Alumina refining 4.0: What digital transformation looks like

By **Jonas Berge***

To improve reliability, safety, productivity and throughput, many alumina refineries have begun digital transformation of how the plant is run and maintained, changing from manual and paper-based tasks to new ways of working based more on digital automation and software. To enable these new ways of working, successful alumina refineries are deploying digital operational infrastructure, with wireless sensors, purpose-built data analytics, industrially hardened tablet computers for digital document and software forms, location awareness for personnel and assets, and connected services using cloud computing technology and the Industrial Internet of Things (IIoT).

Industry challenges

Alumina refineries face challenges with reliability, maintenance and energy cost, safety and compliance, and production. The workforce may already be stretched. Many of these challenges stem from manual and paper-based work practices.

Reliability and maintenance challenges

A plant may struggle with unscheduled downtime due to unexpected equipment failures or too long scheduled downtime for turnarounds losing several days of production every year. Personnel struggle to keep up with the preventive maintenance schedule and may not be able to complete required tasks within turnaround window. The plant may have escalating maintenance costs due to repair, and opportunity cost for lost production. Some process equipment may see premature end of life. This may be due to a reactive maintenance culture. Loss of containment due to eroding and corroding piping and vessels is another challenge. Moreover, plants are expected to improve without increasing headcount.

Energy and emissions challenges:

Plants see energy consumption going up, but not knowing why, compounded by increasing or unstable energy price. Again, plants can't hire more people to help energy conservation.

Safety and compliance challenges

Plant safety record has improved but incidents still occur, there are near misses, and the response time is sometimes too long. It is hard to keep up with inspection and verification requirements in new HS&E directives. There are fines for non-compliance. Again, manpower cannot be added to perform these tasks.

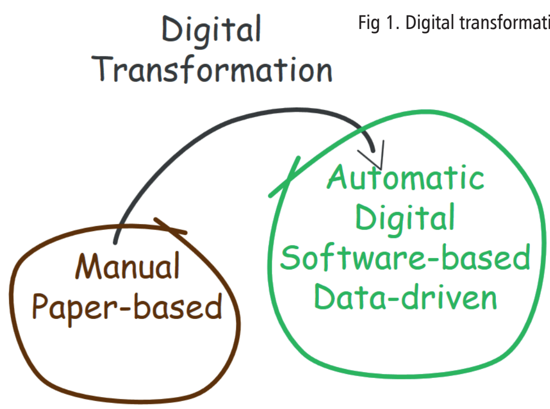

Fig 1. Digital transformation of work processes

Production challenges

Manual operation causes production bottlenecks. Operating cost may be escalating. As staff retire, the remaining personnel are left with more to do.

Digital transformation

Even some of the most technology-savvy plants still have many manual and paper-based tasks. To achieve operational excellence, top-performing alumina refineries are transforming everything about how their plants are run and maintained. Plants are now switching to new automatic, digital, software-based and data driven ways of working. In a more digital, paperless plant, personnel can carry out their daily duties more effectively. A digital plant also enables faster, more efficient turnarounds thanks to advances in areas like predictive analytics.

Maintenance and reliability tasks

A digitally transformed plant is able to minimise routine manual collection of maintenance, reliability, and integrity data from equipment like pumps that require portable testers or time-consuming interpretation. Instead vibration, acoustic, corrosion, erosion, and other data is collected automatically by sensors to detect early signs of problems ahead, transmitted digitally, and analysed by software to predict and distinguish between various equipment failure modes. This prediction capability enables maintenance and asset management along the International Organisation for Standardisation (ISO) 55000 guidelines. Notifications of developing issues can be sent to smartphones or tablets anywhere. Any remaining manual inspection rounds are not by clipboard, paper forms, and pencil, but instead a tablet computer and software. A central pool of domain experts, in-house or external, can use the information to support plant personnel.

Delays waiting for an expert to mobilise to site or trying to explain a problem in the field from the phone in the office or via email are now avoided. Instead two-

*Senior Director Applied Technology, Emerson Automation Solutions

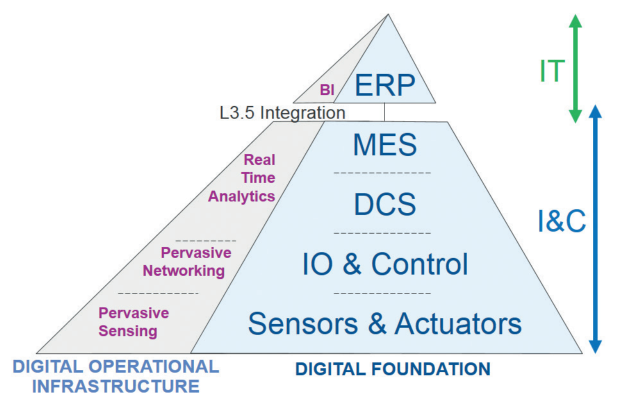

Fig 2. Digital Operational Infrastructure (DOI) is a second layer of automation on the side of the existing automation pyramid

way digital video and audio between field technician with wearable camera at site, and subject matter expert seeing the problem up close and live in software from another location.

Carrying of papers or returning to the office to pick up additional documents is a thing of the past. Instead open up any procedures, drawings, and manuals etc. in software on a tablet or browse information from the company Intranet or the Internet on-the-go in the plant.

Energy management and loss control tasks

Manual collection of energy meter readings or tallying of consumption report is no more. Instead consumption data is collected automatically, with finer granularity for areas and units, transmitted digitally, and overconsumption alarmed by software also generating the ISO 50001 reports.

Finding causes of energy loss no longer relies on manual inspection of steam traps and relief valves. Instead, these issues are detected automatically using steam trap health monitoring and relief valve monitoring.

Similarly, the root cause troubleshooting of energy overconsumption in equipment and machines does not rely on labour-intensive data collection or manual number crunching. Instead the efficiency is monitored by equipment performance analytics software.

Health, safety, and environment management tasks

Getting on the walkie-talkie to make a distress call is not always possible. Instead automatic detection, digital transmission, and alarm on safety shower activation, in operator software and location awareness software.

No ad-hoc visits to the plant to check if a manual valve was closed, dipping to see if a tank is nearly full, or inspect for leaks and spills, etc. Instead automatic detection, digital transmission, and indication in control room software of issues such as these. There are also interlocks using these signals to prevent many issues. For instance, to detect leaks of caustic sodium hydroxide used in the extraction process, and time stamping on manual sampling valves.

No mustering cards, visitor log sheets, and walkie-talkie for headcount during emergency evacuation mustering and no search parties required to find missing personnel. Instead the location of every person is sensed digitally in real-time and automatically tallied in software. Contractors are managed and with geofencing alarm issued if personnel stray beyond permitted work areas or into a high-risk area. Man-down is also detected and alarmed enabling faster response.

Production process tasks

Routine manual collection of operations data on clipboard and paper forms is going away in many plants. Instead data is collected automatically and transmitted digitally to historian and operator software etc. Any remaining manual rounds are instead by tablet with software.

Paper notebooks for jotting down near misses, incidents, hazards, and maintenance needs etc. is no more. Instead notes and digital photos of incidents, hazards, leaks, and damaged equipment is captured digitally on tablets with software and shared with relevant parties.

Tagging along with experienced staff is not the only way for newcomers to learn how to perform manual tasks. Field operators can now also learn new tasks in a very immersive 3D virtual plant environment with virtual reality (VR) technology.

Digital operational infrastructure

Alumina refineries are deploying additional digital operational infrastructure as the enabler for digital transformation of work practices for many tasks around the plant to achieve operational excellence. Existing operational infrastructure in plants typically includes a plant historian, the control system, underlying field instruments like temperature transmitters and flow meters, and final control valves. In digital transformation, the digital operational infrastructure is expanded upon and enhanced to streamline how work is carried out in the plant. There is no need to replace the existing control system since the operational infrastructure is compatible with existing automation (**Fig 2**). There is no need to add another analytics platform layer; the existing historian can be used as a platform.

The principal building blocks for expanding the digital operational infrastructure are:

- Mobility
- Predictive analytics
- Pervasive networking
- Pervasive sensing
- Connected services

Mobility

In a digitally transformed plant, work by everyone from the plant manager down is data-driven. Each person gets data relevant to their responsibility to do their job better. For instance, the reliability manager has a dashboard very different from the safety manager and they don't receive the same notifications.

A key success factor for digital transformation is that the information must be easily accessible in a timely manner. In the infancy of digital transformation of instrument and valve maintenance practices more than 20 years ago, the software was usually installed on a computer located in the control room or an equipment room where instrument technicians could not easily access it. It often quickly fell into disuse. Instead the data should always get to the desk and pocket of the person responsible. For instance, predictive instrument alarms and information goes to the laptop and smartphone of the instrument technician.

Dashboards and alarms are generated by mobility software using information from underlying analytics apps like equipment condition monitoring. Dashboards contain KPIs specific to the person's responsibilities displayed on tablet computers or smartphones, making information immediately available wherever you are, be it in a meeting in the admin building, in the canteen, or on your way to or from work. Tablets and smartphones are available in industrially hardened models for use in the plant.

Predictive analytics

Many digital transformation solutions monitor simple process variables, such as corrosion and erosion (metal loss), temperatures and pressures, etc., that

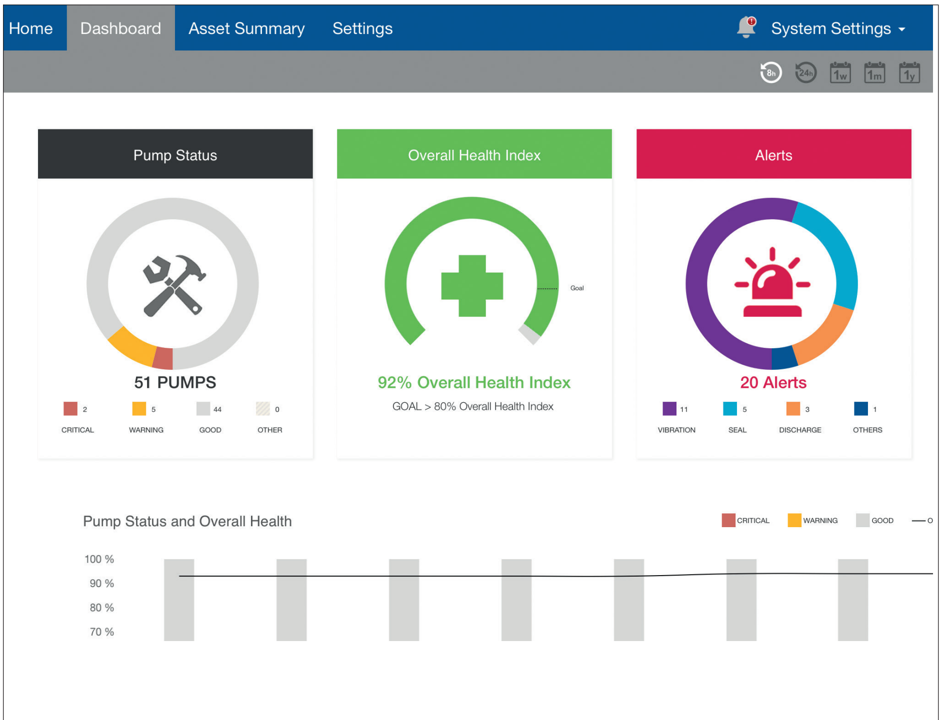

Fig 3. Intuitive equipment analytics apps for use by maintenance and reliability engineers

need no additional analytics. Predictive equipment analytics apps which encode subject matter expertise are used for performance and condition monitoring of complex process equipment with multiple measurements such as for compressors, blowers, fans, pumps, heat exchangers, cooling towers and air-cooled heat exchangers to anticipate problems, allowing failures to be predicted and averted. Raw data from sensors is distilled into actionable information. When a problem arises the technician already knows what to do and what to bring before going to the field. And it is not just vibration, the fault models also uncover early signs of trouble and distinguishes between many types of equipment-specific failures. The disruptive learning periods associated with machine learning are not required.

Equipment analytics can feed into plant-wide dashboards, business intelligence software, and ERP workorder management systems. Software provides predictive analytics to predict failure in advance, as well as prescriptive analytics recommended action. The analytics software can be installed on servers on-premises or on virtual machines in the cloud. A layered open architecture has real-time analytics at the sensor level, edge analytics done in higher level devices and servers, feeding up to business intelligence at the enterprise level 4.

Web-based analytics apps are "platform agnostic" since they do not depend on any particular brand of control system or historian. The plant's existing historian remains in place for big data storage, it need not be replaced by another middleware platform, and there is no need to add another middleware platform thus protecting the plant's investment and keeping the administration cost low. The analytics uses data aggregated from multiple sources, including new and existing sensors, wired and wireless, package unit PLCs, control systems, safety systems, machinery protection systems, intelligent device management (IDM) software, and any historian or future platform through the OPC Foundation's Unified Architecture (OPC-UA) application programming interface (API) technology, which works regardless of vendor. Conversely, analytics from equipment apps can feed into analytics and dashboards for the whole unit or plant. Similarly, information can be integrated in augmented reality (AR) visualisation solutions.

Use apps purpose-built for real-time equipment monitoring and that are designed to be easy for maintenance and reliability professionals (including managers, engineers, and technicians) to use. The best apps come with overview dashboards, alarm summary with simple health index, priority, plain text problem description, and the ability to zoom into detail and see history trends to spot accelerated degradation and estimate remaining life. You need not be a data scientist to use purpose-built analytics (**Fig 3**). Apps for steam trap, pump and heat exchanger analytics help drive better maintenance management. The analytics uses verifiable first principle models, failure mode effect analysis (FMEA), and statistical algorithms to detect signs of developing equipment issues, predicting failure and providing early warnings based on these leading indicators so breakdown can be prevented. These apps are pre-engineered so no long algorithm learning periods are required; it's only necessary to capture the baseline.

Pervasive networking

Data-driven practices requires sensors to collect the missing data. It would be impractical to hardwire hundreds or thousands of sensors point-to-point using the 4-20 mA or on-off signals. Plants built with FOUNDATION® Fieldbus networking can simply add instrumentation to existing field junction boxes with minimal wiring to the sensors. All plants should deploy wireless infrastructure for sensors. One method is to deploy a plant-wide wireless sensor network and optionally also a wireless local area network (WLAN) infrastructure depending on which operations tasks will be digitized. The wireless network infrastructure consists of wireless gateways for the wireless sensor networks, and optionally wireless access points for the Wi-Fi network as the central nervous system of the plant. The wireless gateways can be embedded inside the wireless access points when WirelessHART® and Wi-Fi are deployed together. Since these networks are used for operational functions, both wireless networks are managed by the instrumentation and control (I&C) department and integrate with the control system, historian, machinery protection system, safety system, and other operations systems.

Location awareness is technology used to locate people and assets in the plant. This is used for automatic emergency mustering headcount and rescue locating. Location awareness is also used for geofencing of restricted or high-risk areas, meaning if unauthorised persons stray into the area an alarm will be generated. The wearable ID tags used for location detection include a panic button for distress call and senses if there is no movement (man-down).

Wearable video collaboration, tablet computers in the field to assist in various tasks such as retrieving maintenance history or documents, data collection and reporting, are examples of functionality which make use of industrial Wi-Fi in the field.

Pervasive Sensing

Data-driven work practices start with

Fig 4. EGA Dubai wireless sensors for digital transformation energy efficiency

the raw data from sensors. Sensors bridge the gap between the physical and digital world. Without sensors there is no analytics and no Big Data. Process equipment like pumps, compressors, heat exchangers, blowers, cooling towers, air cooled heat exchangers, manual valves, and tanks – even steam traps usually have no transmitters for condition monitoring; missing measurements. This equipment is now being instrumented with additional sensors to cover these missing measurements thus yielding smart connected equipment. Automatic data collection is much faster than manual data collection, providing early detection of markers of developing problems, thereby making the asset management more predictive, and far more productive.

Wireless sensors often take the place of mechanical instruments, portable testers, and clipboards. Wireless sensors include pressure, flow, level, position, on-off contact, vibration, temperature, corrosion, erosion, acoustic noise, and electric power as well as level switch, which are installed as needed to feed data to analytics and other software for reliability, energy efficiency, personnel safety, and production. Wireless sensors are deployed without having to lay more cable and installing more I/O for 4-20 mA and on-off signals. Control valves and flow meters not already digitally integrated are fitted with wireless adapters. Many of these new sensors are non-intrusive or reuse existing process connections meaning they can be installed while the plant is running without shutting down the process. Wireless sensors can be deployed without opening cable trays or junction boxes avoiding the risk of damaging existing cable. Some transmitters such as for vibration include edge analytics pre-processing the raw data.

Connected services

Often there are not enough experts on-site. Some plants opt for an IIoT-based solution with subject matter experts in a central location monitoring equipment across multiple sites. It can be the company's own fleet management center to manage process equipment in the company's fleet of plants around the world, or it can be a third-party connected service provider monitoring process equipment in multiple companies' sites globally. The service provider's IIoT center has a pool of experts in the areas of rotating machinery vibration, control valves, analysers, corrosion/erosion, static process equipment, and steam traps, etc., to guide on-site personnel with real-time advice. In the cloud, analytics software monitors the equipment in the plants. Staff extract reports listing equipment condition and what actions are required. The reports are reviewed by domain experts before sending to plant personnel. The report format has been created specifically for each kind of equipment including the relevant information allowing plant personnel to act immediately. The reporting frequency depends on the type of equipment. In a new business model for connected services, instrumentation such as acoustic and vibration sensors are not purchased but included as part of the subscription fee, requiring little or no upfront investment for the plant.

Digital transformation in the aluminium industry

Alumina refineries and smelters around the world are already digitally transforming how work is done.

Switchgear monitoring

An alumina refinery in Brazil was operating their rectifier stacks well below the rated 100kA due to operating temperature uncertainty because they were relying on infrequent manual infrared (IR) thermography for temperature checks. Surface acoustic wave (SAW) temperature sensors were installed on nine rectifiers, providing continuous temperature measurement at the control switch incoming and outgoing buses. The data is transmitted digitally to the monitoring system. The solution allowed a 10 percent increase in operating current and total material throughput without fear of catastrophic failure.

Energy management and loss control

Emirates Global Aluminium's (EGA) smelter site in Dubai had a problem with the compressed air consumption. Air demand was varying through the day and the company wanted to improve measurement of the variations to optimise air usage and production. More than 50 wireless flow meters measuring the compressed air consumption of each plant area covering a total plant of 480-hectares were installed (figure 4). The measurements are integrated with the manufacturing execution system (MES) which allows the company to know in which area and at what date/time air consumption increases. Based on this, each area is reviewing its processes and procedures to optimise air usage. The solution has eliminated the need for daily visits to air flow meters. Continuous monitoring shows spikes and trends in air use, allowing improved management. They now have a better understanding of the compressed air consumption in the plant with improved ability to plan and control cost. As a result they have reduced energy use and have created plant-wide awareness of the importance of compressed air. Since then they have added wireless temperature measurement in remote substations mainly to identify breakdown of air-conditioning as well as wireless vibration monitoring for air-cooled heat-exchangers.

Overfill and spill prevention

An alumina refinery in Brazil using the Bayer process had problems with their red mud stacking. Originally the site relied on manual inspection of the level in a large area to determine which valves to open and close. Critical points may overflow if not detected fast. Due to the dynamics of red mud stacking a movable level sensing solution was required. Wireless level switches were installed to detect high level reporting much faster than ever possible with manual inspection. Since the sensors are wireless, moving them around is easy. The wireless gateway is integrated with the existing DCS and mud level displayed on operator screens. As a result they were able to reduce the risk of red mud overflow.

Alumina 4.0

In the aluminium industry, applying digital automation technology and rethinking how the entire plant is run and maintained has increasingly become the best way to achieve operational excellence. To stay competitive, alumina plants must be prepared to expand their digital operational infrastructure with more software and sensors, digitized work processes, wireless monitoring, and training on wireless devices and software in order to improve production, energy efficiency, safety, and reliability. ■