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XELIOS VIBROCOMPACTORS PERFORMANCE AND RELIABILITY

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Abstract

Throughputs and anode quality requirements for vibrocompactors are continuously increasing. Meanwhile, properties of raw materials are decreasing and expectations for cleaner and safer working environments are higher. A few years ago, Fives developed a new generation of vibrocompactors called "XELIOS". Its first industrial implementation was done on a demanding site with the highest throughputs and solicitations. Reliability had to be improved.
This paper introduces the latest developments done, based on operations feedback from the Gulf area:

- Environment and Health conditions have been improved to comply with new expectations and process parameters
- Overall Equipment Efficiency has been increased thanks to dedicated monitoring, on site measurements and off line models leading to an improved mechanical design
- New features have been added to meet highest requirements i.e. increase of green anode density and easy monitoring

Today 21 formers are installed.

Introduction

Over the years qualities of raw materials are deteriorating: Pitch softening point is increasing and average density of petroleum coke is decreasing. Equipment or process improvements can partially compensate for these changes in the anodes.
A few years ago, Fives launched an ambitious investment program for a new generation of vibrocompactors called "XELIOS". The main target was to transmit up to 30% more energy to the anode during compaction:

- A full scale prototype has been validated in 2008 with RTA at the St Jean de Maurienne green anode plant.
- The first industrial version was installed at Qatalum in 2010. Based on feedback from that site, improvements have been made to increase mechanical reliability and to improve environmental conditions.
- Today 21 formers are installed in Europe, China, Gulf countries and North America.

Xelios start up

Prototype in St Jean de Maurienne

A full scale prototype has been implemented in 2008 in St Jean de Maurienne, one of the smelters of RTA located in France. The vibrocompactor was operating at a moderate production rate of 22 anodes / hour with one former only.

That allows Fives to validate the range of the main settings and the new technologies implemented for Xelios:

- Design principles of Counter Pressure has been validated and tested up to 150 kN. Inflating sequence and standard set points have been tuned also: After locking, the cover to the mould a preset of pressure is applied. The final set point is applied when vibration is started.
- Rotary vanes pumps are used for the vacuum system. They are air cooled and so do not required any additional cooling water or cooling skid.
- Hydraulic movements of mould, hood, or anode pushers are controlled by proportional valves. They were tuned to have fast movements but with smooth transitions to protect equipment.

Figure 1 - Xelios at St Jean

This prototype gave the following results:

- More than 90% availability.
- The plant production rate was achieved with 22 anodes per hour. For this normal operation, settings of the machine were far from their maximum design capacity and cycle time was confirmed to be able to produce up to 30 anodes per hour with 1 former only. Vibration time was set in the range of 30 to 40 seconds.
- Quality of the anodes was far above the expectations. Compared to previous generation of former, improvement of the green anode density was +3 to +5 pts. By adapting the settings of the machine to the quality of incoming paste, it allows the smelter to increase average Green Anode Density (GAD) and to

maintain it to very high values which were considered as benchmark ones.

Design principles of the machine being fully validated, the new machine was ready for industrialization.

First Industrialization in Qatar

First industrial implementation of Xelios compactors was done in Qatar [1] where anode production started in February 2010:

- This Green Anode Plant (GAP) is composed of one single line of 60 tph, the highest throughput ever done. The anode production rate is up to 62 anodes / hour with only two formers. It means that for each former, one anode is produced within less than 120" with a vibration time in the range of 40 to 45s. Green anodes are neither slotted nor tapered.
- GAP is equipped with IMC technology (Intensive Mixing Cascade with two RV32 Eirich mixers) which brings a high operation comfort and contributes to better anodes quality but requires more compacting energy to achieve common level of green anode densities.

In order to deal with these two points, the full capacity of the machine had to be used. Although design was successfully tested and validated at St Jean de Maurienne, unexpected fatigue failures appeared at Qatalum in 2012.

- Cracks occurred on the mould and hood. Although it was designed to reach high performance, we understood the necessity to assess more accurately the actual stresses on the equipment involved in such demanding working conditions. Extensive destructive test campaign and lab analysis were conducted on damaged parts in order to qualify the failures. Dynamic stresses and movements were measured on site on the equipment in operation. This allowed to fine tune the dynamic mechanical model and to sharpen the FEM calculations. Then, design of both mould and hood was revised to fit to the actual conditions. Improvements were made to reduce the stress level with a greater mechanical inertia, to eliminate stress concentration areas and increase the welding quality
- On another side, reliability of the lifting system of the print mass was low. Originally, the hoist was catalogue equipment from a sub contractor. Fives had to take over and redesign the complete system from the hydraulic motor to the selection of the cables to fully comply with the specific requirements and specificities of the application.
- Breakage of the suspension rod of the print mass occurred once. After investigation, swivel joint which is guiding the rod was redesigned to change the resonance frequency which eliminates the breakage root cause.

Several root cause analyses were conducted and led to equipment field measurement campaigns:

- Vibration analysis of print mass and table during compaction were done to measure accelerations. Vibration monitoring is normally used to check the relative displacement of print mass versus table. Target is to maximize energy transmission to the anode by having opposite motion (figure 2). It can be used also to define the best settings in order to find the optimum between counter weights, counter pressure cycle level and vibration time without exceeding the design limit. We have used it also to check the influence of paste parameters on the stress of the equipment.

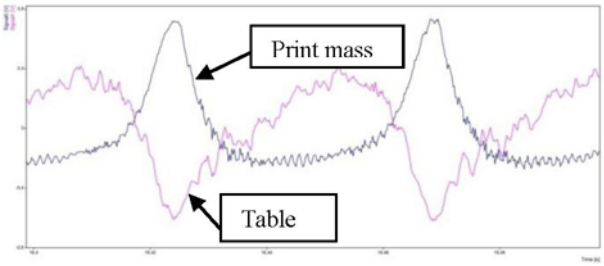

Figure 2 Vibration monitoring
(Acceleration in g versus time in second)

- Mechanical stress measurements were done also on the hood and mould. Based on results of previous FEM calculations and cracks analysis, stress gauges were implemented on the mould and hood (refer to figure 3 for locations of stress gauges). Measurements were performed during production. Figure 4 is showing a typical measurement of stress gauges during the production cycle. So variations of stress were compared to theoretical calculations. Differences were identified and it allowed us to fine tune the FEM calculations.

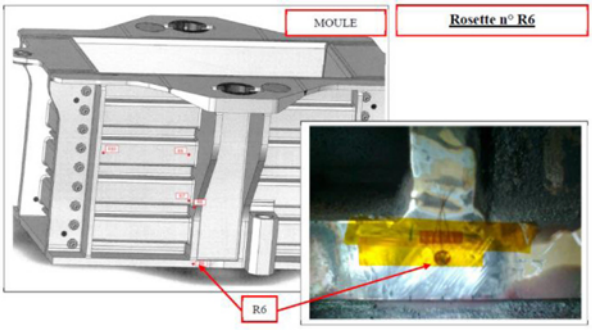

Figure 3 Stress measurements on the mould

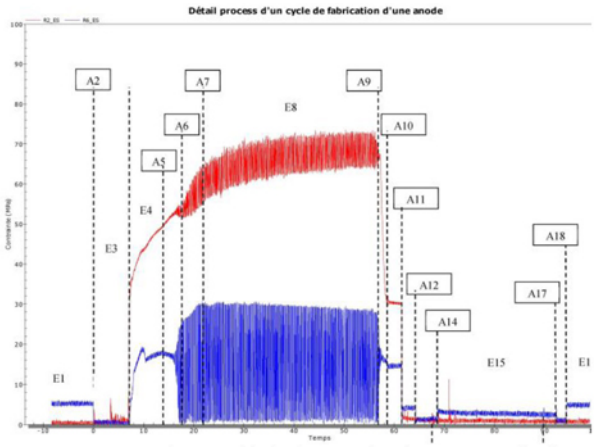

Figure 4 - Stress on the mould during production (constraint in MPa versus time during one production cycle)

An off-line model has been developed and tuned with site results. It simulates compaction process and how the vibrocompactors settings (anode size, compaction energy) influence this compaction. Paste compaction simulation gives intermediate results similar to monitoring on field in terms of level of acceleration and interaction of components.

Data collected on site during vibration monitoring and stress measurements gave us information to redesign mould and hood to fit to the actual conditions. Improvements were made to reduce the stress level thanks to a greater mechanical inertia, to eliminate stress concentration areas and increase the welding quality. FEM calculations were redone based on these upgraded hypotheses.

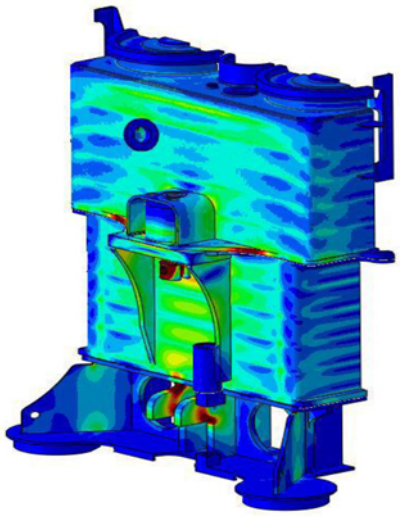

Figure 5 - Xelios FEM calculations

Previous generation of compactor was designed to work with lower energy of compaction. Xelios allows transmitting 30% more energy.
Mould and hood are now designed based on double wall principle to increase mechanical inertia. The upgraded quality of welding joints and their improved location out of stressed areas, allow to transmit that increased energy and to reach the expected fatigue life higher than 1 billion cycles (which corresponds to 22Hz x 55" vibration time x 30 anodes x 6000 hrs x 5 years).

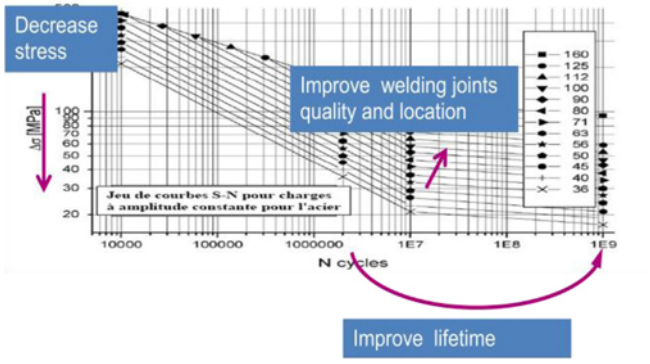

Figure 6 - Lifetime for mould

Some others mechanical components were also improved to reduce maintenance requirements.

- New design and material for counter pressure bellows is currently tested at Ma'aden smelter located in Kingdom of Saudi Arabia (KSA).
- Redesign of cover lifting system is fully operational in KSA or under commissioning in Canada
- Improvements have been done also on the vacuum system. Vanes pumps are used and are protected by two sets of filters and one cyclone to collect pitch fumes to allow lower maintenance frequency.

Environment, Health and Safety

Through the Xelios implementation in Qatar, it was also noted that environmental and operating conditions had changed in Vibrocompactor area:

- Implementation of the vacuum allows to increase forming temperature up to 175°C: +20°C on forming temperature means that pitch fumes concentration are multiplied by 3.
- Throughput increase was possible thanks to speed increase on the equipment. Most of pitch fumes are emitted during transfer of paste from one equipment to the other. And so by doubling the production throughputs, the pitch fumes flows have also doubled.

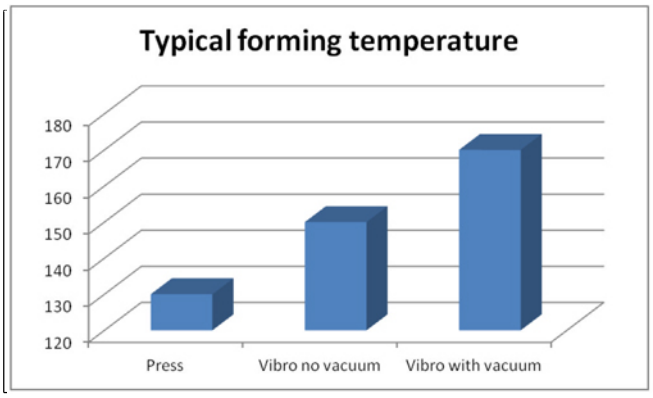

Figure 7 - Evolution of forming temperature

Vibrating feeder and filling operations of hoppers and moulds were identified as the main sources of emissions to be treated..

Designs improvements are based on following constraints:

- Pitch fume collection should be efficient also during transfer of paste from hopper to mould: 1 m^3 of paste is transferred in less than 2". So Air suction should be higher to 2,000 m^3/hr. Flow and pressure drop of the network were recalculated to fit with such specific operations where fumes emissions are important.
- Fume collection have to be done closer to emission points.
- Air flow to be treated should not increase. Gaps between equipment should be limited to improve suction efficiency

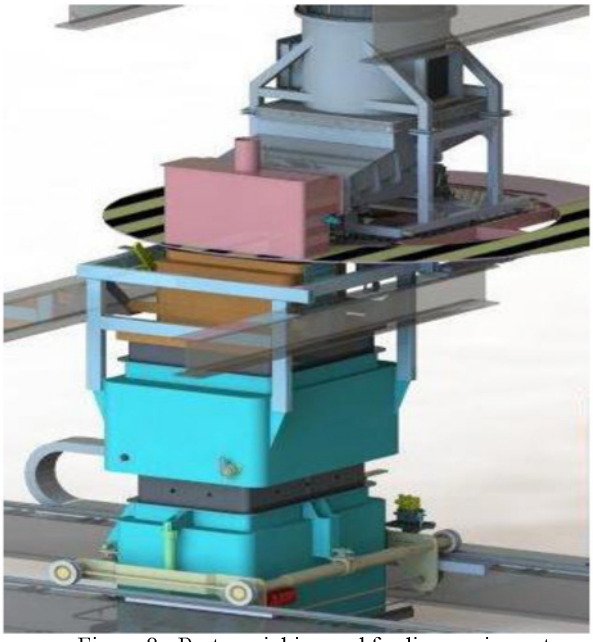

Figure 8 - Paste weighing and feeding equipment

And so the prototype in St Jean de Maurienne and the first industrialization in Qatar have brought many improvements on Xexlio vibrocompactors.
Most of them have been already or will be soon implemented on most of the sites equipped with Xelios.

Xelios New Features

Led by the continuous quest for performance, Fives continues to develop this new generation of vibrocompactors. The target is to increase its availability, performance, and quality of delivered anodes. New features are related to the use of high tech components for hydraulic or instrumentation. But it also includes the development of advanced software functions and a dynamic model of compaction of paste.

OEE

Overall Equipment Effectiveness (O.E.E.) quantifies how well a manufacturing unit performs relative to its designed capacity, excluding scheduled downtime events.

O.E.E.= Availability x Performance x Quality

- Availability decreases when downtime increases
- Performance decreases when equipment do not produce final parts at its full capacity: It represents paste rejects
- Quality decreases when defectives parts rate increases so it represents anode rejects

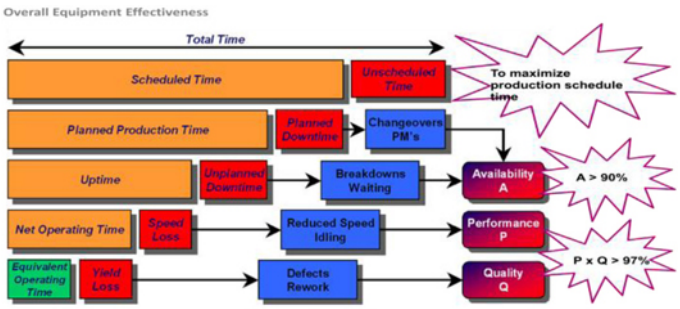

Figure 9 – OEE

After the first industrial implementation, Fives decided to improve Xelios vibrocompactors with the following targets:

- To reach quicker an availability > 90% during start up phase
- To keep (Performance x Quality (PxQ) > 97% with design capacity of 60 anodes /h
- To reduce schedule maintenance: i.e. by increasing expected components lifetime: the target is to have equipment able to run several weeks without maintenance schedule downtime.

Hydraulic High Performance Components

To achieve high performance, high tech components and technologies are required.
On the hydraulic side, proportional components allow high speed and softer stop and start in order to shorten cycle times and reduce mechanical stresses. But requirements are higher: oil has to be cleaner and temperature should be better controlled. So design is upgraded to maintain high quality for oil over the time and to minimize maintenance requirements:

- Oil temperature is controlled via automatic loop and heat exchanger technology is adapted to fit with extreme ambient conditions of Gulf area: temperature, sand, coke particles…
- Oil filtration is also reinforced to guarantee the best working conditions of these high performance components and at the same time frequency of planned downtime is decreased.

New Instrumentation Concept

Sensor breakages represent a significant portion of the non availability of the equipment: i.e. loose connection or wrong wiring during replacement. Some work was done to improve reliability of instrumentation:

- By selecting new sensors which were better adapted to the environment and by choosing the right location:
  - I/O modules implemented directly on the machine with keyed quick connect system are IP 69 (according IEC 529)
  - Status of the components are viewable via LED lights
- We worked also on the type of connection and protection of cabling in order to decrease repair time in case of a problem.
- This network design allows also auto diagnosis to detect failure of the sensors or their cabling to prevent undesired stoppage of the automatic sequences.

During Start up, fine tuning of automation sequences or Variable Speed Drive (VSD) parameters was also a key aspect. So to quickly reach nominal availability, a "plug and play" design has been selected:

- A standard drive package which includes the motor and VSD. It allows having standard programming and settings of VSD. Tuning phases after start up or replacement will be shortened and secured. Behavior will be also reproducible and it will allow some advanced functions for future
- To connect instrumentation, we selected a network architecture which allows us to perform tests during pre assembly at workshop and reduced significantly the pre-commissioning time.
- Standard automation package (software including the standard functions) is order independent and fully tested. It will allow carrying out dedicated platform tests on project specificities and speed-up commissioning.

Advanced Functions

To improve Quality, other additional advanced functions are currently under implementation:

- Paste weight management: during production start up, paste weight is automatically controlled based on historical data. Target is to maximize carbon weight and minimize reject due to too high or too low anode height.
- Amelios [2]: automatic and friendly reporting of the machine is done via an historian for an easy monitoring of the production. It checks and reports evolution of:
  - Availability: maintenance and shutdown time are monitored
  - Performance: Settings like vibration time, or Counter Pressure (CP) level are registered
  - Quality: GAD and weight average or standard deviation are displayed
- Vibrating monitoring system (VMS) including:
  - Protection of equipment versus maxi acceleration
  - Optimization of settings to improve GAD
- Remote monitoring: for assistance to diagnosis

Conclusion

Xelios is a high performance vibrocompactor. After a phase of reliability improvement with extensive site investigations as well as high effort of modeling, the machine can now be considered as a proven technology. Twenty-one formers are now installed and the first 4 formers, which fully beneficiate from the reliability program results, have been in operation for 2 years at Ma'aden in KSA, with an excellent availability since start-up.
The present version of Xelios includes all these developments and provides:

- High performance vibro compacting: +3pt GAD and 60 anodes / H
- Reference for OEE: Availability >90% and QxP>97%
- Eco design for better working conditions
- Advanced Process control functions for higher stability and easier monitoring of production.

References

[1]. C Bouche & Al –"60 tph single line green anode plant commissioned at Qatalum" – Light Metals (2012)

[2]. X Genin & Al –"A green anode plant performance analysis tool fully embedded in the plant control system"- Light Metals (2013)