SmartMelt: a data-driven twin-furnace system to increase productivity and reduce energy of melting processes

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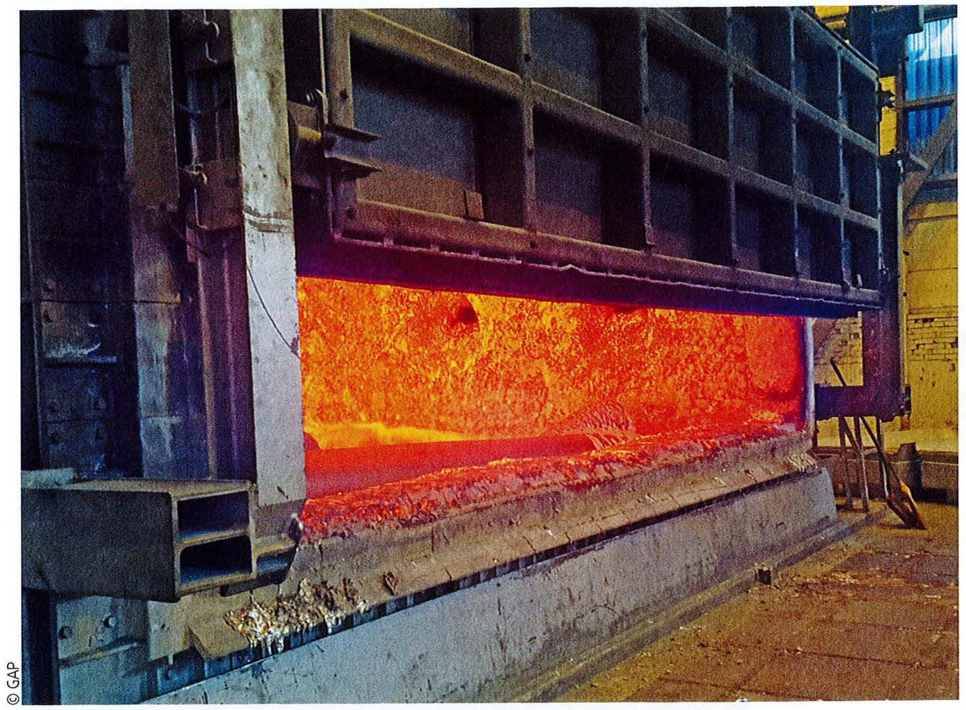

Fig. 1: A typical gas-burning furnace used for melting secondary aluminium, with the front door partially opened

Digitalization of the melting process

Today a huge quantity of process data, including loading and sensors data, is available from furnaces for melting of aluminium. Novamet has developed SmartMelt, an innovative solution which exploits this process data on-line, and so enhances productivity and reduces energy consumption and the environmental impact of melting.

The SmartMelt solution includes a digital-twin furnace, which integrates the main features of the real industrial melting furnace in a digital world. This twin is a super-fast digital model of the whole physical process, combined with big data analysis and with a supervisory control and data acquisition (Scada) system developed in collaboration with GAP Engineering. SmartMelt enables accurate prediction and optimization of process events – features which were previously unobtainable with conventional process optimization approaches. SmartMelt is a key element towards implementation of Industry 4.0 and digitalization of the melting process.

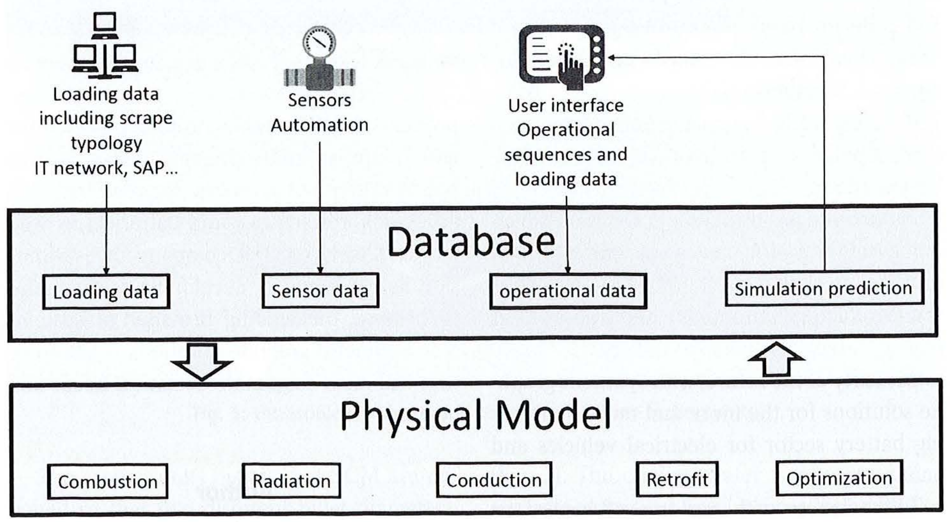

Fig. 2: Basic structure of SmartMelt, showing the flow of data between the furnace controller, the casthouse operator, the IT or SAP information system giving the scrap load and type, and the data base

Significant room to enhance cost-effectiveness and environmental impact reduction

The cost of energy associated with melting of aluminium ingot and scraps amounts to about USD12 billion per year worldwide. To this cost should be added the cost associated with the melt loss of metal due to dross generation during melting and to the maintenance and depreciation cost of melting furnaces, as well as the human resources cost [1]. Besides these costs, secondary aluminium melting has an impact on the environment, with emissions in the order of 50 million tonnes of CO_2 per year worldwide.

Melting efficiency (in gas furnaces) has around 60% margin for improvement! For example, an energy consumption of 750 kWh/t is currently considered as a good performance. However, this last number is still about three times the theoretical energy need associated with melting aluminium (about 278 kWh/t).

Improving efficiency by only 5-10% will already have a huge impact on the total energy consumption and on the associated CO_2 emissions (a decrease in the order of 2.5-5m tonnes of CO_2 per year), while also improving the productivity and thus slowing down the degradation of furnaces. That could save operational costs in the order of half a million dollars per year for a medium size furnace (30-60 tonnes capacity).

Digital-twin furnace, a new data-driven approach to improve melting efficiency

It is now standard practice to apply conventional modelling in 3 dimensions to heat exchanges in a melting furnace, or to combustion associated with a burner. However, these models are CPU-intensive, and they can only be used off-line to design a new burner or furnace. But although such optimization is highly desirable prior to putting a furnace into service in a casthouse, several operational procedures can lower the final efficiency of the melting process: multiple charging operations, door opening, stirring, skimming, etc.

Based on such considerations, Novamet has developed a revolutionary solution, SmartMelt, that combines a super-fast physically based numerical model (~1,000 times faster than conventional models) with Big Data analysis and integrated Scada system.

On-line data acquisition from the furnace controller enables SmartMelt to account for the heat input from burners via a combustion model, combined with heat loss contributions, which include radiation, conduction and convection within the furnace and the melt. Ad hoc approximations have been made to make the numerical implementation of the model very efficient, and to run it much faster (typically less than 1 s) than a typical time step of data acquisition (10 to 20 s). This has two major advantages: first, some of the parameters of the model can be adapted on-line during the process so as to best fit the measurements; second, the optimal time for any event, such as door opening or melt skimming, can be predicted accurately on-line, based on the real and current furnace conditions.

The basic flow chart of SmartMelt is presented in Fig. 2. The melting furnace controller transfers data to a database via a dedicated local data collector module, with a typical data acquisition time of 10-20 s. Additional data, such as scrap load, and scrap type, can be obtained via the IT network, either through a software such as SAP, or else manually by the casthouse operator. Other operations, such as door opening or melt skimming, are introduced by the operator via a dedicated user interface.

Using this input data, the digital model of the whole physical melting process is run and updated concurrently each time a new operation occurs. The super-fast model enables on-line recalibration of some of the parameters of the model, based on past measured data, e.g., temperatures in the vault or at lateral surfaces of the furnace. Being calibrated on-line, the model can predict the future, e.g., the time at which a thermocouple should be inserted into the melt, or the final melting time at which a given melt temperature will be reached.

Useful information provided via a user-friendly control interface

Results of the data processing and process optimizer are transmitted to the operator and line manager via a user-friendly interactive interface. This information includes the optimal times for the next operations, such as inserting the thermocouple into the melt, stirring and skimming together, with an estimated evolution of the melt temperature up to the end of the melting cycle. The same interface allows the operator to enter the amount and type of scrap loaded during multiple loading operations.

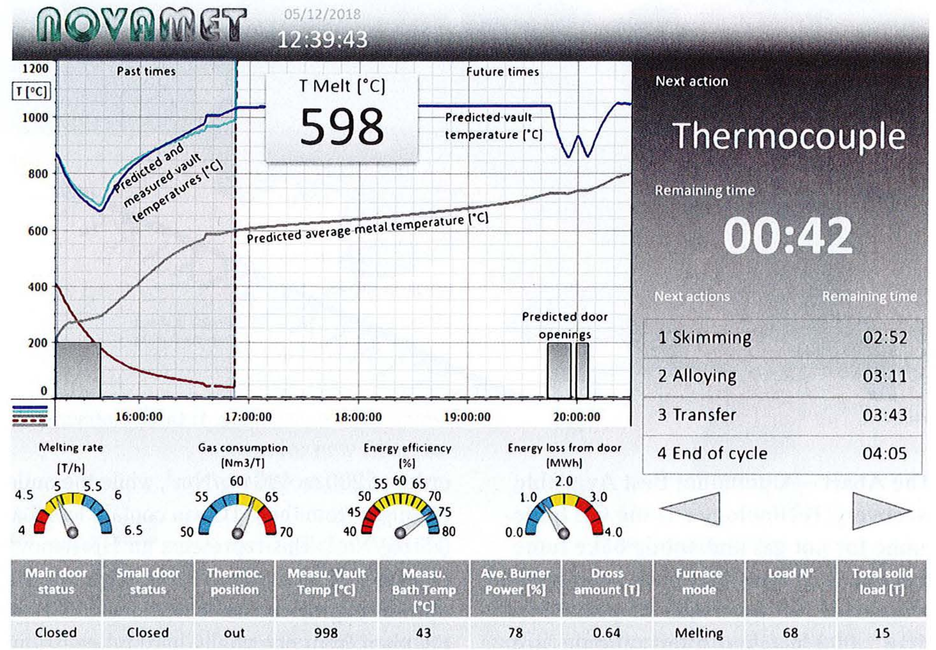

Fig. 3: SmartMelt operator interface

The calibrated digital-twin furnace enables SmartMelt to provide very useful information to the engineers, supervisors and operators of the casthouse. Most of this information could not previously be provided using other conventional methods or direct measurements. This information includes:

- Quantified heat loss contributions through various elements of the furnace (door, vault, fumes, etc.) or associated with various procedures (door opening, melt skimming, etc.)
- Abnormal functioning of the furnace indicating quantified energy loss due to e.g. a not-tight door closure, heat exchanger clogging, burner problem
- Gradual and quantified drift of the furnace due to damaged or worn ceramic liners
- Efficiency comparison of various melting process batches and / or various furnaces and / or various types of scrap via new key performance indicators.

About Novamet and GAP Engineering

Novamet Sàrl, St-Sulpice (VD) Switzerland, was founded in 2014, with a close connection with the Ecole Polytechnique Fédérale de Lausanne (EPFL). Novamet has a unique combination of expertise in the field of metallurgy, casting, numerical simulation, process optimizing and digitalization of industrial processes.

GAP Engineering Ltd, Sierre, Switzerland, was founded in October 2000 and is specialized in the field of the industrial automation and turnkey machines for direct chill (DC) and electromagnetic (EMC) casting equipment.

References

[1] Wenjing Wei, Energy Consumption and Carbon Footprint of Secondary Aluminum Cast House, Master thesis, Royal Institute of Technology, Stockholm, Department of Materials Science and Engineering, Sweden (2012).

Acknowledgement

The development of SmartMelt has been made possible thanks to the support of Constellium Valais SA, Constellium C-Tec, Innosuisse – Swiss Innovation Agency, Foundation for Technological Innovation (FIT), SPECO and Climate-KIC.

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