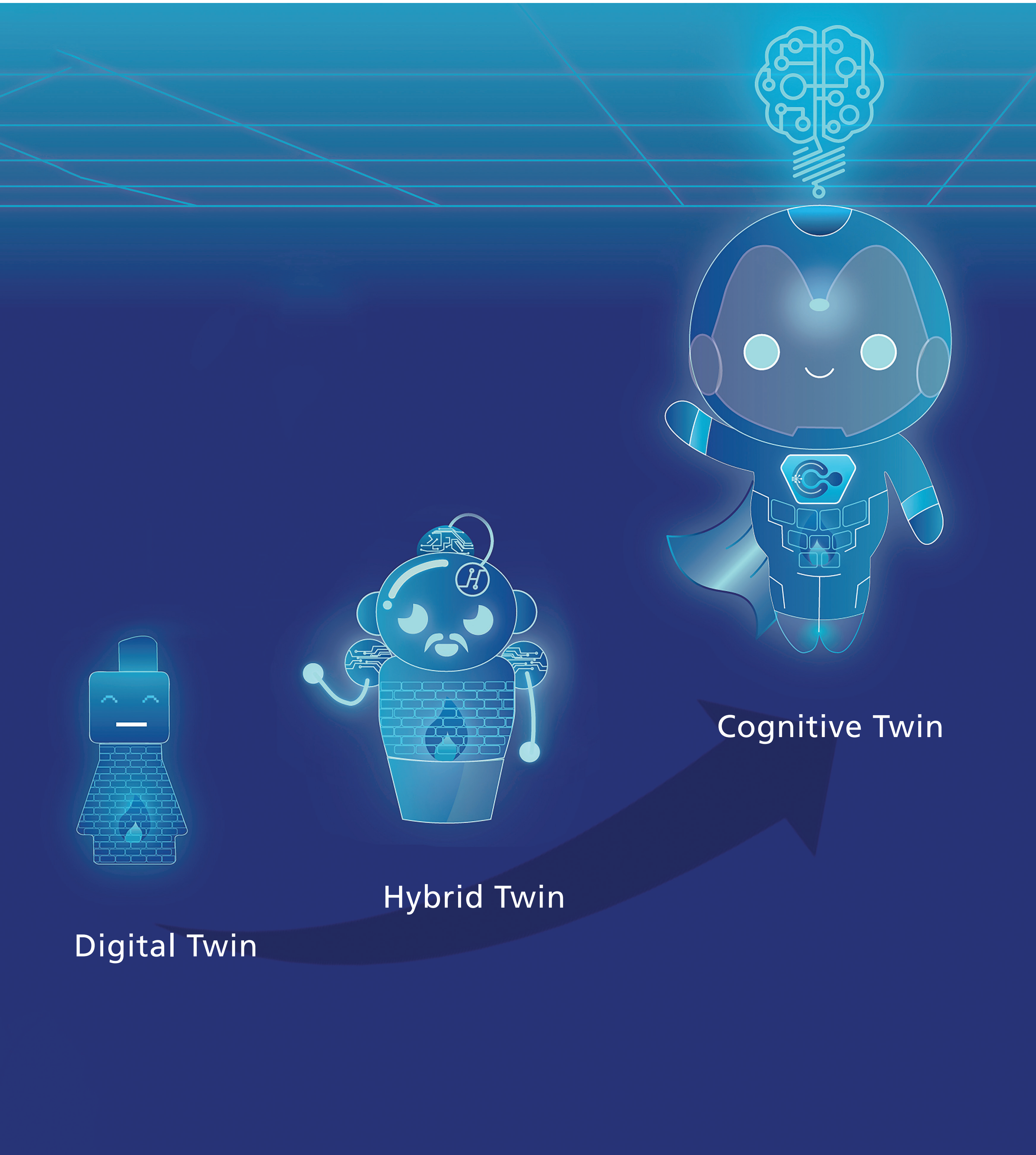
COGNITWIN



CONTENT

COGNITWIN Project Information

42 Months (1-September-2019 to 28-February-2023)

€ 8,653,170.00

14 Partners (6 Process Industries, 4 Technology Providers, 4 R&D Partners), 7 Countries

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European Commission

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Dear readers,

we are pleased to share with you the 3rd COGNITWIN newsletter.

After the first newsletter, which introduced the COGNITWIN project, and the second newsletter, which focused on the technical aspects of the project, in this newsletter we concentrate on the use cases.

The COGNITWIN project includes six challenging pilots in the areas of aluminum production process, silicon production process, steel production process and engineering boiler operations. The goal of the pilots is not only to achieve a fully digitized system, but more importantly to improve performance in cognitive production plants by using the technical results of COGNITWIN.

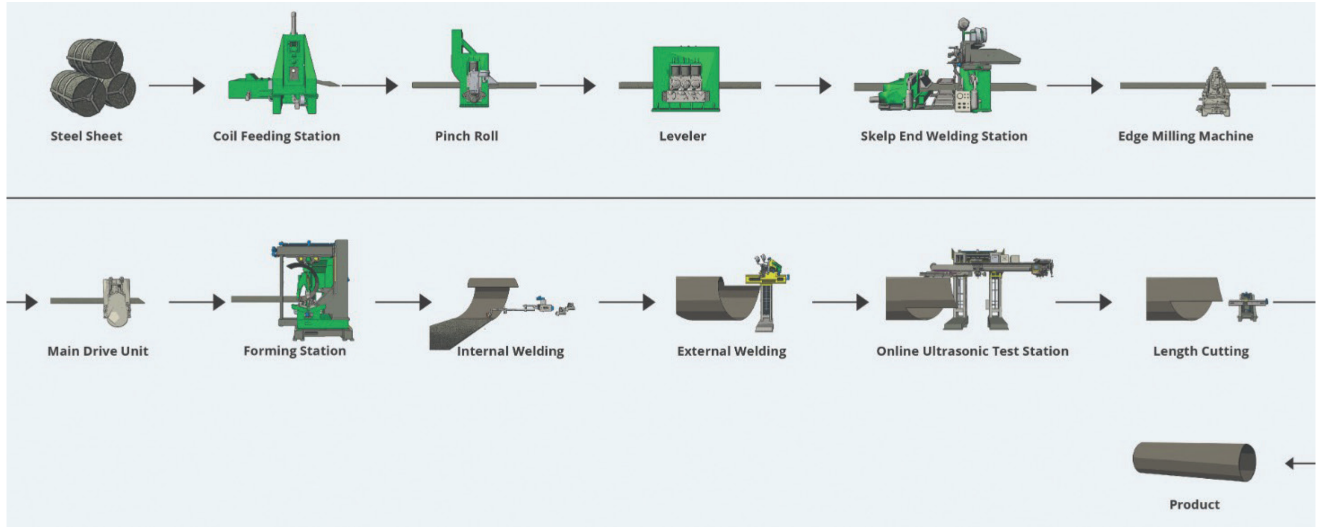
All COGNITWIN pilot projects follow the same approach, with all developments taking place in four phases: Based on the requirements specification and the definition of the KPIs delivered in February 2020, the initial digital twins were delivered in February 2021, demonstrating the collection of the existing data and the application of the physics-based and data-driven models. After the completion of the third phase, which is about the implementation of the best hybrid modeling scheme for each industrial case, in February 2022, the last phase, which will be completed in February 2023, will extend the hybrid digital twins with the cognitive aspects.

In this newsletter, the descriptions of all pilots have the same structure: For each pilot, we provide a brief description, explain the need for digital twins, and highlight the key results we have achieved so far. We also describe what we are currently working on, why hybrid digital twins are needed for this, and what next steps we are planning. To make the newsletter more attractive and draw the attention of a wider audience, the representative images for each pilot are also included.

The results achieved so far are tangible and the public videos could be found on the COGNITWIN YouTube channel. For more information about our pilots, please join our webinars. Information about the next webinars will be announced on the COGNITWIN LinkedIn.
Enjoy the reading & contact us if you have questions or suggestions!

Best regards
The COGNITWIN project

NOKSEL PILOT



NOKSEL process.

PROBLEM TO BE SOLVED

The NOKSEL pilot case is about cognitive digital twin (DT) powered condition monitoring development in steel pipe manufacturing [1]. High energy consumption and machine failures are important problems of the pilot case. Unplanned downtimes of machinery can result in large losses.

RESULTS ALREADY ACHIEVED

A DT was developed. A real-time condition monitoring system has been completed, and it is in use to support the DT to enable predictive maintenance. A demo was performed. An easy to deploy open platform was successfully established. Sensors were selected and implemented by TEKNOPAR. A service-oriented cloud architecture model was developed to integrate PLC's, smart devices, sensors, machine models and automation system information. Data acquired by the platform were preprocessed for condition monitoring and anomaly detection. SCADA interfaces were developed. MES data retrieval and integration was established. MATLAB, Simulink, and Python were used for ML/DL studies. Using the real data and data sets from the internet, different AI models were tested and compared. A library of TEKNOPAR machine learning library was enriched [2].

Feature extraction was applied, different algorithms were trained, and the trained models were tested. An application to run and compare performance of ML and DL algorithms for predictive maintenance was developed. A synthetic data generator for electro mechanical components were developed [3].

For selected ML algorithms, best performance values were presented. The trained algorithms were compared. Energy analysis and Overall Equipment Effectiveness were conducted. A DT pipeline for steel pipe welding was developed [4].

The development of virtual dashboards, showing condition monitoring was completed. The GUIs include visual representation of the machinery, dashboard items in various forms. New 3D models were developed. Role based and user-selected customizations in visualization parameters were implemented. Below table lists peer reviewed and accepted publications, and participated events

Dissemination/Exploitation Activity	Number	Dissemination/Exploitation Activity	Number
International Journal Article	1	International/national Webinars Online	2
International Conference Proceedings	4	International Conference presentations	3
Book Chapter	1	International Workshop presentations	1

CURRENT ACTIVITIES

Together with TEKNOPAR, the solution developed for the NOKSEL pilot case is being evaluated periodically. New experimental systems and demonstrations are being planned. TEKNOPAR will develop a toolbox that will be utilized by the other related pilots in the COGNITWIN project. The reason behind to develop Hybrid DTs is to prevent unpredicted downtimes which causes a big loss.

NEXT STEPS

Studies regarding calibration of the hybrid DT, and generation and testing of machine learning algorithms will continue. A cognitive DT will be developed.
A figure representing the use case is to be inserted here.

References

[1] Albayrak, Özlem and Perin Ünal: "Smart Steel Pipe Production Plant via Cognitive Digital Twins: A Case Study on Digitalization of Spiral Welded Pipe Machinery." In Cybersecurity workshop by European Steel Technology Platform, pp. 132-143. Springer, Cham, 2020.

[2] A. F. Ünal; A. Y. Kaleli; E. Ummak and Ö. Albayrak: "A Comparison of State-of-the-Art Machine Learning Algorithms on Fault Indication and Remaining Useful Life Determination by Telemetry Data," 2021 8th International Conference on Future Internet of Things and Cloud (FiCloud), 2021, pp. 79-85, doi: 10.1109/FiCloud49777.2021.00019.

[3] Selçuk, Şahan Yoruç; Perin Ünal; Özlem Albayrak and Moez Jomâa: "A Workflow for Synthetic Data Generation and Predictive Maintenance for Vibration Data." Information 12, no. 10 (2021): 386. Retrieved on https://www.mdpi.com/2078-2489/12/10/386

[4] Ünal, P.; Albayrak, Ö.; Jomaa, M. and A. J. Berne: "Data-driven Artificial Intelligence and Predictive Analytics for the Maintenance of Industrial Machinery with Hybrid and Cognitive Digital Twins", Technologies and Applications for Big Data Value, 2022-02-23.

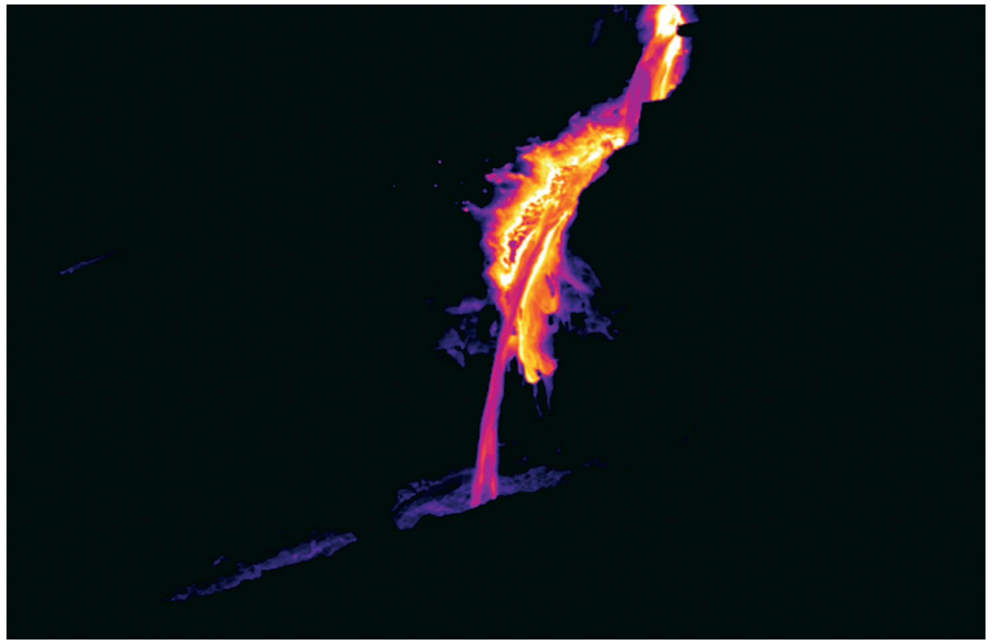
ELKEM BREMANGER PILOT: HYBRID TWIN FOR PROCESSING OF FERROALLOYS

PROBLEM TO BE SOLVED

During batch processing of liquid ferroalloys it is necessary to control the chemistry as well as the temperature of the molten alloy. Process control is based on theoretical mass/energy balance models, as well as empirical data and experience. However, due to the complexity of the system (high temperature, fluid flow, heat transfer, fluctuating input parameters) it is extremely important to measure various parameters during the process.
In particular, the temperature of the system rely key information regarding status of chemical processes. The actual measurement(s) can be done in several manners, but in general a contact free measurement does not disturb the process and is the preferred method. In the Cognitwin project, Elkem Bremanger is developing a solution for continuous temperature surveillance of the ferrosilicon (FeSi) refining process utilizing infrared cameras mounted above the ladle with liquid metal.

RESULTS ALREADY ACHIEVED

An online digital twin has been developed and installed, reproducing the current process variables and output by combining direct access to measured process parameters (such as weights, temperatures, chemical compositions) with a complete mass-energy balance developed in the early stages of the project. There is very good agreement between predicted process output and measured process output, i.e. the digital twin has been demonstrated.



Infrared picture of the tapping of molten ferrosilcon (1800 ^{0}C) from the electric arc furnace.

CURRENT ACTIVITIES

Two cameras have been installed; one at the tapping platform and one at the refining station. The idea is to have a semi-continuous monitoring of both temperature and slag during tapping of ferrosilicon as well as during refining and alloying of ferrosilicon. To obtain this, we are developing algorithms that will allow for quantification of the amount of slag as well as temperature profiles. This will provide additional input to the twin (digital/hybrid) which ultimately will allow for defining the optimal processing route for any given batch of ferrosilicon.

NEXT STEPS

Completion of algorithm development and getting these new process measurements (temperatures and slag amounts) online will be the main focus for the next 1-4 months. In addition, a third infrared camera will be installed at the casting station. This camera will be aimed at the ladle spout during casting in order to directly observe the metal stream as it is pours out of the ladle. One important issue during casting is that the quality of the final product is influenced by the amount of (unwanted) slag following the metal from the ladle. Slag in the cast product has negative effect in the customer process (foundries). By using an infrared camera to quantify the amount of slag, similar to what we are trying to achieve for the furnace tapping process, the operator will have access to precise information about the slag amount in the cast metal, and will immediately know if the quality requirements on slag contamination are met.

HYDRO PILOT: HYBRID DIGITAL TWIN FOR STABLE ALUMINA FLUORINATION AT ALUMINIUM PRODUCTION PLANT

PROBLEM TO BE SOLVED

The core electrolysis process at Aluminium Production Plants generates a process off-gas that is rich in hydrofluoric acid (HF). Because HF is a toxic contaminant, the off-gas fumes must be cleaned before being emitted to the local environment. The Gas Treatment Centre (GTC) removes the majority of the fluoride (up to 99.95%) from the fumes and returns it to the potroom, where it has an important role in maintaining the optimal chemistry of the electrolysis cell. The various activities in the Hydro pilot focus on reducing the expenses and improving the efficiency and performance of the GTC.

One of the key activities in the Hydro pilot has been to development a Hybrid Digital Twin for the HF adsorption process in the GTC. The Hybrid Digital Twin is based on a first-principles, physical model. The first-principles model is combined with data from multiple sources and augmented with data-driven methods (Kalman filter). The goal of this activity is to achieve a stable and even HF-content in secondary alumina feed by matching the feed of primary alumina through the GTC to the HF concentration in the off gas.

RESULTS ALREADY ACHIEVED

The HF concentration levels in off gas are affected by many factors, including the quality of raw material fed to the electrolysis cells, ambient weather as well as GTC and electrolysis cell operation. Furthermore, ambient conditions influence the recovery of HF from the off gas by dry scrubbing using Smelter Grade Alumina (SGA) as a porous adsorbent. If the SGA is at a constant rate based on alumina consumption in the electrolysis process, the content of HF adsorbed in the alumina will vary with the off-gas concentration levels and ambient conditions. This will accordingly influence and add undesired disturbances to the electrolysis cell operation. Due to the complex dynamics and multiple data streams, a Digital Twin is needed to capture and anticipate the impact of all these factors.

So far, the first principles based Digital Twin demonstrates good agreement with process measurements. We observe responsiveness to both long-term (mainly weather) and short-term variations (mainly process data).

Recently, the first-principles Digital Twin was installed online and preliminary connections to the different data streams were established. Figure shows an example of online, live Digital Twin predictions.

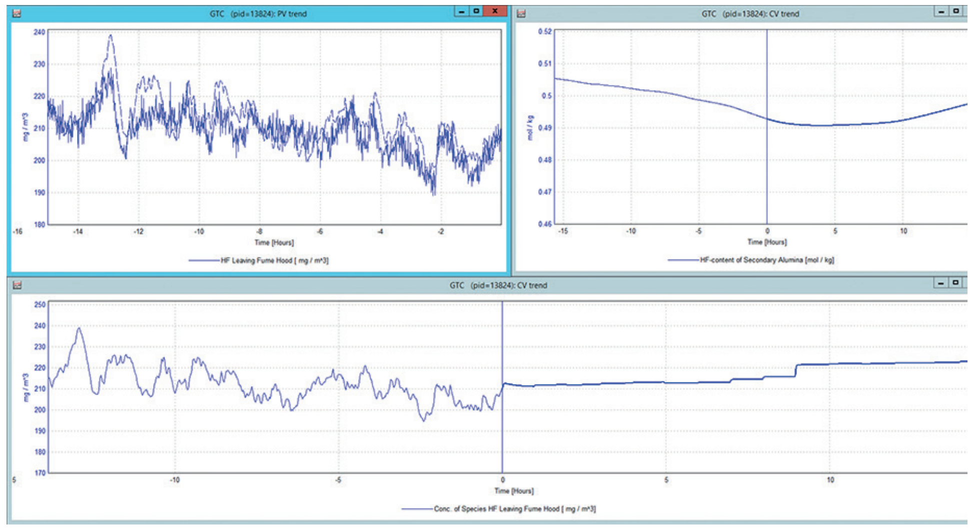
CURRENT ACTIVITIES

Currently, one of the focuses of the pilot work is defining a control scheme based on the Digital Twin predictions. In order to achieve an even distribution of HF in secondary alumina, the primary alumina feed through the GTC must be adjusted to match the HF emissions levels. Over relatively short periods of time (2-4 days), the control scheme will use the Digital Twin predictions in order to plan the plan the primary alumina feed and GTC operation that give the most even HF-content.

Extending the Digital Twin to a Hybrid Digital Twin is valuable for several reasons: 1) different data streams require processing on different timescales, and 2) the first-principles model and its predictions should be adapted to real-time measurements in order to ensure best accuracy and efficiency of the Digital Twin-based control scheme.

NEXT STEPS

Upcoming priorities for the pilot work include: 1) implementing an online Digital Twin-based control scheme for GTC operation, 2) testing the online control scheme, and 3) developing methods for quality monitoring of the Digital Twin system.



(Top left) Historical measurements (solid) and predictions (dashed) of the HF concentration in the off-gas. (Top right) Historical (to the left of the vertical line) and future (to the right of the vertical line) predictions of HF-content in alumina. (Bottom) Historical and future predictions of the HF concentration in off-gas. The future predictions only show a response to the weather forecast, as future process inputs are unknown.

SAARSTAHL AG PILOT

PROBLEM TO BE SOLVED

In one of Saarstahl's rolling mills, the mill train is not continuous. This means that rolled bars can overtake one another at certain points. The aim is to implement a computer vision tracking system to keep track of individual bars throughout the mill train.
Different components of this are for example a system for automatized billet ID identification from punch stamps, an anonymizer system for video data to protect employees' rights when working in the tracked area, and a billet tracking using Computer Vision based on monitoring camera images.

RESULTS ALREADY ACHIEVED

COGNITWIN is part of the strategic initiative AI-powered steel production at Saarstahl AG: In-house developed Deep Learning based systems for punch stamp reading and anonymization of people in video streams help lift production to the next level of cognition.
Moreover, 3D-modelling of the production site and rolled bars set up a workflow for synthetic training data generation for Deep Learning based billet/bar tracking.

A billet in the Nauweiler rolling mill.

CURRENT ACTIVITIES

Hybrid DTs are used in the punch stamp reader and the anonymization system for enhancing performances and ensuring robustness and reliability of the systems. The steel production process is characterized by harsh conditions and a demanding environment. To achieve a reliable and robust performance under such circumstances, different approaches need to interact to compensate their individual weaknesses and harvest the benefits of an interactive collaboration. The combination of data-driven models and expert knowledge surpasses any of the individual approaches in performance.

NEXT STEPS

Next steps include developing Deep Learning based systems for billet tracking and fusing these with 1st principles approaches following the hybrid and cognitive twin concept to ensure suitable performance. As for the punch stamp reader and the anonymizer system, relying only on data-driven or 1st principles approaches would not generate the level of robustness required in such a billet tracking system for a productive usage. Leveraging the benefits of both however in a combined system provides a means of getting the best of both sides. Work on the punch stamp reader system and the anonymizer system will continue as well.

SUMITOMO SHI FW PILOT: TWIN TECHNOLOGY HELPS IN MITIGATING THE EFFECTS OF VARIABLE FUEL QUALITY

PROBLEM TO BE SOLVED

Variability in the quality of the fuel needed for their operations is a big challenge for today's thermal-energy producers. Poor quality fuel can significantly contribute to harmful phenomena like fouling and corrosion in the critical structures of an energy boiler, including on its heat-exchange (HX) surfaces.

Fouling and corrosion often arise when the use of biomass and waste fuels is increased. More intensive fouling on HX surfaces demands excess cleaning, which costs time and money.

The issue stems from the fact that the quality of biomass and waste fuels may vary a lot depending on their source and structure. The quality profile of a specific batch of fuel is typically not known in enough detail that the combustion process can be optimized. This is why we believe it would be beneficial for our industry to implement new online methods to recognize fuel quality, and to find an optimal way of dealing with the HX fouling problem.

To this end, Sumitomo SHI FW (SFW) and our partners #SINTEF AS and the #University of Oulu have been working on a pilot case with COGNITWIN – a new process-industry framework that integrates AI, smart sensors and machine-learning. The pilot boiler unit is a commercial-scale Circulating Fluidized Bed (CFB) boiler designed by Sumitomo SHI FW for wood-based fuels such as clean wood, recovered wood, and demolition wood collected from both households and industry. The unit is fueled primarily by wood waste from households and industries.

RESULTS ALREADY ACHIEVED

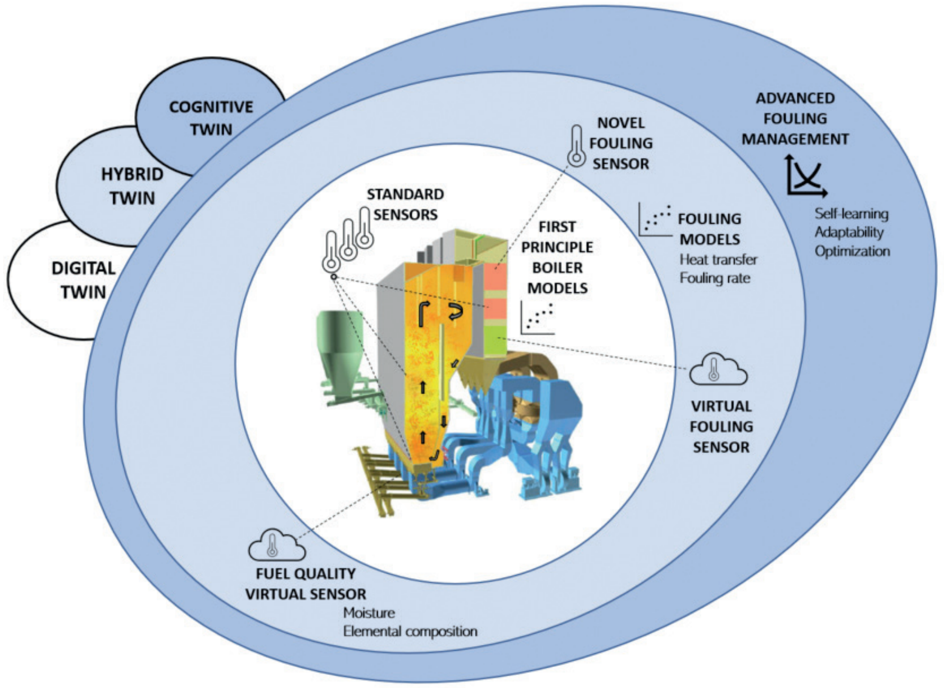
Through the pilot we are aiming to learn new ways to improve the monitoring of fouling on HX surfaces, and how to better support the control of fouling through the use of a digital twin with some cognitive capabilities. We want to improve management of the fouling phenomenon through a combination of more efficient direct and indirect monitoring methods, physical models, and the latest approaches in data science. We've been getting some promising results from these initial machine-learning-based modeling efforts.

We're also bringing new data on fuel quality into the physical model of our process, and we've developed a novel approach to the indirect characterization of fuel quality. The approach has already been tested with real operational data for integration with the pilot environment at a later stage.

In what is our second year working with COGNTWIN, we've also been setting up the required digital environment at our pilot plant. Now more than 2,000 signals are being processed and collected by our new IoT and cloud platform.

CURRENT ACTIVITIES

Currently, we are developing a novel approach toward more efficient fouling management in our pilot CFB. This means combining the physical process model, machine-learning models, online and historical process data, and sensor data to create a new kind of hybrid modelling and optimization approach for mitigating HX fouling.



Sumitomo SHI FW Pilot in COGNITWIN.

As a part of this next-generation fouling management system, we are also piloting a novel condition-monitoring scheme based on modal analysis that may provide a direct way of estimating the degree of fouling on heating surfaces. Following a successful installation, we have already gained some promising results from this.

NEXT STEPS

The results of the study highlight the relatively unrealized potential of combining physical models with machine-learning in process monitoring and optimization. We will continue to develop a more advanced fouling-monitoring system, including new self-learning and decision-making capabilities. Our expectation is that adaptive and/or cognitive capabilities can make the system even more flexible in finding optimal solutions to real-world challenges like variable fuel quality.

SIDENOR PILOT

PROBLEM TO BE SOLVED

The SIDENOR pilot case deals with operations in steel ladles. In the steel plant scrap steel is melted in electro arch furnaces. The steel is then tapped into one ladle, which serves first as an intermediate container for the tapped steel and is then transported to stations where refining and alloying is taking place. When each ladle has been through the required steps the metal is poured into a continuous casting steel tundish, which next supplies the steel to a casting machine. In addition to the metal flowing through the system, gases and alloy materials are added and off-gases, dust and some slag may be created.

The ladles are built with refractory bricks, which reduce the heat loses of the liquid steel and thermally protects the ladle. The control of the refractory life is critical in terms of productivity, environment and security. The ladles store storing the liquid steel during the production processes and are checked after every heat. SIDENOR's Cognitive Digital Twin will help to reduce refractory wear and increase operational ladle lifetime.
The goal is to increase ladle refractory lifetime to 80 heats for full relining and 40 heats to partial relining. As part of this the ambition is to reduce the critical refractory depth for renewing the refractory lining.

Merging the twin virtual replica with the production process data will improve the efficiency of the refractory change. Up to now, the decision of rebuilding the ladle is based on visual inspection and refractory thickness measurements done by workers, who are located near the hot ladle. Thanks to the digital Twin this decision will be obtain remotely, what will contribute to improve the security of the workers. Moreover, the model will give more repetitive results.

RESULTS ALREADY ACHIEVED

During the first period of the project, the limits of the refractory wear, and the relevant process data were established. All the information was shared with the COGNITWIN partners so that the first approach of the physical and thermal models was done.

The partners identified the most important parameters in terms of predicting the temperature and wear of ladle refractory. As an example, the tapping temperature was revealed to be a key parameters to obtain good values from the model.

Ladle analysis after casting the liquid steel.

CURRENT ACTIVITIES

The partners are involved with the model definition and development, checking the production parameters and the correlation among them in order to predict in the most accurate way the life of ladle refractory.

On the other hand, the results obtained from the first version of the physical model are being analyzed for assuring that the results match with the reality. Moreover, industrial trials are planned to obtain data for validating the already defined theoretical models.

The partners are defining a new share data based, where the production parameters from Sidenor will be stored. These parameters will be used by the rest of the partners so that the models will run online and evaluate the refractory condition.

NEXT STEPS

SIDENOR's Cognitive Digital Twin will be installed in Sidenor. The digital twin will be feed with the online production data, and so it will predict the ladle lifetime. Moreover, a traffic light, which informs about the refractory condition, will be install in the ladle controller computer.

CONSORTIUM

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