Grid-Powered Electric Transfer Crane

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In response to the growing need for environmental friendliness, Mitsubishi Heavy Industries (MHI) has developed an electric rubber-tired gantry crane (RTG) powered from a standard ground terminal box of a city electrical power grid. This replaces the conventional RTG powered by an engine generator set. We estimate that this new electric RTG reduces both the energy cost and CO_2 emissions by approximately 90% compared to our conventional RTGs. Incorporating our innovative cable reel control technology, this new electric RTG can travel at 135 m/min, as fast as a conventional RTG, while stable straight-line travel is guaranteed with an auto-steering control system. When moving from one operating area to another, the crane disconnects from the ground terminal box and switches to a mobile power pack that it picks up and carries with it. This technical review describes how these technologies work in our new electric RTGs.

1. Introduction

In port container terminals, RTGs are used to move intermodal containers from trucks to stacks and back again. An RTG equipped with an engine generator set can travel over the entire terminal area, changing its tire direction by 90° for lateral and longitudinal movement.

Recent increasing concerns about environmental issues, including reduction in energy consumption and CO_2 production, make powering cranes from the electrical grid essential instead of relying on engine generator sets. To meet this demand, we developed an electric RTG with a cable reel to supply power from a grid terminal box, resulting in a lower energy cost and reduced CO_2 emissions. This crane has a traveling speed equivalent to that of a conventional RTG. It has a power cable with a detachable connector, and a mobile power pack. When operating, the crane is connected to the electrical grid; however, the crane picks up its mobile power pack and draws power from it while cross traveling between container blocks. The following sections describe the product specifications, environmental performance, and technical features of our new electric RTG.

2. Electric RTG specifications and environmental performance

2.1 Product specifications

Table 1 lists the basic specifications of our electric RTG, and **Figure 1** shows the overall equipment configuration. The cable reel and high-voltage receiving equipment are installed where the engine generator set was located on a conventional crane. The absence of the engine generator set eliminates engine maintenance, noise, and exhaust, and thus improves the working environment. The cable reel rolls in and out automatically at a speed that is synchronized with the crane's traveling speed. Because electric RTGs travel over long distances at high speeds without a track (rail), excessive or insufficient cable tension is a challenge. We solved this by using

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innovative control techniques.

As a result, our cable reel electric RTG can travel faster than a conventional cable reel model. We also introduced a robust auto-steering control system, which permits stable straight-line travel in spite of variations in cable tension or yard inclination.

RTGs usually operate in designated lanes. However, lane changes are sometimes necessary to move cranes to the maintenance area or to other busy areas of the facility. When moving to a new location, the RTG picks up its mobile power pack to obtain electrical power and disconnects the detachable connector from the ground terminal box before moving away.

Table 1 Product specifications

Item		Specifications			
Storage		6 lines	1 over 4	6 lines	1 over 5
		7 lines	1 over 4	7 lines	1 over 5
Speed	Main hoisting	23 to 52 m/min			
	Transverse traveling	70 m/min			
	Gantry traveling	135 m/min			
Rated load		40.6 t			

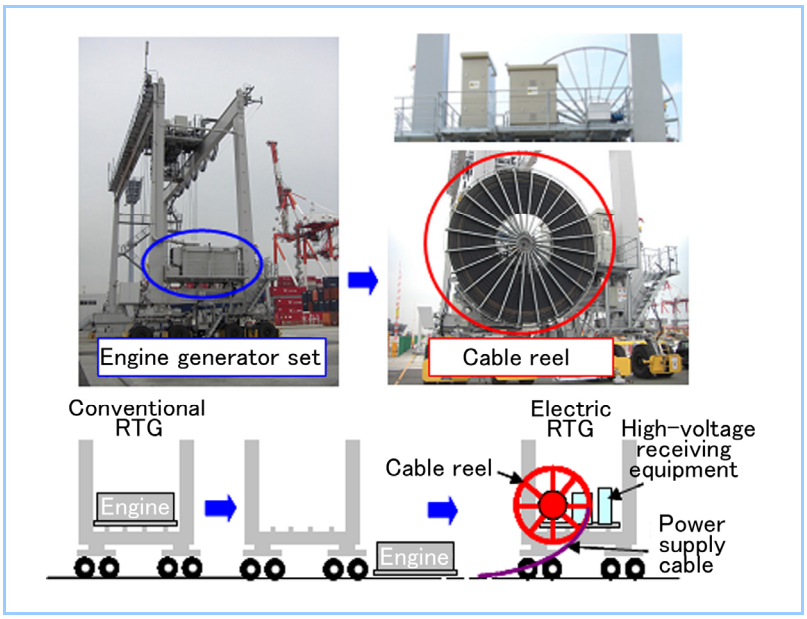

Figure 1 Electric RTG configuration

2.2 Environmental performance

Electric RTGs are economical and environmentally friendly. **Figure 2** shows an estimate of the improvement in their economic and environmental performance compared to conventional models. In conventional engine-powered RTGs, the power regenerated while a load is descending is dissipated as heat in a resistor, and the fuel consumption during standby periods is not insignificant. With our new electric RTG, on the other hand, the power regenerated as a load is descending can be used to operate other equipment in the terminal facility, and the energy consumption during standby is kept to a bare minimum. As a result, both the fuel consumption and CO_2 emissions are reduced by an estimated 90%. The cable reel RTG has significant economic and environmental advantages compared to a hybrid RTG equipped with an engine and secondary batteries.

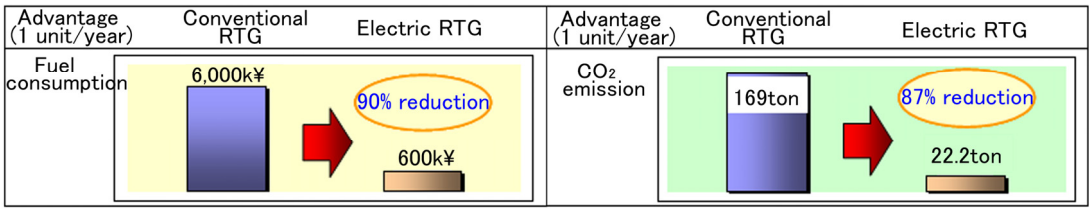

Figure 2 Environmental performance

3. High-speed traveling with tension control

Because the cable reel RTG travels long distances at high speeds without a track, it requires sharp acceleration and deceleration, or auto-steering controlled transient acceleration and deceleration. With conventional technology, such operation results in excessively high or low cable tension. To solve this problem, we developed a new type of cable reel control system using our machine control technology.

In a conventional cable reel crane, the rotational speed of the cable reel is synchronized with the crane traveling speed. For our new crane, we adopted a torque control system that applies an optimum torque to the reel in the roll-in direction. This is to control the cable tension, not the motor torque; the applied torque varies according to the rolled diameter of the cable to maintain the optimum constant tension.

The traveling acceleration is measured and used to correct the torque reference value to cope with fluctuations in the cable tension. This system also corrects for the cable reel rotational resistance corresponding to cable roll-in and -out directions. As a result, our electric RTG can travel faster than conventional cable reel RTGs, at a speed of 135 m/min (10 s acceleration and 6 s deceleration), equivalent to the speed of conventional engine-powered RTGs. **Figure 3** shows the fluctuation in cable tension of a conventional reel control system compared to that of our new system. Our new RTG crane exerts stable tension control without any excessive cable tension.

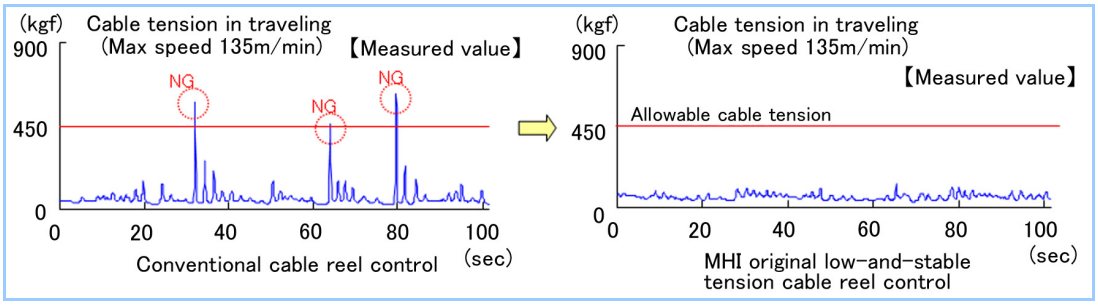

Figure 3 Stable cable tension control

4. Straight-line traveling performance

The RTG is equipped with two auto-steering sensors, as shown in **Figure 4**. By detecting deviations from the magnetic guideline buried in the yard, the auto-steering control system provides stable motion along the guideline. For example, when the crane deviates from the guideline, the control system causes the tires on one side to run faster than those on the other side to correct.

Recovering from a major auto-steering deviation requires a long time. To reduce the chance of such a deviation, we reduced the influence of cable tension and yard inclination by calculating the directional deviation angle during straight-line traveling and taking this angle into consideration. **Figure 5** shows the measurement result of deviations when traveling at the maximum speed of 135 m/min. This shows how the crane is capable of stable straight-line movement.

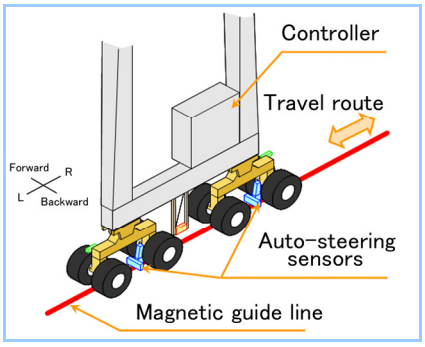

Figure 4 Auto-steering control

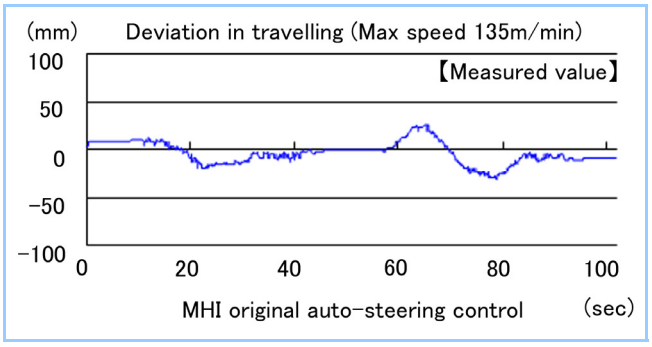

Figure 5 Stable straight-line motion

5. Lane changes using mobile power pack

During normal container handling operations, the electric RTG is powered from a terminal box installed at the end of each lane as shown in **Figure 6**, and the crane travels up and down the lane. On occasion, however, the RTG needs to move to another lane or to the service area for maintenance. To cater to such contingencies, we equipped the power feed cable with a detachable connector (**Figure 7**) and provided a mobile power pack (**Figure 8**) that the RTG can pick up and use as a power source when traveling outside a lane. **Figure 9** shows how the crane switches from one source of power to the other.

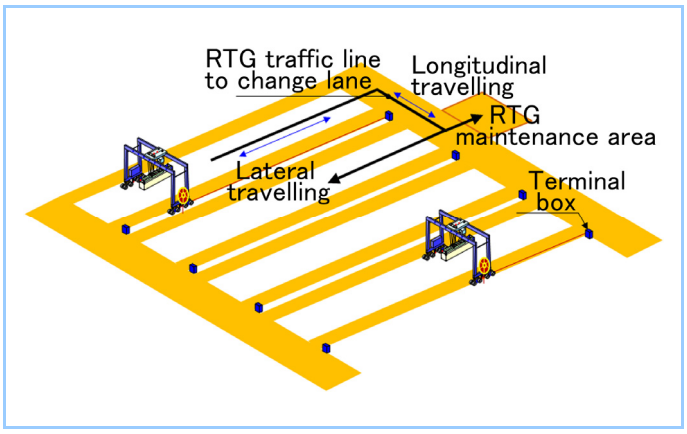

Figure 6 Lane change traveling

Figure 7 Terminal box

Figure 8 Mobile power pack

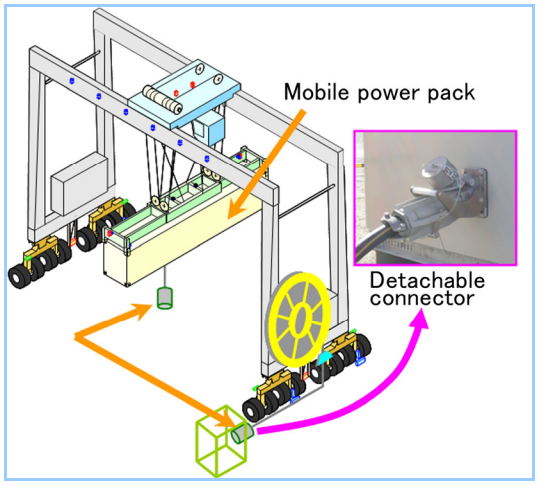

Figure 9 Switching between power sources

6. Conclusion

We have developed an innovative cable reel control system to reduce the fluctuation in tension in our new environmentally friendly and economical electric RTG, and included a new auto-steering control system to ensure robust performance. We have solved the problems associated with lane changes by using a power cable with detachable connector, and a mobile power pack for power while disconnected from the power grid.

We also offer a remote controlled automated RTG. With this model, transloading between the stack and trucks is controlled from the administration building. Fully automatic operation of the RTG will be possible when an automated guided vehicle system is introduced to replace chassis trucks.

We are developing hybrid RTGs that use both an engine generator set and secondary batteries. We are working on a complete line of automated electric RTGs for better environmental performance and energy efficiency in container terminals.

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