Applying IIoT and AI in foundries for process monitoring and scrap

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Abstract: Implementing an IIoT solution can swiftly provide an integrated, real-time digital overview of foundry processes, establishing a reliable database for monitoring, reporting, and analysis. Integrating Artificial Intelligence (AI) optimization enhances the value of this process data, yielding performance improvements unattainable through traditional manual methods. This paper explores how data collection and storage via an IIoT system can offer significant benefits for any foundry, from identifying bottlenecks and faultfinding to measuring energy consumption, reducing scrap, and providing precise quality improvement metrics. It will detail how to integrate data from various vendors’ equipment and systems like ERP and MES through a single IIoT cloud platform, how a phased cloud implementation minimizes project risk, and how to effectively translate data insights into process improvements. With an accurate foundry database, full process optimization using service-based AI and machine learning software is now a mature and proven route to substantial performance enhancements. The paper will share IIoT and AI insights from multiple global green sand and die casting foundry implementations, including Grede (USA), Lenaal (Poland), Condals (Spain), and Morikawa (Japan). Deployed with foundry application knowledge, AI has driven an average of 40% scrap reduction in projects to date. The paper will also discuss full casting-level traceability, linking every casting to the process parameters used in its production, enhancing IIoT effectiveness in faultfinding and scrap reduction, and improving AI modeling accuracy for faster, more successful optimization.

Keywords: Foundry; IIoT data collection; energy and emissions monitoring; real-time process optimization; AI; machine learning; process control; casting tracking

1 Introduction

The casting process, which dates back centuries, can range from simple manual techniques to sophisticated, fully automated lines or cells encompassing every production aspect. Each sub-process involves numerous variables, from sand temperature to injection speed, making it challenging to manually monitor production and identify improvements. Troubleshooting often relies on experience and guesswork, and as experienced staff retire, a skills gap emerges, making it harder to control casting quality, reduce costs, and lower emissions.

After decades of manual management and optimization, digital tools are now the most effective—and often the only—way to achieve substantial gains, whether in reducing scrap levels or increasing productivity, sustainability, and equipment utilization. Foundries can apply digital tools to collect, visualize, and analyze process and machine data, then optimize their process based on these insights. Able to handle the complexity and data volumes involved, AI-driven optimization takes this further to optimize the process as a whole and automatically generate prescriptions (recommended material and machine settings) for stable, high-quality, low-scrap production.

2 Foundry digitalization – first steps

The initial stage of digitalization aims to replace manual, paper-based data collection and storage with an automated digital system. For example, a critical measure like melting furnace fill levels might be checked at regular intervals, with charging times recorded on paper and later typed into a spreadsheet. Adding a laser sensor to the shaft allows continuous measurement and monitoring to automate and optimize charging cycles, with this data routed via the machine's PLC, monitored locally, and stored for future reporting and analysis of the melting sub-process.

Many foundries already have digitally-enabled equipment: standalone systems on individual machines that make live data available locally during production. These machines may also store a limited amount of data to support reporting. A foundry may want to collect, combine, and report on data from standalone systems to build a partial or whole view of its process that staff inside and outside the facility can access. However, due to standalone system incompatibility, it is usually impossible to view data from different machines and sub-processes together in real time. The data is trapped in silos and inaccessible, requiring offline integration using spreadsheets or similar tools to construct a more complete process view.

Manual integration is slow, inefficient, and error-prone, taking days or even weeks. Merged data and derived variables are too old for day-to-day operations or to spot emerging problems in time. If sub-process data is hard to access and inconsistent, it is often not trusted by technical staff, who prefer traditional heuristic methods. This makes fault-finding ineffective, with slow root cause identification and restricted process monitoring, resulting in more scrap, longer unplanned downtime, and higher overall costs.

A single IIoT (and AI-enabled) solution like the Monitizer platform is a superior basis for foundry-wide digitalization. A secure in-house network connects standardized and compatible sensors, PLCs, gateways, and edge devices to a central storage platform. Sensor data can then be forwarded to the central database, stored, and combined with other data from across the process. This approach enables phased deployment without creating incompatible data silos. Foundries can begin by digitalizing one or two machines or sub-processes and gradually build out their infrastructure to connect every site and support their entire operation.

3 System selection and implementation: key challenges

3.1 Scalability

The initial systems and suppliers must support continued growth as a foundry's ambitions increase. A modular approach is preferred, allowing foundries to "switch on" new functions as required.

3.2 Compatibility

A foundry typically contains equipment and systems from multiple vendors. The IIoT system should gather data from any of these vendors' machines, new or old, by fitting sensors and an edge device or, if required, an upgraded PLC.

3.3 Standardization

Data from every source must be recorded, transmitted, and stored in a standardized format, allowing real-time automatic integration in the central database for a unified view.

3.4 Timestamping

Each digital data sample must be timestamped with the collection time, based on a central clock, supporting subsequent reporting and visualization, and allowing multiple variables to be merged and transformed to create derived variables.

3.5 Unique pattern identifiers

Where possible, add unique identifiers to sensor data for each product/pattern during data collection. This allows the creation of pattern-specific model training and testing data sets that increase the effectiveness of AI recommendations for machine and other settings.

3.6 Encryption and security

Data should be encrypted by the edge device as it is forwarded to the central database, preventing malicious access to foundry equipment. Foundries must ensure the entire IIoT system and supporting services are properly accredited by reputable standards bodies.

3.7 Supplier experience

Suppliers should demonstrate experience in the relevant foundry equipment and processes, previous digitalization projects and process optimization, increasing project success probability and implementation speed.

3.8 Prioritization

In phased deployments, prioritize data collection from the most important sub-processes and equipment to maximize value from the data and investment.

4 The role of IIoT infrastructure

IIoT infrastructure employs interconnected hardware and software, combining machine control systems, networking, and cloud services with specialized interfaces, processors, sensors, and other elements. Monitizer[1] is an example of an IIoT infrastructure platform (one that is also integrated with an AI platform). IIoT networks facilitate internet-based data exchange in various applications, ideally increasing system security by employing a one-way data stream to a central database. Initial foundry digitalization equipment includes edge devices, cloud systems, and more.

4.1 Edge devices

An edge device (or IIoT gateway) controls data flow between networks, performing functions like data processing, caching, routing, encryption, and streaming. An example is the NoriGate[2] IIoT gateway device.

Fig 1: NoriGate IIoT edge device.

4.2 Cloud systems

On-demand cloud storage and computing services minimize on-premise hardware and system maintenance costs, handling vast data volumes, remote high-speed processing, data sharing, visualization, analysis, and global connectivity requirements.

5 The central data platform

The central data platform should be instantly compatible with all system components, automatically fetching, validating, and storing input data while computing derived variables in real time. It should display base data and derived variables immediately, offering secure remote access via any device. The platform should have a standardized Application Programming Interface (API) for secure, automated data export to other analytics applications, store historical data for reporting, and make stored data available for comparison with live data for benchmarking and other functions.

A web browser-compatible HTML interface ensures wide display device compatibility. It should be easy to create and edit dashboards and KPIs without SQL or back-end coding knowledge, allowing users to construct personalized data views. This makes the system more effective and drives more rapid adoption. The platform should include visualization features like charting, tabular reporting, and color coding, which should be customizable without IT support. Staff should be able to access and alter dashboards and KPIs in their local language.

Notifications and alarms are essential, allowing automatic monitoring of live operations, and generating alerts if a variable exceeds a defined threshold. Alarms should be configurable based on multiple conditions or thresholds to minimize false alarms.

The central platform can be in-house or cloud-based. Cloud solutions make it easier to link multiple global sites to a single system, though this is also possible with in-house systems. Both allow monitoring and comparison of separate sites and equipment from a single remote location.

A reliable, integrated data platform offering a real-time digital process picture transforms casting operations. Accessible from any location, it supports effective decision-making and faster problem response. A merged process view reveals bottlenecks and allows data to be combined and compared to find casting defect root causes. Digitization has reduced scrap at many foundries.

6 Energy monitoring and emissions reduction

Sustainability reporting has become a fundamental aspect of business operations. For example, the EU's Corporate Sustainability Reporting Directive (CSRD) has, since 2024, mandated audited emissions reporting for large companies operating in that region.

IIoT systems can automatically collect and present accurate data on energy consumption, which, along with other inputs like material consumption (sand, water), can be translated into emissions data. Access to reliable process data makes scope 1 and 2 carbon reporting much more feasible, especially for multiple sites.

This data clearly indicates which process improvements are effective, guiding the foundry towards the most efficient and productive operational methods. Reducing scrap directly benefits sustainability by decreasing electricity consumption for remelting. For instance, a foundry melting 50,000 tons annually that reduces its scrap rate from 5% to 3% can save energy equivalent to 604 tons of CO_2 per year[3].

7 Next steps: optimization

Digitalization and analysis, as described above, are highly effective in improving individual sub-processes and revealing links between them. However, the complexity and volume of data needed to optimize the entire process can overwhelm conventional analytics. AI offers a solution. Built on a mature data platform, an AI-driven Expert Execution System (EES), such as Monitizer | PRESCRIBE, can consider all process parameters from an entire production line to maximize casting quality.

The AI first examines historical data to understand how specific parameters influence each other and affect final casting quality. It then calculates the optimal combination of machine settings and material properties for each pattern. Through advanced, unsupervised machine learning, the AI's neural network model establishes connections between final casting quality data and hundreds of input process and machine variables, such as sand grain size and inoculation rate in green sand processes or furnace pressure, die temperature, and die cooling channel timings in high-pressure die casting. This produces an initial model that specifies the optimal operating regime for the casting the data relates to.

If a part fails any quality test, it is deemed a failed part. This allows the AI model to learn and so create a generalized model to improve overall quality percentage (or decrease scrap percentage). Additionally, if detailed quality results from different tests are available, specific AI models can be created to optimize production parameters to decrease individual defect types.

However, considering all defect types together for overall quality improvement is a better approach, as prescriptions focusing on one defect type may increase the likelihood of other defects[8]. Individual-defect-level prescriptions are used to understand the relation between production parameters and quality only.

During production, the EES updates its recommendations for the control plan every 30 minutes based on AI predictions from real-time data, maintaining stable, high-quality production despite varying factors like air temperature. The EES's clear, real-time prescriptive instructions enable the foundry to make complex changes correctly on the first attempt. The model updates with new parameter and quality data during both testing and production, continuously improving optimization results.

8 Overcoming AI implementation challenges

8.1 Coverage

Collecting data from as many lines and castings as possible maximizes the data available for modeling, enhancing prescription effectiveness and confirming the AI's impact on scrap reduction. Prioritize testing and data collection from high-volume products, then extend this to lower-volume castings. This is more challenging for foundries with short runs and many products.

8.2 Compliance

Operators must precisely implement the AI's prescriptions on their machines for optimization to be successful. This can be difficult to achieve during high-speed production. AI optimization methods suggest a compliance rate of 80% or more is required for optimal performance. Lower compliance rates reduce the statistical significance of the modeling and the AI's effectiveness.

Operators must be sufficiently trained or motivated, while the screens by their machines showing conventional and AI-prescribed setpoints must be clear and easily readable. Foundries must strive to set achievable tolerances on different machines during operations (and also incorporate these limits in their future AI modeling).

8.3 Culture

System adoption is crucial for any digital initiative's success, including IIoT and AI platforms. Experienced integrators may tailor a digital system to fit a foundry's needs, but if staff fail to use it, results may disappoint. Senior management commitment and a strong change management program that empowers users are vital.

Digital tools must be user-friendly, designed for foundry use, and allow users to create and edit tools like alarms themselves. Workshops to discuss and decide on real-time KPIs and dashboard layouts before system design and deployment can shorten deployment time and system time to value. Additional steps include training, regular workshops to discuss system updates, and daily pre-shift meetings to outline goals and system usage.

9 Tracking individual castings

Process data gathered via IIoT has many applications, but conventional batch-level data in green sand molding processes often lacks the resolution needed to pinpoint quality problem root causes. Even when parameters like pouring temperature are sampled for every mold or casting, it's impossible to know precisely which data points relate to defective castings. There can be multiple interwoven reasons for defects like porosity or sand inclusions.

Using a tracking system to add a unique physical ID to each casting allows it to be tracked through the entire process. Scanning or digitally entering any casting ID calls up its individual process parameters and defect type from the process database. Casting-level data reveals when in-tolerance process parameters interact and cause scrap, which is hard to diagnose at batch level.

Casting-level tracking improves IIoT and AI optimization effectiveness, making it faster to identify influential process parameters, solve tough scrap problems, and find optimal settings for any pattern.

Basing those optimum settings on casting-level analysis should also deliver a lower scrap level.

Though casting-level data is not a prerequisite for AI optimization, it accelerates deployment and improves process performance. Because there are far more 1:1 correlations available compared to batch data, the AI model can be trained much more quickly while its process modeling should be more accurate and its recommendations more effective, maximizing scrap reduction.

10 Digitalization case studies

10.1 Condals

Condals Group operates three DISAMATIC moulding lines: two in Spain and one in Slovakia. Deploying an IIoT solution[4] brought all its data together in a unified cloud-based database, replacing multiple data silos and slow manual data integration. The next stage was full process optimization using Artificial Intelligence-driven analytics[5].

In 2021, initial testing on two patterns reduced scrap rates by 39% and 45% respectively. In the following years, Condals has implemented AI-driven optimization on its two Spanish lines, with Slovakia to follow later in 2025. The two main influences on optimization effectiveness have been model coverage and compliance with prescriptions.

Coverage is vital. applying AI optimization on both Spanish lines for as many patterns as possible maximizes the amount of data available for process modelling and helps confirm the influence of the AI's prescriptions on scrap reduction.

The AI shows the foundry which parameters have the largest impact on scrap. Then the operators must comply, ie, precisely follow the AI's prescriptions on their machine settings. However, this can be challenging to implement during high-speed production.

Cultural change is vital here. Condals works constantly to motivate operators to implement prescriptions exactly and also to discover from its personnel the tolerances that are actually achievable on different machines during operations. These "real-life" constraints are now fed into the AI modelling to ensure the prescriptions are adjusted for easier compliance. Compliance and model development is also aided by regular meetings with its digital partner and continuous KPI reports that track compliance and coverage.

Whether it is the foundry's own setpoints or those suggested by the AI, training operators to focus on precisely following instructions has improved the foundry's process. Operator compliance is greatly aided by using the integrated Monitizer[1] platform, which combines IIoT dashboards and the AI's prescriptions in a single view.

Condals has recently implemented casting-level tracking[6] and expects this more accurate view of its process to further improve the precision of the AI-driven prescriptions.

10.2 Lenaal

Polish high-pressure die caster Lenaal connected all aluminum cells at its 10,300m² production facility to a digital furnace monitoring system[7] to improve operational efficiency and increase production capacity. The solution continuously checks dosing furnace fill levels against metal consumption in the die casting process. Real-time KPIs are displayed on a simple dashboard, indicating when to refill, which alloy to use, and the required metal weight.

Following a successful pilot in 2023, more lines were added to the solution and two more casting cells added, increasing production output by 65%. Lenaal now monitors all 13 of its dosing furnaces. Engineers use the system to track and compare KPIs from each line, including furnace temperatures, dosing cycles completed over specific time frames, and average metal dosed per cycle. Since implementing the system, Lenaal has recorded 25-50% extra production uptime.

10.3 Grede

Grede is implementing IIoT[4] and AI-driven optimization[5] at all nine of its US foundries, connecting melt, sand, and molding sub-processes in the first phase, followed by AI in the second. The project aims to create a single standardized database and replace slow manual processes with automated data collection, timestamping, and integration. Upon full implementation, Grede's foundries and senior management will be able to view historical and real-time production data side by side across all processes at all locations.

Choosing a foundry-specific supplier has cut 80% of the time required to configure KPIs and dashboard reporting. The supplier's engineers are considered an extension of Grede's IT team. As experienced senior staff retire, the IIoT and AI systems aim to support and guide operators and engineers. In a pilot project at one facility, Grede is deploying a system to track castings at an individual level.

Sophisticated alarm functions enhance production control and support inexperienced users. If an issue needs attention, the system contacts different groups in waves, depending on how the problem develops and whether the first alerted group reacts. Grede has connected its sand equipment and molding machines, allowing operators to see if their machine and other process elements are on track. If a machine drops out of tolerance, they can act immediately to prevent scrap. The first five connected foundries reported scrap reductions by mid-2024, with one facility cutting scrap by 50% by reducing sand inclusions.

10.4 Draxton

Draxton, a global manufacturer of cast iron and aluminum components with a total annual casting capacity exceeding 620,000 tons, has reduced downtime, energy use, and resource consumption after deploying an IIoT solution[4] at its foundry in Barcelona, Spain. The foundry produces complex components for brakes, powertrain, and transmission systems, primarily for the automotive industry in North America, Europe, and China.

Draxton's furnace and pouring unit, sand plant, two DISA molding lines, the entire suction system, and the shotblast machines were all digitally connected. Data was securely collected from equipment and brought together within the IIoT solution's cloud database, presenting a single view of the process. Different dashboards were established to ensure Draxton could view the most useful KPIs as needed to monitor production and facility parameters. Authorized users have personalized dashboards showing information most relevant to their roles and requirements.

Alarm functionality has enabled Draxton to convert employee expertise into automatic monitoring based on conditions and thresholds met, identifying upcoming problems—a capability that has dramatically transformed production control. The system supports monitoring, analysis, and insight across all production areas and equipment. If potential problems are flagged, the Draxton team uses their digital platform to analyze them by querying process data to find the root cause and the right course of preventative action. For example, Draxton can now digitally identify premature wear in furnaces: when any parameters fall out of specification, the system automatically notifies both the maintenance and production teams.

Before implementing their digital solutions, Draxton struggled to remove a bottleneck caused by insufficient molding sand for their two lines. By using data, it was possible to vary the sand plant's cycle time to match the amount of water added to the sand plant. This has removed the bottleneck and stabilized sand quality while also cutting water and energy consumption. By optimizing processes across its entire production setup, casting quality has improved, and energy and resource consumption has reduced, aiding Draxton in lowering its carbon emissions.

10.5 Shot blasting

A large German manufacturer of hand tools digitalized its shot blast processes to make real-time process data available to drive process optimization. A better-controlled and more stable blast process reduces the amount of reworking required, improving product quality. By making the blast process digitally visible, it can be monitored in real time so supervisors can spot deviations from permitted ranges and initiate countermeasures immediately. One of the most important goals was to constantly optimize the abrasive mix, which significantly influences blast quality, intensity, and stability.

A Wheelabrator MB400G tumblast machine was digitized in a pilot project. IIoT system dashboards were created to generate and track metrics and KPIs, such as power use, turbine speeds, and operating status. A traffic light system alerts operators and managers if target values are exceeded. The data quickly revealed a maintenance error that regularly caused a clogged rotary screen, leading to abrasive overconsumption and process instability. Discovering and correcting this error has significantly improved process stability and reduced the rework rate. The manufacturer extended the IIoT system to its other blast machines.

10.6 Results from AI-driven process optimization[5]

For commercial sensitivity, the following results do not specify starting-point scrap rates; instead, improvements are shown as percentage decreases. Note that uplift percentage is expected to be proportional to baseline scrap rate when utilizing prescriptive AI as outlined in this paper. For example, if the baseline scrap rate is 10%, achieving an uplift of 50% is easier than starting from a baseline scrap rate of 2%. However, in real scenarios, a high uplift is achievable even with a very low baseline scrap rate.

A global automotive OEM utilizing low-pressure die casting implemented an AI-driven Expert Execution System (EES) to reduce scrap produced during its light-alloy wheel manufacturing process. A scrap reduction of 29% was achieved. Extrapolating this result to all products and furnaces at the site, it was concluded that this scrap reduction would result in a gross annual saving for the plant of more than €0.5m and a production volume increase of 2.4%.

Following AI-driven process optimization, a Chinese automotive parts die caster reduced its average scrap rate by 52% in its first production batch. This performance was maintained in subsequent batches, with predicted annual savings of €130,000 if rolled out foundry-wide along with additional energy savings and productivity gains.

Japan's Morikawa foundry started to implement its digital platform in early 2021, rapidly progressing to AI-driven optimization of its green sand process, with initial testing starting in 2022. The first tests on two different patterns cut scrap rates by 66.6% and 86.9%, respectively.

11 Conclusion

Traditional manual techniques are insufficient for the needs of a modern foundry. Digitalization provides the data and tools required to manage and further improve casting production. An IIoT system that can collect and send data to a single, central database is the optimal solution. The central database must be easily accessed and combined with tools that allow monitoring, visualization, reporting, and analytics.

Any IIoT system and associated services must offer a pathway to future expansion to allow a foundry to easily extend digitalization to its entire process or implement digitalization of all functions is the best way to build a live, unified view of production and unlock the benefits digital platform and a single central database to support outlined above. The supplier that the foundry partners full process optimization. Again, employing the same with should have substantial foundry experience and demonstrate success in foundry digitalization.

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