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ANODE BAKING FURNACE FIRING SYSTEM LEAN ENGINEERING

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Abstract

Smelters are more and more implementing Lean manufacturing principles in the way they manage operations. Rio Tinto Alcan, deeply involved in this approach, has been applying Lean principles also to the engineering process for the development of its new 'in house' anode baking furnace firing system in 2011. First, the new firing system has been designed to fit the voice of customer. A large survey was conducted across RTA smelters to collect client feedback on existing equipment/systems and their recommendations for system improvement and user flexibility. Secondly, an efficient internal partnership was established within RTA (Technology and R&D and Alesa) to define and develop the system with the support of a very experienced smelter team for the industrialization process (St Jean de Maurienne). Finally, the time to market was exceptionally fast with the first full-scale firing system being commissioned flawlessly in April 2013 at the Aluminium Dunkerque smelter.

Introduction

RTA has a long experience in furnace operation, design and baking process. Teaming up internal competences across the company from process to commercial made it possible to design, develop and manufacture a complete firing system. The decision to proceed with this development was motivated by the desire to achieve a flexible and evolving system that will meet customer expectations, without 'nice to have' features and enable integration of future innovation and experience. In order to design a Lean firing system, a Lean engineering approach was undertaken to lead the project. The project was designated 'TIGER'.

Lean engineering approach

Very often, Lean is associated to Manufacturing. But there is also a Lean Engineering methodology devoted to product development. It is more important to understand the supporting philosophy instead of trying to copy/paste methodology tools developed by Lean Champions. There are several companies that may be qualified as 'champions' of Lean engineering, the more successful being focused on mindset, behavior and concept rather than trying to implement straight forward methodology tools.

Lean engineering philosophy is very close to that of Lean manufacturing. The goal is to eliminate waste. In a project development process, time is crucial. Lean engineering should reduce iterations, quickly address problems, improve quality and risk management, with the end result of an improved overall lead time. For a project such as developing a new control system, based on similar engineering experience, the time to market was anticipated to be more than 24 months. In the project, it was reduced to 14 months thanks to the Lean approach. (cf. Figure **1**).

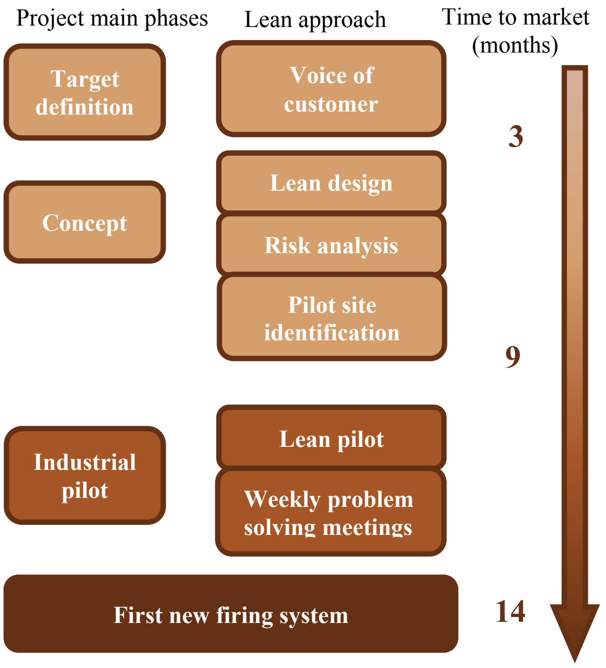

Figure 1: Lean engineering process

Voice of customer

At the beginning of 2011, a voice of customer exercise was conducted across all the European RTA carbon plants. This represented at this time more than 10 open top furnaces and 26 fires operating with firing systems of several types.

Sites were visited by the two engineers in charge of the design and engineering for automation and mechanicals parts. Anode Baking Furnace (ABF) operation and maintenance teams have been interviewed to collect best practices, improvement ideas and needs.

The results of the voice of customer process being 35 new ideas by our users were selected. These ideas have strongly influenced the development phase of the final product and have been integrated into the automation and mechanical component technical specifications. One of the client main concerns was the lack of flexibility and the extensive list of ineffective functionalities of existing firing systems that tend to make use of the system more complex and less robust.

Lean system architecture

Within a spirit of simplification, a detailed review has been made on the global architecture of the control system. The availability of fast real time networks now allows the use of only one central controller for managing all firing ramps and auxiliary equipment.

A single Safety Integrated Programmable Logic Controller (SIPLC) manages remotes Inputs/Outputs (I/O) for each of the ramps and auxiliary equipment. An optical fiber loop links SIPLC, servers, clients and WiFi access points together. This architecture (cf. Figure 2) offers the following benefits:

- Latest generation industrial safety wireless networks [1] simplifies the infrastructure and eliminates maintenance troubles with control cables and plugs
- The centralized architecture offers a reduction in the amount of control equipment.

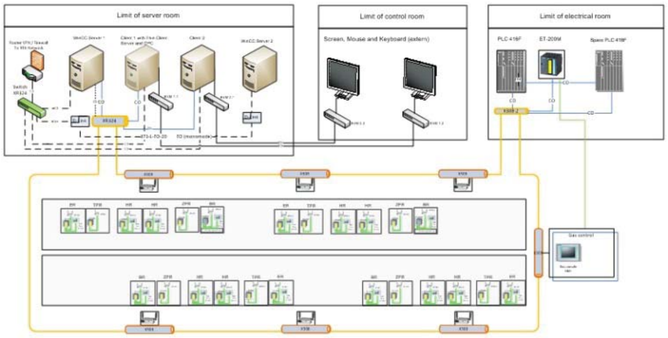

Figure 2: Control System Architecture

Lean process control

As a tool for managing the baking furnace process, the basis was to be fully adaptable to the process needs. Preheating, heating and cooling zones can be managed and moved independently to provide flexibility in fire group definition. The fire group configuration (number of sections per zone) and fire cycle time of each zone is able to be modified without the need of software modification as well as a variable number of HRs in operation in the heating zone. It also offers independent control of the flue wall line and a new and dedicated management of the furnace crossovers.

To support fast baking cycle times, as a standard feature the gas injection efficiency is continuously monitored to ensure all fuel is burnt, improving combustion efficiency and reducing CO emissions and optimizing flue wall heat-up. In order to maximize the life span of refractory materials in the heating zone, the temperature rise of each flue wall is monitored and HRs are not permitted to inject gas if the system requests a too fast temperature rise.

To facilitate the use of the control system and to avoid user misunderstanding, considerable effort has been made to the user interface. A selection of essential alarms to be displayed has been made in order to avoid that too much information potentially conceal important issues. Equipment that must be moved within the next shift is identified with a predicted work schedule

Industrial demonstration

Next step of the project was industrial demonstration. It was necessary to install the whole control component of a complete fire group in a standard ABF and operate it for a minimum of six months (cf. Figure 3).

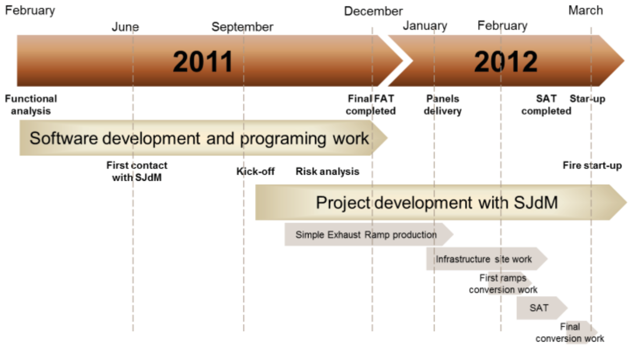

Figure 3: Development Phase Schedule

The ideal demonstration site should have spare ramps available, an automated firing system having mechanical hardware similar enough to be representative. It was also fundamental that the demonstration plant team have an in-depth knowledge of the baking process.

For these reasons and after a review of European RTA plants, Saint Jean de Maurienne was identified as the best location for the demonstration fire group (cf. Figure 4). First contact with the plant was established at the end of June 2011, the project launched in September 2011 and the demonstration fire group commissioned in March 2012.

Figure 4: Demonstration fire at Saint Jean de Maurienne

The complete demonstration fire group was comprised of eight ramp control cabinets, a main cabinet including the SIPLC and servers, a dedicated Level 2 workstation and communication networks for the furnace and control room. The eight ramps used for the demonstration included two Exhaust Ramps (ER) for safer fire moves, one Temperature & Pressure Ramp (TPR), three Heating ramps (HR), one Zero Point Ramp (ZPR), and one Blowing Ramp (BR) (cf. Figure 5 & Figure 6).

Figure 5: Level 1 ER Screen

Figure 6: Level 2 Fire View Screen

All phases of the demonstration project including preparation, installation, operation and conversion of the ramps to their original configuration required the close collaboration between the plant and the pilot implementation teams. In a lean mindset, regular follow-up and trouble-shooting meetings were used to share all project information and to remain focused and adaptable to meet any unexpected operational conditions. As a complement to these meetings, the plant team also participated in the first acceptance test phases in the Alesa workshop.

As it was crucial to avoid any production losses, it was necessary to install the demonstration fire group without production stoppages; this presented a real challenge as an ABF runs continuously (24 hours a day, 7 days a week). A SMED approach was undertaken. A specific schedule to secure the smooth transition from the existing fire group to the demonstration one was established. All infrastructure equipment was installed and commissioned prior to any ramp cabinet change. Then, as the plant had spare ramps available, ramp conversion commenced to create a reduced fire group comprised of one ER, one TPR, one HR, one ZPR and one BR. This complete group was tested and pre-commissioned outside of the furnace. As soon as this step was completed, the demonstration fire group start-up and the hot change of the three remaining ramps began. The hot change occurred over three fire cycles and the complete demonstration fire group was fully operational. During this transition phase, the ABF continued under normal and safe operational conditions.

The product development team remained on site until after the first crossover passage. Then, weekly meetings and regular site visits continued to closely monitor ongoing performance.

Finally, the demonstration fire group was closed in November 2012 after 7 months of industrial operation having fully achieved its goal. The product capability has been demonstrated: no anode quality or baking level issues were reported over the period, positive user comments regarding fire management with good reliability results.

Technical results in the first implementation

In May 2012 Aluminium Dunkerque (AD) ordered the first commercial control system for the scheduled startup date in April 2013. The AD furnace, erected in the early 1990's has 72 sections with 6 pits and 4 fires in operation. It has been refurbished in 2013 and the opportunity was taken to increase the size of the pits.

The scope of work was to replace the control cabinets of the existing firing system and to modify the ramps to match the new furnace dimensions. The ramp conversion had to be completed during the 2.5 month furnace stoppage for the civil works and refractory installation. The complete revamping of the four fire groups represented the supply and installation of 33 control cabinets, modification of 43 firing and furnace maintenance ramps, two new HRs and a new dedicated communication network.

A tight global schedule (cf. Figure 7) of the firing system conversion period during the ABF shutdown was established. The industrial trial conversion return of experience was really useful for this first implementation as similar constraints were applied.

Figure 7: AD Project Development Schedule

The four fires were commissioned on time without interruption (cf. Figure 8).

Figure 8: Firing System in operation at Aluminium Dunkerque

During the first months of full operation, the new firing system has been operating flawlessly, delivering typical technical result below (cf. Figure 9 & Figure 10).

The focus now for the firing system is a continuous improvement process. The aim is to propose and reinforce features that help operation teams to face new challenges, maximize furnace productivity [2] and optimize operation costs.

Parameter	Units	Value
Number of fires		**4**
Pit capacity	Anodes	**18**
Section capacity	Anodes	**108**
Cycle time	h	**24**
Baking level (L_C)	nm	**3,37**
Average gas consumption	GJ/mt baked anode	**2,4**
Monthly baked production	mt	**12 400**

Figure 9: Average data of AD furnace over 4 months

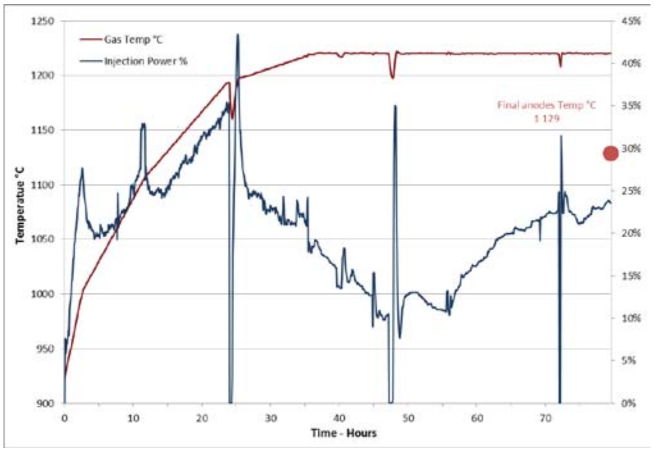

Figure 10: Heating curve at AD

Conclusion

The ‘TIGER’ firing system project is good example of how time to market can be reduced when a product is developed with a Lean approach. The firing system engineering, the industrial demonstration and the first implementation was conducted faster than expected. The system is less complex and so there are fewer sources of errors and iterations needed. By collecting user expectations through an extensive voice of customer exercise and applying it in the design system, the final product fits user needs and the opportunity to implement the first equipment in an operational environment is highly increased.

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[2] F. Ordronneau, M. Gendre, L. Pomerleau, N. Backhouse, A. Berkovich, X. Huang; Meeting the challenge of increasing anode baking furnace productivity; Light Metals 2011