System analysis of the features of using information models in shipbuilding

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Abstract. One of the important tasks of the modern stage of development of the shipbuilding industry is the creation of an information model of the vessel and its systems using CAD, PDM, PM, PLM and ERP automated design systems for pre-production. The information model of the vessel and its systems is the most important step in the presentation of data about the ship in digital form during the design and preparation of its construction. Due to the fact that in the Russian shipbuilding industry there is still no common understanding of what the “ship information model” is, according to the authors, it is required to disclose this concept and determine the need to create and use the ship information model at all stages of the ship’s life cycle. The article provides a brief overview of computer-aided design systems used at enterprises in the shipbuilding industry, shows the advantages of using the ship’s information model over paper documentation, lists obstacles to the development of the ship’s information model as an optimization basis at all stages of the ship’s life cycle when all participants in the cooperation interact.

1. Introduction
The development of global transport systems is becoming a priority activity in business and politics of the leading countries of the world. For example, in the Russian Federation, water transport is one of such systems, the development of which conditions shipbuilding as a basic industry when introducing high-tech innovative technologies and modern production management into it. A shipbuilding corporation has been established and is successfully functioning, uniting leading shipbuilding enterprises and design organizations of both a central and regional nature.

The development of shipbuilding and its competitiveness are associated with a number of factors that reduce the cost of production. These should include reducing the cost of designing and building ships, in-depth specialization of enterprises, reducing the share of labor costs by increasing productivity while ensuring the required quality of products.

Reducing the costs associated with the design and construction of ships is impossible without the integrated use of information technology [1].

Thus, ensuring the competitiveness of products of the domestic shipbuilding industry in modern conditions of development of world shipbuilding, competition of manufacturers of marine equipment,
the growth of its high technology, increasing the information richness of projects is a highly relevant task.

In this regard, the creation and use by enterprises of the industry information model of the ship as an optimization basis for the design, construction, operation, repair and disposal of the ship in the interaction of all participants of cooperation is one of the most important conditions for the innovative development of domestic shipbuilding.

This study aims to identify the main conditions under which the use of the ship information model will be ensured as an element of effective interaction between enterprises, design offices and industry institutes.

To achieve this goal, it is necessary to analyze open domestic and foreign sources of information describing the main trends in the design and manufacture of modern ships, and it is necessary to pay special attention to the system integration of all stages of the object’s life cycle based on electronic models and ideas, as well as organizing joint projects in accordance with the concept of “virtual enterprise”.

2. Computer-aided design in shipbuilding
To optimize the process of creating a vessel, it is necessary to have highly efficient production for all participants in the process. For this, the production level should be increased both at the designer and at the shipyard. This is achieved through the introduction of information technologies - automation of production processes and design, planning and project management [2]. Key technologies for the successful application of information models in shipbuilding are:

- technology of forming a complete (geometric, physical and functional) electronic model of the vessel and its elements and systems;
- technology of electronic submission of information on ship systems, including design, engineering, technological, and other documentation;
- technology of integrated databases of ship systems, covering the development, storage, updating of information about the components of the systems at the place of its creation (design office, plant, etc.) and the system of authorized access of any of the project participants to this information;
- technology of integrated logistic support for the stages of operation, repair and disposal of the vessel and its systems.

Systems used in CALS technologies are divided into the following classes:

- CAD / CAE / CAM (Computer Aided Design, Computer Aided Engineering, Computer Aided Manufacturing) - product design, engineering analysis, processing technology;
- PDM (Product Data Management) - product data management;
- PM (Project Management) - project management;
- MRP / ERP (Management / Enterprise Resource Planning) - planning and management of an enterprise, its resources.

CAD / CAM / CAE systems are the core of CALS technology. Shipbuilding systems of computer-aided design are a wide range of modern software products for design, both specialized for shipbuilding and universal. CAD systems are widely used at all stages of the life cycle of ships, vessels, component equipment and products. To date, a large number of various CAD systems have been introduced and operated at the enterprises of the domestic shipbuilding industry, most of which are foreign-made systems [3].

Through the use of modern CAD / CAM / CAE-technologies, designers have the opportunity to create more and more complex engineering projects while reducing development time. With the help of these technologies, a single information space is formed - an information model of the vessel, in which all the design documentation is located.
The functional shipbuilding CAD systems are divided into three groups:

- special systems: Tribon, Foran, Catia, Unigraphics AutoSHIP, ShipModel, Defcar, Sea Solution;
- universal systems: Inventor, Solid Edge, Solid Works, Pro / Engineer, Sea Solid;
- systems for the preparation of working design documentation: AutoCAD, Compass [1].

The information model of the vessel and its systems is the most important step in the presentation of vessel data in digital form during the design and preparation of its construction.

The formation of the information model is based on the use of high-level automated CAD / CAM / CAE / PDM systems to support the activities of the enterprise-designer.

The first experience of using the full electronic three-dimensional description of the vessel was the model of the submarine SeaWolf, developed in the design process for the US Navy by Newport N.S. The model was a single object, including a three-dimensional representation of the submarine and its components, including 1.5 million units and parts. Currently, full electronic modeling of products is actively being mastered by aircraft manufacturers and shipbuilding enterprises.

Building an electronic model of the product involves the transition to a completely paperless design technology. Paper drawing and specification cease to be the main data carrier of the product. The electronic model made it possible to radically improve the design process in terms of ensuring the operational properties of the product based on the transition from a sequential design process to a so-called parallel design based on a comprehensive analysis of the electronic product model by experts in the field of vessel operation and repair.

The traditional approach, which corresponds to the paper technology of ship design, is the sequential execution of work by the designer, technologist, maintenance man, repairman. With the transition to electronic modeling of products such a process can be replaced by parallel (joint) work on the project of a designer, technologist, operator, repairman. The designer forms the first version of the electronic model of the vessel, and then the technologist, the operator and the repairman are connected to the work, analyzing the first version of the product, each from its own positions. This design method is a very effective method of improving production, operational and repair manufacturability, product testability, while reducing the design time. Even before the first part will be manufactured on the machine, the product will already be comprehensively examined for adaptability to operation and restoration, all the identified shortcomings will be eliminated.

The technology of parallel design was developed by the order of the Office of Advanced Military Projects of the US Department of Defense (DARPA) and in developed foreign countries is mandatory for military projects. Currently, it has become a standard in the commercial practice of developing high-tech engineering products. Commercial high-level design and production automation systems used by Russian shipbuilding enterprises (for example, CATIA, FORAN, Tribon, UNIGRAPHICS, CADAM, EUCLID, PRO / ENGINEER, etc.) allow organizing a parallel design mode, and enterprises are striving to master this mode in the form of parallel works of designers and technologists.

To date, full-scale use of CAD and general automation of enterprises of the domestic shipbuilding industry (“USC-Iceberg” Central Design Bureau, Severnoe Design Bureau, “Severnaya verf” shipbuilding plant, Production Association “Sevmash”, PHC “Zelenodolsk Plant named after A.M. Gorky” and others) allowed one to bring the design processes to a new level. To ensure the relevance of the electronic model data, it is necessary to accept the condition under which the model is unique for all and is not divided into “design” and “construction”. Fulfillment of this condition implies a departure from the method of construction “by place”. The development of a three-dimensional model with a high degree of detail and taking into account the parameters of the pipe bending and other equipment of the builder plant made it possible to use it as the main source of data for the design documentation. The degree of model content is such that each element of the model serves as a source of data for a different type of documentation (saturation drawing, specification for an electrical assembly
kit, cable magazine, interactive electronic manual, etc.). Due to this degree of elaboration of the model, design documentation can be released as soon as possible and with any degree of detail.

The model is created taking into account the optimal mutual arrangement of mechanisms, equipment, cable routes, piping systems and ventilation ducts, taking into account the ease of installation, fastening, maintenance and repair, as well as exploring the possibility of unloading equipment during repairs.

The study of the model in the early stages of design allows us to provide information to the construction plant for a preliminary assessment of the quantity, range and location of equipment [2].

Thus, information technologies have become firmly established in the arsenal of enterprise management tools of the domestic shipbuilding industry.

3. Information model of the ship as an optimization basis for modern shipbuilding

The information model of the vessel is a powerful and modern tool of the designer, technologist, customer, which allows one to significantly increase the efficiency of design, production and support of the vessel during operation. In terms of content, an information model is an object structure, described in the dictionary of the library of basic elements and necessary for the formation of mathematical models used in various design operations of the ship’s life cycle.

The currently used systems of geometric three-dimensional modeling are based on the construction of mathematical models of the external and internal surfaces of the product, each of its systems, subsystems, and individual elements. Special application programs allow you to simulate not only geometric, but also physical, operational properties.

The greatest effect from the use of an electronic model of the vessel is achieved by working out the internal layout, researching and improving its operational and repair manufacturability, testability, testing assembly conditions - disassembling units, modeling operational loads, consequences of failures, conditions of use, maintenance and repair of the vessel.

Thus, the spatial alignment of the elements of the vessel without the manufacture of physical models significantly speeds up and reduces the cost of design, and the cost of creating and maintaining an electronic model pays off at the stage of construction and operation.

For practicing maintenance and repair operations, electronic models of a human operator reproducing the physiological capabilities of a person are used. All these operations to refine the design of the product can be performed at the early stages of design, before the start of the physical manufacture of parts and units of the product, and therefore any design changes are carried out quickly and with minimal cost.

When performing design operations, the information model is continuously updated and modified. Such an update of the information model is carried out during the entire period of designing the vessel and its systems. At the final stage, the information model is a complete description of the design object in the formats of the internal presentation language and serves to generate documentation on it. According to the structure, the information model is a semantic construction with formally regulated sections of records, partially empty and to be filled in during the structural and parametric synthesis of the design object.

Electronic information (virtual) model of the vessel, formed during the design and construction, is the basis of information support of the vessel and at subsequent stages of the life cycle - during operation, repair and disposal. The main object providing information needs at these stages of the life cycle is an interactive electronic manual. It is a part of the electronic model of the vessel and its systems, formed during its design, contains the necessary information during the operation and maintenance phase and simulates the processes that are typical for the operation, repair and disposal phases of the vessel.

4. Regulatory support of CAD application

At various scientific and practical shipbuilding events, it was claimed that the three-dimensional design was included in the set of mandatory technologies in virtually all shipbuilding enterprises (including design bureaus and construction plants). At the same time, despite the insufficiently developed legal status of these models, their transfer from the designer to the plant has become the de facto standard.
Obtaining documentation by means of three-dimensional models (both graphical - drawings, and tabular - specifications, statements) is in fact a non-trivial task in the conditions of the need to comply with the current regulatory documentation [4].

Currently, the current standards for CAD are GOST 23501.101-87 [5], GOST 23501.108-85 [6], as well as GOST 22771-77 [7], which establish the basic requirements, determine the classification of computer-aided design and information support requirements. In addition, a number of guidance documents and recommendations, also developed back in the 1980s and 1990s, operate in this area. There is the inconsistency of existing standards for CAD with modern conditions and requirements for the regulatory support of the use of various CAD systems in a single lifecycle management system.

So, one of the problems in the application of heterogeneous CAD systems is the problem of information integration of the systems used, which began to be addressed abroad in the late 70s of the twentieth century. The way out of this situation in this direction is the use of a single data structure for transmission between different systems, since the common method of data transmission through two-way interfaces between various CAD systems does not allow one to fully implement the creation of an electronic-digital model due to the destruction of a number of logical connections between the components of objects, the complexity of monitoring the relevance and correctness of data [8]. Neutral data formats are STEP, IGES, XML, etc.

Standardization works within the framework of the concept of an electronic description of a technical product in a neutral format that contains all the necessary information about it and its subsystems in a form that is available for exchange between independent software products used at all stages of the object's life cycle are carried out by the International Organization for Standardization ISO. The mechanism for describing data in a neutral format throughout the entire product life cycle is established in the ISO / IEC 10303 Standard for Product Data Exchange (STEP) series documents.

In the Russian Federation, this area of work is handled by Technical Committee TK459 “Information Support for Product Life Cycle”, which has developed a number of standards of the GOST R ISO 10303 series, which are identical to the corresponding international standards.

To ensure effective intersystem interaction, the accumulation, structuring of electronic information about a product and the organization of distributed work with it, product data management systems (PDM) are created. PDM systems allow to translate electronic information into the category of the most important production resources of an enterprise, ensuring its safety, relevance, ease of access and reuse at all stages of the product life cycle from concept to after-sales service, anytime and anywhere [8].

It should also be noted that not a single Western “heavy” shipbuilding CAD system allows automatic or automated production of shipyard design drawings in accordance with the applicable standards that define the requirements for shipyard design documentation [9]. This problem should not be considered as a deterrent for the introduction of modern CAD systems, but as a basis for further standardization work in terms of revising the current regulatory documents of the ESKD and ESKD shipyards, bringing them in line with the requirements of international standards, since it is the ESKD standards that establish general rules presentation of design documents.

5. Conclusion
Today, in the arsenal of domestic shipbuilding enterprises there is a set of modern information technologies that serve and automate various ship production processes and ensure the interaction of design participants. The various technological environments created by enterprises of the industry make it possible to manage data and projects up-to-date. Existing systems provide enterprises with a powerful technological foundation and a vector of information technology development.

However, despite the fact that three-dimensional design has become the de facto standard in all shipbuilding enterprises, the Russian shipbuilding industry does not yet have a common understanding of what a ship’s “information model” is, each participant sees its cooperation in its own way [4].

This contributes to the imperfection of the current regulatory framework - the inconsistency of existing standards for CAD with modern conditions and requirements for regulatory support of the use of various CAD systems in a single lifecycle management system.
In the current situation, the main objectives in the field of regulatory support for the application of CAD in shipbuilding are the updating of existing regulatory technical documents, as well as the development of new documents defining the composition of the systems, requirements for compatibility and integration of various CAD systems in the lifecycle management system. Realization of these goals will allow regulating the use of information technologies, including CAD, at all stages of the life cycle, which will help improve the quality of life cycle management and reduce the life cycle cost of shipbuilding products [10].

Summing up, it should be noted that we are faced with a very serious task of creating a single “information model of the vessel” as an optimization basis for automating the design process. Creating a complete information model of the vessel and using it to develop a technology for assembling structures will fundamentally change the organization of production and the management system of the enterprise engaged in the construction of marine equipment. Previously, this was not possible due to the volume of data on a single product and the level of development of computer technology. Also, shipbuilding full-cycle CAD systems in the recent past (such as FORAN, TRIBON) could not work with the engineering part of the product [11].

Solving this task will allow us to come to a common understanding of the “information model of the vessel”, to form a general policy in the field of information technologies for all enterprises in the industry, which means that all design participants work in harmony. It will be possible to apply the principles of end-to-end design and create “virtual enterprises”. All this will lead to an increase in the competitiveness of domestic shipbuilding along with foreign ones, to a reduction in the labor intensity of design and production, as well as to a reduction in the costs and timing of production.

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