Title:
Digital Enterprise Test Bed and Model-Based Work Instructions

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Introduction:
With new technology emerging, companies strive to continuously improve their management and manufacturing processes. Digital Enterprise capabilities development is the strategic initiative for organizations in adopting to Industry 4.0 revolution. Creating product digital twin, adopting Internet of Things (IoT) for supply chains and production environment, digital manufacturing capabilities, 3D printing, and big data analytics are the core elements for manufacturing companies in next generation manufacturing [1,4]. As a result, with digital product data and advanced analytics, organizations improve the process efficiencies and make data-driven informed decisions [2].

Elements of Digital Enterprise reconfigure and streamline all the process right from procuring raw materials, manufacturing products, delivering to customers, providing after sale maintenance support and managing end of life product returns in right time at right place and in cost-effective way. Digital enterprise testbed focuses on setting up a platform for companies to adapt to the digital revolution [1,6].

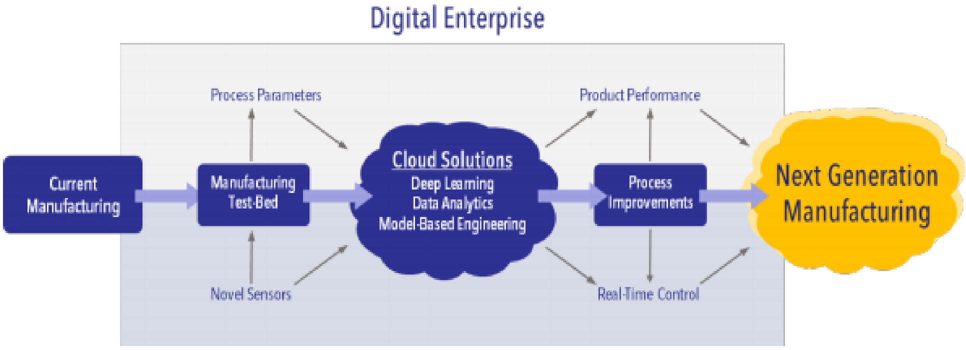

Fig. 1: Diagram of digital enterprise testbed benefits to current manufacturing.

This paper focuses on defining a test bed instance that is pioneered to adopt the technologies and systems that are required to build digital enterprise in the era of Industry 4.0. The testbed will allow next-generation workforce development by strengthening the digital enterprise connectivity, product and process R&D, and facilitating active translation service with MEP. Moreover, the testbed will demonstrate the validation of smart technologies/applications and showcase innovative methods to modernize manufacturers and their supply chain. Other content such as education programs will be held for industry personnel in mid-level management by showcasing the testbed capabilities. This paper also discusses about explanatory research study of one of the applications of test bed in a manufacturing environment.

Main Ideas:

The testbed platform is developed by building two core elements: Digital thread of software tools and physical testbed factory. Sensors and network enabled ecosystem models connects the digital thread with test bed factory to create the Smart Factory.

The proposed digital thread of the testbed is built through: integration of CAD system, PDM system, MES system, ERP system, and CRM system. In addition to these systems, software tools for digital manufacturing to create process planning, plant simulation, product visualization, model-based work instructions are added to the software tool thread. Tools from leading vendors like Siemens, PTC, Dassault Systemes, and Anark core were installed in the testbed to facilitate digital enterprise pilot projects for the manufacturing companies.

Fig. 2: Testbed capabilities.

The physical testbed factory will include wide range of machine tools such as CNC lathe, coordinate measurement machine, drilling machine, Grinder, Welder, Furnace, 3D printers, laser cutter, robots, and testing machines. The machine tools collection will comprise of both cutting end new technologies and traditional simple machines without any advanced capabilities to replicate real world scenario.

Application of Test Bed: Model-Based Work Instruction:

Model-based Work Instructions utilize 3D product models to create digital graphical work instructions for manufacturing of products. Model-based Work Instructions contains text instructions, visual displays and animation of assemblies for instructing standard work for each manufacturing process step. Model-based Work Instructions develop product view in exploded manner and contains embedded 3D visualization of process steps in the work instructions. As most of the current manufacturing work instructions exists in paper form with 2D images and 2D product drawing, the implementation of digital, model-based work instructions would be beneficial for companies to improve the overall manufacturing quality.

Few companies are moving towards the implementation of digital, model-based, interactive forms of work instructions. Required technical capabilities of different data formats and tools to products and access model-based work instructions. Model-based Work Instructions would be beneficial in reducing operator errors and operator training time, improve manufacturing quality and process capability and eliminate process of replacing paper work instructions on production floors when there is a change to work instructions.

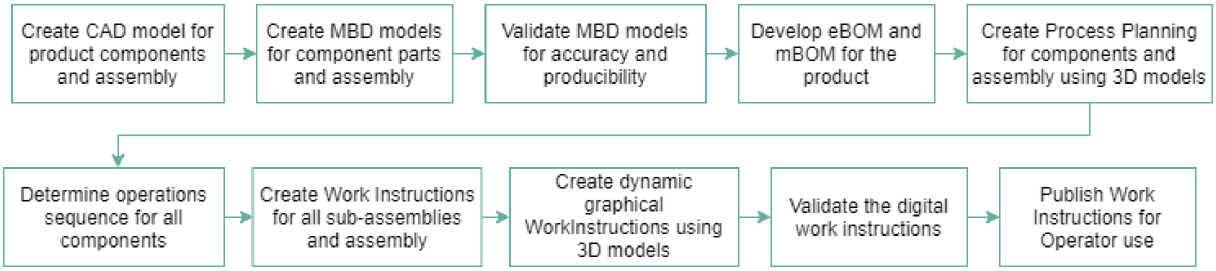

Fig. 3: Steps in creating model-based work instructions.

Required technical capabilities of different data formats and tools to produce and access model-based work instructions, have the potential to confound the user's ability to derive benefit. With the Model-based work instruction, we are able to provide a toolset for companies to quickly and confidently modify current designs and work instructions. Alongside the project stakeholders, the project aims to answer:

- How do we economically generate model-based work instructions and make it available for operators to use?
- How do we identify appropriate software tools and data formats for developing model-based work instructions?
- How do we determine whether we require customized tool (or) Out of the Shelf functionality tools for providing required access to stakeholders of model-based work instructions?
- How do we sustain model-based Work Instructions on long run, as the tools and data format used to create model-based work instruction is expected to change over time?

Augmented Reality and Model-based Work Instructions

In conjunction with the standard model-based work instruction, augmented reality (AR) is used to enhance the usability of interactive instructions. Using a RealWear AR headset, assemblers are able to interact with animations that guide them through the assembly process by displaying a holographic animation on the assembler's workstation. Unlike virtual reality (VR), AR headsets allow the operator to view both the holographic image and their surroundings.

Using a QR code located on a workstation, the glasses recognize at which assembly station the operator is working, and display the animation for that assembly station. The operator is able to play the 3D animation once they are ready to being assembly.

This functionality is currently in development, the glasses recognize the QR code and display a 2D animation on the assembly workstation.

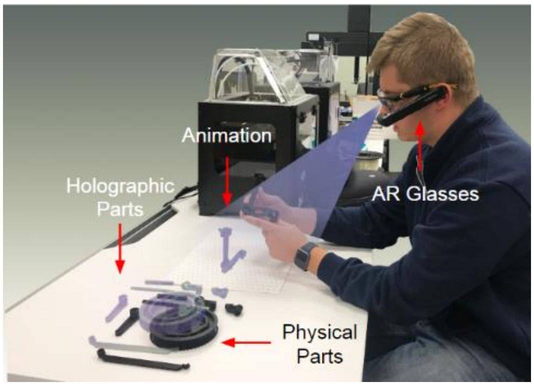

Fig. 4: AR workstation setup.

Throughout the research, our group refer back to our fundamental research questions:

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1) How do we move digital product and process data through an enterprise across the lifecycle of the product?
2) What are the technologies, tools, and capabilities are required for adopting digital manufacturing enterprise?
3) How can we use the testbed to develop model-based work instructions and what is the streamlined process to achieve it?

Conclusion:
With an industry growing and continuously evolving, the use of IoT, digital enterprise, Model-based Work Instructions, and AR, help support the growth and improvement in industry [3, 5]. Shorter lead times on creating work instructions and quicker, more efficient, delivery to the manufacturing floor [7]. The Testbed allows for companies to digitize their processes and continuously improve their manufacturing capabilities, quality, and safety. This paper outlined a research study that aims on developing a test bed environment to enable manufacturing companies experiment various pilot projects for the digital enterprise transformation. One such project is creating Model-based work instruction for operators in manufacturing floors. This paper provided a framework for developing model-based work instructions capability and steps for creating model-based work instructions in a manufacturing environment.

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