Jeong, Duk-Kyoon
Senior Vice President, POSCO ICT

Accelerating Digital Transformation with Smart Factory to Unlock New Value: Case of POSCO

The Fourth Industrial Revolution is bringing massive changes to mankind through accelerated integration of traditional industries and ICT. The Internet of Things (IoT), Big Data, and Artificial Intelligence (AI) are forcing traditional industrial structures to rapidly change. The scale, scope, and complexity of these changes will be unlike anything mankind has experienced. It is no coincidence that new startups such as Google and Tesla have outpaced traditional market leaders such as IBM and GM. This is a sign that the time has come for companies to move beyond the limitations of traditional practices and seek innovative transformation.

Manufacturing plays a fundamental role in the economy, accounting for 16% of the world's GDP and 62 million diverse jobs. Since the start of the Industrial Revolution 200 years ago, manufacturing has changed the world through relentless advancement in the automotive, chemical, machinery, electronics, and materials industries. There is no doubt that manufacturing will continue to lead technological innovation in the future. Products that will totally change our way of life are continuing to emerge: electric vehicles, self-driving cars, drones, and humanoid robots.

At the heart of the Fourth Industrial Revolution, manufacturing is poised to shift from "traditional" to "smart" through integration with ICT. Leading global companies are already seeing new growth opportunities through breakthrough innovations. General Electric is moving away from its core financial business towards smart manufacturing under the name "Industrial Internet." Siemens's Amberg factory has significantly reduced defect rates through IoT technologies, and boasts the world's best production quality rate at 99.9988%.

POSCO, one step closer to smart factory

In the face of the great paradigm shift brought on by the Fourth Industrial Revolution, many Asian steelmakers are taking preemptive measures to maintain competitiveness and contribute to the advancement of manufacturing. POSCO is also

Figure 1. Goals of Smarter POSCO mandate

one of the leading global steelmakers in this arena.

POSCO has been working diligently to adapt to this paradigm shift with the Smarter POSCO mandate, not only to continuously reinforce the competitive edge of its core business, but also to contribute to the advancement of manufacturing industries. The Smarter POSCO mandate calls for creating new, differentiated value through digitalization and intelligence to unlock potential value. Digitalization involves storing, analyzing, utilizing, and emulating the data generated by people, products, assets, and operations. Intelligence harnesses the power of advanced machine learning technologies to enable machines to understand, execute, and improve best practices.

Encompassing the goals of the Smarter POSCO mandate, POSCO defines smart factory as an intelligent factory that senses, analyzes, and controls itself by closely investigating and analyzing production processes using ICT to optimize production, thereby reducing costs, eliminating defects, and minimizing downtime.

In concrete terms, a smart steelworks is a facility that gradually evolves through "smart sensing," "smart analytics," and "smart control." Smart sensing means collecting, translating and connecting data from production sites in real-time, increasing data's visibility. Smart analytics predicts the status of production processes, that is, the flow of products on the factory floor and the conditions of manufacturing assets, based on the integration of technological (metallurgical) theory, expertise, and big data analysis. Smart control means that intelligent machines learn best practices and optimize production.

The world's first continuous-process steel plant model

POSCO's Gwangyang Steelworks produces plates for ships and offshore structures. The factory houses integrated processes for steelmaking, continuous casting, and rolling. In formulating smart factory for steel manufacturing, the following indus-

The Fourth Industrial Revolution has already started and is expected to have a great impact on the survival and development of companies. Steelmakers will strive for long-term innovation to realize smart factories by interconnecting data across production operations, quality and maintenance, upstream and downstream production processes, followed by lengthwise alignment of material-to-final product data.

try-specific requirements have to be factored in.

First, it is difficult to determine the root cause of defects in plates by tracing processes because the physical properties of steel change when molten steel solidifies into plates during the continuous casting process, and plates are frequently cut, flipped, and rotated. Second, adjusting or changing upstream and downstream production processes that are online is costly and difficult. For example, all materials are scheduled to go through production routings and steps in a predetermined order. If trouble occurs in the middle of a process, former processes might be suspended until the problem is solved. Third, various materials are processed in the same facility, and a number of facilities and production methods are involved in making one kind of product, making it difficult to find the exact cause of a problem.

Recognizing these complexities in producing "World Premium (WP)" products, the Gwangyang plate factory is building a model for the smart factory by applying IoT, big data, and AI to production, worker safety, and cost management.

POSCO tailored Germany's Industry 4.0 approach to meet industry-specific requirements with the following refinements: 1) Converted academic and conceptual theories into practical, applicable actions at the shop floor level; 2) adopted a value-centered, outcome-driven approach aligned with relevant policies; 3) integrated domain knowledge with information and communications technology, rather than simple information technology-driven implementation; 4) employed an evolutionary approach rather than a big-bang approach, and 5) flexibly adapted strict Industry 4.0 standards that made sense for deployment at the shop floor.

Here are the details and major outcomes by phase of the smart factory at Gwangyang Steelworks.

1. Selection of smart factory projects

In order to increase global competitiveness and maximize customer value, POSCO developed a mid- to long-term vision for the Smarter POSCO mandate. Initiatives were then derived in the

Table 1. Industry 4.0 vs. POSCO Smart Factory Approach

Industry 4.0 Approach	POSCO's Approach
Academic / Conceptual	Practical / Applicable
Policy-driven	Value-driven
ICT-oriented: Low domain knowledge integration	Convergence-oriented: Full domain knowledge integration
Big Bang approach	Evolutionary approach
Strict Standards	Quasi-standards

areas of production operation, quality, maintenance, safety and energy. New ideas were born through cooperation between experts in steel, R&D, and IT, and were given shape in integrated projects involving IoT technologies focusing on sensing, analytics, and control.

Feasibility and potential outcome were among the high priorities in the selection of projects, with goals including quantification and automation of work that used to depend on experience, combined analysis of interconnected processes, utilization of forecasting and prediction models, and expansion of autonomous control.

2. Development of the "digital genome map" to tackle challenges of smart factory initiatives

POSCO undertook an extensive, thorough assessment of data residing not only in production control systems, e.g. PLC/DCS, but also in business systems such as ERP and MES, as well as the data generated by individual sensors installed on production machines. This rigorous exercise was geared towards the following: 1) identifying data likely to impact production operation and quality that had not been captured, stored, or used (structured/unstructured and macro/micro data); 2) standardizing descriptions and attributes of about 60,000 data entities to ensure that all stakeholders involved have a common understanding; and 3) charting out the digital genome map of steelworks by interconnecting data across production operations, quality and maintenance, upstream and downstream production processes, followed by lengthwise alignment of material-to-final product data.

To achieve this goal, POSCO has made full use of microdata on manufacturing, where previously we used only 6% while discarding the remaining 94%. Additionally, we have collected new, additional data using IoT technology.

In cases of customer claims, it is now possible to quickly and easily trace the exact point where a defect occurred, all the way back to raw materials. An issue can be addressed before it carries into the next process and the cause of a previous process' issue can be resolved in the middle of production.

3. PosFrame—POSCO's smart factory platform for continuous process industries

Generally, a software platform is common software where various applications can be developed and serviced. A smart factory platform works as a software substructure that supports smart sensing, smart analytics, and smart control to realize a smart factory.

PosFrame is POSCO's purpose-built platform

> Generally, a software platform is common software where various applications can be developed and serviced. A smart factory platform works as a software substructure that supports smart sensing, smart analytics, and smart control to realize a smart factory.

for process industry applications. It empowers POSCO to: 1) apply the digital genome map to production operations through high-speed collection and inter-connection of structured/unstructured and macro/micro data; 2) rapidly convert smart factory initiatives in domains such as production operation, quality, maintenance, safety and energy into applications with the same ease and speed as building and deploying apps for smart phones; 3) leverage a common platform to adopt emerging technologies, including IoT, big data, and deep learning, which are required for smart factory implementations at the enterprise level; and 4) cost-effectively roll out the smart factory model to other similar factories with standardized, re-usable software components. In the future, POSCO will continue to adopt new ICT for this platform and blend it with global best practices.

4. Smart factory project execution and results sharing

POSCO ran pilot projects to validate business cases and to secure success stories before initiating full-blown smart factory projects. The experience of each preliminary project was applied to the next project, leading to a continuous evolution and development of technologies and experiences. Success cases were replicated at similar plants in order to reproduce outcomes.

The smart factory plant, scheduled to be completed in 2017, seeks to change maintenance, operations, quality, safety and energy as follows:

1) Maintenance: Pre-scheduled and regular maintenance and repairs of defects will be replaced by predictive maintenance that finds defects in advance.

2) Operation: Pre-scheduled production will be replaced by real-time, adaptive production, resilient to changes in demand, quality, and maintenance status.

3) Quality: Reactive quality control will be replaced by real-time, on-the-spot quality control.

4) Safety: Worker safety has historically depended on physical barriers and safety training, but IoT technology will automatically identify danger

Table 2. Changes Implemented by Smart Factory

Area	Change
Maintenance	Corrective maintenance → Predictive maintenance
Operation	Pre-scheduled production → Real-time adaptive production
Quality	Reactive average quality control → Real-time on-the-spot quality control
Safety	Passive safety guidelines → Active preventive safety
Energy	Fixed Allocation → Demand-based Allocation

and sound alarms.

5) Energy: Pre-arranged energy production and distribution will be replaced by optimal energy production and distribution based on changes in supply and demand as well as changes in the operating environment, thus saving costs and reducing CO_2 emissions.

In addition, virtual factories, which are currently used for training, will make product development possible in cyberspace, reducing time and expenses.

Key smart factory projects of POSCO

The following are some smart factory projects for the Gwangyang steel factory: analyzing causes of defects using a digital genome map, addressing issues using big data, and utilization of AI and virtual factories.

1. Material to final product defect tracking

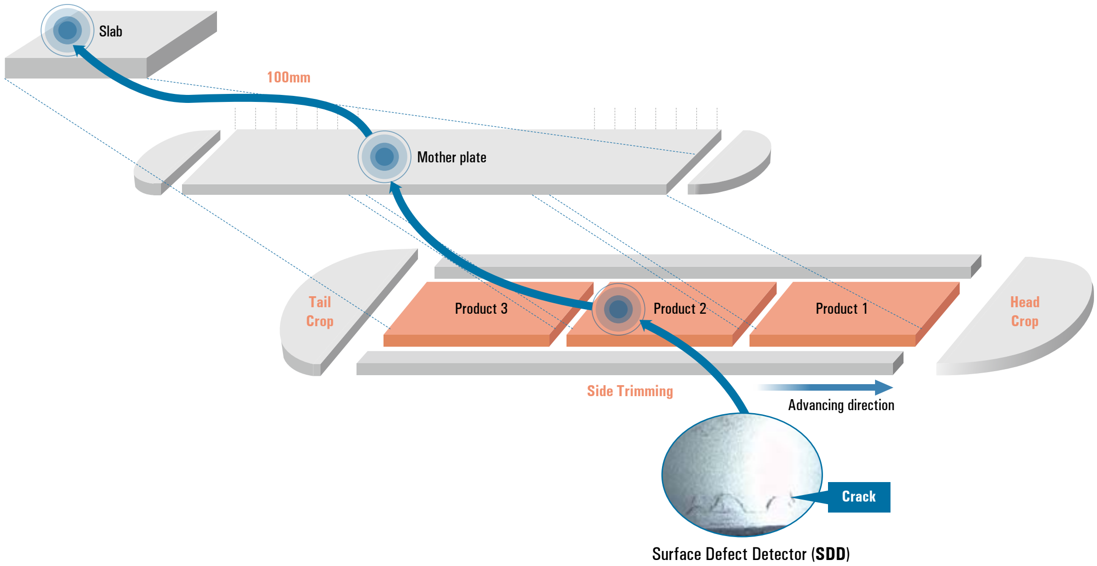
During the course of processing plates, the steel frequently changes length and shape. Therefore, quality control engineers need much time and effort to collect and analyze hundreds of thousands of data sets generated during each process in order to identify the causes of defects. It is also difficult to find the precise cause. To solve this problem, POSCO has devised a way to collect real-time macro and micro data on operations, quality control, and maintenance corresponding to each unit of length and width of products, and connecting the data from each process phase, thus more than halving the time needed for engineers to analyze data. For example, if the surface defect detector (SDD) detects any cracks in a plate, operation, quality control, and maintenance data from the previous processes are analyzed in 100mm increments of the product in each phase, tracing back from plates to mother plate and slab, as shown in Figure 2. Doing this allows engineers to determine the precise cause of a defect, leaving more time for product improvement.

2. Minimizing unnecessary scarfing in the continuous casting process

The scarfing process, which removes surface defects from slabs, is the highest bottleneck process. WP products are all scarfed, as they demand high quality. However, in the case of general steel products, only slab samples are examined, and if there is a defect, the whole lot of slabs with the defect is scarfed. This means that normal slabs are unnecessarily scarfed. The recent increase in production of WP products has overloaded the scarfing process, necessitating the expansion of production capacity.

The Gwangyang smart factory analyzes struc-

Figure 2. Surface Defect Traceability



tured and unstructured data from connected processes and automatically detects surface defects on individual slabs. This allows the scarfing process to be conducted only when necessary, thus reducing the load and using the current scarfing capacity to produce more WP products. Finding the root cause of quality defects improves the upstream processes (steel-making and continuous casting), and guides the downstream processes (rolling and shearing) to optimal operation, profoundly reducing defects in the final product. This is a prime example of problem solving using data and software without expanding capacity.

3. New product development simulation in cyberspace

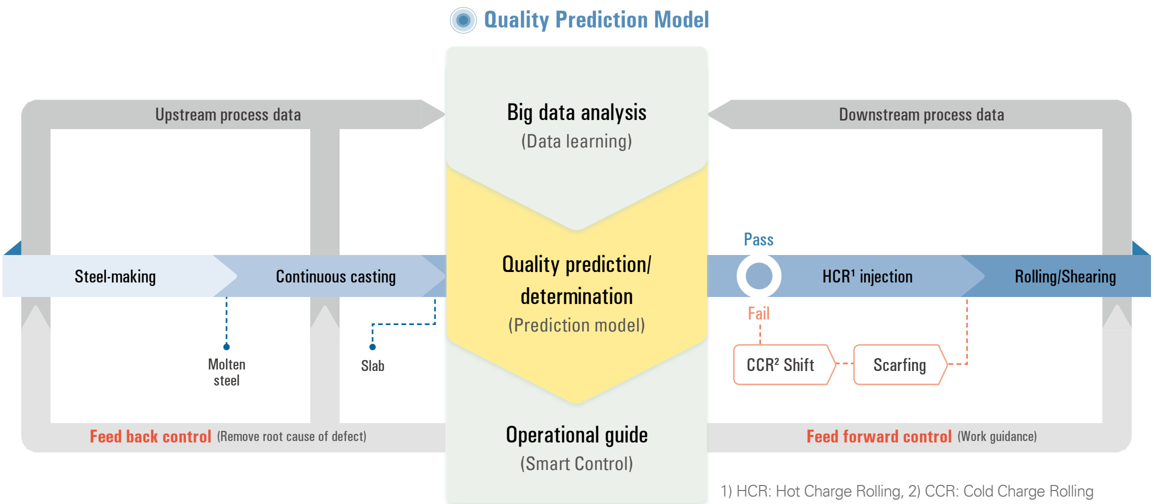
The steel-making process entails large-scale facility investments, so it is difficult to have separate processes to test new products. Moreover, owing to the innate characteristics of steel production, it is also difficult to create a new product and test functions through design and simulation software, as is done with home appliances such as refrigerators and washing machines. To address these challenges, on-going research into virtual factories is required to enable new product development and simulation in a cyber environment. In a virtual factory, facilities built by 3D technology are integrated with advanced control algorithms and operational technologies, based on steel production knowhow, and used for training and advanced commissioning. In the near future, virtual factories will be able to conduct pilot production, which would otherwise require tremendous expense.

The Fourth Industrial Revolution has already started and is expected to have a great impact on the survival and development of companies. Taking this as an opportunity for growth, companies should strive to advance manufacturing and create new value for humanity.

Implications for the Asian Steel Industry

Not resting on its exemplary success in manufacturing, POSCO will strive for relentless, long-

Figure 3. Slab Quality Prediction Using Big Data Analytics



term innovation in order to become a role model for the advancement of global manufacturing. Many Asian steelmakers are also actively developing advanced technologies to respond to the massive paradigm shift caused by the Fourth Industrial Revolution. In cooperation with industry, academia and research, the leading steel mills will continue to develop technologies such as AI and virtual factories and apply them to production sites. They will strengthen integration along value chains by connecting clients and suppliers through smart factories.

Figure 4. Training and Commissioning in a Virtual Factory