선박의 조종성능과 조종곤란도의 상관관계 분석을 위한 협수로 항행 실시간 시뮬레이션

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Abstract

Yaw-checking and course-keeping ability in IMO's ship manoeuvrability standards is reviewed from the viewpoint of safe operation. Three types of assumed series-ships, which have systematically different instability on course, are taken as tested models. The numerical simulation on Z-test is carried out in order to examine the correlation between known manoeuvrability and various kinds of overshoot angle. Then simulator experiments are executed with series-ships in situation of curved, narrow waterway by five pilots in order to examine the correlation between known manoeuvrability and degree of manoeuvring difficulty. Three kinds of IMO's criterion concerning yaw-checking and course-keeping ability are discussed and new criteria are proposed.

Keywords : IMO's ship manouvrability standard, yaw-checking ability, course-keeping ability, simulator study

1. Introduction

Recent marine disaster of large ships often causes serious oil pollution (Song 1993). To prevent or reduce such a disaster, International Maritime Organization (IMO) has been endeavoring to improve ship's manoeuvrability, and adopted the interim standards for ship manoeuvrability A751(18) in 1993 (Kang 1993). These standards cover the typical manoeuvrability including turning ability, initial turning ability, yaw-checking and course-keeping ability, and stopping ability.

In this paper the authors review the manoeuvrability standards particularly focusing the criterion for the yaw-checking and course-keeping ability. Firstly, the authors take three types of original actual-ship built in Korea recently, from which they prepare the series-ships with systematically different spiral loop widths, and carry out numerical simulation on Z-test to examine the yaw-checking and course-keeping ability of the series-ships in terms of overshoot angles. Then, simulator experiment is carried out to grasp the correlation between known manoeuvrability and degree of manoeuvring difficulty felt by pilots. Finally, the IMO's standards are discussed, and new criteria are proposed and compared each to each in view of degree of manoeuvring difficulty.

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2. Assumed series-ships and simulated overshoot angle of Z-test

The authors take a training ship, a container ship and a bulk carrier as tested models for the present study. Table 1 shows principal dimensions of three actual-ships. In order to prepare three groups of series-ships with different, systematic manoeuvrability from the actual-ships, four linear hull derivatives are changed according as stern frame line such as U or V shape of stern body plans (Yoshimura 1995) and rudder area ratios are also changed for consideration of profile effect at stern. Fig. 1 shows rudder area ratio and stability index of hull for preparation of three groups of series-ships with different spiral loop widths. Fig. 2 shows simulated spiral curve of three groups of series-ships with various spiral loop widths from 0 deg to 10 deg at intervals of 2.5 deg.

Table 1. Principal dimensions of original actual-ships

			Training ship (3,700 GT)	Container ship (4,300 TEU)	Bulk carrier (207,000 DWT)
Length bet. per.	L	(m)	93.0	274.0	300.0
Breadth	B	(m)	14.5	32.25	50.0
Depth	D	(m)	7.0	21.7	25.7
Draft	d	(m)	5.2	13.5	18.0
Block coef.	C_b		0.604	0.65	0.8388
Design speed	V	(kt)	15.0	23.5	13.5
L / V			12.0	22.7	43.2

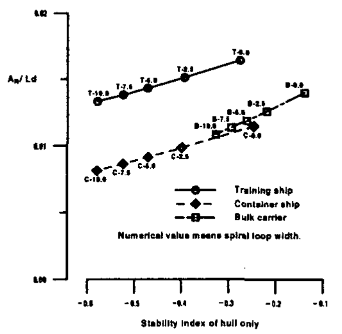
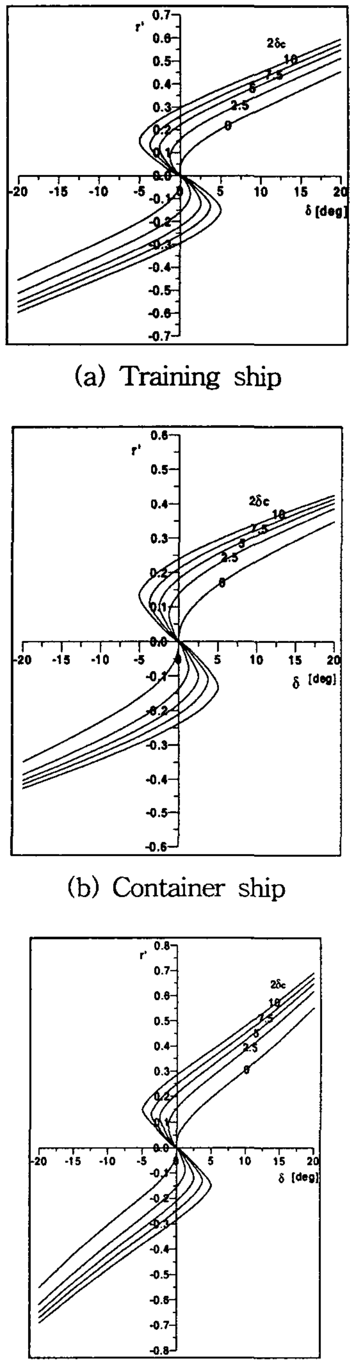


Fig. 1 Rudder area ratio and stability index for generation of series-ships with systematically different spiral loop widths



(a) Training ship

(b) Container ship

(c) Bulk carrier

Fig. 2 Spiral curves of series-ships with different spiral loop width : 2δc

In this paper the modular type mathematical model is employed for prediction of manoeuvrability in numerical simulation and simulator experiment as well. The model was proposed by one of the authors for the practical prediction of manoeuvring motion at low advance speed with large drift angle and relatively high advance speed as well (Sohn 1992). The model originated and was modified from Takashinas study (Takashina 1986). Hirano (1992) also suggested the same mathematical model as that used in this paper. Hydrodynamic derivatives and many other coefficients appearing in mathematical model can be obtained from a variety of references (Inoue 1981, van Lammeren 1969, etc.).

Figs. 3, 4 and 5 show the result of numerical simulation on Z-test. The initial speed of series-ship is the same as design speed of original actual-ship shown in Table 1. The simulation result shows that the spiral loop width has strong relationship with the 1st overshoot angle of 10 deg Z-test, and the 2nd overshoot angle of 10 deg Z-test is almost 2 or 2.5 times as large as the 1st one of 10 deg Z-test, and the 1st overshoot angle of 20 deg Z-test is almost 5 or 10 deg larger than the 1st one of 10 deg Z-test. So the overshoot angle of Z-test can be well applicable as index of yaw-checking and course-keeping ability.

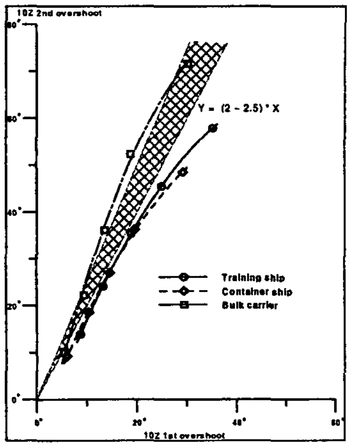


Fig. 4 Relation between the 1st and the 2nd overshoot angles of 10 deg Z-test

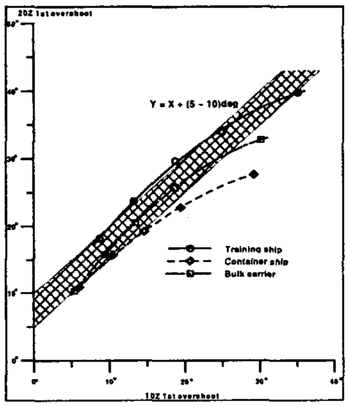


Fig. 5 Relation between the 1st overshoot angle of 10 deg Z-test and the 1st overshoot angle of 20 deg Z-test

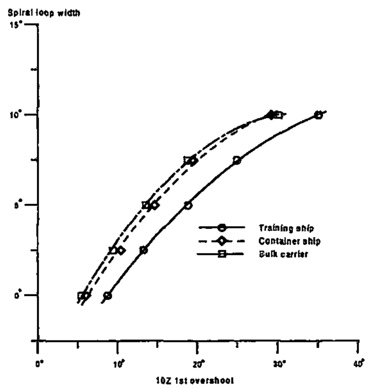


Fig. 3 Relation between spiral loop width and the 1st overshoot angle of 10 deg Z-test

3. Simulator experiment

The authors carry out simulator experiment in order to grasp correlation between overshoot angles provided in IMO's standards and the degree of manoeuvring difficulty felt by pilots. The shiphandling simulator has been constructed by the authors for this purpose. The schematic of system configuration for the present simulator is shown in Fig. 6.

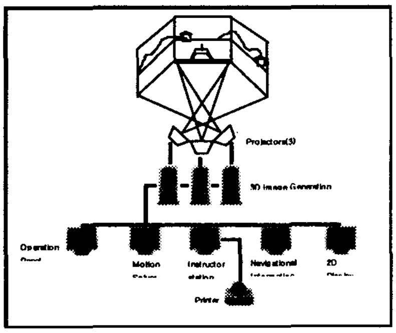


Fig. 6 Schematic of system configuration for present simulator

The situation of passing in a curved, narrow waterway is taken as simulation scenario. The authors select the east waterway of designated area of Inchon Harbour Approaches. Fig. 7 shows the map of selected waterway. The depth of waterway is assumed to be deep enough. Wind and current are applied to ship as external forces. Wind velocity is considered as 10 m/sec from WNW(293) and current as 2 kt to NE(050).

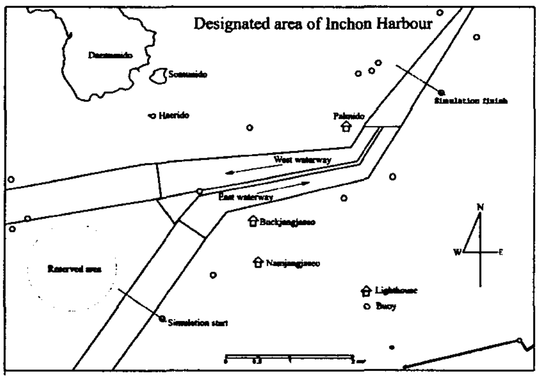


Fig. 7 Map of waterway and Inchon Harbour Approaches employed for present simulator study

The mission to shiphandling is that one is passing along the waterway centerline as far as possible and the other is keeping propeller revolution constant as that of harbour full speed. Harbour full speeds are 12 kt in training ship, 17.6 kt in container ship and 10.8 kt in bulk carrier respectively. Only rudder command is allowed and pilot issues orally the order to helmsman.

Five ship operators participate in the simulator experiment. All of them are pilots on service in Korea, who have pilotage experience of one to five years after serving on merchant ships for around 10 years or more.

Before the simulator experiment, purpose of experiment, tested ships, waterway, external environment, mission to shiphandling and so on are briefly explained to pilot. In order to save time, without any preliminary simulation for familiarization, the regular simulation using each type of series-ships is executed one by one in the order of ship's instability on course.

Fig. 8 shows averaged root-mean-square values of ship's lateral deviations from waterway centerline. Some differences in magnitude are appeared according as type of series-ships but no differences according as spiral loop width of same type of series-ships. On the contrary, the lateral deviations of series-ships with large spiral loop width are smaller than those of series-ships with small spiral loop width. It may result from familiarization due to repeated simulation of same type of series-ships. Fig. 9 shows averaged root-mean-square values of applied rudder angles. Some differences in magnitude are appeared according as type of series-ships

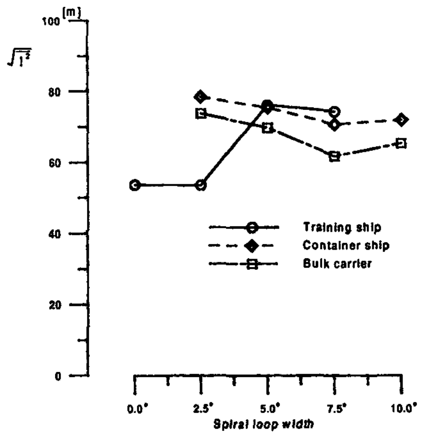


Fig. 8 Averaged root-mean-square values of lateral deviations from waterway centerline during simulation

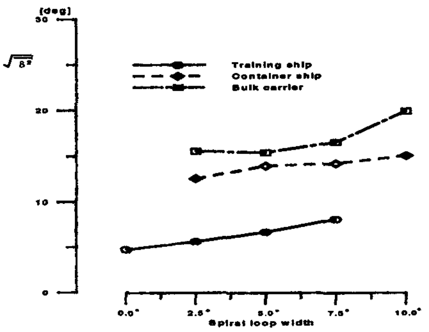


Fig. 9 Averaged root-mean-square values of applied rudder angle during simulation

and also spiral loop width of same type of series-ships as well. Applied rudder angles come to be larger in the order of ratio of ship length to design speed (L/V) and ship's instability on course or spiral loop width as well. Fig. 10 shows degree of manoeuvring difficulty in terms of subjective evaluation rating scale felt by pilots. The authors employ three kinds of subjective evaluation item. They are skill required, difficulty of task and stress level felt by pilot during shiphandling simulation. Every evaluation item has 10 rating scales from 0 to 9. Larger rating scale means more skill required, more difficulty of task and higher stress level respectively. These rating scales are evaluated by pilots immediately after every execution of simulation. Fig. 10 shows averaged values of three kinds of rating scale evaluated by five pilots concerning each ship. Averaged subjective evaluation rating scale has strong relationship with instability on course or spiral loop width. Fig. 11 shows correlation between averaged subjective evaluation rating scale and averaged root-mean-square values of applied rudder angle during simulation. It is obvious that applied rudder angle is proportioned to subjective evaluation rating scale. But the magnitude of applied rudder

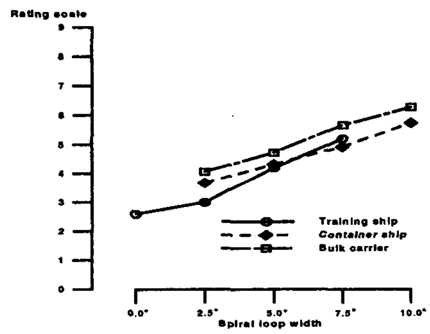


Fig. 10 Averaged subjective rating scales evaluated by pilots during simulation

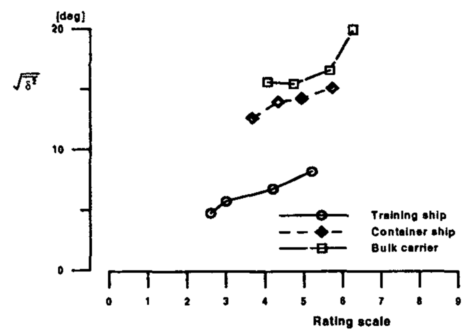


Fig. 11 Correlation between averaged subjective rating scales and averaged root-mean-square values of applied rudder angles during simulation

angles is different with one another according as a type of series-ships.

Figs. 12, 13 and 14 shows rating scale data by simulator experiment, marked on IMO A751(18) criterion diagram. In Fig. 12 the IMO criterion on the 1st overshoot angle of 10 deg Z-test was decided to different values along L/V in order to take the steering speed into consideration. However the simulator experiment shows that even though L/V is less than 30 sec, manoeuvring difficulty does not become larger than that when L/V is 30 sec or more. So the authours propose 20 deg as the limit line of the 1st overshoot angle of 10 deg Z-test regardless of L/V values, which means almost 5 in rating scale. In Fig. 13 the authors propose 45 deg as the limit line of the 2nd overshoot angle of 10 deg Z-test regardless of L/V values, which has been decided in consideration of rating scale 5 and also numerical simulation result on the relation between the 1st and the 2nd overshoot angles in 10 deg Z-test. In Fig. 14 the authors propose the same value as that of IMO A751(18) in consideration of rating scale 5 and also numerical simulation result on the relation between the 1st overshoot angle of 10 deg Z-test and the 1st one of 20 deg Z-test. Fig. 15 shows the comparison of three proposed criteria in terms of the 1st overshoot angle of 10 deg Z-test, which has been prepared from simulated result on Z-test(Figs. 4 and 5). Three proposed criteria shows almost the same level in manoeuvring performance. Therefore the proposed criteria are thought to be more reasonable than existing IMO criteria:A751(18). Additionally the authors think the 3rd criterion, namely the 1st overshoot angle of 20 deg Z-test,

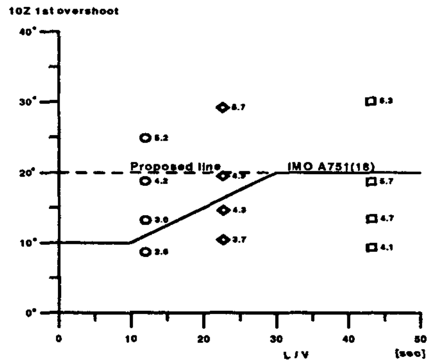


Fig. 12 subjective rating scales marked on IMO's standard diagram (the 1st overshoot angle of 10 deg Z-test)

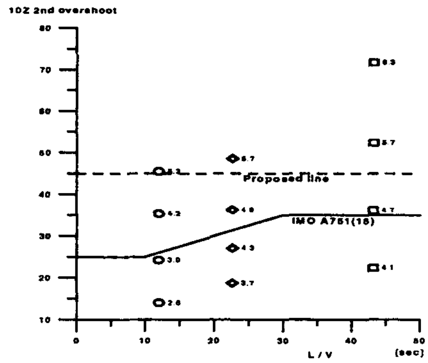


Fig. 13 Averaged subjective rating scales marked on IMO's standard diagram (the 2nd overshoot angle of 10 deg Z-test)

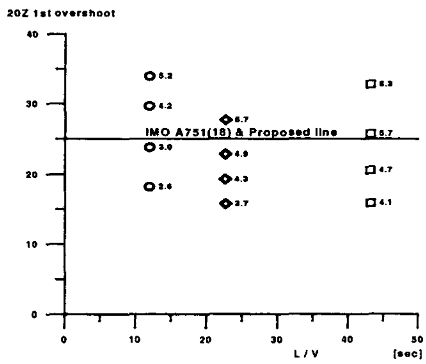


Fig. 14 Averaged subjective rating scales marked on IMO's standard diagram (the 1st overshoot angle of 20 deg Z-test)

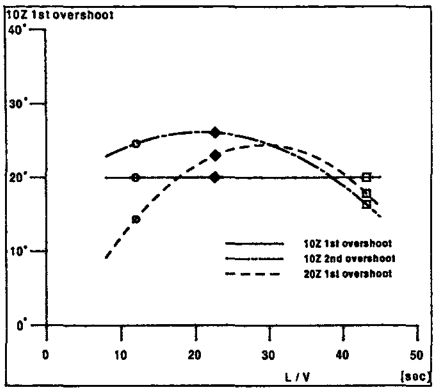


Fig. 15 Comparison of three proposed criteria in terms of the 1st overshoot angle of 10 deg Z-test

unnecessary because almost all ships with extremely poor manoeuvrability on course-keeping and yaw-checking ability can be checked by application of the 1st and the 2nd criteria, namely the 1st and the 2nd overshoot angles of 10 deg Z-test. Simulator experiment reveals that even though spiral loop width are the same among three types of series-ships, handling of series-ships with larger L/V, on the whole, is more difficult than that w

4. Conclusions

Through the simulator study using three groups of series-ships with the different instability on course, the authors have reviewed IMO's ship manoeuvrability standards particularly focussing the criterion for yaw-checking and course-keeping ability. As far as the present simulator study is concerned, the major concluding remarks are pointed out as follows.

(1) Overshoot angle of Z-test can be well applicable as index of yaw-checking and course-keeping ability.

(2) Applied rudder angle during simulation has strong relation with her instability on course and with subjective evaluation rating scale as well.

(3) New criteria on yaw-checking and course-keeping ability are proposed as Figs. 12, 13 and 14 in view of degree of manoeuvring difficulty.

(4) Even though spiral loop widths are the same among three groups of series-ships, handling of ships with larger length to speed ratio, on the whole, is more difficult than that with smaller length to speed ratio.

Even though some large ships satisfy IMO's standards, pilots may feel difficult in passing through in curved, narrow waterway.

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