Cranes and Forklift Trucks
– Material Handling Systems Designed for Safe Transportation –

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1. Introduction

Recently, the information technology (IT) has made remarkable progress, and information can be provided instantaneously. On the other hand, due to globalization of industrial production, speedy material handling is needed, and the material handling systems are now being subject to change. Throughout the world, the container transport volume is increased 5% every year. In Japan, approximately 90% of goods is imported and exported by containership. It is expected that exports and imports will be increased about 60% in 2010, and about 90% in 2015, compared with 1999.

Since the transport volume is increased in this way, containerships used for marine transportation are being large-sized. Nowadays, containerships having 10 times larger carrying capacities than the initial-stage containerships are in service. In addition, containerships having much larger capacities are now being developed. Material handling systems are varying with the increase of imports and exports.

As the equipment necessary for material handling, Mitsubishi Heavy Industries, Ltd. (MHI) is manufacturing quayside cranes, mill service cranes, overhead cranes, bulk handling cranes, grain silo plants, various material handling systems, such as automatic storage & retrieval system, and various vehicles for material handling, such as forklift trucks and automatic guided vehicles (AGV).

This paper describes the history and future technology of quayside cranes that are necessary for marine container transportation, and also describes the history and future technology of forklift trucks that are taking an important role to meet the diversified needs for material handling.

2. Period of rapid growth and past of material handling systems

This section introduces MHI's initial quayside cranes and forklift trucks, and describes the period when these initial products were manufactured.

2.1 Past of quayside cranes

In 1956, the first container transportation business in the world was started in the U.S. In those days, containers were handled by the hook-type quayside cranes and the deck cranes, not by the dedicated container terminals. In 1958, the first dedicated container terminal equipped with container cranes was installed in San Francisco in the U.S., and started services.

Container transportation services were started during the high-speed growth era of the 1960's between the U.S. and Australia. This period is regarded as the first generation of container transportation. After that, since the round-the-world line, transpacific line, and transatlantic line were used for container transportation, larger-sized containerships were built, and larger-sized container cranes were developed. As shown in **Table 1**, we are now in the fifth generation.

In the second generation, MHI started production of container cranes. Since then, MHI has delivered about 300 container cranes.

2.2 Past of forklift trucks

On the other hand, the typical equipment used for handling of respective materials are the forklift trucks. Forklift trucks can be roughly classified into 2 types: the counterbalanced type and the reach type. The counterbalanced type shown in **Fig. 1** can swiftly transport a

Fig. 1 Counterbalanced type forklift truck

Table 1 Transition of containership size and cranes

Period	Container crane	Characteristics of containership	Typical customer of container crane	Products sold
Before 1966	1st generation	Between the U.S. and Australia Transport volume: 400 products		
1966 to 1970	2nd generation	From the U.S. to Europe via Japan and Australia Transport volume: 700 to 1 500 TEU	1968 Ports and Harbours Bureau, City of Yokohama 1970 Hanshin Gaibou Futou Corporation	2
1971 to 1984	3rd generation (Panamax)	Panamax Size Ship Transport volume: 2 000 TEU Stacking on deck: 13 rows Crane outreach: 36 m or more	1972 Keihin Gaibou Futou Corporation 1975 Nagoya Container Bureau 1978 Port of Brisbane 1982 Port of Singapore	119
1985 to 1995	4th generation (Post Panamax)	Post Panamax Size Ship Transport volume: 3 000 TEU	1988 APL (LA/Oakland) 1989 Port of Singapore 1991 MTL (Hong Kong)	125
1996 to Present	5th generation (Super Post Panamax)	Super Post Panamax Size Ship Transport volume: 4 000 TEU Stacking on deck: 17 or more rows Crane outreach: 45 m or more	1997 Port of Singapore 1998 Yokohama Port Development Public Corporation 2000 Osaka Port Corporation 2002 Tokyo Port Terminal Public Corporation	54
Total				300

Fig. 2 Reach type forklift truck

large amount of heavy materials, and is used at spacious places in and out of doors.

Since the reach type shown in **Fig. 2** can turn in a small space and can lift materials to high places, this type is suitable for transportation of materials in narrow warehouses and storage of materials on racks.

The above-described material handling equipment is subject to change. For example, due to growing tendency toward environmental protection, the motive power sources of these vehicles are now being changed from the engine type to the battery type. In addition, due to the diversified and upgraded material handling method, various indoor material handling vehicles are now being developed.

In 1971, MHI came onto the market. In these 32 years, MHI has been making efforts to develop products, to provide better services, and to extend the sales network. At present, MHI is manufacturing the engine-type vehicles of 1-ton to 42-ton classes, and battery-type vehicles of 1-ton to 3-ton classes, and various attachments. In this way, MHI is providing various products to meet the customer needs.

MHI advanced into the foreign markets at the early stage. Establishment of three MCF companies(Note) together with Caterpillar Inc. in 1992 particularly promoted globalization of MHI's business. These 3 companies are in charge of marketing, production, sales, and services in their respective areas. On the other hand, MHI functions as the design center, and collects information from three companies to develop new models, and new technologies. In this way, MHI and the other companies are organically and efficiently cooperating with each other.

Note: These 3 companies are Mitsubishi Caterpillar Forklift America, Mitsubishi Caterpillar Forklift Europe, and Mitsubishi Caterpillar Forklift Asia established in America, Holland, and Singapore, respectively.

3. Globalization and present situation of material handling equipment

This section describes the present state of material handling business from the viewpoint of internationalization of production bases, diversification of material handling methods, and needs for speedy material handling.

3.1 Present situation of quayside cranes

The present container terminals consist of container cranes (designed for material handling in containerships) (**Fig. 3**), mobile harbor cranes (**Fig. 4**), transfer cranes (designed for material handling in yards) (**Fig. 5**), and straddle carriers (**Fig. 6**).

Among them, the main units are the container cranes, and the container cranes are equipped with anti-sway control devices and automatic operation systems for the

Fig. 3 Container crane

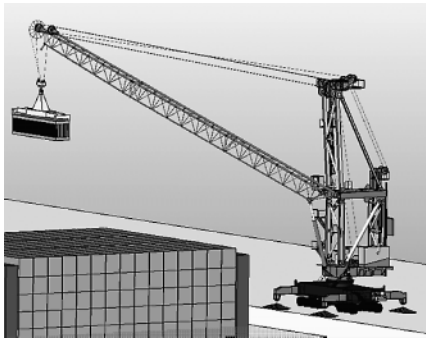

Fig. 4 Mobile harbor crane

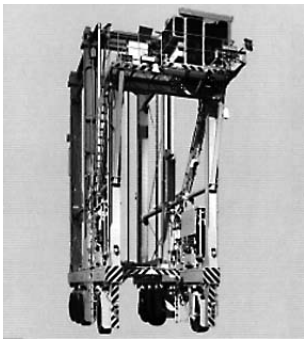

Fig. 6 Straddled carrier

Fig. 5 Transfer crane

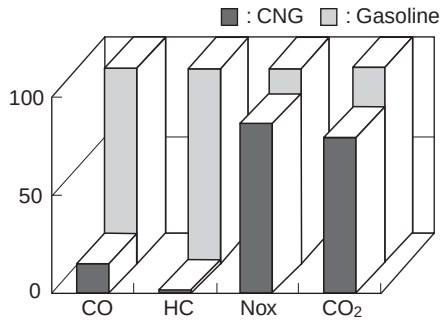

Fig. 7 Characteristics of gas exhausted from CNG forklift trucks

huge containerships and can be high efficient operation. In addition, the remote monitoring and maintenance system is adopted to facilitate maintenance. So MHI's specialists can remotely monitor the current crane operation status and the error status. In this way, MHI is making efforts to raise the operation rate.

Considering the damages of the Great Hanshin Earthquake in 1995, MHI has developed and delivered quayside container cranes equipped with the seismic isolation system so that the container cranes in charge of lifelines can operate without any damages even after a great earthquake.

In addition, since mobility and versatility are needed for the mobile harbor cranes, MHI has applied the anti-sway control technology developed for the container cranes to the mobile harbor cranes. In this way, MHI is developing and delivering easy-to-operate cranes.

3.2 Present situation of forklift trucks

Environmental protection is considerably important now. This section therefore describes environmental problems and typical examples of cooperation with other companies in the world.

(1) Purification of exhaust gas

Considering the excellent characteristics of compressed natural gas (CNG), MHI has developed 1.5-ton to 5-ton class CNG-engine forklift trucks. Generally, CNG engines have some problems that operable time per each gas charge is short and special equipment is required for charging the gas. As shown in **Fig. 7**, however, an in-house test has showed an excellent result that the CO2 content in exhaust is less by approximately 25% than that of a gasoline engine, and the fuel cost in CNG engine is estimated to be one half or less compared with that in gasoline or diesel fuel engine. MHI installed a quick gas charge installation in MHI Sagamihara Machinery Works the year before last. In addition, being authorized to be a model plant producing CNG powered forklifts, MHI is striving to provide necessary information to customers and popularize CNG forklifts through a number of presentations.

MHI is also making efforts to purify the exhaust gas of conventional forklift trucks of gasoline-engine type and diesel-engine type. Electronic control engines will be adopted for the 3.5-ton to 5-ton class gasoline-engine type vehicles at their next minor change, and while preventing performance deterioration and cost rise, MHI will develop vehicles that can meet the exhaust gas control standards specified by the U.S. Environmental Protection Agency (EPA), and the secondary exhaust gas control standards (CARB tier 2) specified by the State of California.

(2) Battery-type forklift trucks

Since the battery type forklift trucks are driven by the electric motors, this type of vehicles will not damage the environment. The problem is that the power of this type is not strong, but since the AC motor drive technology has been developed, this type has been upgraded to have the same power as the engine type. It is therefore said that more attention will be paid on the battery type from now on. So MHI will develop

Fig. 8 Rear drive 3-wheel electric counterbalanced forklift truck

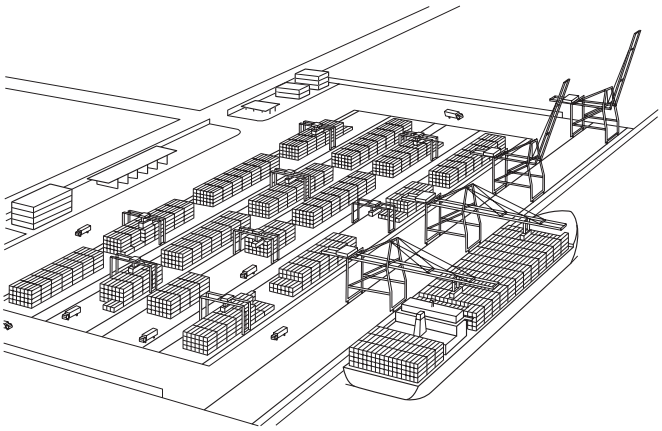

Fig. 9 Container terminal

products using our own technologies and will develop element technologies for the future.

In 1998, MHI developed the 3-wheel electric counterbalanced forklift truck, and in 2000, MHI fully changed the 4-wheel electric counterbalanced forklift truck to put it on the U.S. and Europe markets. Last year, MHI newly developed the 1-ton to 1.5-ton class 3-wheel electric counterbalanced forklift truck (lower class forklift truck compared with the above-described 3-wheel forklift truck) (**Fig.8**). In this way, MHI has been putting new products on the markets one after another.

(3) Cooperation with Nissan Motor Co., Ltd.

Ignoring the conventional thinking, various manufacturers are now cooperating with each other throughout the world. In 2000, Nissan Motor Co., Ltd. and MHI agreed that two companies should cooperate with each other to develop forklift trucks, to purchase parts, and to provide products. The purpose of this joint venture is to provide good products by effectively using the other company's resources each other, such as the personnel, technology, information, and associated companies. Until now, MHI has provided 4-ton to 5-ton class engine-type forklift trucks to Nissan Motor Co., Ltd. In addition, the next-term engine-type forklift truck is now at the final stage of model change. In this way, our cooperation is now obtaining good results one after another.

4. Material handling systems designed for safe transportation

4.1 Future of container terminals

Due to globalization of the society, companies all over the world are making efforts to further expand their business areas. So the needs for container transportation is being increased, and container terminals should satisfy such needs (**Fig. 9**). For example, container terminals should provide better services to meet such needs, should handle materials more speedily, and should reduce the cost. Since there are the same needs in Japan, the 365-day 24-hour operable container terminals should be constructed.

To meet the above-described needs, MHI should establish:

(1) Terminal control systems that can ensure effective operation of the entire terminals

(2) Automatic container terminals that enable labor saving and ensure high efficiency

Regarding (1), after being unloaded from a containership, any containers should be speedily transported and useless movement should be eliminated. Considering this point, MHI is now developing software to enable efficient container storage and control, and to efficiently operate the transfer equipment. In addition, MHI is also developing unmanned gates to shorten the gate passing-through time.

Regarding (2), MHI is now developing automatic transfer cranes, AGV, and highly efficient container cranes to establish unmanned automatic systems in various yards.

In addition to the conventional anti-sway control devices, MHI has adopted "Magic Eye" for the automatic transfer cranes in order to develop upgraded control systems for realization of automatic stacking (**Fig. 10**).

MHI has realized low pollution and low fuel consumption by adopting electric motor drive for the AGV. The electric motor drive enables the AGV to travel freely to oblique directions by 4-wheel drive mechanism and to realize high efficiency in material handling. Moreover MHI can provide the best systems to the customers by proposing the operation management systems together with the vehicles (**Fig. 11**).

4.2 Future material handling with forklift trucks

MHI thinks that the future material hadling will be as described below. So MHI will positively develop technologies and opens markets.

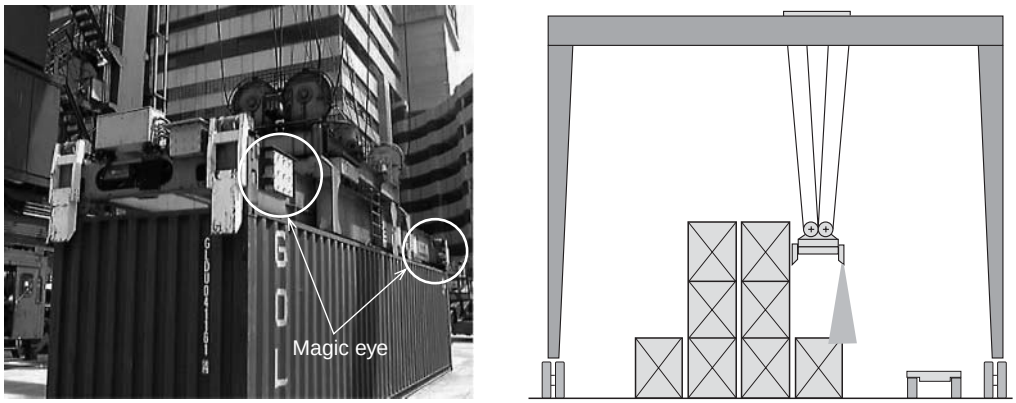

Fig. 10 Magic eye

Fig. 11 AGV

(1) More demands for environmental protection and safety

Since engines and power electronics are the key components for environmental protection, MHI will place importance on development of technologies for these key components. Regarding safety, MHI will adopt electronic control method to ensure safety.

(2) Rational “use” of vehicles

A concept that material handling vehicles should be "exclusively used" for certain specified economic purposes is spreading among customers. From the viewpoint of this concept, therefore, it is needed that the maintenance cost should be reduced, and the vehicle operation conditions should be properly managed in order to improve the efficiency in material handling. Accordingly, besides the means prolonging maintenance intervals and proving remanufactured parts (recycled parts) for maintenance at low prices, it becomes important to further develop the information technology (IT) for material handling, such as collection and management of vehicle operation data, upgrade of failure diagnosis technology, and preventive maintenance based on reliability analysis. The vehicle related data accumulated will be very useful for providing the better services in the future. For example, such data will be used for proposal of optimum maintenance plans and of upgraded services.

(3) Expansion of market and development of cooperation

Markets are now being expanded, as shown regionally in China, and also product diversity such as recently developed various indoor material handling vehicles is proceeding. According to this situation, various types of cooperation between manufacturers are inevitably increased. However, such cooperation is not so easy because of difference between the regional and corporate culture, or difference in decision-making systems. Nevertheless, through the experience obtained in cooperation with the MCF and Nissan Motor Co., Ltd, MHI will promote globalization, aiming at good partnership.

5. Conclusion

Since MHI has been developing and manufacturing the material handling systems, quayside cranes and forklift trucks are described above as MHI's typical products. Due to spreading of ubiquitous computing, information is freely provided in these days. Under such conditions, MHI will develop and provide high-quality information systems and material handling systems to our customers at low prices in order to meet customer needs.

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