

Mass Customization with Intelligent, Modular, and Adaptive Production Technology: FlexiMon

EXECUTIVE SUMMARY

Today's Industrial manufacturing environments are increasingly characterized by high product mix, high product diversity, the need for rapid response times in transitioning from one product build to another, and the ability to rapidly adapt to new and emerging designs. This requires not only flexible automation, but automation with a reasonable measure of autonomy and the ability to make intelligent decisions. The present case study presents such a flexible automation system with Edge Intelligence – the FlexiMon – and shows specific applications that leverage these capabilities.

THE CHALLENGE

Craft production prior to the last three Industrial Revolutions was highly flexible and agile, but it had neither standard methods of production nor standard definitions of acceptable quality. Mass production standardized both the means of production and the assessment of quality, but any flexibility or agility was lost and thousands to millions of components had to be made to rationalize the cost of a production system and associated tooling. The introduction of machine numerical control starting in earnest in the 1970's enabled mass production to proceed in a faster, more precise, and more controlled manner but did not introduce flexibility or agility. Lean Production in the 1980's and 1990's restored to a significant degree the skill of the worker as a critical enabling element. Some measure of flexibility and agility was also restored as cellular manufacturing captured defects and faults much sooner, and just-in-time strategies prevented mountains of scrap from being produced.

However even Lean Production methods may not be up to the challenge of future production needs where mass customization will be the new normal: high product mix, high fluctuation in volume and demand, high product diversity, and many configurations within any family of products. In short, the ability to deal with unprecedented complexity has emerged as a dominant driver for future production systems. Industry 4.0 and Industrial Internet based solutions are therefore evolving as a response to this high level of complexity.

HARTING is a manufacturer of connectors as well as network and connectivity solutions. Within its product line is the Han-Modular® family of connectors, which can have many different variations and configuration styles. This the strength of the Han-Modular® product

line – the ability to allow the user to configure the connector to transmit power, data signal, fiber optic, and even pneumatics all within a single connector assembly. The challenge in manufacturing is that the product diversity is now enormous, the volumes for any given configuration are highly variable and could even go down to lot size 1, and the manufacturing system responsible for producing such diverse assemblies must be agile, flexible, and dynamically reconfigurable in space and over time. In short, Han-Modular® production is an ideal test case for Industry 4.0 and Industrial Internet based solutions.

THE SOLUTION

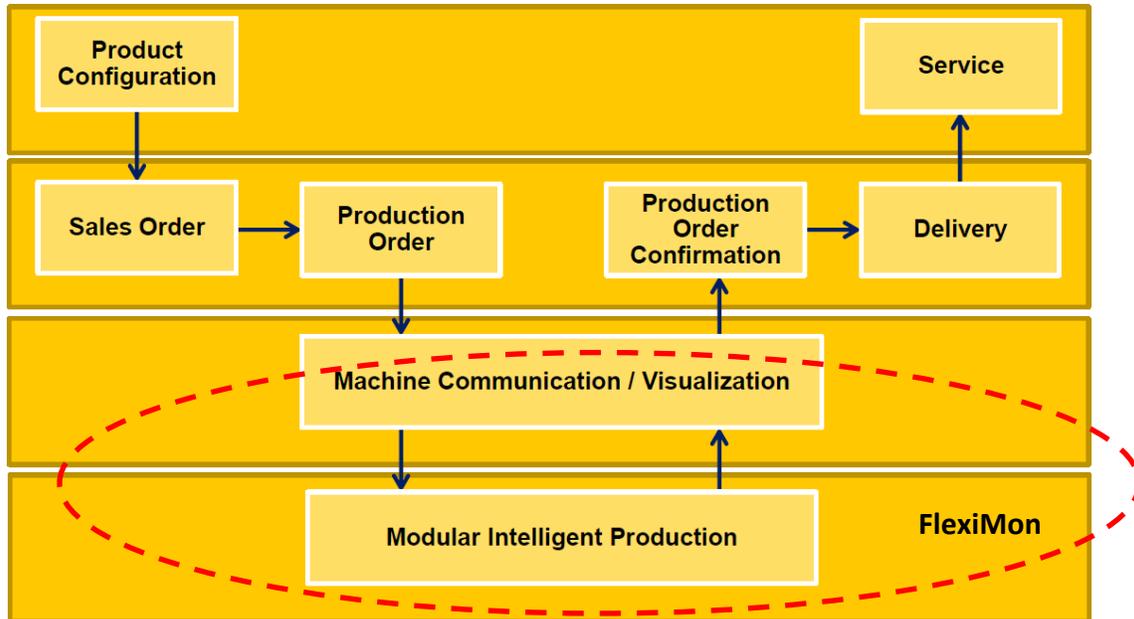
FlexiMon, the flexible production system designed to address such production challenges as those posed by Han-Modular® production, has six underlying principles which help guide its design and concept of operations: modularization, identification/virtualization, integration, digitalization, miniaturization, and customization. A brief operational definition is provided for each concept below.

- **Modularization**
This means a system that is comprised of separable, reconnectable, reconfigurable elements that have standardized interfaces for mechanical connections, electrical and power connections, and data and information connections.
- **Identification/Virtualization**
Identification goes beyond just labelling and encompasses the “cyber” aspects of cyber-physical objects, i.e. virtualization. Virtualization is not just the virtualization of a physical object through the formation of an administrative shell, but also encompasses the virtualization of production processes and supply chains. Virtualization includes the creation of a digital model of physical objects as well as all associated metadata.
- **Integration**
Integration refers both to horizontal and vertical integration. Horizontal integration is machine to machine, factory to factory, etc. vertical integration spans the range from sensors to machine to processes to ERP systems to global supply chains and networks.
- **Digitalization**
This could be viewed as being related to virtualization, but in a more comprehensive and all-encompassing sense of the widespread and ubiquitous use of digital and IT technologies at all levels right down to the machine and manufacturing process level.
- **Miniaturization**
This does not necessarily have to be limited to micro and nano scale miniaturization, but more generally refers to doing more in a smaller footprint, or higher power density, or with high information density. So miniaturization more generally is maximizing function and utility within a minimum achievable size or form factor.

- **Customization**

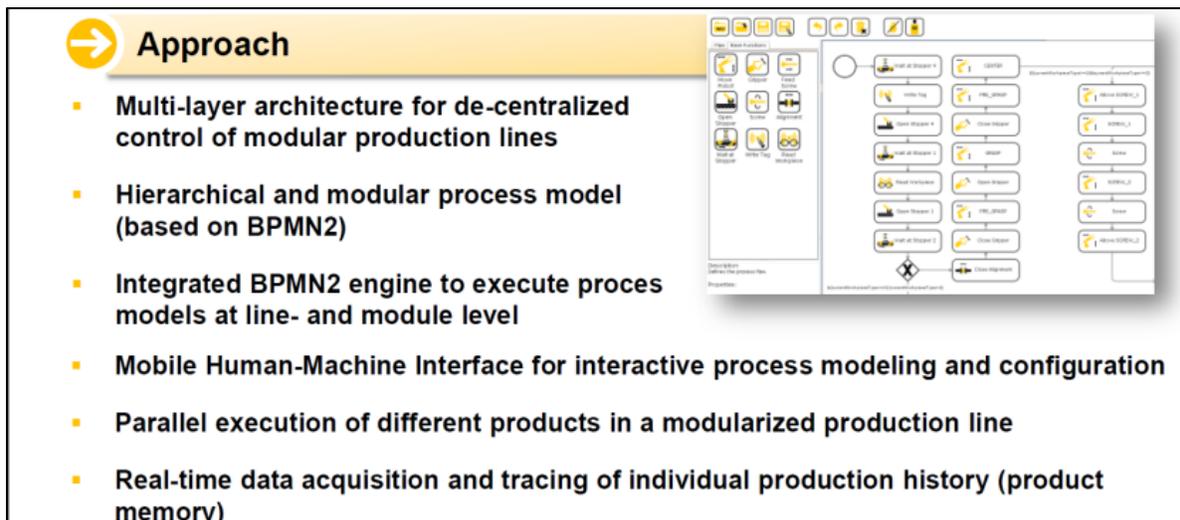
As mentioned above, customization on the product end manifests itself through mass customization, lot size 1, etc. Customization embodies the concept of high complexity and this drives the design of manufacturing systems capable of delivering mass customized products.

FlexiMon is part of a larger process flow which is the Integrated Industry concept, and can be best understood from the following flowchart.



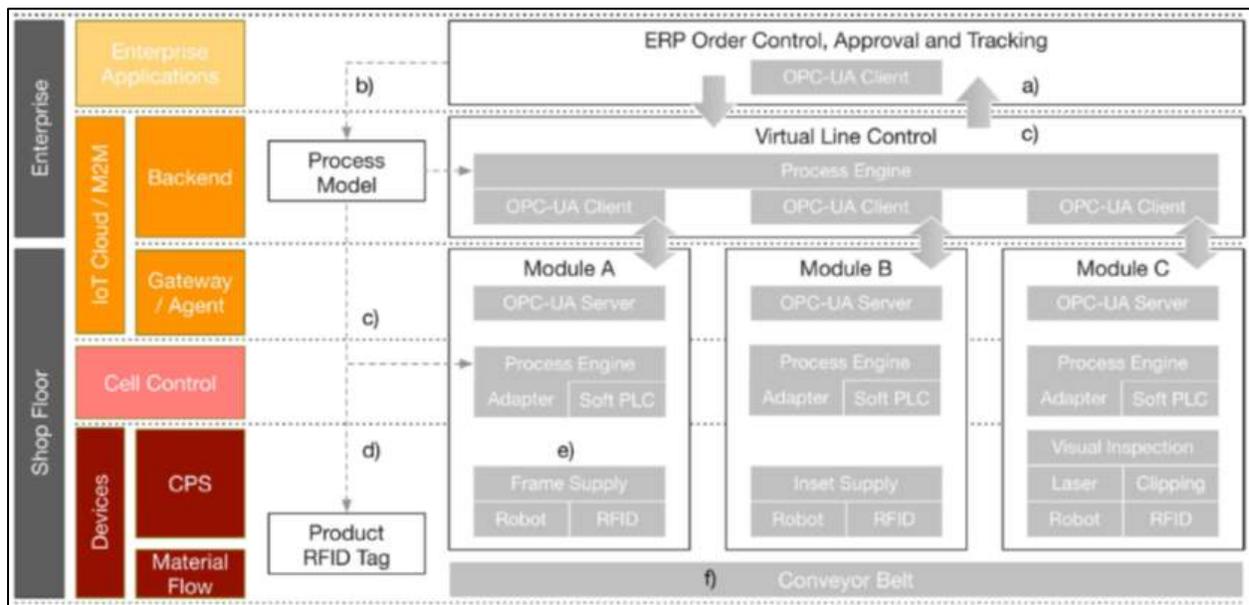
FlexiMon as a Part of an Integrated Industry Solution

The detailed description of FlexiMon concept of operation is further described in the figure below.



FlexiMon High Level Operational Concept

At a high level, the process flow is described by a process model using BPMN2 – which stands for Business Process Modeling Notation. This is a method used to map and describe value streams and business processes, but can also be used to model detailed steps of a manufacturing process (which is viewed as a smaller value stream or process). The advantage of using such an approach is that a common set of IT tools can be used all the way from the Enterprise level where high level business functions are mapped, all the way down to detailed manufacturing processes and steps. This helps facilitate the decentralized modular production approach embodied by FlexiMon. A much more detailed concept of operation for robotic workcell operations in general is shown below which better explains the IIoT bi-directional data flows within the FlexiMon architecture.



Detailed Operational Concept for Flexible Robotic Workcells (Ref. 1)

RESULTS

The practical manifestation of this concept for the application to the construction of Han-Modular® Connectors is in the form of the modular, flexible robotic workcell line shown above. This system supports the assembly and production of Han-Modular® connectors with high product diversity, high product mix, highly fluctuating volumes for each type of connector, and even can support lot size 1 builds of specialty connector assemblies – all within a single assembly line. With its Integrated Industry approach, HARTING is demonstrating the creation of new solutions with extended, multiple customer benefits, driven by the perfect interaction of expertise in the mechanical engineering, automation technology, information technology and robotics and sectors.



REFERENCES

1. Kuhlenkötter, B., Schyja, A., Hypki, A. and Miegel, V.,2010. Robot Workcell Simulation with Automation ML Support - An Element of the CAx-Tool Chain in Industrial Automation, *Robotics (ISR), 2010 41st International Symposium on and 2010 6th German Conference on Robotics (ROBOTIK)*, 7-9 June 2010, Munich, Germany, pp. 1076-1082.

ABOUT HARTING

The HARTING Technology Group, family owned and based in Germany, employs more than 4,000 people globally with subsidiaries and branch offices in 40 countries. With production facilities in Europe, Asia and the United States, the HARTING portfolio of connectivity solutions focuses on multiple levels, from the machine to the device and into the communication infrastructure. The U.S. facility in Elgin, Illinois is one of three HARTING locations that manufactures the HIS product line (HARTING Integrated Solutions - backplanes) and custom cable assemblies. The company's core business is intelligent and high-performance connection technology. HARTING works in almost all industrial markets with a focus on requirements for robust, reliable connectivity solutions. HARTING is also developing and making special purpose machines for a wide range of high and low volume applications within its own business units for internal production needs. HARTING has been a member of the Industrial Internet Consortium since October 2015.

ABOUT THE INDUSTRIAL INTERNET CONSORTIUM

IIC is a global, member supported, organization that promotes the accelerated growth of the Industrial Internet of Things by coordinating ecosystem initiatives to securely connect, control and integrate assets and systems of assets with people, processes and data using common architectures, interoperability and open standards to deliver transformational business and societal outcomes across industries and public infrastructure.