Towards 4.0: The Smelter of the Future

This fourth industrial revolution was preceded by mechanisation, electrification and automation. This revolution is mainly illustrated by Information Technologies (IT) and Operation Technologies (OT) convergence i.e. Internet linking previously isolated control and operation systems, allowing the transition to an open and interconnected “Digital supply network”. The development of this “plant of the future” aims at reaching a new threshold of competitiveness and sustainability leveraging the following main drivers:

- Improving asset efficiency and use
- Reducing waste, improving recovery and quality
- Optimising processes and flows for cost reduction
- Reducing capital employed and work in progress through virtual supply chain integration
- Improving employee safety, reducing environmental impact through efficient resource usage, in particular energy, ... 

The smart factory marks a shift from automated mass production to personalised mass customisation. This latter element, coupled with the above-mentioned aspects, opens up synergies between production hubs and customers, suppliers or partner locations and shortens the value chain (Fig. 1).

“4.0 factories” are more developed in manufacturing industries. In contrast, there are only few examples in process and commodity industries such as cement, paper, chemicals or - closer to us - steel and aluminium. Based on this observation, we studied the manufacturing developments to identify concepts transposable to the “Smelter of the Future” and evaluate the industrial, technical and economic conditions that would make them attractive to decision makers in our industry.

1. Smart Factory overview

Industry 4.0 marks the transition from partially automated plants, often managed in silos, with loose horizontal and vertical integration - factories 3.0 - to “smart” factories based on flexible, connected and optimised workshops composed of collaborative machines[1].

The plant of the future is therefore: A connected factory:
- Digitally linked with partners, suppliers and customers, allowing real time, fully traced, adjustment of processes and products.
- Based on advanced self-controlled flexible robotic tending equipment, collaborating with operators.
- Allowing a shop-floor decision-making process and interaction through cyber-physical systems (CPS), machine-
to suggest this journey will consist of independent, incremental modernisations, decided on a case by case approach satisfying usual short-term profitability criteria.

Company digitalisation requires a holistic vision of the end state and demands significant investments in order to fully reap the benefits provided by the synergies between the different transformations undertaken at plant and company level.

When looking at existing smelter situation through the lenses of the sketch (see Fig.3), it becomes obvious that numerous initiatives have already been implemented, however often without a coordinated approach and, more importantly, without the compulsory competency portfolio and organisational shifts required.

A more detailed analysis of the different smelter workshops helps identify which technologies are already available or in an advanced development stage.

a. Substation

Seen in the past as a “fire and forget” investment, the last twenty years have reminded the criticality of this workshop. Its failure leads to catastrophic loss of production and massive restart costs.

Maintenance practices from manufacturing (predictive maintenance, remote servicing, ... ) could be implemented immediately. This workshop is critically sensitive to real time action carried out by staff in emergency situation. Virtual training and remote expert engagement can prevent huge financial losses.

b. Carbon plant

Green Anodes Plant and Rodding Shop are very close to manufacturing lines, with high level of automation and process instrumentation. A Smart Data approach, combining process improvement and predictive maintenance[1] is well suited to support the continuous improvement (average level and spread) of anode characteristics.

Anode Baking Furnace is probably the current weak point with a disappointing level of automation for a workshop which could be seen mainly as handling activities (green and baked anodes, raw material, equipment, ...). Technology is already available[8, 9] to support anode tracking from raw material, and to predict reduction cell up to feedback loop with butt characteristics at rodding shop. This is the critical element to improve, in an integrated way, carbon plant and reduction performance and is a perfect illustration of the “intelligent plant” concept.
c. Casthouse

Casthouse is also very close to manufacturing and will benefit directly from a Smart Data approach.

However, casthouse specificities are elsewhere. This could be the place where Mass Customisation enters the Smelter of the Future. Less attractive for mega smelters producing commodities for the global market, it is much more relevant for small/medium size smelters producing Value Added Products, closer to downstream customers and final users, as commonly found in Europe.

The smelter can reach another level of competitiveness by full metal flow integration from reduction to fabrication, moving from a “push” mode to a “pull on demand” using advanced control systems and automation in casthouse, reduction and transport.

d. Reduction

Finally, the reduction line also holds a key challenge of the Smelter of the Future.

Even today, reduction performance is too often characterised by periods of underperformance in comparison with the technology’s full potential. These periods, as illustrated by curve 1 in Fig.4, range from limited disturbances to major process excursions, often caused by:
- Cell operation disruption, possibly worsened by unreliable operating practices (intrinsic quality or timing inconsistency)
- Poor adjustment by technical management and/or process control to external disturbances (raw materials, …)

Moving from situation 1 to 2 and 3 implies a significant improvement in operational performance and, obviously, competitiveness.

Such improvement is at reach, with technologies already available or in advanced stages of development, through a step change in automation associated with Smart Data tools.

For example:
- Heavy load handling by unmanned vehicles
- Autonomous devices for tapping, measurement and sampling
- Self-powered sensors enabling next generation of process control and Big Data usage

However, the critical element will remain the automatic anode change. Several tests and attempts have been made during the last decades (Rechinay/ECL; Rio Tinto/Fives ECL; Hydro / NKM; …)[10,11,12]. They have demonstrated the difficulties associated with safety (extreme complexity of safety systems until potrooms are considered as restricted area) and technical hurdles. Attempts to automate manual sequences have led to high complexity, long cycle times and insufficient success rate. It is now clear that an integrated cell and anode handling design could overcome those difficulties and unlock expected return on investment in a retrofit context.

e. Smelter network

The Factory Network concept is also perfectly suited to develop “Connected Smelters”:
- Shared technical management, based on Smart Data and possibly Excellence Centres
- Shared high level expertise
- Real time support for crisis management
- Integrated supply chain management when geographically applicable

A progressive development of such network (both through the number of connected workshops and plants) is achievable as demonstrated by Rio Tinto [4]

f. Smelter of the Future: an integral part of utility network

The ever-increasing ratio of renewables in the energy mix (35% for electricity in Europe in 2030[3]) further complicates the utility network management. With time and experiments, most smelters are now able to offer basic utility network demand response systems by modulating power input, fully or partially, for a limited time, with acceptable impacts on process efficiency. This enables utilities to optimise their cost structure and smelters are rewarded by a lower average energy rate[2]. However, this calls for higher integration of the smelters in those networks.

4.0 tools will also support this welcome development:
- The “Connected Smelter” will be part of the utility network, enabling more accurate preventive actions ahead of modulation needs
- Automation and advanced process control systems will enable real time plant operation adjustments
- Smart Data will feed self-learning simulation models which will minimise efficiency loss, particularly by supporting decision makers on their best compensation strategy

g. Change management

As with any transformation, the journey to 4.0 raises a human challenge probably even higher than the technical one. Here are some of the hot topics to be addressed:
- Design of target organisation and identification of future competencies (see Smelter of the Future Organisation textbox)
- Staffing of new competencies that cannot be developed internally
- Destaffing of obsolete competencies
- Management of “detraining-retraining” of internal competencies through individual development plans

4. Conclusion

The advent of the Smelter 4.0 is today an opportunity triggered by the availability of Smart Factory tools and a necessity to unlock the next level of competitiveness. Unlike manufacturing where advanced
automation gave birth to the Smart Factory, the availability of smart tools will support the Smelter of the Future full automation, with more attractive return on investments.

The Smelter of the Future is not restrained to a hypothetical still-to-be-designed Greenfield plant. Digitalisation of existing smelters is not only feasible but desirable to preserve their competitiveness. This transformation will deliver its expected value only if the following fundamentals are fulfilled:

- This transformation cannot only consist of isolated opportunistic incremental modernisations. A holistic vision of the end state is required. To be relevant, this vision needs to be developed by a multidisciplinary team as digitalisation encompasses the whole value chain.
- Coordinated investments are required to fully capture the benefits of integrating the different workshops and of connecting smelters together.
- This transformation requires a large portfolio of competencies which do not necessarily exist within the organisation: it needs to rely on an ecosystem all along its journey
- Last but not least, this transformation requires a vision of the end state organisation, of the target competency portfolio and a change management plan meticulously prepared and rigorously executed.

The advent of the Smelter of the Future therefore requires a strategic vision of the whole primary aluminium value chain and this is where it converges with manufacturing.

### Bibliography

4. C. Vanvoren, (2016, October) ICSOBA Conference “Data connectivity, a Key Feature of the Smelter of the Future”
5. EU (2014, October) “2020 climate & energy package”

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Smelter of the Future organisation

During the past half-century, smelter’s organisations have evolved, pushed by technology evolution, along two main streams:

- Direct productivity increase through headcount reduction, which today, due to lack of new technological breakthrough, has started to level off.
- Concurrently, attempts to flatten organisations with self-managed teams have fallen short of delivering expected results, mainly because of misalignment between company – set team objectives and those set by the teams for themselves. This often led back to pyramidal organisations with the reintroduction of front line management. This mid-management is however often overloaded with administrative tasks, sometimes leading them to overlook core technical tasks.

Today, due to its working conditions, competency profiles and organisational structure, process industries don’t appeal to young graduates who cannot grasp how their professional aspirations will be met.

To address this challenge, new organisations are proposed (i.e. F-form company®). However, we don’t think they will better perform until the root cause described earlier is addressed.

The 4.0 plant as an enabler for such innovative organisations

By drastically improving working conditions through automation and by increasing work attractiveness by the usage of smart tools, the 4.0 plant creates the conditions for more homogeneous teams, which is the key element to achieve satisfactory alignment between company and team objectives.

With such level of expertise and accountability, each team member will feel on equal terms and will share the same objectives set through fact-based concerted decision-making processes.

However, such organisations need to be sized with operation crisis in mind, as such situation in a smelter requires significant human resources on the shop floor. Thorous crisis situation analysis (i.e. blackout) would be required ahead of organisation design. In order to achieve expected productivity target, smelter employees would be required to be trained to crisis situation contingency roles and remote high-level expertise would need to be available, for example from a centralised Excellence Centre.

All those competencies would need to be rigorously maintained, typically using a mix of virtual training tools and on-the-ground drills.