



# International Journal of Automobile Engineering

E-ISSN: 2707-8213  
P-ISSN: 2707-8205  
IJAEE 2023; 4(1): 08-10  
Received: 06-01-2023  
Accepted: 15-03-2023

**EL Pankratov**  
Nizhny Novgorod State  
University, 23 Gagarin  
Avenue, Nizhny Novgorod,  
Russia

## On control of movement of a ship with account of changing of load

**EL Pankratov**

### Abstract

In this paper we introduce a model of movement of a ship with account of changing of cargo. The model is a generalization of the previously considered models and the analytical approach, which were used to analyze the introduced model, is also more general and gives a possible one to take into account a larger quantity of factors affecting the movement of the ship. The analysis of the influence of various factors on the movement of the ship is carried out.

**Keywords:** Model of movement of ship; analytical approach for analysis of movement

### Introduction

An analysis of the dynamics of the movement of ships is necessary for prognosis the occurrence of difficult situations and to optimize cargo transportation. One of the classical stages of choosing a ship's route is the calculation of its possible trajectory depending on various parameters [1-5]. It is also attracted an interest to increase the stability and buoyancy of the ship. In this paper we introduce a model, which is more general in comparison with the models recently published in literature. An analytical approach for analyzing the model is also introduced.

### Method of analysis

Movement of ship could be described by solving of the following equations [1-6]

$$\begin{cases} (L_{xx} + L_x) \frac{d\omega_x}{dt} = M_{kr} - \rho g V x_1 + \sum_{n=1}^N P_n x_{2n} + M_{x1} + M_{x2} \\ (L_{yy} + L_y) \frac{d\omega_y}{dt} = M_{diff} - \rho g V y_1 + \sum_{n=1}^N P_n y_{2n} + M_{y1} + M_{y2} \\ (m + m_z) \frac{dv_z}{dt} = \rho g V - F_g - \sum_{n=1}^N P_n + F_{z1} + F_{z2} \end{cases} \quad (1)$$

where  $dz/dt = v_z$ ;  $d\psi/dt = \omega_y$ ;  $d\theta/dt = \omega_x$ ;  $m$  is the mass of ship;  $z$  is the vertical coordinate of ship;  $\psi$  is the trim angle of ship;  $\theta$  is the roll angle of ship;  $m_z$  is the added mass of water;  $L_x$  and  $L_y$  are the added moment of water;  $\omega_x$  and  $\omega_y$  are the roll and differential angular velocities;  $v_z$  is the projection of the ship's speed on the axis  $Oz$ ;  $\rho$  is the density of water;  $g$  is the acceleration of gravity;  $V$  is the volumetric displacement of the ship at the given embarkation;  $F_g$  is the ship's gravity (weight displacement);  $\sum_{n=1}^N P_n$  is the total

weight of the cargo received on the ship at a given time;  $F_{z1}$  is the force of resistance of water to movements of the body;  $M_{x1}$  and  $M_{y1}$  are the moments of resistance of water to movements of the body;  $F_{z2}$  is the disturbing vertical force;  $M_{x2}$  and  $M_{y2}$  are the moments in roll and trim from the action of waves;  $L_{xx}$  and  $L_{yy}$  are the central moments of inertia of the ship's mass relative to the longitudinal and transverse axes;  $x_1 = x_{1c} - x_{1g}$ ,  $y_1 = y_{1c} - y_{1g}$ ,  $x_{1c}$  and  $y_{1c}$  are the abscissa and ordinate of ship center,  $x_{1g}$  and  $y_{1g}$  are the abscissa and ordinate of center of gravity;  $M_{kr}$  is the heeling moment of external forces acting at a given time;  $M_{diff}$  is the trimming moment of external forces. Integration of the left and right sides of equations of the system (1) on time leads to the following result.

**Corresponding Author:**  
**EL Pankratov**  
Nizhny Novgorod State  
University, 23 Gagarin  
Avenue, Nizhny Novgorod,  
Russia

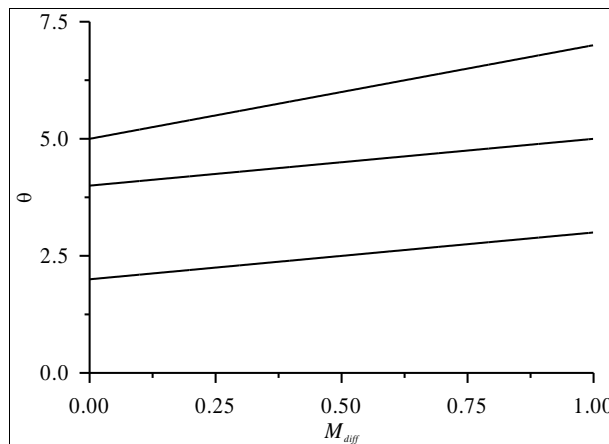
$$\begin{cases} (L_{xx} + L_x) \omega_x = M_{kr} t - \rho g V x_1 t + \sum_{n=1}^N P_n x_{2n} t + M_{x1} t + M_{x2} t \\ (L_{yy} + L_y) \omega_y = M_{diff} t - \rho g V y_1 t + \sum_{n=1}^N P_n y_{2n} t + M_{y1} t + M_{y2} t \\ (m + m_z) v_z = \rho g V t - F_g t - \sum_{n=1}^N P_n t + F_{z1} t + F_{z2} t \end{cases} \quad (2)$$

The initial values of coordinates and speeds of movement, as well as the angles of rotation and the corresponding speeds were considered be zero. Re-integration of the equations of system (1) over time gives a possibility to obtain equations of motion of the considered ship in the final form

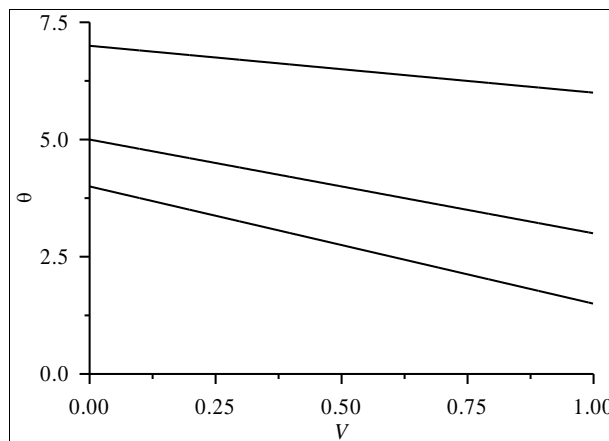
$$\begin{cases} 2(L_{xx} + L_x) \theta = M_{kr} t^2 - \rho g V x_1 t^2 + \sum_{n=1}^N P_n x_{2n} t^2 + M_{x1} t^2 + M_{x2} t^2 \\ 2(L_{yy} + L_y) \psi = M_{diff} t^2 - \rho g V y_1 t^2 + \sum_{n=1}^N P_n y_{2n} t^2 + M_{y1} t^2 + M_{y2} t^2 \\ 2(m + m_z) z = \rho g V t^2 - F_g t^2 - \sum_{n=1}^N P_n t^2 + F_{z1} t^2 + F_{z2} t^2 \end{cases} \quad (3)$$

**Discussion**

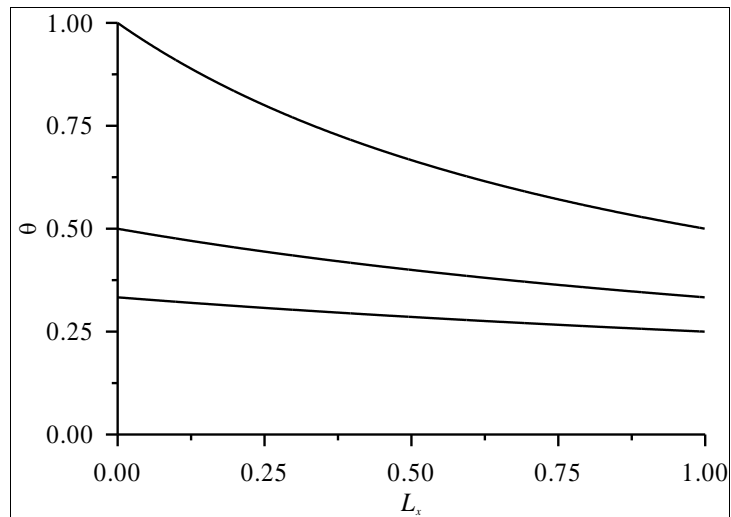
In this section we analyze the equations of motion (3) for different values of considered parameters. Figs. 1 and 2 show dependences of the coordinate  $z$ , angles  $\theta$  and  $\psi$  on various parameters. Figs. 3 and 4 show similar dependences of the velocities  $v_x$ , as well as the frequencies  $\omega_x$  and  $\omega_y$ .



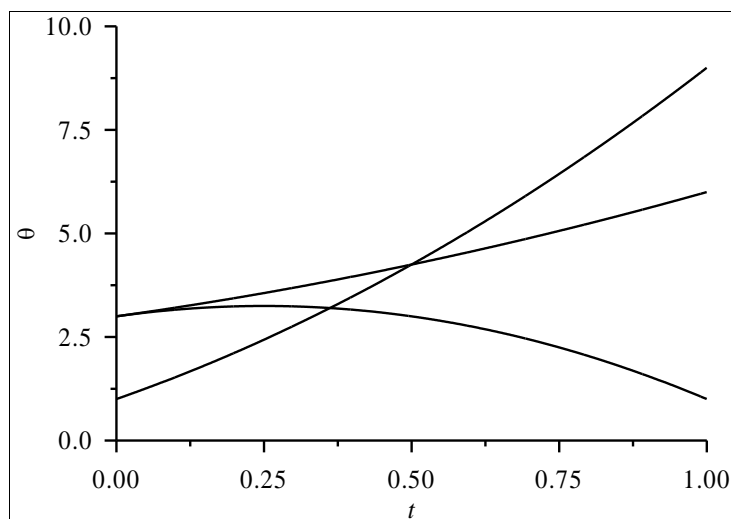
**Fig 1:** Typical dependences of the ship's roll angle  $\theta$  on the heeling moment of external forces  $M_{kr}$ . Similar will be the dependences of this angle on the moments  $M_{x1}$  and  $M_{x2}$ , the weights of the cargo  $P$ . The dependences of the  $z$  coordinate on the density of water  $\rho$ , the acceleration of gravity  $g$ , the volumetric displacement of the vessel  $V$ , the forces  $F_{z1}$  and  $F_{z2}$



**Fig 2:** Typical dependences of the ship's roll angle  $\theta$  on the volumetric displacement of the ship  $V$ . The dependences of this angle on the density of water  $\rho$  and the acceleration of gravity  $g$  will be similar. The dependences of the  $z$  coordinate on the gravity  $F_g$  of the weights of the cargo received on the ship  $P$



**Fig 3:** Typical dependences of the ship's roll angle  $\theta$  on the central moment of inertia of the ship's mass  $L_{xx}$ . The dependence of this angle on the added moments of water  $L_x$  will be similar. The dependences of the trim angle of the ship  $\psi$  of the same moments will be similar. Also, the dependences of the  $z$  coordinate on the masses  $m$  and  $m_z$  will be similar



**Fig 4:** Typical dependences of the ship's roll angle  $\theta$  on time  $t$ . The time dependences of the ship trim angle  $\psi$  and the  $z$  coordinate are similar

## Conclusion

In this paper we propose a quantitative approach for analyzing the movement of the ship, taking into account the change in load. The analysis of the influence of various factors on the movement of the ship is carried out.

## References

1. Yu I, Yudin II, Sotnikov. Mathematical models of plane-parallel movement of a ship. Classification and critical analysis. Bulletin of the Moscow State Technical University. 2006;9(5):200-208.
2. Smolentsev SV, Isakov DV. Simulation of ship movement based on a simplified kinematic model. Bulletin of the State University of Maritime and River Fleet named after Admiral S.O. Makarov. 2018;52(6):1111-1121.
3. Kostyukov VA, Maevsky AM, Gurenko BV. Mathematical model of a surface mini-ship. Don's Engineering Bulletin. 2015;3:3297.
4. Zuev VA, Gramuzov EM. New approaches to modeling the ice environment during model tests of ships. Proceedings of the Nizhny Novgorod State Technical University by R.E. Alekseev. 2015;4:107-114.
5. Tarovik OV, Topazh AG, Krestyantsev AB, Kondratenko AA. Modeling Arctic sea transport systems: the basis of an interdisciplinary approach and practical experience. Arctic: ecology and economics. 2017;1:86-101.
6. Kuz'michev VE. Laws and formulas of physics (Naukova Dumka, Kiev). 1989.