Quayside Container Cranes in Year 2013

Suk-Jae Lee* and Keum-Shik Hong*†

* *School of Mechanical Engineering, Pusan National University; San 30 Gumjeong-gu, Jangjeon-dong, Busan 609-735, Korea*

*† *The author to whom all correspondence should be addressed.*

ABSTRACT: *In this paper, design specifications for a new generation container crane in year 2013 is investigated. After analyzing the trend of the development of container cranes from the 1950s to date, a prospective size for targeting year 2013 is proposed. Introductory specifications of the frame, trolley, hoist and spreader for the proposed new crane are discussed. Considering that the mega-ships will load and unload more than 15000 boxes at one stop, rough dimensions of the crane including outreach, rail gage, lift, backreach, etc. are also suggested. Although the sheer size of the cranes already present some challenges, the biggest challenge is to improve productivity by maximizing the moves per hour. For this, the speeds of trolleys and hoists, rail loads, stability, etc. are discussed.*

KEY WORDS : *container crane, performance specification, design criteria, cargo handling, port automation*

1. INTRODUCTION

Container cranes are used to transport containers from a container ship to trucks and vice versa. The size of container cranes has more than doubled since the first generation container cranes were built in the late 1950s. Container transportation using ships begun in 1957 with the first container ship "Gate Way City" that was converted from an oil tanker between Huston and New York by Sea Land (Sunwoo Information). The Matson container cranes built by Paceco in 1959 were designed to lift 22.7t boxes 15.6m over the rails with an outreach of 23.8m [16]. Later, Sea Land has opened the era of container transportations in the Atlantic Ocean using a full container ship "Fairland" in April 1966.

Container traffic continued to grow worldwide at about eight percent a year. To keep up with this growth, container ships got larger and larger. At first, all container ships could pass the Panama Canal; these ships were called as Panamax. In the late 1980s, American President Lines introduced the C10 vessel with 16 lanes on deck. The C10 vessel was too large to pass the Panama Canal and it was referred to as post-Panamax. The Regina Maersk introduced a ship with 17 lanes on deck. Furthermore, Maersk ordered cranes accommodating vessels with 22 lanes on deck. Liftech Consultants INC. has developed wharf loads for ships with 23 containers on deck; these ships are referred to as Suezmax. In 1999, Delft University Press published a book describing the "Ultimate Container Carrier" with 24 containers across: the Malacca-max (Jodan, 2001).

To increase productivity, the cycle time to move containers on and off the ship must be decreased. Each step in the cycle must be analyzed to determine possible ways to increase the speed, how much increase can be attained, and the cost and effect of the increased speed to the total crane system. The most efficient solution to the problem balancesthe cost and practicality of each action in the cycle.

For the largest ships, the efficiency of the terminals that serve them is especially critical. This is today's challenge to terminal operators. Dockside new generation container cranes will service these ships. Concomitantly, the new generation container cranes require optimum structural design and operational sophistication. Therefore the new generation container cranes must move containers higher, further, faster, and more accurately than ever before. Fig. 1 shows a new generation container crane (Jodan, 2001).

The structure of this paper is as follows: In Section 2, current status of the container ships and cranes

* sjlee@pusan.ac.kr 061)510-1481

*† kshong@pusan.ac.kr 061)510-2454

Table 1. World top 10 container handling ports.

Ports	Rank	Country	2000(TEU)	2001(TEU)	2002(TEU)
Hong Kong	1(1)	China	18,098,000	17,826,000	19,144,000
Singapore	2(2)	Singapore	17,0869,00	15,571,100	16,940,900
Pusan	3(3)	Korea	7,540,387	8,072,814	9,453,356
Shanghai	4(5)	China	5,613,000	6,334,400	8,620,000
Kaohsiung	5(4)	Taiwan	7,425,832	7,540,525	8,493,000
Shenzhen	6(8)	China	3,993,000	5,076,000	7,613,754
Rotterdam	7(6)	Netherlands	6,274,556	6,095,502	6,515,449
Los Angeles	8(7)	USA	4,879,429	5,183,520	6,105,857
Hamburg	9(9)	Germany	4,248,247	4688669	5,373,999
Antwerp	10(11)	Belgium	4,082,334	4218176	4,777,151

(Source: Port of Hamburg, Ci-Online)

* world rank figures in brackets are for 2001

analysis. In Section 3, introductory specifications of the frame, trolley, hoist and spreader for the proposed new crane are discussed. In Section 4, rough dimensions of the crane including outreach, rail gage, lift, backreach, etc. are also suggested. Finally, section 5 concludes the paper.

2. Current Status

The quantity of containers transported in Asia in 1998 was 84 million TEU (twenty-foot equivalent unit) and occupied 44.6 % of the world volume. In 2010, it will increase to 220 million TEU and is expected to occupy 50.1 % of the world volume. Currently, Hong Kong, Singapore, Shanghai, and Kaohsiung as well as Busan are competing each other to become an hub-port in Asia. Table 1 compares the quantities of containers transported in the world top 10 ports in three consecutive years. The fast growth of container volume calls for the appearance of giant container ships and cranes.

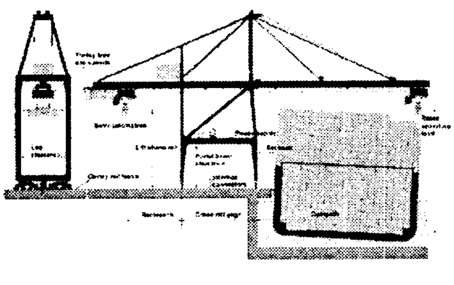


Fig. 1 A new generation container crane (Jodan, 2001).

Table 2. Resources of large ships.

Classifications	TEU	Length (m)	Hall	Width (m)	Lanes
Super post-Panamax	8,800	347	14	45.3	17
Maersk	12,000	350	14.5	57	17
Suez-Max	12,000	400	17.04	50	23
American shipper	15,000	400	14-15	69	25

(Source: http://www.sunwooinfo.co.kr)

Hyundai Heavy Industry has already delivered a 7,200 TEU container ship to Hapag-Lloyd, Germany, in 2001. It was reported that China Shipping ordered two 9,800 TEU container ships, which will be in operation in 2004. Table 2 demonstrates the resources of large ships. The appearance of these large ships expedites the increase of size and automation of container cranes. Table 3 illustrates the trend of the development of container cranes. Based upon these observations, it is conjectured that a new generation container crane in year 2013 should be able to handle a ship of 15,000 TEU. In the sequel, introductory specifications for the n ew generation container crane in terms of configuration, dimension, and performance are discussed.

3. Configuration of Future Crane

3.1 Conventional frame

The conventional and modified A-frame crane with a single trolley and one operator is the work horse of the industry. Most new cranes are conventional, with 50′ backreach, 100′ gage, and 145′ to 160′ outreach to service 16 wide Post-Panamax ships. Some cranes on order have 172′ outreach and can service 18 wide ships. Even if 18 wide capacities are not needed, the extended outreach improves production since the trolley does not go into the slow down zone at the end of the boom (Jordan, 1995).

3.2 Machinery Trolley

Both types of trolley systems the rope-towed and the machinery-on-trolley have beneficial site specific applications. For each crane purchases, the owner will need to evaluate each design and then choose the Table

3. Specifications of container cranes: the past and future.

	1st generation	2nd generation	3rd generation	4th generation	future
Year	1960 ~ 1980	1984 ~ 1994	1994 ~ 2003	2004 ~2013	2014 ~
Ship size	Panamax	Post Panamax	Super Post Panamax	Macrsk	American Shipper
Rated load (t)	35	Over 40.6	40.6 ~ 50.8	50 ~ 60	60 ~ 75
Outreach (m)	39	45 ~ 47	48 ~ 55	65	75
Span (m)	16 ~ 30	30	30	30.48	30.48
Lift (m)	21 ~ 28	32	34 ~ 36	40	50
Hoist speed (mpm)	36 ~ 45	55	60 ~ 75	90 ~ 180	90 ~ 180
Trolley speed (mpm)	120 ~150	180 ~ 210	180 ~ 210	240 ~ 300	240 ~ 300
Weight of crane (t)	450 ~ 850	900 ~1000	950 ~ 1250	1100 ~ 1450	1550 ~ 1850

design which best suits the site and the all-round operational needs (Bhimani and Kerenyi, 1995).

The machinery trolley is self-driven and contains the main hoist machinery. The machinery trolley has heavy, underhung frame with the main hoist equipment and trim/list/skew/snag device on the lower platform. All four wheels are driven for the machinery trolley with separate brake/motor/reducer (Bhimani and Hoite, 1998)

A factor in a decision to use machinery trolleys is the increased travel distance of the container cranes. The use of a machinery trolley substantially reduces the amount of rope, simplifies the reeving, and eliminates the need for catenary trolleys, although it also increases the weight and wheel loads (Bhimain et al. 1996).

3.3 Structural systems

Generally, for recent rope-towed trolley cranes, the trolley rails are on twin trapezoidal girders. Generally, for machinery trolley cranes, the trolley rails are on rectangular or trapezoidal monogirders. In a relatively few cases, some manufacturers have built rope-towed trolley cranes with monogirder booms.

A properly designed monogirder boom crane weighs less than a properly designed twin girder boom crane for both rope trolley cranes and machinery trolley cranes. The eccentric lifted load applies additional load

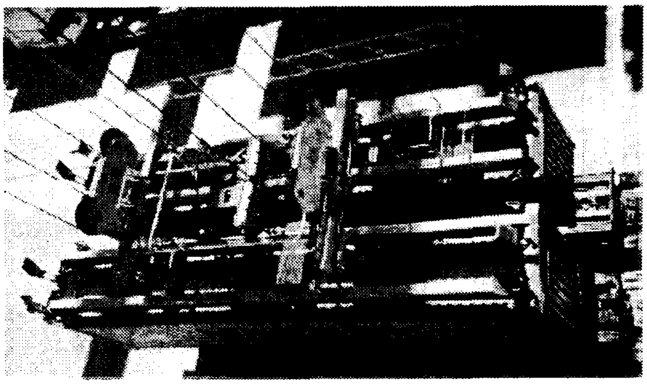


Fig. 2 Tandem forties spreader

on one side of the twin girder booms and forestays, resulting in bigger sections. For monogirder booms, the eccentric lifted load causes torsion in the boom. Since the torsion does not increase the axial stresses of the monogirder boom or the forestays, the sections do not need to be increased. Eccentric loads are not considered for fatigue, so this is not a factor if fatigue stresses govern the design (Bhimani and Kerenyi, 1995).

Many factors affect the cost of the crane. The lightest crane may not be the most economic. Typically, the fabricators have a standard design that they have learned to build. For them, their standard design is the least costly and the most reliable. For some fabricators, the monogirder design is best. For others, the double girder design is the best.

3.4 Spreader

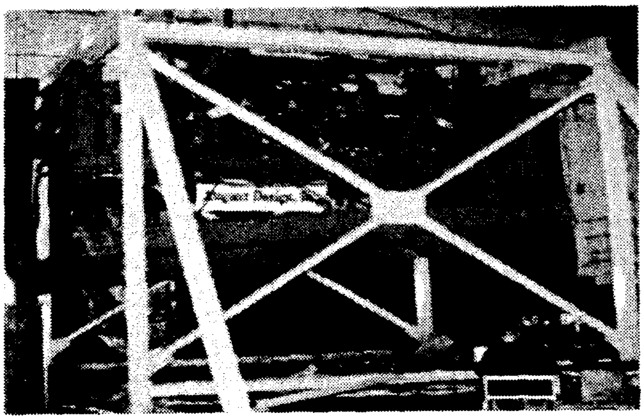
3.4.1Tandem Twin Spreader

Fig. 2 shows a tandem forties spreader. Tandem containers are handled by one head block and two spreaders. The spreaders can handle 40's or twin 20's. Container cranes with tandem spreaders are currently being designed. ZPMC will supply a tandem 40's crane with two independent head blocks and spreaders to the Port of Dubai (Bhimani and Jordan, 2003).

3.4.1 Intelligent Robotic Spreader

August Design, LLC has designed and built working scale models of intelligent robotic spreader bars for handling ISO containers at in-stream, military, and intermodal terminals (August). The intelligent robotic spreader bar has two major features.

First, it is able to be rigidly positioned in any combination of six degrees of freedom (roll, pitch, yaw, x, y, and z), under electronic control. In other words,



(Source: http://www.august-design.com)

Fig. 3 Intelligent robotic spreader

regardless on the orientation of the container with respect to the crane, the spreader bar can be positioned to pick up the container.

Secondly, the spreader bar has an innovative, yet simple laser-based sensor system that allows a computer to accurately detect the location of a container and develop the commands to position the spreader in 6 degrees of freedom directly over the container. The spreader can even detect, track, and position itself over containers that are moving, such as those on the deck of a small ship in high seas.

This spreader has been developed for use in transferring cargo at sea from one ship to another, but can be used in many others shipping applications particularly where automation is desired. Fig. 3 shows a intelligent robotic spreader of advanced robotic container crane.

4 Dimensions

4.1 Outreach:75m

We think the future beam will end at 25across and for many ports, perhaps 17 across. We suggest planning for the 17 wide vessels today and the 25 wide vessels in the future. Generally, it's much more economic to design for 25wide now than to increase outreach later. The outreach was calculated using the following (Jordan, 1997):

Outreach beyond waterside rail = 8.05 x (containers on deck - 0.5) + setback + increase due to 1°list + overrun.

The overrun was assumed to be 2m. This overrun is reasonable for current controls that automatically reduce trolley speed as the trolley approaches the end of the runway.

4.2 Crane rail gage:30.48m

Although there are some good arguments for increasing the gage to as much as 45m, the cost of shipping the erected crane will be much greater, since the larger gage cranes cannot be shipped athwart ships. So instead of four or six cranes being shipped on one vessel, only two cranes can be shipped on one ship (Jordan, 2001).

4.3 Lift above rail: 40m now, 50m future. Total lift: 57m now, 72m future

The higher the trolley is above the wharf, the more difficult it is to control the load. Therefore, the current height should be kept to a minimum. The 40m will suit current needs for vessels with 7 containers on deck. If the crane is designed now so the height may be increased to 50 feet later, the crane will then be able to handle the 24wide ships when they arrive. Providing for the future raise now increases the cost now, but only nominally. The cost is offset by future savings in time and cost when the future raise is made by simply adding segments to the legs and making the concomitant changes (Jordan, 2001).

4.4 Backreach: 25m

This allows for handling hatch covers and container landside of the landside rail. Less backreach may be reasonable, but the cost reduction is low (Jordan, 2001).

4.5 Clearance between the legs: 21m

Container lengths will increase to 16m. The current maximum of 14.4m provides 1.8m of clearance on each side, which provides for flipper clearance. By the time the container length increases to 16m, the landside operations will be automated and the crane controls will automatically verify that the flippers are either up or down as the container passes through the legs (Jordan, 2001).

4.6 Dual-Hoist

A dual-hoist crane means that there are two hoisting

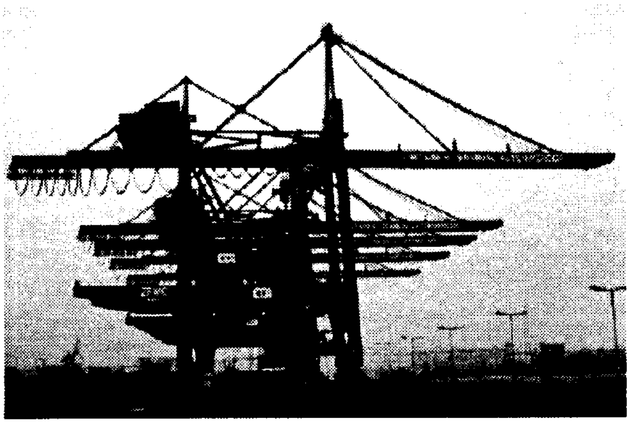


Fig. 4 HHLA dual hoist container cranes.

mechanisms in the crane: one in the sea side and another in the land side. When comparing the time consumption in a cycle, i.e., picking-up, trolley-traveling ,dropping on a truck or into the slot, the picking-up and dropping processes take more time than the trolley-traveling. Therefore, by using two hoists, the picking-up and dropping processes can be split into two hoists and also the traveling time of the sea side trolley can be reduced because it needs to travel only a portion of the total traveling distance.

Dual hoist cranes were developed in the 1980's, first by ECT Rotterdam, and then by Virginia Port Authority and Maryland Port Authority. Although the cranes could actually produce 45 to 50 moves per hour, the yard could not keep up, so the system did not meet expectations. Typically, crane production is limited by the shore operation typically, so the second hoist does not have as great of an effect as analysis of the crane might indicate. Unless the shore operation is fully automated, a second hoist requires a second operator. Dual hoist cranes are heavy and expensive and require two operators and more maintenance. In practice, dual hoist cranes were not economic (Rudolf III, 1990).

Today, dual hoist cranes may be making a comeback. One operator is needed on the ship trolley. The shore hoist may be fully automated using modern technology. The HHLA terminal in Hamburg, Germany purchased dual hoist cranes. Time will tell if these prove to be economic. Fig. 4 shows a HHLA dual hoist container cranes (Jordan, 2002).

4.7 Performance

Rated operating load: Twin twenties at 30 long tons each; single forty at 50 long tons; cargo beam to suit strength determined by the normal operating load. Container loads may increase beyond the recommended values. But the heavier containers will not suit most highway limits, so higher loads will only occur for containers that are not taken over the highway.

Another limitation is the capability of the container ship. The ship can carry TEUs with a maximum average weight about 12 long tons. Since FEUs are used for bulkier cargo, the average FEU weighs less than 24 long tons. The duty cycle effective fatigue load will be less than 60 long tons. The design should include a rational development of the fatigue load spectrum. Typically, the effective fatigue load is about 37.5 long tons.

In some cases, a much heavier cargo beam load is justified. For some ports, a 100-long ton cargo beam capacity is economic. The extra revenue from an occasional heavy lift may more than pay for the added capacity cost. This is true at some berths in the Port of Oakland (Jordan, 2001).

4.8 Speed

The key to productivity is, of course, reduced cycle time. For every cycle, components must be analyzed - how fast, how soon, how long to find the hole, latch the boxes, find the vehicle, unlatch and go. The best solution balances cost, practicality, and reliability. Computer simulation of old concepts and new ideas, tempered by experience and judgment, finds the way (Bhimani et al., 1996).

Increased trolley and hoist speeds and accelerations are obvious targets for increased productivity. Today's machinery can be much faster, but there are economic and functional limits.

The container cranes must be fast enough to handle more containers over greater distances in less time. A minimum rate of 75 moves per hour is the standard requirement. Trolley type and speeds: Machinery on Trolley; Hoist at 90 mpm loaded and 180 mpm unloaded; Travel at 240 mpm to 300 mpm.

4.9 Automation: Provide some now and plan for more lately

One of the major contributions to cycle time is dwell times - the time it takes to find, pick, and set a container. This time is affected by mechanical/electronic load control and operator skill.

Lasers and optical devices are being used now to make the landside operation semi-automatic. The position of the chassis on the wharf is sensed and signals direct the driver to adjust the load. The spreader is brought to near the pick and set positions automatically. The load is controlled using hardware and software (Jordan, 2001).

In the near future, improved technologies will allow automation of all loading operations, except the fine positioning over the ship. Later, the entire operation will be automatic.

5. Conclusion

This paper presents performance criteria of a new generation container cranes with our expectations of the future and some ideas. The new generation container cranes must allow for increased automation, while maintaining a cost effective structural design and require optimum structural design and operational sophistication. Therefore the new generation container cranes must move containers higher, further, faster, and more accurately than ever before. In this sense, the authors hope that the analysis provided in this paper will provide a helpful guideline in designing a future crane.

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