Calculated characteristics of the load-lifting device of non-self-propelled floating crane

V N Savinov

Nizhny Novgorod State Technical University n.a. R.E. Alekseev, Minin str., 24, 603950, Nizhny Novgorod, Russia

E-mail: vladimirsavinov6@gmail.com

Abstract. The approach used for solving of the task concerned, corresponds to an early design stage of the floating crane. The floating crane size is defined and the optimum trim system is proposed in this paper. The scheme of the declined arm of the crane, allowed to calculate and construct cargo and geometrical characteristics of the load-lifting device. Preliminary tests of the vessel’s stability at carrying out cargo operations have shown satisfactory results.

1. Introduction
Development of the Arctic shelf is carried out using stationary, self-elevating, semi-submerged installations and under-water-subglacial drilling complexes. Building of such constructions in factory conditions and also carrying out manufacturing and erection works in the sea is impossible without floating cranes of the large load-carrying capacity. The aim of this research is to suggest a choice of the floating crane trim system, to calculate trim, compensating moments and angles depending on the load lifting and also to present calculation scheme of cargo and geometrical characteristics of the load-lifting device of a non-self-propelled floating crane with 500 tons load-carrying capacity. Designing of floating cranes in general, and calculations of characteristics of their load-lifting devices in particular, are urgent and, at the same time, insufficiently covered in the foreign and domestic press. Now a considerable part of assembling, loading-unloading, hydraulic engineering, ship raising and other kinds of work on river and sea water areas is carried out with floating cranes of large load-carrying capacity. It allows increasing the mass and size of the assembly units used in work of floating cranes. Such an approach results in reducing terms of work that is especially important when carrying out assembling and cargo handling operations depending on environmental meteorological and hydrological conditions. The approach used for solving the task in question, corresponds to an early design stage of the floating crane and is partially observed in works [1, 2].

In work [1] characteristics of the floating crane class under the Russian River Register - KL4 [1] IISP - as a floating non self-propelled with non-rotary top structure, designed according to the Rules and under the supervision of the Register is given. This class having ice strengthening for possibility of incidental swimming in petty-smash ice in coastal areas of the freezing southern seas and rivers, satisfies the requirements of Part V “Division into compartments” so that the floating crane remains afloat in a satisfactory state of equilibrium when one compartment is flooded. Its function is to perform cargo handling operations on the water area protected from waves and wind impacts, of force being no more than 5 points. Operation area: the floating crane can perform cargo handling operations on protected from waves factory, port, and roadstead water areas and in the absence of heavy seas in the rivers. Navigation area is IISP (navigation in internal waterways, and also in the sea areas with
sea roughness of no more than 6 points; distance from a refuge place in the closed seas being up to 100 miles). The vessel has the main hoist with two separate mechanisms, each with a hook; an auxiliary hoist with two separate mechanisms, each with hook as well.

2. The analysis and the approach to the problem solution

The analysis of available materials on floating cranes and vessels equipped with cranes with swinging arm has revealed that design problems and calculation of the load-lifting devices are paid little attention to. The requirements of the Register to the floating crane pontoons are the following: durability of design, buoyancy and stability. The floating crane pontoon is made of steel, its sizes are accepted in terms of restriction of the heel and trim angles. Water ballasting is used to pontoon alignment. Stability improvement is reached by low position of the centre of gravity of the top structure. The load-lifting device consists of:

- a direct declined arm, hinged against the low base at the extremes of the pontoon;
- winches located in the middle and after parts of the floating crane;
- swinging rack, its head top connected to the guys with an arm and with pulley block of its boom change;
- stationary support in after part of the floating crane, connected with the pulley block by guys.

Stability of the floating cranes is usually considered concerning the joint action of the initial heeling moment created by cargo on a hook or a counterbalance, the static heeling moment created by wind pressure and rolling. In [3] the maximum heel angle is given at joint action of the above-mentioned heeling moments. This angle should not exceed 8° for floating cranes, intended for work in rough seas, and 6° for floating cranes which work in such conditions is not envisaged. There are no recommendations for floating cranes, working only in changing trim conditions. Considering the circumstance, that in all classification rules there are no points strictly regulating key parameters of trim systems, the choice of characteristics of trim systems being designed is made on the basis of available experience and operation of such vessels. Usually trim systems are designed according to the centralized or independent principle. In this case, for providing normal operation of the load-lifting device a developed system of ballast tanks located in the extremities of the floating crane is provided. The trim system eliminates, changes or purposely creates a trim of the floating crane. It is an important element in ensuring safe work during cargo handling operations.

3. Results of calculations

Let’s consider the heaviest episode of the floating crane operation using the trim system when cargo, weighing 500 tons, is hoisted at the maximum swinging radius and at adverse influence of the wind of 5 points force. Calculation is carried out separately and the following results are obtained: specific wind pressure upon unit of the area of the upper works \( p_v = 400\ \text{Pa} \) (40 kgs/m²); windage of all elements of the upper works \( A_v = 1890\ \text{m}^2 \); windage z-axis centre \( z_v = 36.8\ \text{m} \).

The trim moments and angles which are to be compensated by the trim system of the floating crane are calculated. Calculation results are shown in Table 1.

The results obtained show, that the trim angle which is to be compensated by the trim system is equal to 3.3 degrees. Thus the compensatory moment necessary for flattening the vessel is equal to 27 400 tons/m. In Table 2 calculation of the given compensatory moment is presented. The results given in Table 2 show that the trim system allows to compensate the arisen trim. Besides, peculiarities of stability calculation of floating cranes, considering heel and trim influence allow to assume that the floating crane without cargo should have a trim on the stern, and with cargo - on the bow. This circumstance facilitates working conditions of the personnel, makes them more comfortable while carrying out cargo handling operations. A little increased volume of an accepted ballast allows to decrease z-axis of the floating crane centre of mass.

And increase its stability. More detailed study of the project will allow to optimize parametres of trim systems. In Drawing 1 calculation scheme of cargo and geometrical characteristics of the floating crane are shown; and characteristics of its load-lifting device are shown in Figure 2.
**Table 1.** Calculation of the moment and a trim corner floating crane from lifting of loads 500 t.

| Name                                | Designation | Dimension | Formula | Numeric values |
|-------------------------------------|-------------|-----------|---------|----------------|
| Working displacement                | $\Delta_{\text{max}}$ | t         | -       | 6600           |
| Longitudinal metacentric height    | $H$         | m         | -       | 71.86          |
| Cargo weight                        | $m_c$       | t         | -       | 500            |
| Arm weight                          | $m_a$       | m         | $\delta x_a$ | 670 |
| Load coordinate                     | $x_c$       | m         | -       | 80             |
| Coordinate of the center of mass of the arm | $x_a$ | m | - | 30 |
| trimming moment from cargo          | $M_c$       | t m       | $m_c x_c$ | 40 000 |
| trimming moment from boom           | $M_a$       | t m       | $m_a \delta x_a$ | 20 100 |
| Wind trimming moment                | $M_v$       | t m       | $M_v = 0.001 \rho_v z_A v^4$ | 405 |
| Total trimming moment               | $\Sigma M_\Psi$ | t m | $\Sigma M_\Psi = M_c + M_a + M_v$ | 60 505 |
| Trimming moment for 1°              | $M_\Psi^{\circ}$ | t m/degree | $M_\Psi^{\circ} = \frac{\Delta_{\text{max}} H}{8.300}$ | 8 300 |
| Trim angle at lifting 500 tons      | $\Psi_c$    | degree    | -       | 7,3            |
| Pontoon deck entry angle            | $\Psi_d$    | degree    | -       | 4,0            |
| Compensable trim angle              | $\Psi$      | degree    | $\Psi = \Psi_c \cdot \Psi_d$ | 3,3 |
| Compensable moment                  | $M_\Psi$    | t m       | $M_\Psi = M_\Psi^{\circ} \Psi$ | 27 400 |

**Table 2.** Calculation of the compensatory moment of the floating crane necessary for flattening.

| №№ | Volume of ballast tanks, 1 x b x h, m$^3$ | Numeric values, m$^3$ | Shoulder relative midsction, m | Moment relative midsction, t m |
|-----|------------------------------------------|------------------------|-------------------------------|-------------------------------|
| 1   | 10 x 5 x 2                               | 100                    | 30                            | 3 000                         |
| 2   | 10 x 5 x 2                               | 100                    | 50                            | 5 000                         |
| 3   | 10 x 8 x 1.5                             | 120                    | 50                            | 6 000                         |
| 4   | 10 x 8 x 1.5                             | 120                    | 50                            | 6 000                         |
| 5   | 10 x 5 x 2                               | 100                    | 50                            | 5 000                         |
| 6   | 10 x 5 x 2                               | 100                    | 30                            | 3 000                         |
| 7   | 10 x 5 x 4                               | 200                    | 30                            | 6 000                         |
| 8   | 10 x 5 x 4                               | 200                    | 50                            | 10 000                        |
| 9   | 10 x 8 x 3                               | 240                    | 50                            | 12 000                        |
| 10  | 10 x 8 x 3                               | 240                    | 50                            | 12 000                        |
| 11  | 10 x 5 x 4                               | 200                    | 50                            | 10 000                        |
| 12  | 10 x 5 x 4                               | 200                    | 30                            | 6 000                         |
|     | Amount of ballast received               | 1920                   | -                             | -                             |
|     | Compensating moment $M_\Psi = (7-12)-(1-6)$ | 28 000                 | -                             | -                             |
Figure 1. Calculation of cargo and geometrical characteristics of the floating crane (H^A – height and auxiliary lift; H^M – height and main lift).

Since arm of crane variation can reach several meters because of trim or heel impact then the calculated outreach is assumed to be the one which the crane has at horizontal position of the pontoon. As can be seen from Drawing 2, geometrical characteristics of the main and auxiliary hoisting of the floating crane change in such a way that with the outreach increasing the weight of the hoisted cargo decreases. Besides, calculations of characteristics of the main lifting have shown, that:
• Cargo of 800t weight can be lifted 60 m high over the water level when the arm of crane is equal to 23 m;
• Cargo of 800t weight can be lifted 55 m high over the water level when the arm of crane is equal to 32 m;
• Cargo of 600 weight can be lifted 45 m high over the water level when the arm of crane is equal to 50 m;

Considering characteristics of the auxiliary lifting, it is also possible to observe that:
• Cargo of 250t weight can be lifted 140 m high over the water level when the arm of crane is equal to 45 m;
• Cargo of 250t weight can be lifted 120 m high over the water level when the arm of crane is equal to 70 m;
• Cargo of 170 t weight can be lifted 105 m high over the water level when the outreach (over the ship’s side) is equal to 85 m;
Figure 2. Characteristics of the load-lifting device of non-self-propelled floating crane with no rotary top structure.

Conclusions
For providing normal operation of the load-lifting device of the floating crane a trim scheme is offered.

Moment and trim angle when hoisting cargo of 500 t at the maximum arm of crane and at the adverse influence of wind force of 5 points are calculated. The size of the compensatory moment necessary for flattening the floating crane, with reference to the chosen trim scheme is calculated. Scheme for calculating cargo and geometrical characteristics of the floating crane is made. Valid characteristics of the load-lifting device are received on its basis. Suggested scheme of the trim system shown in Drawing 2 makes possible to increase floating crane and its load-lifting device capabilities. This circumstance allows to have some margin in load-carrying capacity in case of emergency, but it is required to check the basic units of the floating crane and its load-lifting device on durability.
References
[1] Savinov V N 2016 Definition of characteristics of non-self-propelled floating crane Electronic scientific magazine «Transport systems» 2
[2] Savinov V N 2016 Calculation of towing resistance wake structure and power requirement of a pusher Modern technologies in ship-building and aviation education, science and manufacture: Reports of the All-Russian scientific-practical conference devoted to the 100 anniversary of R.E.Alekseev 140 – 144
[3] Christmas V V, Lugovsky V V, Borisov R V and Mirokhin B V 1986 Statics of the ship Leningrad publishing house Shipbuilding 240
[4] Rules of classification and construction of sea vessels CH IV Stability 2018 (the electronic version of the printed edition) V59