NCO automatic motorized rest bars for rolling guides in hot rolling mills: automation, precision and reliability for increased safety and reduced time

Nuova Carpenteria Odolese (NCO) has developed automatic, motorized rest bars for rolling guides in Hot Rolling mills. This technologically improved solution simplifies standard repetitive tasks and the precise activities typically demanded of operators.

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Fig 1 **Automatic motorized rest bars**

Today's demands on productivity, quality and safety in hot rolling mills require continuous investment in automation and precision. These investments reduce processing mistakes and process risk; they also minimize the need for operator intervention. They increase safety and the quality of operations. The motorized rest bars can reduce the cost of personnel intervention and plant shutdowns (*Figure 1*). They can improve plant efficiency and optimise intervention time. The system is able to change the working groove on the roll in a hot rolling stand when the groove is worn, without any manual intervention on the rest bars, or on the guide for its repositioning.

The solution can be provided as an original part on a new stand or as an upgrading of existing manual rest bars, with only few adaptions of the basic design (typically only the supporting flanges). They're typically fully interchangeable with standard rest bars, independently if static or movable with manual screw.

Thanks to a dedicated automation system included in the package, the rest bar can be set with the stand offline, or as standalone equipment by the operator. This dramatically reduces interventions required for setting up the line, allowing automatic recipe selection, according to the size produced and the rolls installed.

The Automation system can easily be integrated in all major existing plants, via international vendors, such as Siemens, Allen Bradley, or ABB. The Human Machine Interface (HMI) is typically installed in the main pulpit, for daily safe use by operators. It can be also replicated locally in a safe area near the stands for an intervention in 'jog mode'. The HMI displays clear information to the operator for easy daily operations. Intregration between the existing HMIs and automation is guaranteed. The system may be certified according to the major international standards such as the CE European standard and UL North American standard.

ADVANTAGES OF NCO MOTORIZED AUTOMATIC SLIDING REST BARS

This technology is based on NCO's consolidated knowhow and design of adjustable rest bars, which has been installed on modern NCO stands for rolling mills. The motorized rest bars have a range of key features, as described in the following.

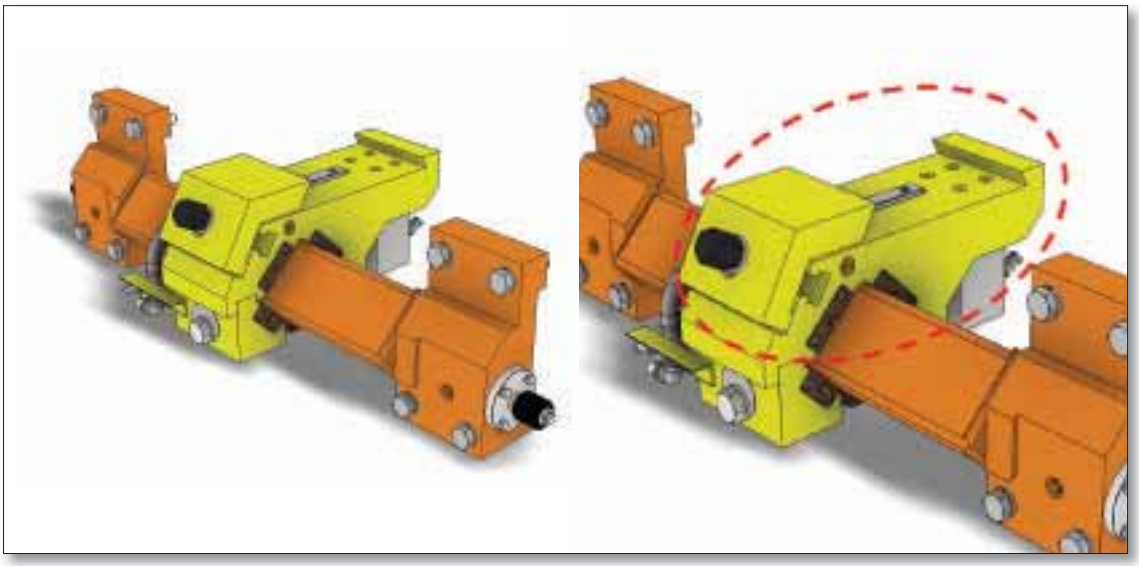

Fig 2 **Standard NCO design permits to have dedicated tailor design of the guide support**

All drives for movement and locking are electrical, thereby avoiding hydraulic systems. The guide support is positioned automatically, driven by a variable speed electric motor. The precise screw gearbox and precise longitudinal screw result in reduced backlash. Different speeds can be selected to adjust the guide support, with a faster speed for the approach and slower for precise final positioning.

The motorized rest bars, on both entry and delivery, are designed as a sturdy frame, with integrated longitudinal guides and a mechanism that ensures smooth movements. All the parts are properly covered and protected against scale and mill water. There is optimal fixing of the rolling guides, thanks to their self-retained position. No intervention by operator is required to screw, or unscrew the braking system. The position is maintained thanks to a self-aligning design and automatic release-brake system. The final position is firmly controlled and held in position remotely, using a self-braking motor and irreversible screw gearbox. No hydraulics, or additional screw for tightening is needed after positioning.

The rolling guides may be adjusted easily and accurately, by an automatic motor moving parallel to the roll axis along the sliding base, by use of a worm screw and bronze bushes. The position of the guide support is fixed by precise mechanical movements, constantly controlled by precise and dedicated sensors. This automation and the easy zero setting, guarantees a perfect position in all working conditions, without operator intervention during operations. There is quick alignment of rolling guides, thanks to the fast, precise electric motor and gear reducer, with reduced backlash. This gives precise intervention of the mechanical response and low latency of electrical and automation systems. Vertical adjustment is possible, allowing for use of different guides, or base, as a standard adjustment during the tooling of the stand. This can be done offline by the operator.

It is possible to have a horizontal installation on the stand, as well as a vertical installation, with only minor adaptations required of flanges and lugs on the anchoring system. The same solution can be fully manually operated, or driven automatically by a dedicated electric gearmotor. The position of the guide can be easily adjusted electrically, or manually during the tooling of the stand, or during a line stoppage. A manual safety mode is provided to guarantee manual intervention is possible under any conditions. A manual lever enables the motor brake to be disengaged and to permit manual movements of the guide during maintenance, with no need for electrical power.

Each rest bar is equipped with onboard cabling and a junction box to connect, or disconnect the electric signals and electric power for maintenance. Fast electric connections are properly covered and accessible for an easy plug, or unplug by the operator.

DESIGN AND BENEFITS

The symmetric design enables the system to be accessed for operation from both the operator side and the drive side. All of the parts are properly covered and so protected against scale and splashes of mill cooling water. The standard NCO design allows for tailored design of the guide support and flanges (*Figure 1*). This enables full interchangeability with any existing rolling guides for refurbishment, or upgrading of any existing equipment from a fully manual stand to a fully automatic stand. ▷

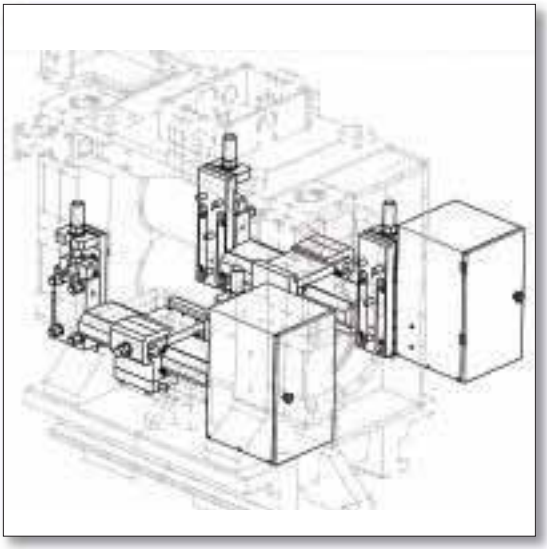

Fig 3 **Motorized rest bars inlet and outlet – typical configuration on horizontal stand**

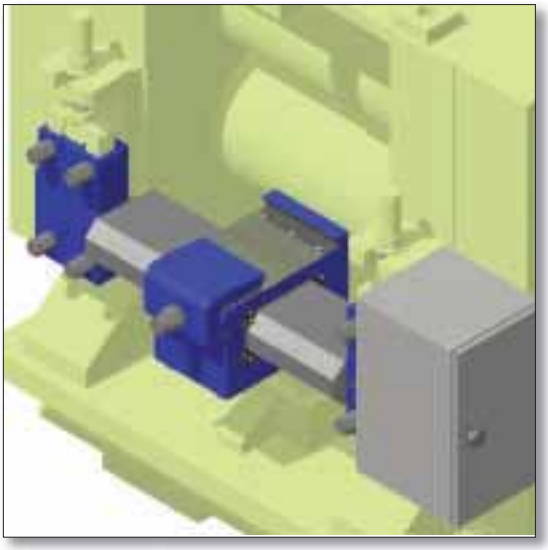

Fig 4 **Motorized rest bar – typical configuration on horizontal stand**

The design of the self-aligning system ensures low wear of movable parts. They are always aligned, with no occurrence of hyperstatic effect in these precisely guided sliding parts. Precise mechanical positioning guarantees that in standard configuration. The longitudinal position of the guide is controlled to within ±0.05mm. This control is achieved directly by automation and the encoder. There is no impact of extra weight on the stand, as compared with manual systems and optimal stand balancing can be achieved during multi-slit rolling operations.

The NCO dedicated design can guarantee general improvement in: safety, time saving, handsfree setting operations, general reliability, repeatability of working phases, interchangeability, and automatic process and flow sequences

NCO offers a remote assistance service for automation systems, which allows the connection of workstations and automation on the plant, with the workstations at the NCO server room and Headquarters. This optional module, 'NCOLink', allows for full supervision by dedicated personnel, as well as full integration in the automation system remote control. NCO personnel can have complete remote access to the single equipment automation system, or to the entire plant automation system and to operate on-line, according to the client wishes. NCO personnel can assess process parameters, set up, events and the alarm list, to monitor the situation in real time and solve problems highlighted by the client, or the end user.

A major technological advantage of this solution is the ability to install the new system in the limited space available on the stand, whether that is a brand new plant, or an existing one.

NCO has provided this equipment to premium clients worldwide, both new and as a revamping of existing manual systems. This has been achieved by combining the existing stand design with the NCO proprietary rest bar design. These features allow this system to be applied to most existing plant layouts. A typical configuration of the motorized rest bars on a rolling stand is shown in *Figure 2*, while *Figure 3* shows a render of one motorized rest bar. *Figure 4* shows a typical configuration on a horizontal stand.

CONCLUSIONS

The main advantages and overall benefits of this solution include:

- Low environmental impact, with reduced stoppage of the line for repositioning of the guide and for a reset.
- More reliable equipment and a positive improvement in plant capacity.
- Increased safety for service personnel and operators.
- Overall increase in product quality.
- No negative impact on the existing process, or general layout.
- A flexible solution for future expansion with minimal investment.

The success of this project was reliant on NCO's technology capability, demonstrating how knowhow, reliability and service are of utmost importance to the company. **MS**

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Integrating machine learning into Condition Monitoring Systems using DataXpert

Reducing the global carbon footprint in increasingly complex and volatile markets requires new ways of thinking, a willingness to change and the use of disruptive technologies. SMS group already offers not only new processes and equipment for the production of high-performance materials in the field of metallurgy, but also digitalized and connected processes as part of Industry 4.0 aimed at realizing the fully autonomous steel plant.

Machine learning models are an integral part of condition monitoring systems, as they are commonly used for processing image and time series data. In this article, we explain the approach that DataXpert takes to facilitate the integration of machine learning and provide examples of such integrations in existing condition monitoring systems.

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Fig 1 **The DataXpert applications monitor processes and control performance, enabling higher visibility of the plant condition**

Digital applications provide the leverage for resource-efficient and sustainable production processes, which are now playing an increasingly important role in the manufacturing industry. They enable plant operators to make accurate, machine learning-based predictions about production processes, product quality, and the plant's condition. Similarly, energy consumption can be predicted and optimized through the targeted calculation of raw materials.

The possibility of making accurate process predictions means that raw materials and feedstock are used according to demand, thus reducing waste, downtime, and costs. By relying on digitalization, companies can generate enormous added value from the possibilities offered by new technologies such as machine learning for the holistic optimization of production processes.

Another important topic, however, is occupational safety, and machine learning methods provide an opportunity to make important further developments. Today, for example, camera systems allow problems to be detected without humans having to enter hazardous areas. New sensor technology helps to assess the state of the production line with ever-greater precision. Condition and process monitoring systems combine data from multiple sources to provide plant operators with meaningful information and recommendations. Predictive asset management and automation will be instrumental in improving safety and mitigating risks in steel production facilities. Digital tools enable us to anticipate, respond to, and solve problems before they occur. The aim is to create next-generation steel plants that operate fully autonomously, efficiently, and safely.

SMS group developed the DataXpert platform to facilitate the collaboration between interdisciplinary teams of software developers, experts with process and hardware knowledge, data engineers and data scientists (*Figure 1*).

So, what are the specific possibilities for using platforms for efficient plant management?

LOW-CODE PRINCIPLE PLATFORM FOR EASY EXPERT EXCHANGE

DataXpert is a complete platform for developing and managing condition monitoring and expert systems that provide real-time recommendations and notifications. The platform uses the low-code principle, which allows users with little or no programming knowledge to use the tools with little training. DataXpert consists of three main modules – BIXpert, AIXpert and RulesXpert – coupled with a powerful time series database. Each platform tool is modular and can be extended to include additional functions via plugins, for example new data connectors, new visualization types and modules with new function blocks. Thanks to the use of web technologies, the platform can be deployed in the cloud and on a server close to the plant.

The DataXpert platform and its components is shown in *Figure 2*. The platform provides software solutions for:

- Data acquisition, storage, description, validation, and replication (a data lake).
- Logic/model generation and testing (RulesXpert Designer, AIXpert).
- Logic/model execution (RulesXpert Scheduler).
- Data visualization (BIXpert).

INTEGRATION OF MACHINE LEARNING MODELS USING DATAXPERT

The field of machine learning provides a set of powerful techniques for different use cases like image classification, data clustering and more. Machine learning has rapidly increased in popularity in recent years, due to the increase in affordable computation power and the availability of free software libraries for training such models. Additionally, success stories in image classification **[1]** or the defeat of the "Go" champion **[2]** exerted global interest in the topic. Machine learning also plays an increasingly important role in condition and process monitoring systems as many of the appearing problem classes can be tackled using data-based approaches. Typical applications include image processing, pattern detection, pattern classification or signal predictions.

Defining and training a machine learning model is only a small part of the complete picture. Major parts of the work to bring a model to market generally consist of tasks regarding data pre-processing, as well as for the deployment and integration of the model. Major software companies have developed their own platforms ▷

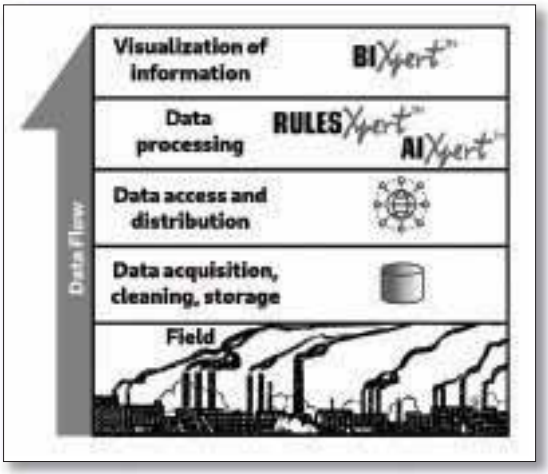

Fig 2 **DataXpert overview**

Fig 3 **Integration of a Julia model in a rule in RulesXpert**

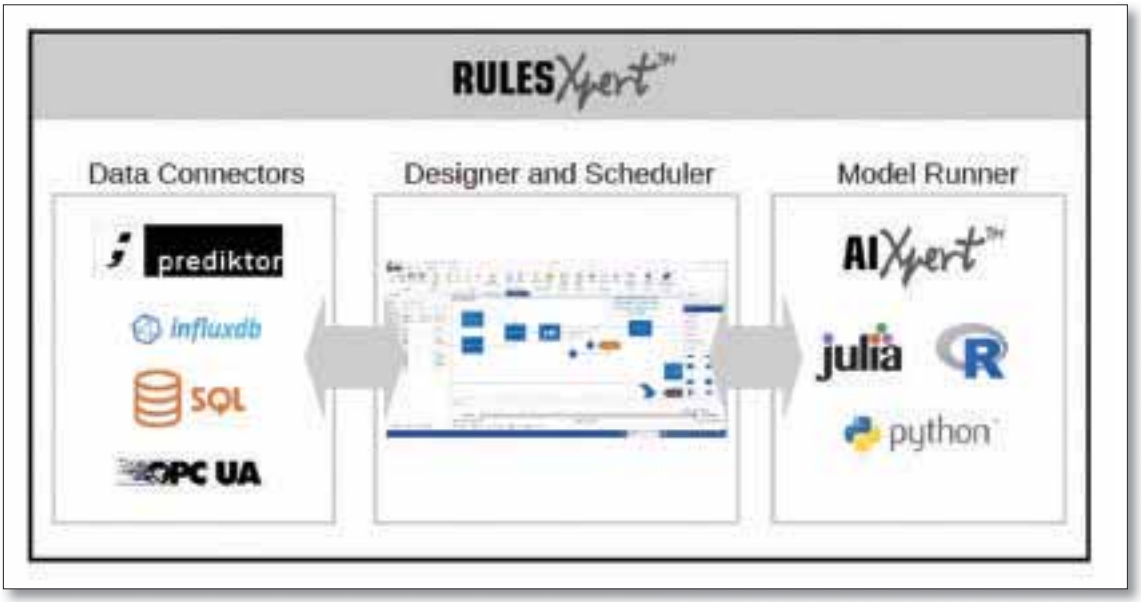

Fig 4 **Overview of RulesXpert**

to leverage this workload, such as AWS Sagemaker, Azure Machine Learning, TensorFlow TFX, and others. While the mentioned platforms focus only on machine learning, the solution developed in DataXpert is tailored towards a cyclic execution with real-time sensor data as the input. This can be done on-site without an internet connection, as well as by process engineers in a low code development environment and easy integration in a complete monitoring system that consists of more than just machine learning.

INTEGRATION IN THE DEVELOPMENT ENVIRONMENT

In DataXpert, machine learning models are indirectly integrated into condition monitoring solutions. First, the model is integrated into the development environment by the data scientist, and only in a second step by the process expert into the monitoring solution. This allows for easier separation of disciplines and gives the developer of the condition monitoring system full autonomy over his product. Using standard programming, this step would require writing a wrapper for the model, or defining and running web services. RulesXpert also uses web services as micro-services, but hides the complexity from the user.

If the data scientist develops a model using a text-based language, they only need to provide three code files. The first file defines custom functions and loads the model files. When the model process is created, this file is loaded and executed only once by RulesXpert. A second file defines the scoring function that is called, in regular intervals, by RulesXpert. Finally, a third file defines the inputs and outputs of the model. These files are then copied into a template folder containing all the additional code required to communicate with RulesXpert. The system provides a graphical user interface to select and import the folder containing the model files. After the files are imported and the run-time for the model is selected, the model is ready to be used in rules. While a run-time for each mentioned language is included by default, multiple run-times for the models can be installed in case there is a package version conflict. When using AIXpert, a single model file contains all the information required by RulesXpert and the importation is as easy as opening the model file in RulesXpert. The graphical user interface to integrate a model into RulesXpert is also used to update, enable, disable, or delete existing models in RulesXpert. The graphical user interface is shown in *Figure 3a*.

MODEL EXECUTION AND INTEGRATION IN THE CONDITION MONITORING SYSTEM

The data scientist or engineer that develops and maintains the machine learning model might be a person different from the developer of the underlying condition monitoring software. Therefore, the integration of the machine learning model in the logic of the condition monitoring system should be as easy as using any other functionality of RulesXpert. Each model loaded in RulesXpert is available as a block placed via drag and drop in the rule logic. As such, the developer of the condition monitoring system controls the cyclic model execution and all pre-processing and post-processing steps in the rule logic. An example of integration is shown in *Figure 3b*. In this example, a

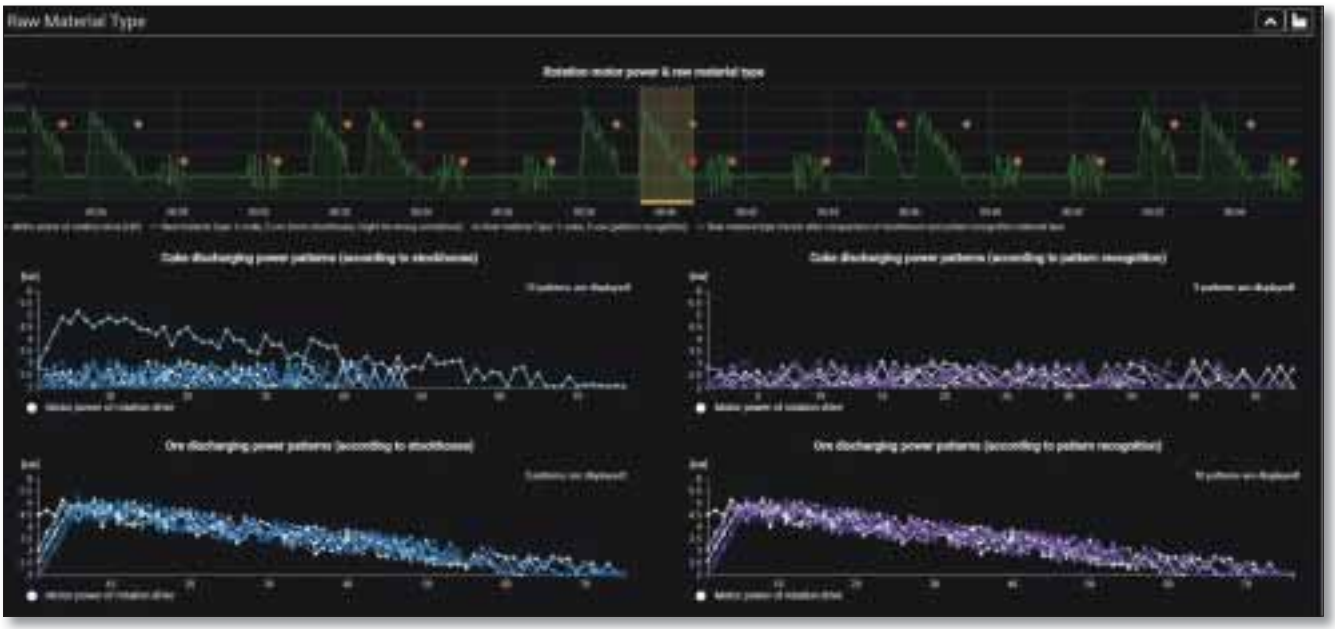

Fig 5 **Justification dashboard for pattern detection in BLTXpert**

Julia model is dragged and dropped into a rule as a simple block that is called after some conditions are checked and the input data is pre-processed.

RulesXpert schedules the rules, and starts and stops the model process as necessary and manages the data queries using the data connectors available in its graphical user interface. As such, the model can be used easily with data stored in different databases. Each model execution as well as each rule execution are automatically logged, and logs are available directly in RulesXpert. For each model execution, the model runner logs the execution time, eventual error messages of the model, and the user that executed the model. The user only interacts with the RulesXpert Designer. Data queries, model executions, or rule schedules are handled by RulesXpert. An overview of the connections of RulesXpert is given in *Figure 4*.

When a model is running in production, model updates and retraining may be necessary at regular intervals. The separation of the model, its run-time and the rule execution, allows updating of machine learning models without stopping the rule scheduler. An update is as simple as providing the new model files and selecting "update model" in the RulesXpert ModelManager GUI.

APPLICATION EXAMPLES FOR CONDITION MONITORING

The integration and utilization of machine learning models in the DataXpert platform are further illustrated with user case examples. The platform is an integral part of the Smart Maintenance program at Paul Wurth, from which the following examples are taken, and became the Asset Optimization Platform at SMS digital for steelmaking processes. DataXpert is already being used to combine various machine learning models in different programming languages or to tag time series data and then invoke a model based on that data in a low-code environment.

Pattern recognition for discharging the bell less top

The first example is a model written in Julia for detecting charging patterns in BLTXpert. BLTXpert is a condition monitoring solution for the Bell Less Top that provides alerts and notifications on a range of phenomena or anomalies as well as recommendations for equipment maintenance and operation. SMS has deployed a machine learning model as part of the rules that cross-check signals received from the stock house. The model is executed for every discharge of the Bell Less Top. A pattern detection algorithm, based on a convolutional neural network and trained with the Flux library **[3]**, analyzes motor signals from the rotary and tilt motors to distinguish between material types. Integration of the model as a simple block in RulesXpert is shown in *Figure 5*.

Notifications for potentially incorrect material information and a dedicated dashboard for the justification of the machine learning output is provided in BIXpert by clicking on the triggered notification. This justification dashboard, taken from a BLTXpert demo, is shown in *Figure 4*. A data scientist is responsible for developing, integrating, and maintaining the machine learning model. An equipment ▷

expert defines and implements the rules and notifications for this use case, resulting in a clear separation of responsibilities and efficient application of the skills available in each department.

Opening detection for tapping machines

Paul Wurth collaborated with TMT to develop a process and condition monitoring system for cast house machines called Tapman. One process rule of Tapman deals with the classification of tapping operations and the distinction between "pre-drilling" and "opening".

To detect an opening of the taphole immediately after drilling, a machine learning model analyzes the shape of various signals, mainly the feed position, to classify the taphole. In the case of a misclassification, the signal is subsequently corrected when the taphole is closed. The model in this case is a convolutional neural network written in Python using the Tensorflow library **[4]**. The model is being developed by data scientists at Paul Wurth, while TMT defines and implements the rules of Tapman.

In this case, DataXpert is used not only to separate work activities and responsibilities but also for data labeling. Process experts from TMT labelled the data in BIXpert to provide training targets for the data scientists. The output of this model is an input to several other rules, such as a rule that determines the taphole depth and the recommended clay mass to close the taphole.

Hot metal temperature prediction

The third example of a machine learning application is taken from ProcessXpert. ProcessXpert is part of BFXpert and provides process information and recommendations for actions for the blast furnace process. As an optional add-on to ProcessXpert, a machine learning model can predict the temperature of the hot iron up to three hours in advance. This information can be used to adjust the process in cases where there is an undesired temperature profiles.

A model ensemble approach is used to predict the hot metal temperature [5]. As described previously, the models that are part of the ensemble are deployed, invoked, and combined in RulesXpert. Some of the models are written in the R language using libraries such as xgboost and randomForest, while some models are trained in AIXpert. Here, DataXpert facilitates the deployment and use of the model by combining and managing the execution of all models.

CONCLUSION

The tools in the DataXpert platform facilitate the development and deployment of machine learning models. The workflow in DataXpert enables the separation of responsibilities and the invocation of machine learning models from a low-code environment. In the future, RulesXpert will be available as a web application to provide even easier access for people from different backgrounds to integrate their knowledge and models in one central location. In addition, an option for Git, a popular system for code version control, will be integrated into ModelManager to allow models to be updated remotely in an automated manner.

High plant availability and maximum product quality are key performance indicators in the operation of a plant. Artificial intelligence and machine learning have made great strides in recent years and are being used in industrial manufacturing to achieve these goals. Machine learning enables us to draw better conclusions in data-rich decision areas and helps us to assess equipment health and detect complex anomalies from real-time sensor data. Thanks to machine learning, equipment failures can be predicted, or at the very least a probability of failure assessed days in advance. It uncovers characteristics and sensor-level factors that cause a failure. Finally, it reduces huge volumes of data down to a specific amount of relevant information.

When plant know-how, process modeling experience, and modern data science are intelligently combined, the profitability of a steel mill can be significantly increased. MS

REFERENCES

[1] Alex Krizhevsky, Ilya Sutskever, and Geoffrey E Hinton: 'Imagenet classification with deep convolutional neural networks', *Advances in neural information processing systems,* 25, 2012.

[2] David Silver, Aja Huang, Chris J Maddison, Arthur Guez, Laurent Sifre, George Van Den Driessche, Julian Schrittwieser, Ioannis Antonoglou, Veda Panneershelvam, Marc Lanctot, et al: 'Mastering the game of go with deep neural networks and tree search', *Nature*, 529(7587): 484-489, 2016.

[3] Mike Innes: 'Flux: Elegant machine learning with Julia', *Journal of Open Source Software*, 2018. doi: 10.21105/joss.00602.

[4] Martín Abadi et al.: 'TensorFlow: Large-scale machine learning on heterogeneous systems', https://www.tensorflow.org/
Software available from tensorflow.org., 2015.

[5] Y. Reuter, P. Bermes, C. Schockaert, R. Lin, and J-P. Simoes: 'Blast furnace process optimization with data-driven models', *Berichtsband 32 Aachener Stahlkolloquium*, 2018.

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