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MEGACRANES FOR MEGASHIPS

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INTRODUCTION

Ports and shipping lines are ordering larger than post-Panamax ships, the *megaships*. Dockside *megacranes* will service these ships. The large cranes require optimum structural design and operational sophistication. Although the sheer size of the cranes present some challenges, the biggest challenge is productivity - to optimize the moves per hour. The megaships will load and unload 4000 boxes or more at one stop.

Most agree that advanced electronic controls are needed and most use computer simulation to study performance. But there is disagreement on the structure. Some want an almost impossibly stiff crane. Others, like American President Lines, don't care about stiffness.

When APL ordered twelve new machinery trolley megacranes for their new Los Angeles hub facility, APL specified strength requirements for the crane structure but did not specify deflection limits. APL plans to control the load and accommodate the crane deflections using electronics.

On the other hand, an extremely rigid structure was specified for Mitsubishi Heavy Industries' twelve new machinery trolley megacranes. The stiffness requirements are so severe that a conventional design would not do. and Liftech met the challenge and developed the optimum geometry and a revolutionary stiff forestay concept. The sag in the forestay contributes to boom deflection. The concept eliminates the effect of sag.

BIG SHIPS - BIG CRANES

The cranes are bigger and heavier.

DESCRIPTION	MEGACRANES		TYPICAL POST PANAMAX
	MHI	NOELL/APL	
Outreach from WS Rail	55.5 m	52.4 m	45 m
Lift Height from WS Rail	34.7 m	33.5 m	30-34 m
Backreach from LS Rail	21.0 m	15.2 m	15 m
Total Height (Boom Down)	75 m	73 m	55-60 m
Total Weight, including Trolley and Lift System	1233 t	1156 t	850-950 t

Table 1: Key Crane Dimensions

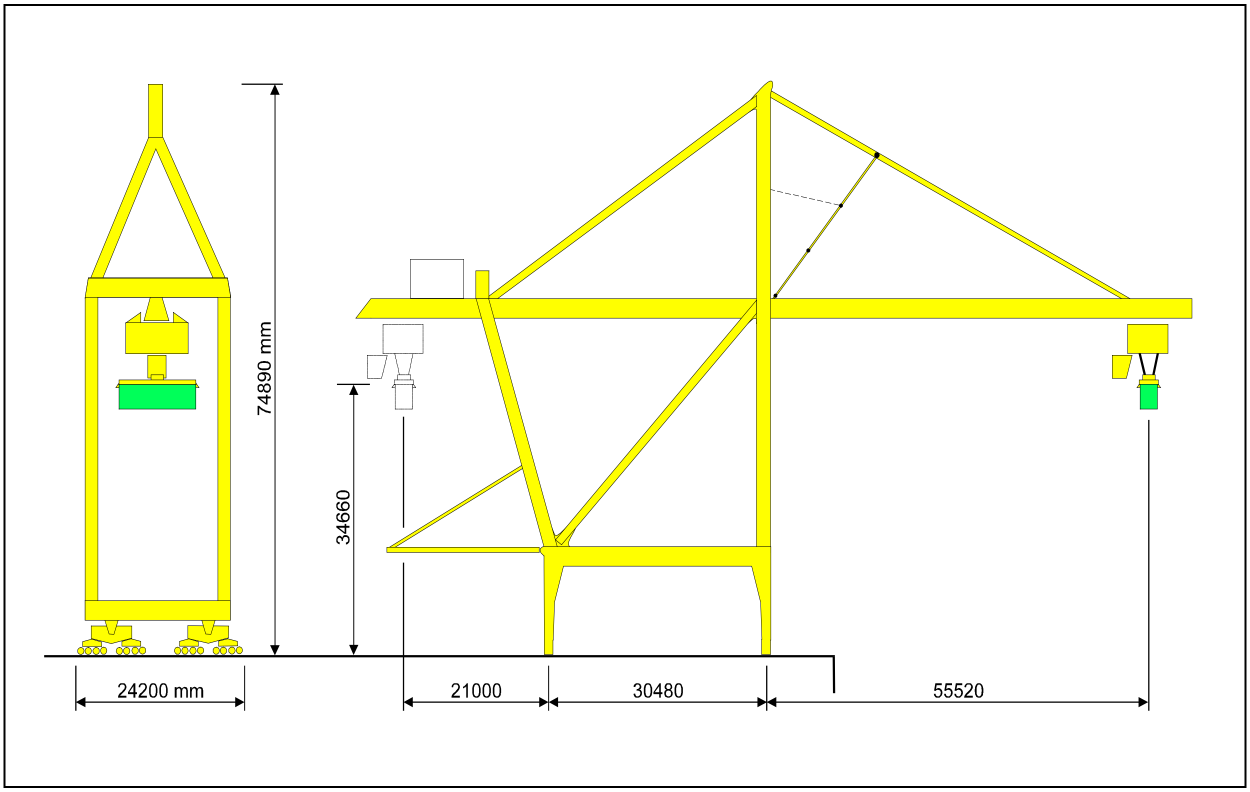


Figure 1: MHI Crane

APL chose machinery trolleys over rope trolleys to improve performance and reduce maintenance costs. The use of a machinery trolley substantially reduces the amount of rope, simplifies the reeving, and eliminates the need for catenary trolley. While weight and wheel loads are increased, the total cost is not increased when operating costs are included.

INCREASING PRODUCTIVITY

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 box, 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.

Increasing Speeds and Accelerations

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. Simulation programs, such as Liftech's Cranesim, can predict performance and help determine the optimum speeds and accelerations.

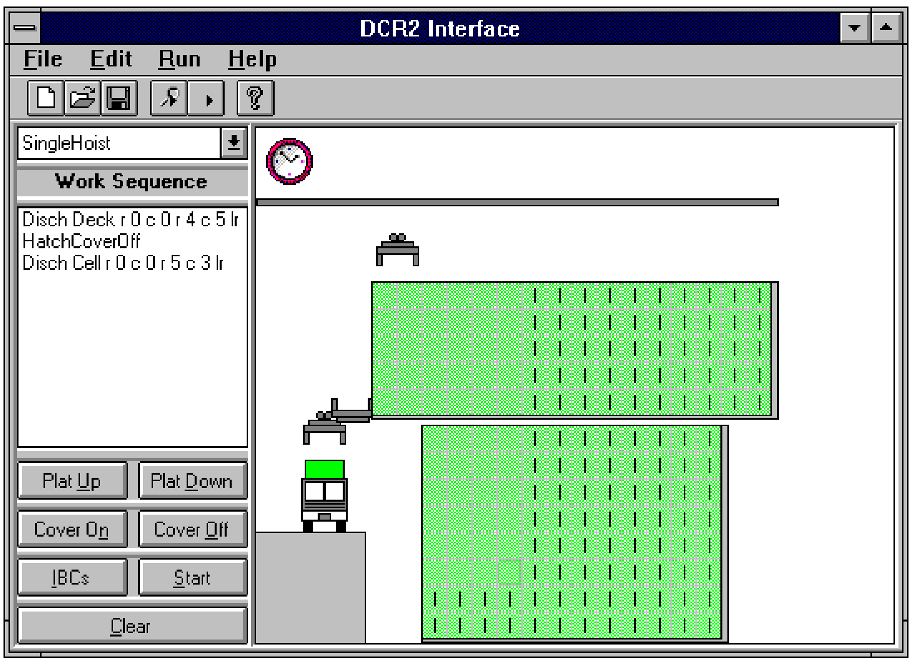


Figure 2: Liftech's Cranesim

Increasing Load Control and Decreasing Dwell Times

One of the major contributions to cycle time are 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. Automation can help. Electronic load control always helps. MHI's cranes will automate the trolley motion between the ship and quay and landing and picking up of containers.

CREATING THE BEST DESIGN

The Missing Ingredient

For years the design team members - the mechanical, the structural, and the electrical engineer - have worked together to produce economical designs that meet operational demands and can be efficiently fabricated and erected. This worked because the crane components were mechanical, structural, and electrical. This is the tradition. But now something new has been added, *automation*. Where is the automation engineer? Why hasn't he joined the team?

The crane is not only part of the terminal system, but is also a system in its own right. As always, the best design requires balance. The cost and benefits of each alternative should be considered in concert.

So far, we have worked without the automation engineer on the team. His requirements are there, but he isn't. This should change. He should be on the team. We need him.

Structural Design for Automation

In order for automation to work, the location of the components in the system must be known - easy for fixed objects, not so easy for moving objects.

Is structural deflection a problem? Some say yes; APL says no. While the logic for APL's automation will be more complex than for a deflection controlled crane, the APL crane will be about seven percent lighter.

Frame Stiffness

MHI's cranes have strict deflection requirements in all three directions.

DIRECTION At full outreach	SPECIFIED DEFLECTION	CONTRIBUTING EFFECTS OF MEMBERS
Perpendicular to Gantry Rails	5 mm	Stretch of the Backstay Bending of the Portal Frame
Vertical	120 mm	Elongation of the Forestay Stretch of the Backstay
Parallel to Gantry Rails	75 mm	Rotational Stiffness of the Crane Stiffness of the Boom

Table 2: Deflection Requirements for MHI's New Cranes

This is a stiff crane. Liftech and MHI studied geometry, member sizes, and fabrication cost. One member, the forestay, deserved special attention. When subjected to dead load, only the forestay sags and bends. When the trolley moves to full outreach, the stay straightens. Can this be controlled? We took a second look.

Optimizing the Forestay Design

Elastic stretch, linkage straightening, and curvature cause forestay elongation. See figure 3. The elastic stretch is lengthening to axial strain. The linkage straightening is the reduction in sag when an axial load is applied to a linked beam. Under load, the triangle flattens. The curvature is the beam bending between the links. The curved shape is nearly a catenary. Under load the beam straightens.

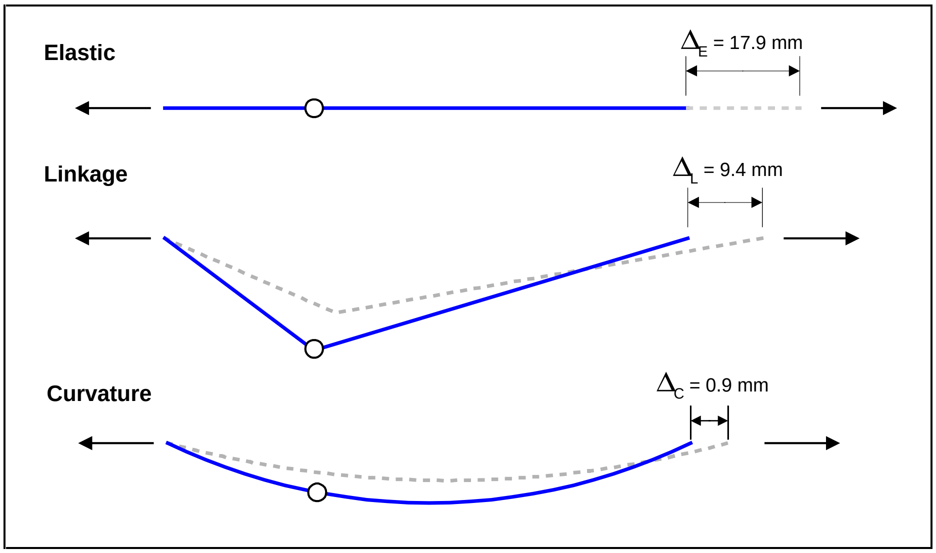


Figure 3: Forestay Elongation

The natural reaction to decreasing elongation is to increase the forestay's area. This only works to a point. The elastic elongation decreases as the forestay area is increased, as one expects, but the elongation due to linkage sag and curvature increases. Imagine holding a linked beam with one end in each hand. If there is a 5 kg weight hanging from the link, and the tension in the beam increases, the sag will decrease. If there is a 0.5 kg weight, and the tension increases by the same amount, the sag will also decrease, but because the sag of the first system is considerable more than the second, the difference in the lengthening is greater.

If we apply the above theory to MHI's crane, the best forestay has an area of about 500 cm^2. An area of 522 cm^2 was chosen, considering the stress in the forestay, and the available sections.

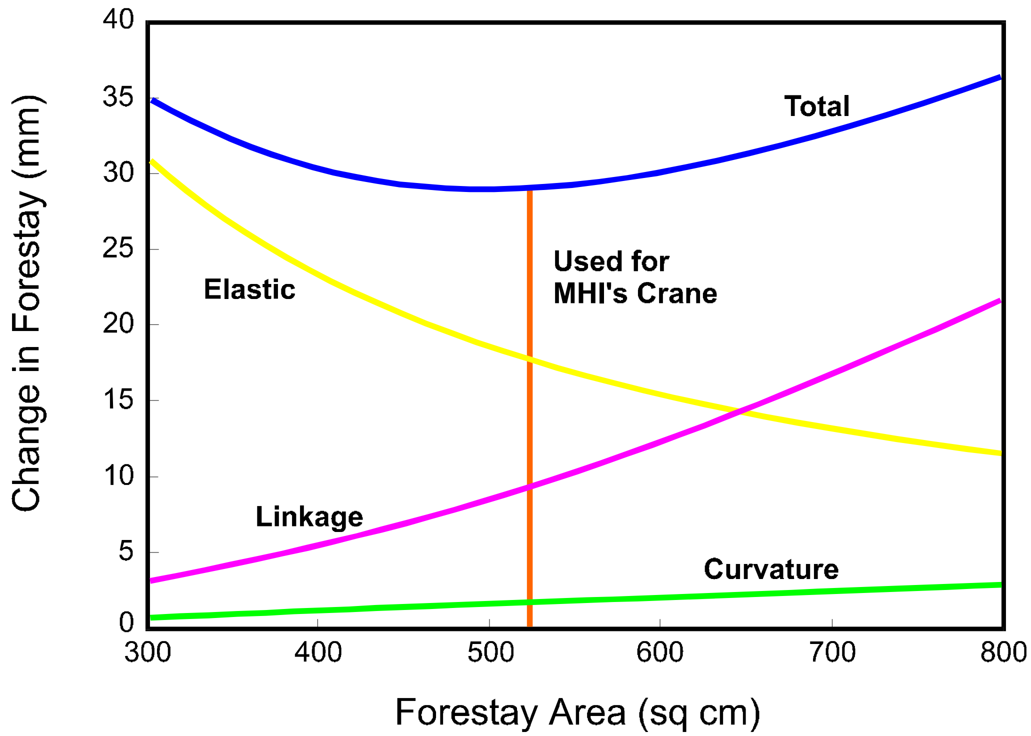
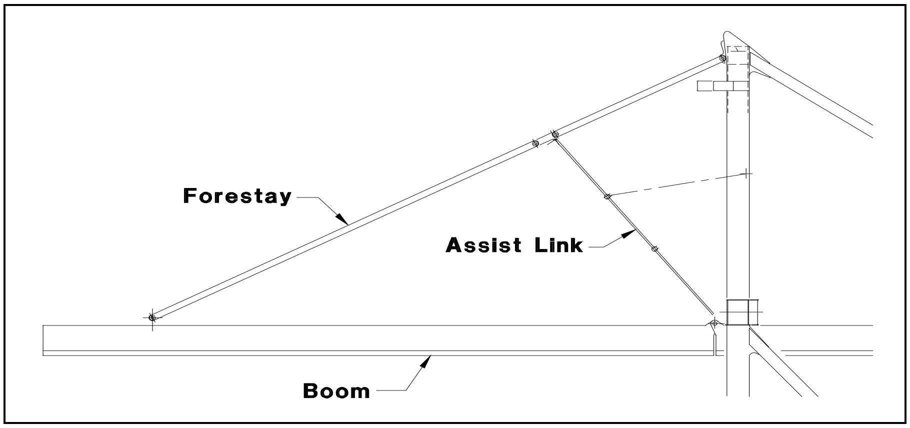


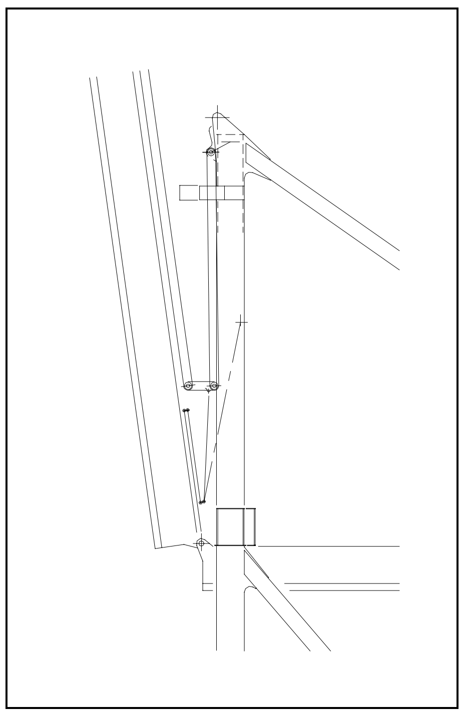
**Figure 4: Forestay Length Change vs.
Forestay Area without Assist Link**

If the linkage sag and curvature were eliminated or controlled, then the elongation would be significantly reduced. The assist link does just this. The vertical deflection was reduced 20 mm.



MHI patent pending

Figure 5: Assist Link, Boom Down



MHI patent pending

Figure 6: Assist Link, Boom Stowed

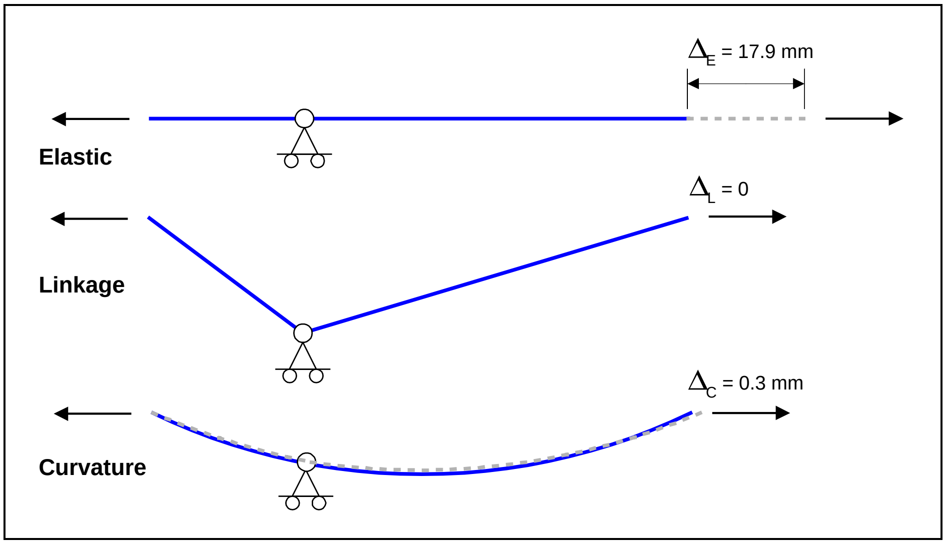


Figure 7: Forestay Elongation including Assist Link