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DIVING VESSEL SPEED DETERMINATION DURING TOWING TESTS

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Abstract- The model tests are performed to evaluate movement speed of diving support vessel during towing experiments and the tests results are given. Towing system arrangement diagram is proposed for the model test and measurement system of the test basin is described. Processing of towing test is carried out with special software. Algorithm of the software and diagram of speed determination of diving support vessel is introduced. Based on the results of the model tests, it was found that wave formation is minor in slow speed but it increases in medium speed. Observed increased wave in aft side while sailing in estimated speed. The model propulsion evaluation results were applied to full-scale vessel. Obtained graphical dependencies in between of towing resistance and towing power of full-scale vessel. Reliability of the measurement results is confirmed with series of experiments and statistical criteria.

Keywords: Sailing Speed, Diving Vessel Model, Towing Test, Measurement System, Experimental Pool.

1. INTRODUCTION

Progressive development of deep-water oil and gas fields in the Caspian Sea creates new tasks for shipbuilders. These tasks are regarding optimization of design and operational characteristics of diving vessels serving in sea depths more than 60 m. Further development of offshore fields requires providing safety of subsea operations, analysis of design solutions for building of specialized vessels [1, 2]. Therefore, improvement of the design of diving vessels for operations in the Caspian basin is particular topicality nowadays. Another aspect of the topicality is necessity of establishing enhanced methodology for designing diving systems in order to provide optimum performance characteristics of the vessels [2, 3]. Nowadays, ASCO owns specialized diving vessels. These vessels are capable to perform subsea construction activities in sea depth up to 600 m. Design and construction of new vessels would be expedient in order to perform such subsea activities in more shallow waters by means of cost effectiveness. In compare with Russia there are 10 and USA 40 such type of vessels. This type of vessel has diver system and remote operated equipment in order to perform diving operations in sea depth more than 60 m.

High cost of the diving equipment makes design optimization task very important [4, 5]. Thus, development prospects of Caspian offshore deep-water resources and necessity of establishment of diving systems for serving oil and gas trades in sea depth more than 60 m, confirm urgency of the issue. In general, its highlighted that research of optimization of design and operational characteristics of diving vessels almost has not carried out yet, so it makes this task more complicated [6, 7]. It is true that developments for tug boats might be used partially but task of establishing integrated effective design method remains as current demand [8]. Important aspect is application method of CALS-technology to diving vessels throughout life cycle of shipbuilding: design, construction, exploitation, repair and disposal of vessel [9]. So, purpose of presented work is to determine sailing speed during towing tests on the basis of analysis of diving vessel model characteristics for sea depth till 60 m.

2. METHODS AND FACILITY OF THE RESEARCH

As experimental facility, 400 m capacity pool of Odessa National Maritime University (ONMU) has been used. The pool refers to a gravity-type laboratory, in which the movement of the vessel model occurs under the action of gravity of the load falling to special pit. The pool is equipped with a plate-type wave generator driven by an AC motor with frequency driver. There is a wave stabilizing system which allows to conduct research of the vessel's dynamics on regular waves with given characteristics in wide range of wave frequencies. The pool is made of steel-concrete structure with parabolic shape transversal section. Main characteristics of the pool: full length dock inclusive 35 m; breadth 6m; maximum depth of water 2.2 m, Volume is 400 m^3.

Movement of the model in the pool is carried out with the help of a towing system which is consisting of endless looped cable, system of tension and guide rollers, a traction drum, accelerating system and compensation weights [1]. The arrangement diagram of the towing system of the pool is shown in figure 1. Towing wire rope passes 1-passes through sheave of driving block 2, measuring sheave 3, diverter sheave 4 and through tension sheave 5 which is located at opposite side of the pool end).

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Model forms a cable rhombus with help of special suspensions (view A in Figure 1) and connects to lower part of the towing wire rope. Such connection provides stability of the model on the course and sailing trim does not interfere.

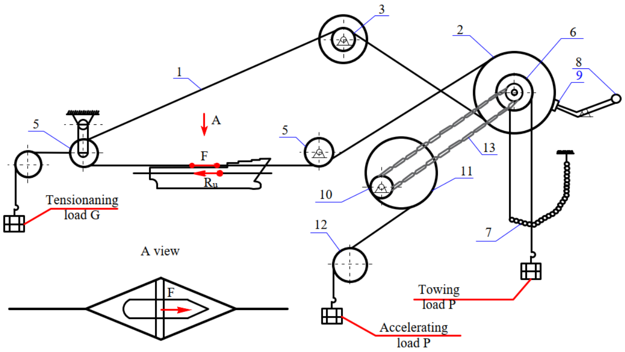

Figure 1. Towing system arrangement diagram of the experimental pool

Driving block 2 double sheave: diameter ratio of the sheaves is 2:1. Wire rope of the towing load *P*, descending to the pit and pulling smaller sheave 6. Applied force to the model F is equal to half of the load weight P by subtracting the blocks friction Δ_{Pfr} . The tension pulley 5 is mounted to necks on swivel and fitted with a tensioning weight G. Weight of load G is chosen in order to avoid slipping of the wire rope on the sheave. Wire rope of the towing load lowers to the well during movement of the model with the load P. As the load lowers, its weight increases. Installed compensating chain 7 to balance additional weight of the wire rope and set of loads on the wire rope which is wound on shaft of the driving block [2].

The loads are selected so that the weight momentum of the wire rope is lowered into the well in order to be equal to the weight momentum of the compensating chain which is acting in the opposite direction. Taken account jerks during braking, the wire rope can withstand a load up to $10\,kg$ The weight of a running meter of such a wire rope is extremely smaller, even though in compare with a small towing load (0.1÷0.2 kg). In the case of usage of such wire rope, the compensative chain 7 is not installed. Startup of the model is performed by use of lever 8 and starter friction brake 9. It is necessary to achieve uniform movement of the model in the pool during towing tests. In order to meet these criteria acting inertial forces are excluded and value of water resistance is determined by the towing load. In order to reduce the acceleration part of the model, an accelerating device is applied for movements at a certain constant speed (Figure 1). The driving block 2 is connected with the shaft of the accelerating device 10 with help of a chain drive 13.

A pulley 11 is eccentrically mounted on the shaft which is connected to the wire rope passing through the diverting pulley 12 with the accelerating load. During one rotation of the eccentric pulley, the moment of the accelerating load increases to a certain maximum value initially due to changing arm and then decreases to a minimum value. This arrangement achieves smooth engagement of the accelerating force at the beginning and smooth deactivation at the end of the accelerating part of the model test. After a complete rotation of the pulley 11, the accelerating device is automatically disconnected from the shaft of driving block. Further movement of the model occurs only under the acting towing load P. Thus, value of the accelerating load is selected according to weight and running speed of the model. Main evaluation criteria are to achieve and maintain steady speed during movement of the model.

3. RESULTS AND DELIBERATION OF THE EXPERIMENT

To carry out towing test in the pool, the model movement speed measurement system has been used which is specially developed. The system consists of computer with processor Intel Core2Duo, analog-digital convertor E14-140, strain gauge amplifier АНЧ7М and speed sensor of model motion. Separate procedure has been implemented for recording and processing of datum of the towing tests in software part of the system. Recording speed changing process during towing tests is carried out with software analog-digital convertor E14-140 recorder L Graph 2. The L Graph 2 software has a wide range of possibilities of data displaying and editing [1]. Data on the change in the speed of the model during its movement are stored on the PC disk and used in the processing of the experimental results.

Processing of obtained data during towing tests is carried out by using the Tow speed software [3]. As a result of processing the model run data, Tow speed creates a text file and displays the process of speed changes of the model in a graphical form. Let's look through more details of the software algorithm. The following scheme has been used in order to determine the speed of the model in the basin (Figure 2).

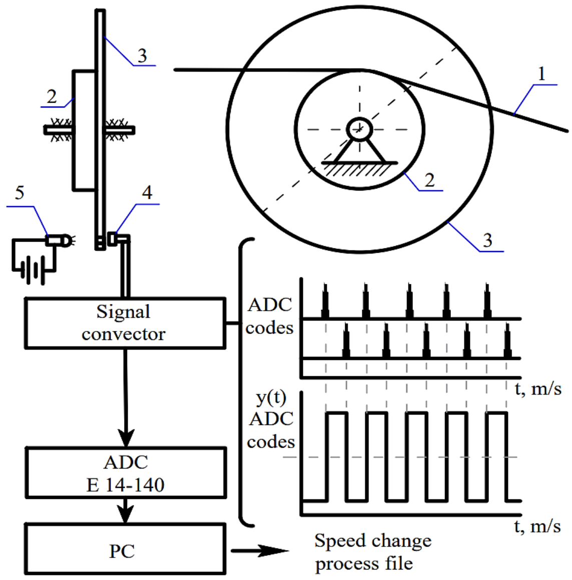

Figure 2. Scheme for defining of model motion speed in basin

During the run of the model, the wire rope of the towing system 1 rotates the measuring pulley 2 and the disc 3 which is coaxially fixed with it. There are two holes size 1.5×6.0 mm on the disc 3 which are located on opposite sides of the rotation axis. While light beam from light source 5 passes through one of the holes hits to the photo sensor 4, it leads to appearance of an electrical impulse, which enters the signal converter. The object of research is a diving vessel with trim to fore and aft end. Technical characteristics of diving vessel project no. 1550 are shown in Table 1.

Table 1. Technical characteristics of the research object

Description, sizes	Symbol	Value
Length in between perpendiculars, m	L_{bp}	28.80
Length in waterline, m	L_{wl}	29.97
Overall breadth, m	B	6.35
Middle draft, m	d	1,94
Fore draft, m	d_{f^1}	1.94
Aft draft, m	d_a	1.94
Weight displacement, t	Δ	248.58
Volume displacement, m^3	∇	245.63
Overall completeness coefficient	C_b	0.641
Mid frame completeness coefficient	C_m	0.962
Waterline completeness coefficient	C_w	0.799
Watered surface area, m^2	S	222.97

Diving vessel model project no. 1550 has been made of polystyrene and coated with paraffin wax alloy, in scale of 1:15.875. Installed two turbulators made of 1.5 mm wire, in fore end of the model, in region of forward perpendicular and the first frame. Presented model in conjugation with towing system, in Figure 3. Three possible scenarios have been considered during the towing tests. The first scenario accepts that the value of the accelerating load is excessive, while the graph of measuring the speed of the model falls on the measurement section. In the second scenario, it was accepted that the speed on the measurement section is constant, i.e. the model motion is steady. In the third scenario, the value of the accelerating load is insufficient, while the speed graph grows up in the measurement section.

Figure 3. Model paired with a towing system

The speed of movement of the model in the process of testing is considered constant unless its deviation from the average value does not exceed 0.5%. To control accuracy of speed defining during the experiment, the closest points fixed according to calculated values, at which the speed increases and falls. Figures 4 and 5 show interfaces of the measurement system, which shows speed decrease and increase during model diving vessel movement [5].

The vessel model towing tests were carried out with draft of 0.122 m (full-scale vessel draft is 1.94 m in ahead motion complied with above-described method in the speed range of the ship model relevant to the Froude numbers from F_r=0.105 to F_r=0.367 with step relevant to the resistance of the model 0.20–0.30 kgf. Towing tests were carried out in deep water for maximum draft in compliance with marine navigation rules. The results of the model towing tests are shown in Figure 6. The tests have set up that, wave formation is moderate while moving in slow speed; when moving at medium speeds, distinct wave occurs, which becomes significant while moving at maximum speeds. Increase of aft waves is observed in movement with calculated speed while moving at calculated speeds. The average value of the speed is given in blue and is 0.357 m/s. Average speed performed in this interval: start time: 56.945 s, end time: 79.335 s.

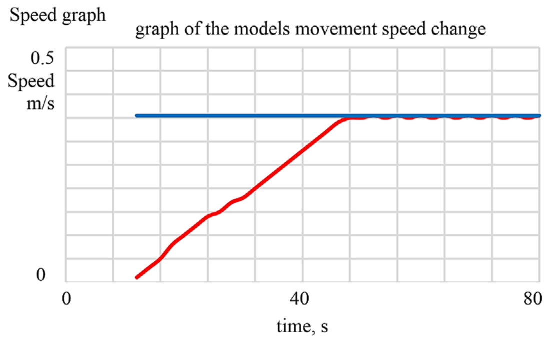

Figure 4. Interface of measurement system: speed drop of the model movement

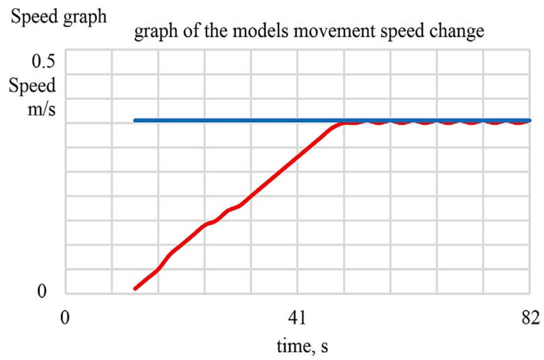

Figure 5. Interface of measurement system: speed increase of the model movement

The average value of the speed is given in blue and is 0.348 m/s. Average speed performed in this interval: start time: 57.020 s, end time: 81.475 s. The results of model tests were recalculated for a full-scale vessel according to the standard methodology adopted in the experimental basin. To assess the accuracy and reliability of speed measurements results, a series of experiments was carried out, consisting of ten experiments. The test was carried out in the pool for two days under standard environmental conditions, using polystyrene model of a Project 1550 diving vessel.

The terms for to carry out series of measurements are as follows: the value of the pulling load P_t=2.3 kg, respectively set resistance R_t=1.15 kg and the value of the accelerating load R_{accel}=2.4 kg. Defined arithmetic mean value of speed and interval limits for 10 measurements. Average value of two closest velocities (V_0=1.35289 m/s) was chosen as the baseline, difference (V_1-V_0) and squares of differences $(V_1-V_0)^2$ have been determined [8, 10, 11].

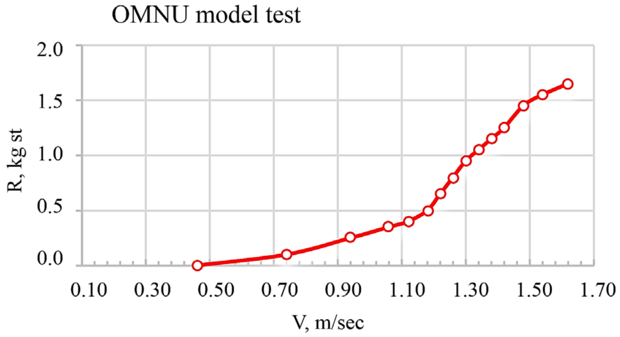

Figure 6. Towing resistance of diving vessel model

4. CONCLUSION

Thus, a method has been developed for determining of movement speed of diving vessel model during towing tests. Proposed diagram of towing system in order to perform model test. Operation of experimental pool has been described. Processing of towing tests is performed with help of special software. A graphical presentation of the towing system operation facilitates design engineering decision making. The algorithm of the program operation and the scheme for determining speed of the diving vessel model in the experimental pool have been presented. The technical characteristics of a diving vessel inclined to bow and stern ends and model of the vessel project no. 1550 which is made of polystyrene have been presented. Based on the results of model tests, it was found that wave formation is moderate during movement in low speeds but wave formation increases in medium speeds. Observed developing of waves in the stern while moving at calculated speeds. Results of the assessment of the model propulsion are given and recalculated for a full-scale vessel. The results of towing resistance assessment and towing power of a full-scale vessel are presented by graphical dependencies. Series of experiments have been carried out in order to assess reliability of the measurement results and average value of the speeds, limits of confidence interval, absolute and relative errors have been determined.

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