Extension of Life of Cranes in Aluminium Smelters

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Abstract

The life cycle of aluminium smelters is comparable to the life of human beings. All over the world aluminium smelters need to work longer to sustain an ever competitive economy. As smelters age, their health must be checked. Often, corrective actions must be taken in order to ensure safe and efficient duty for the remaining lifetime. Based on Fives' 70 years of experience and a comprehensive installed base of more than 1300 ECL Tending Machines operating in the world, Fives is able to provide accurate and valuable assessment of the health of aging equipment. The assessment is a theoretical and field study performed in six steps. Such assessment is especially important for equipment that are more than 20 years old.

Keywords: Smelter life time, pot tending machine, assessment of equipment health.

1. Introduction

Some 85 % of aluminium smelters which are currently producing metal are over 20 years old. And with the aluminium prices regaining their strength, many of these old smelters are under pressure to produce metal safely and efficiently for longer than they were originally commissioned for. Their industrial equipment has aged. Although it may still be operating, it has reached a stage where an overall assessment of its remaining life is required, and the necessary actions taken.

2. Maximizing the Efficiency and Safety of Mature Smelters

In particular, many of the world's potroom cranes were built during or before the 1980s and are close to 40 years old. They were designed according Fédération Européenne de la Manutention (FEM), (the European Materials Handling Confederation), rules with a limited life span, equivalent to 10 years for mechanical assemblies (gearboxes, wheels, hoisting, etc.) and 20 years for structures. Computerized calculations were not available at the time, and conservative safety factors were applied during the design and manufacturing phases. Many cranes are still in use, providing a high level of safety, operating performance and serviceability. Nevertheless, a thorough asset management program is needed for this equipment to ensure that it complies with the latest safety standards and that they will continue to do so for the remaining operational life of the smelter. To maximize the customer's safety and efficiency, FIVES has devised an Extension Of Life (EOL) program based on the company's 70 years of experience on a fleet of over 1 300 operating cranes. Around 50 % of ECL cranes have exceeded their theoretical design life span for structures and the EOL program has been designed to help clients build an appropriate asset management plan for their machines. It will also help them face, or anticipate, insurance companies' requirements.

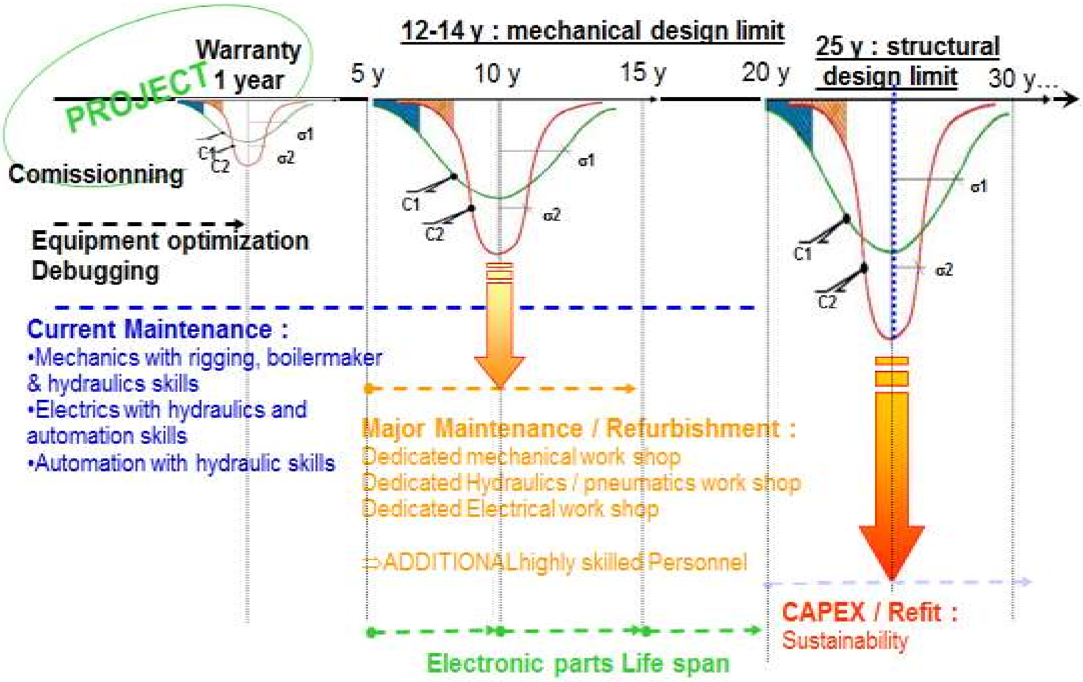

Figure 1. Smelter crane life cycle.

Curves in Figure 1, show different design limits, around 5 to 10 years for mechanical parts and 25 years for structure. The likelihood of failures increases closer to the end of design life. Proper maintenance and use will assure service exceeding any projected "life expectancy". Conversely, the lack of maintenance and operational abuse will reduce greatly the estimated "life expectancy". C1 and C2 are curves that represent distribution of reliability characteristics versus constraints distribution. Operation costs increase over time as the crane needs more frequent maintenance and spare parts.

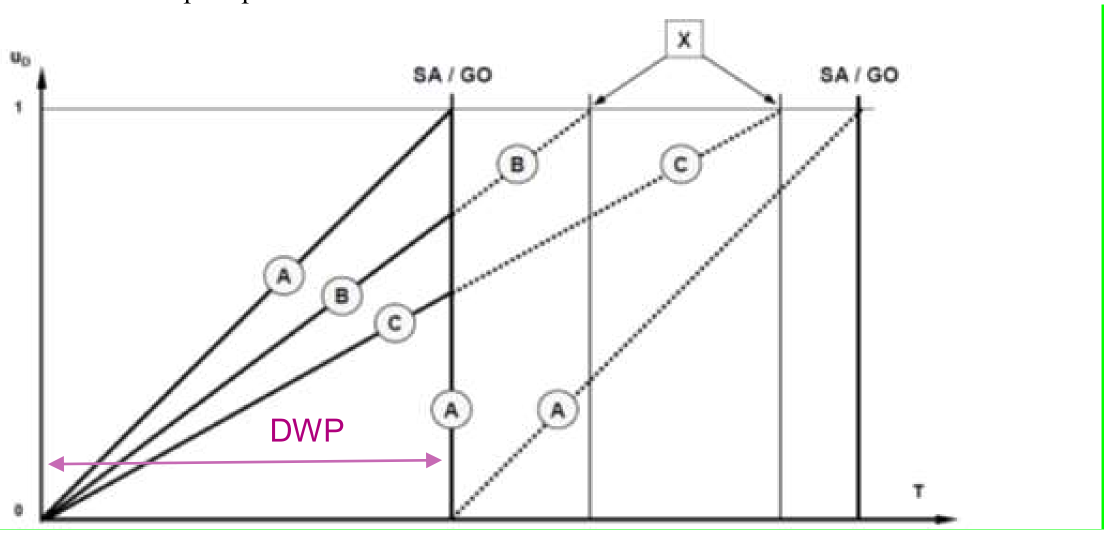

Figure 2. ISO/DIS 16716 Cranes with suspended load - Crane life cycle design. SA: Special assessment (Specific inspection), DWP: Design working period, GO: General overhaul, UD: % use compared to original design, T: Time of use, A: Component replaced at 1st GO, B, C: Component inspected at 1st GO, X: Design working period of components B and C (actions to plan).

Typically the operational period for industrial cranes is from 10 to 20 years. Fives ECL make calculation of its equipment for a life cycle of 20 to 25 years for structures, and 10 years for mechanisms. In figure 2, X axis is the Time and Y axis is the number of cycles. Each equipment is designed for certain number of cycles. Once the number of cycles is reached, if it is requested to make an extension of life study, various scenarios can be followed such as: General overhaul, reinforcement of components or replacement of complete sub-assemblies in order to give back more cycles and life expectancy to the equipment (A).

(A) Represents the case of a nominal use in conformance with original specifications. B and C are cases where crane is underutilized in terms of cycles. The assessment will validate the remaining life cycle before reaching the number of theoretical cycles (defined by the design) before carrying a possible overhaul. A, B and C can be considered as complete equipment or components depending on the scale study undertaken.

3. A Six-Step Program

The EOL program is implemented through six phases. Each program is tailored to be specific to the customer's needs and operational conditions. The first step is a preparation phase. The critical equipment of the smelter is listed by family. According to FIVES' database, the equipment type and production site are prioritized (if the program is conducted over several smelters). This step is necessary to ensure that the on-site asset study will meet the customer's interest and its economic and social realities. The second phase of the program is that of data collection. A thorough collecting campaign is conducted with the customer and covers cycle-duty data (anode changing operation, metal tapping, anode beam raising, etc.) in great detail, dimensional and quantitative data (number, type and weight of new and used anodes, amperage of the potline, number of pots and cranes, etc.), and historical data (smelter milestones, refurbishment work, etc.).

To build an accurate picture of the machine and its life to date from our own or the client's files, the following data need to be gathered:

- The original design statement; FEM.1.001 1970 [1] to which standard the Machine was designed and any specific references for those items when a general "Crane" standard did not cover. Examples are the DIN reference for Hooks, pulleys, rails etc.
- The comparison of the OEM's recommendation for sustainable maintenance and that found on site via the client's Computerized Maintenance Management System (CMMS).
- Review of third party examination reports of critical items including pressure vessels and ultrasonic testing of axles, pulley shafts and pins.
- Review of historical load cycles report as issued from the client.
- The original as built General Arrangement, detailed drawings and operational manuals giving tested speeds, loading and Proof/Safe Working Load (SWL) testing as well as any deflection tests carried out were reviewed. Original certificates were not made available by the client.
- Any modifications instigated by the client and any related drawings.
- From all of these and the inspection reports a comprehensive catalogue of data giving the as-recorded status against the original condition can be tabulated.

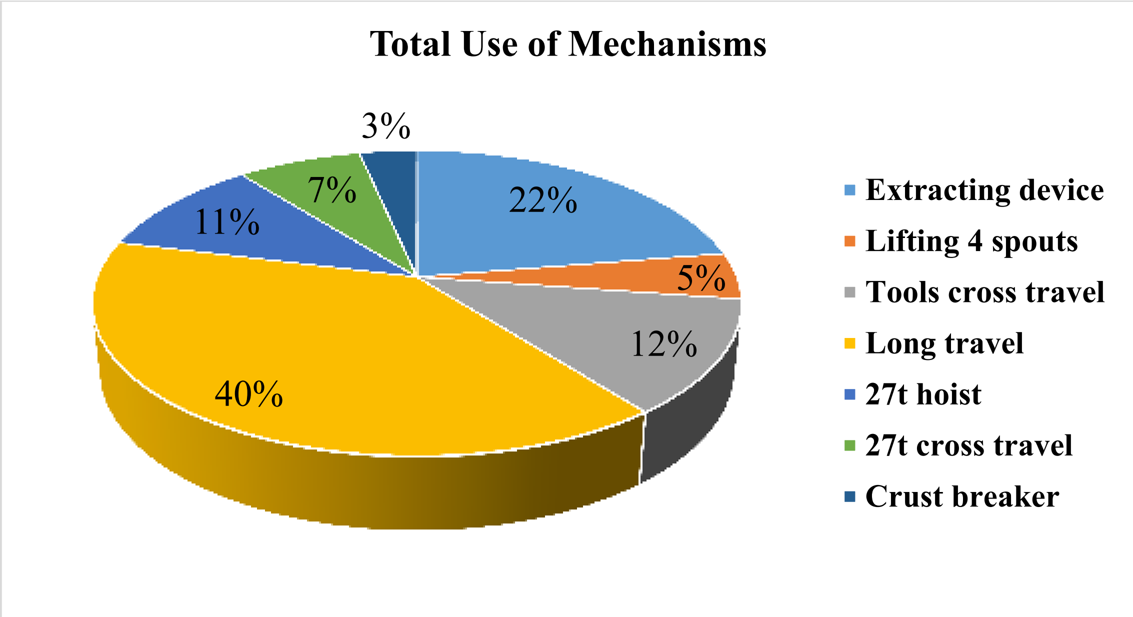

Figure 3. Total use per mechanism.

A precise chart of the duties of each machine is created, allowing assessment of the exact machine components' cycles (Figure 3). Based on this, preliminary cycle calculations are made by FIVES's engineering department to identify the stressed areas and the most probable failure points of the machines. In the third phase of the EOL program, these results are compared to the original and theoretical FEM class in relation to number of cycles. In addition to this, a cumulative damage study, according to the Palmgren-miner's rule (Cumulative damage model based on ISO 16716) will help determine the criticality of the machine's structural wear and fatigue [2]. A new calculation of the equipment FEM class is conducted, based on actual requirements of the standards. Finite element calculations are carried out on identified and critical structures (Figure 4). Weak or areas not meeting today’s design criteria are consequently selected for particular attention during the on-site inspections and for further action, such as: extension of the subassembly lifetime, replacement, refurbishment or a bespoke surveillance program.

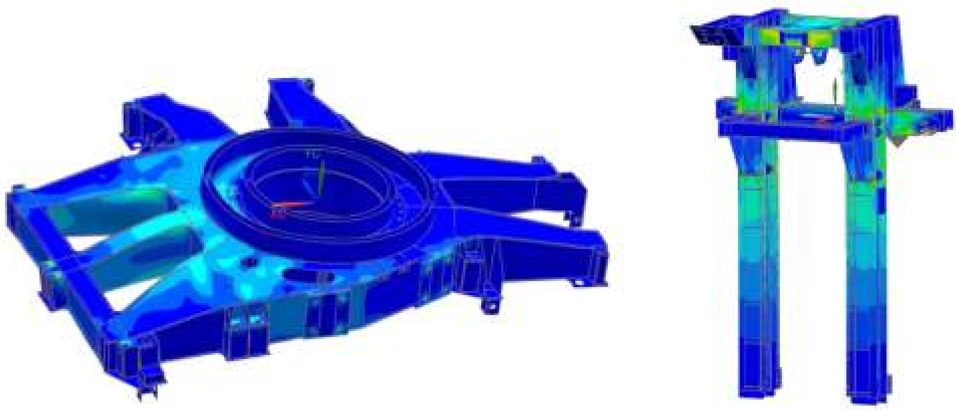

Figure 4. Finite element calculations are carried out on identified and critical structures

A thorough structural, mechanical and electrical inspection is performed by a team of FIVES’ experts in the customer's premises (Figure 5). This constitutes the fourth phase of the EOL program. The team will inspect all parts of the cranes, particularly concentrating on the known identified problematic areas (Figure 6). During inspection, all mechanisms are tested and hoisting units are load tested per local regulations. The structural parts identified as sensitive in the Finite Element Analysis are controlled with non-destructive tests. The electrical components are thermally checked to detect possible faults and all the safety facilities are controlled.

Subsequently, a fact-based inspection report is produced. A crane map and check-list precisely identifies all of the crane's issues, their location, their type (safety, production, maintenance, etc) and gives a criticality classification along with recommendations. The report also highlights: maintenance procedure deficiency, outdated components with limited availability with recommended replacements and potential machine improvements to increase productivity and reliability.

The Status assigned to actions in the report are based upon the criticality scale included in AS 2550 [4] for the assessment of fitness for purpose and can be read as follow:
A = Inspected - No action required Safe for Continued Use
B = Adjustments/Repairs made Safe for Continued Use
C = Additional repairs required Not Safe for Continued Use
D = Urgent repairs required Not Safe for Continued Use
E = WARNING: DO NOT USE

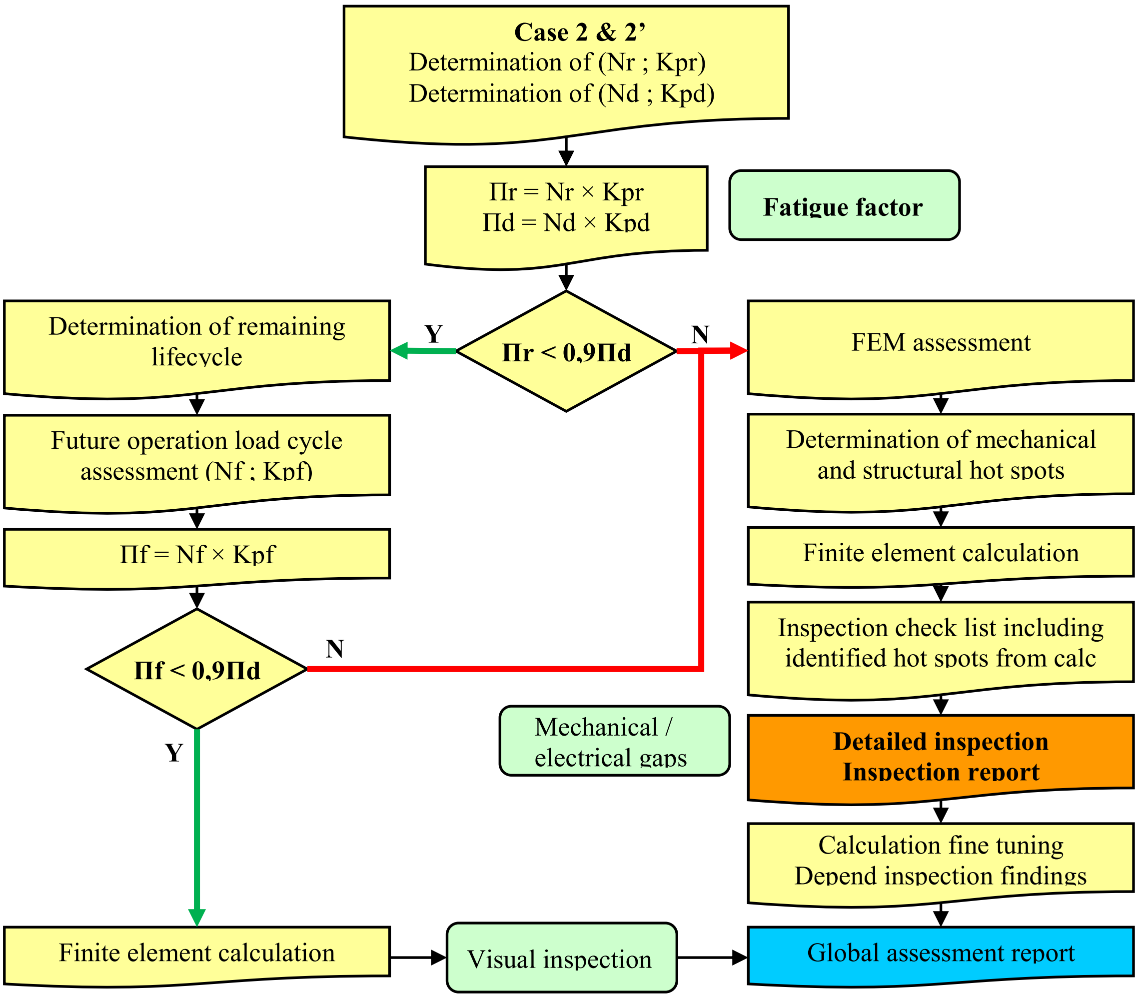

Figure 5. Study process flowchart.

Technical problems can be benign and only require adjustments or repairs, or at the other end of the scale, they could require the withdrawal of the crane from the production site for urgent repairs to ensure safe continued use. This classification is based on a risk analysis process that combines recalculations using real operating cycles with finite element modelling, and the structural, mechanical, hydraulic and electrical data from the on-site audit. The final and most important phase of the program consists of the preparation of a life extension scenario. This strategic approach is built jointly by FIVES and the customer's management. It aims to produce an added-value document that will enable the building of a successful asset optimization plan for the forecasted operating future of the smelter. Based on factual data, calculations, simulation and FIVES' 70 years long experience, the EOL program concludes with the production of a report with fact-based tool-set designed to assist the aluminium smelter in adopting the right technical directions and actions to reach their safety and economic objectives.

Figure 6. A team of FIVES experts carries out a thorough inspection of a crane in a customer's smelter.

4. A proven approach

Fives' EOL program has been constructed not only according to the expertise on crane audits but also in application of international standards such as the Australian AS1418 / AS2550 standards [3 - 4]. Fives' expertise in tailor-made cranes is used for interpretation of the results and for building the conclusions and the solutions in order to extend lifetime of the cranes. As part of the development phases, the EOL approach was used for audits on Rio Tinto sites in Australia (BSL, Tomago) and the Alcoa Portland site. The EOL program in its mature form has been implemented at the request of Alcoa (Deschambault, Baie Comeau and San Cyprian) for its complete crane fleet, comprising ECL stud-pulling cranes, Pot Tending Machine (PTM) and Furnance Tending Assembly FTA. It has also been engaged at Aluminérie de Becancour (ABI), Albras, Alouette, Alucam, Rio Tinto Grande Baie, Intalco, TRIMET St Jean de Maurienne, Lochaber, Laterriere, and Aluminium of Greece smelters.

5. Reference

1. Fédération Européenne de la Manutention – F.E.M. 1.001, Rules for the design of hoisting appliances, 3rd Edition Revised, 1998.10.01.
2. ISO DIS 16716, Cranes – monitoring for crane design life, 2012 edition. November 5 2012.
3. Australian AS1418 Standard Set, Cranes hoists and winches, the following are pertinent:
   - AS 1418.1 – 2002, Cranes, hoists and winches - General requirements
   - AS 1418.1 – 2002, Cranes, hoists and winches - General requirements
   - AS 1418.2-1997, Cranes (including hoists and winches) - Serial hoists and winches
   - AS 1418.3-1997, Cranes, hoists and winches - Bridge, gantry, portal (including container cranes) and jib cranes
   - AS 1418.14-1996, Cranes (including hoists and winches) - Requirements for cranes subject to arduous working conditions
   - AS 1418.18-2001, Cranes, hoists and winches - Crane runways and monorails
4. AS 2550.01-2002/AMDT 1-2004, Standards Australia, Cranes, hoists and winches – Safe use.