Materials Processing Institute

INDUSTRY 4.0 DIGITISATION OF THE NORMANTON STEEL PLANT AT THE MATERIALS PROCESSING INSTITUTE

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Abstract

Many steel making companies operate on brown field sites, often with legacy equipment and bespoke process models. Applying Industry 4.0 technologies to these sites requires the digitisation of aging kit and improvements to the programable logic controller (PLC) data logging infrastructure. The Materials Processing institute used Innovate UK funding under the InTiFi project to realise a vision to create an open access industrial demonstrator of the application of Industry 4.0 to brownfield steel sites. The steel plant main facilities at the Institute consist of a 7 tonne electric arc furnace (EAF), combined vacuum degassing and ladle furnace (LAF) and continuous caster for billets and mini slabs up to 20m cast length.

After investigating and trialling several Industrial Internet of Things (IIoT) platforms the PTC ThingWorx IIoT platform was selected due to ease of connectivity to the Kepware OPC UA server and its built-in machine learning / AI model development analytics. The ThingWorx server and Prequel database were installed on a demilitarised zone (DMZ) at the Institute to allow secure access to the Normanton Steel Plant Kepware server and to allow external workers / project partners to the institute to view live melt and cast data. Further, this arrangement will allow European project partners secure connection to the IIoT server for data transfer and modelling.

The work concentrated mainly on the casting machine although attention was given to the EAF and vacuum degasser for temperature monitoring of the transformer and electrode drives together with energy monitoring. Under another project it is intended to install a digital regulator that ThingWorx will incorporate to offer operator advice / control. Further, digitising of the optical emission spectrometry (OES) steel analysis was also undertaken.

Brain storming sessions were held to identify areas for improvements that were scored on benefits and ease of implementation. As the caster is used for a wide variety of non-standard and research purposes benefit scores were different between research and process improvements. High benefit and ease of implementation were initially chosen for progressing. Following the identification of areas for improvement key KPIs were identified for benchmarking purposes.

Installation of various sensors was undertaken for pressure, flow, temperature, and energy measurement together with live video allowing the processes to be remotely viewed by partners during live casts.

In conjunction with upgrading of the PLC ethernet network a wireless network was also installed for wireless sensor signals and also to provide information to tablets for both operators and process maintenance engineers.

To date Thingworx has captured live data during a melt and cast.

Introduction

This paper summarises the work undertaken to date on the Industry 4.0 digitisation of the Normanton Steel Plant at the Materials Processing Institute. The vision is to create an open access Industry 4.0 demonstrator for the Steel and Process Industries initially funded by Innovate UK under the Industry 4 Technologies into Foundation Industries (InTiFi) project. The UK already has demonstrators for Industry 4.0 at the Catapult centres but they are purpose built from the ground up with Industry 4.0 in mind. The challenge therefore is applying Industry 4.0 technology to existing foundation industries that have legacy equipment from different vendors with data in multiple formats and bespoke process models.

The work undertaken at the Normanton Steel Plant included the evaluation and selection of (IIoT) platforms with PTC ThingWorx being the chosen platform. An Industry 4.0 digitisation gap analysis was performed to identify areas for improvements that were scored on benefits and ease of implementation. As the plant is used for both commercial products and research purposes benefit scores were different between research and process improvements. The work concentrated mainly on the casting machine although attention was also given to the Electric Arc Furnace (EAF) and vacuum degasser. Further, a 3D laser scan of the Normanton plant was undertaken by Technical Simulation Consultants (TSC) based in Nottingham and a navigable 3D laser scan model created.

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Normanton Steel Plant

The steel plant consists of:

- 7T AC Electric Arc Furnace
- Combined vacuum degassing and ladle furnace
- Continuous caster cable of casting:
  - Section size 300mm by 142mm with a cast length of 15m
  - Section size 180mm by 180mm with a total cast length of 24m
  - Section size 140mm by 140mm with a total cast length of 36m
  - Suitable as direct mill feed
- Ingot casting: slab, 5T and 5.9T square

Figure 1. The Normanton Steel Plant and Caster

The Normanton Plant and its equipment is used extensively for Research and Development projects together with some revert and assay melting.

Selection of Industrial Internet of Things (IIoT) Platform

A review of existing IIoT platforms was undertaken and Siemens MindSphere and PTC ThingWorx were selected for trials as they offered the most functionality of those surveyed.

Required functionalities evaluated during the trials included:

Required functionalities evaluated during the trials included:

- ability to store data from several edge devices / process in real time
- ease of connection to multiple large data sources via OPC-UA
- ease of adding code to the platform, speed of implementing modifications and new versions
- ease of dashboard creation for mimics
- ability to explore and export historical data
- event recognition and alarms
- data analytics with machine leaning and Artificial Intelligence (AI) model build
- cost and customer support.

Following the evaluation PTC ThingWorx version 9 was selected as it scored highly and has inbuilt analytics with the main AI and machine learning modelling capability together with good connectivity to Kepware version 6

ThingWorx data is stored on the PostgreSQL open-source database and both were placed on a secured firewalled (DMZ). Secure Sockets Layer (SSL) certificates were put in place to allow external workers and project partners to securely view live melt and cast data together with live video streaming of the process. This also provisioned the ability to connect to external customer databases and Kepware servers for data transfer, modelling and provision of IIoT services.

Figure 2. Remote monitoring of caster mimics and data displays whilst watching live CCTV of a cast

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Gap Analysis

A gap analysis was undertaken utilising process mapping, and brainstorming was performed with both process operators and research personnel. Due to the pandemic this was undertaken online using Teams. This resulted in the identification of areas for improvement that were scored on benefits and ease of implementation. As the steel plant is used for several different purposes it resulted in different benefit scores between research and process uses. This process also identified the required measurements for the plant and subsequently the instrumentation requirements. Further, the need for an improved Programmable Logic Controller (PLC) network and its redundancy was also identified. High benefits and ease of implementation were the areas chosen to progress. In order to quantify the improvements resulting from the digitisation the following KPIs were identified for benchmarking purposes:

- Slab surface quality
- Missed casts
- Failed starts
- Energy
- System failures
- Availability

Sensor Installation Equipment and Network Upgrade

A key requirement for the digitisation process is the reliable and secure transmission of sensor and instrumentation signals. The PLC network was upgraded from Control Net to ethernet/IP using dual port cards to create a redundant ring providing a more secure and fault tolerant system together with better system integration. Together with the PLC network upgrade the Kepware server was also upgraded from version 5 to version 6 to allow connectivity with the ThingWorx IIoT platform.

A wireless network was also installed in the steel plant to allow communication with wireless sensors, tablets and smart glasses in order to provide timely information for the process operators and maintenance engineers. The intended information for maintenance engineers includes access to maintenance records and equipment manuals. Further, the smart glasses allow process engineers to have access to process information, measurements and advice in real time.

Although the steel plant and caster at the Institute have been established for over 20 years the level of instrumentation is low and is more specific to gathering data for research and development projects. A variety of sensors were identified and purchased covering measurements for temperature (thermocouples, caster strand pyrometers and thermal camera), pressure, flow, energy, weight and steel analysis. The use of Arduinos was investigated for connection to wireless mould thin film thermocouples. These sensors will allow the development of machine learning / AI models for predictive maintenance, operator advice and product quality.

A CCTV system with 32 analogue inputs for remote viewing of live melts and casting was also purchased and installed.

ThingWorx IIoT Mimics and Data Display

ThingWorx provides the ability to bring in data from several sources. At the Institute it brings in data from the plants' Kepware V6 server that is connected to the PLC network and sensors. Some devices, such as thermal cameras, are not part of the plants' PLC network and therefore do not store data in the plants' Kepserver database. For these devices, custom edge applications will be developed, tested and implemented. The data from the steel plant can be displayed in a variety of display formats developed using Java script mashups. These displays can be accessed securely and remotely together with live CCTV of casting allowing clients and project partners to observe live casts as shown in Figure 2. IIoT platforms also have business management benefits for resource planning and operations scheduling that are currently being developed for the Normanton Steel Plant.

See graphs on page 5.

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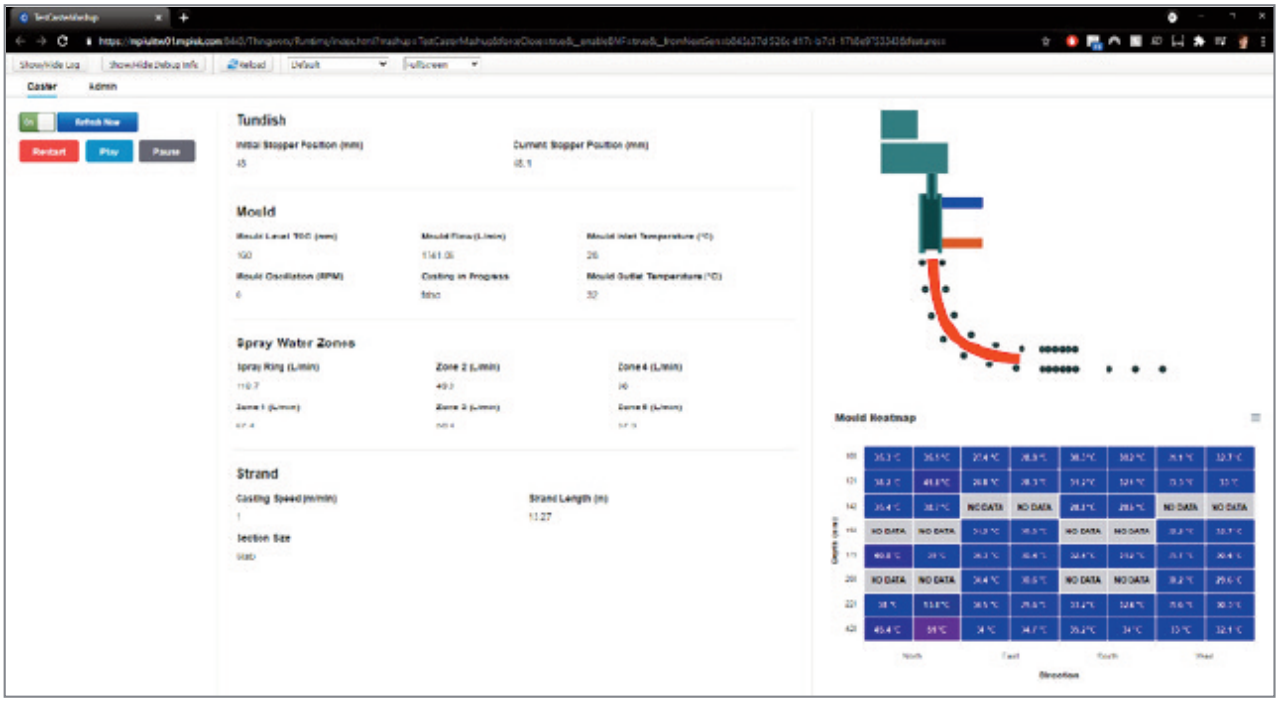

Figure 3. ThingWorx caster mimic showing casting data

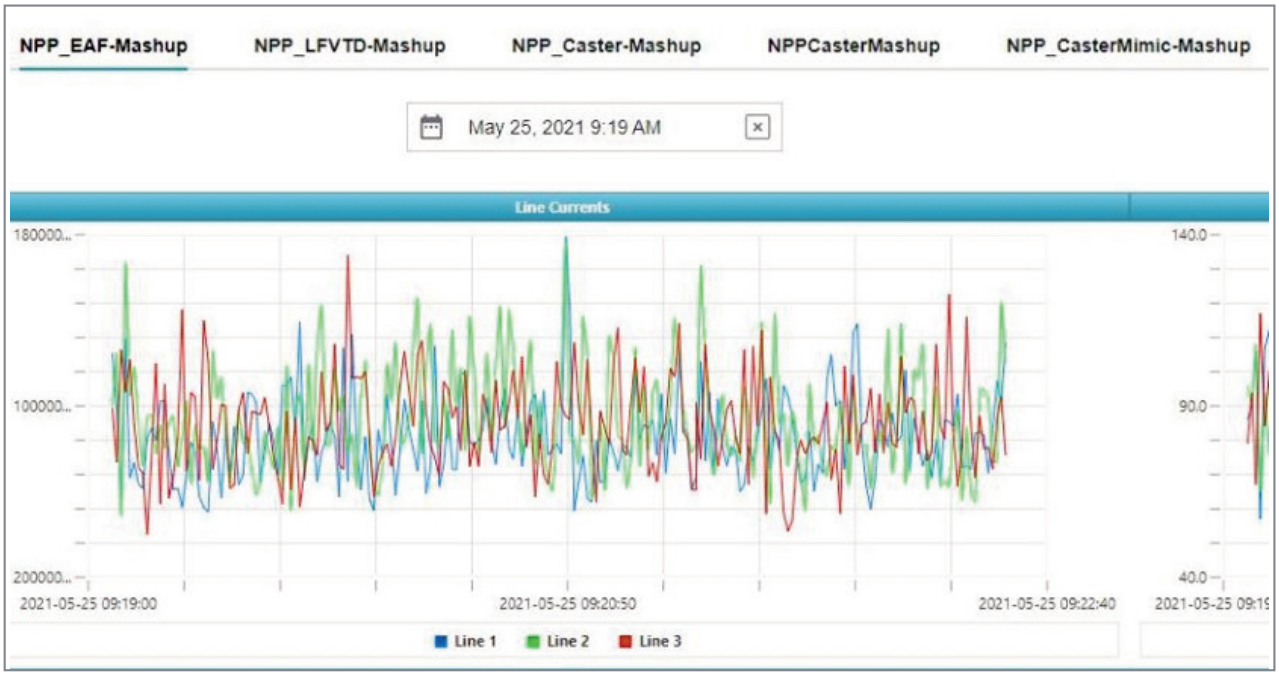

Figure 4. ThingWorx data display of live EAF currents

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Digital Twin

As part of the digital twin development TSC Simulations performed a digital scan of the steel plant and developed a 3D navigable model of it that will be used to create it's virtual environment. Such models allow the training of personnel without the associated safety or environmental risks of using the actual live plant.

The Institute has created many caster models over the years in different programming languages running on varying platforms. These models will be put into the digital twin. However, a digital twin is more than a simulation; by including live plant signals real time updates can be included in the simulations together with machine learning models to provide predictive maintenance, identify departure from desired operating conditions and provide real time advice to operators.

Figure 5. 3D Navigable Laser Model of the Normanton Steel Plant

Augmented Reality (AR)

The Institute is exploring the use of PTCs Vuforia Studio linking to ThingWorx to provide AR allowing computer generated enhancements to the real-world environment which can include audio, visual and haptic information. This information can be provided via smartphone, tablet devices or via smart glasses which show images directly in the wearer's field of view. Operators can therefore be provided with data to allow them to make informed decisions and identify potential problems before they occur.

The Institute is also exploring the use of Vuforia Chalk to provide remote assistance. By using Vuforia chalk an expert at the Institute can see what the field operative can see via his mobile phone and annotate the video image. This annotation remains anchored to the item even when the view is changed therefore when the view is changed back to that item the annotation can still be seen. It is expected that this will result in cost savings for both the Institute and clients by removing the need in some cases for our experts to travel to remote locations.

Figure 6. Image showing the use of AR on the caster with data being displayed on Vuzix smart glasses

Conclusion and Further Work

The Materials Processing Institute has embarked on the creation of an open access Industry 4.0 demonstrator for the Steel and Process Industries initially funded by Innovate UK under the InTiFi project. Using structured workshops, the Institute performed an Industry 4.0 digitisation gap analysis identifying how the application of Industrial Digital Technologies such as Industrial Internet of Things platforms, Machine Learning, Augmented and Virtual Reality could be used to improve the process and product.

Live dashboards to display the relevant process data have been created for the Normanton plants' EAF, LAF and caster. The LAF and caster are PLC controlled and monitored so that data is available on the current operational state of the machine as well as key metrics from the ancillary equipment. These dashboards can be viewed remotely together with live CCTV of the caster

during operation. This arrangement allows the Institute to offer this service securely to its clients over the internet. Further, the use of Vuforia Chalk will allow the Institute to provide augmented reality-based remote assistance from our experts.

The Institute will continue to develop the ThingWorx platform, pre-processing of signals, create and improve dashboards for connected equipment and create edge

Work will also be undertaken in the field of big data analytics / machine learning / AI models for predictive maintenance, operator advice and product quality.

Digital twin development will commence by using caster models, PLC models and live signals.

Augmented reality development will continue to provide real time data and warnings to process engineers together with remote assistance from our process experts.

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