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INNOVATION IN THE DEVELOPMENT OF SHIP SYSTEM DRAWINGS AND SCHEMATICS

Introduction. Shipbuilding is one of the key industries of modern mechanical engineering, responsible for the production of vessels of various purposes: cargo, passenger, military, and so on. One of the most important stages of this process is the development of drawings and diagrams of ship systems, which include power plants, pipelines, ventilation, hydraulic, and other engineering systems.

The development of innovations in the creation of drawings and diagrams of ship systems has become a decisive factor in maintaining the competitiveness of shipbuilding enterprises. The gradual implementation of advanced technologies, investment in personnel qualification improvement, and optimization of production processes allow the industry to remain at the forefront of high technologies worldwide [1].

Drawings and diagrams perform the following functions:

- Clear visualization of design solutions.
- Integration of all systems on the vessel.
- Simplification of installation, operation, and maintenance processes.

Aim of the study. To reveal the main principles of creating ship system drawings, review modern tools and technologies, and assess their impact on the efficiency of the shipbuilding process.

The rapid development of design technologies has led to the emergence of new international standards in the shipbuilding industry [2]. It is important to study how these innovations meet international requirements, which contribute to navigation safety and ensure competitiveness in the global market. The development of drawings and diagrams of ship systems is a strictly regulated field, as design errors can lead to serious consequences for the safety of the vessel, crew, and passengers.

The main standards and regulations of the shipping industry [3]:

International Standard:

International Maritime Organization (IMO) — the main regulator responsible for developing norms to ensure the safety of navigation and environmental protection. Key documents for the design of ship systems:

- *International Convention for the Safety of Life at Sea (SOLAS):* requirements for fire-fighting systems, ventilation, emergency lighting, and more.
- *International Convention MARPOL:* regulates environmental standards, particularly for systems that handle oil waste and wastewater.

ISO (International Organization for Standardization) offers standards that ensure the unification of drawings and diagrams:

- *ISO 128:* standards for conventional symbols in drawings (e.g., symbols for pumps, valves, tanks).
- *ISO 10628*: requirements for the creation of process flow diagrams, including ship systems.
- *ISO 9001:* quality management system for drawing creation processes.

National Standard. Each country may have its own regulatory acts influencing the creation of drawings. For example:

- *GOST (CIS countries):* standards for conventional symbols and drawing formats.
- *DIN (Germany):* standards for manufacturing and designing ship system elements.
- *ASME (USA):* requirements for pipelines, fittings, and tanks.

Regulation oft Design Organizations. In addition to international and national standards, shipbuilding companies often develop their own regulations, taking into account:

- Specifics of the production process.
- Features of vessel operation in different conditions.
- Recommendations from equipment suppliers.

All these regulations ensure the unity of approaches to drawing development, which guarantees:

1. Compatibility of equipment: drawings from different suppliers easily integrate into a unified system.
2. Clarity of drawings: standardized symbols simplify work for technical staff.
3. Minimization of errors: standardization reduces the risk of design flaws.

This approach to standardization ensures high-quality drawings and contributes to the creation of safe and reliable vessels [4].

Analysis of Recent Research and Publications. Recently, increasing attention has been given to innovations in the creation of automated ship control systems, which include the automation of management and monitoring processes, as well as integration with cargo and safety management systems. These changes require new approaches to the design of drawings and diagrams.

Innovative technologies enable more efficient use of new materials for creating ship systems, which can significantly reduce weight, increase strength, and lower maintenance costs. Modern engineering solutions in the design of ship systems take into account new materials and constructions, improving both the economic and operational characteristics of vessels [14].

The use of innovative technologies in the development of drawings and diagrams significantly enhances the accuracy and detail of ship projects. Digital tools allow for easy verification of geometric characteristics, load calculations, and structural optimization, which is crucial for improving the safety and reliability of ship systems [5].

Innovations such as the use of computer-aided design (CAD) systems, 3D modelling, virtual reality, and technologies such as artificial intelligence and machine learning are actively changing the process of creating ship system drawings and diagrams. These technologies allow for a more accurate representation of complex ship structures, reducing the number of design errors and increasing the efficiency of development [6].

Main Body. The development of technologies has significantly transformed the process of creating drawings and diagrams for ship systems. Innovative tools and methods have enhanced the accuracy, efficiency, and speed of design, as well as provided opportunities for the integration of different systems and improved project management [7].

The increasing complexity of ship systems and the growing demands for their efficiency are forcing the shipbuilding industry to seek new approaches to design processes. Modern innovations (see Fig. 1), among which digital technologies stand out, are revolutionizing the field of ship system drawing and schematics [8].

Digital Technologies in Design

In modern shipbuilding, CAD (Computer-Aided Design) systems are widely used, enabling the creation of accurate three-dimensional models of ship components and systems. The use of programs such as AutoCAD, SolidWorks, and Siemens NX promotes the precision of drawings and provides the ability to quickly make modifications [9].

The application of software tools for design is the foundation of the modern process of creating drawings and diagrams. The most common programs include 2D and 3D CAD systems:

a) AutoCAD: used for creating detailed 2D drawings and basic 3D models of ship systems.

b) SolidWorks: allows the design of parts and components of ship systems in 3D (Fig. 2).

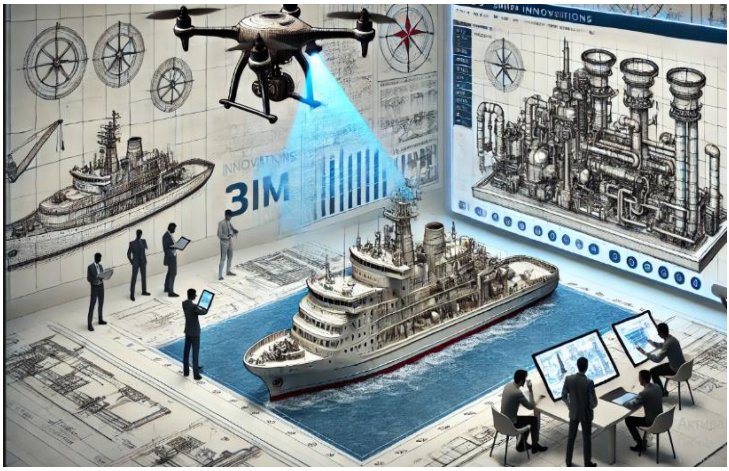

Fig. 1. Illustration demonstrating examples of modern innovations in the creation of ship system drawings and diagrams

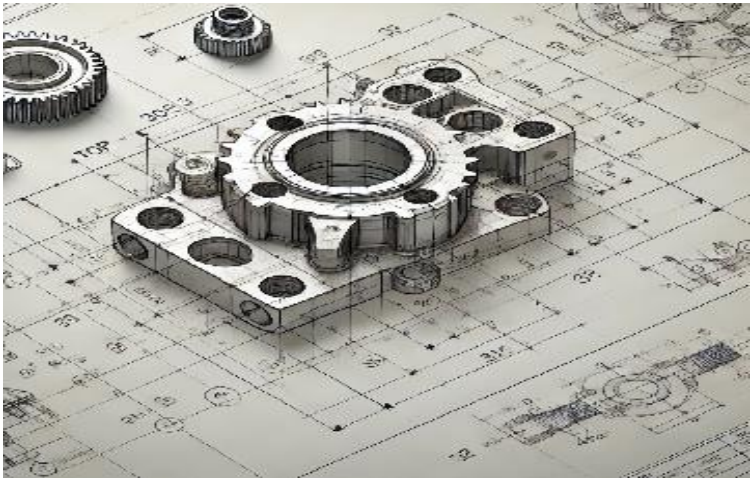

Fig. 2. Example of a modern technical drawing created using SolidWorks

Specialized Programs for Shipbuilding:

a) AVEVA Marine: enables the development of integrated ship models, including ventilation, piping, and fuel systems.

b) Ship Constructor: allows the creation of drawings for pipelines, electrical systems, and the ship's hull structures.

Software for Hydraulic and Pneumatic Schemes:

EPLAN Fluid: develops diagrams for hydraulic and pneumatic systems with integration of standard symbols according to international standards.

Software for Analysis and Simulation:

a) ANSYS Fluent: models fluid and gas flows in ventilation, cooling, or fuel supply systems.

b) CFD modelling (Computational Fluid Dynamics): used for analyzing the efficiency of systems.

BIM Technologies

More complex systems are oriented towards BIM (Building Information Modelling), which are successfully applied in the design of ship systems. BIM technologies allow for the creation of integrated schematics, reduce potential errors, and facilitate coordination among various specialists.

Integration of BIM Technologies (Building Information Modelling)

- *Lifecycle Modelling of Systems:* BIM enables the creation of digital models of ships that include all systems, from design to operation.
- *System Interaction*: All drawings are integrated into a single model, simplifying coordination between different engineering teams.
- *Automation of Updates*: Any changes in the model are automatically updated in the drawings and schematics.

Use of Drones and Scanning

The use of drones for surveying ship systems and laser scanning for collecting accurate data on existing components has gained significant popularity. This ensures high precision when creating drawings and schematics.

Automation an Artificial Intelligence

- *Drawing Generation:* Modern systems automatically generate drawings based on input parameters of the ship (length, tonnage, system type).
- *Error Checking:* AI-based tools analyse drawings to detect errors (e.g., incorrect pipe connections, excessive pressure in the system, etc.).
- *Optimization of Component Placement:* AI helps find optimal configurations for placing pumps, valves, and pipelines while minimizing material and energy costs [10].

Cloud Technologies and Collaborative Work

- *Cloud Data Storage:* Platforms like Autodesk Cloud and Bentley Systems enable the storage of drawings and provide access to them from anywhere.
- *Real-Time Collaboration:* Teams can work on the same model or drawing simultaneously, synchronizing changes in real time.
- *Data Protection and Archiving*: Cloud technologies ensure project backup and data security.

Use of VR/AR Technologies

- *Virtual Reality (VR):* Allows users to "walk through" the ship in a virtual environment, verifying the correct placement of systems and detecting potential issues at the design stage.
- *Augmented Reality (AR):* Engineers can view drawings and schematics directly on-site using tablets or smart glasses (see Fig. 3).

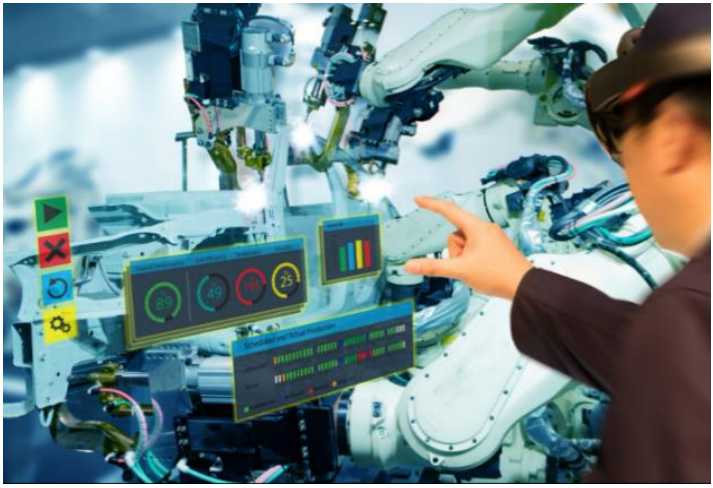

Fig. 3. Application of Augmented Reality (AR) and Virtual Reality (VR) Technologies in Shipbuilding

Use of Digital Twins

A digital twin is an interactive model of a ship that reflects all its systems in real time.

System condition monitoring: Engineers can track the operation of ship systems (such as fuel consumption or ventilation) and make timely adjustments.

Operational forecasting: Data from sensors is analyzed to predict potential failures.

Energy-Efficient Design

Design Flow optimization systems: Simulation software is used to minimize air or fluid losses within the systems. Selection of eco-friendly materials: Innovative programs assist in selecting materials with minimal environmental impact.

Examples of Innovations in the Development of Ship System Drawings and Schemes

To better understand the innovations, let's compare traditional approaches to developing ship system drawings and schemes with modern technologies. This comparison highlights the use of specialized software, cloud platforms, VR/AR technologies, and digital twins [11].

1. Design Software: A Comparison

Traditional Approach: Previously, ship system drawings were created manually or with basic 2D drawing software (e.g., AutoCAD for simple plans). This process was time-consuming and often lacked the precision needed for complex integrated systems.

Modern Software: Today, specialized programs like Ship Constructor, AVEVA Marine, and AutoCAD 3D enable the creation of integrated 3D models of ship systems. This significantly improves design accuracy and reduces the time required for drawing creation and modification [12]. The software also allows:

- Automatic generation of drawings based on given parameters.
- Early detection and correction of design errors.
- Simulation of system behavior in real-world conditions, considering physical constraints.

Example. Using AVEVA Marine for the design of ship piping and ventilation systems allows designers to quickly integrate various systems (electrical, mechanical, pneumatic) into a single model and verify their interactions during the design stage. This greatly reduces the number of errors during the installation phase.

Piping System on a Tanker

AutoCAD 3D allows for the creation of detailed models of piping systems, taking into account the ship's dimensions, equipment placement, valves, and connections.

- Features: 3D visualization shows the exact routing of pipes from pumps to tanks.
- Efficient clash detection identifies problems before installation.
- Easy modification: Engineers can adapt the project according to requirements.

2. Cloud Technologies and Collaborative Work

Traditional approach: Before the introduction of cloud technologies, designers stored drawings on local servers or physical media. This limited collaboration opportunities, especially when teams were spread across different geographical locations. Storage and access systems were less efficient, increasing the risk of data loss or mistakes due to unsynchronized project versions.

Modern cloud technologies: Today, cloud platforms like Autodesk BIM 360 and Bentley Systems allow real-time data storage, enabling all team members to work simultaneously on the project. Thanks to cloud services, the latest updates are immediately available, reducing the likelihood of errors and accelerating problem-solving.

Example. The Bentley ProjectWise cloud platform ensures effective project management for large shipbuilding companies. All ship system drawings—from structures to electrical and mechanical diagrams—are stored in a single database, allowing teams at different stages of design and production to quickly access the necessary information.

3. Virtual Reality (VR) and Augmented Reality (AR): Technologies in Ship Systems Design

Traditional approach: using traditional drawings and diagrams for ship system visualization was often limited and did not provide a full representation of the future vessel or its individual parts. This complicated communication between team members and clients, and made it harder to identify possible design flaws before production began.

Modern VR/AR technologies: Virtual and augmented reality systems enable the visualization of the ship or its individual systems in three-dimensional space, allowing engineers to "walk through" the future vessel and inspect all elements at real scale. Augmented reality also allows overlaying drawings onto the real environment, facilitating installation and providing visualization of complex elements directly on the construction site [13].

Example. Using HTC Vive in ship design allows engineers to "enter" the ship model, inspect the placement of ventilation systems, piping, and other equipment, and detect clashes or design flaws before the production of components begins.

4. Digital Twins: Advantages for Ship System Design

Without digital twins, the design of ship systems was limited to physical models and static drawings.

Traditional approach: Compliance checks and system testing mainly occurred after the vessel or its parts had already been built.

Digital twins are accurate replicas of real ship systems, created based on collected data and models. They allow real-time monitoring of the ship's condition, forecasting system behavior under different conditions, and testing new solutions without the need for physical prototyping. This is especially useful for ship systems where energy optimization and safety assurance are critical.

Example. ABB Marine Advisory uses digital twins to monitor ship system operations and ensure energy efficiency. This enables optimization of fuel usage, ensures the necessary air exchange, and tracks the wear of key components, helping to reduce vessel maintenance costs.

Container Ship Modernization

During the modernization of an old container ship, AVEVA Marine was used to create a digital twin of the vessel. This allowed for the effective upgrade of piping and ventilation systems, taking into account new environmental standards.

Results:

- A 15% reduction in operating costs through system optimization.
- Rapid adaptation to IMO 2020 standards with minimal expenses.
- Use of drones for 3D scanning of existing structures and integration of this data into AVEVA Marine.

Conclusions and Prospects for the Implementation of Innovations:

1. Modern innovations in the creation of ship system drawings and diagrams are significantly transforming approaches to ship design and construction. Transitioning from traditional methods, which involved manual drafting and static models, to the adoption of BIM technologies, cloud platforms, VR/AR, and digital twins, has greatly improved accuracy, efficiency, and safety.

2. The use of software that supports the integration of various engineering disciplines, along with the application of virtual and augmented reality, not only enables the creation of precise models but also allows testing under real-world conditions. Digital twins, as exact replicas of real systems, provide opportunities to monitor the ship's condition in real time and optimize its operation.

3. Thanks to cloud technologies, designers can work on projects from anywhere in the world, ensuring efficient collaboration and reducing the risk of errors. Innovations in shipbuilding lead not only to improved

design quality but also to lower maintenance costs and increased energy efficiency.

4. In the future, even greater integration of these technologies can be expected, optimizing all stages of a vessel's lifecycle — from design to operation. This will enable shipbuilding companies to create safer, more environmentally friendly, and more efficient ships.

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