Development of Environmentally-Friendly Container Carrier "eFuture 13000C"

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Plans for the energy-saving, environmentally-friendly 13 000 TEU Container Carrier have been developed and its conceptual design is complete. Green House Gas (GHG) emissions and fuel consumption will be reduced by about 30% compared to conventional container carriers of the same size. Propulsive performance will be improved through the newly developed twin-skeg hull form, and energy efficiency will increase due to the waste heat recovery system of the main engine. The carrier will use natural energy from photovoltaic panels and store it in large-capacity storage batteries. This newly developed container carrier is called "eFuture 13000C," and it is the first ship of IHIMU's environmentally-friendly ship series "eFuture."

1. Introduction

GHG (Green House Gas) emissions reduction is being called for worldwide by society in recent years. There is also a demand for ships built with this in mind to serve as the ocean-going vessels that provide international maritime transportation. IHI Marine United Inc. (IHIMU) has been working on the research and development of technology for the reduction of the GHG emissions of vessels, and has now completed the conceptual design of an environmentally-friendly 13 000 TEU container ship that incorporates this new technology. GHG emissions have been reduced by approximately 30% compared to conventional vessels. We present here an outline of the individual technologies for reducing GHG emissions and their effects.

2. Concept of the environmentally-friendly "eFuture 13000C" container ship

A conceptual design was completed for the environmentally-friendly 13 000 TEU container ship. The ship will reduce both GHG emissions and fuel consumption by approximately 30% compared to conventional ships. It features a significant improvement in propulsive performance by employing a newly developed twin-screw (twin-skeg) hull form and energy-saving devices at the stern and an improvement in the plant efficiency of the engine plant system based on making the most of waste heat recovery. Additional innovations include photovoltaic panels, which are installed to enable the storage of natural energy in large-capacity batteries.

We named the environmentally-friendly ship based on these new concepts the eFuture, and the 13 000 TEU container ship, whose conceptual design we present here, the "eFuture 13000C" (**Fig. 1**).

The greatest feature of these concepts is that an approximately 30% GHG emissions reduction per container can be achieved by combining readily implementable technologies. The various technologies employed this time and the effect each one has on GHG emissions reduction are presented in **Table 1**.

3. Improvement in propulsive performance

3.1 Twin-skeg hull form

Because propulsive performance improvement is directly linked to energy saving and further to GHG emissions reduction, it is the fundamental technology that

Fig. 1 Appearance of the "eFuture 13000C"

Table 1 GHG emissions reduction technologies and their effects in the "eFuture 13000C"

Purpose	GHG emissions reduction technology	Effect (%)
Improvement in propulsive performance	Twin-skeg hull form and low-friction coating	14
	Forward bridge and front bonnet	5
	Rudder bulb and tip rake propeller	4
Efficient energy use and improvement in plant efficiency	Hybrid propulsion system with waste heat recovery	10
	Use of shore-side electricity while moored	
	Photovoltaic power generation and lithium ion battery	1
Total		30

differentiates this product. The "eFuture 13000C" employs a twin-skeg hull form, which is a large factor in propulsive performance improvement.

In this twin-skeg hull form, each propeller shafts are enclosed by a part of the hull (skegs) (**Fig. 2**). Compared to ordinary twin-screw ships, this has the advantage of smooth water flow to the propeller; however, compared to single-screw ships, ship resistance is increased, because the area of wetted surface is increased.

By improving the hull form, IHIMU succeeded in achieving the same level of ship resistance for the "eFuture 13000C" as a single-screw ship. CFD (Computational Fluid Dynamics) was used intensively for the hull form modification (**Fig. 3**). Because ship resistance is equal, the propeller load is half that of a single-screw ship. Therefore, cavitation is less apt to occur at the propeller blade surface, and it is possible to employ propeller blades of higher efficiency. In addition, as the propeller load becomes smaller, the operating point of the propeller shifts to a point of higher efficiency (**Fig. 4**). Tank tests confirmed that these effects give an energy saving of approximately 10%.

For the underwater ship surfaces, a low-friction coating was employed to reduce the frictional resistance of the ship. Together with the effects of the twin-skeg, a total energy saving of approximately 14% is expected.

3.2 Rudder bulb and tip rake propeller

In addition to the improvement of propeller efficiency achieved by the usage of the twin-skeg hull form, energy-saving devices around the propeller were introduced to achieve further improvement in propeller efficiency.

One such device is a rudder bulb. This bulb is fitted to

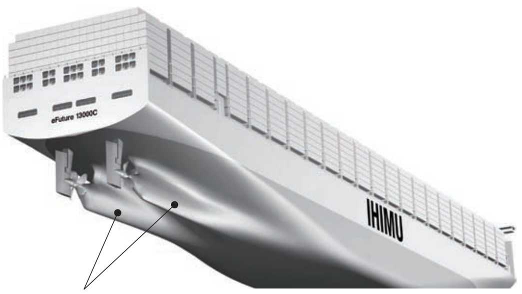


Fig. 2 Twin-skeg hull form

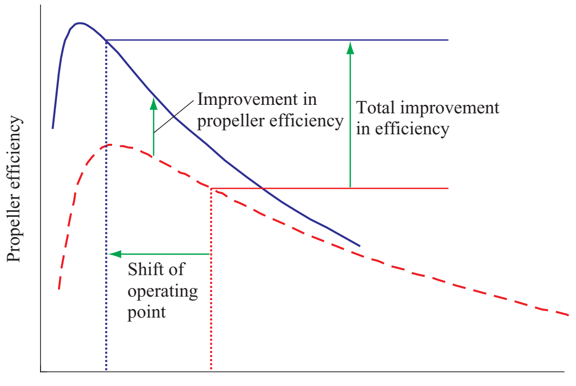
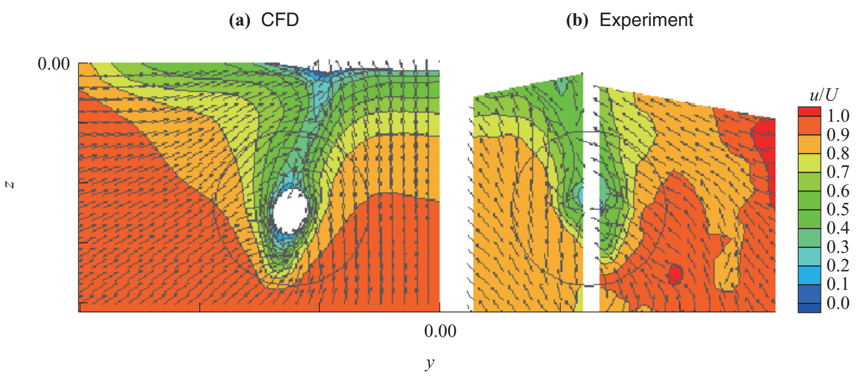


Fig. 4 Improvement in propeller efficiency achieved by usage of twin-skeg hull form



(Notes) 1. The vectors represent cross-plane flow velocity vector and the color represents the magnitude of axial flow velocity.
2. The symbols in the figure are as follows:
z : Position relative to ship depth
y : Position relative to ship width
u : Magnitude of axial flow velocity
U : Ship speed

Fig. 3 CFD results for flow around twin-skeg hull compared with experimental data (Section at propeller position) the rudder close to the propeller boss, thereby reducing the vortex (hub vortex) caused by the propeller and increasing the propeller efficiency.

Another such device is a tip rake propeller. The propeller blades are somewhat bent at the tip to further improve the propeller efficiency.

Introducing these technologies improves propeller efficiency by approximately 4%. An image of a stern into which these innovations are incorporated is shown in **Fig. 5**.

3.3 Forward bridge and front bonnet

The bridge and cabins are situated at the forward part of the ship. Because forward visibility is ensured in this arrangement, the restrictions on container stowing are eliminated and the cargo capacity in terms of TEU is increased. Thus, the GHG emissions per container can be reduced.

The ship is fitted with a huge front bonnet covering from the bow end to this bridge to smooth the air flow and to reduce wind resistance.

The adoption of this forward bridge and front bonnet (**Fig. 6**) achieves a total energy saving of approximately 5%. For the front bonnet, a view of a wind tunnel test (**Fig. 7**) and results of CFD calculation (**Fig. 8**) are shown.

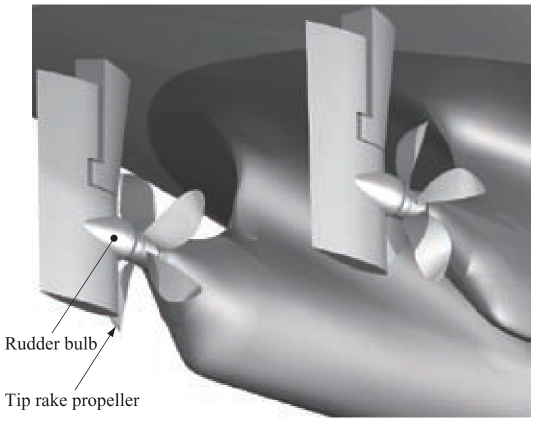
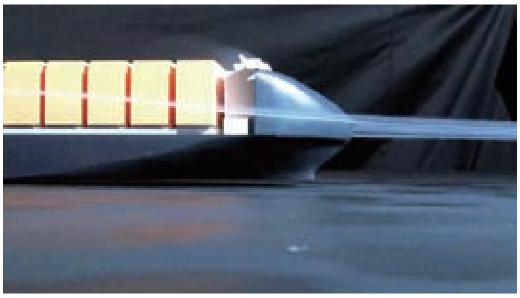


Fig. 5 Tip rake propeller and rudder bulb

Fig. 6 Forward bridge and front bonnet

(a) "eFuture 13000C"



(b) Conventional ship

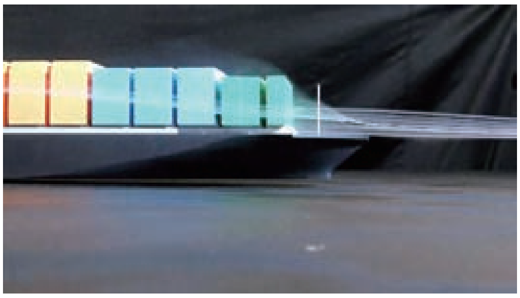


Fig. 7 View of air flow around bow in wind tunnel test

(a) "eFuture 13000C" (b) Conventional ship

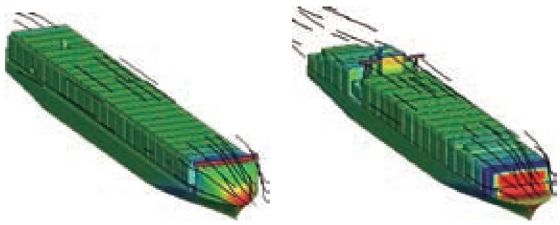


Fig. 8 Air flow and pressure distribution around ship by CFD analysis

4. Efficient energy use and engine plant efficiency improvement

4.1 Outline of engine plant

With the "eFuture 13000C," the horsepower per shaft is reduced to a half of that of a single-screw ship. Thus, the engine plant is equipped with two low-speed, long-stroke diesel engines that have a lower speed of rotation than the main engine of conventional container ships. These main diesel engines are controlled electronically to improve fuel consumption. To recover waste heat from the main engines as much as possible and convert it into electricity, two waste heat recovery power generating plants are installed. These make a hybrid propulsion plant that is capable of propulsive power assist using electric motors. The concept of the energy-saving propulsion plant is shown in **Fig. 9**, including the use of other natural energy sources.

By operating the plant using a combination of these energy-saving technologies, an energy saving of approximately 10% is achieved.

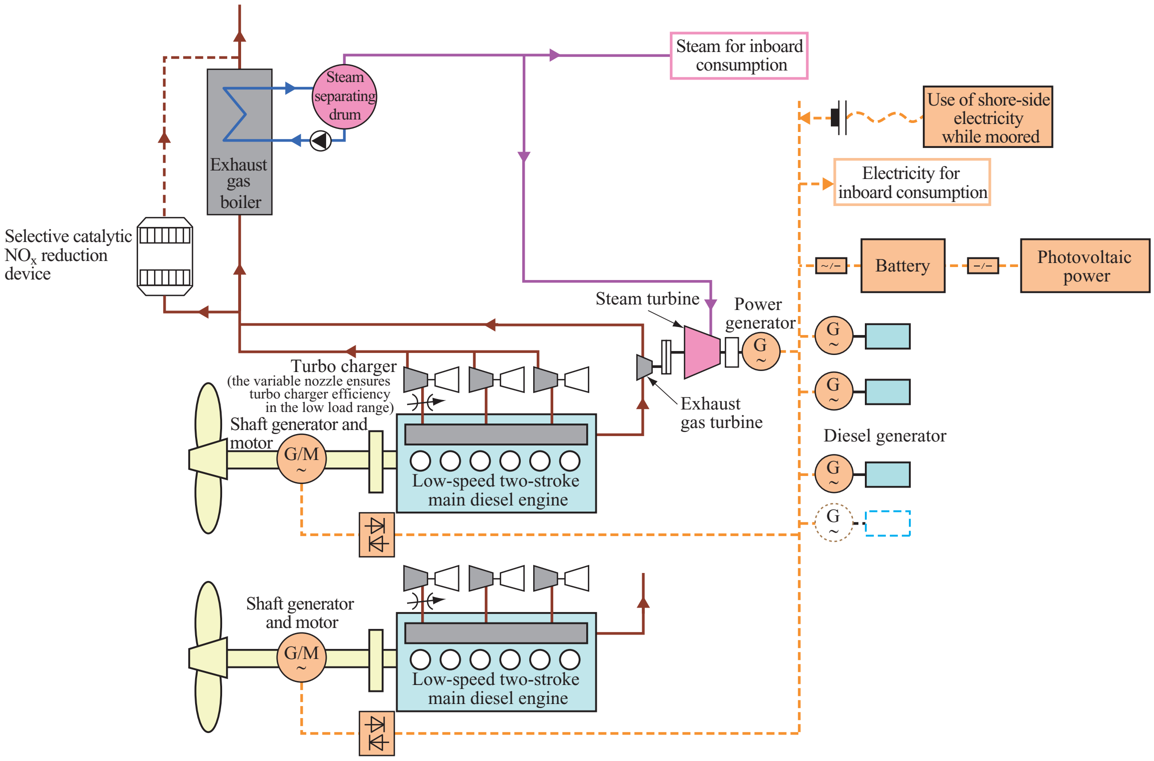


Fig. 9 Concept of machinery plant

4.2 Hybrid propulsion plant

Shaft-mounted electric generators/motors are installed on the intermediate shafts between the main engine and the propeller. If there is surplus electricity in the ship, this hybrid propulsion plant can provide propulsive power assist. While propulsive power assist is in effect, an energy saving can be achieved by reducing the load on the main diesel engine by the amount equal to the assist.

4.3 Waste heat recovery power generating plant

In any vessel, the largest energy consumer is the main engine. It is a very effective energy-saving technique for a plant to recover heat energy from waste heat worthlessly emitted from the main engine and to give it back to the power demand in the ship. In one system already implemented, the waste heat of exhaust gas from the main engine is used by an exhaust gas economizer to generate steam, which drives a steam turbine to generate electricity. The concept in the "eFuture 13000C" aims at further recovery; that is, the above mentioned steam turbine is added and an exhaust gas turbine (power turbine) is introduced. A part of the exhaust gases from the main engine is introduced into a power turbine without passing through a turbo charger and power generation also takes place there.

4.4 Variable turbine nozzle area turbo charger

The variable turbine nozzle area turbo charger has a mechanism that can vary the nozzle opening. In an ordinary fixed turbine nozzle area turbo charger, the gas supply nozzle area is designed according to the gas flow rate at the maximum power output of the main engine, and specification selection and matching take place to satisfy the efficiency required by the diesel engine in the normal load range. Therefore, the optimum efficiency in that state is not necessarily achieved at loads lower than normal (that is, at low speeds). The variable turbine nozzle area turbo charger can improve the engine performance by arbitrarily varying the nozzle area to the optimum setting in any state in the load range lower than normal. By making the variable nozzle area control coordinate with the electronic control system of the main engine itself, the optimum turbo charger nozzle area can be automatically maintained at all times according to the load and condition of the engine.

4.5 Use of shore-side electricity while moored

By equipping the vessel with a power receiving facility to receive external electricity, it becomes possible to receive shore-side electricity at ports. While the vessel is moored, its power demand can be covered in this way without operating the power generator installed in the vessel and the GHG emissions from the vessel become zero.

4.6 Use of natural energy and storage of electricity

Natural energy, if efficiently recovered and utilized, is the cleanest ideal energy source. Photovoltaic power generation has seen remarkable technological progress, and its usage and development are likely to continue in the future. A module made of a photovoltaic panel with a frame is installed separately above the stacked containers on the deck (**Fig. 10**). The same corner castings as those used on ordinary containers are used on the module's frame, so the module can be handled using a gantry crane in the same way as containers.

By storing electricity generated by these photovoltaic panels in the lithium ion batteries specially installed

Fig. 10 Arrangement of photovoltaic panels

inboard, the power system becomes capable of effectively using natural energy when needed. One example of operation is using the electricity stored during the voyage to supply power to the thrusters when they are used when the ship is berthed. This results in a reduction in the generator capacity or the number of generators required on the ship. It may also result in a reduction in size of the generating plant the ship requires.

5. Other environmentally-friendly methods

The previous sections described individual technologies for GHG emissions reduction in the "eFuture 13000C." These are hardware technologies that enable the "eFuture 13000C" to reduce GHG emissions for transport per container by approximately 30%. These technologies can also be used in container ships of other sizes in addition to 13 000 TEU vessels.

Further GHG emissions reduction is also made possible through the innovation of the way the ship is operated. These innovations can also be applied to conventional vessels and contribute in the same way as the technological innovations described earlier. We briefly present here several examples of these innovations of the operation of the ship that have been put into practical use recently or that are being investigated.

The first example is to reduce ship speed. Fuel consumption is proportional to the square of ship's speed over the same distance, so larger energy-saving effects are obtained if the ship is operated at lower speed. For example, when the ship's speed is reduced by 10%, the energy saving and the reduction in GHG emissions are both approximately 20%. For ship speed reductions of approximately 10%, tank tests confirmed that the effects of the twin-skeg described in **Section 3.1** remained unchanged.

The second example is the so-called optimum ship operating system, which calculates the shortest course, minimum fuel consumption route, and other factors while taking into account the latest weather and sea condition data and the ship's actual performance at sea. If the ship follows the calculated course, a GHG emissions reduction of 4% to 8% is achieved.

Incorporating these innovations into the ship's operation in the "eFuture 13000C" means that a GHG emissions reduction of up to 50% will be quite possible.

6. Conclusion

The "eFuture 13000C," an environmentally-friendly 13 000 TEU container ship, has been developed and its conceptual design is completed. GHG emissions reduction is approximately 30% compared to conventional vessels. The major technologies that contribute to GHG emissions reduction are as follows.

(1) Propeller efficiency was greatly improved by employing a twin-skeg hull form.
(2) Propulsive efficiency was further improved by a tip rake propeller and rudder bulb.
(3) Ship resistance was reduced by a low-friction coating and a front bonnet.
(4) Cargo capacity in terms of the number of containers was increased by situating the bridge at the forward part of the ship.
(5) Fuel economy of the main engine was improved by employing electronic control, a variable turbine nozzle area turbo charger and waste heat recovery system in the main engine.
(6) Photovoltaic panels that can be handled in the same manner as intermodal containers were devised to be installed on the container top. The generated electricity is stored in large capacity lithium ion batteries before use.

Most of these technologies can currently be implemented and can readily be used to meet the demand for a 30% GHG emissions reduction. Each of these technologies can be applied to container ships of other sizes, and we hope this will lead to orders in the future.

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