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Metal-from-waste processing in perfect "health"

Euro-Titan's AI-powered Big Data Platform (BDP) will be the "digital brain" of a new, low-carbon process for converting Ti-rich metallurgical wastes into high-value titanium powders. By connecting the latest modelling tools to real-time data from the process, it will be able to dynamically optimise energy and hydrogen consumption and detect failures before reaching downtime. In existing metallurgical plants, the main issue is not a lack of information but its overabundance, as thousands of signals are generated every second. The first step is therefore to filter, structure and prioritise these data streams to test the AI assistant without risking production interruptions. Typically, in an existing plant, full implementation takes about one year, with six to eight months of careful testing, deployment and software refinement. In R&D projects, the challenge is reversed, as little data are available at the beginning and even at the end of the projects. The Euro-Titan project started populating the platform with laboratory results and high-quality literature data, progressively enriching it with measurements from pilot trials. The AI models can then be deployed and fine-tuned during the industrial ramp-up, learning alongside the process during upscaling.

Euro-Titan's feed materials (bauxite residues and titanium dioxide production residues) undergo a complex combination of physical, pyrometallurgical and hydrometallurgical process steps. We use variable types of energy, H2 as a reductant, solvents and water in a circular mode, with the purpose of decarbonising the entire process value chain. H2 plasma reduction as the first step will be monitored for chemistry through inline LIBS and for mineralogy offline X-ray diffraction analysis of the feed materials. This crucial process step is constantly modelled based on direct observations on the melt, as temperature and partial crystallisation are difficult to directly control. Each processing mode produces high data volumes at each step. The difficulty lies in achieving "real-time decision-making". The specificity of the Euro-Titan BDP lies in its ability to continuously integrate these heterogeneous data streams into a single integrated digital system which can monitor the health of the process in real time. The platform can use advanced analytics and AI-driven models to identify early deviations, anticipate quality and equipment anomalies, and suggest corrective actions while processing is ongoing. Operators and process engineers are given recommendations in a timely manner, which are easy to analyse and interpret.

Imagine Euro-Titan is like a living patient under continuous medical care. Reactors, furnaces, pumps, filters and pipes are the "organs" of the process system, and the liquids, gases, slurries and hydrogen that move through the system are its "blood". The control room and operators in this "body" make up the nervous system, which senses and reacts to incidents as they happen. If one organ in a human body fails, the whole body can quickly deteriorate. The same happens with a single faulty pump or furnace: energy use increases and titanium compound qualities go down, while pollution and downtime go up. To prevent dysfunction, the plant is fitted with "medical devices" that measure temperature, pressure, flows, gas composition, material quality and the amount of electricity and hydrogen used. These are the thermometers, blood pressure cuffs, ECGs and blood tests of the industrial patient. They send in a continuous flow of vital signs to a bigger care system. The Euro-Titan Ti metal production relies on a complex combination of dynamic continuous steps which closely interact with one another, much like organs in a human body. These steps are connected by gas and water flows which digest and transport materials, just like the blood in a human body. Controlling and adjusting key parameters and consumables in this system to continuously produce Ti metal of the highest quality standard needs a Big Data Platform and fast data management to make decisions in order to avoid downtimes and inefficient operations.

As with any machine learning application, the Euro-Titan Big Data Platform has two paradoxical obstacles to overcome. Firstly, at the beginning of process development there are not enough data. Secondly, once the platform is deployed there will be too much data to handle. During initial model development, there are few examples of abnormal operating conditions such as breakdowns, process upsets or off-specification batches. There may also be insufficient logged data on details such as maintenance activities to provide important context. In contrast, when the solution is connected to a live plant it will need to analyse vast real-time data streams and determine which anomalies are important, all while avoiding alert fatigue and loss of user trust ("data deluge"). To tackle the "cold start", the Euro-Titan team curates a "teaching dataset" consisting of focused pilot plant runs, high-fidelity laboratory experiments and simulations that cover both nominal and intentionally disturbed conditions. This information is supplemented by knowledge from operators and metallurgists who label the data and create rules-based checks to help ground machine learning models in physical reality. To avoid a "data deluge" once production-scale deployment begins, a cross-functional "data and operations" team will monitor the system and function like a medical board to prioritise alerts, improve the overall explainability of the platform and ensure that cybersecurity and reliability standards are upheld. This feedback-loop approach should help the platform gradually become a digital support system that adapts to the plant.

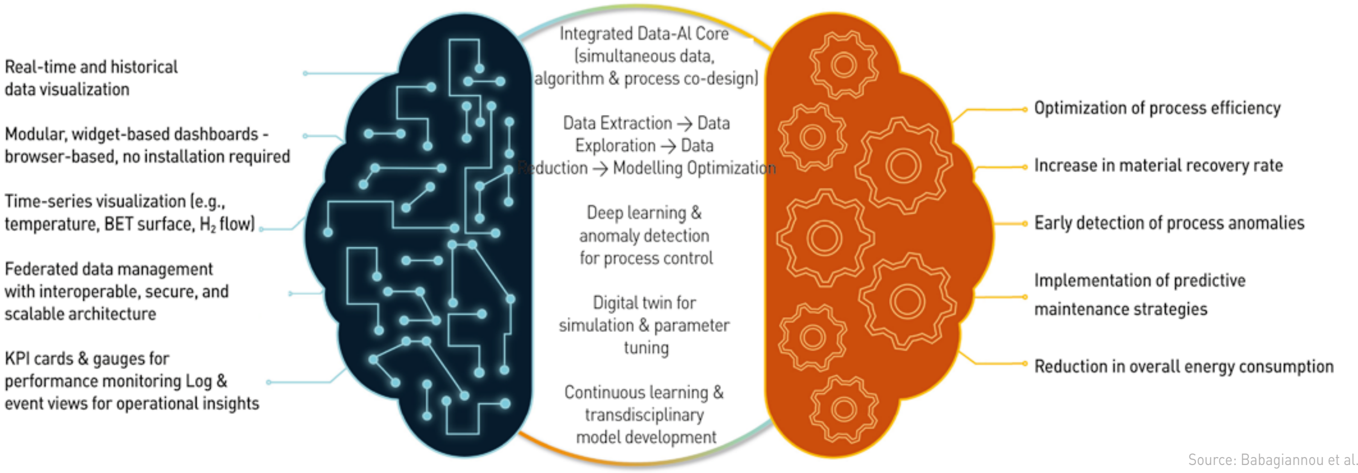
At Euro-Titan, all the experimental activities are conducted with all data fully labelled, allowing each measurement to be assigned to a given process step. Then, upon feedstock selection, subsequent management is provided by the platform of key descriptors including provenance and pre-treatment history, bulk chemistry, mineralogical phases and abundances, particle size and moisture content, reactivity indicators and inline critical operating parameters such as feed rates and temperatures. The system's intelligence will operate as a learning machine that gathers data from each melt cycle along with parameter changes to discover relationships between mineralogy and operational conditions which affect recovery stability/resource efficiency while predicting product quality and identifying equipment or process issues before they manifest. Predictive outputs will be rapidly actioned by real-time optimisation algorithms that automatically translate predictions into actions by adjusting set points/stabilising flows/reducing energy and hydrogen consumption and scheduling preventative maintenance, enabling the hydrogen plasma-melting and downstream hydrometallurgical circuit to operate at low-carbon efficiency.

Computational fluid dynamics (CFD) models provide a "virtual window" into the electric arc furnace during the H2 plasma reduction of bauxite residues. These models can show how molten slag flows within the furnace and calculate residence time and the contact efficiency of slag with plasma as well as each reactor zone. Validated by measured reaction yields, CFD models can then be used to safely test changes to design or operating parameters within the computer before they are attempted on the actual furnace. As running CFD calculations in real time is not computationally feasible for closed-loop control, Euro-Titan will leverage the accuracy of its CFD models to train a machine learning model, also known as a "digital twin" of the furnace, that can provide nearly instantaneous predictions of furnace behaviour. This digital twin enables the real-time optimisation (RTO) and input of high-quality data into the BDP. Together, these tools provide a data-driven foundation for continuously improving the process as well as a life cycle assessment (LCA).

Euro-Titan provides a "one-stop shop" solution for Europe, addressing sustainability and competitiveness in equal measure: by processing large volumes of Ti-bearing metallurgical residues that would otherwise be stockpiled or landfilled; by decreasing the carbon footprint compared to traditional titanium production routes such as the Kroll process through H2 reduction, renewable power and the circular reuse of solvents and water; and by increasing supply security through the provision of traceable, standard European titanium on-cost competitive with non-standard imports.

By Rosanna Babagiannou (SAIS LAB); Beate Orberger (Géosciences Conseils, Catura Geoprojects); Olga Petrova (Xtract GmbH); Irmak Sargin (METU); Dimitra Skentzou (SEC); Konstantinos Sakkas (SEC); Bengi Yagmurlu (TUC); Panagiotis Kolokathis (Novamechanics)

From data visualization to intelligent Euro-Titan process optimization



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