A Study on the Influence of Mathematical Models of Manoeuvrability on the Simulation of Ship Berthing Operation

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Abstract: As trade across the world is increasing these days, safe and effective management of harbour system is becoming important issue. With this background, the development of automatic time-domain simulation program for ship berthing operation has been performed and PD (Proportional Derivative) controller has been used to control the speed and the heading angle of ships. This paper provides feasibility study for developing the time-domain simulation program for berthing operation of ships with analysing advantages and drawbacks of the two different mathematical models, one is for low advance speed of ships by Kose (1984) and the other is MMG model for normal advance speed, through the simulations with various initial heading angles and positions of the ship.

Key words: berthing, time-domain simulation, PD controller, initial heading angle, initial position

1. Introduction

As trade across the world is increasing these days, safe and effective management of harbour system is becoming important issue. In particular, berthing operation of ships takes much time and requires various technical supports from harbour masters, pilots and engineers. In this point of view, precise prediction and practice of berthing operation are required and development of automatic simulation tool is requested for planning and managing effective harbour system (Chung et al. 2013).

2. Mathematical Model

Kose’s Mathematical Model for this study is as follows.

$$X^*_H = X^*_v v^* r^* + X^*_{uu} \left| u^* \right| u^* + X^*_{uuv} u^* v^* / U^* \right. + X^*_{vvv} v^* v^* / U^* \right) \right) (1)$$

$$Y^*_H = Y^*_v v^* U^* + Y^*_v v^* U^* + Y^*_{uuu} v^* U^*$$

$$+ Y^*_{rrr} v^* r^* + Y^*_{uuv} u^* v^* / U^*$$

$$+ Y^*_{vrv} v^* r^* / U^*$$

$$N^*_H = N^*_{uu} u^* v^* + N^*_{rr} r^* + N^*_{vrv} v^* r^*$$

$$+ N^*_{uuv} u^* v^* + N^*_{vvv} v^* v^*$$

where * means nondimensionalised values as follows.

$$X^* = X / L g, \quad Y^* = Y / \frac{L^3 g}{2}, \quad N^* = N / \frac{L^4 g}{2}$$ (4)
\[
m^* = m/\left(\frac{L}{2}L^3\right), \quad I^* = I_{zz}/\left(\frac{L}{2}L^5\right)
\]
(5)
\[
u^*, v^* = u, v/\sqrt{Lg}, \quad r^* = r/\sqrt{L/g}
\]
(6)
\[
u^*, v = u, v/g, \quad r = rL/g
\]
(7)

3. Control Algorithm

Fig. 1 shows the PD (Proportional Derivative) control algorithm of berthing simulation of a ship.

4. Simulation

Fig. 2 shows the trajectory for berthing simulation of the tanker ship using PD controller with Kose’s mathematical model in case where the initial position of the ship is \((-5L, 4L)\), the initial heading angle is \(-40\) degree and the initial speed of the ship is 3 m/s. Also, Fig. 3 shows the trajectory of the berthing simulation with the normal MMG model.

5. Conclusion

The main conclusions drawn from this study are summarised as follows:

- Time-domain simulations of ship berthing operation have been performed with Kose’s mathematical model and the normal MMG model using PD control algorithm.
- Various initial heading angles and positions of the ship have been applied for the simulation and the results have been analysed.
- Further research will be performed for the speed control of ships in the simulation of berthing operation.

Acknowledgements

The authors would like to express their sincere thanks to Professor Youngsub Kwon, Chosun University for providing his advice.

References