

On the Development of an Anchor Watch Supporting System for Small Merchant Ships

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ABSTRACT: This paper describes the results of a study that aimed at developing an effective anchor watch supporting system to prevent dragging anchor accidents of small domestic merchant ships. The authors performed an experimental study using a training ship in order to investigate the characteristics of the hull movement of a ship lying at single anchor, the cable tension caused by the above movement and etc. Based on the results of the study, the authors propose a standard procedure for safe anchor watch and a new anchor watch supporting system using a PC, a DGPS and an anemometer.

1 INTRODUCTION

In the Japanese coastal waters, many disasters involving small domestic merchant ships dragging anchor are reported every year. Domestic merchant ships often anchor temporarily when waiting for their berths or avoiding storms. Accidents by dragging anchor often occur during the above temporary anchoring and it is reported that no anchor watch is provided in most of the accidents because domestic merchant ships are operated by a limited number of crew members.

One way to prevent accidents caused by dragging anchor is to develop an anchor watch supporting system that will monitor the anchoring condition and detect a risk of dragging anchor in advance.

From the above points of view, the authors conducted the full-scale experiments in order to investigate the following characteristics of a ship at anchor; the eight-figure horsing movement of the hull (horsing) when lying at single anchor, the cable tension caused by the horsing, the hull movement at dragging anchor, the effect of a secondary short-scope anchor to reduce the horsing.

The test ship was a 5,800 G.T. training ship and her principal particulars are shown in Figure 1.

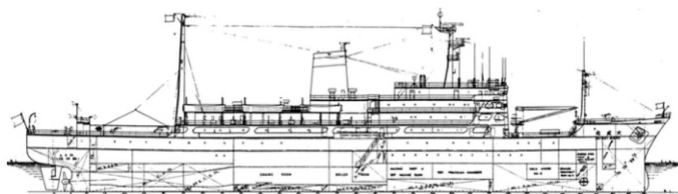
Based on the results of the above experiments, the authors proposed a method to establish the standards of safe anchoring and anchor watch to prevent a dragging anchor accident. A new anchor watch supporting system with a function to detect a risk of dragging anchor is developed for small domestic merchant ships.

2 STANDARDS OF THE ANCHORING

2.1 Horsing movement lying at single anchor

The eight-figure horsing movement of the hull (horsing) when lying at single anchor and the cable tension caused by the horsing were measured using the test ship (Saitoh 1986).

Figure 2 shows an example of the time history of the cable tension during horsing when lying at single anchor with 7 shackles of her cable. The depth of sea water was 27m and the wind velocity was 20 m/s in average. The strong cable tension (shock load that acted on her cable) was measured 4 times during one cycle of horsing.



Hull		Anchor	
GT. (ton)	5886.0	JNR type	3.455 ton x 2
Loa (m)	124.8	Cable (56φ)	250 m x 2
Lpp (m)	115.0		
B (m)	17.0		
D (m)	10.5		

Figure 1. Principal particulars of the test ship

The relationship between the measured shock load and the wind velocity is shown in Figure 3. The values of the cable tension in this figure are the average of the above shock loads that appeared 4 times during one cycle of horsing.

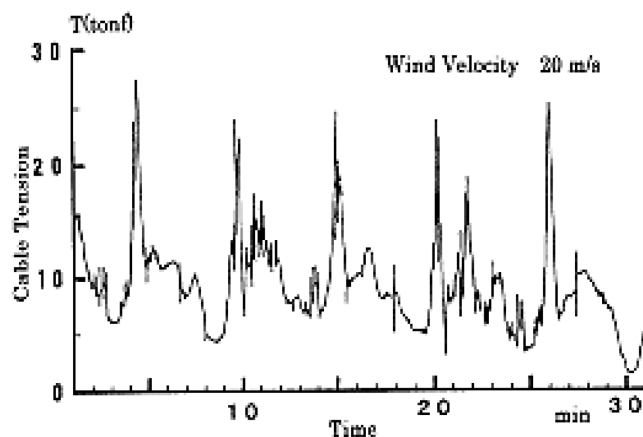


Figure 2. Time history of the cable tension during horsing

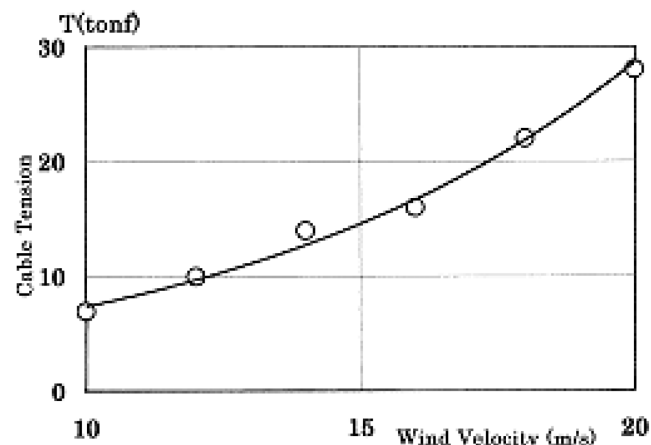


Figure 3. Relationship between the cable tension and the wind velocity

The horsing movement was observed when the wind velocity exceeds 10 m/s and the shock load seems to increase significantly in the range of wind velocities of 16 m/s or more. It is well known that this shock load is one of the main causes of dragging anchor. When the shock load is greater than the holding power of an anchor, it pulls the anchor and the flukes start overturning. The holding power of an anchor is reduced significantly due to the overturning of flukes. An overturned anchor can not bite into the seabed firmly and starts sliding over the bottom.

2.2 Effect of the secondary short-scope anchor

There is a possibility to reduce the shock load by controlling the degree of horsing, and some horsing control methods have been proposed. The use of a secondary short-scope anchor is one of the effective and easy countermeasures to reduce horsing. This method utilizes a dragging resistance of the secondary short-scope anchor and the cable length of it is recommended to be 1.25 to 1.5 times the depth.

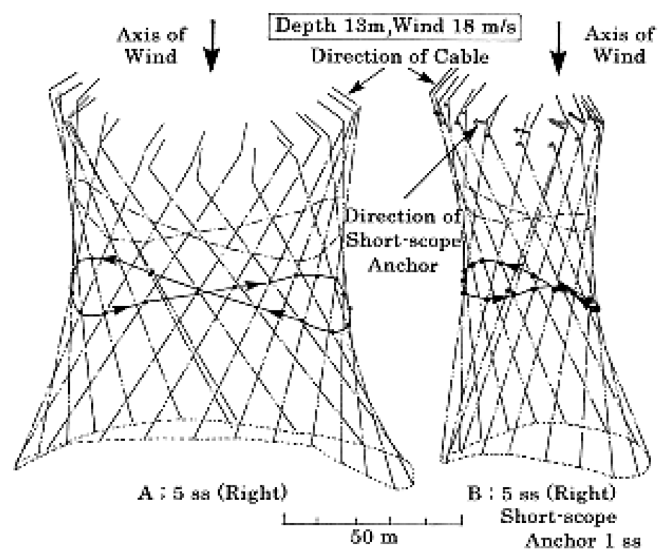


Figure 4. Effect of a secondary short-scope anchor to reduce horsing

Table 1. Example of the Standards of anchor watch (Depth; 15m)

wind (m/s)	Counter measure
15 or less	5 ss
15 - 17	6 ss
17 - 20	7 ss, short-scope anchor
20 - 22	8 ss, short-scope anchor
	Office's anchor watch
22 or more	S/B Eng. & Rudder

Figure 4-A shows the trajectory of the test ship while horsing on a single anchor with 5 shackles of her starboard cable. The water depth was 13 m and the wind velocity was 18 m/s in average. The test ship sheers violently back and forth across the wind. Figure 4-B shows the hull movement of horsing with

5 shackles of riding cable and one shackle of the secondary short-scope anchor under the same conditions. In this case, the lateral movement range of the center of gravity with a secondary short-scope anchor is 50 % smaller than that without a short-scope anchor. As these experiment results agree with those of model tests qualitatively, it seems that the use of a secondary short-scope anchor is very effective and useful to reduce horsing.

2.3 Standards of the anchoring and anchor watch

Table 1 shows the standard procedure of the anchoring and anchor watch for the test ship when anchored at 15 m depth of water. Usually, the cable length that should be veered out at the first stage of anchoring is calculated by the following formula; $(3D + 90)$ m, D means the depth. This empirical formula is widely used among the Japanese seafarers. After anchoring, the test ship veers out her cable and drops a secondary short-scope anchor according to the increase of wind velocity. When wind exceeds the designated velocity, an officer's anchor watch is started for earlier detection of the risk of dragging anchor, and her main engine, rudder and other necessary machinery are prepared.

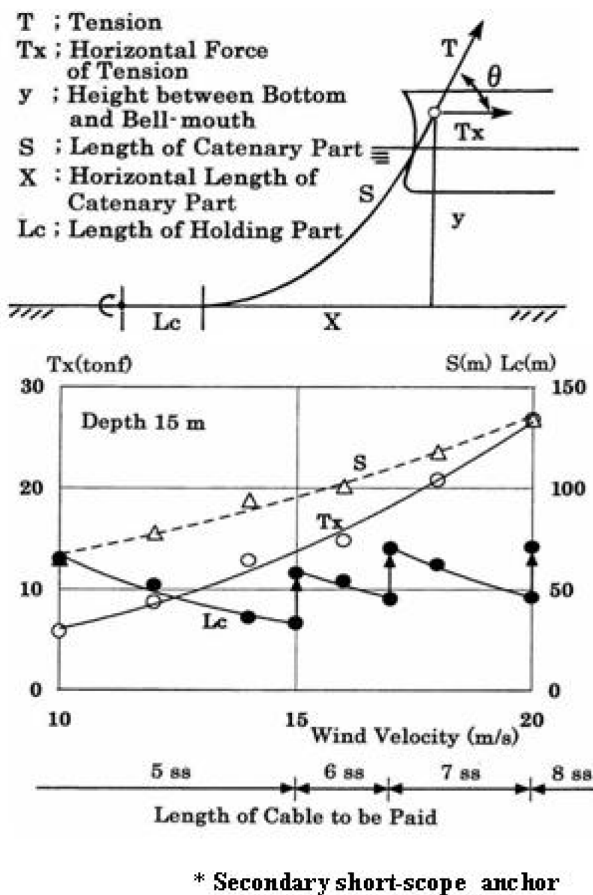


Figure 5. Estimated length of holding part during anchor watch by the standard procedure

Figure 5 shows the estimated length of cable that remains on the sea bed (L_c ; holding part length of the cable) when the test ship performs her anchor watch in accordance with the above standard procedure. The holding part length (L_c) is estimated using the following equations and the horizontal force of shock load (T) shown in Figure 3.

$$\left. \begin{aligned} L_c &= L - \sqrt{y \left(y + \frac{2T_x}{w'_c} \right)} \\ T_x &= T - w'_c \cdot y \end{aligned} \right\} \quad (1)$$

where L = total scope; and w'_c = weight of chain per unit in the sea water.

A certain length of the holding part should be kept for the safe anchoring because it acts as a spring in preventing the anchor from being jerked when the ship is yawing from side to side. In the case of the test ship, her cable is veered out in accordance with the increase of wind velocity in order to keep the holding part length at least two shackles. To include the above method in the standard procedure of anchor watch is considered to be useful and helpful for small domestic merchant ships.

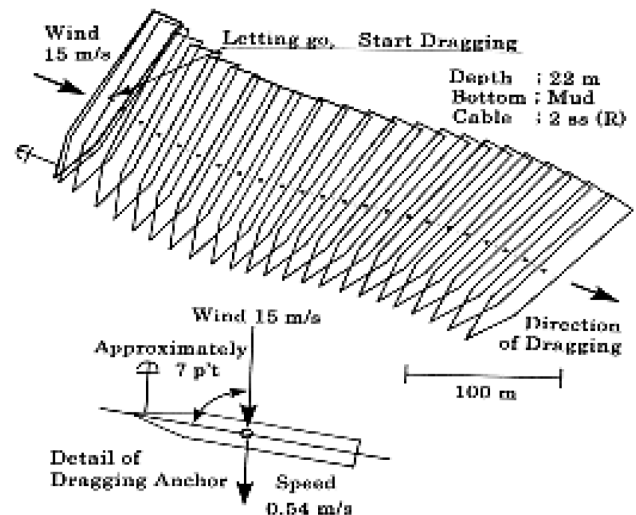


Figure 6. Trajectory of a ship during dragging anchor

3 DEVELOPMENT OF AN ANCHOR WATCH SUPPORTING SYSTEM

3.1 Detection of a risk of dragging anchor

Figure 6 shows the trajectory when the test ship drags her anchor under 15 m/s of wind. The hull is drifted at a very slow speed of 0.54 m/s to the leeward by the beam wind. Her heading is about 7 points to the left of the wind axis during dragging anchor. As the above experiment results agree with the simulation results (Inoue 1988), we can conclude, when the regular horsing movement is stopped and ship's weather side becomes fixed, that the ship is likely to be dragging anchor.

Once an anchor starts to drag, it is difficult to stop. Therefore, it is important to detect the possible danger of dragging anchor at an earlier stage in order to take counter measures to prevent it in advance.

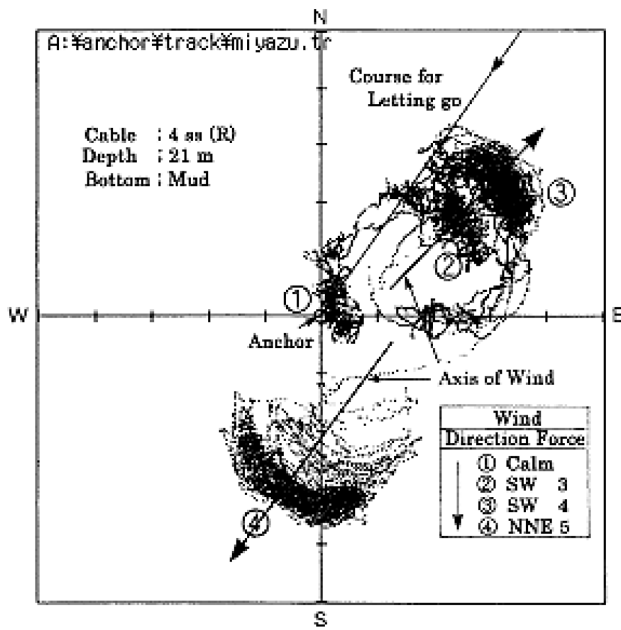


Figure 7. Trajectory of horsing lying at single anchor (96 hours)

Figure 7 shows the 96 hours trajectory of the test ship lying at single anchor with 5 shackles of her cable. The location of horsing is moved in accordance with the change of wind direction and its force. The center of the horsing is not located at the anchor position but around the point at the end of the Catenary part of the cable that is touching the sea bed. As described in 2.3, this is due to a certain length of the cable is always kept on the sea bed during anchoring. Consequently, there is a possibility to judge the existence of the risk of dragging anchor when the length of Catenary part is equal to that of riding cable and the holding part is missing.

The authors propose the method to detect the risk of dragging anchor that compares a horizontal distance between anchor and the bell-mouth (d) and horizontal length of the Catenary part (X_{max}) when its length is equal to the riding cable length as shown in Figure 8. The distance " d " is monitored using the DGPS. The diagram in the Figure 8 shows the time history of the distance " d " when the test ship was anchored in 18 m depth of the water under 20 m/s wind with 8 shackles of riding cable and a secondary short-scope anchor. The time history reflects the back and forth movement of the test ship that is induced by the horsing.

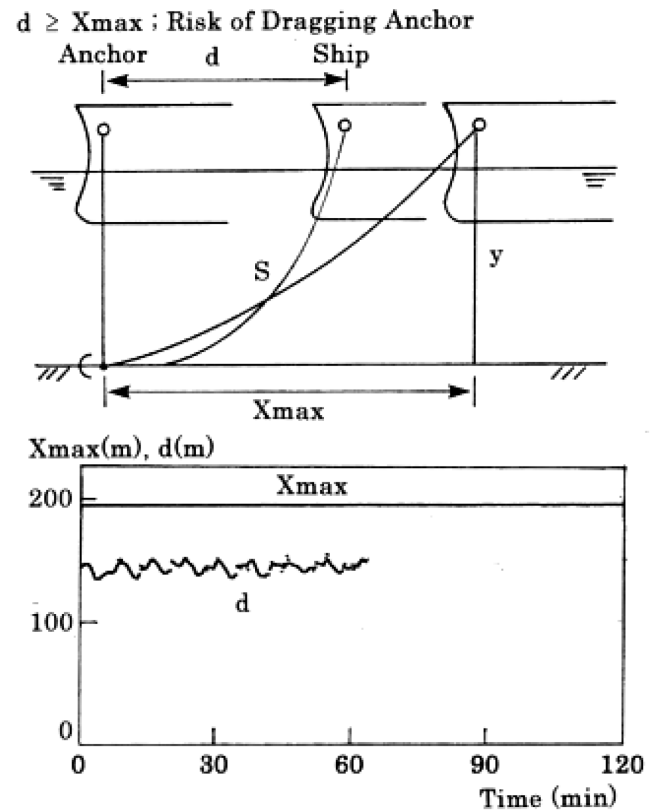


Figure 8. Method to detect the risk of dragging anchor and monitoring result of the distance " d "

The possible danger of dragging anchor can be judged using the following observation results.

- 1 Existence of a strong wind
- 2 The direction of anchor almost agrees with the wind axis.
- 3 The trend of " d " approaches toward the threshold " X_{max} ".

3.2 Anchor watch supporting system

As domestic merchant ships are operated by a limited number of crew, the following functions are desired for their anchor watch supporting system.

- 1 Detecting function of dragging anchor and possible danger of dragging anchor.
- 2 Monitoring function of wind, horsing movement, hull posture against the wind axis, location of an anchor and etc.
- 3 Anchor watch supporting function
- 4 Alarm function

The authors propose a simple and user friendly anchor watch supporting system with the above functions. This system consists of a PC, DGPS, Gyro Compass and Anemometer, which are common navigational equipment onboard domestic merchant ships.

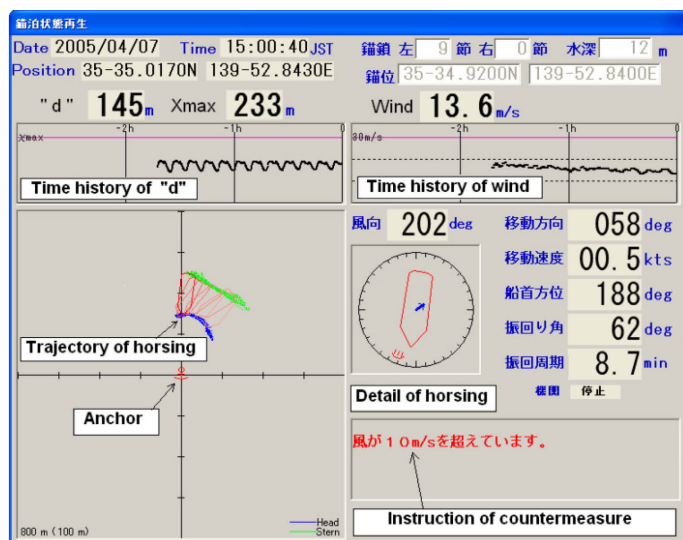


Figure 9. Display of the anchor watch supporting system

Figure 9 shows the display of the system that was developed for the test ship and the following data can be monitored; horsing trajectory, heading, moving direction and speed of hull, horsing angle, location of anchor, hull posture against the wind axis, wind direction and its velocity. The possible danger of dragging anchor can be detected by comparing the displayed time history of “ d ” and “ X_{max} ”. When the wind velocity exceeds the threshold that is designated in the standard procedure of anchor watch shown in the Table 1, the necessary countermeasure in accordance with the procedure is displayed with alarm.

4 CONCLUSION

The authors performed an experimental study in order to develop a method to establish the standard

procedure of safe anchoring and an anchor watch supporting system for small domestic merchant ships. Results obtained in this study are summarized as follows.

- 1 A ship at single anchor starts horsing at the wind velocity of 10 m/s and the shock load caused by horsing acts on her cable. Ship sheers violently back and forth across the wind when it is at 16 m/s or more and the shock load increases remarkably.
- 2 The secondary short-scope anchor is very effective to reduce horsing in stormy weather.
- 3 For the prevention of disaster caused by dragging anchor, it is important to establish the standard procedure of anchoring and anchor watch. The proposed method for establishing the above procedure is considered to be effective to prevent dragging anchor.
- 4 The developed anchor watch supporting system with a function to detect a risk of dragging anchor in advance is useful and effective to prevent the dragging anchor accident.

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