Development of 8 700 TEU Type Mega Container Carrier

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Because of strong growth in the global container trade, container vessels engaged in main service routes such as Europe-Far East and Northern America-Far East have been getting larger with increased container stowage capacity every year. IHIMU (IHI Marine United Inc.) has developed the Mega Container Carrier with a container stowage capacity of 8 700 TEU (Twenty-feet Equivalent Unit). The vessel was designed to maximize container stowage capacity and propulsive performance. Advanced technologies achieved by IHIMU related to hydrodynamics and hull structural design have been reflected in the design of the vessel. This paper presents the outline of the vessel and such technologies for container vessels.

1. Introduction

IHI Marine United Inc. (hereinafter called IHIMU) constructed more than 100 container vessels since completing of "JAPAN ACE" (completed in 1968). As shown in **Fig. 1**, most of these vessels are of the largest class of the period. In other words, IHIMU has been the industry's leader worldwide in upsizing container vessels, and IHIMU kept on improving its technology for developing high-efficiency hull forms and technology for developing high-reliability hull structures on every occasion.

The volume of containerized cargo has greatly increased worldwide, bringing about the increase in container ship sizes, particularly, a significant upsizing was seen in the main service routes from China and other East Asian countries to Europe and the North America. As larger vessels can carry more containers, the reliability of vessels is more important. Furthermore, because of higher fuel prices as a result of the recent higher crude-oil prices, energy saving is becoming increasingly important. In particular, high fuel consumption of large container vessels has a major influence on the profits of their owners, who are now seeking more contributions to their economy by means of energy-saving ships.

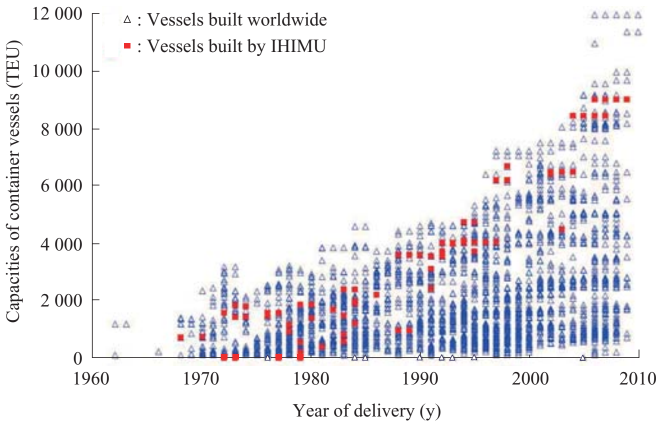


Fig. 1 Delivery of container vessels and sizes

IHIMU has developed a container vessel with a capacity of 8 700 TEU (Twenty-feet Equivalent Unit) for Kawasaki Kisen Kaisha, Ltd. For the development, IHIMU took advantage of know how and basic technologies related to container vessels that had been accumulated over many years. As a result, IHIMU was able to accomplish a hull form design that can carry the required number of containers with less fuel consumption.

This paper presents an outline of this vessel, and describes technologies that contributed to the development of the hull form and the ship's hull structure, which are basic technologies of IHIMU.

2. Outline of 8 700 TEU type container vessel

Major design requirements at the planning stage of this vessel are as follows.

(1) The loading capacity of this vessel is 8 000 TEU or more containers with a unit weight of 9 t/TEU.
(2) This vessel has service speed of 24.5 kn while

minimizing consumption of fuel.

The principal particulars (as planned) of this vessel are as follows, and the general arrangement is shown in **Fig. 2**.

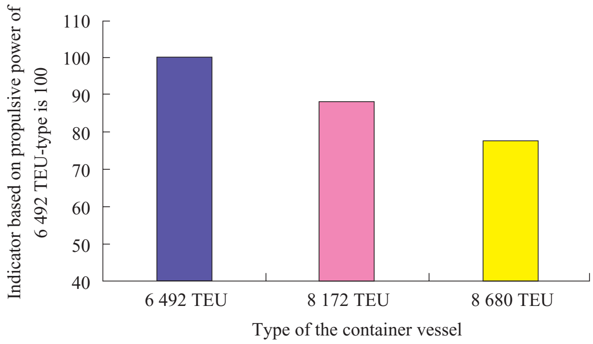
Length overall	336.0 m
Breadth, moulded	45.80 m
Depth, moulded	24.40 m
Summer draft	14.00 m
Deadweight	96 700 t
Gross tonnage	99 400 t
Number of containers (7 tiers on deck)	8 680 TEU
Main engine	12K98ME
Maximum continuous output	67 270 kW × 93.4 rpm
Service speed	24.5 kn

The main feature of this vessel is that 18 rows of containers can be loaded across the deck.

At the planning stage of this vessel, the hull form, principal particulars, and arrangement were carefully considered in view of the design requirements. When the planning took place, the container vessels with the largest breadth at the time were only capable of loading 17 rows on deck (15 rows in hold), IHIMU chose to propose to the buyer a new design of 18 rows on deck (16 rows in hold) as shown in the particulars and the general arrangement (**Fig. 2**) and eventually this proposal was accepted.

Figure 3 presents the improved propulsive performance of this vessel by a comparison of propulsive power to carry 1 TEU of container (9 t/TEU) among 6 492 TEU-type (completed in 2002), 8 172 TEU-type (completed in 2004) (previous vessels), and 8 680 TEU-type (this vessel), which were constructed by IHIMU. The vertical axis of the graph shows an indicator based on the propulsive power of 6 492 TEU-type is 100. The difference in performance between 6 492 TEU-type and 8 172 TEU-type is primarily achieved by the improved performance of hull forms, and the difference in performance between 8 172 TEU-type and 8 680 TEU-type is primarily achieved by the selection of the suitable hull form, principal particulars, and arrangement corresponding to the given design requirements.

In other words, taking advantage of the high technological capabilities of the hydrodynamics, IHIMU set the principal particulars and arrangement appropriate to the design requirements to develop the hull form with high propulsive performance. Through the full use of high performance of structural analysis for ship's hull structure, this hull form was achieved by solving problems associated with upsizing of container vessels including the deformation of hatch opening, longitudinal strength, and vibrations.



(Note) Propulsive power per 1 TEU of container (9 t/TEU)

Fig. 3 Mega carrier characteristics compared with previous vessels

3. Development of hull form of container vessel with high propulsive performance

3.1 Circumstances of hull form development

As described in the introduction, the owners of large container vessels expect significant energy-saving effects. In addition, as propulsive power becomes higher, propeller cavitation and rudder erosion tend to be severer than ever before. Therefore, an adequate design of hull form, propeller and rudder for addressing these problems is essential. This chapter describes the current situation of a development associated with hydrodynamic performance.

3.2 Development of energy saving hull form

For hull form development, CFD (Computational Fluid Dynamics) was mainly used to optimize the hull form.

The ratio of wave-making resistance to total resistance for a container vessel is larger than that of a full ship, and a reduction in wave-making resistance significantly contributes to energy saving. Therefore, we made efforts to reduce wave-making resistance by means of CFD. **Fig. 4** shows a comparison of simulated wave profiles obtained from CFD calculation between an existing ship and the new ship. Hull form optimization suitably works to reduce the wave profile near the bow.

Figure 5 shows the measured wave-making resistance coefficients of these ships derived from model tests. It was verified that the wave-making resistance of the new ship was significantly lower than that of the existing ship caused by improved hull form and the reduction in Froude number due to increased ship length. For the new ship, the

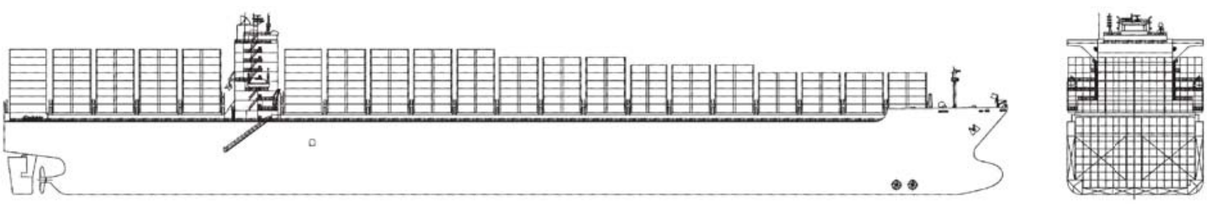


Fig. 2 General arrangements

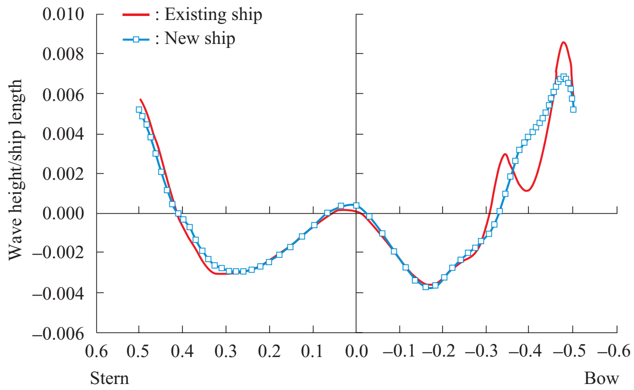
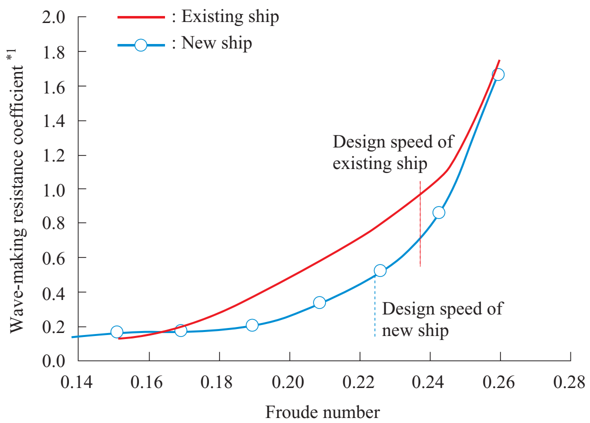


Fig. 4 Wave patterns calculated by CFD



(Note) *1: It is assumed that the value at the design speed of the existing ship is 1.

Fig. 5 Wave-making resistance measured by tank model tests

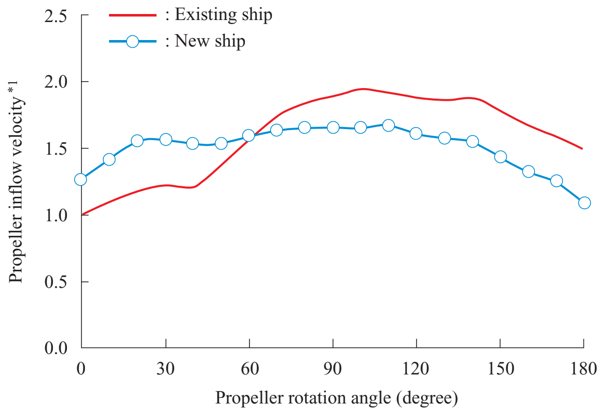
self propulsion factor was improved at the same time by improving the stern shape, and its effect was also verified in the model tests. The design concept of the new ship described in this section is based on the above mentioned design principles.

3.3 Improvement of stern flow field

As the dimension of vessel and corresponding propulsive power become larger still with the draft limitation imposed, the propeller cavitation of larger container vessels will present severer problems because propeller is working with the limited diameter in higher power. For this reason, cavitation performance was improved by improving not only the propeller itself but also the stern flow field.

Figure 6 shows a comparison of wake distribution measured at a propeller position between the existing ship and the new ship. In comparison with the existing ship, the inflow velocity just above the propeller (at 0 degree) is higher, and the flow field is more uniform in the rotation direction. These changes in stern flow field can soften a cavitation phenomena appreciably.

Figure 7 shows a photograph of cavitation observed in a model test. The cavitation test verified that the pattern of cavitation on the blades are so-called sheet which means



(Note) *1: It is assumed that the value at a rotation angle of 0 degree is 1 in the case of the existing ship.

Fig. 6 Wake distribution on propeller surface

Fig. 7 Observation of propeller cavitation in cavitation tunnel

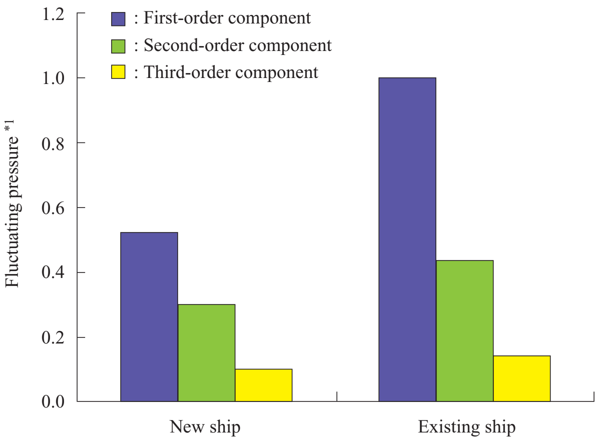
a moderate condition. During the test, it was found that propeller fluctuating pressure was approximately half that of the existing ship. **Figure 8** shows propeller fluctuating pressure measured in model tests.

3.4 Measures against rudder erosion

Another problem associated with the higher propulsive power of large container vessels is the cavitation erosion generated on the rudder surface. In parallel with the above improvement of propeller cavitation performance, the following measures for preventing rudder erosion were taken for the new ship.

(1) Equipment of horizontal and vertical plate (between rudder horn and rudder)
(2) Improvement of the section profile of the rudder
(3) Adoption of a flare-type propeller boss

Figure 9 shows the appearance of the rudder of this vessel observed after an official sea trial. The rudder of a vessel with measures applied was observed after 1 year



(Note) *1: The first-order component of the existing ship is taken as 1.

Fig. 8 Measured pressure fluctuation

Fig. 9 Improved rudder against erosion

from her delivery. No paint damage on the rudder surface was observed, and the effectiveness of these measures was verified. In addition, no traces of cavitation on the propeller blade surface were observed.

4. Strength evaluation for realizing the wider-breadth hull form

When the number of rows of containers in the hold is increased from 15 to 16, an increase in load on the hull, wave impact load on the bow flare and the influence of increased deformation of hatch opening on the hull structure are expected.

For development of this vessel, strength evaluations for improving soundness were conducted so that the owner can operate the vessel with security. Among them, the following 4 items are introduced.

4.1 Front loading for study of hull structural arrangement

3D models were used for the entire vessel at the initial stage of design while design alterations could be flexibly made. **Figure 10** shows an example structural arrangement examined by means of a 3D model. Locations were extracted where the structural arrangement is not continuous and reinforcement is difficult in terms of construction as well as strength because of the short distance between the outside plate and the container flat. The results of strength evaluation using a finite element analysis (FEA) model based on this model for study of arrangements can be fed back into the study of arrangements. At the same time, the double hull width, the container flat of the forward hold part, and the continuity of girder arrangements were verified, and soundness was successfully improved.

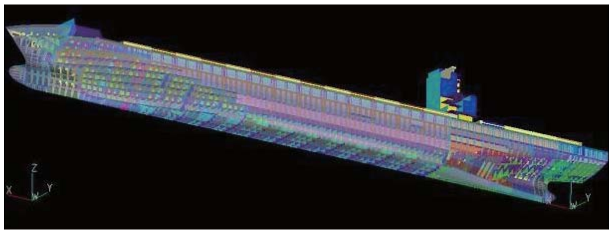


Fig. 10 Study of hull structural arrangement with 3D model

4.2 Influence of increased deformation of hatch opening

An increase in the number of rows of containers in the hold has an influence on the span of the transverse bulkheads and container loads on transverse bulkheads, and causes an increase in forward and backward deformation of transverse bulkheads. As this increase in deformation influences the principal particulars of the vessel, accurate estimation of deformation is required, and a deformation reducing design is required.

For accurate estimation, it is necessary to combine each amount of deformation caused by hull torsion, longitudinal bending, and forward and backward loads in consideration of the phase of each load component. Based on a results of motion analysis by strip method, a combination of each load component is determined, and the amount of deformation is calculated by FEA (**Fig. 11**). Through the above calculation, the safety of the entire vessel including its laded cargo was verified.

4.3 Bow strength against wave impact load on bow flare

While the breadth near the upper deck in the bow part is expanded because of loading of containers, the breadth near the draft line does not significantly change because of propulsive performance. Therefore, bow flare, which is hull expansion above full loaded water line, is significantly increased. Based on the rules for steel vessels, local strength evaluation for panels, stiffeners, etc. can be carried out, but overall evaluation for significantly flared structure just like this vessel cannot be carried out.

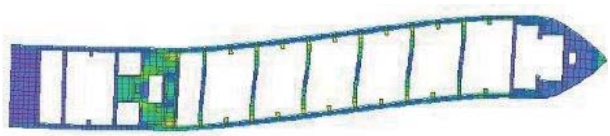


Fig. 11 Deformation by torsional bending moment

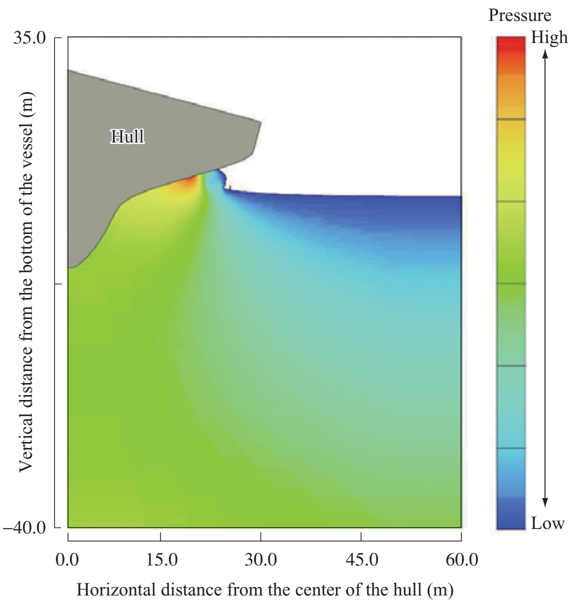


Fig. 12 Pressure distribution on bow flare

For this reason, in order to consider the wider area effect of the hull form, strength evaluation based on FEA was conducted using impact pressure and its distribution based on CFD. For calculation of a load, a velocity relative to a wave surface and a heel angle are important parameters. Therefore, based on motion calculation by the strip method, long-term prediction was made, and a comparison with an example of the measurement was considered to determine a load. **Figure 12** shows an example of the calculation of pressure distribution. Through this evaluation, sufficient strength against impact loads on a wide area of the bow flare part was verified.

4.4 Hull structural strength in the sea

For structural strength analysis of this vessel, strength analysis for acquiring PrimeShip DA & FA, which is the notation of Nippon Kaiji Kyokai, was conducted in addition to the conventional method of analysis of bending and torsional strength of the entire vessel and calculation of transverse strength using a selected load condition. In addition, a strength evaluation system called SPB-HULL, in which load estimation, strength calculation, and evaluation were conducted in series, was used to improve the safety of the hull structure. **Figure 13** shows an example of the analysis of the entire vessel using SPB-HULL.

In this system, strength calculation for all wavelengths, wave heights, and phases that may occur in ship's life is conducted, and a stress response function (**Fig. 14**) for each part throughout the entire vessel is determined to estimate a long-term prediction of stress and fatigue life.

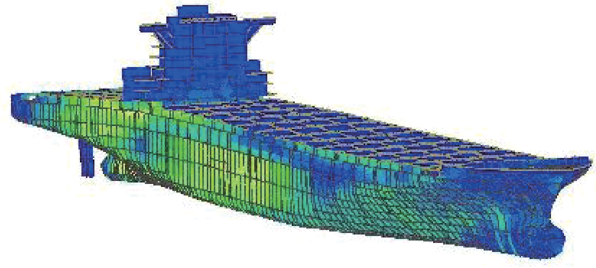


Fig. 13 Extensive structural analysis by SPB-HULL

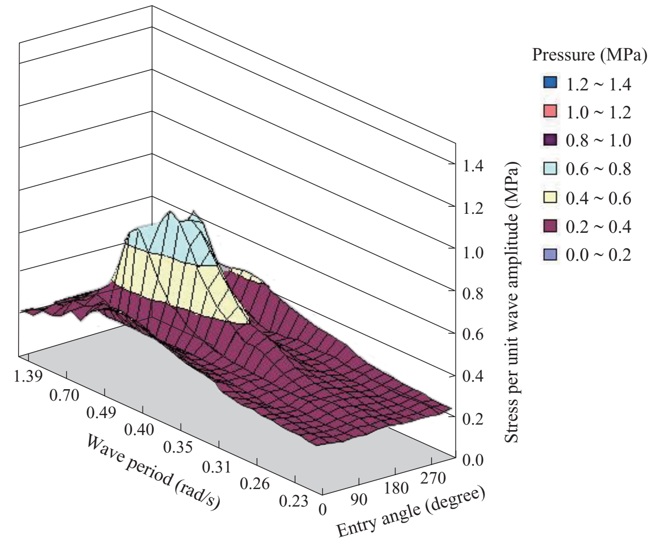


Fig. 14 Stress response function

This system allows strength evaluation for various parts for all load conditions where the conventional method was possible on evaluation on limited load conditions. By this system, it will be possible to verify the reinforcement effect by conventional methods, to extract the areas where further detailed assessment is required, thus improving safety.

5. Conclusion

Basic technologies accumulated by IHI Marine United Inc. through experience of design and construction of container vessels were integrated to establish the methodology to select suitable principal particulars and general arrangements, and the high-reliability mega container carrier with high stowage efficiency and propulsive performance has been developed. This vessel is one of a series of 8 vessels. The first vessel was successfully delivered, and is engaged in Europe-Far East service. At the official sea trial of the first vessel, the planned performance was verified.