It's Supercrane!

Liftech Consultants and Mitsubishi Heavy Industries present their thoughts on the container crane of tomorrow, basing them on improvements made to the crane designs of today*

Super productive quay crane designs have come in many forms: Panamax; post-Panamax; machinery on trolley; rope towed trolley; single hoist; and dual hoist. There have also been new ideas, like rubber tyred quay cranes, elevating girder cranes, dockside bridge cranes, and the Paceco Supertainer®. The productivity varies. Based on ideal conditions, the calculated production of advanced quay cranes is 67 moves per hour while loading and unloading a sixteen-container-wide post-Pananax ship. If this were actually achieved, existing yard systems could not keep up with the shoreside cranes.

In actual, less than ideal conditions, maximum production realised is limited to about forty moves per hour. One reason that the calculated crane production is so much higher than reality is that the calculations are based on the assumption that a chassis, strad, or AGV will always be ready to service the crane. Of course, this doesn't happen. The crane often waits for service.

Effective crane design requires the designer to understand that the cranes are part of the terminal system. One approach to solving the integration problem is to design the entire system to work like a giant materials handling machine. Totally integrated systems produce a continuous flow of containers that, in theory, greatly increase throughput. A major disadvantage to a giant machine, however, is that all of the components must work in unison. If one component fails, the system fails. If one component is delayed, it is simply the case that the whole system is delayed.

Nevertheless, even though there are significant disadvantages to such expensive machines, a sophisticated continuous system will someday be the best choice to service a few specialised markets.

In the meantime...

Until that day arrives, the traditional 'segmented systems' will need to be improved and refined. For crane designers, existing requirements present a clear choice between the tempting option of simply making cranes bigger and more powerful to deal with bigger ships without making fundamental changes, starting afresh, or, looking at what we have now, and instead of making bigger and more powerful cranes, making significant improvements.

Taking the last of these options, the work which is currently going on to make such improvements can be encapsulated in a choice between the following:

- extremely rigid structure and electronic load control system to control the load or
- specify strength requirements for crane structure and electronic load control system to control the load and accommodate the crane deflections.

American President Lines used this approach when it ordered twelve machinery-on-trolley cranes for its new Los Angeles hub facility, completed earlier in 1997.

The key dimensions for both the rigid structure and the load control approaches, as well as for a typical post-Panamax crane, are summarised in the table below.

Key crane dimensions

Description	Megacranes		PostPanamax
	Rigid structure	Load control (APL)	
Outreach from WS Rail	55 m	52.4 m	45 m
Lift height from WS Rail	35 m	33.5 m	30-34 m
Backreach from LS Rail	21 m	15.2 m	15 m
Total height (boom down)	75 m	73.0 m	55-60 m
Total weight, including trolley and lift system	1200-1300 t	1156 t	850-950 t

Weight and speed

The result of increased crane size is a heavier structure, increased wheel loads, and increased trolley travel distance. Since many of the newest cranes are on new wharves, the increase in weight and wheel loads is usually not a problem. Still, the designer must look at ways to reduce the wheel loads whenever possible. Some factors to consider are the location of the machinery house and the overall structural configuration. A factor in a decision to use machinery trolleys is the increased travel distance of today's megacranes. 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.

To increase productivity, the cycle time to move containers on and off the ship must be decreased. Each step in the cycle must be analysed to determine possible ways to increase speed, by how much speeds can be increased, and the cost and effect of the increased speed to the total crane system. The most efficient solution

**This article has been prepared from two source papers. One, entitled 'Dockside container crane design for the 21st Century', was written by Arun K Bhimani, President, Liftech Consultants Inc, Catherine A Morris, SE, Principal, Liftech Consultants Inc and Shuji Karasuda, Assistant Manager, Electric & Control Designing Section, Mitsubishi Heavy Industries. The other, 'Super Productive Cranes', was written by Michael A Jordan, CEO, Liftech Consultants, and was presented at TOC Barcelona in June 1997. More details can be obtained on Liftech's homepage, http:\\www.jwdliftech.com.*

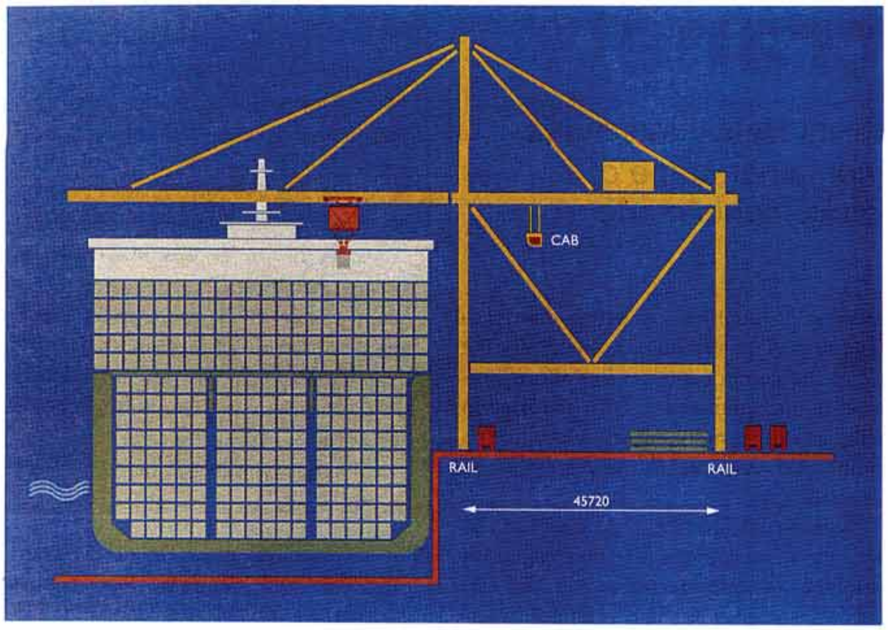

Figure 1: Conventional wide gauge crane

to the problem balances the cost and practicality of each action in the cycle.

Increased trolley and hoist speeds and accelerations are obvious targets for increased efficiency. Today's machinery is much faster than earlier models, but there is a limit to speed before the effects on the total crane system become adverse, and the cost becomes too high. One of the major contributions to cycle time is the time it takes to pick and set a container. This time is primarily affected by mechanical load control and operator skill. By adding automation to the system, the load control can be increased, and the dwell time decreased. Systems can be added to automate the trolley motion between the shipside and chassis lanes, including automatic landing and pick-up of containers.

Given enough rope?

The decision to use a machinery trolley or a rope-towed trolley requires careful consideration of many factors including productivity, reliability, maintenance, necessary spare parts including ropes, operator preferences, manufacturers' preferences, weight and wharf loading, and cost. Although a complete discussion of machinery vs rope-towed trolley is beyond the scope of this article, some of the features may make the machinery trolley a better choice for automated cranes. Because there is no stretch of trolley tow ropes and the hoist ropes are much shorter, the machinery trolley provides better load control.

More generally, for automation to operate correctly, the location of all of the components in the system must be known. For fixed objects, this is an easy task. For moving objects, such as the crane structure flexing with the movement of the trolley, the task becomes more difficult.

One approach is to require a very stiff structure to limit crane deflections. A stiff structure helps with load control and provides an easier ride for the operator, but a heavier structure is required. A detailed structural design process is required to minimise the weight and optimize the geometry and sections.

APL has chosen to account for the crane movement in the load control system design, and not specify deflection limits. While the logic for APL's automation will be more complex than for a deflection controlled crane, the weight and wheel loads of the APL crane will be about seven percent lighter.

The frame design is optimised by choosing an overall geometry, considering both the deflections and fabrication cost. Individual members are then examined to determine their contribution to each of the three deflections. Those sections of individual members that contribute the most to the overall stiffness are then increased.

Most of the optimisation is structurally straightforward, but the forestay requires a second look to evaluate its contribution to the vertical deflection.

Boom deflections could cause problems when two trolleys are operating simultaneously over the ship. The deflections can be significantly reduced - practically eliminated - by an active 'assist link' like the one developed by Mitsubishi Heavy Industries and Liftech Consultants Inc. for the new PSA cranes.

A considerable part of the total elongation of the forestay is due to the linkage and curvature. If these two components were eliminated or controlled, then the elongation would be significantly reduced. The 'Assist Link' (on which there is a patent pending), shown in *Figure 2*, is a proposed modification designed to do this (its effect is shown in *Figure 3*). A large deflection analysis has shown a 20mm decrease in vertical deflection due to the addition of the Assist Link.

The ultimate quaycrane

Taking a wider view, in order to meet dockside requirements for more efficient terminals and to serve the increasing demands of megaships, owners and designers must carefully balance the mechanical, structural, electrical, and automation systems.

The new megacranes must allow for

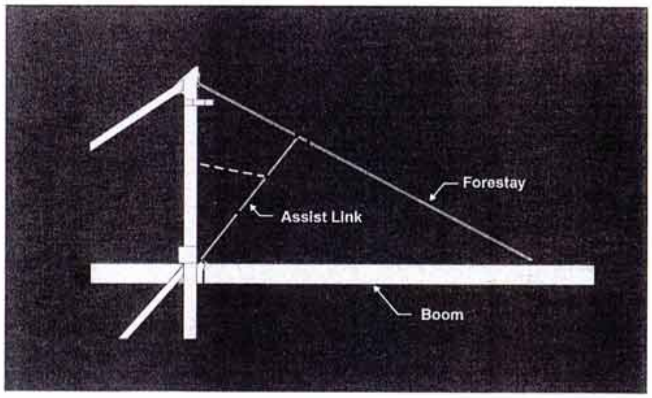

Figure 2: The 'Assist Link', a proposed modification to the forestay of a quayside crane to reduce elongation, itself one consequence of larger, faster, heavier cranes

increased automation, while maintaining a cost effective structural design. Failure to reach the balance between the systems may result in a less productive and more expensive crane. Success will be achieved when we all work together.

Significant recent developments in crane design include sophisticated electronic load control systems, power transmission through an inductive current loop, and wave-guides in place of fibre optics.

Rapidly developing improvements in electronics and optical and acoustical equipment will reduce dwell times and increase productivity.

But even with all the advancements, the real productivity of single hoist dockside cranes will be limited to 40 to 50 moves per hour because of service to the quay'.

Eventually, though, service to the quay will be improved. What then? What crane will be suitable?

A few simple changes may help. Consider the 45720mm gantry rail gauge. What is the appropriate gantry rail gauge: 15240, 24500 or 30480mm? Why not 45720mm? If the gauge is increased to 45720mm, the waterside wheel loads are reduced for both operating and stowed conditions. Since an additional intermediate backstay reduces the weight of the trolley girder, the crane weight is only slightly increased. The wide gauge crane is simpler and more stable. The sum of the maximum landside and waterside quay reactions decreases, since the moving load reactions decrease.

Again, although the elevated girder will increase the quay cost, the crane girder is required either way, so the increase is small. The advantages of increased access to the yard and increased structural rigidity may justify the added cost. The structural rigidity is increased because the landside leg is shorter.

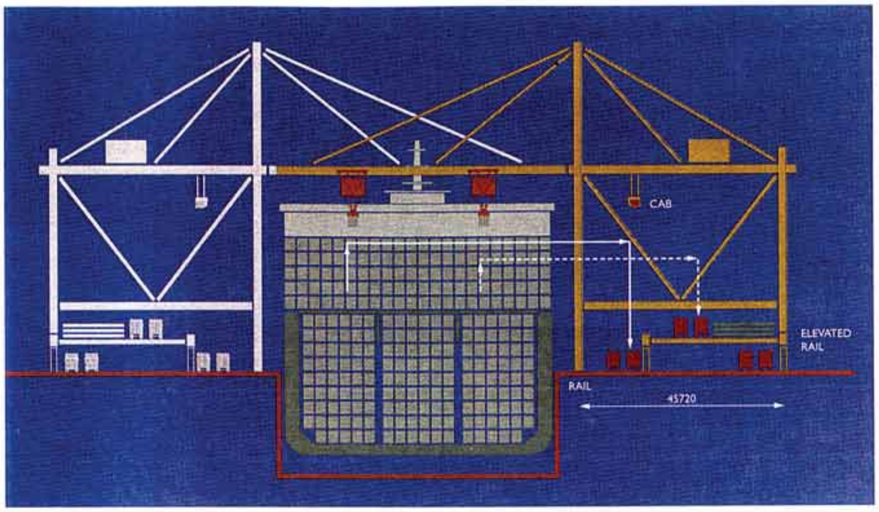

Figure 4: Slip with double trolleys: problematic, but better than the bridge crane concept

Figure 3: Forestay elongation including Assist Link

Another proposal is the elevated landside platform. In this case, the hatch could be stowed on a raised platform. Since container traffic can travel under the platform, the yard area used by the landside traffic lane can be recovered. The increased usable yard are will offset the cost of the platform.

Elevated landside traffic lanes can reduce the demand on the yard. In effect, the cranes will be serviced by two yards. If the traffic on the elevated lanes eventually goes to grade level, long ramps will be required. The elevated roadway concept is workable, if traffic is directed to the yard on roadways.

What if the productivity of a single hoist is not enough? Will a double trolley crane help? The answer is Yes. Liftech suggests that two trolleys operate on the same runway. The electronic, optical, and acoustical systems, which will eventually lead to a driverless crane, will provide control sufficient to keep the trolleys and the suspended loads from colliding without seriously increasing cycle time.

The realistic productivity of the double trolley crane will be 45 to 70 moves per hour. New yard systems will be needed before double trolley cranes are practical.

How many cranes can work effectively on one quay? The practical limit is six cranes servicing one ship on one quay. If the yard works well, traffic can get on and off the quay, and if the stow plan is just right, cranes could operate on alternate hatches.

What if this isn't productive enough? The ship could be serviced from both sides of the slip. This creates many problems but has some advantages.

If berthing pace is limited, the slip allows more ships per unit length of the quay envelope. The width of the slip plus the two quays is less than the length of the ship. With six double trolley cranes per side, less than the absolute maximum but more than is practical in a real operation, and each dual hoist crane producing 55 moves per hour, the productivity is 660 moves per hour total. This seems unrealistic now, but it could be done. If more cranes are used, the productivity gets higher. It's worth thinking about.

In this case, the berth should be at least 60m wide, in order to accommodate ships with 22 containers on deck (see *Figure 4*). It should also allow two smaller vessels to use the slip. But with the overlapping booms, imagine the interference problems.

Would a bridge crane be better? Liftech thinks not. The bridge cranes would need to span 100m at least. And this doesn't consider where to store the hatch covers. The runways will be costly. The greatest disadvantage, however, would be that the cranes could not pass the ship superstructure or each other. ❏