EVALUATION OF TIMBER CARRIER DECK CARGO JETTISON DYNAMICS

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ABSTRACT

The paper evaluates timber carrier behaviour when a part of deck cargo of timber is being jettisoned under emergency in a controlled or spontaneous way.
With the help of a specially written program, timber carrier stability parameter variation is analyzed under the conditions of dynamic application of a heeling moment due to jettison, variations in the ship's displacement, centre of gravity position and trim when heaving and rolling. In this case variations in the area of effective water line and nonlinearity of stabilizing and damping moments are taken into account.

Keywords: *timber carrier, jettison, heaving, rolling*

1. INTRODUCTION[1]

Statistics of the world fleet accident rate shows that timber carriers whose share in the world volume of sea carriages is 10%, leave all the other types of ships behind, without exception, in the number of wrecks; at the same time until recently such accidents ended in their loss extremely seldom: timber carriers capsized and perished many times more rarely than other types of ships.

In recent years, however, we witness loss of a whole number of timber carriers: the motor ships "Pallada" and "Alga" capsized at berths in port, the motor ships "Victor Vikharev", "Vest", "Sinegorye", "Kastor-1" and others sank at sea having cargo on board.

Within two weeks of December 2005 six timber carriers sailing from ports of the Russian Far East lost their deck cargo of timber off the north-west coast of Japan endangering safety of life at sea and threatening by damage to marine environment.

In autumn and winter 2006 another eight ships sailing from Russian ports and navigated by Russian seafarers jettisoned their deck cargo in the Sea of Japan.

Irrespective of the place where emergencies occur (in port or at sea) they follow the same scenario: *an initial list occurs, deck timber cargo securing structures are destroyed, deck cargo shifts, the ship's list increases sharply, the deck cargo is jettisoned spontaneously or controllably and then the ship is restored or, in relatively rare cases, capsized.*

If stanchions are destroyed, timber is shifted overboard hanging on lashings, thus creating a heeling moment that while the cargo shift caused by the ship's vibration, rolling and

[1] This paper was translated from Russian with computer software and may be difficult to read in English. As the National Committee did not have resources for professional translation of this paper, Russian text was used for peer review and included in the electronic version of the proceedings for further references.

pitching continues, reaches the value causing the ship's list of up to 30-40°. This list makes it possible for the lashings to break and a part of the deck cargo jettisons spontaneously, or the crew, for fear of further increase of the ship's list and loss of seaworthiness, lets go the lashings.

A mass of the cargo jettisoned overboard may reach 10-15% of the ship's net carrying capacity and the time within which the cargo leaves deck is comparable with 2-3 sec.; therefore, when a typical timber carrier's period of rolling is 20-30 sec., the righting moment from the deck cargo jettisoning is of a dynamic nature.

The force of weight of the cargo being jettisoned and the heeling moment caused by it disappear instantly, the ship loses a part of her weight load, her displacement, centre-of-gravity position, trim and inertia characteristics change and a righting moment begins acting on her.

Under certain circumstances (small initial stability, availability of not pressurized ballast and fuel tanks, appropriate wind and wave conditions) the value of the righting moment can be quite comparable with the capsizing moment for a timber carrier that met with an accident. Therefore, when taking a decision to jettison deck cargo of timber purposefully, it is important to know and assess its possible consequences for a ship.

2. SETTING A PROBLEM

In principle, methods of dynamic stability theory make it possible to solve the problems connected with dynamic application of a heeling moment to a ship. The problem of a squall impact on a ship experiencing rolling and pitching when there is sea and initial static list is a typical one and the closest to the problem under consideration among the problems solved in professor N.F. Voyevodin's monograph (1973). A considerable difference is that when jettisoning cargo from deck along with a dynamically applied moment, a ship's weight load, buoyancy and stability characteristics change. Therefore, in assessing a ship's behaviour when jettisoning deck cargo of timber, ship's general design characteristics (main dimensions, displacement, centre-of-gravity coordinates and arms of form stability curves), sizes and mass of deck timber being jettisoned, initial heeling angle, heavy sea parameters etc. should be used as initial data for calculation.

The problem should be treated as a time process; therefore, when a time step is set, the quantity of timber left on deck, its centre-of-gravity coordinates, acting efforts, movements, speeds and accelerations due to heaving and rolling should be calculated, and corresponding graphs enabling to take into account the acting water line area variation and nonlinearity of righting and damping moments should be drawn. Dependences of arms of form stability on displacement should also be approximated to be able to evaluate time variation of the lever arm of static stability curve.

To automate calculation of dependence of such a vast array of variables on a timber carrier behaviour when jettisoning deck cargo, an algorithm was worked out and a special calculation program was written.

3. PRINCIPAL ASSUMPTIONS AND CALCULATION DEPENDENCES

When a ship is alongside two-dimensional heavy sea, she will experience rolling, heaving and swaying motions. There is correlation between those types of motions; therefore, a rigorous solution of the problem presupposes combined consideration of three equations.

This paper examines isolated equations as there is a negligible cross-effect of heaving and rolling motions. The effect of swaying vibrations on rolling is significant, but the reverse effect is small. To make approximate calculation of the stated effect, following recommendations Y.I. Voitkunsky (1985) swaying motions are calculated according to an isolated "complete" equation and rolling motions according to an isolated "shortened" equation that are of the following form:

$$\left(\frac{D}{g}+\lambda_{33}\right)\ddot{\zeta}+\mu_{33}\dot{\zeta}+\gamma S\zeta = \kappa_{\zeta}\left(\gamma S-\omega^2\lambda_{33}\right)\zeta_A\cos\omega t-\kappa_{\zeta}\zeta_A\omega\mu_{33}\sin\omega t \quad (1)$$

$$\left(I_x+\lambda_{44}\right)\ddot{\theta}+\mu_{44}\dot{\theta}+Dh\theta = Dh\kappa_{\theta}h_0\sin\omega t \quad (2)$$

where: D is the ship's weight displacement;
g is acceleration due to gravity;
I_x is a ship's mass moment of inertia relative to a centroidal longitudinal axis;
λ_{33} and λ_{44} are added mass at heaving motions and added moment of inertia when rolling respectively;
μ_{33} and μ_{44} are coefficients of resistance for those kinds of motions;
S is an area of functional water line;
ζ is shifting of the ship's centre of gravity when heaving (dots above the symbols of shifting mean time differentiation);
κ_{ζ} and κ_{θ} are coefficients of reduction when heaving and rolling, taken as identical for all disturbing forces;
γ is specific weight of water;
ω is frequency of incoming waves (disturbing force);
ζ_A is wave amplitude;
α_0 is the maximum wave slope angle;
h is an initial transverse metacentric height;

$$h_0=\frac{2\pi\zeta_A}{\lambda}$$

λ is length of incoming waves.

Equation (1) describes heaving motions and equation (2) rolling motions. Both equations are linear; therefore, nonlinearity of a restoring moment is taken into account with the help of linear, quadratic and combined laws of resistance and approximation of dependence of arms of form stability on displacement used in drawing a present curve of static stability arms.

The program written makes it possible to use a model of random sea; for this purpose the following operations are done:

- An integral curve of spectrum of wave ordinates is drawn in the function of frequency (with perpetual frequency the curve ordinate is equal to dispersion of wave ordinates D_{ζ});
- Dispersion is divided into a chosen number of equal parts and frequency intervals are built according to an integral curve with identical elementary dispersions;
- frequencies located in the centres of intervals obtained are evaluated – it results in n values of wave frequencies with identical dispersions D_{ζ}/n**;**
- an occasional wave is obtained from adding n waves to the mentioned frequencies, identical amplitudes, but occasional phase angles.

Constructions and auxiliary calculations are made beforehand for a dimensionless form of spectrum, then the program makes recalculation ensuring the given parameters of irregular rough sea (typical height and mean period). Since the process of jettisoning deck cargo is brief as compared with the rolling period, there is no need to make models of heavy sea more precise and it is possible to use its simplified physical model.

It is supposed that before shifting the cargo of timber corresponded to a right-angled parallelepiped whose length, height and width are set. Then a part of cargo limited by a parallelepiped fell over the starboard side and the remaining part took a trapezoid form with its short side on the port side and long side on the starboard side. As a result, a ship heels initially to starboard. The heeling angle is set in initial conditions subject to adopted parameters of the ship's stability and cargo mass. In this case the length and height of a regular wave and the ship's motion initial angular velocity related to the design parameters of motions on a set rough sea.

At the initial moment the weight of timber that fell overboard disappears and the heeling moment caused by it is removed. Timber remaining on deck slips off without changing its form, a part of timber that is overboard stops affecting the ship. As a result the mean draft changes, as also the parameters defining rolling and heaving motions.

As mentioned above, a righting moment is calculated not according to a metacentric formula of stability, but through an arm of static stability which in the problem under consideration depends not only on the heeling angle, but also on the current status of load (the ship's displacement and centre of gravity applicate). To calculate it, the interpolation form stability curves available in the ship's documentation are used.

In computer simulation technique, form stability arm curves are described analytically; to do so, values of arms are taken from the curves for each angle with regard to three values of the ship's displacement when jettisoning (minimal, medium and maximal one) and then the form arm-heeling angle curve for each of these three displacements is approximated by a polynomial of 3^{rd} degree. Dependencies of polynomial coefficients on displacement are approximated by a quadratic polynomial to be able to calculate a form arm for an arbitrary heeling angle and any displacement. The error in determining an arm of stability with the help of this method of calculation does not normally exceed 2 cm, which is comparable with the error in taking values from graphs and quite satisfactory for solving the problem set.

Differential equations of rolling and heaving motions are integrated by the Euler method.

4. EXSEMPLARY CALCULATION

Numerical valuations of timber jettisoning dynamics are made in respect to timber carriers of the "Pioner Moskvy" type [3]. The sizes of the deck timber cargo jettisoned (length, width and height) are 8.0, 17.0 and 6.5 m respectively. The mass of the cargo jettisoned exceeds 400 t. When shifting, up to 40 % of the total mass of deck cargo hangs overboard on lashings. The ship's initial metacentric height is 0.20 m. The initial heeling angle is less than 30^0. The design wavelength is 120 m, height 6m and period 8.8 sec.

Since the period of design waves is about 3.5 times less than the ship's period of motions, their effect on amplitudes of rolling is small; in fact, the amplitude of rolling is determined by the ship's vibrations. The design time of jettisoning is 2.5 – 3.0sec., which agrees with the available data. The time step adopted in calculations is 0.05sec.

The calculations done enabled to obtain a number of dependences describing timber carrier behaviour when deck cargo is being jettisoned.

Fig. 1 and 2 show kinematics of angular and heaving oscillations for the case where at the initial moment a wave lists the ship to starboard side tilted by shifted cargo. It is evident that the rolling period is considerably bigger than the heaving period, in such a case heaving oscillations decay rapidly and the final draft decreases about 10 cm as compared with the initial one. The list decreases gradually as after jettisoning timber from deck the ship's load becomes more symmetric relative to the centreline.

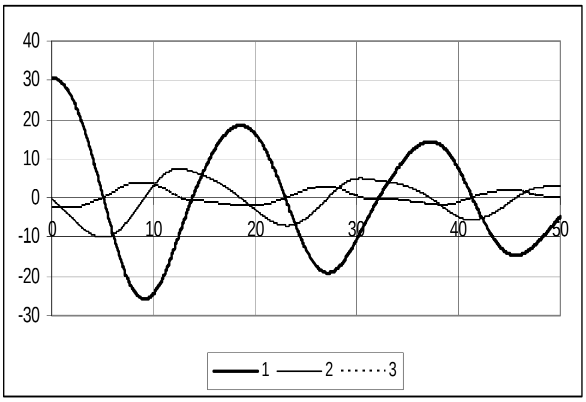

Figure 1. Parameters of rolling motions.
1 – heeling angles, degrees; 2 – angular velocities, deg./s; 3 – angular accelerations, deg./s^2.

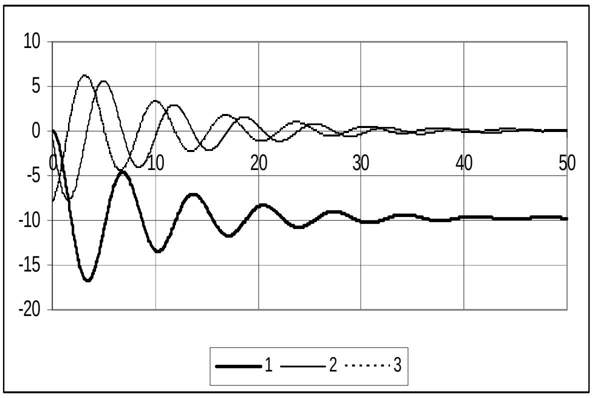

Figure 2. Parameters of heaving motions
1 – movements, cm; 2 – velocities, cm/s; 3 – accelerations, cm/s^2.

Fig. 3 illustrates kinematics of rolling motions when the initial wave phases change by 180^0, and Fig. 4 when the initial metacentric height grows from 0.2 to 0.4 m (notation conventions are the same as in Fig.1)

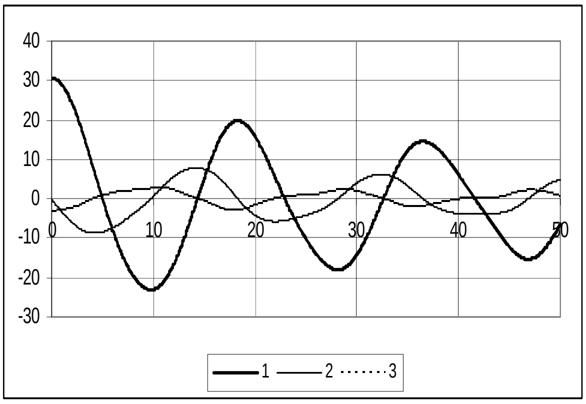

Figure 3. Rolling motions when the initial wave phase changes.

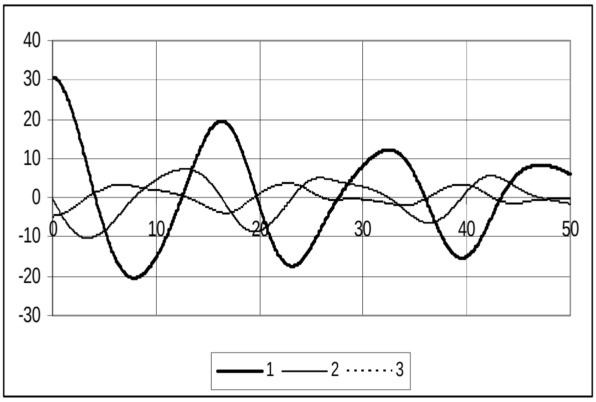

Figure 4. Rolling motions when the metacentric height changes.

5. CONCLUSION

The developed program of calculating the timber carrier rolling and heaving motions when a part of the deck cargo is jettisoned makes it possible to assess whether the ship may capsize taking into consideration the ship's mass change and inertia parameters, effect of rough sea and initial static heeling angle.

6. REFERENCES

Voyevodin N.F., 1973, Ships' Stability Change. – Leningrad: Shipbuilding – 200 p.p.

Naval Architecture Handbook: Three volumes, 1985, Vol. 2. Ships' Statics. Ships' Motions / Editor Y.I. Voitkunsky. – Leningrad: Shipbuilding. – 440 p.p.

Barabanov N.V., Rybalkin Y.G., 1986, Features of Designing Sea-Going Timber Carriers' Structures. – Leningrad: Shipbuilding. – 176 p.p.