Enhancing performance of aluminium recycling furnaces beyond Industry 4.0

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In an increasingly competitive environment, aluminium recyclers are looking for efficient, sustainable and cost-saving equipment and production facilities. Within this context, GHI Smart Furnaces has been constantly improving product designs, developing new technologies and offering innovative services. To move towards the fourth industrial revolution, the company has launched its own analytics services, called Beyond 4.0, for capturing and exploiting relevant data of industrial processes and convert it into deeper engineering knowledge. The following article sets out evidence on how GHI Smart Furnaces has leveraged its experience and know-how in process and equipment in the aluminium industry based on advanced data analytics. The platform is aimed to detect operational anomalies, identify usage inefficiencies, ensure furnace performance and track traceability and quality metrics. These data are used to adapt equipment behaviour to customer needs, adjust maintenance practices to machinery degradation, and establish energy-saving policies. Furthermore, Beyond 4.0 enables moving from data-driven insights to data-driven actions by offering advanced services, such as smart production support and smart preventive/predictive maintenance.

There has been a huge increase in the aluminium consumption industry driven by the construction and automotive sector. Aluminium gives great advantages compared to other traditional metals; properties such as high corrosion resistance, electrical and thermal conductivity, reflectivity and ductility result in thousands of applications worldwide in different sectors. Keeping the properties of this metal intact after recycling has made the secondary aluminium market a key factor for global sustainability. The importance of aluminium recycling relies in its flexibility, economic and environmental benefits, related to energy saving and recyclability properties, as this process saves around 95% of the energy required to produce aluminium from bauxite ore and about 95% of the greenhouse emissions are saved compared to the primary production process [1].

The global aluminium scrap recycling market is rapidly growing, and most researches point out the continuity of this trend. For this reason, as technology advances, the use of aluminium is generalized and a growing demand for this metal is expected in sectors of high consumption level, driving the search of highly efficient equipment for this process. Several different furnace designs and technologies are available in the present day, all striving to become the most efficient and versatile, with the highest metal yield and the best process quality.

The purpose of the aluminium recycling industry is to recycle all kind of aluminium scrap, whenever it is technically conceivable, economically feasible and environmentally possible. GHI Smart Furnaces, a Europe-based company specialized in the tailor-made supply of industrial furnaces and turnkey plants, with more than 80 years of experience in process and equipment, has undertaken a great R&D effort geared towards supplying fully automated turnkey-plants with smart furnaces designed to obtain the highest metal yield for any kind of aluminium scrap (Fig. 1).

Depending on the subsequent transformation process that is chosen, the aluminium adopts different forms: slabs for later lamination, billets for further extrusion, ingots, sows, T-bars, among others, for later remelting or moulding of complex pieces.

Process reliability and safety, increased productivity, efficient, flexible and sustainable production are the main purposes for aluminium recycling companies. The fourth industrial revolution is changing the paradigm and is allowing companies to take data-driven decisions related to these objectives.
BEYOND 4.0 SOLUTION

GHI immerse in its digital transformation, creates Beyond 4.0 for Smart Furnaces, aimed to support customers during the entire lifecycle of industrial furnaces and auxiliary equipment. And goes a step further on connectivity and data visualization, by providing to the end user answers concerning their daily tasks and future decisions based in big data, advanced algorithms, and the analysis of these data by specialized engineers to provide smart preventive maintenance and remote technical assistance to its customers.

The Beyond 4.0 platform includes an analytics engine for capturing and exploiting relevant data of industrial processes and convert it into deeper engineering knowledge. GHI furnaces are heavily sensorized with process measurements that are collected through the Beyond 4.0 platform. The Beyond service has two pillars: Engineers with a deep expertise of the furnace and machines and software capable of running big data algorithms. Combining the experience, the power of the tools for big data analysis and the real time data that is collected continuously from the furnace, it is possible to calculate the key parameters that give GHI the information about the performance of the equipment, alarms origin and frequencies, anomalies analysis and tendencies to predict the subsystems status. The customer who integrates the furnace in the Beyond 4.0 services receives recommendations and advise about the steps to be done to maintain the best performance and increase productivity, based on the studies done over the big data analysis.

The platform is conceived as an open architecture, consisting on three layers: data acquisition, data analytics and data visualization.

Data acquisition

Raw data is gathered from furnaces PLC, external sensors and operator panels. The system allows to capture up to

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**Fig. 1:** Turnkey plants for aluminium recycling: The different sized scraps are melted in different furnaces, e.g. medium size scrap in melting towers, contaminated scrap and dross in tilting rotatory furnace. Afterwards it goes to the reverberatory maintenance furnace with porous plugs to be treated into liquid aluminium and ingots.
Data analytics
Using from applied statistics to artificial intelligence techniques. According to Gartner Data Analytics [2] there are four ways in which data can be transformed to generate value. GHI applies this approach to aluminium recycling equipment and plants as follows:

- **Descriptive analytics**: Replies to what is happening in the furnaces and processes. This approach can be used when the objective is to visualize the performance of the furnace in terms of OEE and energy consumption and have summarized results in order to compare different periods.

- **Diagnostic analytics**: Answers to why it has happened. It is used when an anomalous behaviour is observed and drilled down to the root cause. Furthermore, when the purpose is to obtain a better understanding of parameter settings and gain process knowledge.

- **Predictive analytics**: Relates to what might happen. When the intention is to forecast when a component needs to be maintained or replaced, and the prediction of parameter related to quality of the product and process as metal yield, homogeneity of temperature and the alloy, among others.

- **Prescriptive analytics**: Response to what should be done. When the production line requires time-sensitive responses in order to obtain the best outcome and when the redefinition of the production strategies is needed to save energy and time.

Data visualization
The display layer can be divided into real-time visualization and reporting visualization (non-real time). The visualization in real-time is an online visualization that aims to give the right information to the right person at the right time. Therefore, screens and alarms are customized according to the role and responsibilities of the end-user. This information can be seen in multi-platform (mobile, tablet, pc, smartwatch) and accessible at all times via internet, and allows a quick and responsible decision-making by the end user.

On the other hand, the visualization in reports has the form of aggregated information and display that helps to understand what has happened and what is likely to happen according to the results obtained after analyzing existing data. These results are always validated and ‘commented’ by expert technicians at GHI. The objective of these reports is that customers can have a greater knowledge of their production process.

In addition, the client is assisted in the decision-making phase with GHI recommendations, to move to the stage of actions that, for example, could involve the performance of maintenance tasks, adapt the equipment behaviour based on experience or offering GHI’s production assistance services, allowing to move forward from data-driven insights to data-driven actions.

The approach that is used when facing data analytics for aluminium recycling companies is the Cross-industry Standard Process for Data Mining (CRISP-DM) methodology. This methodology describes common approaches used by data mining experts. It is the most widely-used analytics model. The phases that are carried out for the Beyond4.0 services are: Business understanding in terms of case study definition or focus situation; data preparations (performed by the platform); modelling, related to algorithm programming, evaluation and deployment.

DISCUSSION
The service is aimed to detect operational anomalies, identify usage inefficiencies, ensure furnace performance and track traceability and quality metrics. These data are used to adapt equipment behaviour to customer needs, adjust maintenance practices to machinery degradation, and establish energy-saving policies.

Case 1: Early detection and solution of operational anomalies
Vortex furnaces are used to process fine-grade scrap as chips or UBC. They are reverberatory furnaces with a side-well including an agitation system, either electromagnetic or electromagnetic, that generates a vortex which efficiently submerges the load and melts it with maximum metal yield.

**Challenge**
An operational anomaly was detected by remote monitoring; the vortex furnace was not maintaining the set point temperature with a nominal chip load velocity.

**Solution**
The hypotheses of the possible origin of the problem and the necessary algorithms to confirm these hypotheses were made. The developed algorithms correlated several variables that could have an impact on the melting capacity of the equipment (gas and air flow rates, ratios, regenerative burners, cycle times, bath temperature etc).

The anomaly was detected in the electrical consumption of the combustion fan and the opening degree of a servomotor in relation to the reported measurement of the air in the flow meters.

The conclusion was that the reading of the flow meter was incorrect, since the effect of the opening of the servomotor of flow control caused an increase of the electric consumption of the combustion engine, but it was not reflected
in the registered flow. In this way, the control ratios were regulating a false reading, causing the combustion ratio to be much higher than the stoichiometric ratio, which implied an excess air intake in the furnace. This air absorbs part of the energy released by the combustion of the gas, so that the heat available for the melting of aluminium was reduced. Consequently, the sum of the energy demanded by the aluminium, the introduced air, and the losses exceeded the one provided by the burners, causing a drop in the temperature of the combustion chamber. This information was checked in the same way by analyzing the evolution of the raw data (Fig. 2).

Result
The flowmeter was replaced in a timely manner, recovering instantly the performance of the furnace with the maximum rate of chip loading.

Case 2: Smart Preventive maintenance 4.0
The rotary tilting furnace is used for melting of all types of scrap, which makes it very versatile for recycling aluminium from dross and dirty scrap. It is a headwater equipment on which the rest of the production line depends, so minimizing downtime is critical.

Challenge
The internal refractory of the furnace is subject to significant wear in the first phases of the melting due to the mechanical shock produced by the scrap into the walls and the incidence of the oxy-gas flame. Therefore, it is a key parameter to monitor in order to predict wear and assess the time at which to make a change during a scheduled stop. The traditional solution to overcome this need consists in carrying out a manual measurement labor inside the furnace, which requires it to be stopped and at a low temperature.

Solution
Through the incorporation of sensors, GHI has managed to monitor the temperature of the external metal casing of the furnace, avoiding manual measurements and giving a first diagnosis without stopping the furnace.

The graphs shown (Fig. 3) correspond to three sensors that measure the temperature at three points of the external casing of the furnace: closer to the mouth, in the intermediate zone and in the base. As can be seen in the graph, the zone of the base remains at normal temperature without major changes, because it is the area that suffers least. However, the central and upper zones of the refractory are subject to a higher temperature and an upward trend line is observed that does not appear in the base area.

Result
The calculated data is a decision source to evaluate the suitability of the refractory replacement throughout the scheduled stops of the year, making sure that the optimum
usage of the refractory is made. This allows to prevent any unexpected stop of the furnace and plan any replacement during a scheduled maintenance in a safe and continuous way. The development of the algorithm allows the automatic warning of the degree of wear and the specific anomalies that can be detected through the same sensors to plan the corresponding maintenance actions.

**Case 3: Smart Plant**

In a competitive environment and an increasing scrap market, aluminium recycling companies are preparing their processes to melt any kind of scrap with different equipment. The plants include, but are not limited to, the following equipment: tilting rotary furnaces, salt slag cooling systems, vortex melting furnaces, reverberatory furnaces with porous plugs technology, casting machines and transport ladles.

**Challenge**

The customer wanted an integral solution for the melting process in order to obtain the highest metal yield for each type of scrap and have an integral solution to control the melting process in order to establish optimal operating conditions and prevent usage inefficiencies.

**Solution**

GHI designed and supplied the complete solution that included seven furnaces: three rotary tilting furnaces for low-grade scrap, one vortex furnace for fine-grade scrap such as chips of UBC and three reverberatory holding furnaces with porous plugs to homogenize the temperature.

**Fig. 3:** Tilting rotary furnace – Temperature evolution. The graphs correspond to three sensors for temperature at three points of the external casing of the furnace: closer to the mouth, in the intermediate zone, in the base.

**Fig. 4:** Smart plant from GHI with seven furnaces: 3 rotary tilting furnaces for low-grade scrap, 1 vortex furnace for fine-grade scrap, 3 reverberatory holding furnaces with porous plugs.
and the alloy (Fig. 4). All the furnaces are sensorized and more than 1,500 variables per second are collected and analyzed by the Beyond4.0 platform and are interpreted by the Engineering 4.0 team at GHI.

**Result**

These tailor-made, flexible, eco-friendly and scalable plants, include cutting-edge technology and are conceived from the design stage to be integrated into Industry 4.0 enabling process control, optimization and continuous improvement. Furthermore, a corrective, predictive and preventive maintenance is achieved thanks to the Beyond4.0 services.

**CONCLUSION**

Digital transformation and Industry 4.0 are key levers for differentiation and competitiveness in a volatile, uncertain, complex and ambiguous metal industry. Companies must step up their ability to digitize and exploit data analytic and redefine their processes and their core competencies to adopt these advanced technologies that could have a direct impact in future competitiveness and may result in new business opportunities, better productivity and efficiency. More flexible processes, higher quality products and shorter lead times will increase the need of having smart factories that imply smart, connected and efficient equipment, and a complete integration with a better process control.

GHI provides smartization to existing and new equipment, by installing data acquisition devices and deploying data warehouses. Before data analytics is performed, it is defined operational KPIs to be monitored and predicted together with the customers. Once it is obtained new knowledge based on data, results are evaluated by senior GHI engineers and any required action is carried out. Furthermore, the Beyond 4.0 solution enables moving from data-driven insights to data-driven actions by offering advanced services, such as smart production support and smart preventive/predictive maintenance.

**LITERATURE**

[1] https://www.european-aluminium.eu


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