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Why Modern Manufacturing Needs the Digital Twin

The digital twin helps manufacturers see, understand, and improve the manufacturing process.

by: Chris Parsons in Automation & Motion Control, IoT on May 07, 2019

We live in a digital era. Data is all around us and, at the manufacturing level, the huge volumes of real-time data available provides new insights into processes. Used intelligently, these data offer a pathway to continuous process improvements and significant increase in production efficiency. For these benefits to be brought to bear, however, requires clear visualization, contextualization, and advanced analysis of the data, which is most efficiently achieved using a digital mirror of the physical world – a 'digital twin.'

Indeed, digital twins were cited by Gartner as being in the Top 10 Strategic Technology Trends for 2018. In 2017 the report IDC FutureScape: Worldwide IoT Predictions projected that "by 2020 "30% of G2000 companies will be using data from digital twins of IoT connected products and assets to improve product innovation success rates and organizational productivity, achieving gains of up to 25%."

The problem is that there many companies that still do not have a clear understanding of what a digital twin is, the real benefits it brings, or how to harness its power. Although a Manufacturing Execution System (MES) is a first form of digital twin, the evolution of the Internet of Things (IoT) and Industry 4.0 manufacturing concepts have opened new possibilities regarding how real-time data can be used to better control and optimize production.

The Real and the Virtual

Enabling an Industry 4.0 manufacturing solution requires complete, contextualized, real-time data in an integrated fabric of devices, data, connections, processes, and people; weaving together all the different assets and technology available with digital information. It relies on the "cyber-physical," a combination of the virtual and the real. Cyber-physical systems (CPS) are smart sensors, products, and materials. Cyber-physical production systems (CPPS) are the smart machines that deliver the required processes to produce the final product. Both CPS and CPPS have the virtual and real in one entity.

In 2002, Dr. Michael Grieves developed the concept of a digital twin, having a real space and a virtual space with data flowing between them. In 2017, he went on to write a paper with John Vickers about using a digital twin in a complex system titled, "Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems." This is is what we want within a manufacturing plant.

The Manufacturing Digital Twin

The complete digital twin supports the lifecycle of a product, covering product design, manufacturability, all shop floor activities, logistics, and usage. The manufacturing digital twin looks after the portion of this lifecycle that relates to manufacturing. For a digital twin to reach the potential of what it can deliver for manufacturing efficiency requires modelling of the whole process flow or plant. This enables analysis of the complete production system, identification of areas that can be improved, and even predictions of what will happen. An MES has historically offered some of this, but the full potential and application of the digital twin is still not widely understood.

The digital twin covers everything from sensors and assets, up to complete process lines or plants, and even a network of multiple plants. It contains layers of models with different types and structures of data – including 3D models, specifications, and real-time data. For it to work across the production lifecycle it requires different views for the many different stakeholders. For example, maintenance personnel need to see very different aspects of the plant than designers.

Once a framework for a digital twin is created to mirror the physical world to which it relates, consideration then must be given to how this is maintained, data corruption avoided, and real-time data accessed for live views onto the plant. This requires the "digital thread."

The Digital Thread

The digital twin partially separates the virtual and real portions of the system. But to reflect the shop floor, the virtual and real need to be connected. This is where the digital thread comes in.

The digital thread is a collection of digital communications that integrates and drives modern design, manufacturing, and product support processes, including product and process definitions that start in design engineering and flow through the entire production chain. Data flows include quality requirements and compliance, specifications, test results, maintenance schedules, and more, and also include feedback loops such as lessons learned and planned versus actual processing results.

The digital thread serves the digital twin, helping to maintain its model and provide effective data feeds. In turn, the digital twin sits at the intersects of the digital thread and ensures data sets are organized and contextualized. Together, these form the fabric needed for an Industry 4.0 production model.

Embracing the Benefits of the Digital Twin

The manufacturing digital twin offers many benefits to production. Primarily it provides complete visibility onto the whole plant to give greater confidence in performance. The view it provides onto processes presents clarity on where to focus and where continuous process improvements can be made. It enables the allocation of smart resources in real time and provides a clean foundation, with the complete, real-time data required for technologies such as virtual and augmented reality.

With the continuous process improvement and greater production efficiency they offer for businesses, the digital twin and Industry 4.0 can be used to defend a company's position in the market. They are, however, also being used to create new lines of business with premium products and faster product introduction.

From MES to a Manufacturing Digital Twin

The manufacturing digital twin is a set of virtual information constructs that fully describe the potential or actual physical product. It has become more compelling in recent years because of the evolution of devices with computational and graphical capabilities at lower prices and the dawn of the IoT, which offers an easy way to collect information.

The digital twin gives the operator all the data that can be obtained from physical inspection of the product in a digital presentation of the real world. For manufacturing execution, it monitors, analyses, and controls all aspects of production.

If a company has an MES, which uses real-time inputs to track, trace, and control manufacturing processes, it already has the basis for a manufacturing digital twin.

An MES is designed to increase production throughput and reduce costs. It enforces quality and compliance with strict control of processes and process steps and provides a level of flexibility to respond more quickly to market demands and reduce the time for new product introductions. It maps manufacturing processes, improves visibility, controls and documents processes for greater production optimization.

Many companies already have an MES, and therefore, by definition, a form of digital twin. To take advantage of Industry 4.0 and the IoT however, they also require an IoT platform, a digital twin for visualization, and other capabilities such as augmented reality. The problem is that if these are not integrated using common languages and platforms they become silo solutions that have huge overheads in terms of their integration and maintenance needs.

Modern MES Is a Platform for the Digital Twin

For companies with a modern MES solution that has been designed to embrace the potential of the IoT and Industry 4.0, a digital twin can be built onto this platform. All manufacturing physical objects have three main elements: a physical location; a state; and additional parameters. So, all that the MES needs to have to implement this first level is x,y,z coordinates; a state model; and a data set for storing values of parameters. These then need to be represented on a screen for the operator with updates in real time as changes happen in the physical world. The first level would be a 2D model of the factory floor, providing a simple overview of operations in a digital format with information collected and updated in real time. A 3D model, however, offers much greater potential and a truly interactive experience for the user.

There are numerous ways in which 3D views can be created. 3D shapes can be created within the MES and associated with physical objects, including equipment, containers, products, and even people. Factory blueprints can be uploaded to give a layout upon which the 3D objects can be placed. Equipment information can be loaded from packages such as Excel, and quickly associated with 3D entities on screen.

For even more compelling and realistic views of the shop floor, CAD models can also be loaded into the MES. Libraries of equipment representations can be pre-loaded, requiring the user to simply select the equipment type and 'drag and drop' it into position. All of this means a digital twin can be created in a matter of hours rather than weeks. This makes the time to value exceptionally short and removes the need for expensive, specialist programming as the shop floor develops and changes are required.

3D models also give a pathway to virtual realith (VR) and augmented reality (AR) scenarios, enabling virtual navigation throughout the shop floor with exciting training and simulation opportunities. Machines can be color-coded to give clear and obvious status of the process lines. Moving assets such as products, people, and robots can be added with real-time positioning coordinates using RFID tags and readers, WiFi triangulation systems, or image recognition solutions.

The Layers of the Digital Twin

The digital twin can have many layers to suit individual and business needs. At the very top level this could be a global view of multiple factories. The user can then move through the levels to view individual factories, process lines, or individual pieces of equipment. Business intelligence cards can also be integrated into the digital twin screens to show key performance indicators such as overall equipment efficiency (OEE), mean time between failure (MTBF), etc.

The manufacturing digital twin provide a level of visibility that gives a clear picture of what is happening on the shop floor. It is a window to understanding where issues lie, where improvements can be made and how to better optimize production. A modern MES provides a platform on which the digital twin can be delivered without the need for multiple, separate systems that will require unsustainable ongoing integration and maintenance. Indeed, with a truly future-ready MES, a company can implement and gain the benefit of a manufacturing digital twin in a surprisingly short amount of time – creating opportunities for greater business agility, growth, and innovation into the future.

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