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COMPUTER DECISION MAKING SYSTEM FOR INCREASING EFFICIENCY OF SHIPS' BUNKERING PROCESSES

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Abstract: *This paper deals with increasing efficiency of ships' bunkering processes (SBP) based on their automation by using specialized decision making system (DMS). DSS allows a control of cargo operations for fleet replenishment tankers (FRT) in conditions of non-stationary external disturbances and dynamic restrictions.*
Key words: *Ship, bunkering process, decision making*

1. INTRODUCTION

Bunkering of ships with diesel fuel, oil, black oil and other oil products is the integral element of the operation of merchant, fishing and military fleet. Therefore increase of a level of safety, efficiency and profitability of the technological process (TP) is the actual problems in marine transport.

The bunkering operations assume transfer of fuel from the FRT to the ship-receiver (Werners & Kondratenko, 2009). Thus the basic control facilities and the control over a TP's schedule are concentrated onboard the FRT. Further, a set of actions on preparation and realization of cargo operations of the tanker will be considered as bunkering TP. An automation of SBP is one of the most effective ways of improvement of TP quality. For today there are a lot of systems of an automated control of cargo operations on tankers which allow carrying out remote control of loading and unloading operations (Onboard-NAPA, CargoMax FAQ's, Autoload, Saab MaC/501, etc.). But previous concept and research are oriented basically on a design for installation such systems on ships of a merchant fleet and do not take into account specific conditions for small tonnage fleet (FRT). At the same time cargo operations on such class of tankers are carried out in conditions of essential external wind and wave perturbation influences, the account and indemnification of which will allow increasing appreciably efficiency of tankers operation (Snopkov, 2004 & Likhachov, 2004) and avoiding a collision between tanker and served ship.

The necessity of creation of the FRT's computer DMS for effective realization of the SBP is caused by a big variety of problems (permanent current control of FRT's roll, trim, draft) solved by human-operator (H-O) in uncertainty (Maltsev & Vilsky, 2007; Nechaev, 2001). Such DMS allows essential raising quality of control of bunkering TP.

2. THE ANALYSIS OF BUNKERING TP

Bunkering TP can be divided into preparatory and the basic stages: stage stage. The formation of preliminary cargo (PCP) and ballast (PBP) plans are carried out at a preparatory stage for optimal distribution of the given quantity of cargo and ballast on corresponding compartments in view of requirements to stability of a tanker, characteristics of durability and popularity in various conditions. Thus, beside the information about the type of cargo and quantities of discharged/loaded cargo, it is necessary to take into account a lot of the factors influencing quality of SBP: weather conditions (wind force, sea roughness, and undercurrents), presence of a free surface and temperature expansion of a cargo in tanks, age of tanker's hull, etc. The mistakes and the inaccuracies, admitted by the H-O at a formation of PCP, can also result in overturning a vessel and a damage or destruction of the hull (Snopkov, 2004 & Likhachov, 2004). Further, it can lead to significant ecological pollution, financial losses and human victims. Among the factors which influence a choice of the PCP is the productivity of pumps and throughput of pipelines.

At the intermediate stages of cargo operations the big roll of bunkering tanker (static or dynamic) can result in: stability loss of the vessel and its overturning, a fuel plug breakage or breakage of cargo pipes. The warming process of cargo (i.e. black oil) during winter time can also be related to a preparatory stage. It significantly influences on general time and quality of cargo operations. Delayed engaging or un-optimal working mode of the cargo warming system can result in failure of cargo operations or additional power losses, and hence leads to additional economic expenses.

The second stage is the basic one for a direct implementation of the SBP. A fuel transferring is usually carried out either open or the closed ways. A pressure of cargo in a pipeline system is created by cargo pumps of the tanker (at cargo discharging process) or coastal pumps (at process of a cargo reception). Control and distribution of streams of a cargo is provided by means of cargo sluice valves.

The basic stage of bunkering TP can be carried out both at berth and at internal or external road of port (Snopkov, 2004 & Likhachov, 2004). In the first case the tanker is moored directly to a berthing wall or to a ship-receiver fixed to a berthing wall. Such scheme SBP is optimal as soon as external disturbances are reduced to a minimal influence rate.

The variants of SBP at a road are presented in Fig. 1: a - tanker is moored closely to the ship; b – tanker is situated at Δl distance from the ship. The bunkering mode (Fig.1,a) is typical for cases when the ship-receiver either is completely loaded by cargo or has approximately straight-sided contours of the hull at any draught. The bunkering mode (Fig. 1,b) is typical for cases when the ship is in a ballast and ballast tanks are devastated up to a minimum with the purpose of draught minimization. In this case tanker is fixed only by the mooring ropes that strengthen tanker's rolling considerably in comparison with the previous case. Thus, in the second case (Fig. 1) the system "the tanker – bunkered ship" is exposed to more essential influence of wind and wave disturbances. Their negative influences are aggravated with presence of a tanker's cargo free surface.

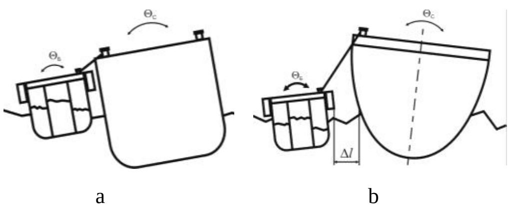

Fig. 1. Technological process of bunkering at road

Apparently from all aforesaid, the bunkering operations represent complex TP, a realization quality of which depends on many factors and features of their interaction and interference. At the intermediate stages of SBP the list of necessary actions is included to the schedule of cargo operations. Thus "stability" of vessel, "durability of the process", as well as time of cargo operations and reliability of units of the cargo pipeline completely depends on correctness of drawing up and realization of a schedule of cargo operations. Let's note that the technological sequence of stages of cargo operations appreciably depends on type of a cargo and its physical properties, in particular, viscosity, temperature, etc.

3. STRUCTURE OF THE COMPUTER DMS

Proposed computer DMS with hierarchical structure includes: sensors for parameters of the tanker, cargo system, ballast systems and stocks, external disturbances (SPT, SPCS, SPBS, SPED); the block of data preparation (BDP); - blocks of formation of optimal cargo and ballast plans (BFOCP, BFOBP); local systems of automatic control for elements of cargo (CS) and ballast (BS) systems of tanker (ACS); BAIPR - the block of adaptive identification of pipeline section's parameters of flow control (FCS); the block of the analysis and localization of damages of cargo system (BALD CS); block of forming of dynamical restrictions (BFDR).

DMS assumes the distribution of control functions between the interconnected structural elements of the system. Hierarchical organization of the DMS provides the decision making for problems of optimal planning of SBP at strategic level (SL), the formation and the timely correction of its technological schedule at a tactical level (TL), identification of cargo system elements' damages and adaptive control of the rotary sluice valves by means of parametrical identification of FCS during realization of TPBV at executive level (EL).

The structure of DSS subsystems is able to ensure the functioning of technological control object on the base of the entrance information which is usually given by the H-O. Thus all other significant information, which is necessary for decision-making, should be received from both databases and sensor system. There are indications and recommendations on the current and final distribution of a cargo and ballast in tanker compartments, operating modes of cargo warming system, the technological schedule of the bunkering process, and also the information on malfunctions in cargo system and the recommendation on their elimination. All kind of the information will be formed at outputs of DMS. Currently the following results are received:

- the algorithmic and program means (APM), as a components of DMS, for synthesis of optimal cargo plans of tanker at the strategic planning stage are developed and tested;
- the APM and program-technical means (PTM) of DMS tactical level functioning for forming and current correction of technological schedule of the TPBV in conditions of nonstationary external disturbances are developed and tested;

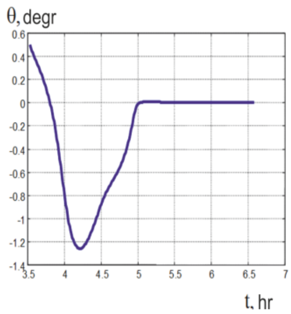

Fig. 2. Modeling of tanker's roll for real SBP

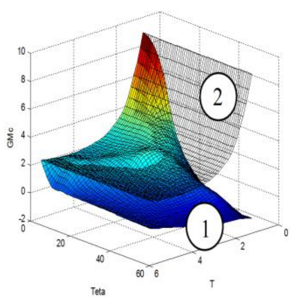

Fig. 3. Metacentric height of the tanker: modeling results

- APM and PTM for correction of control signals at the DMS executive level taking into account nonstationary physical parameters of cargo and structural changes in the cargo pipelines of tanker are developed and tested;
- the efficiency of the developed APM, PTM and subsystems of the DMS was tested using the developed imitation models, namely: the static and dynamical models of tanker in the bunkering mode, physical model of the tanker's cargo compartment under DMS control.

4. MODELING RESULTS

The modeling results of tanker's roll Θ changes during SBP (with DMS support) are shown in Fig. 2. For increasing efficiency of SBP it is necessary to take into account that: distribution of a cargo is carried out symmetrically to diametrical section of a tanker in compliance with the schedule of cargo distribution; the temperature of a cargo essentially influences on intensity of cargo operations and can vary during their realization; at distribution of a cargo there is a necessity for creation of a roll (i.e. on the right board), that allows to concentrate the rests of a cargo near receivers of cargo pipeline; real term of cargo operations considerably exceeds previously computational term, that conditioned by non-stationary character of physical parameters of a cargo in tanks owing to hit of air in system of pipelines, temperature of a cargo, etc. Fig. 3 present the results of the investigations of the tanker's virtual model using Tribon M1 (computer aided ship design system). In particular, the surface of change of transverse metacentric height of the tanker (as basic measure of tanker's stability) is shown (Fig. 3) depending on a degree of loading of the tanker and its roll (note 1); a surface of change of its minimal-allowable values at various draft (note 2) is presented also. It is well visible, that the area of allowable values (note 1) of this magnitude is limited and essentially depends on parameters of tanker position at sea surface. The given results and as a number of others have allowed to make conclusions about necessity of tanker parameters correction during realization of SBP and obligatory correction of appropriate restrictions with dynamic character (values of roll, trim, draft etc.) at each of hierarchical levels of proposed DMS.

5. CONCLUSION

The analysis of SBP for multi-coupled control object "tanker-served ship" is a base for developing the hierarchical structure and main APM and PTM components of specialized DMS for efficient control of bunkering operations of FRTs in non-stationary marine environment. Practical implementation of such DMS will increase safety of bunkering operations, profitability and decrease a risk of environmental pollution. In future, it is reasonable to investigate the changing of dynamic restrictions (the different limited values of FRT's roll, trim and draft) for bunkering TP depends on the state of the open sea.

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