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MIDDLE AGED CRANES: REJUVENATION

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1. INTRODUCTION

When operations demand more than an existing dockside container crane can provide, the choices are to buy a new crane or rejuvenate a middle aged one. Which is more profitable? Finding the answer requires investigation and objective evaluation.

This paper offers some information that will help you make your investigation and choose.

2. NEW CRANE

If price is no object, a new crane will always perform better than a rejuvenated aged crane. The new crane option may be better. The electrical, mechanical and structural design will be state of the art. Potential productivity of 40 or more moves per hour is practical for post-Panamax cranes with load control and digital drives. And it makes you feel good to get a new crane.

But these are hard times, so take a second look at a rejuvenated crane and make a rational choice. Only detailed analysis will tell which choice is correct.

3. SATISFICE

Before we look at tactics, let's take a moment to look at strategy.

In The Art of Problem Solving, Russell L Ackoff states:

> "One who seeks a solution that is good enough is said to satisfice...Choice exists only (1) when there are at least two possible courses of action available to the decision maker, (2) where there are at least two possible outcomes of unequal value to him, and (3) where the different courses of action have different effectiveness. In other words, choice exists when the action of the decision maker makes a difference in the value of the outcome."[1]

Maybe a rejuvenated crane will be good enough. Now let's look at tactics.

4. REJUVENATION - CASE STUDIES

Rejuvenation includes relocation, modernization, refurbishment and renovation. Rejuvenation can cost up to 60% of the cost of a new crane and take six months to complete; it could cost much less.

Perhaps the best way to imagine what can be done is to review what has been done. The following examples are taken from Liftech's remodel projects which have either been completed or are underway.

5. GEOMETRIC CHANGES

5.1 INCREASE LIFT HEIGHT

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[1]Ackoff, Russell L., The Art of Problem Solving, John Wiley & Sons, New York, 1978.

Lift height can be increased a few feet by modifying the trolley to reduce the clearance between the spreader and the trolley, it can be increased a few meters by adding short stubs below the sill beam, or it can be increased twenty feet or more by inserting sections in the legs and reinforcing the frame.

The Port of Oakland added about three feet of lift by modifying the trolley on its low profile crane so the baloney cable basket could pass through the trolley framing. The man-basket on the head block was enclosed in a metal cage to prevent contact between the basket passengers and the trolley frame. This modification cost about $50,000.[2]

When Matson Terminals needed only five feet more lift, short stub columns were installed under the sill.

The ubiquitous Paceco A-frame cranes, the Matson cranes in Honolulu, and the Virginia Port Authority cranes, among many others, have been raised about 20 feet by supporting the upper works on jacks, installing new sills and legs, and adding diagonal braces to reinforce the frame. See Fig. 1.

This operation requires about two months and costs between $350,000 and $550,000. In many cases, grooves can be added to the main hoist drum to accommodate the concomitant increased hoist rope length.

After the crane is raised and the new legs and sill beams are in place, the original sill beams may be removed to provide clearance for the moving spreader. When the original sill beams are left in place, the frame is stiffer and requires less strengthening.

Often the frame is strong enough to resist offshore storm wind loads without additional diagonal portal braces. But we have always added these braces to improve stiffness.

APL raised their Oakland low profile cranes by cutting the legs above the existing sill beam and inserting new leg sections. Some contractors prefer inserting leg sections and some prefer new legs and sill beams. Either scheme does the job and the cost is comparable.

5.2 INCREASE THE CLEARANCE UNDER THE PORTAL BEAM

When Matson Terminals began operating new straddle carriers under their Honolulu cranes, the vertical clearance was a bit too small. The solution was to remove the portal tie beam and reinstall it a few feet higher. See Fig 2. The cost was about $85,000/crane.

5.3 INCREASE THE OUTREACH

For most cranes, the outreach can be increased a few feet for about $75,000. Paceco typically places the sheave platform on the trolley beam. The outreach can be increased about five feet by simply extending the trolley rail beam and sheave platform without extending the boom. See Fig 3. Fortunately, additional structural reinforcement is usually not required. This change is becoming common.

A variation of this scheme was used on the Oakland low profile cranes. Since extending the sheave platform would have required the shuttle boom to retract more, the platform was raised so the trolley could pass underneath. This provided an additional 4 feet of outreach.

When the needed increase in outreach exceeds 5 feet, a major change in the boom arrangement is usually required. Matson gained 20 feet of outreach by the adding a new midsection to their Hawaii boom. This required new forestays and other changes to the frame and boom hoist. The boom hoist rope factor of safety was maintained by increasing the number of parts in the topping lift. The increased length of rope was accommodated by adding flanges to the boom hoist drum and double wrapping the last few wraps. The double wrapping did not create a problem, since the rope load is small when the boom is nearly raised.

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[2]Costs are stated when they are available from past projects and where they have some meaning. The costs are in USD and adjusted to today's market. The cost for the same scope of work may easily vary by a factor of two from project to project.

5.4 INCREASE THE CLEARANCE BETWEEN THE LEGS

Although the 1960 era Paceco cranes were not designed to handle 45 foot boxes, they can. Problems develop if the box hits the bolted flange at the leg to portal beam joint. Fig. 4 shows a solution to this problem. The inside flanges are removed and a bolted lap plate is installed. The new bolt holes are oversized so the joint can slip ever so slightly and accommodate the flexing of the flange joint during the design wind storm. This scheme has been used by VPA and Sea-Land and costs $12,000 per crane.

If removal of the flange doesn't provide enough clearance, notching the legs near midpoint where the bending stresses are low provides a little more room. See Fig. 5. The scheme is being proposed in Taiwan.

If a significant increase is needed, the legs can be separated and new sections can be added to the trolley girder support beams and the sill beams. This was done to the world's first dockside container crane built by Paceco for Matson. The crane, which originally handled 24 foot boxes, was modified to handle 40 foot boxes. See Fig.6. This crane has been in service since 1958; it has been rejuvenated many times in 34 years, and now resides in China,

The Washington Iron Works crane, originally located on rails with a 90 foot gage in Grays Harbor, Washington, was relocated on rails with a 50 foot gage to Charleston, South Carolina . See Fig. 7. This required major reconstruction. The machinery and structure above the legs was unchanged. An elevator, supported by a vertical 18 inch diameter pipe extending from the portal level to the machinery house level, was added. The clearance between the legs was increased by 5 feet. This was a cost effective rejuvenation; the move and modifications cost about 30% of a new crane price.

5.5 MODIFIED GANTRY RAIL GAGE:

Occasionally, as for the Charleston crane, a relocated crane requires a change in gage. If the change is only a few feet, the frame legs can usually be moved and the portal tie can be increased to carry the resulting increase in stress. When the change in gage is large, a trussed scheme, such as that used at Charleston, is generally most economic.

6. STRUCTURAL IMPROVEMENTS

The capacity of Matson Terminals' trussed boom cranes in Honolulu, the Oakland low profile Paceco cranes, and most of Sea-Land's Paceco 1960 series trussed boom cranes have been increased by adding stiffening to the boom chords and verticals. Additional diagonals were added where the boom diagonals were in-adequate.

The booms have performed well except for a few cracks that developed at panel points where new stiffeners connected to the upper chord. We believe these cracks were due to local stresses caused by Poisson's effect. When the chord is stressed, the diameter changes. At the panel points, the incoming members and the stiffeners restrain this deformation causing excessive local stresses at the stiffener to chord welds. The solution is to remove the stiffener to chord weld at the panel point. See Fig. 8.

Sometimes a structural detail that meets all the rules doesn't perform well. The blades which support the shuttle boom on Sea-Land's and Maher Terminal's low profile cranes in New Jersey and the Oakland low profile cranes developed cracks at fracture critical details. Since the cracks were difficult to control and the fracture toughness of the steel was unknown, new plates and angles of tough materials were bolted to the blades to bypass the critical zones. See Fig. 9. This reduced the stresses, making the cracking less likely, and provided a redundant load path. The reinforced structure is as reliable as a new structure built according to current standards.

7. MECHANICAL AND ELECTRICAL IMPROVEMENTS

Most of the projects described above included mechanical and electrical improvements. Some generalizations regarding the mechanical and electrical can be made.

Often the cost of improving speed is not justified. Table 1 shows the relationship between crane size, trolley speed and hoist speed for cranes with and without mechanical or electrical load control. The net productivity values shown on the table are close to the productivity we have observed in the field. The differences in productivity are even less for gross productivity, after the time for lashing, removal and replacement of hatch covers, crane positioning and scheduled breaks are taken into account.

Whether to add load control or not is even more problematic than whether to increase speeds. For some operations, either mechanical or electronic load control may be justified. According to Mr. David Olsen, mechanical engineer with APL, replacement of electrical systems is economic only when old systems become unreliable and spare parts are no longer available. The advantages of a new digital system are not enough to warrant replacement of an existing analog system.

Safe operation justifies load weighing and snag protection devices. A snag load develops when an empty spreader, while being raised at maximum speed, snags in a ship's hold and the kinetic energy of the rotating machinery must be absorbed by the mechanical and structural system. Without snag load control, something is going to break. Although the risk may be low, the consequences of failure can be great. One accident can pay for many snag protection devices.

8. WORK SITE

While a crane is being rejuvenated, it may be in the way. For a cost of about $160,000 the crane can be relocated to the backlands or relocated along the wharf.

It may be economic to remove the crane from the terminal during modification. The most recent VPA crane raise was completed at the contractor's nearby yard. A heavy lift barge crane transported the crane to and from the yard. The economics of working in the contractor's yard rather than at the wharf more than offset the transportation costs.

9. BUT WHAT ABOUT STRUCTURAL FATIGUE?

Structural failures, other than accidents, can be sorted into two groups: infant failures and aging failures. Infant failures occur during the initial operation of the crane and are due to faulty design, workmanship, or a combination of both. Infant failures are not of concern here.

Application of fluctuating stresses causes small undetectable cracks to grow. If uncontrolled, these cracks grow until fatigue failure occurs.

Although the phenomena is called "fatigue", it is only crack growth due to fluctuating stress. The steel does not get tired. The material beyond a crack is like new and is not affected by a nearby crack. If the crack and the small yield region in front of the crack are removed and the weld is repaired, the life of the structure starts over. Our experience indicates that most cracks occur at details that are either poorly designed, poorly made, or both. Once the crack is properly repaired, a new crack is unlikely to occur.

Fig. 10 shows the frequency of occurrence of fatigue cracks during the structure's life. The curves were derived from a statistical analysis of fatigue test data given by Maddox.[3]

With proper inspection and repair of fatigue cracks, the frequency of occurrence of new cracks is reduced. This result is due to three factors: 1) the details that crack first are inferior to the average; 2) the repairs, being made under special conditions, are superior to average; and 3) for a given detail, there is a stress range, "threshold stress", below which cracks do not propagate.

This phenomena can be understood by considering a chain subjected to fluctuating stress. Links are inspected periodically for cracks. Cracked links are replaced with better than average links. If the links are good enough, the stress range will be below the threshold and no cracks will occur. As inferior links fail and are replaced with superior links, on the average, cracks are less likely. Eventually the frequency of

[3]Maddox, S. J., Fatigue Strength of Welded Structures, Abington Publishing, Cambridge, Second Edition, 1991

cracked links will stabilize. The frequency will be less than that for the new chain. The chain becomes more and more reliable.

Properly designed and executed structural modification results in a more reliable structure.

10. CONCLUSION

Maybe good enough is good enough, maybe not. When the crane can't get the job done, there are two choices: new cranes or changed cranes. As with most decisions, the correct choice requires careful evaluation of the alternatives.

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