement.
4. Schedule the work for developing a new product manufacturing technology.
5. Develop a route for making a nomenclature of product components.
6. Develop a manufacturing process with control programs.
7. Determine the labor-intensive manufacture of a product.
8. Set norms of direct materials of a product nomenclature.
9. Development of industrial equipment.

It is easy to understand that the workflows are interrelated.

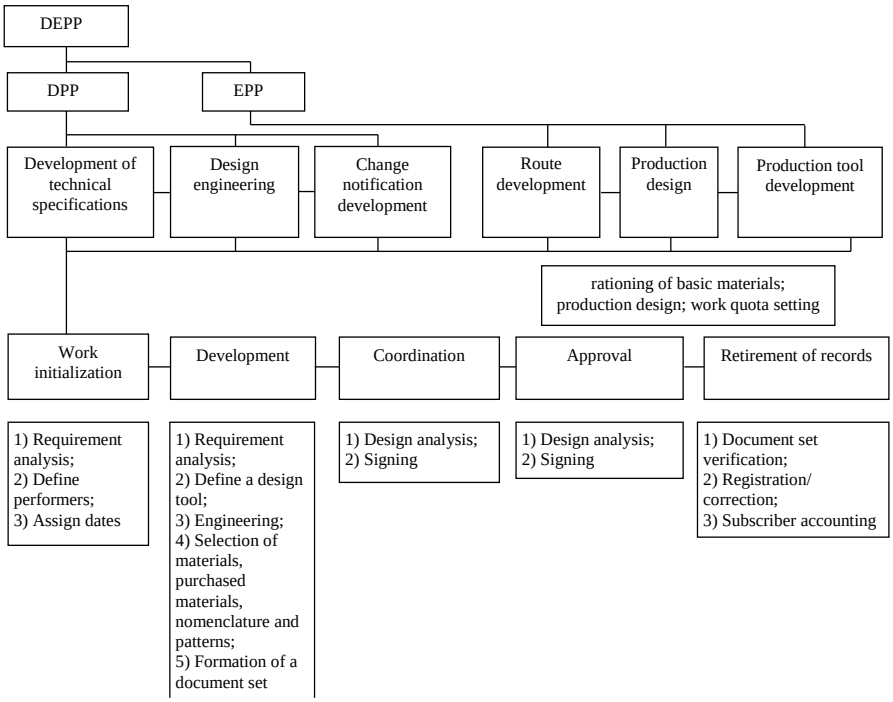

Fig. 3. Diagram of processes of design and manufacturing production planning

5 Modeling a standard workflow of design documentation coordination

Let us consider one of design pre-production tasks in order to create a model of design and manufacturing workflows: a standard process model for detailed design documentation coordination.

In order to build a model, we designed a business process for the DD development and coordination, defined the rules for the CD set's formation, chose tasks, and identified their performers. A special software called Workflow Designer of Project Management System (PMS) by RC Ascon-Volga was used as a tool for designing a workflow model.

We built a sequence of tasks; developed scripts in order to change the documents' states in the coordination process and filling the matching attributes in Loodsman: PLM. Fig. 4 represents the workflow model for the DD development and coordination in the specialized language of PMS.

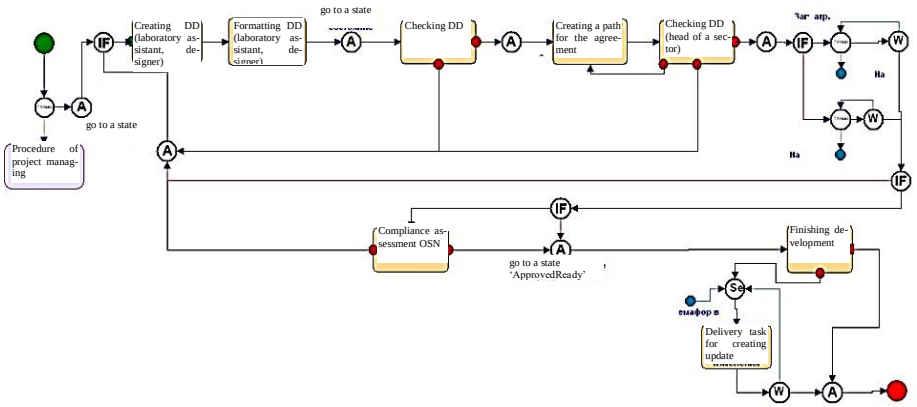

Fig. 4. Model of design coordination of DD in the specialized language of the ASCON-Volga company.

We use Petri nets in order to simulate a process of design coordination, and evaluate properties as safety, liveness and deadlocks. Petri nets were used to analyze the developed model for DD coordination (Fig. 4). The model was developed in Visual Object Net ++. The design documentation coordination model based on Petri nets is shown in Fig. 5.

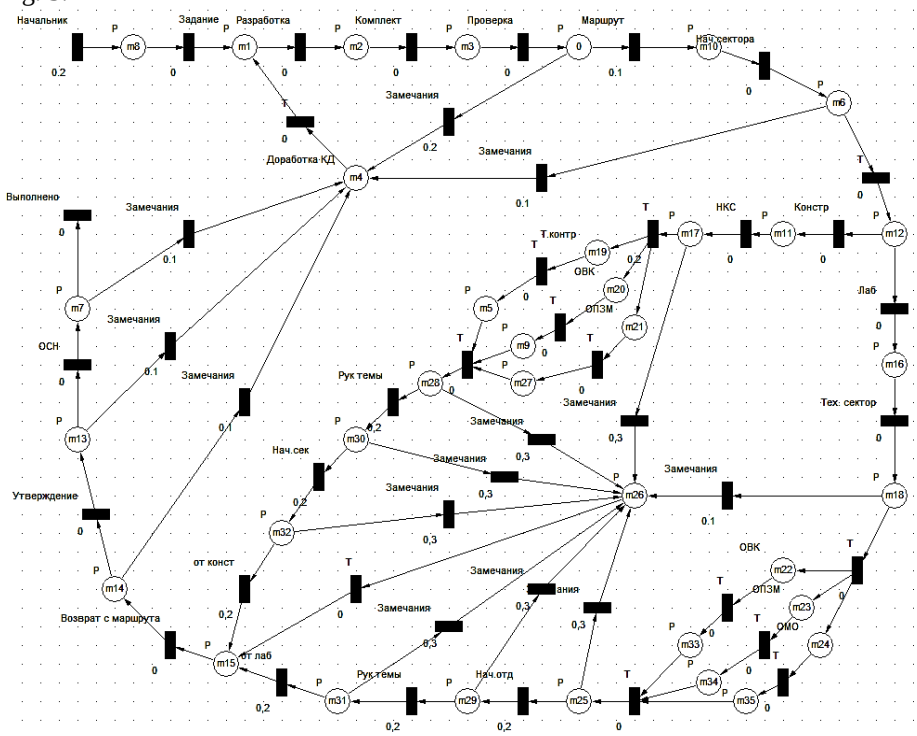

Fig. 5. Model of DD development and coordination.

6 Analysis of workflow model properties of DD coordination

The developed model of design documentation coordination was tested in the specialized software Visual Object Net++. The model was tested for the following properties:

- reachability - it establishes that the final state of the system will be achieved in any sequence of transitions from *i* position. This property also means that when the end position of this network is reached, there are no chips in the intermediate positions;
- safety – it establishes that there are no deadlocks, loops, dead ends in the processes;
- liveness – it establishes that the system does not contain unnecessary positions that will never be fulfilled. Lack of liveliness means either redundancy of a business process in the projected system, or indicates the possibility of loops, dead ends, locks.

The analysis of the workflow model of the design documentation coordination, presented in Fig. 5, showed that some properties of the network depend on the qualification of a designer. So:

- The model does not have a very good reachability property, since it may accumulate chips in m_1 position. The number of chips that can accumulate in the specified position depends primarily on the qualification of a designer who develops the design documentation. The lower the qualification of a designer, the more times the documentation will be returned for revision, which means that the more chips will accumulate in m_1 position;
- The model has a good liveliness property, because there is no redundancy in the business process. This property also depends on the qualification of a designer. The higher the qualification of a designer of design documentation, the smaller the "liveliness" of the workflow, since many operations associated with the completion of the design documentation will not be performed;
- The model has a good security feature, since there are no hang-ups, loops, dead ends and locks.

As a result of the analysis, a paradox of the liveliness property was discovered. It is traditionally believed that the higher the indicator of the liveliness property, the better the system model was developed. However, in reality, the higher the qualification of a designer, the less errors he makes, and the documentation is less often sent for revision. Therefore, it is better for a design and manufacturing production planning. As a result, the model blocks responsible for sending the design documentation for revision are used less often. And this leads to a deterioration in the quality of liveliness.

It should be noted that any process of coordinating documentation, both design and manufacturing, contains blocks of code that allow you to operate objects, their states and their attributes in the process of coordination. For example, changing the state of an object in the coordination process, for managing its lifecycle, or filling in an authorization signature at the coordination stages.

As you know, any program code can contain errors. And the more lines of program code, the more errors a programmer can tolerate. Errors are divided into two types: syntax errors or semantic errors. Syntactic errors can be easily identified, any compilers

of code or specially written unit tests do this. Most of these errors are detected at the time of writing the code. And if syntax errors are found and fixed quite easily and quickly, it is very difficult to identify semantic errors, since they often occur at the stage of the application execution.

Semantic errors are divided into two groups.

1. Logical errors.

Errors of this type can be identified by constructing a logic model of the program code. The analysis of the model will reveal deadlock situations, the feasibility of the program. This question is considered in detail in many sources, therefore methods of revealing such errors in this paper will not be described.

2. Errors of data integrity.

Most errors of this type can be avoided if the architect of the information system intelligently projects data integrity constraints at the database level: determines whether the value of the attribute can be empty, sets foreign keys, imposes a unique constraint, and establishes the validity of the entered value. In some cases, this is not possible.

To identify errors of this type requires the development of a special software application that verifies the possibility of filling the attribute with valid values. As a method for determining such errors, it is proposed to use the Checklist, which lists all the necessary attributes of the coordination process. For example, when coordinating the design documentation, the list of attributes of the document is filled. For the correct operation of the program, you need to develop a Checklist, which lists the invalid errors.

Checklist of errors in the coordination of design documentation:

- check the presence of the specified attributes for all possible types of design documentation.
- check the mandatory attributes.
- check the documentation files.

Conclusion and future works

Features of design and manufacturing production planning in a large enterprise are analyzed. A structural and functional scheme of typical design workflows processes has been developed. A list of tasks to be solved in the process of design and manufacturing production planning has been determined. We developed workflow models for the development and coordination of the design documentation based on the specialized language Ascon-Volga RC and Petri nets, and also analyzed the workflow model of the design documentation coordination, which has the properties of liveliness, safety, and reachability. As a result of the research work, the analysis of the types of errors that occurred in verifying the diagrammatical workflow was made. The future directions of our work will deal with the development of methods for eliminating the errors of diagrammatical workflows, using the classification of permissible structural error types.

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