Bulk Handling Equipment – Replacement vs Refurbishment

Richard Morgan, Frank Gatto and Mark Biggs
Aspec Engineering Pty Ltd.

Abstract

At many existing bulk material handling facilities, equipment such as stackers, reclaimers and ore car dumpers are nearing the end of their design lives. Owners are faced with the decision on whether to refurbish existing or procure replacement machines. There are also continuing pressures for increased throughput and in the case of ports, to accept larger ships.

Traditionally, owners would carry out a refurbishment to allow the life of their equipment to be extended. However, due to the continuing strong demand for commodity exports and high equipment utilisation levels, downtime is critical. Thus, decisions between refurbishment and replacement equipment can have a big impact on plant availability, cost and revenue. ASPEC has developed a program called FULS (fatigue useful life simulation) to assist owners making decisions on when to carry out machine replacement or major refurbishment.

Figure 1: Reclaimer and Stacker for Iron Ore

1. Introduction

Materials handling facilities require significant capital investment in physical assets as a necessary part of their operation. Many existing facilities have pieces of equipment, that are well advanced in their design life, and the intention is to continue to use them in excess of this period. In addition, there is a need for ongoing upgrades to equipment to improve occupational health and safety standards and to improve productivity and throughput.

Assessment of the condition of the equipment and extending its useful life is therefore one of the major issues for facilities involved in the import and export of bulk materials. Engineering for projects associated with such facilities has special challenges, including the need for work to be carried out in such a way as to minimise the effects on production.

2. Equipment types

2.1 Ore Car Dumpers

Car dumpers, sometimes called tipplers, are used for unloading trains at the receival station to the terminal. This equipment is subject to many cycles at a repeatable load per cycle. Metal fatigue and cracking needs to be managed carefully on this type of equipment once it gets older.

Figure 2: Ore Car Dumper

2.2 Shiploaders

Shiploaders are the last link in the loading chain from mine to ship. High reliability is essential to maintain through-put to the port. Issues for shiploaders include hatch coverage for the required range of ship types, deterioration, physical damage due to collisions and overloading and obsolescence of mechanical and electrical equipment on older machines. Where extensive trimming out of material into the ship's holds is required, metal fatigue can also be an important consideration.

Figure 3: Shiploader

2.3 Stacking and reclaiming machines

Stacking and reclaiming machines are highly loaded structures and are generally very sensitive to changes in balance. Issues affecting the condition of the machines include corrosion, equipment obsolescence, electrical and control safety compliance, physical damage due to overloads and collisions and metal fatigue, particularly for reclaiming machines. As machine balance is a major issue, changes in weight and weight distribution need to be monitored carefully. These types of machines (Figure 4, Figure 5 and Figure 6). are usually highly automated, and a lot of effort goes in to maximising throughput by having the correct settings and sequences.

Figure 4: Bucketwheel Reclaimer

Figure 5: Stacker

Figure 6: Stacker Reclaimer

2.4 Age at Replacement

A survey of some typical machines in Australia found that the average replacement age for each machine type was:

- Reclaimers 29 years
- Stacker-reclaimers 36 years
- Shiploaders 42 years
- Stackers 40 years

Purchase specifications for machines of these types typically define a life of 25 years. However, age is a function of the material and utilisation. Iron ore machines tend to be replaced more often as they are more highly utilised than coal machines.

Historically, equipment has been installed in phases as operations were expanded during commodity booms. Groups of machines are now approaching end of life from the expansion projects that occurred in the 1980's and 1990's. Organisations that own large numbers of machines need a strategy to replace their fleets at a sustainable rate over the next 20 years to be able to maintain equipment availability and plant capacity.

3. Machine Failures

Bulk materials handling machines are large moving structures with dynamic loads and have shown failure rates higher than standard static structures such as buildings.

An investigation of the failures of over sixty materials handling machines found that about ten percent of failures could be attributed to fatigue failure. In most cases these failures were unexpected and lead to catastrophic consequences. Figure 7 shows the number of machine failures versus the age of the machine at failure. About ten percent of all failures or about one quarter of the failures that occurred when the machine was greater than ten years old can be attributed primarily to fatigue damage.

Figure 8 shows a machine collapse due to fatigue failure.

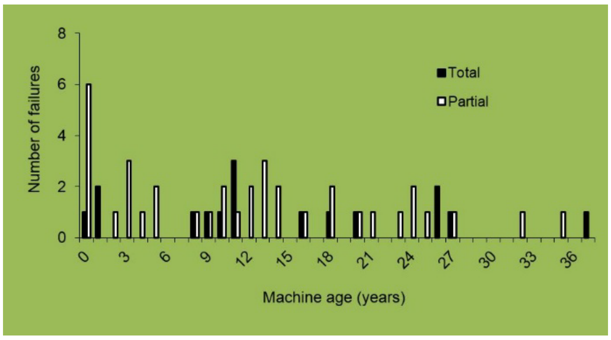

Figure 7: Number of Failures vs Machine Age

Figure 8: Machine Failure due to Fatigue

4. Failure Mechanisms

4.1. Fatigue

Structural fatigue occurs when cyclic stresses cause progressive failure of the material, in most cases on machines this is steel. Fatigue damage is typically greatest at welded joints or other discontinuities.

Figure 9 shows what a fatigue crack looks like.

Figure 9: Fatigue Crack

Most materials handling machines operate in a corrosive environment, so corrosion control is a very important element to maintaining the structural integrity. Obviously severe corrosion such as that shown in Figure 10 will drastically reduce the cross-sectional area and hence increase stresses. However, another effect is that corrosion will also reduce the fatigue resistance of the cross-section.

Figure 10: Corroded Steel Section

5. Risk of Failure

Organisations such as the UK HSE Directorate have statistics on levels of risk for various industry types. For bulk ports and mines, the accepted approach is to control the risks to be as low as reasonably practicable (ALARP) within the tolerable region on the diagram in Figure 11. Should damage to the equipment from cracking, corrosion etc bring risks into the unacceptable region, additional controls are required. This may involve things such as;

- A stringent inspection and repair regime,
- Keeping people off the machine while it is operating,
- Replacement of major damaged components,
- Total replacement of the equipment.

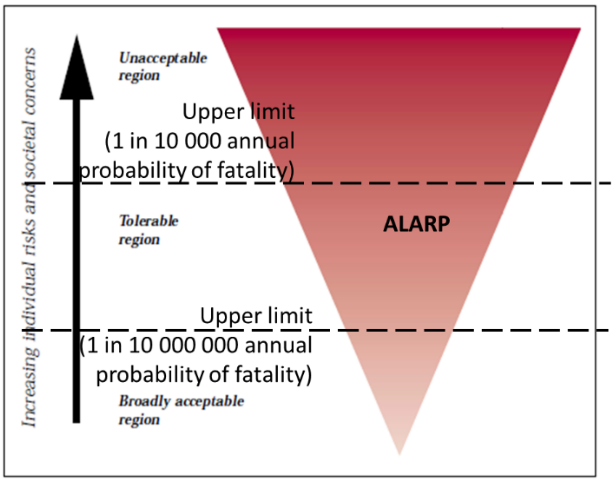

Figure 11: Tolerable Risk

It is incumbent upon owners, operators and engineers to provide a safe place of work for the equipment operators and maintainers. Managing catastrophic risks such as machine collapses needs to be high priority and requires a lot of attention.

6. Refurbish or Replace

6.1 Useful life

Apart from metal fatigue and corrosion, other reasons for refurbishing or replacing are**:**

- Obsolescence of Equipment – items of mechanical and electrical equipment can become outdated such that they are no longer supported by the manufacturer. Hence, it may be necessary to replace this equipment within the life of the machine.
- Configuration changes such as the need to accommodate larger ships may be required as the shipping mix and terminal throughput changes over time.

To summarise the process for evaluating if the structures need to be refurbished or replaced.

Firstly, a detailed fatigue study should be carried out based on actual working loads for the machine in operation. The study will show the accumulated fatigue damage on elements of the machine. This can be compared to the design standard to show the remaining fatigue life.

Routine inspections for cracking and corrosion should be carried out throughout the life of the machine.

Fatigue damage will be different on different components of the machine as some parts are more heavily utilised than others. The useful life assessment will balance the repair cost for heavily utilised components with the overall state of the machine to determine for how long the machine can be used safely.

When it's not feasible to keep repairing the machine, the useful life has expired. If the useful life hasn't expired, there will be a need for ongoing inspections for cracking and corrosion. However, if the useful life has expired, steps should be taken to replace the machine in its entirety or conduct repairs and refurbishment which may involve replacing major components on the machine.

During the interim period until replacement or major repair/refurbishment carried out, a fatigue/corrosion management strategy needs to be adopted to control the risk. The actual extent and interval required for the interim strategy needs to be determined on a case to case basis.

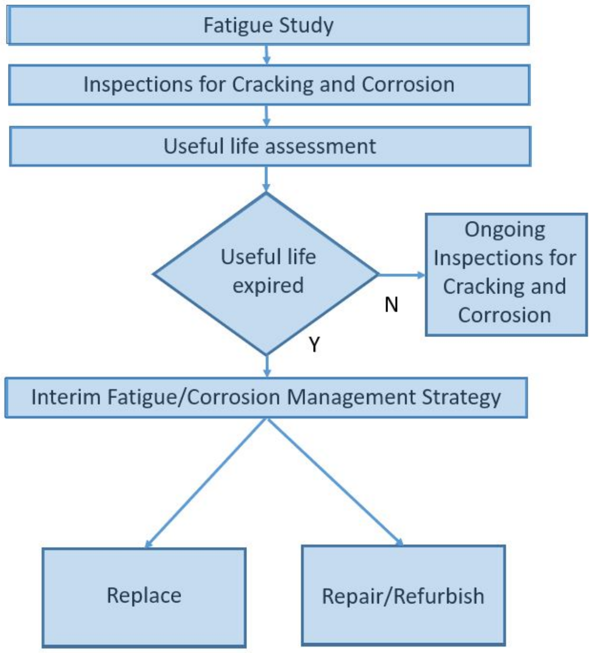

Figure 12: Flowchart for Life Extension Process

6.2 Load Measurements

On an existing machine, some of the loads can be measured more accurately than the values assumed in the design standard particularly for operational load conditions. For example, digging forces can be found from the bucketwheel and slew drive power. Live load on the boom can be found from belt weigher measurements. The corresponding position of the machine can also be recorded. These loads can be used to calculate the fatigue damage to date and predicted fatigue usage of a machine in the future.

Figure 13: Working Load Measurement

6.3 Strain Gauging

It is useful to validate the working loads with strain gauge measurements at strategic locations on the machine as shown in Figure 14.

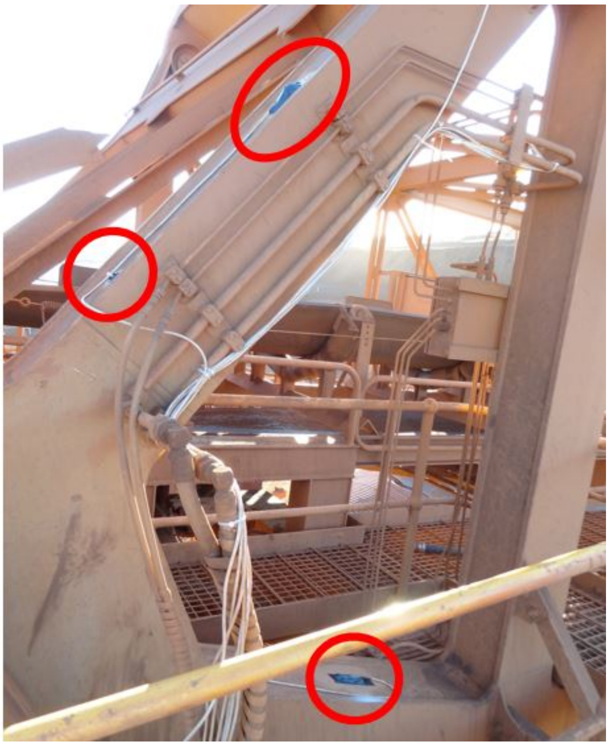

Figure 14: Strain Gauging

6.4 Inspection Interval

Cyclical stresses cause fatigue damage in steel resulting in cracking. Once cracking initiates, crack growth occurs exponentially. The graph shows the crack depth growth against throughput in million tonnes for a typical detail.

Structures must be inspected periodically to ensure that actual crack size is smaller than critical crack size, otherwise the structure is sure to fail. In Figure 15, the right-hand red line approximates the critical crack size. Inspection intervals are set to allow two inspections before the crack becomes critical.

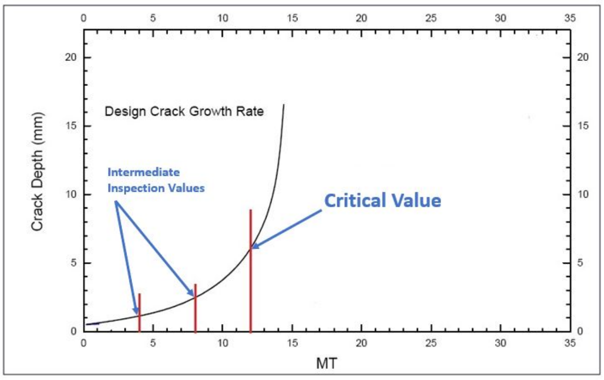

Figure 15: Crack Growth

6.5 Probability of Detection

There is a chance inspection may not detect cracks particularly in difficult to access locations. The Probability of Detection (PoD) shows how likely it is that a crack of a certain size will be detected during an inspection. The PoD depends on the inspection technique as well as on the crack size and increases with bigger crack sizes. Common inspection techniques for steel structures are:

• Magnetic Particle Inspection (MPI),

• Ultrasonic Testing (UT), and

• Visual inspection.

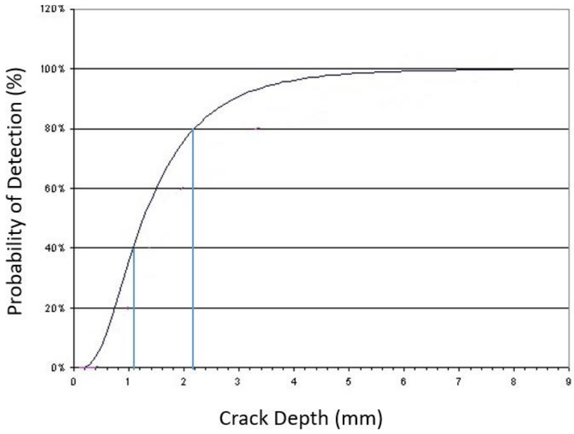

Figure 16: Probability of Detection

6.6 Crack Repairs

In general, the ability to repair structures with fatigue cracking is quite limited. Some of the issues are

- A weld repair on parent metal can reduce the fatigue life of the original component by a factor of ten.
- Corrosion repairs using cover plates typically reduce the fatigue life by a factor of ten.
- Repairs to existing welds can have a fatigue life of about one-quarter to one-half of the original component.
- Repairs at the same location will further degrade the fatigue life. It is only practical to repair a weld at the same location 3 or 4 times.
- Welds repaired under stress will have a reduced fatigue life – steel should be destressed to less than 20MPa prior to repairs being carried out.

6.7 Corrosion

It is important to inspect structures regularly to ensure that the structural integrity is maintained.

Protective coatings are the first line of defence against corrosion which, as discussed, reduces both strength and fatigue resistance.

Inspection and repair of paint coating is the main defence against premature failure of this type.

Once the paint coating is damaged, corrosion of the underlying steel will occur.

6.8 Useful Life Simulation

ASPEC has developed a program called FULS (Fatigue Useful Life Simulation) as shown in Figure 17. The simulation estimates the number of cracks that should occur each year in the future and calculates the repair time

Aspec

and cost based on the quantity of cracks and difficulty of repairs.

Crack repair cost inputs are:

1. Fixed cost per crack

2. Variable cost per crack

3. Production loss; this is triggered when total repair time exceeds the available shutdown time.

This approach shows there will be a time when the available shutdown time is exceeded which quickly causes high production losses that make machine replacement more economic. Essentially, the machine availability and therefore annual production capacity will decrease as the number of cracks increase relatively quickly. This type of situation has occurred with machines at several locations in Australia.

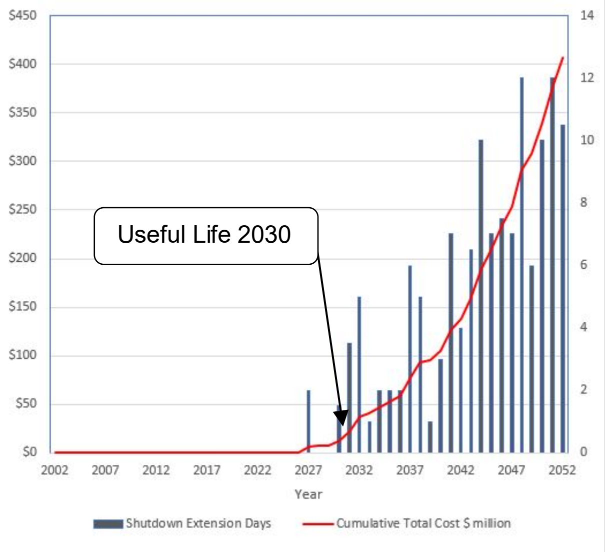

Figure 17: FULS Simulation

The simulation uses experience with how cracks are typically repaired when they are found during a shutdown. Cracks usually need to be repaired in the same shutdown as the inspection (critical locations), or sometimes the next shutdown (overflow for non-critical cracks) to manage the risk of catastrophic failure.

6.9 Machine Replacement

The decision to replace a machine will usually be done on both economic and risk/safety issues. Figure 18 shows a replacement shiploader being installed on an existing wharf. This is the simplest scenario as the change over time and logistics can be minimised.

On the positive side, a new machine can be designed to current standards. Fatigue and corrosion issues are minimised as fabrication and painting off site will generally get better quality. Upgrades such as higher throughput or improved clearances can be incorporated in the new design for improved economic returns. The downtime for a changeover can be reduced due to less requirement for site work.

Figure 18: Shiploader Replacement

One of the negatives for machine replacement can be higher loads. A new machine to current standards will generally be heavier which will impose greater loads on existing structures. There may be a need to upgrade infrastructure to cater for higher wheel loads and electrical requirements. Another disadvantage can be the logistics required for transporting and erecting a new machine on an existing site which may have constrained access.

6.10 Machine Refurbishment

Figure 19 shows a machine which was refurbished rather than being replaced. The machine was relatively new and was converted from being a stacker reclaimer to a reclaimer only. The boom was shortened, a new bucket wheel was installed, and the throughput rate was increased.

Figure 19: Machine Refurbishment

On the positive side, a refurbished machine will generally have less impact on existing infrastructure e.g. rails can be reused. The learning curve for operators and maintainers will be minimised as they will be familiar with the existing equipment. Refurbishment can be appropriate where substantial parts of the machine are in good condition and only limited component replacement or repairs are required.

On the negative side, there can be a lot of unknowns with the condition of existing equipment and structures which can cause unanticipated scope and cost blowouts. Longer shutdown times are generally required for refurbishment. Shutdowns can be several months with high uncertainty as the shutdown time can increase unexpectedly due to the unknown condition of the existing machine and the need for additional work outside of the original scope. Cost savings with refurbishment need to be balanced against a higher residual risk for this option rather than replacement.

7. Conclusion

In conclusion, fatigue is real and can develop relatively quickly on structures such as reclaimers and shiploaders. It is important to carry out fatigue studies and regularly update the useful life predictions for machines.

When the study shows that the machine is approaching the end of its useful life, it is important to have plans in place for replacement or refurbishment so that the organisation is prepared to act in a timely manner to avoid high risk situations developing.

Refurbishment is generally more suitable for machines with low utilisation at sites with some equipment redundancy. Replacement is generally more suitable for sites where the new machine can be constructed at one end of the yard while the old machine continues to operate, with a short cut over period.

8. References

1. British Standards Institute (2014). BS 7608:2014 Guide to fatigue design and assessment of steel products
2. Morgan, R. and Gatto, F. (2002). Defying Time, World Coal.
3. Morgan, R (2014). Asset Risk Management of Bulk Materials Handling Equipment, PIANC Congress, San Francisco
4. PIANC 2019, Design Principles for Dry Bulk Marine Terminals
5. Standards Australia (2017). AS4324.1 - Mobile Equipment for Continuous Handling of Bulk Materials, Part 1: General Requirements for the Design of Steel Structures.

For any enquires regarding this document, please email: admin@aspec.com.au.