Prediction of Ship Hull Hydrodynamic Force and Moment in Low Speed

by Kyoung-Gun Oh*, *Student Member* Kazuhiko Haseagawa*, *Member*

***Key Words:** Mathematical model, Low Speed, Hydrodynamic force and moment*

1. INTRODUCTION

There are several ship operation requiring low speed and large drift angle conditions such as harbor berthing, anchor handling, pipe laying, subsea equipment installation, offloading, etc. For this low speed manoeuvring, several prediction models are proposed by the other researchers.

According to the ITTC report[1)], the models for the prediction of hydrodynamic forces and moment in low speed are categorized into cross-flow model, polynomial model, Fourier expansion model, tabular manoeuvring model and RANS-based CFD model. Although there are many methods and models, in this study, three of them are chosen for the comparison. The three model are proposed by Karasuno[2)], Yoshimura[3)] and Kang[4)] and these models are discussed in the present study.

2. PURPOSE OF THIS STUDY

The present study is aimed to propose more improved prediction model which expresses not only the quantity of forces and moment but also its physical characteristics.

Oblique towing test is carried out using Panamax tanker model in low speed with various drift angle conditions. As the results of experiment, obvious asymmetry distribution of forces and moment is found around β(drift angle)=90°.

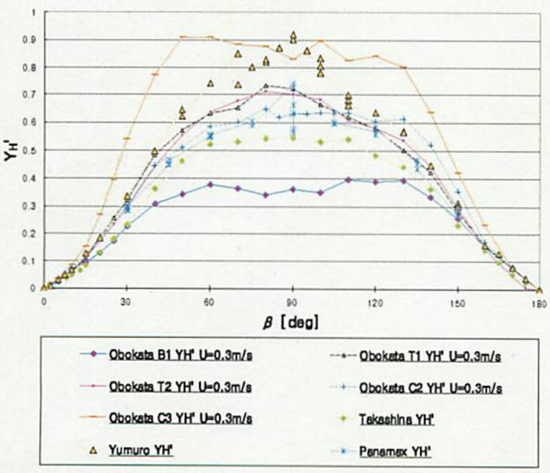

Fig.1 Sway force distributions.

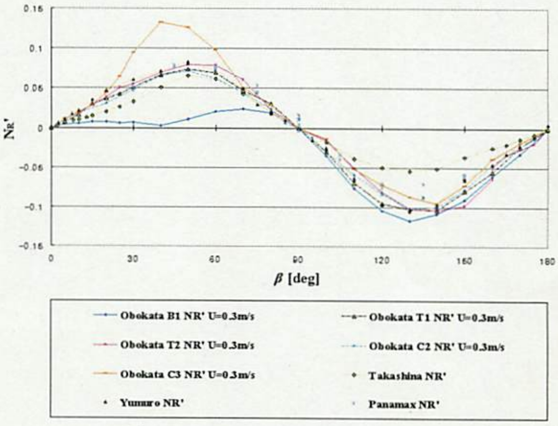

Fig.2 Yaw moment distributions.

Table 1 Principal dimensions of several ships for cross flow drag model, and force and moment comparison.

Ship type	L	B	d	C_B
Self propulsion Barge (B1)[5)]	3	0.821	0.115	0.81
Tanker (T1)[5)]	3	0.504	0.194	0.83
Tanker (T2)[5)]	3.683	0.577	0.205	0.84
Cargo ship (C2)[5)]	3	0.4286	0.171	0.7
Slender Model (C3)[5)]	3	0.3	0.18	0.58
LNGC[6)]	2.5	0.415	0.1	0.69
VLCC[7)]	4	0.652	0.268	0.83
Fish carrier boat (225GT)[2)]	2	0.391	0.165	0.65
Fishing boat (6.5GT)[2)]	1.76	0.446	0.715	0.68
Fishery research ship[2)]	0.28	0.056	0.023	0.69
Fishing boat[2)]	2	0.5	0.18	0.69
Tanker[2)]	3.75	0.572	0.229	0.85
PCC[2)]	3	0.537	0.137	0.54
Box model[2)]	1.6	0.4	0.13	1.00
Triangle section box type ship model[2)]	1.6	0.4	0.13	0.93
Panamax tanker[8)]	3.94	0.58	0.22	0.83

* Osaka University

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This asymmetry is also conformed in other collected experiment data as shown in Figs. 1 and 2.

Figs. 1 and 2 show the sway force and yaw moment in low speed with various drift angle conditions for various ships whose principal particulars are given in Table 1. Especially, the force and moment of blunt body ships like C3 show significant asymmetrical distribution.

3. REGRESSION MODEL

Considering this physical characteristic, three representative prediction models are selected for the comparison study, and they are discussed below.

3. 1 Karasuno's model

Karasuno's model consists with summation of several components. These components are ideal fluid's force due to the stream, viscous lift due to the stream by Kutta's condition, cross flow lift/drag due to the interaction between cross flow vortex wake and bound vortices and induced drag due to the interaction between the trailing and bound vortices. This component type model has the pros and cons at same time. The first advantage of this model is that the asymmetry distributions of ship hydrodynamic forces and moment are expressed well by the induced drag component. Second, the hull hydrodynamic forces and moment are estimated well, if the ship's particulars including m'_x and m'_y are given. However, it is not easy to apply relatively, comparing to Yoshimura's model.

3. 2 Yoshimura's model

The principal of this model is based on linear hydrodynamic force and cross flow drag. One of the merits of Yoshimura's model is simple to apply, because of the minimized coefficients or parameters. As an example, the cross flow drag which is dominant for sway force model, is expressed with only two variables, L and d. In addition, this model expresses asymmetry distribution, although it is not appeared significantly, comparing to Karasuno's model.

3. 3 Kang's model

Kang[4] proposed the prediction model for blunt body ship. The model is made on the basis of Kijima[9], Karasuno[2] and Yumuro[7]. At first, using the Kijima's and Karasuno's model, the hull hydrodynamic forces and moment of 21 ships are calculated in entire of drift angle range. Considering the applicable range of those 2 models, the model is connected. Then, the actual model is expressed using Yumuro's form as in eq. (1). The merit of this model is that the sway force and yaw moment of blunt body ship are well fitted for tuned coefficients.

$$\left.\begin{aligned} Y' &= (ay1 + cy1\cdot\gamma'^2)\sin\beta \\ &\quad + ay3\cdot\sin 3\beta + ay5\cdot\sin 5\beta \\ &\quad + (dy\cdot\gamma' + ey\cdot\gamma'|\gamma'| \\ N' &= (an2 + cn2\cdot\gamma'^2)\sin 2\beta \\ &\quad + an4\cdot\sin 4\beta + dn0\cdot\gamma' \\ &\quad + (en0\cdot\gamma'^3 + dn2\cdot\gamma'\cos 2\beta \end{aligned}\right] \quad (1)$$

where *ay1, cy1, ay3, ay5, dy, ey, an2, cn3, an4, dn0, en0* and *dn2* are coefficients.

4. DISCUSSIONS

Fig. 3 shows the relation between cross flow drag and $C_B{*}L/d$, used in Karasuno's model at $\beta=90^{\circ}$[2]. The Karasuno's formula for cross flow drag coefficient is made using the experiment data of 5 fishing vessels and 3 tanker ships. In the same way, Fig. 4 shows the relation between cross flow drag coefficient and L/d, proposed by Yoshimura[3]. This formula for cross flow drag coefficient is made using 2 fishery research ships and 5 different types of commercial ships like VLCC, container and PCC, etc. Their regression formulae are given in Table 2.

Table 2 Regression models for cross flow drag.

Researcher	Prediction formulas
Karasuno	$C_D = -0.027(C_B\cdot L/d)+1.166$
Yoshimura	$C_D = -0.0591(L/d)+1.848$

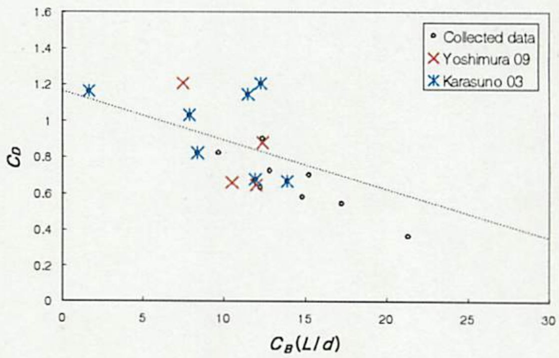

Fig. 3 Cross flow drag coefficient for Karasuno's formula, and some collected data.

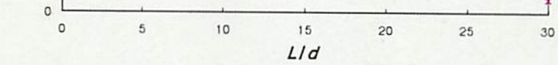

Fig. 4 Cross flow drag coefficient for Yoshimura's formula, and some collected data.

The authors modify their formulae to predict the cross flow coefficient more exactly. To make the new formulae for cross flow drag coefficient, several other ship's experiment data which collected from other published paper, are used, and some extreme data like box type vessel or fishing boat, were excluded from them. Because of this reason, the new formulae has a applicable range. The new formulae are expressed in eqs. (2) and (3), and in Figs. 5 and 6, they are compared with Karasuno's and Yoshimura's formulae respectively.

$$C_D = -0.0374(C_B{*}L/d)+1.216 \quad (2)$$

$$C_D = -0.0319(L/d)+1.283 \quad (3)$$

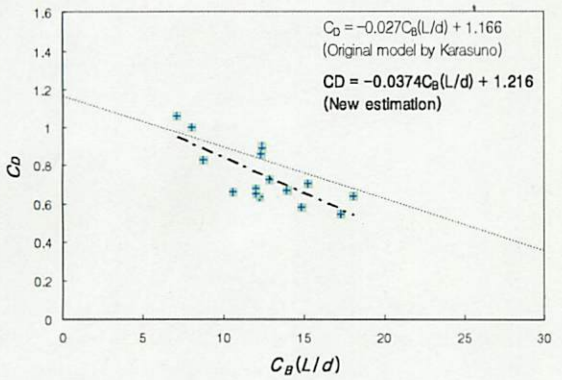

Fig. 5 Comparison result between newly proposed formula and Karasuno's formula.

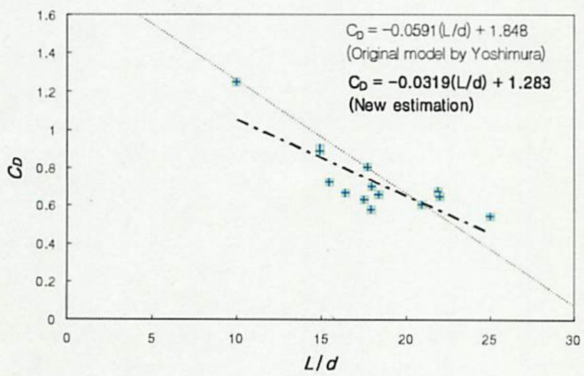

Fig. 6 Comparison result between newly proposed formula and Yoshimura's formula.

In Figs. 7 and 8, sway force and yaw moment of Panamax tanker model are calculated using Karasuno's, Yoshimura's and Kang's models, and the results are compared with experiment data. In addition, sway force is also calculated using the experiment data of cross flow drag coefficient at β=90° replacing Karasuno's and Yoshimura's formulae. Then, these modified models are also plotted.

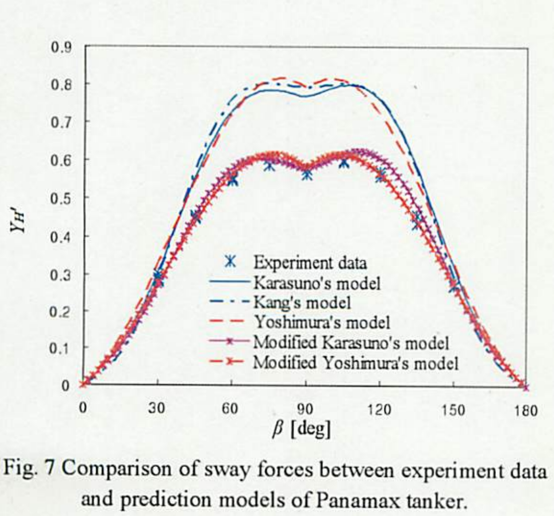

Fig. 7 Comparison of sway forces between experiment data and prediction models of Panamax tanker.

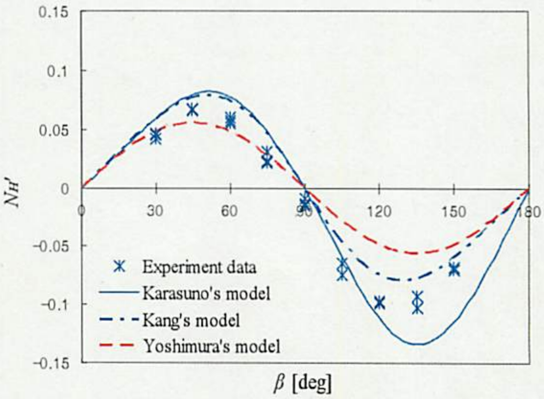

Fig. 8 Comparison of yaw moment between experiment data and prediction models of Panamax tanker.

Through the analysis of sway force and yaw moment in Figs. 7 and 8, the importance of cross flow drag coefficient and the necessity of research about the asymmetry distribution was confirmed.

5. CONCLUSIONS

The present study is aimed to predict the ship hull hydrodynamic force and moment in low speed condition. For this purpose, available published experiment data were collected, and additional oblique towing test were carried out for sway force and yaw moment for various drift angle, and other proposed prediction models are reviewed. The following conclusions are obtained.

1) As the results of oblique towing test, asymmetry distributions of sway force and yaw moment are found, and this asymmetry distribution is also found in other researcher's experiment data.

2) New prediction formulae for cross flow drag coefficient are proposed, modifying Karauno's and Yoshimura's formulae.

3) The cross flow drag coefficient should be researched more to obtain the sway force more accurately.

References

1) ITTC Manoeuvring Committee: Final report and recommendations to the 26th ITTC, Proc. of 26th International Towing Tank Conference (ITTC), Vol. I, pp.161-165, 2011

2) Keiichi Karasuno, Seiji Okano, Jun Miyoshi, Kazuyoshi Maekawa: Predictions of Ship's Hull hydrodynamic Forces and Maneuvering Motions at Slow Speed based on a Component-type Mathematical Model, Proc. MARSIM'03, Kanazawa, pp. RC-4-1 - RC-4-11, 2003

3) Yasuo Yoshimura, Ikao Nakao, Atsushi Ishibashi: Unified Mathematical Model for Ocean and Harbour Manoeuvring, Proc. MARSIM '09, Panama, pp. 1-9, 2009

4) Donghoon Kang, Kazuhiko Haseagawa: Prediction Method of Hydrodynamic Forces Acting on the Hull of a Blunt-body Ship in the Even Keel Condition, Journal of Marine Science and Technology, Vo. 12, Number 1, 2007

5) Jun Obokata, Norio Sasaki, Jitsuro Nagashima: On the Estimation of Current Force Induceed on a Ship Hull by Some Model Tests, The Japan Society of Naval Architects and Ocean Engineers, Vol. 108, pp. 47-57, 1981

6) Junshi Takashina: Ship Maneuvering Motion due to Tugboats and Its Mathematical Model, The Society of Naval architects of Japan, Vol. 160, pp. 93-104, 1986

7) Akinori Yumuro: Some Experiment on Maneuvering Hydrodynamic Forces in Low Speed Condtions, The Japan Society of Naval Architects and Ocean Engineers, Vol. 209, pp. 99-101, 1988

8) Kyoung-Gun Oh, Kazuhiko Hasegawa, Keiichi Karasuno, Seung Keon Lee: Ship Manoeuvring Hydrodynamic forces and moment in Low Speed, Pro. of AMEC 2012, (In press)

9) Katsuro Kijima, Yasuaki Nakiri: On the Practical Prediction Method for Ship Manoeuvring Characteristics, Trans West Japan Society of Naval Architects, Vol. 105, pp. 21-31, 2002