Performance of SSTH-70 after Delivery and Future of SSTH

Masahiro Itabashi , Ryoji Michida
Ishikawajima-Harima Heavy Industries Co.,Ltd.

ABSTRUCT

The SSTH-70 “Ocean Arrow” designed under the concept of the SSTH (Super Slender Twin Hull), which IHI developed with the University of Tokyo, has been in operation for about three years. The speed of SSTH-70 is almost twice compared with the conventional ship. During the half year after delivery, the ship motion and wave impact load for the hull structure were measured. This paper describes the design method of hull structure for SSTH as a fast ferry and the full scale measurement on an actual ship to evaluate the estimated ship motion and wave loads. This paper also introduces the future design of the 110m length SSTH Car Ferry based on the results of full scale measurement which will have good sea-keeping performance and feature less wake wash.

1. Introduction

SSTH-70 “Ocean Arrow” adopting the Super Slender Twin Hull (SSTH)[1] has entered service between Kumamoto and Shimabara since 1998. Fig. 1 shows the general arrangement of the SSTH-70 “Ocean Arrow”.
IHI developed the SSTH ship, which is suitable for medium/large size high-speed car ferries, Ro-Ro ships, etc., beginning in 1987 in cooperation with Prof. Miyata of the University of Tokyo. The SSTH-70 reduced the Kumamoto-Shimabara sailing time to about 30 minutes from one hour or more by sailing at about 30 kt more than twice the speed of the conventional car ferry, thus making a great contribution to the convenience of local transportation and local economy such as sightseeing.

In Europe, many fast ferries made of aluminum alloy are in service, but in Japan, the fast ferry is not so common because of several problems as wake wash, trouble of high-speed main engines, and hull damage due to wave.
To avoid the wake wash problem, the hull of SSTH is very slender and her section is round. This design concept also accomplish good sea-keeping quality.

On the SSTH-70, measurements were made over about six months after it entered service and various measured response values obtained in the navigation sea area were compared with those estimated at the time of design. Based on the comparison results and the data obtained through the actual service of three years of this ship, an investigation was conducted to determine the feasibility of an ocean-going SSTH, and this paper introduces the principal particulars, operation limit performance, etc.

2. Design and operation performance
2.1 Outline

For designing a high-speed ship, lighter and safer structures than for an ordinary merchant ship are required to satisfy such design conditions as ship speed and dead-weight capacity. But structural design technique for the high-speed ship has not been sufficiently established due to lack of experience in comparison with the ordinary merchant ship. The structural design of this ship was, therefore, based on short-term and long-term predictions combining the wave data in the navigation sea area with the response calculations of ship motion and wave load.

The direct calculation method was used in combination with the structural analysis using the Finite Element Method (FEM) to choose the optimal shape, dimensions, and arrangement of structural members of the hull. As previously reported,[2] the portions for which the direct calculation was made are the transverse strength calculation of the hull, including the strength of the joint part between the twin hull accompanying the wave load, and strength calculation of the tunnel top between the twin hull for wave impact pressure attributable to vertical motion of the hull, strength calculation of DSB (Double Step Bow), etc. The structural analysis using the FEM in the direct calculation method is already established, and there is no problem in terms of accuracy.

The characteristics of ship motion have been verified through sea-keeping tank tests. But the ship motion in the navigation sea area and the absolute value of the wave load estimated from the wave data have not been sufficiently confirmed. To confirm the validity of the design load, therefore, actual ship measurement was conducted to obtain the data of the ship motion and the structural response in the navigation sea area. Followings outlines the direct calculation of the SSTH-70 and full scale measurement results in the navigation sea area.

2.2 Direct calculation method

The structural design of the SSTH-70 was made using the direct calculation method based on the ship motion calculation. Fig. 2 shows the design flow chart. For the direct calculation of the SSTH-70, two methods were adopted, as shown in the flow chart.

First, the wave conditions ship will encounter in its service life are set using the long-term wave data of the navigation area , the maximum wave height under which the ship operation is stopped is determined and long-term prediction of the severest load to work on the hull is made. With this load as the design load, structural strength analysis is made on such important structural strength investigation items as strength of the joint part between the twin hull and transverse strength including fatigue strength.

Second, the severest wave conditions ship will encounter during one navigation are set using the same wave data, and the short-term prediction of the wave load acting on the hull during one navigation is made using the analysis results on the ship motion in regular waves and wave load. The short-term prediction of the wave impact pressure attributable to ship longitudinal motion (bow slamming) showed that the estimation through the short-term prediction was severer for this ship than the long-term prediction, and therefore, the expected value by the short-term prediction made the design load. The dimensions and arrangements of the bottom plates and the longitudinals of the tunnel top between the twin hull were decided by the plastic design method.

To make a proper structural design, it is important to secure the estimating accuracy of the wave conditions and ship motion closely related to the setting of the design load. Therefore a full scale measurement using an actual ship was conducted in the navigation sea area.

2.3 Outline of full scale measurement

To evaluate the validity of the load estimated by the direct calculation method, full scale measurement was conducted in the navigation sea area of SSTH-70 and measured the sea climate conditions at that time.

The motion response of ship, structural response, and wave impact pressure around the bow were measured centering on the normal navigation state for about six months after the ship was placed in service. During the measurement an automatic measuring equipment developed by IHI that detects the ship operation and starts measuring without human help was used. Fig. 3 shows the arrangement of the motion sensor and strain gauges.

(1)Motion response of ship
The motion sensor was installed at the center of the ship and the pitching angle, rolling angle, and heaving acceleration were measured.
(2)Structural response
The strain gauge was attached to the cross beam of the joint part between twin hull, and the stress acting on the joint part was measured.
(3)Impact pressure of bow
The strain gauges were attached to the bottom plate and longitudinal of the joint part between the twin hull of the bow portion, and the wave impact pressure acting on the bow portion was measured.

As an example of measured data, Fig. 4 shows the time history of the rolling motion during navigation. In this figure, the time changes from top to bottom and from left to right of the four axes of abscissas.
Table 1 shows an example of the measured data of pitch. During this measurement, the significant wave height was 0.7-1.1m and mean wave period was 2.8-3.8s

Table 1 measured Pitch RAO

Ship speed	Pitch (RAO)
Stoppage(moored)	0.87
Cruising(High speed)	0.60
Cruising(Low speed)	0.66

3. Future of SSTH
3.1 Desired fast car ferry

The fast ferries exceeding 30 kt have entered service along the coasts of Europe centering on the periphery of Britain. Most of these fast car ferries are catamaran made of aluminum alloy to reduce the hull weight while maintaining the rigidity for increased deadweight and higher service speed, and higher speed and larger size are promoted year by year. These fast ferries are operated not only in coastal areas but also for crossing channels with a relatively long navigation distance and are operated under rather severe sea climate for their size. For this reason, cases have been reported of hulls being damaged and motion sickness occurring among passengers due to deteriorated ride quality. In one accident in Ireland, a swimmer drowned due to the wake wash of a fast ferry, and with this as a turning point, stringent control against wake wash was enforced in Britain from April 2000.

As the demand for fast ferries increases, it is necessary to develop a type of ship to reduce wake wash, which adversely affects coastal facilities and fishing boats. Less motion will be required to reduce the adverse effects on the local structural strength for higher operation limit and for increasing the service rate in terms of sea worthiness. The SSTH with very slender hull features less wake wash and less influence of wave exciting forces. The feasibility of developing ocean-going ferries was studied, and some investigation items are introduced below.

3.2 Sea-keeping performance in waves of ocean-going type SSTH

For the medium size SSTH capable of ocean-going (hereinafter called ocean-going type SSTH), the sea-keeping performance is important in determining its various performances because it navigates at high speed under severe sea condition for its displacement. Here we show the effects of the ride control system, a principal particular that greatly affects the sea-keeping performance ranging in length between perpendiculars from 70 to 130 m and at service speeds from 30 to 40 kt, leading trend of the medium size fast ferry. And also the operation limit is investigated from the point of sea-keeping performance, and the ride quality of the ocean-going type SSTH is shown as an example of medium size fast ferry.

3.2.1 Principal particulars of ocean-going type SSTH

To clarify the effects on the sea-keeping performance of the principal particulars of the ocean-going type SSTH, the ship motion was investigated by changing the ship length, distance between twin hulls, and ship speed as parameters using numerical calcuration. Before this investigation, the accuracy of the method was checked. Fig.5 shows the comparison between the estimation results of the calculation of sea-keeping of a fast twin hull ship and the experimental results. From this, it is known that the significant values of heaving motion in irregular bow sea show a good agreement between the experiment result and the estimated one and this method has a sufficient accuracy for investigating the sea-keeping performance of the SSTH.

As a result of investigating the ship motion by changing the principal particulars, it was known that the following type of ship can operate as an ocean-going type SSTH at a ship speed of 35 to 40 kt by means of a diesel propulsion engine and has a sufficient operation performance.

Length o.a.	Approx. 110 m
Breadth mld.	23.6 m
Designed draft	Approx. 2.45 m
Service speed	35 kt
Main engine	
Diesel main engine total output	
	Approx. 28 000 kW

On the responses of vertical acceleration in bow sea and rolling motion in beam sea as the sensitivity effect of principal particulars on the sea-keeping performance, Fig. 6 shows changes when main dimensions of the ship are changed with the ship length/width ratio held constant, and Fig. 7 shows changes when the ship speed is changed. The axis of ordinates show the ratio with the response with the aforementioned type of ship(110m SSTH) as one. It became clear that if the ship is made larger, the resonance point of waves is shifted toward longer wave length, making it possible to reduce the vertical motion, and even if the ship speed is increased, the motion increases only about 20%.

3.2.2 Ride control system

This ship will equip with the Ride Control System (RCS) to increase the operation rate and improve the ride quality during high-speed navigation. Here the hull motion reducing effect was investigated in the cases of T-Foil installed at the bow and the trim tab installed at the stern as the RCS.
Figs. 8 and 9 show the value in irregular waves at a ship speed of 35 kt. This is one of the results that shows the ship motion is greatly reduced by the RCS.

3.2.3 Operation limit

For the fast ferry, operation limits are set against sea climate conditions from the point of safety, etc., and it is required to secure high service rate within such a range. For this ship, tank test and numerical simulations were conducted and the effectiveness of the ocean-going type SSTH was investigated using the following as evaluation indexes for the operation limits.

- Ride quality in the passenger room
- Load on vehicle lashing apparatus on the vehicle deck
- Wave impact pressure of deck between twin hull

As to the ride quality, the estimation was made at a seat on the window side of the passenger room in accordance with the ISO Standards. The result revealed that it had superior operation performance without motion sickness when it was navigated at a ship speed of 35 kt for two hours under rough sea of significant wave height of 2 m (Fig. 10). As to the lashing apparatus and wave impact pressure, too, it was known that it can sufficiently withstand the navigation at 35 kt under the rough sea of significant wave height of 2 m.

4. Conclusion

This paper showed the effectiveness of the design technique of SSTH based on motion and structural response measurement results obtained over a period of about six months after the SSTH-70 was placed in commission and estimated response value by numerical calculation.

Assuming ocean-going service of the SSTH, this paper also outlined the relations between principal particulars and operation limits. The future fast ferry must secure the service rate in the sea area where it navigates or stipulated operation limits. It was determined that the SSTH with a ship length 110 m and service speed of 35 kt had a sufficient performance as an ocean-going type SSTH, though the RCS was installed.

In the future, SSTH will be proposed as a fast ferry that can navigate as an ocean-going type to contribute to the modal-shift of distribution by making the best use of the operation performance of the SSTH-70.

5. Acknowledgment

We express our heartfelt thanks to those concerned of Kumamoto Ferry Corporation who kindly cooperated with us in the full scale measurment.

REFERENCES

(1)H. Nogami and S. Mizoguchi : SSTH Fast Ferry and Tests on 30 m Ship in Sea, Ishikawajima-Harima Engineering Review Vol.32 No.4 July 1992 pp.231-236

(2)R. Michida, T. Ishiguro, M. Itoh and T. Ichikawa : SSTH-70 Ocean Arrow Super Slender Twin Hull Fast Ferry, Ishikawajima-Harima Engineering Review Vol.38 No.5 Sep. 1998 pp.339-345

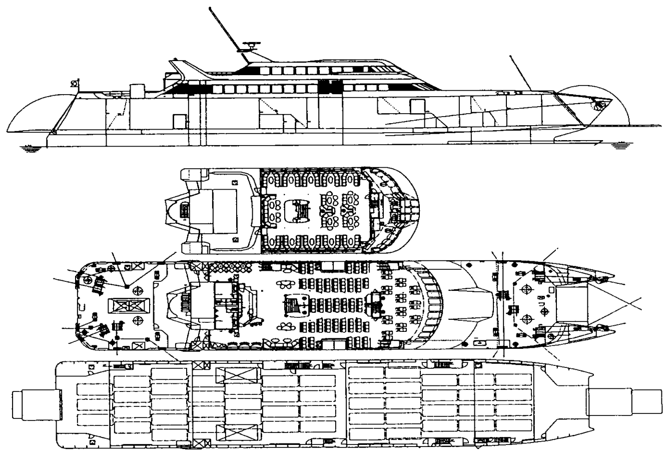

Fig. 1 General arrangement of SSTH-70

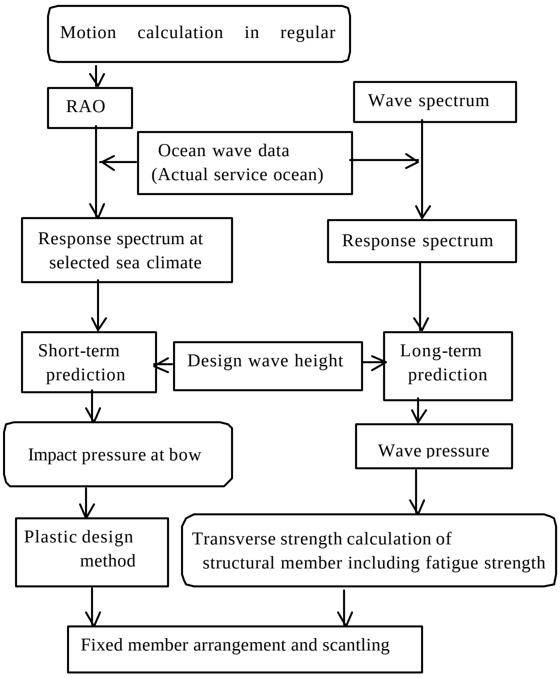

Fig. 2 Design flow chart

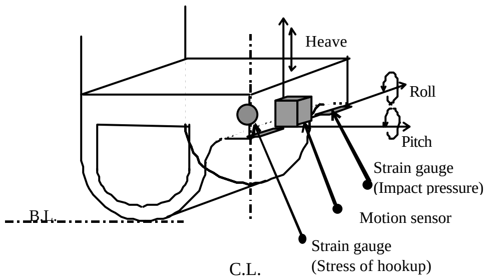

Fig. 3 Arrangement of motion sensor and strain gauge

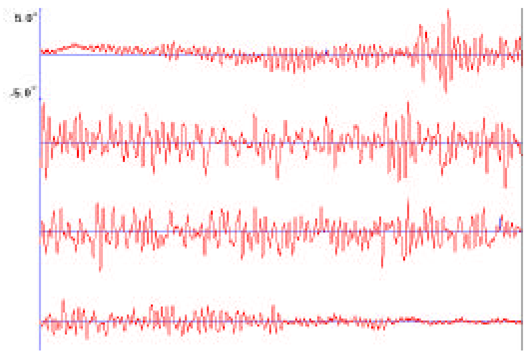

Fig. 4 Measured roll data

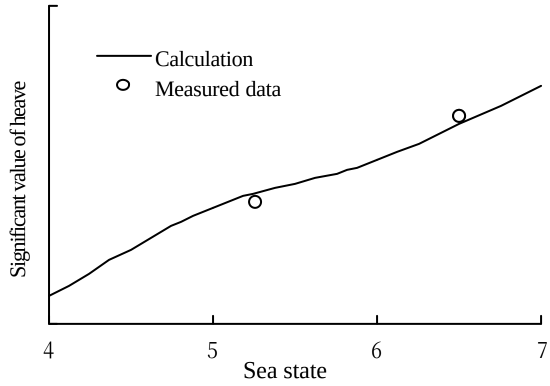

Fig.5 Measured data and calculation results in bow sea

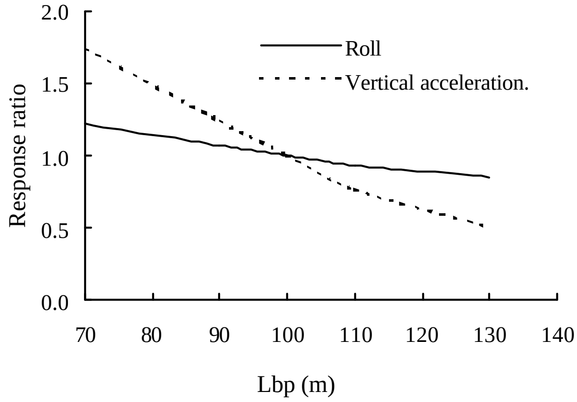

Fig.6 Roll and vertical acceleration

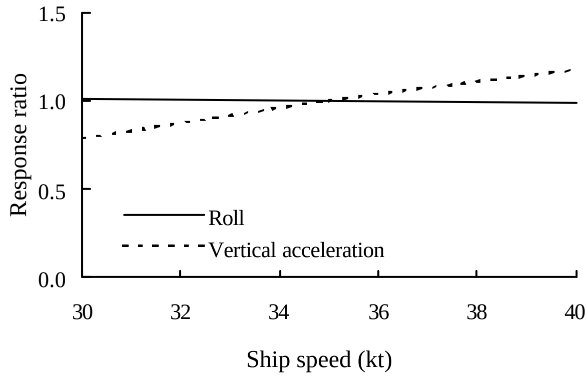

Fig. 7 Roll & vertical acceleration

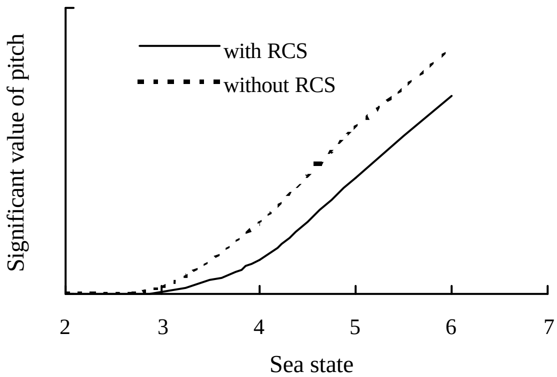

Fig. 8 Pitch in bow sea (ship speed 35 kt)

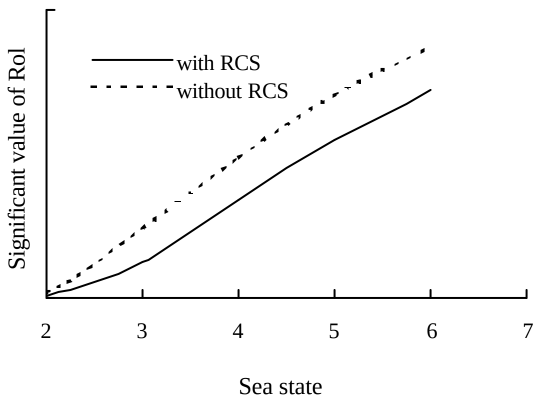

Fig. 9 Roll in beam sea (ship speed 35 kt)

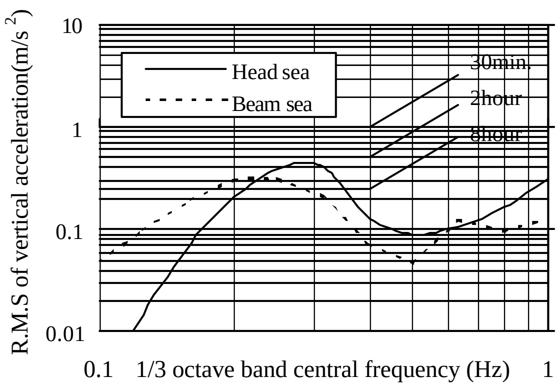

Fig. 10 Motion sickness indices