

TEXTILE INDUSTRY 4.0 – PREPARING FOR DIGITAL FUTURE

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ABSTRACT

The classical textile industry in the US, Europe and Japan has been in a state of flux for the past few decades. This has been characterized by massive reduction in work force, production outsourcing to SE Asia (mainly China and India), virtually no new infrastructure/asset investment, reduced R&D spending with no novel polymers developed which forms the basis of man-made fibers, etc. Companies like DuPont, Celanese, and Toray which were once synonymous with fibers are now a shadow of their former prowess. The rise of the fourth industrial revolution, or Industry 4.0, is likely to hold the growth panacea, drive changes for a better future and set a trajectory to attain its former glory.

Key Words: Industry 4.0, Digital Transformation, Cyber Physical Production Systems, Textile Industry

1. INTRODUCTION

The textile sector, as we know it, in the US, Europe and Japan must give way to the emerging new paradigm of an industry driven by innovation, agility, technology, growth and profits. Some promising areas are technical and smart textiles, composites, biomimetic, nonwovens, Cyber Physical Systems (textile touchpads, health care monitoring) to name a few. These are indeed heady times for textile and fiber science poised for growth in a fascinating high-tech field with enormous potential. This can only be realized if the industry has a robust and up-scalable intelligent manufacturing systems. With emergence of industry of the fourth industrial revolution, or Industry 4.0 this sector can aspire to again be the model of growth it once was for the other “classic” industries to emulate.

2. WHAT IS INDUSTRY 4.0?

There have been three previous cycles of industrial revolution each providing major gains in productivity, efficiency, and innovation. The salient features of each phase are summarized in Table 1.

Table 1. Main characteristics of industrial revolutions.

Period	Transition Period	Energy Resource	Main Technical Achievement	Main Developed Industries	Transport means
I. 1760-1900	1860-1900	Coal	Steam Engine	Textile, Steel	Train
II. 1900-1960	1940-1960	Oil, Electricity	Internal Combustion Engine	Metallurgy, Auto, Machine Building, Chemistry	Train, Car
III. 1960-2000	1980-2000	Nuclear Energy, Natural Gas	Computers, Robots	Auto, Petrochemicals, Pharma	Car, Plane
IV. 2000 - Present	2000-2010	Green Energies	Internet, 3D Printers, Genetic Engineering	High Tech Industries	Electric Car, Ultra Fast Train

A. The First Industrial Revolution

If there is one thing that defines the first Industrial Revolution which began in Britain, it is steam power. The idea of capturing the heat and energy in steam has been around for millennia. But to capture steam as an energy source requires an incentive. The driving force for this major disruption in Britain was an ecosystem of patents which rewarded the rightful owners of ideas and risk-takers. In addition, it had abundance of coal and iron, demand for industrial sectors such as textiles, and an understanding of metallurgy. Hence, harnessing of water and steam to deliver mechanical production transformed the society with the introduction new modes of transportation: steam ships and steam engines. It also resulted in mechanisation of agriculture and manufacturing.

B. The Second Industrial Revolution

The second wave was defined by electricity and light invented by Thomas Edison in New Jersey, USA. It was clear the electricity could do far more and to maximize the utility of large steam-powered industrial devices, there had to be a way to light factories after sunset. Edison solved the problem with his invention of the incandescent lightbulb. Thus, electrification resulted in mass production via assembly lines to yield bulk production of chemicals and plastics based in division of labour powered by electrical energy.

C. The Third Industrial Revolution

The third industrial revolution began in the United States with the invention of semi-conductors, wide spread adoption of computers, and new systems for information storage and processing. Hence, digital communication technologies streamlined automation production. This has manifested as an information revolution. It is important to note there were decades of overlap between the First and Second Industrial Revolutions and that electricity did not then, or even now, replace steam entirely.

D. The Fourth Industrial Revolution

So, what is Industry 4.0? It is transformation of “classic,” industries by the Internet of things (IoT), data and services with real time integration of products, processes, and infrastructure which marks the start of the fourth cycle. This is possible through increasing interconnectedness via internet of supply production, maintenance, delivery, and customer service. Hence, seemingly rigid value chains turn into highly flexible value networks. The goal is an intelligent factory, “smart factory,” which is characterized by adaptability, resource efficiency, and ergonomics as well as the integration of customers and human partners for joint value creation. The technological bases are the cyber-physical systems and IoT.

Hence, it is the next-generation manufacturing system that is obtained by adopting new models, new forms, and new methodologies to transform the traditional manufacturing system into a smart system. This gives rise to a smart and connected factory with Internet of Things and Cyber Physical Systems for the classical five level automation architecture as technology basis consisting of machine level, station level, cell level, process control level, and factory operation management level. In the Industry 4.0 era, an intelligent manufacturing system (IMS) uses service-oriented architecture via the Internet to provide collaborative, customizable, flexible, and reconfigurable services to end-users, thus enabling a highly integrated human-machine manufacturing system. This high integration of human-machine cooperation aims to establish an ecosystem of the various manufacturing elements involved in IMS so that organizational, managerial, and technical levels can be seamlessly combined [1].

As we explore the ways in which information is used to create value, it is important to understand this from the perspective of the manufacturing value chain, where organizations create value from information via the movement from physical to digital, and back to physical. Industry 4.0 combines the connected technologies inherent in the Internet of Things (IoT) with relevant IT and operations technology (OT), including cyber security, horizontal and vertical system integration, analytics, additive

manufacturing, robotics, high-performance cloud computing, artificial intelligence, cognitive technologies, advanced materials, and augmented reality, to drive the physical act of manufacturing. Industry 4.0 incorporates and extends these connected technologies to complete the physical-digital-physical cycle. The physical-to-digital and digital-to-physical leaps are unique to manufacturing processes; it is the leap from digital back to physical—from connected, digital technologies to the creation of a physical object or an improved process—that constitutes the essence of Industry 4.0 [2]. Hence the key principles are (i) the factory becomes digital and flexible, (ii) The use of advanced simulation tools and powerful big-data processing and analysis, and (iii) an efficient factory for energy and resource use. This leads to flexibility, efficiency, productivity, quality, mass customization, and competitiveness. It thus enables companies to cope with the challenges of producing increasingly individualized products with a short lead-time to market, improved decision making and higher quality. Typical resources are converted into intelligent objects so that they are able to sense, act, and behave within a smart environment to perhaps reverse the fortunes of the textile sector and lead us to nirvana. How much of this “star gazing” will come to pass may be estimated by the Gartner Hype Cycle for Emerging Technologies (Figure 1).

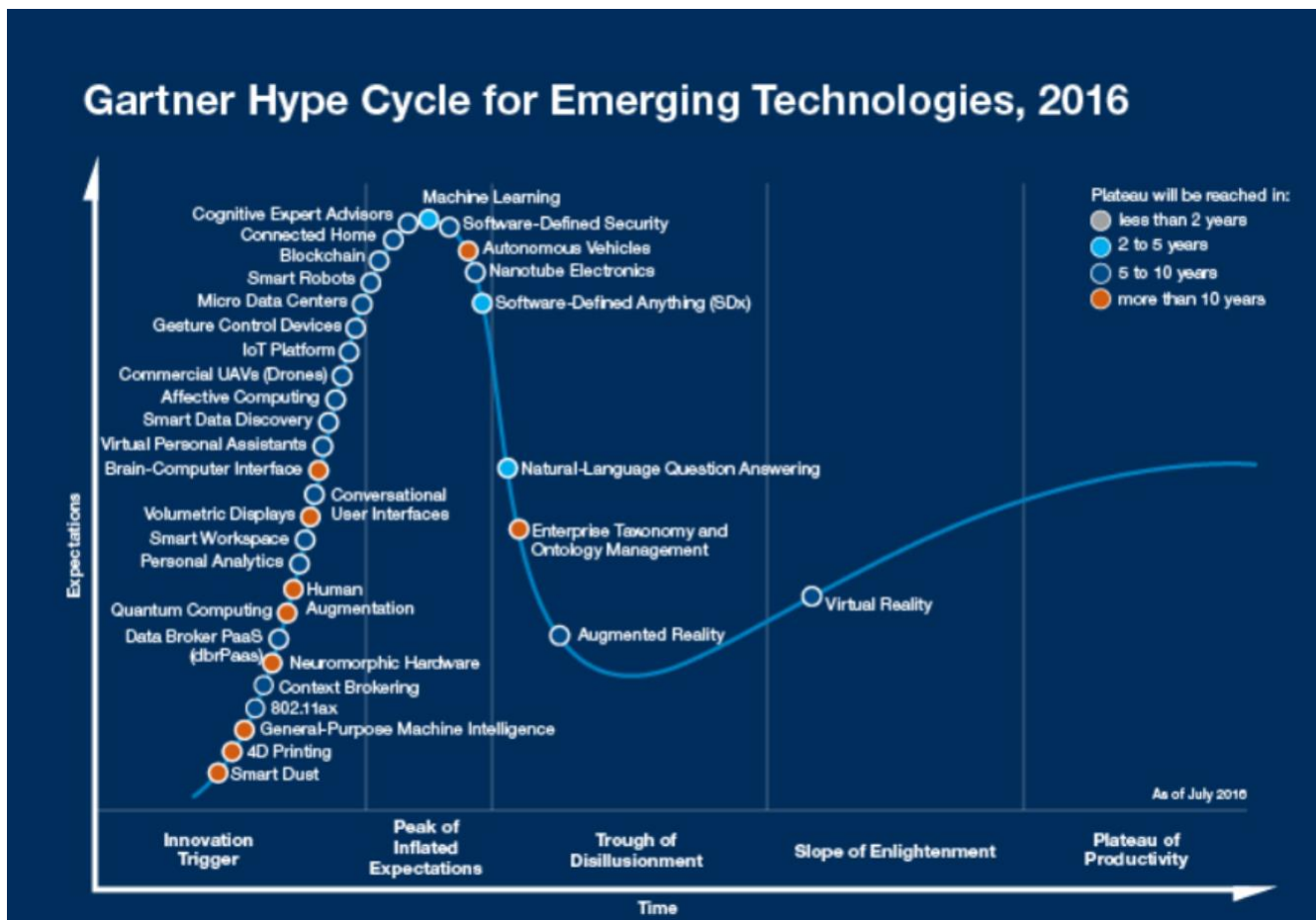


Figure 1. Gartner Hype Cycle for Industry 4.0

3. KEY COMPONENTS OF INDUSTRY 4.0

There are four key components of Industry 4.0. They are:

A. Cyber-Physical Systems

An important component of Industry 4.0 is the fusion of the physical and the virtual world. This fusion is made possible by Cyber-Physical Systems (CPS) as seen in Table 2. CPS are integrations of computation and physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa.

Table 2: Interlinking of real (physical) and virtual (cyber) world for Cyber-Physical Systems

Physical World		Cyber World		Industry 4.0 Solutions	
<ul style="list-style-type: none"> • Robotics • Automation equipment 	+	<ul style="list-style-type: none"> • Advanced algorithms • Machine learning • High performance hardware 	+	<ul style="list-style-type: none"> • Self-learning Robots 	
<ul style="list-style-type: none"> • Traditional machinery • Traditional and semi-conductor based sensors 		<ul style="list-style-type: none"> • Advanced data analytics • Data management systems • Cloud computing 		<ul style="list-style-type: none"> • Predictive maintenance 	
<ul style="list-style-type: none"> • Traditional machinery • RFID • Automation equipment 		+	<ul style="list-style-type: none"> • Embedded Systems • Real-time image processing • Data storage hardware 	+	<ul style="list-style-type: none"> • Self-reconfiguration machines
<ul style="list-style-type: none"> • Camera & imaging systems • Visual sensors • Traditional sensors 			<ul style="list-style-type: none"> • Real-time image processing • Advanced data analytics • Advanced algorithms 		<ul style="list-style-type: none"> • Smart environment recognition

B. Internet of Things (IoT)

The integration of the Internet of Things (IoT) and the Internet of Services (IoS) in the manufacturing process has initiated the fourth industrial revolution. The IoT allows “things” and “objects,” such as RFID, sensors, actuators, mobile phones, which, through unique addressing schemes, interact with each other and cooperate with their neighboring ‘smart’ components to reach common goals. Therefore, the IoT can be defined as a network in which CPS cooperate with each other through unique addressing schemes. An application example of IoT are smart factories.

C. Internet of Services (IoS)

The Internet of Services (IoS) enables “service vendors to offer their services via the Internet. The IoS consists of participants, an infrastructure of services, business models, and the services themselves. Services are offered and combined into value-added services by various suppliers; they are communicated to users as well as consumers and are accessed by them via various channels.” This development allows a new way of dynamic variation of the distribution of individual value chain activities.

D. Smart Factory/Smart Manufacturing

Smart factories constitute a key part of Industry 4.0. The smart factory can be defined as a factory where CPS communicate over the IoT and assist people and machines in the execution of their tasks. Hence,

smart manufacturing is a highly connected knowledge enabled industrial enterprise where all business operation actions are optimized to achieve substantially enhanced productivity, energy/sustainability, an economic performance. The technical enablers consist of the convergence and application of nine stand alone digital technologies, these are:

- Advanced robotics- autonomous cooperating robots
- Additive manufacturing- 3D printing
- Augmented reality – for maintenance, logistics, and SOP
- Simulation – real-time optimization based on data from intelligent systems
- Horizontal / Vertical integration / fully automated value chain (from supplier to customer, from management to shop floor)
- Industrial internet – network of machines and products and multidirectional communication between networked objects
- Cloud – management of huge data volume in open systems and real time communication of production systems
- Cyber security- operation in network and open systems and networking between intelligent machines, products and systems.
- Big data analytics – full evaluation of available data and real-time decision-making support and optimization

4. CASE FOR TEXTILE

The textile value chain presents its own unique set of challenges with several implementation barriers. These include risk and uncertainty about financial gains, no clear leader to educate the value of concept and demonstrate benefits of transformation, lack of skills and talent, and reluctance of participating in cyber space due to intrinsic conservative historical beliefs. Fiber production is capital intensive with large multinational entities in control while as we move downstream to fabric and garments the market becomes more fragmented. Furthermore, the circumstance varies from country to country. Thus, adoption of Industry 4.0 in textile will most likely occur in the early stages of product transformation i.e. fiber and fabrics. A prototype Textile Learning Factory 4.0 exists in Aachen, Germany [3]. Their case studies have shown smart personal devices can be used to make production more transparent by providing relevant production key parameters in a sophisticated way [4, 5]. Aspects of tele-maintenance, such as repair of machine supported by the machine produces are possible with self-optimization of the warp tension in a weaving process by using digital technologies.

5. CONCLUSION

The challenges of Industry 4.0 confronting the textile sector are daunting. These include communication reliability and quality of service, cyber security, maturity of machine intelligence and ability to handle big data. Further exacerbating the issue, from a societal perspective, are general reluctance to change by shareholders, availability of adequate skill sets, and concern of unemployment. However, Textile Industry 4.0 offer numerous benefits:

- Increased productivity thru a higher level of automation that reduces production time, enable better asset utilization and inventory management.
- Increased manufacturing flexibility thru machines and robots that can execute the production steps for a wide variety of products.
- Increased speed from the first product or factory idea to the finished product thru consistent data and new simulation opportunities
- And finally, increased quality of products via sensors and actuators that monitor the current production in real time and intervene to correct an error, if necessary.

How will the textile sector participate in this moment? Time is of essence. Will we be the leader of tomorrow or part of the “heap dust” of missed opportunities. Only time will tell!

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