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SYSTEM OF AUTOMATED CONTROL OF TANKER CARGO OPERATIONS

СИСТЕМА АВТОМАТИЗОВАНОГО КОНТРОЛЮ ВАНТАЖНИХ ОПЕРАЦІЙ ТАНКЕРА

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ABSTRACT

Liquid cargo is transported by the tanker fleet in different climatic zones. Significant changes in ambient temperature are observed in these zones. At elevated temperatures, the volume of liquid cargo will increase. Consequently, there is a risk of spillage of the cargo onto the ship's deck. The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) and the International Safety Guide for Oil Tankers and Terminals (ISGOTT) regulate the filling of tanks when transporting liquid cargo. It is allowed to use only 98% of the volume of tanks, the remaining 2% is a reserve of tank volume for an unforeseen increase in the volume of the cargo when its temperature rises. The sender of the cargo must provide the tanker captain with complete information about the cargo and its properties. After receiving it, download operations can begin.

The intensity of cargo operations when the tanker is loaded with various types of liquid cargo has led to an increase in the role of the "human factor" in ship power systems. Reducing the number of ship crews, in turn, contributes to the accumulation of fatigue, distraction of ship operators (masters) in the process of carrying out cargo operations on the ship. Watch assistants must constantly monitor the filling level of each tank, taking into account the weight, temperature and volume of the cargo.

Statistics state that a significant proportion of accidents when loading a tanker occur as a result of loss of control over the volume of liquid cargo that is taken into each tank of the vessel. The operator's lack of accurate information about the filling status of each tank at the current moment in time leads to the risk of its overflow. Such an overflow, in turn, can lead to the spillage of liquid cargo, for example, petroleum products on the ship's deck and the water surface of the port's water area.

At present, it is possible to monitor the level of liquid cargo in real-time using various models of liquid cargo level gauges: float, pneumatic, ultrasonic, magnetostrictive, microwave, and others. Creating a system that would allow for constant dynamic control of the volume of liquid cargo in tanks during tanker loading and would take into account all restrictions is a promising direction.

Keywords: liquid cargo, tanker, level gauges, safety margin, loading control.

РЕФЕРАТ

Наливні вантажі танкерним флотом перевозять у різних кліматичних зонах. У цих зонах спостерігається значні зміни температури навколишнього середовища. При підвищені температури буде збільшуватися об'єм наливного вантажу. Отже, виникає ризик виливання вантажу на палубу судна. Міжнародною конвенцією по запобіганню забруднення з суден (MARPOL 73/78) та Міжнародним посібником з безпеки для нафтових танкерів і терміналів (ISGOTT) регламентується заповнення танків при перевезенні наливних вантажів. Дозволяється використовувати тільки 98% об'ємів танків, залишок 2% – це запас об'єму танку для непередбаченого збільшення об'єму вантажу при підвищені його температури.

Відправник вантажу повинен надати капітану танкера повну інформацію про вантаж і його властивості. Після її отримання можуть розпочатися операції завантаження.

Інтенсивність вантажних операцій при завантажені танкера різними видами наливних вантажі призвела до зростання ролі «людського фактору» в суднових ергатичних системах. Скорочення чисельності екіпажів суден, в свою чергу, сприяє накопиченю втомленості, розсіюваню уваги суднових операторів (судноводіїв) в процесі проведення вантажних операцій на судні. Вахтові помічники повинні постійно контролювати рівень наповнення кожного танка з урахуванням маси, температури та об'єму вантажу.

Статистика стверджує, що значна доля аварій при завантажені танкера виникає як наслідок втрати контролю за об'ємом наливного вантажу, який приймається в кожний танк судна. Відсутність у оператора точної інформації про стан заповнення кожного танка на даний момент часу призводить до виникнення ризику його переповнення. Таке переповнення, в свою чергу, може стати причиною виливу наливного вантажу, наприклад, нафтопродукту на палубу судна та на водну поверхню акваторії порту.

В дійсний час контроль за рівнем наливного вантажу у режимі реального часу можливо здійснювати з використанням різних моделей вимірювачів рівня наливного вантажу: поплавкових, пневматичних, ультразвукових, магнітострикційних, мікрохвильових та інших. Створення системи, яка дозволила би здійснювати постійний динамічний контроль за об'ємом наливного вантажу в танках під час виконання завантаження танкера і буде враховувати всі обмеження – це перспективний напрямок.

Ключові слова: наливний вантаж, танкер, вимірювачі рівня, коефіцієнт безпеки, контроль завантаження.

Statement of the problem in a general form and its connection with important scientific or practical tasks

The growth of the transport processes, transportation of various types of cargo, including liquid, different liquids, has increased the importance of the "human factor" in the ship's industry. Reducing the number of ship's crew leads to the accumulation of fatigue, distraction of attention in the process of increasing the intensity of carrying out cargo operations. A significant share of tanker fleet accidents occurs as a result of overflows, breaches of safety requirements for storage and transfer, lack of ship staff knowledge. Lack of accurate information about the filling level of each tank at the current moment leads to the risk of overflowing of a separate tank, which, in turn, can cause the spillage of cargo, for example, petroleum products on deck and the water surface within the port's area. One of the effective methods of solving this problem, in our opinion, is the creation of a system that would allow automated control of the process for carrying out tanker cargo operations.

Analysis of the latest research and publications, in which the solution to this problem was initiated and the selection of previously unresolved parts of the general problem

Transportation of crude oil and petroleum products is regulated by international conventions and codes, and tankers transporting bulk cargo must be equipped in accordance with their requirements and recommendations [1, 2, 3]. The technology of transportation of four types of oil products on the tanker "JO PROVEL" is described in [4]. Transportation of liquid chemical cargoes is presented in the publication [5]. Regulatory documents provide for the use of only 98% of the tanker's cargo capacity to avoid the risk of spillage of oil cargo onto the tanker's deck or overboard, and to leave 2% for the expected increase in cargo volume when its temperature rises. To achieve this goal, the ship administration during the loading of the ship must carry out constant control over the filling of the tanks. Different types of level gauges (level gauges) are used to determine the height of the bulk cargo level in real-time. Types of various sensors, liquid level meters are given in publications [6, 7]. The device for a laser liquid meter is described in the material [8]. Laser meters for bulk cargoes are given in the information [9]. Radar waveguide level gauges are shown in the publication [10]. Determination of the surface configuration, volume and mass of a stack of bulk cargo in the ship's hold using laser rangefinders is described in articles [11, 12]. The device for information provision of the process of controlling the loading of a ship with bulk, bulk and general cargoes is reflected in works [13, 14]. The method of controlling the placement of bulk cargo in the ship's hold is described in [15].

Formulation of the goals of the article (statement of the task)

The purpose of this article is to describe the system of automatic control for the process of carrying out cargo operations on tankers and the construction of a functional block diagram. In order to establish the optimal ratio between the carrying capacity of the vessel and the total mass of the liquid cargo loaded on board, it is proposed to use the developed method of continuous control for cargo operations with such cargoes.

Presentation of the research material with a full justification of the obtained scientific results

It is proposed to create a system for automatic control of cargo operations for constant dynamic monitoring of the conformity of tanker parameters during loading and parameters that maximally satisfy the requirements of maritime safety and take into account all restrictions, such as the maximum permissible volumes of liquid cargo in tanks.

System input data:

1. Data with the condition of the tanker at the time of loading, including: weight of fuel, water, ballast in each tank, other reserves, draft of the vessel.

2. Data on the required condition of the vessel at the time of completion of loading: volume and weight of cargo, fuel, water and supplies; loading rate along the cargo line, the number of cargo lines used for loading; performance of the ballast system. permissible sediments, trim and stability parameters.

3. Updated data from sensors corresponding to a given moment are automatically received: ballast level measurements in each tank, ballast pump performance, vessel draft measurements, data on the volume and weight of cargo loaded into each tank.

Boundary conditions: minimum bending moments and shearing forces at the end of loading, minimum bending moments and shearing forces during loading; the minimum amount of time for ballasting and loading the tanker.

Limitations: maximum volumes and mass of bulk cargo in each tank, maximum drafts, roll and trim (maximum and minimum for ballast system operation), bending moments and shear forces, number of cargo lines used for loading.

During download, the following are performed:

- calculation of the total mass of ballast based on the results of level measurement (automatic data);

- calculation of the total mass of ballast based on the performance of the ballast pump and its operation time;

- calculation of vessel tonnage, volume and mass of liquid cargo on board (automatic data);
- determination of the mass of the cargo loaded on board based on the terminal calculations (data from shore meters);
- determining the sequence of loading tanks, which maximally satisfies all the necessary conditions, taking into account the restrictions, control of the sequence of operations;
- signalling the inconsistency of operations in the event of an error between the actual values of the quantities and their permissible values.

Automation of the loading process (creating a program for automatic control of cargo and ballast operations) is presented as the sum of several separate tasks:

1. Automation of ballast operations.

2. Automatic control of the cargo work process.

3. Development of a method of synthesis of loading strategy and ballast operations to ensure the maximum result.

In turn, the automation of ballast operations includes:

- automatic determination of the mass of ballast in each tank at any time;
- automatic opening and closing of valves by control command;
- signalling malfunctions, errors or inconsistencies.

Automatic tanker loading control includes:

- automatic assessment of the vessel's stability at any time;
- determination of volume and weight of cargo in tanks and coordination with data received from the terminal;
- control of values of bending moments and shearing forces;
- control of the compliance in real mode for loading of the ship with the planned, calculated one.

The program for automatic control of loading and ballast operations must perform:

- loading and unloading of cargo with verification of emerging static loads;
- ballasting of the vessel with a load check;
- control of compliance with restrictions at all stages of cargo operations (maximum draft, tonnage, trim);
- provision for trimming by stern to perform some stages of cargo and ballast operations;
- accounting for the dynamics of tides in the port;
- calculations of optimal loading and unloading parameters, based on the specified parameters: the number of used cargo lines and pumps, drafts, loading speed, ballast system productivity, ensuring the seaworthiness of the vessel at any time during cargo operations and environmental protection.

It is proposed to create an information support system for automatic control of tanker loading with liquid cargoes.

The basis of such a system is the principle of improvement of primary processing and the introduction of additional blocks for calculating the volume and weight of the cargo, taking into account the transport characteristics of this cargo and the state of the environment.

The system ensures high accuracy of cargo mass calculation results, operative control by the operator (master) of the process of loading the tanker with liquid cargoes for further calculations of the seaworthiness of the vessel and preservation of the environment.

The automatic control system includes units of sensors for the level of cargo and ballast in tanks. Data from these blocks are used to calculate the volume and mass of cargo in tanks, the mass of ballast and determine their coordinates of the centre of mass. The results of these calculations are used to calculate the draft and stability parameters of the tanker.

It is proposed to use the information support system for automatic control of tanker cargo operations.

The structural block diagram of the automatic control system cargo operations of the tanker is shown in Fig. 1.

The information support system of the loading control process contains the main unit with laser rangefinders, connected to the unit for collecting and processing primary information, a computer with software for determining the height of the liquid cargo surface and calculating its volume. The main unit includes laser rangefinders, which are placed in the neck of each tank of the ship and equipped with a remote data transmission system. The unit for calculating the height of the surface of the cargo is connected with: the unit for calculating the volume of the cargo; a block of data on the dimensions of the tank and a computing block; data storage unit and measurement error analysis and assessment unit; a block of data on the loading speed of the tank, a display and a block of the ship's cargo program.

The cause-and-effect relationship between the set of features of the system and the technical result is as follows.

The main unit with laser gauges, which are placed in the center of each tank on top, each provides synchronous measurement of the distance from the deck to the surface of the cargo, while the distance measurement is performed after a time interval set by the operator, depending on the intensity of cargo operations. This allows you to continuously receive data on the level in tank filling, with subsequent calculation of its volume, mass and coordinates of the center of mass (CM).

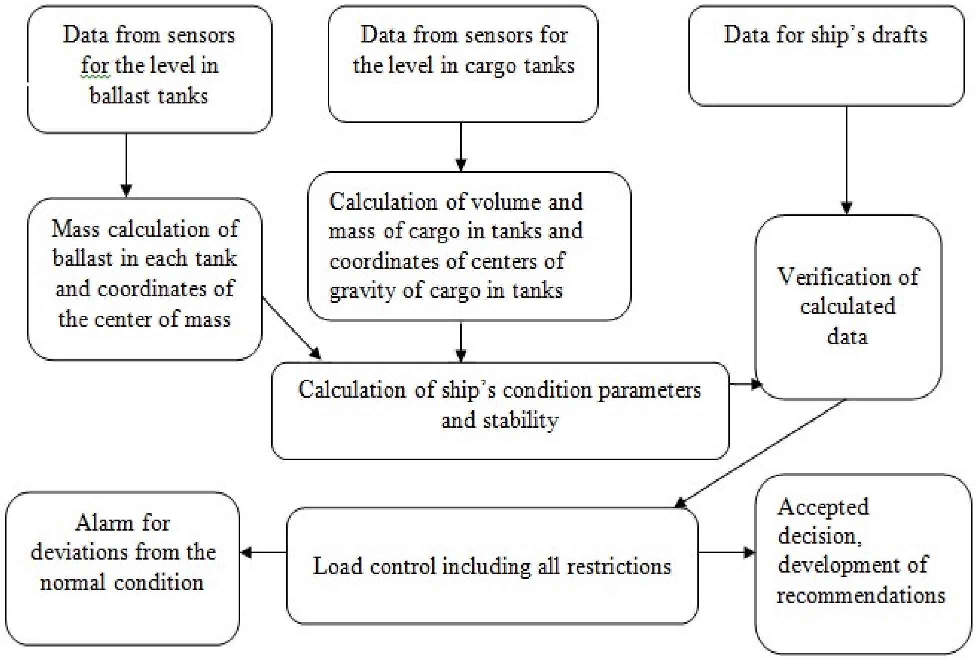

Fig. 1. Structural block diagram of the automatic control system cargo operations

The application of the data block on the size of the tank ensures the determination of the cargo volume, taking into account the data on the characteristics (sizes) of each specific tank.

The use of the computing unit ensures the calculation of the mass of the cargo loaded into the tank, taking into account its temperature and density. This block also calculates the CM coordinates of the cargo that is currently loaded into the tank. This ensures operational management of the process of loading the vessel with liquid cargoes and makes it possible to use the obtained results for further calculation of the seaworthiness of the vessel in order to ensure the safety of navigation.

The application of the pre-calculation data block and the measurement error analysis and assessment block provides a comparison of new data with the previous ones, determines the increase in cargo weight depending on the data obtained from the tank loading speed block. It provides shipmasters with data on the state of loading of each tank and the ship as a whole for any time of carrying out cargo operations for further calculation of cargo mass and seaworthiness of the ship before departure.

The volume occupied by the cargo in the tank is determined with calibration tables, which are provided by the shipyard. The initial data for entering the table are the height of the cargo surface or the height of the free space above this surface.

The principle of operation of the system of information control of loading the ship with liquid cargoes is based on the fact that using the height of the surface of these cargoes, the volume and mass of the liquid cargo loaded into the tank are calculated as follows:

1. The density of the cargo in each tank is calculated, taking into account its temperature

$$\rho^t = \rho_4^{20} + \lambda(20°C - t) \quad (1)$$

where ρ^t - is the cargo density at the actual temperature of the cargo loaded into the tank, t/m³;

ρ_4^{20} - passport (standard) cargo density, t/m³;

λ - temperature correction for density when the cargo temperature changes by 1°C (selected for each type of liquid cargo from special tables).

2. Using the determined cargo density, the mass of the cargo loaded into each tank is determined

$$D = V \cdot \rho^t \quad (2)$$

where V - is cargo volume, m³;

ρ^t - cargo density, t/m³.

The essence of the useful model is explained by the drawing. The block diagram of the system for information support for monitoring the loading of a tanker with liquid cargo is shown in Fig. 2.

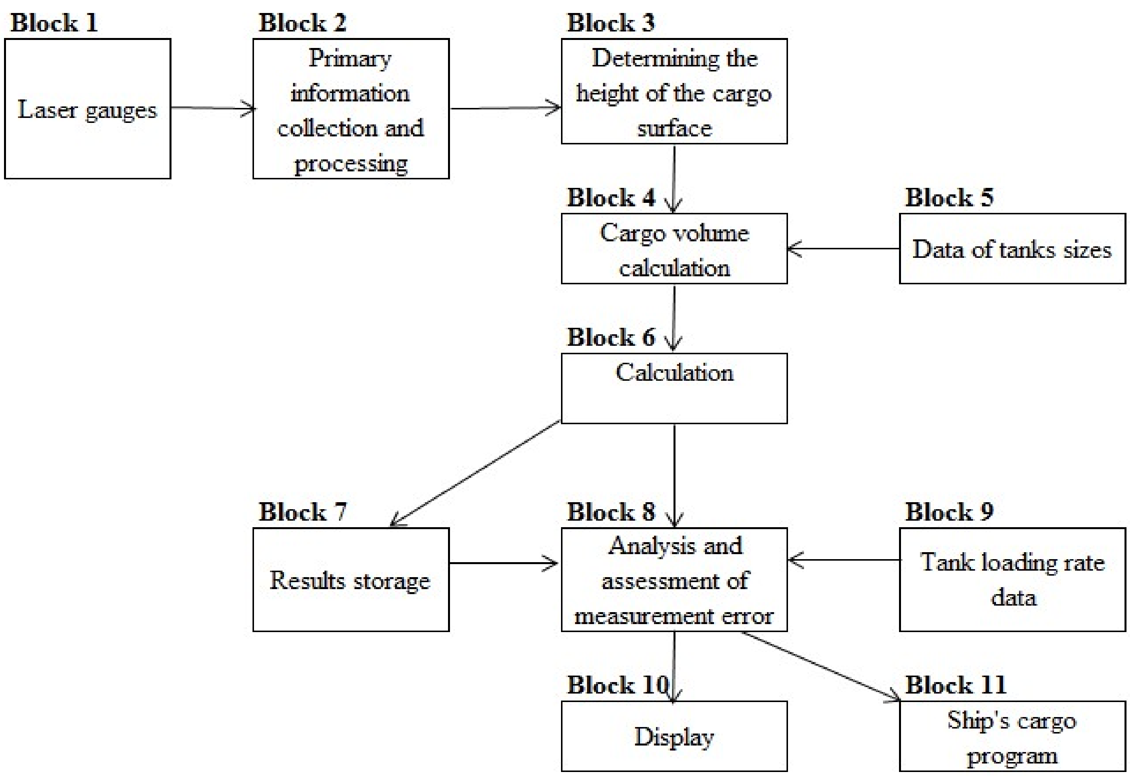

Fig. 2. The block diagram of the system for information support for monitoring the loading of a tanker with liquid cargo

This system includes a main unit with laser gauges 1, located in the geometric center of each tank of the vessel, a unit for collecting and processing primary information 2, a unit for determining the height of the surface of the cargo 3, a unit for calculating the volume, mass and center cargo weight scale 4, tank size data block 5, calculation block 6, result storage block 7, measurement error analysis and assessment block 8, data block on loading speed of each tank 9, display 10 and vessel cargo program block 11.

The systems will work in the following sequence.

The information from the packets in the distant worlds of the main block 1 is transmitted to the primary information processing block 2, in which there are heightened heights of the surface cargo. The coordinates of the points on the surface pitch are transferred to the block of the height designation of the surface pitch 3, from which the alignment is determined (selected), which most accurately describes the surface of the poured pitch.

According to the level, how to describe the surface of the cargo, and also the vicorist block 5 (data on the size of the skin-specific tank) in block 4 is indicated by the volume of the liquid cargo loaded into the tank. Given data about the amount of cargo are transferred to calculation block 6 for the calculation of the weight of the cargo, which is added to the tank with the height of the surface cargo in the tank. This block also has a chance to coordinate the CM cargo, which for a given hour is cargo in a skin tank.

The results of the calculations are transferred to the data storage unit 7 and the measurement error analysis and evaluation unit 8. The unit 8 also receives data on the tank loading speed from the unit 9.

The measurement error analysis and evaluation unit 8 compares the new data with the previous ones and adds the increase in cargo weight depending on the loading rate for each tank.

After analyzing and averaging the received data, they are submitted to the display 10 and, as input data, to the cargo program (block 11) for calculating the stability and seaworthiness of the loaded vessel.

Using the system will allow the shipmaster to quickly manage the tanker loading process. control the mass of liquid cargo in each tank, taking into account the speed of carrying out cargo operations. for the further use of the obtained results in the cargo program when calculating the stability and seaworthiness of the vessel in order to ensure the safety of navigation and preservation of the environment.

Conclusions and further research prospects

1. The analysis of existing sensors (level gauges) with a different type of measurement showed that laser-type gauges are the most suitable for determining the distance to the surface of cargo in tanks. A necessary condition for their use is rigid fixation in the center of tanks.

2. Theoretical studies and field observations, which were carried out on the tankers "JO PROVEL" and "JO PINARI" during cargo operations, confirmed the possibility of determining the surface level of cargo in tanks, at various stages of their loading, with the help of laser gauges. To determine the volume and mass of cargo in each tank, it is necessary to specify the dimensions of each cargo compartment.

3. The implementation of constant dynamic control of cargo operations will increase the efficiency of the tanker loading process, the calculation of its seaworthiness will ensure the safety of navigation and the preservation of the environment.

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