Development of Large-Sized Mobile Harbor Crane

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With the recent trend toward containerization, it has become necessary for local small and medium-sized harbors to use mobile harbor cranes that are capable of handling containers as well as other general cargoes in different styles. Hence, demands for large-sized mobile harbor cranes, which are self-traveling and versatile but do not require any additional civil works to increase the bearing strength of foundation soil, are increasing. Mitsubishi Heavy Industries, Ltd. (MHI), using its latest crane technology, has recently developed a mobile harbor crane that is differentiated from other commercially available models in its easy-to-operate characteristics: (1) crane operation without interference with on-deck 13 rows by 5 stacks containers loaded on Panamax size containerships, (2) capable of handling 40.6 ton containers, (3) interlocking dual-axis anti-sway function and (4) oblique traveling by independent steering mechanism.

1. Introduction

A general outline of the mobile harbor crane is as follows.

It consists of a traveling device with rubber-tired wheels for traveling freely on harbor areas, outrigger and a crane unit to load and unload cargo onto or from a ship. The traveling device of the crane consists mainly of a frame for traveling, an outrigger device, a steering device and an operator's cab. Rubber-tired wheels are used when the crane travels, and an outrigger is used to support the crane unit during cargo handling operations. The crane unit consists of a slewing device to swing around the crane unit, a luffing device to raise the jib and a hoisting device to lift cargo. Cargo handling operation is performed by the three different actions of the crane: slewing, luffing and hoisting.

In addition, various types of cargo such as containers, general cargo, lumber and bulk cargo can be handled by changing the lifting tools.

A mobile harbor crane, when compared to a gantry crane fixed on rails installed on the wharf, is a low-cost, light-weight facility that does not require large-scale civil works for reinforcement of foundation or installation of other wharf equipment such as rails and power supply unit, reducing the initial equipment investment. Also, in handling of cargo, it can be used to rearrange stacks of cargo on the wharf yard as well as loading or unloading them on or from a ship. Thus, a mobile harbor crane has the feature of versatility and accordingly can be used to handle cargo in various ways.

2. Main specifications

Table 1 shows the main specifications of the MHI mobile harbor crane.

It is designed to handle containers loaded on a 40 000 DWT Panamax size containership and hoist 40.6-ton containers. The crane also has a sufficient slewing radius for use as backup of a container crane. To increase the cargo handling efficiency, the operating speed of each action is higher than that of conventional rubber-tired cranes. The crane is equipped with both swivel hook and expandable spreader as hoisting tools to meet the requirement for most handling needs of containers.

3. Features of the MHI large-sized mobile harbor crane

Mobile harbor cranes used in small and medium-sized

Table 1 Main specifications

Applicable containership class	(DWT)	40 000
On-deck container stacks		13 rows by 5 stacks
Rated hoisting capacity	(t)	65, max.
Applicable container	(t)	40.6
Slewing radius	(m)	53
Lift: above GL	(m)	35
Lift: below GL	(m)	−12
Hoisting speed	(m/min)	0 to 72
Luffing speed	(m/min)	Avg. 60
Slewing speed	(rpm)	1.2, max.
Traveling speed	(m/min)	67
Outrigger span	(m)	13.0
Outrigger spacing	(m)	13.5
Outrigger load	(t)	220
Maximum load on wheels	(t)	19

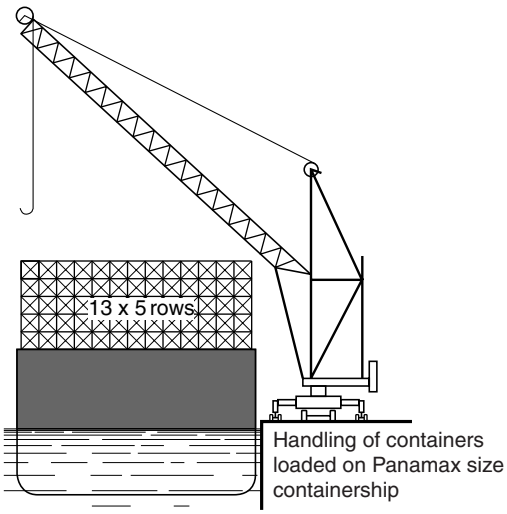

Fig. 1 Sectional view of Panamax size containership
Crane operation without interference with any part of the containers stacked on the ship's deck in 13 rows by 5 stacks is possible.

harbors are, in many cases, required to have a performance comparable to that of gantry cranes in cargo handling capability and maneuverability.

The crane introduced in this paper has the features described below to meet these requirements:

(1) This crane is designed so that its boom does not interfere with the top edge of the stack of containers when it is operated to handle on-deck 13 rows by 5 stacks containers on Panamax size containerships, while the conventional cranes need to be operated while taking care not to touch the on-deck cargo.

(2) It can hoist heavy-weight containers (40.6 tons), which are now increasing by replacing ordinary 30.5-ton containers.

(3) It is equipped with interlocking dual-axis anti-sway function that relieves crane operator from sway control and improves maneuverability and cargo handling efficiency.

(4) It is equipped with independent steering mechanism and oblique traveling function to improve maneuverability and efficiency in bringing the crane alongside containerships, in addition to the conventional curve traveling function.

4. Cargo handling range

Fig. 1 shows a sectional view of a Panamax size containership. This crane is designed to be capable of handling containers without interfering with any part of the 13 rows by 5 stacks containers on the ship's deck. More specifically, the boom pivotting point is located high enough to prevent the boom from interfering with the corner of the top containers, and the operator's cab is installed beside the jib supporting point for ease of operation.

Fig. 2 shows a top view of a popular containership (10 000 DWT class). As the working range of this crane covers the overall length of a 10 000 DWT containership, neither relocation of crane nor shifting of ship is necessary. It offers increased cargo handling efficiency.

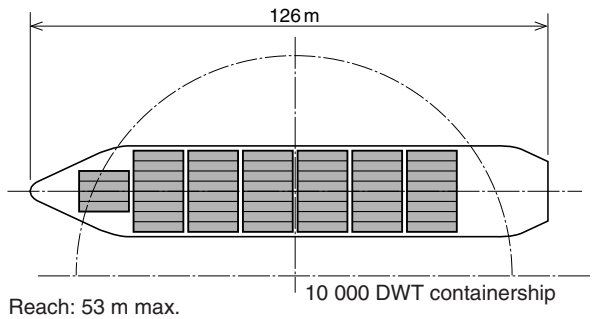

Fig. 2 Top view of 10 000 DWT class containership
The working range of this crane covers the overall length of a 10 000 DWT containership.

5. Interlocking dual-axis anti-sway function

In operating a conventional mobile harbor crane, slewing of the boom for positioning can lead to secondary sway in the radial direction following sway in the slewing direction under centrifugal force, as shown in the left top diagram of **Fig. 3**. As it is not easy to suppress such complex sway, crane operators need to reduce the slewing speed and rate of acceleration to minimize its occurrence. That is one of the obstacles to increasing the efficiency of cargo handling operations. A relatively long period of time is also needed for acquisition of the required crane operating skill.

To solve this problem in developing a mobile harbor crane having higher cargo handling efficiency regardless of the operators' skill, MHI has completed the interlocking dual-axis anti-sway function for the purpose of sway prevention and positioning.

On the basis of the results of the analytical investigations made on the cargo handling operation, the hoisting and lowering controls of this crane are designed not for automatic operation but as an operator-assisting function for moving horizontally.

5.1 Interlocking dual-axis operating function

The sway caused by centrifugal force can be reduced by minimizing the centrifugal force produced during slewing operation. Centrifugal force is proportional to the square of the peripheral velocity and inversely proportional to the slewing radius. However, it is not practicable to sacrifice cargo handling efficiency for reduction of peripheral velocity. The solution is to make the slewing radius infinite, that is to make the trajectory of the top end of the moving boom a straight-line, as shown in the left bottom diagram of Fig. 3. Thus, no centrifugal force is produced, and accordingly, no sway perpendicular to the straight-line moving direction is developed.

Consequently, the lifted cargo sways only in the moving direction as primary sway. To use this principle, a straight line connecting a start point and an end point is drawn to obtain the moving distance of the lifted cargo. Next, a speed command to move the top end of boom along the straight-line trajectory is determined by using the moving distance as shown by the curve in Fig. 3. The speed command is divided into the slewing speed command portion and the

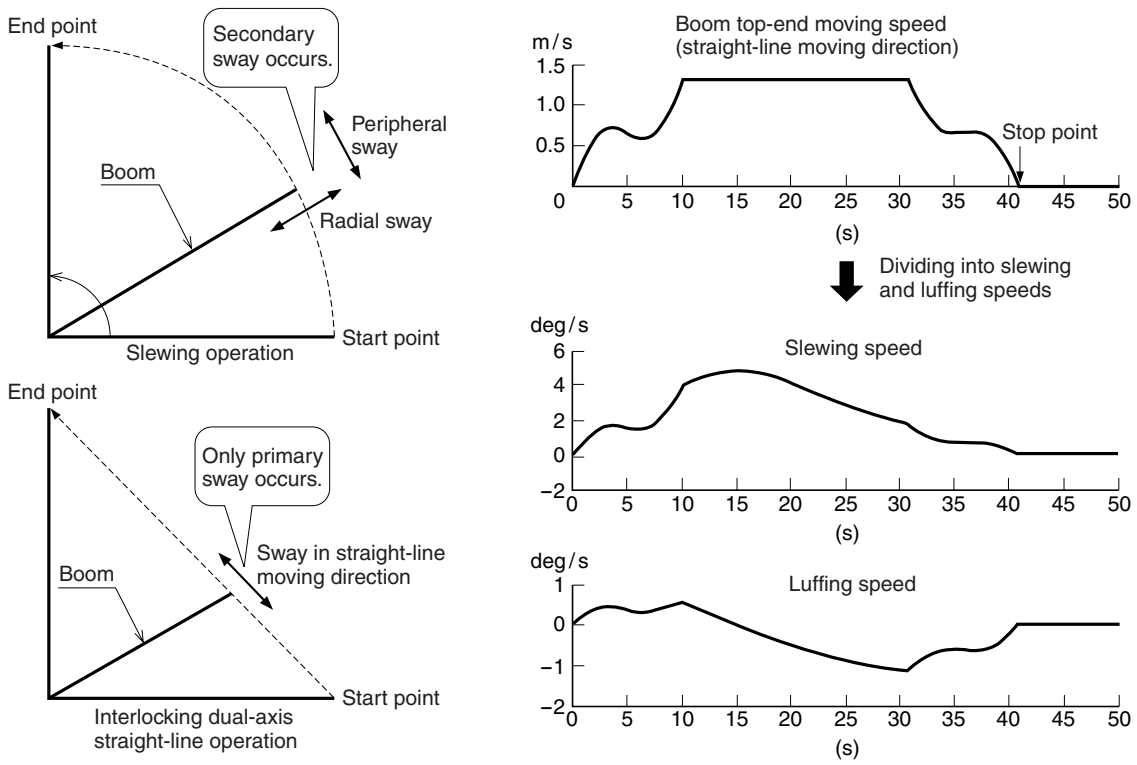

Fig. 3 Interlocking dual-axis anti-sway function
Sway is suppressed by jointly controlling slewing and luffing operations.

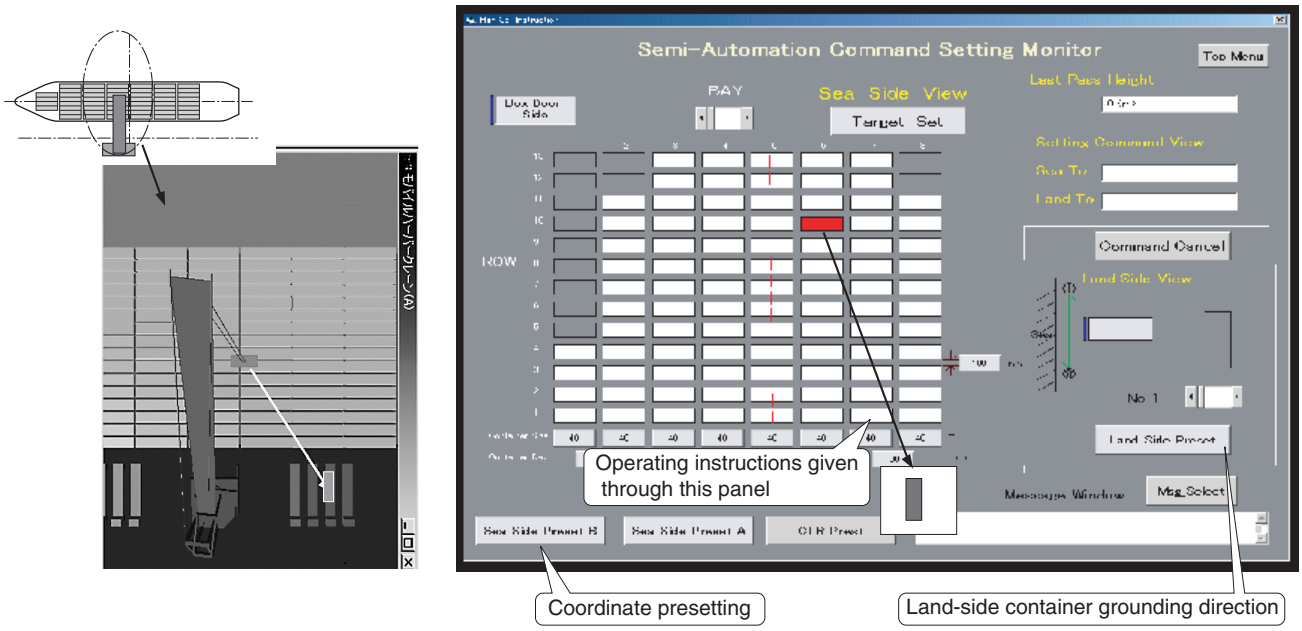

Fig. 4 Touch panel screen Easy input through touch panel screen is possible.

luffing speed command portion. These two different commands are jointly applied to the boom operation so that the top end of the boom moves along a straight-line trajectory for slewing and luffing.

5.2 Anti-sway control function

Primary sway still occurs in the direction of straight-line movement during the interlocking dual-axis operation. To suppress the primary sway, a field-proven feedforward anti-sway system is employed. In addition, the mobile harbor crane has a real-time speed compensation function that maintains the anti-sway effect regardless of the length of the hanging wire rope, because the wire rope length changes with luffing operation being performed by the level luffing function, and also because the hoisting operation is carried out manually by the operator.

5.3 Touch panel control

The interlocking dual-axis anti-sway operation of the mobile harbor crane can be easily controlled on the touch panel screen shown in **Fig. 4** and with the switches on the operation console.

Firstly, coordinate presetting is made on the touch panel screen to determine the position of the containership rela-

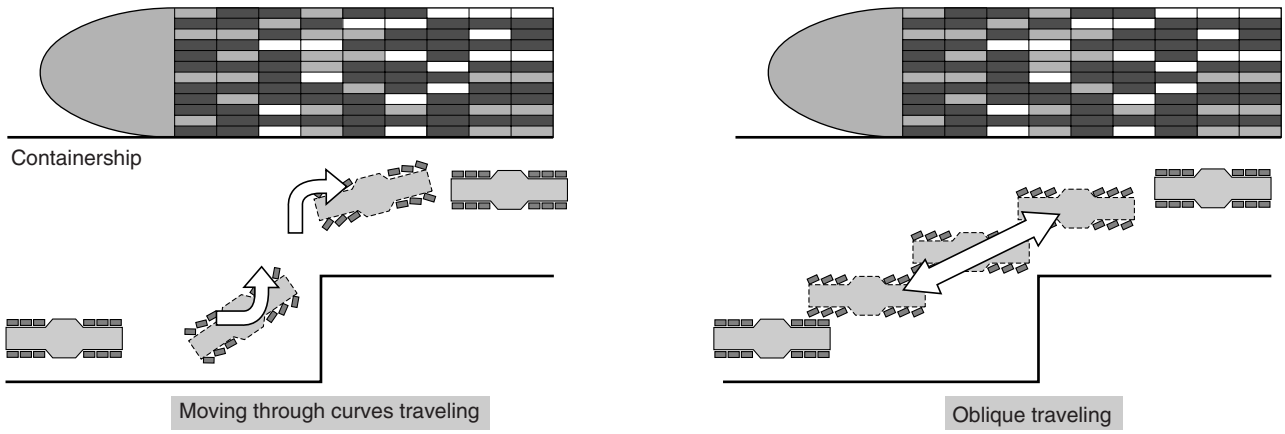

Fig. 5 Steering function for traveling
Independent hydraulic steering mechanism is adopted for moving through curves and oblique traveling function.

tive to the crane. For coordinate presetting, two arbitrary containers are selected from the array of containers on the ship displayed on the touch panel screen, the spreader is brought to the actual position of the first selected container by manual operation, and the preset key is depressed. When the same procedure is repeated for another container, the coordinate presetting is completed. The actual operation command is given to a target container by simply designating it on the screen. After the target container has been lifted to a safe level in the air by manual hoisting operation, the joint operation start command is given. The interlocking dual-axis anti-sway function then starts working automatically and the positioning of the container to the designated position is started. Even if the length of the wire rope varies with the intervention of manual hoisting at this stage, the anti-sway control function remains valid with the support of the real-time speed compensation function.

In addition, when the lifted container is being unloaded on the wharf, it is possible to give an instruction to ground it parallel to or perpendicular to the wharf. Also, the lifted container can be automatically turned around in the air by swivelling the hook so that all the containers are unloaded in the same direction. In this way, the mobile harbor crane can be used for various cargo handling operation.

6. Traveling function

The hydraulically operated traveling device consists of an outrigger unit, a steering unit and a common hydraulic unit for compact design.

The steering unit is provided with an independent hydraulic steering mechanism and feedback control to satisfy various traveling conditions. As shown in **Fig. 5**, when rounding a curve in the usual manner, the rear wheels are steered in the opposite direction to the front wheels to make the turning radius smaller. When adjusting the crane to the position of a ship or in a similar steering operation, the front and rear wheels can be steered in the same direction to perform oblique traveling for ease of position adjustment or to bring the crane closer to the ship.

Furthermore, each axle is synchronously controlled in order to minimize tire wear and axle load.

7. Conclusion

MHI has developed a large-sized mobile harbor crane suitable for use in small and medium-sized harbors. Demand for the crane is expected to increase further because of the following features:

(1) Crane structure allowing container handling operation without interference with on-deck 13 rows by 5 stacks containers on Panamax size containerships,
(2) Capable of handling a 40.6 ton containers, which are becoming increasingly popular in the industry,
(3) Interlocking dual-axis anti-sway function that improves maneuverability of crane and cargo handling efficiency, and
(4) Independent steering and oblique traveling mechanism that improves maneuverability of the crane for positioning close to a ship.

From now on, MHI will explore the possibilities of further improvement of functions through verification tests and cargo handling operations, using the mobile harbor crane in actual operations for improvement of its maneuverability and cargo handling efficiency.

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