Digitalization of Steel Plant Operations

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Abstract

Modern steel operations demand more than traditional automation and supervisory systems in order to push higher the levels of efficiency and optimization. The impact of digitalization is reshaping this industry. Data insights are now available for the optimization of the operations, digital vision systems span from surface defects detection to online inventory updates. The capabilities of the shop floor personnel can be augmented by AR and remote assistance. All these create new paradigms and new tiers where more efficient and more profitable companies are moving to. The paper introduces some aspects of the fourth industrial revolution, including two case studies.

Keywords

Digitalization, Operations, Maintenance, Steel Plant, Industry 4.0

1. Introduction

The steel-making operation works as the basic unit of functionality for multiple industrial sectors that founded the rapid growth of the global economy. It pioneered the emergence of the industrial revolution centuries ago and until currently strikes the force towards a fast-moving modernization. Some of the custom applications of the base metal are evident in the fields of engineering, machinery, equipment manufacture, railway and bridge construction, energy, power, and transportation arrangement. The extensive usage, assuredly, signifies that it is a fundamental backbone component by which the circular economy accustoms its capacity to lead the large market. Furthermore, this powerful application offers a gateway to broader steel demand worldwide, requiring increased production amounts to various business enterprises in heavy industry.

A recent forecast from *The World Steel Association* (2021) shows a massive leap of steel demand that ranges to 5.8% during the current year. The growth in the succeeding year will further, and expectations run until 1,924.6 Mt of heavy metal sales per annum. Such undertaking raises the obligation to revamp the directions of the production chains together with the environmental and operational variables comprising the metallurgical industry. Moreover, the realization that the current peak of steel trade calls after an economical production for running companies implies a momentous alteration to the conventional business model of steel plant operations. While it crosses the commerce line to meet the desired output number supplying manufacturing organizations, operations are transitioning ahead with an improved, competitive, and dynamic framework. To strengthen it, managing to keep up with technological innovations is to coexist alongside the analytical approach of any companies that seek to hone the entire performance of operations at the highest level attainable. Ideally, one of the purposive applications is within the realms of the steel-making industry—the shop floor people, more specifically in the third line of support that resolves major technical concerns, rely on statistics, documentation, or analytics upon sorting out the approach. In simple terms, reliable assistance or database has to coincide with their tier level. As they take the lead in support management under operational patterns, established Enterprise Resource Planning (ERP) system seldom is insufficient and untimely for analytics.

In the current period, steel plant operations utilized ERPs for add-on supervisions. Over time ERPs appears in distinct profiles, and features vary. However, ERP systems are falling behind time because of outdated features displayed at the forefront. As more steel-making companies enunciate an expansion, other ERP systems fail to keep up with efficient operational models. A ripple impact hits, and it opens a vast gap between line automation and ERPs, influencing the deterioration of collaborative interaction across the workforce unit. Promoting digitalization in steel plants signifies a comprehensive restructuring, identifying weaker grounds athwart the workforce's viewpoint and reshaping the obsolete system. The widely popular concept of Industry 4.0, additionally, portrays the adaptation of digital technologies (Gajdzik & Wolniak, 2021). Most steel plant operations can modify the procedures in varying areas from the shop floor and administration or supervisory units using only advanced high-level technologies. The upgrade, presumably, will initiate an enhanced value chain, thus adjusting the company to its maximized potential to generate quality outputs hence preventing significant losses.

1.1 Objectives

The paper aims to introduce industrial IoT and analytics, the core digitalization model, as a viable platform for efficient steel plant operations. It also intends to highlight the imposition of upgraded and highly comprehensive ERP systems designed with Industry 4.0 advanced features.

2. Literature Review

A state-of the-art automation information technology matched with robust connectivity paves the way to the digitalization of steel production, which gradually goes beyond the reach of the traditional method for industrial production (Herzog et al., 2017). Pioneering the movement are highly industrialized countries (U.S.A, Germany, China) with proactive integration of IIoT (Industrial Internet of Things) that mainly covers sensor-based technology mixed to digital models, wise production planning, and control system. A study using a mixed-method approach confirms the digitalization of major European iron and steel industry. Activities and projects that deal with Industry 4.0 concept pioneered automation while not solving technology problems alone but subsequently focused on the organizational perspective. Furthermore, Industry 4.0 implementations take place to provide economic returns while establishing a strategic contribution to the refined status of the company (Neef et al., 2018). Sustainability is one factor considered by the European industry's policymakers. The era of modernization generates a call for new business models while involving the whole value chain and opening opportunities. So that sustainable production process should take over, big data and tools technique enters to fully centralize the large volume of data entering the business pillars. When management sees information conveniently regarding the operational processes, there is no extra job role. (Branca TA et al., 2020). Hence, they focus on optimizing the entire operations and setting forth logical steps to environmentally friendly operations.

3. Approach and Discussion

3.1 Shop Floor

Business production occurs on the shop floor of any manufacturing facility, suggesting a necessity for dynamic and result-oriented performance across many human and tool variables. More often shop floor determines the yield of the production as the real action takes place herein. For example, commercial processes start charging raw materials either in the basic oxygen steelmaking or electric arc furnace (EAF) in a typical steel mill. The first phase subsequently comes after another resource-intensive and complex method continuously until reaching the final manufacturing phase. Proper machining and heat treatment are part of the job specification of personnel handling the operations along the stages followed. They take charge of all the extremities existing around the shop floor operations and, regrettably, seldom lack human or computer-based assistance. There has been little to no shop floor management and service. Unfortunately, the L3 units that seal potential steel plant technical queries do not align with other departments because of inconsistent data acquisition, data and safety, and legacy equipment obstructing the driving forces for Industry 4.0 implementations (Neef, C et al., n.d). Collaboration is scarce, much more strategic approach generation. As a result, even if there is a synchronized programming software, most of its version is poorly functioning, heading to most operations suffer an unpredicted downtime, error in data resources, delayed reporting, and at the latter, badly impacting productivity in the whole site. To a greater extent, more labor hours out of the incapability brought about by old software systems and lacking communication from higher management is not only cost-ineffective but also prone to business crashes.

3.1.1 Capital Expenditure (CapEx) and Operational Expenditure (OpEx)

In any business venture, capital and operational expenditure indicate a monetary investment of a company. Assuring that the daily business process stays up and running, companies leverage funds designated for the expenses incurred. The funds' allocation covers several assets, such as physical property, land, equipment, and operative costs vary from workforce salaries, supplies, maintenance, marketing, and administrative fees, among others, to ensure that the average company routine would carry on besides not halting the operations. Although the two aspects play a substantial role in income generation, it is not a sound business approach to purchase and buy assets impulsively or with critical feasibility justification. Nevertheless, to acquire tools and equipment that will not hold significant value for another year or two. In streamlining the shop floor, it is crucial to consider environmental factors influencing the performance of the skilled workers. According to Merluzzi and Brunetti (2017) the ultimatum faced by the modernized market parallel to the current steel market as attributed by plant underutilization, are the elements leading metal industries are to look after low Capex investments. On the other hand, steel mill production usually demands maximized productivity from the shop floor workers, so it is important that companies are to leverage along with comprehensive systems. There are—however, business enterprises neglecting the rule of wise capital and operational expenditures. Steel operations involved closely towards technical processes have slow technological progressions, let alone a superior software system to help them carry on with production tasks. In this aspect, the essentiality of investment optimization enters. For instance, in warehouse and inventory management, it is known as a detailed task assignment because of logistics tracking. Regular worker operating herein, when provided by Industry 4.0 technology or application, experiences a breakthrough. Checking stock, intermediate products (billets and slabs for steel plants), or the end product one by one and categorically won't take weeks or months-long to finish. In an industrial plant, typically, this process is lengthy, given that there are hundreds, if not thousands, of lining records. Steel plant operations, therefore, that redesigns the process through application of high level operations system frees up investment and capital waste.

3.1.2 Manufacturing Strategy

Manufacturing strategy endorses a measurable plan devised to direct the business into getting an utmost core manufacturing frame, developing the infrastructures, and magnifying the workforce's skill set. It is a range of plans; hence the type of plan that transposes into a long-term goal and it matters for companies to lay out the entire blueprint of how it works across all unit levels. The standard turnaround of getting results and data from the departmental units inside the value chain takes ample time when analyzed more carefully. More often, it happens under the dependence upon old software and paper-based documentation. As a result, there is an absence of real-time visibility, as opposed to an advanced interface and up-to-date technology. For an objective economic return on investments, there is an imposition that a technical solution is developing new business models for digital solutions (Alf J. Isaksson et al, 2017). In this regard, another option companies could resort to meanwhile joining the industry with a competitive advantage in resource production is predominantly known as digital manufacturing. Although familiar to several steel operations, the concept follows an updated version with an edge of helping companies remodel through software configurations enveloped in schematic features of Industry 4.0. Unlike the typical equivalent, detailed management planning can work hand-in-hand, in speed, alongside the touched-up features of programming hence warrants the delivery of an appropriate real-time report, error blocking support, and seldom plan modifications.

3.1.3 Supply Chain

For a product-generating business, the supply chain plays an indispensable role in shaping the stability of a business process. Managing the volume of networks (inventories, energy, spare parts, and raw materials) from sourcing raw materials, manufacturing the products, and shipment carefully triggers extensive logistics tracking and quality assurance on the workforce unit. For this ground it is only of importance that the ferrous metallurgy industry integrates an effective management system as it enters the world market while increasing the product competitiveness (Erkinovna, A. D. et al., 2021). However, the task becomes complicated when one system operation lags behind time or, worse, inexistent. In this regard, the outmost solution to organize bottleneck resources, similar to the prior, would be a renovated digital intervention. The vast array of supply chain networks necessitates one centralized system with exemplary operating configurations. Loaded up with a process control interface reinforcing quick inventory, order and equipment tracking, and convenience, Industry 4.0 software systems now allow access via mobile terminals or tablets. Knowing the position of transport systems and equipment is also possible because configurations allow crane or truck detection. There is of data and resource synchronization. That said, it focused on logistics tracking for order and materials and on the operational terminals. Hence, it becomes more of a requirement than a mere desire for steel plant operations to impose comparable technologies.

3.1.4 Training and Performance Feedback

Regular education and feedback in the various units of the workforce system holds a tremendous benefit in raising the workplace's efficiency and credentials. It attaches an edge to the employees' skills, risk assessment, and scope of expertise. Furthermore, when field training, evaluation, or coaching occurs in shop floor operations, there is an excellent opportunity for flexible workability among the employees. Like the suggested optimization in the shop floor operations, performance management is not far beyond the reality of technological shift. In pioneering the dramatic reformation of transmitting feedback and education to the workforce units, steel plant operations could leverage the propagation of digital tools. In part, several programming software and applications now can deliver virtual-based simulators and feedback presentations as an add-on to the in-person practice. All these mainstream digitalized techniques allow the management to gauge an employee's A+ characteristic and red flags detection. In this way, it helps boost skills growth in a short period through convenient digital mapping of how well or poorly an employee performs as they upskilled by additional virtual education.

3.2 The Management Unit

Higher-level supervisory units in steel mill operation often do not notice the underlying conditions that led to ineffective production planning, logistics regulation, sales inventory, increase labor costs, low yield, or the recurrence of accidents on site. These are common but unattended drawbacks overlooked by the supervisory team in a general setting. The management goal is besides reducing cost whereby creating higher yields in the totality of the operations. In addition, creating quality outputs supplemented with fully-capacitated labor from the active personnel to not waste any invested resources. One cause, of course, is to secure the continuance of revenue generation and keep the entire production moving. However, several cases are unlike the picture of streamlined performance the management adamantly sought. When compared to the shop floor operators, the task assigned for this unit is large-scale and varies across administration parameters. Most of it, in particular, houses a broad array of areas in finance invoicing, product planning, resource monitoring, and quality control. Considering the scope tracking the data across all platforms is, indeed, time-consuming. Not to mention, it becomes costly because of the fluctuating market demand. The upper head units already etched unrestricted dependence on either standard methods or sometimes (both): paper-based documentation technique and age-old enterprise resources planning (ERP) system. Although considered convenient at once, other steel plants with higher supervisory operations are falling behind late. The primary software application utilized as a part of the one systematic data-based is unfortunately embedded with programming configurations hosting incompetent features. Some significantly turn outdated, and some did not warrant software upgrade proceedings. Thus, it holds minor to no use for data acquisition at all. As it is known, data is business essential, even more so towards the job designation played by the management team. The dos and don'ts across each corner of operations could only be determined when there is instant and reliable data source authority that the heads could refer back and forth into without incidental and system-generated conflicts. Across this aspect is where data system modification enters. Considering that pervasive sensing, computing, and unprecedented systems interconnectivity (Jie Xu, et al., 2017) piloted in the recent era of industrialization, the management unit is expected to rely on Industry 4.0 perks and progress.

3.2.1 Enterprise Resource Planning to FRP and MES

Since the metallurgical industry caters to a large volume of daily inputs and outputs, the integration of software systems is a prerequisite in mitigating what is likely to happen in disorganized business discourse- mismanagement. In this regard, the ERP system is brought into play by most steel plant operation solution-driven IT infrastructures to centralize the complex figures coming in and out the cash flow statements and worksite operation-related activities. However, it was explained (Jafarnejad, Ahmad et al.,2012) that the selection of a proper system of Enterprise Resource Planning is a hard road to travel for enterprise managers. ERP serves both as software and a gateway to careful organization of the interdepartmental data resources fundamental for storing financial records, statistical data, and logistics tracking. One that tremendously stands out among its perks is aiding the wide-scale strategic decision-making of administrative and workforce units' combined, short and long-term basis. Although, it is imperative to note that the ERP system flows along with the prevailing technological innovations similar to Industry 4.0 foundation. By that, it signals an adaptation only of up-to-date software. If not, the company could prefer to reconfigure old business ERP into a more advanced system that would help optimize, bona fide, the operational process on board the steel mill. ERP is a de facto state-of-the-art software deployed in medium to large range steel plant operations. In recent years it underwent a notable transformation and now follows series of highly integrated versions. Two highly efficient tools appear under the title with abbreviated names of FRP and MES. Both software systems provide information technology infrastructures that manifest impeccable and next-generation features.

3.2.2 Total Quality Management Optimization

Small to medium-scale enterprises respect customer orientation. In such a way, companies would have to leverage to enhance interdepartmental processes and end product development to meet customer satisfaction. A holistic approach rooting is to secure an efficient total quality management (TQM) design. During the modernization period, TQM acts alongside analytical tools to process big data while aiding the higher-level operations to establish sound and rational worksite decisions. As a result, there is unprecedented progress towards the regular enterprise resource system while entering the landscape with an entirely upgraded configuration. The advanced programming software known as Foundry Resource Planning (FRP) is an all-in-one tool that comes in handy when regulating steel casting, product planning, sales, and quality management, and at the very least, works in progress. Contrary to its original counterpart, the imposed software comes in many applications essential for supervisory control and data acquisition. It encompasses a relatively flexible foundry web-based information system with full accessibility via tablet, mobile phone, and many other electronic devices. It as well as takes the lead for test planning, essential for spotting potential shortfalls or mistakes. The test planning structure determines the appropriate target values, test instructional materials, and limiting factors to understand the consumer specifications language for the product. Besides, it stores the test plan beginning from material included in cast part, core, raw casting, until eventually to the machines end product. The perk of having such incentive is that apart from wrapping dimensional analysis, it enables a seamless flow of information from top to the bottom of departmental units, delivers objective evaluation, prevents backlogs, and pioneers visual planning capacity. When it comes to the dominant functionalities of a well-managed operation, it subsists inside the model interface. It is noticeable under the system's feature that it can quickly track order and external service provider (ESP) status, deliver or send responses to sales inquiry, visualize stock inventories through tables or graphs, and audit reports. It is user-friendly and, at the same time, accordingly proactive because of the long checklist of operation-related activities, and it can monitor onsite data with minimal supervision. To the management team, it is a whole new level of digital intervention as it formulates a diagram on reaching its key performance indicator (KPI) goals. In this regard, it is only noticeable that with the configurations brought about by the FRP system, the supervisory units have the optimal opportunity to administer the supply chain. Moreover, it allows them for simple, directive data processing, and analysis of patterns consistently matched with preliminary error identification in the workflow and production process.

3.2.3 Manufacturing Optimization

The production processes transpiring in steel manufacture are complex, energy, and resource-intensive. Human intervention and intricate supervision are the must-have to conserve working conditions, hence avoiding the additional capital cost, waste of raw resources such as iron ore, scrap, and pre to end product.The term “Industry 4.0” is the coming of a modernized industrial revolution by means of smart manufacturing according to Buntz (2017). For this reason, inability to control manufacturing processes in every corner reflects that of the management unit, the shop floor skilled personnel. Fortunate turns of events surfaced to have a definite software control system as a peripheral tool utilized by the team of employees crewing the operations. One of the radical systems, the Manufacturing Execution System (Mes), powers the anticipated digital breakthrough. The critical components of its features open the road to tailor controlled guidance in every division of the manufacturing processes. It revolves, in particular, starting from the utilization of machines, downtime predictions, and extending until the backing of outputs calculation. The most apprehended part is that the accumulated data, for instance, an analytical representation of product volume, will then transmit upward to the higher-level ERP systems by standard transport adapter. There rolls up a smooth and simplified version of data exchange from the superior MES or traditional ERP systems resulting in aiding the supervision gap among the employees assigned in a particular stage of steel manufacturing. Not to mention, the statistics are indispensably accurate in measurement, going a million miles beyond the reach of manually supervised counterparts. The more driving force for steel plant mills to adapt to the upgraded technology is lesser staff dependence, resource-efficient, and yet appears on top of superior embedded properties in management and operations control. In total, it is stated (Björkdahl, J., 2020) that practical implications of digitalization are to move forward in terms of strategies for optimizing the current business and embracing long-term digital transformation.

3.2.4 Process Control Optimization

To qualify in the competition of steel operations and level up in development, Industry 4.0 (the fourth industrial revolution highlights the trends to achieve more intelligent manufacturing processes, including reliance on Cyber-Physical Systems (CPS) and operation of smart factories (K. Zhou, et al.,2015). In simultaneous trial and error, a customized version of the control system effectively manages the chemical-bounded phase's daily requirements in steel production. Two highly integrated systems are available in the market, specifically the FRP and the new one, Furnace Control System (FCS). Jointly with its wide range of applications, FRP provides steel casting solutions through administering specified diagnostics and notations regarding mold, core, heat treatment, in grounds of machining, and, nevertheless, charge preparation. It will also benefit the operation because it can optimize a furnace and give practical advice driving out conditional practices towards regulatory energy consumption. Not further away from this high-functioning programming software, the FCS set forth a module etched with advanced features. The tool initiates a downstream analysis of total heated treatment and specifications toward the setpoint values fixed to the furnace chamber temperature. Disruptions in the production process like cold drawing decrease since speed adjustment compensate for the gap. Waiting time, at one part, lessens under the timely change integration on the target temperature. The schematic temperature profile and interface scale the technical process in steel production. Moreover, optimizing the processes with the aid of the specified powerhouse tools increases the quality of tempered material and production capacity.

3.3 Industrial IoT and Analytics

As data becomes the center stage and cutting edge for business subsidiaries, including steel plant operations, there resembles a considerable obligation to flow along the blaring digital reformations brought in by modernization. From here is where IIoT enters with a pledge of optimizing the business model of the steel plant industry across varying levels of the workforce, i.e., the shop floor and supervisory units. The principal skeleton of industrial IoT exposes a robust design of intelligent mechanisms of programming software and devices that can work quicker, more precisely, and logically than humans thus enabling transformational business outcomes (i-SCOOP, n.d.). In other words, it is a cyber-physical map of electronic devices, systems, advanced analytics, edge computer, and people interconnected to establish a network fundamental for collecting, monitoring, exchanging, and analyzation of data. Few known examples are sensors, cloud, vision cameras, programming software, connectivity, database systems, and smart factory. It goes, in particular, beyond the ordinary analog devices and outdated computer systems (ERPs) that only have a bare minimum of digitally advanced property. Many available modern technologies are settling under the IIoT classification. So, the edge devices travel far from what is historically considered boundaries in terms of functionality. Today, these devices can sense, communicate, and store information on the cloud or within built-in system memory. It exhibits real-time analytics, seamless connectivity, operation broad performance insights, intelligent alerts, and notifications. Steel plant operations more frequently and can potentially (if not yet applied) employ the combination of IIoT electronic devices, big data, and cloud computing together with a comprehensive ERP system that boosts up the sense of connectedness because of a quicker-than-ever operational process. Therefore, deploying these devices or reconfiguring old software implies placing automation in context the same way establishing onsite activities with the guidance of reliable data acquisition and transmission systems.

3.3.1 Digitalization Optimize Industrial Operations and Links Workforce

The concept of digitalization is not entirely new to the circular economy, just as much in the corners of energy-intensive industries. It is a prerequisite to establishing what is known as Industry 4.0 that also caters steel mill business. In steel plant operations, the new business models brought in by modernization revolves across the framework of smart factory, IoT, mobility, Big Data, virtual & augmented reality, that took the companies into the next level in digital customer responsibilities and high-end simulation (Veres, M. et al., 2020). The scope grants an optimal advantage to the whole operation and has drawn more substantial feedback than the standard counterparts. For instance, manufacturing industrial tools have now acquired the ability to self-identify a systemic problem. The key features enable predictive and corrective maintenance identification for the management and plant workers. All are plausible because of real-time analytics reporting from the program software that recognizes anomalies or potential machine defects. As a result, the workforce unit collaborates and comes up with a statistically supplemented decision about downtime. So even before legacy machine breaks, there emerges a visualization of data suggesting the workforce of the need to fix or restore. Given this information, the L3 and supervisory unit, as a response, stir the maintenance during which there are no working operations to be sure that the uptime continues. Data and error reporting likewise appear herein, and it happens on the go, thus avoiding many back lags. It is made viable through connectivity networks and analysis tools with superior software algorithms. Such is an indication that communication from the working personnel to the top management unfolds as big data fills the large gap brought by legacy equipment or conventional system. Employing automation makes it faster to generate insights from the downstream staff to the higher-level supervisory department. In particular, collaboration becomes quicker at this point. The management will now hear the actual scenario occurring on the floor because the technical analysis consistently matched with an instant and direct outline of incidents from the workers. At the same time, there is a figure-based representation of the company's financial status under the ERP systems since it stores through cloud comparable data and in-flow and out-flow of variables ranging from sourcing raw materials until the sales generation or acquiring yields. Although very time-bound, it offered an urgent resolution to the business, halting the communication barrier between operational levels and providing an intelligent support system for the workforce. AlMuhayfith and Shaiti (2020) stated that the implementation process of ERP system considering the diffusion of innovations and technologies was found to articulate process and administrative innovations. It also offers higher yields while carefully avoiding inefficient CapEx and OpEx investiture. This entire blueprint to which digitalization penetrates boils down to the idea of streamlining operations on total management while winning efficiency level, reducing operational cost and downtime, and allowing the entire business to run to its maximum capacity with lesser capital waste. More importantly, the Industry 4.0 innovations open a platform for the workforce units to exchange perspectives, impressions and create resolutions logically. Transforming the entire supervision and production process into what would look like a standardized cyber-driven operation, nevertheless, is an ongoing process, so forwarding towards it is imperative as steel plant operations flow along with a volatile market. Digitalization, hence, is the most feasible approach.

4. Case # 1 – Digitalization Of Wastewater Treatment Operations In Upstream Industry

4.1 Introduction

The preparation of the raw materials utilized in blast furnace ironmaking is adding deep footprint to the general bill issued to the environment, in order to produce primary steel. The coking process is an important step in the reduction of the ore, therefore deserves full attention in its production steps. There are far too many installations that will continue operating till a viable alternative decarburizing process will replace them at the end of their operating life. The water utilized to quench the coke requires a dedicated treatment process and may pose threat to the environment, or to the coking process itself, when wrongly treated.

4.2 Coking process wastewater treatment

IOMES Group has developed a family of applications based on Industrial IoT connectivity, to compute in real-time sophisticated models on the running process data, acquired by the existing automation hardware, by uploading the said process data to a cloud infrastructure.

China has large coal mines. This is a wealth to the Nation and to the steel industry, which today is taking firmly and by far the first position of steel producer in the world.

Long ago the EPAs (environmental protection agencies) had tackled the pollution problems and the days of hazy and foggy atmospheres are gone. However, part of the invisible still needs to be controlled and eliminated to comply with the mandates of zero waste, which will soon become mandatory in many industries in China, including upstream ironmaking.

4.3 Digital Coke wastewater management

Traditional data collection, processing and analysis are lagging indicators. This is due to the delay between measurements and data reports availability, too slow and not enough frequent to be the acceptable basis of information thoroughly capturing the process and allowing to take informed decisions on the spot.

There are at least 100 data points in a modern coke plant, let's assume the DCS records every 10 seconds, then in 24 hours you will have accumulated > 800,000 data points. And then you can generate (even 25%) more data from operating relationships (kg_{steam}/m3 process flow, differential pressures, etc.), then in 24 hours you will have accumulated >1,296,000 data points.

Some setbacks of traditional data management:

- The data are delayed information, even the real-time data is the result of the previous process, can't be used to predict or control the process proactively and preventively.
- Only linear relationships are presented, the traditional data analysis tools can't visualize the complicated relationships among various performance indicators.
- Traditional operations are segmented, the professionals only focus on the local parameters, can't see the big picture of the whole operation. For instance, the wastewater are generated in coking process, the mix of coal and the coking opera-tion play a significant role in waste water treatment, but usually the coking and waste treatment are different departments and the information is isolated.

Coking process is continuous and dynamic, coke and wastewater, the final products of the process are affected by each and every section of the process plant. The traditional process indicators collection and process is very time-consuming, many excel spreadsheets are generated but the data are not shared in real-time and fully exploited and the information not properly translated into insights to guide better operations.

In general, there are 20-50 employees required for data collection, processing and analysis for a 2 MTPY coke plant. A lot of work is carried out on daily basis to use these data to get the production on track and remain environmentally compliant according to the local government policy; however, little work will help the plant managers to do their job in a proactive way, to predict and keep the environment outrage at bay.

The continuous and thorough data monitoring and proper analysis will help the coke plant find out under what circumstances, i.e., key performance indicators, the operation is under control or ideal.

All the production outages, equipment failure, or the process indictors irritations don't come without any indications; put it in another way, if we can catch these ab-normal situations and take preventive or responsive actions, we will keep these from happening, to make sure the coke plant is working in a safe, efficient and environmentally friendly way.

The data generated in a modern coke plant operation are way larger than the previous one. The coal blending is a simple operation in a coke plant, there were only 5 key indicators in the past practice, today there 30. So, the traditional data processing is far from enough to guide the coking process, there are new data logics and metrics which can only be carried out by big data analysis technology.

4.4 Data make sense – Primary cooler

Primary cooler is critical to cool down the coke oven gas, the operation and practice vary across plants, some plants have to clean the cooler every week, some once every 6 months. There are extra operation costs for these unnecessary cleanings which consume a lot of expensive streams, to make it worse, you would have to shut down the process for the cleaning job.

Coke plants rely on monitoring the pressure to decide if the primary cooler need a flush, but that is a lagging indicator, when you find it, it already happened. However, there are proven technologies that monitoring the condense quality, the Ca, Mg, hardness, CO3, Cl, the consumption of corrosion inhibitor and the anti-scaling to predict the pressure changes.

Even a 1 or 2ºC improvement can have significant impact on your total cost of operation. For example, (based on 1 ton coal):

@ PC outlet of 25ºC = 625 mg/m3 Naphthalene
@ PC outlet of 23ºC = 506 mg/m3 Naphthalene
The difference, 119 mg/ m3 is a huge cost saving in the long run.
Because the naphthalene plugs the pipeline, increase the gas pressure, the extra liquor or light tar flushing will be needed with the surge pressure. Steam cleaning will damage the tubes which has to be replaced when corrosion grade gets serious.
In summary, primary cooler is a simple process, but the operators will have to keep a close eye on the relevant data process and analysis, which includes coal blending, the spray in the gooseneck and Inlet COG temperature, Coke charging procedures, Collector main spray performance, Flushing liquor temperature and flows, Cooling water temperature and flows, Cooling Tower operation, COG flow distribution across the Primary Coolers, Internal Primary Cooler liquor sprays – flows, quality, with these data properly examined the cooler's performance will be determined to maintain at the optimum level, following by a benchmarking with the industry values to find improvement areas.
The coking plant wastewater treatment plant we analyze in this case study, operates with the following parameters:

- Capacity 1 million tonnes coke production
- Typical A^2O Process, anaerobic-anoxic-aerobic(A/A/O)
- Wastewater flow 30 m3/h
- COD inflow 7000 ppm, Discharge limit 80 ppm
- NH3-N inflow 150 ppm, Discharge limit 5 ppm

Process and treatment goals:

- Pretreatment COD 7000 ->6500, NH3-N 150->140
- Anaerobic-Anoxic COD 6500->2000, NH3-N 140->60
- Aerobic COD 2000->500, NH3-N 60->10
- Sedimentation COD 500->400, NH3-N 10->5
- Polishing COD 400->80, NH3-N 5->2

Nowadays the technologies are available to treat the dirtiest water into potable water, the key wastewater challenges are always the trade-offs between performance and cost.
The government environment authorities require 100% compliance of wastewater discharge, if 95% of time a coke plant is within the discharge limits, the local EPA focuses on the rest 5%.
Coke plant wastewater treatment starts from the ammonia still, all the way through equalizer, aerobic cell, anaerobic cell, anoxic cell, sedimentation, secondary clarifier and RO systems. Usually, the wastewater treatment takes 2-4 days. That means when the final water analysis come, it's too late to enable any corrective action.
The big data technology enables us to do things differently, the Digital Coke Waste platform developed by IOMES Group and Wanhe Environment is a total solution for coke plant wastewater data collection, processing and analysis, then used by industry and plant experts to take proactive actions to prevent the outrages from happening.

4.5 A Data-Driven Predictive Approach to BOD and COD Measurement

Continuous monitoring of water quality is essential to reducing the amount of organic matter in effluent from wastewater treatment facilities. This monitoring is traditionally achieved through measuring Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values. However, the several limitations of conventional BOD and COD diagnostic methods often leave water treatment facility operators struggling to comply with effluent discharge regulations.
Chemical laboratory analysis of the BOD5 parameter takes 5 days which is a long time before treatment process corrections can be made. While it takes 2 to 3 hours to measure COD in the laboratory, the test process uses dangerous chemicals that constitute additional problems. These challenges result in costly downtimes, poor compliance with regulations and inefficient operations.

4.6 Application to predict wastewater characteristics

Development in digital technology now enables the collection of data at higher speeds and larger volumes (known as "big data") than ever before. Facilities now collect process data as part of their daily routine. However, they lack sufficient analytics to use the powerful intelligence that these data provide.
IOMES Group provides a faster, reliable, and more efficient data-driven method of measuring BOD and COD in water streams. Combining the power of big data and AI, readily available data is converted into actionable intelligence to enable water treatment facilities to run a smart management model that uses predictive analytics in operational and maintenance strategies.
TECH-IOMES W is an analytical application that uses big data analytics to predict BOD and COD as well as other variables of the finished treated water and effluents. This predictive method eliminates the long waits for laboratory

results and informs decisions on maintenance schedules which in turn reduces downtime, drives down maintenance costs, extends the lifespan of key equipment, ensures compliance, and improves overall operational efficiency.
The application first learns through tracking and analysis of organic carbon levels over time in relation to process parameters like flow rates, tank volumes, ambient temperature, fluid temperature, pH, NH3, alkali and other chemical additives in or-der to establish their correlation with BOD/COD values. It then creates a powerful forecasting model for predicting BOD and COD in water streams with >92% accuracy in all cases. It also provides pattern analysis.
Armed with predictive intelligence from this TECH-IOMES W application, facility operators can quickly decide on necessary actions (whether to dilute further, allow longer processing time, etc.) to ensure efficient performance of the system which eventually drives down operational cost. Furthermore, the application is easy to use as results are displayed on a web interface in a fully customizable HMI on a PC or mobile application, no bulk software packages to install.
The interfaces (HMIs) are web-based and the level of data security is the highest achievable for industrial applications. The configuration of the installed application is very flexible and lean, the experts can monitor the process from a remote location and provide online consulting and support. The process data can be stored in a separate tenant and remain accessible only to the plant personnel, without any risk of being lost or shared inappropriately.
The basic analytical model will elaborate on the following process variables for each process step:

- Flow rates
- Tanks volumes
- Ambient temperature
- Fluids temperatures
- pH
- Alkali
- Chemical additives

to predict:

- NH_3
- BOD
- COD.

The model requires a training phase, followed by a validation phase and a final testing phase before running the application. The training is performed by IOMES Group experts on-site for the first time. The input data set is partitioned into three subsets: one for training (predictors determination), one for selection (validation), and one for testing (prediction). During the training phase, the clients shall collect samples for laboratory tests and assure to strictly associate the results to the specific point of the sampled wastewater, so that the numerical model training is carried out with unbiased data. This calibration phase is required according to a certain schedule, which depends on the frequency of the raw materials changes, process routes modifications, sensors replacement or additions or removal; however, the calibration can be done by the plant automation engineers on a dedicated software application and IOMES experts can support remotely as it may be required.
The results are displayed on a web interface in a separate HMI, which can be configured as additional L2 desktop PC or laptop. Mobile applications are also available for results display functions only.
The HMIs layouts are 100% customizable. The results can be shared in the water treatment plant as well as plant L2/L3 MES systems for further actions (e.g., dilution or longer process times) and reporting.

4.7 Plant configuration: data connectivity

To enable the feature of TECH-IOMES W application, the wastewater treatment plant data need to be collected and uploaded to the cloud computing framework for elaboration. This is done in two steps, currently. There is a mixed IoT (Modbus RTU) platform which is accepting also manual inputs, until all sensors will be implement-ed, to build a TSDB (time-series database). Second step of the code elaborates with a dedicated strategy the data on sufficient number of days and creates a training structure of data (training datapoints) required to train the model on a regular basis, presently every 24 hours. The connectivity configuration is being boosted to cover all critical process variables: at this point in time, there are totally 74 variables and about 20 are manually inputted at defined time instances of the day and saved in the TSDB.
Implemented on an existing and lowly automated wastewater treatment plant, the solution to have automatically recorded data and manually inputs are a must, to have a quick implementation time and also a cost-effective approach, which also allows modularity and scalability. The automatically recorded data, through the PLC, are carried by GSM line. This data gateway ingests the data via the internet to the cloud databases. Other process data may still be ingested by the plant automation PLC to TECH-IOMES W databases through other dedicated data gateways.

4.8 Results and achievements

There is a growing interest in Industrial IoT technology by heavy engineering companies that want to improve efficiency and cut costs. The technology will play a critical role and will be instrumental in the next industrial revolution. A good strategy and selection of reliable hardware and software components are critical in ensuring the success of the system. But even after this, the fragmented networks, different types of sensors, protocols and networks may present some challenges and limit achieving the full potential of Industrial IoT.
In the case of Wanshan Coke, the first impact has been a reduction of cost due to data collection, at present evaluated in excess of 30%. To add the cost for laboratory tests, which is reduced by 50%. An actual calculation of savings is being accounted for and it will be released as soon as possible.
The most important impact is the possibility to enact preventive actions, which are replacing the emergencies of the past operational situation. These actual savings can only be made after one full year of live operations and they remain subject to disclosure conditions of the plant management: till date the new digital system has been running for 3 months and it needs to be compared with the data of the previous years to have a substantial comparison basis, corrected of any seasonal and exceptional effect.
Organizations must also understand all their needs and the specific opportunities Industrial IoT offers them, as outlined in this cased about TECH-IOMES W. This helps them invest in the right solutions in terms of hardware, software, platform, and skills.

5. Case # 2 – Upgrade of steel minimill plant operations with smart digitalization

5.1 Introduction

Rolled long products account for approx. 50% of total rolled products, globally; on a regional level, it is the economy stage driving this percentage, leaning more on long for emerging economies. Long products find application in construction as well as automotive and other engineering industries. Concrete constructions revolution and infrastructure developments at large have driven the growth of these products. Long products at their entry level are construction rebars (reinforcing bars or re-rolled bars, as mentioned in some literature), relatively easy to produce and therefore widely produced in many locations, especially close to markets rather than smelted or other semi-finished products, namely billets and blooms, which are in most cases produced closer to mines or other places rich in resources and energy. Steel can be recycled indefinitely (unlike plastic, to the industrial knowledge of today), therefore scrap generated by old buildings and appliances of the most advanced economies is the big pillar of supply to emerging economies as well as reducing the environmental bill thanks to huge reduction in carbon emissions (this applies to all metals). Electric steelmaking, either by arc furnace or induction melting, allows to set up the so-called minimills, with a production capacity of 1 million ton per year and less. This offers many advantages in terms of CapEx and OpEx, absolute values of carbon emissions, allowing to set up this kind of plants nowadays even in city centers with little to no sensible impact.
Actually, the most recent technologies of rolling directly from continuous casting are shifting the technological and operational game to another level: few solution providers hold these technologies and the transformation time from scrap to finished product is 2 h compared to more than 2 days. Hence, higher efficiency both on production and financial level, transformation of the products from recycled scrap in the same regions, avoiding moving raw materials across the oceans.
For young industrializing countries such as those in Africa, the minimill approach is a very smart option to supply local markets with the right construction materials at affordable costs.

5.2 Project outline

One more advantage of the consolidated minimill concept is to combine equipment of various origin, also at different points in time, in order to optimize materials flow, CapEx and lead time of the whole project. For this reason, in this case study we will present and overview about a steel plant designed to process ferrous scrap into long rolled products (rebars, wire rod), a solution provided by combining new equipment with refurbished machines. Compared to complete turn-key, product-in-hand option, it is a very high level of DIY that requires lots of expertise in the specific solution, to achieve a technical and cost-effective result.
The minimill is constituted by two main divisions: the steelmaking shop and the rolling shop.
The steelmaking is energy intensive process, the scrap is melted and shaped into a semis. The scrap yards stock the materials and material handling systems feed the prepared mix to the electric arc furnace, 40 ton capacity in this case. The molten metal is then transferred to the ladle furnace for steel composition check, carbon reduction when required, additives corrections.
The refined metal is then fed through precise sequence to the continuous billet caster. The hot metal solidifies from outer surface to core. For the hot charge process to feed the hot billets to the rolling mill, it is important that the metal solidifies at the core before it is heated up to the rolling temperature.

The reheating furnace of the rolling mill can handle 3 difference sequences: hot charge, cold charge and mix charged. The hot charge saves the heating energy from ambient temperature to 800-900ºC, the normal rolling temperature is 1,100ºC. There are multiple phenomena and factors influencing the balance of the right rolling temperature: higher temperatures require less rolling energy, but they contribute to generate a lot of scale losses. Lower temperatures are savers for the yield, but require more rolling energy. This is another step for the process optimization in terms of OpEx, but also CapEx and it requires a proper choice of the equipment plus cost of utilities and spare parts.

In this case, starting from raw materials loading to process, the transformation time to finished product in the range of 3 hours. Fully engineered solutions today can reach as low as 2 hours.

5.3 Automation and big data applications

The minimill with steel meltshop, reheating furnace and rolling mill offers much flexibility and quality control of the final products and requires sophisticated planning in order to control transformation costs scrap-to-rebar, lead time and overall efficiency of maintenance planning to ensure that the stable techno-economical conditions are attained and finance does not suffer large capital exposure. This means that it is paramount to decide the production planning (to order or to stock) and each department of the minimill has to follow the planning with tight margins on. This is the business model for all steel plants to remain competitive nowadays.

In order to this, the traditional data collection is not enough. The amount of data is huge and the insights can only be generated through modern software applications. Moreover, the automation of each plant section, usually each system of machines, is stand alone and the only points of communication are ODBC databases or the like (level 2). On top of the organization there is ERP (level 4), accounting and finance of the organization, unrelated to what is happening on the shop floor. Therefore, all inventories and work-in-progress are tracked manually in most cases, till the finished products are available in the inventory and again manually the inventory is updated. MES systems (level 3) come to the rescue in these cases.

Digital technologies find very productive applications in this plant to 1) monitor machines operations and elaborate sophisticated preventive maintenance programs, 2) check and predict online the quality of the semi-finished and finished products. All these features can be enabled by ingesting the data generated by the machines through data gateways and elaborated in the cloud servers.

TECH-IOMES M is the solution to enable these two big families of functions, starting from any equipment and with no disruption of operations. Moreover, they can be fully implemented and maintained from remote. The plant operators access web-based applications (front-end) connected via internet to the cloud-based applications (back-end).

5.4 Flexibility and modularity – focus on what drives profitability and care for personnel

The IIoT applications offer total flexibility, an accurate assessment guided by collaboration partners or internal personnel elaborates devise the roadmap to digitalization: prioritization based on management guidelines has to choose what will come first.

The stepwise approach is also strongly recommended, being digitalization a profound change project. In fact, the most affected personnel can refuse firmly the implementation of such innovations, feared of losing the job. The success case in a small area is beneficial both to management and workers, with the advantage to minimize the risk also to disrupt all operations when rolled out to the whole organization. To emphasize success at all levels, enabling digitalization on final production steps will have catalyzing effects: improving customer satisfaction by delivering better experience impacts both the economical KPIs as well as the brand and the morale of the personnel.

Moreover, the organizational leadership has to emphasize that digitalization, typically enabling artificial intelligence, is augmenting the human intelligence rather than replacing it. In the long term, the profile of the shop floor workers will feature more technically advanced skills than in the past. This is the way to achieve fully optimized, modern operations.

The future approach will be to have more compact plant units, fully operational and automated, with higher intelligent manufacturing systems. These solutions are already available and extensive test runs are in progress.

6. Conclusion

Steel mill operation requires a fundamental redesigning in the age of modernization. Both the shop floor and management units share how inefficient worksite performance-rooted from inadequate data resources and minimal technological intervention. On the other hand, the line automation and regular ERPs generally utilized in the production processes lag behind time as they have a fair share of feature limitations. Further opportunities in streamlining operational procedures in L3 units and management are inexistent, creating gaps across all corners. Digitalization framework interfaced with industrial IoT evolutions that evolve in the face of up-to-date programming software embedded with sensor capabilities, visualization, and data analytics paved the way to bridging the issue. Through securing up-to-date ERPs and technological innovations, there resides an improvement in collaborative insight generation among the units of the workforce. The analytics and statistical representations have become real-time as it delivers reliable resources in integrating decision-making in manufacturing, workforce training, process control, and total quality management. Furthermore, it concludes that investing towards higher-level ERPs, digital technology, and optimized management techniques driven by modernization secures the health of steel-making businesses.

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