RESPONSE TO THE DISABLED SHIPS IN ROUGH SEAS

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ABSTRACT

The emergency towing method is usually adopted for the disabled ships which would cause the secondary potential disaster. The first action to the ships in distress is to set up the towline In the case of crew on board it is rather possible to give the towline from the rescue boats. It is quite difficult such as the case of Nakhodka or no crew on board. In the case of broken or capsized ships it is extremely difficult to estimate the force to tow such ships. It is necessary to carry out the experiment because the theoretical calculation The main research themes in the project are shown below.

The computer simulation system to provide the information for the optimum towing which can be supported by the prediction of the submerged ship forms and accurate drifting course should be developed. The guideline for the safety towing should be made on the assumption of the practical operation in the emergency situation.

The paper describes the ongoing research achievements such as theoretical and experimental results.

1. Introduction

The disabled tanker was broken into two parts due to rough waves and bow part of the ship drifted to the sea shore in the heavy oil leakage accident of Russian ship named Nakhodka January in 1997. The loaded heavy oil flew out of the bow section of the ship continuously and caused the biggest marine pollution in Japan. Approximately 6,200 kl heavy oil leaked out in this accident. The technology for the recovery of the drifting bow part of disabled ship before reaching the sea shore in rough waves would not have caused the serious disaster.

The Erika incident occurred offshore of Brest December in 1999. The tanker Erika broke into two parts and the stern part of the ship was towed by the tugboat in rough seas. Finally both parts of the ship sank into the sea bottom. The incident caused the huge environmental damage due to the heavy oil leakage.

There were many accidents in the past causing damage due to oil leakage without the effective towing measures like Nakhodka. In the oil leakage accident of the tanker 'Braer' which drifted due to engine problems occurring off Scotland, the trial of settling up the towline failed resulting in the oil leakage of 95,000 kl.

Japan imports the large quantity of crude oil, liquid gas, and also transports and exports the domestic produced chemicals. Besides, sea areas are the course of crude oil transportation, so, there are frequent traffic of Japan and foreign tankers. Those ships include old and immature operating technology, moreover, sea conditions around our country is very rough, therefore, that may cause damaged, superannuated ships, or engine trouble, and those wrecked part of the ships would create oil spill, collision, explosion, or fire.

Consequently, it is necessary to establish the preventing technique of disabled ship under the rough weather, and towing technique as soon as possible. Also, it is necessary to research the prediction technique of drifting course, way of selecting and setting up the towline, way of towing while keeping the stabilized position.

2. Outline of the research project

The Ship Research Institute of which name was changed into the National Maritime Research Institute in 2001, started the research project on the prevention of disabled ships in rough seas sponsored by the Ministry of Transport. This is a 5 year research project from the fiscal year of 1998 to 2002. The Research Committee for Towing Technology has been set up including Japan Coast Guard, universities, salvage company and wire or synthetic fiber rope company. In this committee problems of the drifting prevention operation and towing operation have to be clarified and also the project research results have to be validated. Preferably the towing guideline will be proposed. There are three working groups which consists of optimum towing support system WG, towing techniques WG and drift motion simulation WG.

There are 6 main research items as shown below. In this paper 4 items out of 6 are described in detail.

(1) Research on the drift motion

Prediction technology of the drift speed and direction of disabled ships which include extraordinary ship forms due to shipwrecked, broken, capsized situations has to be established. The hydrodynamic force has been estimated by the experimental results using the tanker model divided into 10 parts. The drifting experiment using broken ship model was carried out to estimate the drift speed and direction.

(2) Research on the set-up of he towline

The structural strength test was carried out on the bracket for towing which was installed by the gun named drive-it. The towline force obtained by using the drive-it was measured .

(3) Research on the estimation of the towline tension

The method of estimating the towline tension during tow of the disabled ships in rough wind and waves has to be established. Using the model which can be divided into many parts, the towing experiment was carried out. Changing the experimental parameter such as the breakage status, flooded status, towing speed and wave conditions, the towline tension should be measured.

(4) Research on the needed power for towing

The towing model experiment using the patrol boat and tanker was carried out in waves in the 400 m water tank. The needed power to tow the disabled ships in waves has to be estimated

(5) Research on the optimum towing method

The techniques for the towing with the

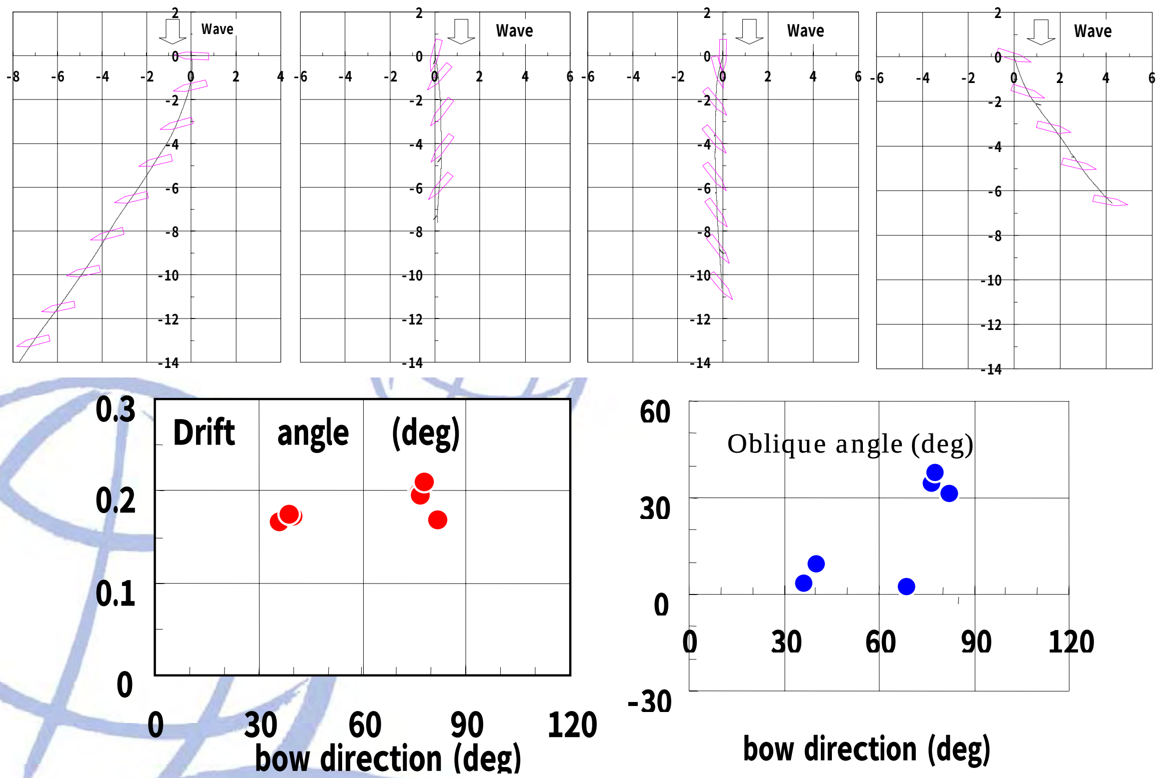
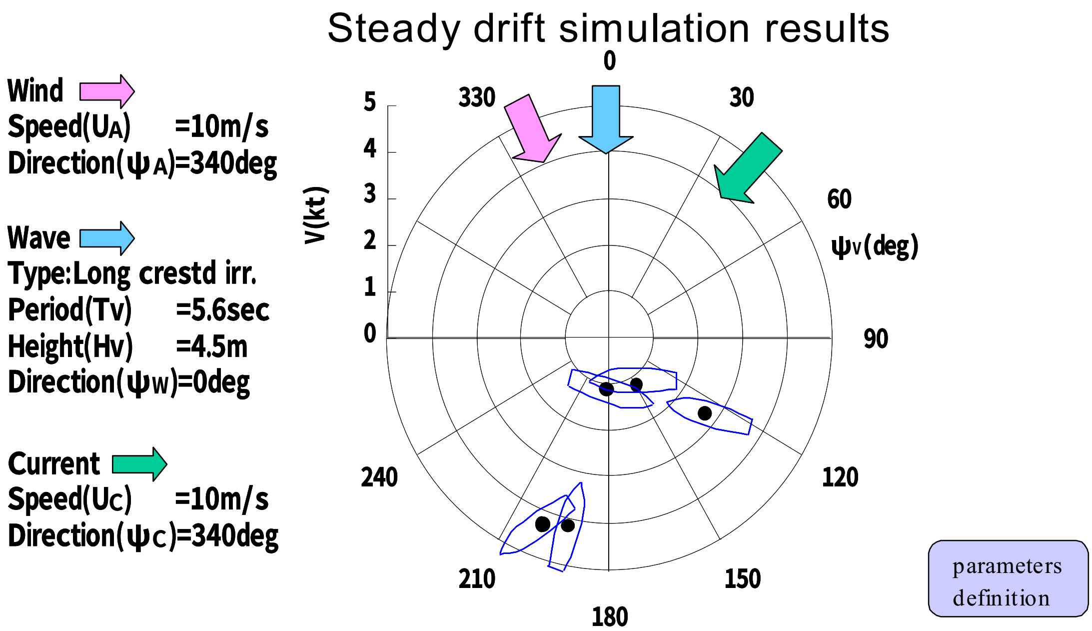


Figure 1 Drift motion of the tanker model in the ballast condition



	Drift Condition			Relative Parameters					
	Drift speed	Drift direction	Bow direction	Ship speed relative to water	Direction of U	Oblique angle relative to water	Wave encounter angle	Relative wind speed	Relative wind direction
sol.no.	V(kt)	ψV(deg)	ψB(deg)	U(kt)	ψU(deg)	β (deg)	χ (deg)	UAr(m/s)	θAr(deg)
1	2.68	127.05	-70.10	1.38	127.05	162.84	109.90	9.93	108.03
2	1.18	148.96	-89.66	0.61	148.96	121.37	90.34	9.72	122.79
3	1.12	-176.41	101.58	0.57	-176.41	-82.01	-78.42	9.49	-70.04
4	4.15	-166.94	13.07	2.13	-166.94	-179.99	-166.93	7.98	21.39
5	4.30	-159.39	-157.38	2.21	-159.39	2.02	22.62	7.83	-169.98

Figure 2 Drift motion simulation result in Optimum Towing Support System

stable condition in rough waves should be established. The decision guideline for the towing point and towing speed which lead to the safety towing in rough waves should be investigated through the model experiment.

The effective method not to sink the disabled ships during towing in rough waves should be investigated.

(6)Development of the synthetic supporting system for the optimum towing

The computer simulation system to provide the information for the optimum towing which can be supported by the prediction of the submerged ship forms and accurate drifting course should be developed. The guideline for the safety towing should be made on the assumption of the practical operation in the emergency situation.

The research themes of (1), (2), (5) and (6) are especially discussed in this paper.

3. Research themes of the project

3.1 Estimation of wave drift motion

(1) Drift motion simulation

Figure 1 shows the drift motion of the tanker model in regular waves. This shows the trajectory of the ship with different initial wave incident angle. It is found that the plural drift condition can be confirmed experimentally in certain wave condition.

Photo 1 Buoy used in the drift experiment

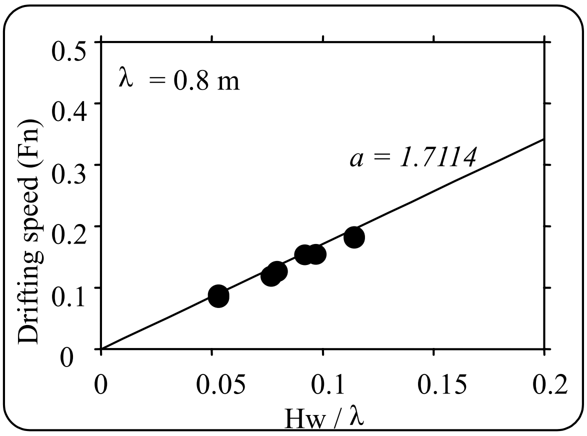


Figure 3 Relation between drift speed and wave slope

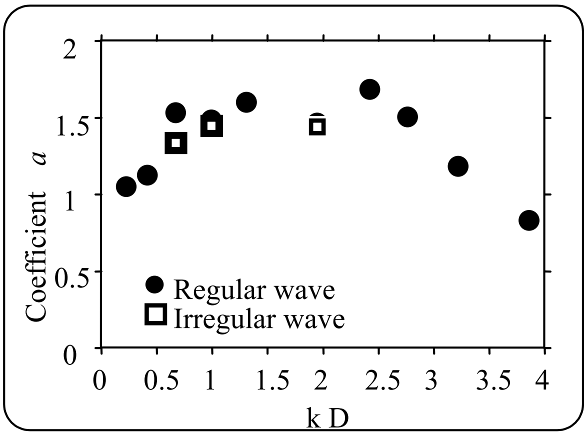


Figure 4 Linear coefficient of wave drifting speed of buoy

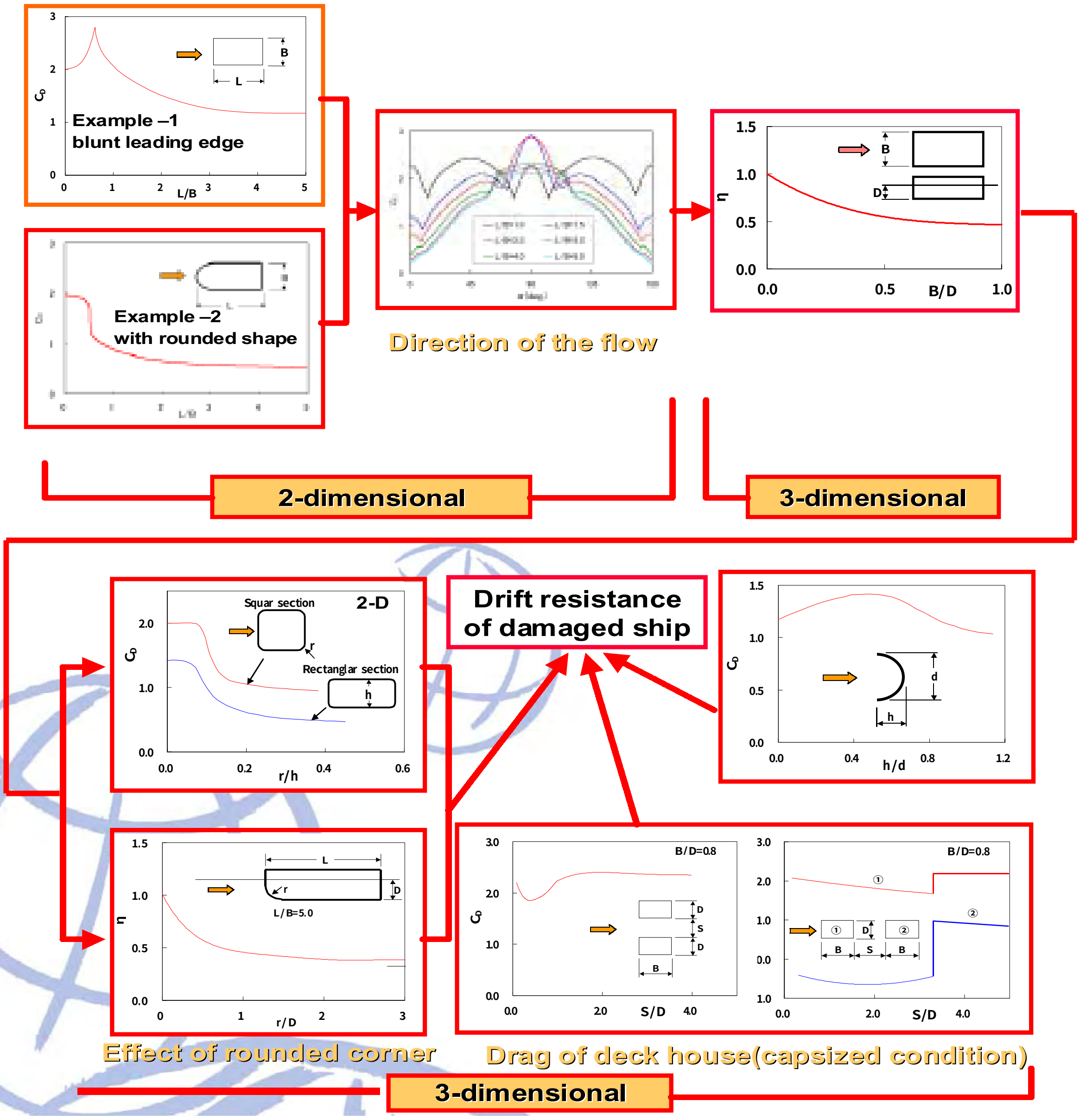


Figure 5 Estimation flow of the drift resistance of arbitrary shaped bodies

Table 1 Principal particulars of the model

	Full-scale	Model ship
Lpp(m)	300	3.0
L(m)	88.32	0.828
B(m)	58.0	0.544
D(m)	19.3	0.181

Photo 2 Bow broken tanker model

Figure 2 shows an example of steady drift simulation results on the certain sea condition. It can be found that we have 5 solutions in this case. This image is the graphic expression of Optimum Towing Support System (OTSS).

Theoretical calculation method of wave drifting speed was derived from the analysis of measured drifting speed of a buoy (Photo 1) in wave basin. In short wave range, drifting speed is decided by the equilibrium of drift force and drag, and it is proportional to wave slope. Figure 3 shows the relation between wave slope and drifting speed and Figure 4 shows the linear coefficient of wave drifting speed of the buoy. In long wave range, drifting speed is decided by wave induced current speed, and it is proportional to the square of wave slope. Taking this wave drifting mechanism, the estimation method covering entire wave range was proposed.

(2) Drift resistance

Figure 5 shows the flow of the estimation method of drift resistance. This method can treat every shaped bodies. Starting from the estimation of 2-D case with different dimension and flow direction, 3-D effect of depth can be considered. It can also include the round corner effect. Furthermore, the drag of deckhouse in case

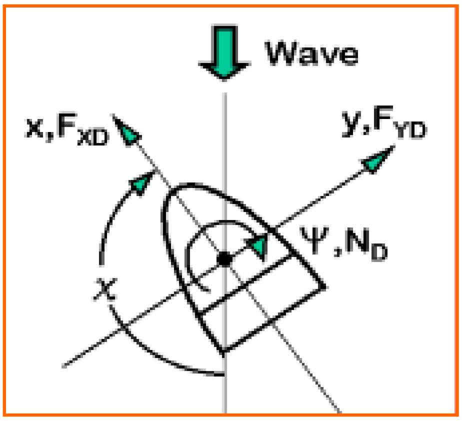


Figure 6 Coordinate system

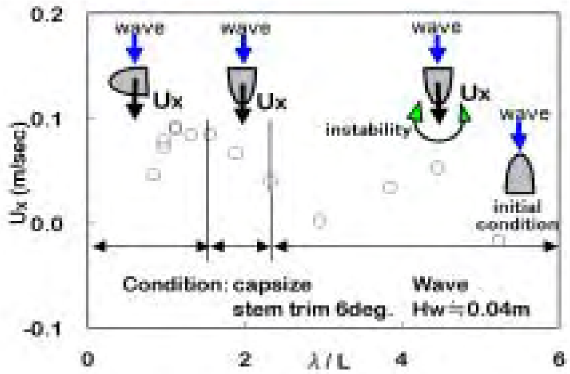


Figure 7 Drifting speed and initial wave incident angle

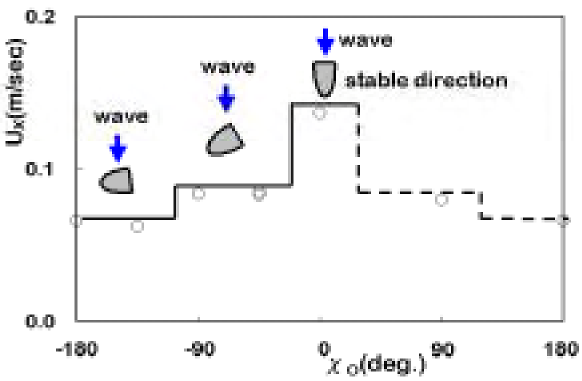


Figure 8 Relation between initial bow direction and drifting speed

of capsized condition and that of fractured surface effect can be calculated.

(3)Drifting motion of the bow broken ship

The experiment using the wrecked fore part tanker model (Photo 2) was made in the Ocean Engineering basin (40m x 27.6m x 1.8m) at NMRI. Table 1 shows the principal

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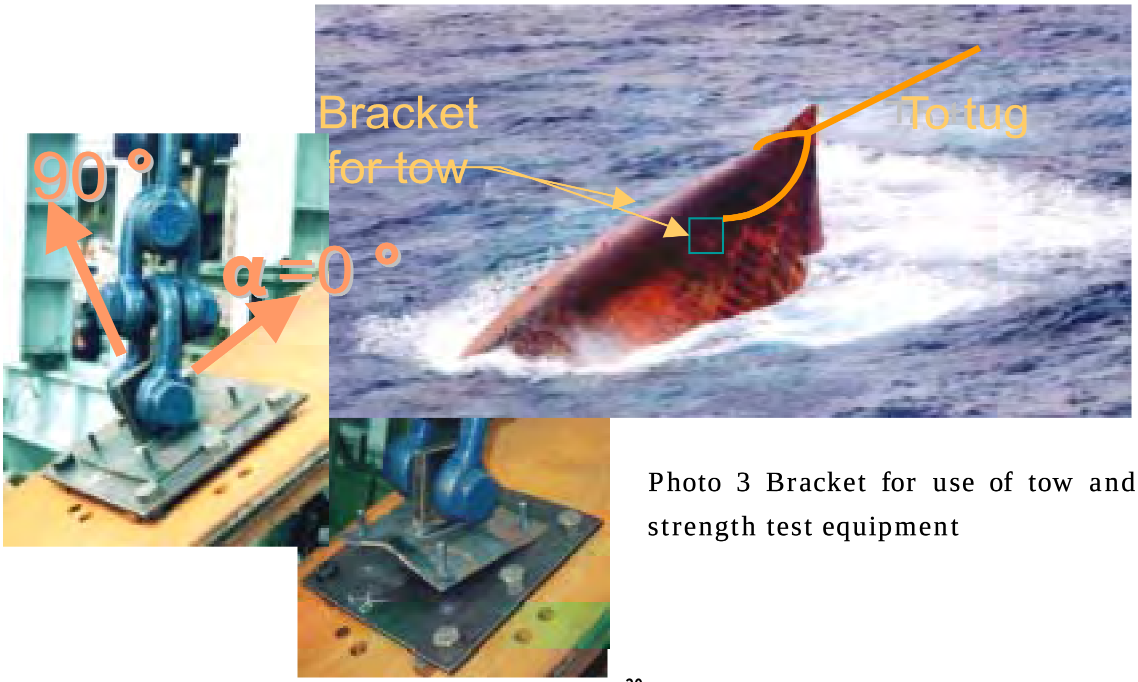
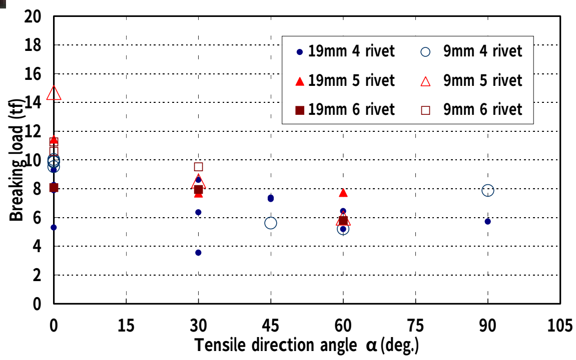


Photo 3 Bracket for use of tow and strength test equipment

particulars of the model. The wave drift force was measured. This figure shows the result of the capsized model. Comparison with the numerical results of 3-D panel method will also be made. The drift speed with respect to the wave conditions and initial ship status effect on the drift speed were also measured.

Figure 6 shows the definition of the coordinate system of drifting motion. Figure 7 shows the component of drifting speed along the wave coming direction U_X on the capsize condition with the trim by the stern of 6 degree and the initial wave incident angle of χ = 180°. The model ship is restrained before passing of the waves and is released slowly. When λ/L (wave length divided by the ship length) is between 1.6 and 2.3, the model rotates 180° from the initial wave incident angle and drifts with its bow toward leeside stably. When λ/L is less than 1.6, it drifts transversely against waves and turns slightly toward wave coming direction. When λ/L is more than χ = 0°, the drift direction becomes unstable and the drifting speed becomes small.

Figure 8 shows the relation between the bow direction and the drifting speed U_X with the initial wave incident angle χ in the case of λ/L = 1.88. The initial wave incident angle χ was set keeping the initial wave incident angle χ constant first and releasing it after waves passed. The bow



direction in the figure indicates the stable ship status during drift and the drifting speed is an average of the speed along the coming direction U_X in the stable drift. In the case of λ/L = 1.88 there are 3 steps of change concerning the drifting speed within the range of given initial χ. In the case of χ = 0°, the drifting speed is much larger than that in other balanced conditions because of great drifting force and small drifting resistance, As is shown in Fig.14, the ship drifts keeping χ 180 degree when the initial direction χ is 180 degree. Therefore there are 4 stable drift status.

3.2 Towline set-up method

The structural strength test concerning the bracket for tow use was carried out. This method is one of the ideas to set up the towline on the drift bodies without fixed point for towing. The bracket for the use of tow is fixed by the gun named drive-it. The full-scale test piece was used for the test varying the tow direction. Figure 9 shows

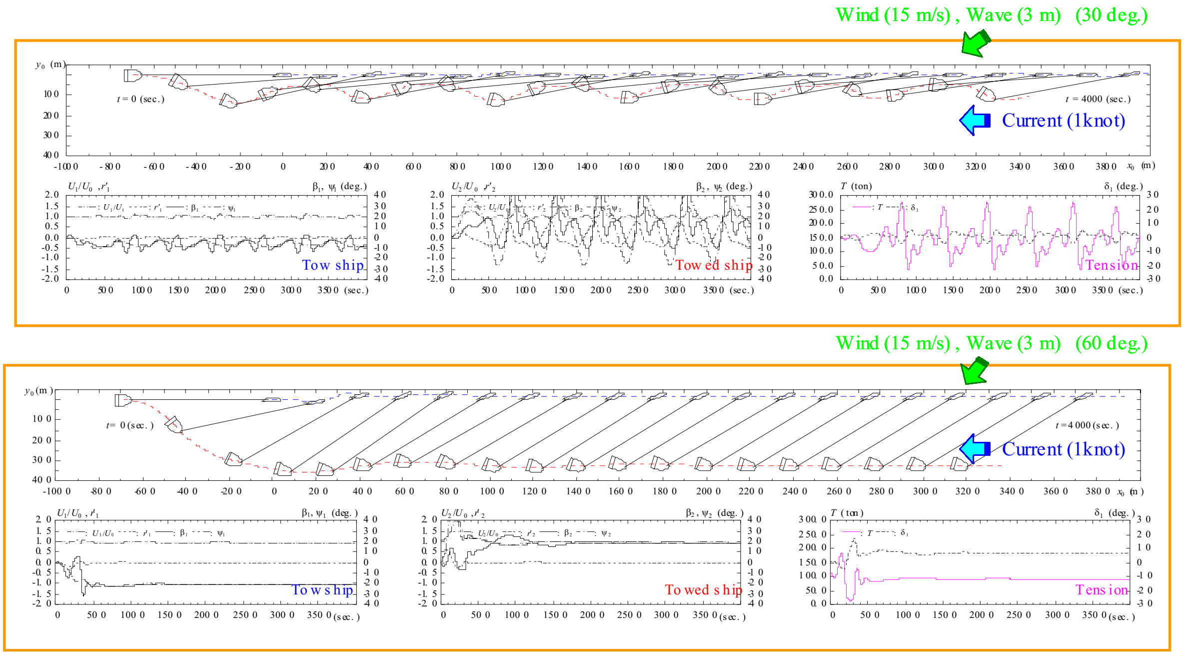


Figure 10 Numerical calculation of unstable motion of wrecked fore part of the tanker

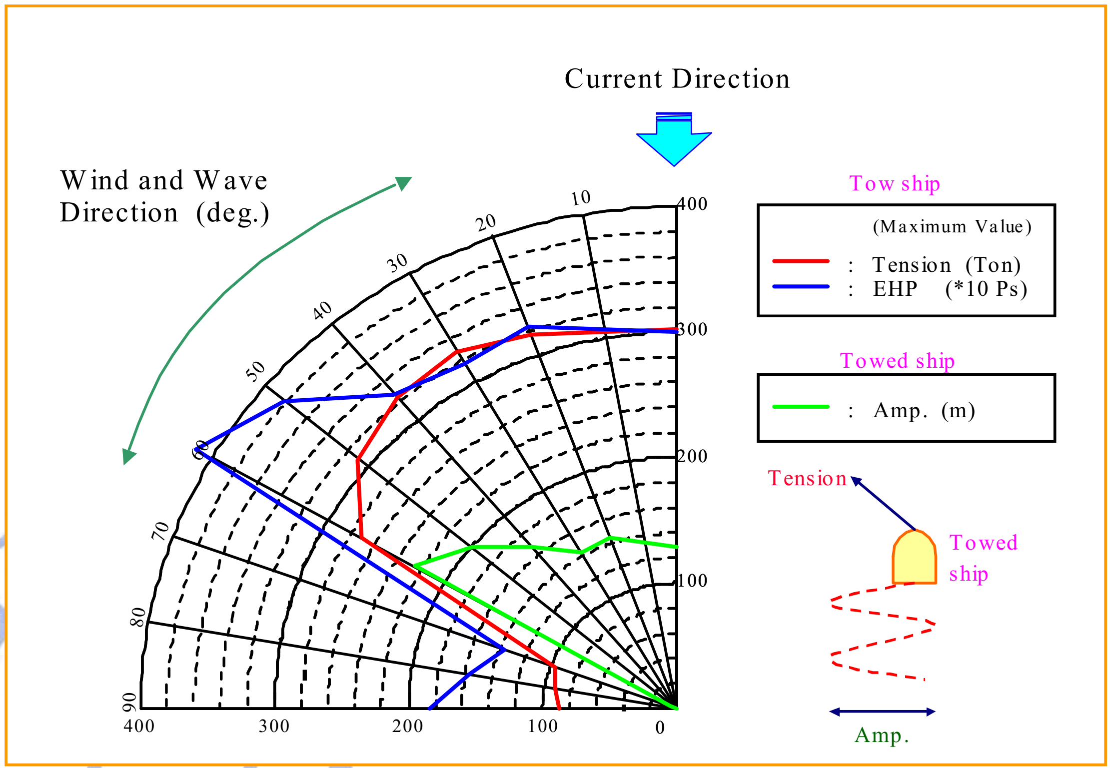


Figure 11 Estimation of maximum towline tension, unstable motion and EHP

the maximum tensile strength was 14.7 tf. This method can be utilized on the certain condition, although it is not enough strength considering the fluctuating towline tension. It is possible to improve the strength by the increase of the number of rivets and bracket form.

By using the drive-it the bracket can be installed on both sides of the ship. Then the loading condition can be quite appropriate because the tensile direction cannot be the worst condition.

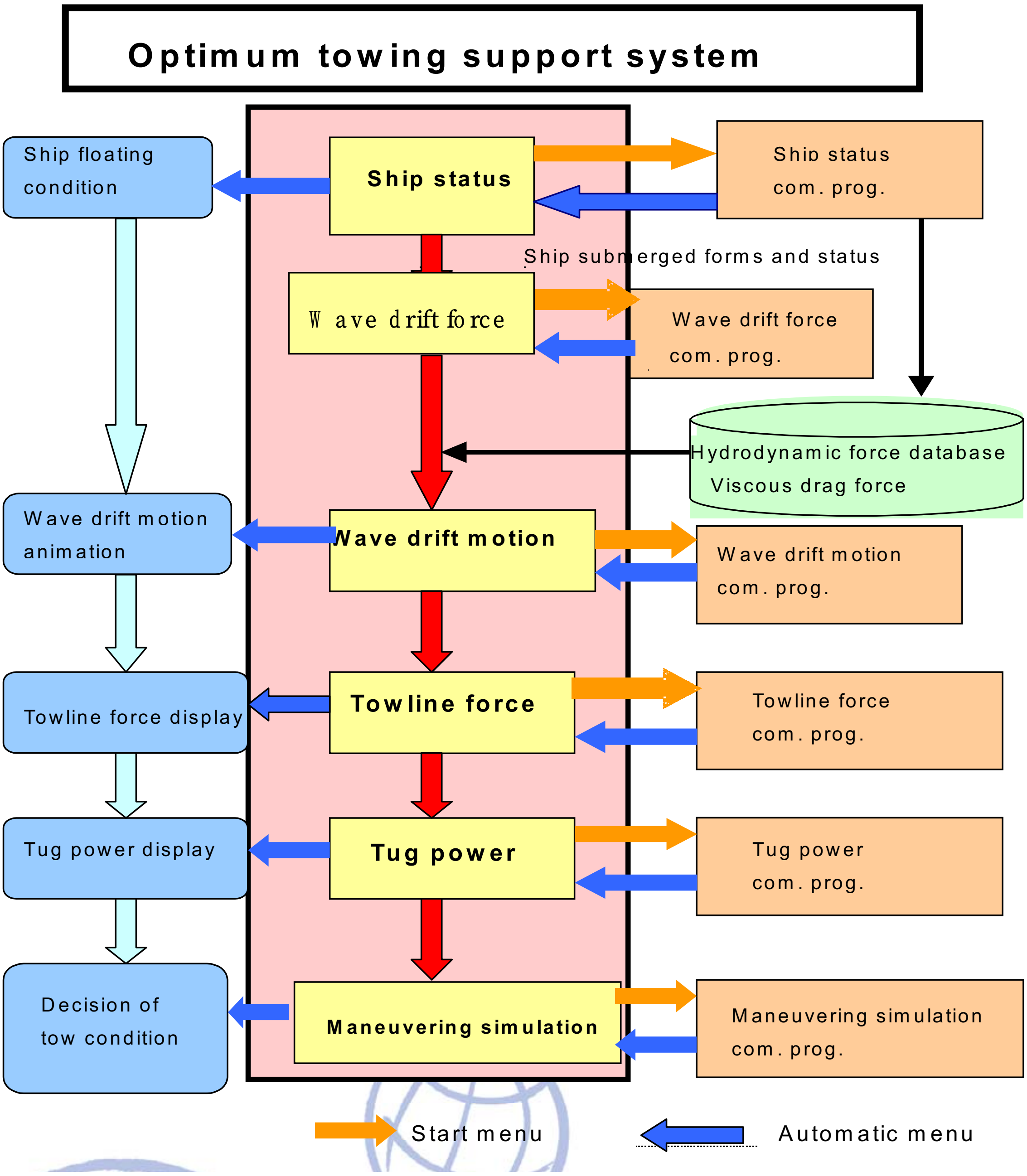


Figure 12 Flow of Optimum Towing Support System

3.3 Unstable motion of wrecked tanker's fore part at rough sea

This figure shows the results of numerical calculation on the unstable motion of wrecked tanker's fore part at rough sea. The dimension of the tow ship is L=83m, B=10.5m,d=3.5m. The towed ship is L=80m,B=58m,d=19.3m.

The sea condition is as follows. Wave height is 3m, wind speed is 15m/s and current speed is 1 kt. Upper and lower figure shows the case of 30 degree and 60 degree of wave direction respectively. The figure shows a quite different feature. The upper figure shows the unstable motion with large fluctuation of towline tension but lower figure shows the oblique towing with constant towline tension.

Figure 11 shows the maximum towline tension and unstable motion with respect to the wind and wave direction having constant current direction. In this figure the direction of wind and waves coincide. In the range larger than 60 degree there is a drastic change of towline tension. Using the numerical calculation results we can select the towing direction with pertinent speed.

3.4 Development of optimum towing support system

The OTSS provides mainly 5 menu such as ship final status, wave drift motion, towline force, tug power and maneuvering method to the operator. He can choose the menu whichever he needs to know the solution. Figure 12 shows the flow of the system. First we can get the information of the main dimensions of the shipwrecks. The similar offset data with compartments will be produced using the type ship database. The loading conditions such as full and ballast can be chosen. The arbitrary compartment can also be produced if its data are obtained. It is possible to predict the damage stability calculation including the broken conditions in the developed computer program.

The optimum towing support system is consisted of the calculation for the element technologies as shown below.

(1) Damage stability

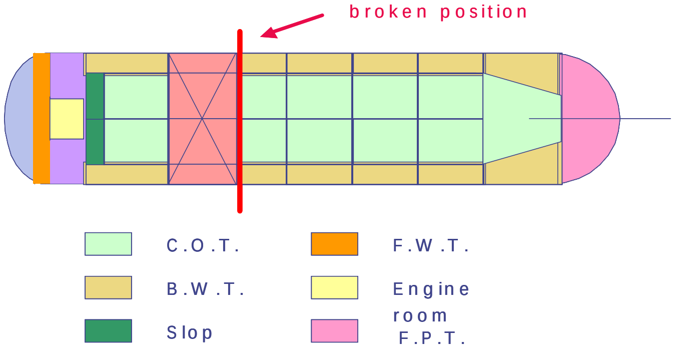


Figure 13 Compartment of the 150,000 tonnage tanker

(2) Hydrodynamic force during tow
(3) Towline tension
(4) Needed horse power in waves
(5) Maneuvering simulation

The thick solid line in the figure shows the main routine of the system. The right hand side of the figure shows the under developing computer program and the left hand side shows the output for graphics such as three dimensional animation.

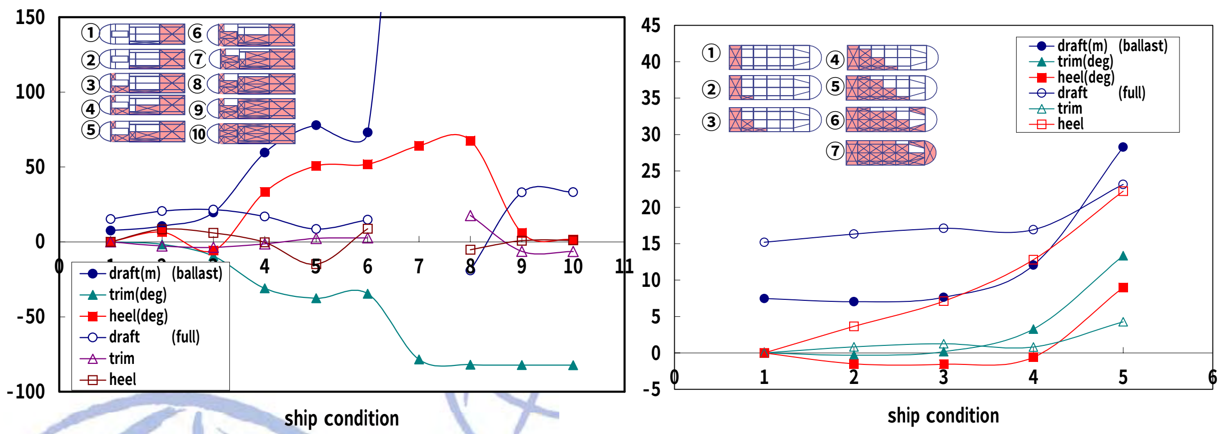


Figure 14 Ship status change of broke ship due to damage

Table 2 Main dimension of type ships

Type ship D/W	Tanker 1 258,000	Tanker 2 150,000	Container 23,700	Barge	PCC 12, 500	Cargo 18,000	Fishing boat 499GT
Lpp (m)	320.00	265.00	200.00	70.00	180.00	156.00	53.00
B(mld) (m)	58.00	48.30	32.00	20.00	32.00	26.60	9.40
D(mld) (m)	28.80	22.40	16.50	4.00	14.00	14.10	3.95
d (mld) (m)	18.50	15.20	10.50	3.80	8.50	9.00	3.60
Cb	0.83	0.83	0.56	0.92	0.55	0.70	0.66
lcb (%)	-3.70	-3.30	2.40	-0.90	2.38	-0.54	1.15
	single hull	double hull					

Figure 13 shows the compartments of the 150,000 tonnage tanker with double bottom. This example shows the broken case at the position of 2/3 from F.P.

The damage stability simulation for calculating the final ship status is shown in this paper. Table 2 shows 7 type ships including two kinds of tankers. The below information is maintained in the system.

(1) Main dimensions and offsets
(2) Compartment information
(3) Basic loading condition
(4) Damage stability on the basic loading condition

Assuming the ship type and main dimension of the disabled ships to be similar to that of type ship, the offset data for similar ships to the type ships as shown in Table 2 is produced. The compartment information is automatically produced according to that of type ship if no compartment information is available. The damage stability simulation in still water including the broken condition can be carried out in order to obtain the final ship status. The computer program of three dimensional panel method for wave drift force as the next step can be started using the generated mesh obtained by the submerged hull form on the final ship status. There are two loading conditions of full and ballast and two cases of remained part such as fore and aft. The longitudinal axis indicates the flooding conditions where number 1 means the original condition. Figure 14 shows the ship status. The final ship status is described by the trim, heel and draft for the respective loading condition of full and ballast.

4. Concluding remarks

The 5 year research project of 'Drift prevention of disabled ships in rough seas' sponsored by the Ministry of Land, Infrastructure and Transport will continue to the end of fiscal year of 2002. The final target is to develop Optimum Ttowing Support System and provide to the organization such as Japan Coast Guard and salvage companies. The element technologies have been nearly completed in the research of these 4 years. Those technologies should be linked in the Optimum Towing Support System.

The achievements of the project should be authorized by the Steering Committee of Towing Technology consisted of Japan Coast Guard, salvage companies, wire rope companies, synthetic fiber rope companies and universities.

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