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5. Evolution of Smart Factory in Textile Manufacturing

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Abstract:

The industrial production of the future will be highly customizable and versatile in terms of production volume, with multiple integrations between customers, businesses, and suppliers. Furthermore, the fourth industrial revolution started within a brief period, changing people's industrial, social, and economic lives. Between capital and labor, this can result in new industrial relations. This paper reviews and analyses recent initiatives and research linked to developing Smart factories and Industry 4.0. It then proposes a reference design for IoT-based smart factories and outlines its critical traits with an emphasis on sustainability. Then it proposes a method for managing energy in smart factories based on the IoT paradigm: a guideline, projected advantages, and the future of manufacturing are reviewed.

Keywords: *Smart Factory, Industry 4.0, internet of things (IoT), Textile Manufacturing, Energy Management.*

5.1 Introduction:

Through the use of numerous technologies, smart manufacturing, also known as Industry 4.0, seeks to achieve industrial flexibility, mass customization, better quality, and increased productivity (Zhong et al., 2017). This study focuses on the development of the smart factory from its early stages in the textile manufacturing industry. The most labor-intensive industry among those that produce goods is textile manufacturing. (Thompson, 2014) By introducing a fully integrated and collaborative manufacturing system that reacts in real-time to meet the constantly changing needs of the factory, supply chain, and customer, the textile manufacturing industry might overcome the effects of the competitive environment and the ongoing rise in manufacturing costs. The garment industry has the most labor-intensive characteristics of all the Manufacturing industries. Automating garment manufacturing processes is challenging since the product frequently changes to keep up with current trends, and the production process varies by size and design. Also, many of the automation technologies that most industries have adopted with success have not proven effective in the manufacturing process. Therefore, the evolution of the smart factory in the textile industry and other aspects related to the implementation of a suitable smart factory were discussed elaborately.

5.2 Literature Review:

Zuehlk (2010) described it as a proposal for fresh approaches to upcoming manufacturing technologies, including demonstrations and research testbeds, the smart factory initiative. Kim et al. organized and presented the growth direction of smart manufacturing trends incorporating machine learning for many types of manufacturing equipment.

According to A. Azevedo and A. Almeida (2011), real-time data and information exchange between various devices and parties is the essential component of smart factories. For example, this data could represent production status, energy consumption patterns, material movements, customer orders and feedback, supplier information, etc. As a result, the following generation of smart factories will need to be able to adjust practically instantly to the market's shifting demands, technological possibilities, and legal requirements.

Wang et al. (2016) state that they introduce a framework that links smart shop-floor items like machines, conveyors, and products with industrial networks, cloud computing, and supervisory control stations. The Framework facilitates the implementation of the Smart Factory and is based on independent decision-making and clever negotiating procedures. The authors also offer a classification of innovative items and assign the resulting agents to coordinators in the cloud. As shown by the research, potential deadlocks can be avoided by improving both the coordinator's behavior and the agents' decision-making.

5.3 Industry 4.0:

The invention of mechanical manufacturing tools signaled the start of the first industrial revolution, followed by a second involving the mass production of commodities. The third revolution, which began in the early 1970s and continues today, is the increasing automation and control of production processes through electronics and IT (digital revolution). W. Wahlster, J. Helbig, H. Kagermann (2013). Utilizing IoT in a production setting may help us reach the fourth stage of industrialization. In a 2014 survey by the American Society for Quality (ASQ), 82% of the firms that claim to have implemented smart manufacturing report greater efficiency. In addition, fewer product problems and more customer satisfaction were reported by 49% of respondents.

Their findings show that 38% of respondents think the Internet of Things would significantly impact most businesses and industries. In addition, 96 percent of respondents anticipate that their company will be using the Internet of Things in some capacity three years from now, 63 percent think that companies that are slow to integrate the IoT will lag behind their rivals, and 45 percent think that adopting the IoT will make their business more environmentally friendly. The Economist Intelligence Unit also polled the international business community in June 2013 to evaluate IoT's existing and future utilization.

IoT and smart manufacturing are Industry 4.0's fundamental tenet: in-progress goods, parts, and production equipment will gather and share data in real-time. Decentralized intelligence replaces centralized factory control systems as a result. Industry 4.0 is described by the German Federal Ministry of Education and Research as "the use of cyber-physical production systems increases the flexibility that exists in value-creating networks" (CPPS). Through self-optimization and reconfiguration, machines and plants adjust their behavior to changing orders and operating conditions. The ability of the systems to sense information, draw conclusions from it, modify their behavior in response to those findings, and store experience-based knowledge are critical areas of study. To successfully integrate distributed and networked production facilities in future Smart Factories, intelligent production systems, processes, and appropriate technical methodologies and tools will be essential.

Figure 5.1 H. Kagermann, W. Wahlster, and J. Helbig (2013) provide a reference architecture for an industry 4.0-based IoT-based smart factory. The following are some examples of the various views and technological sets included.

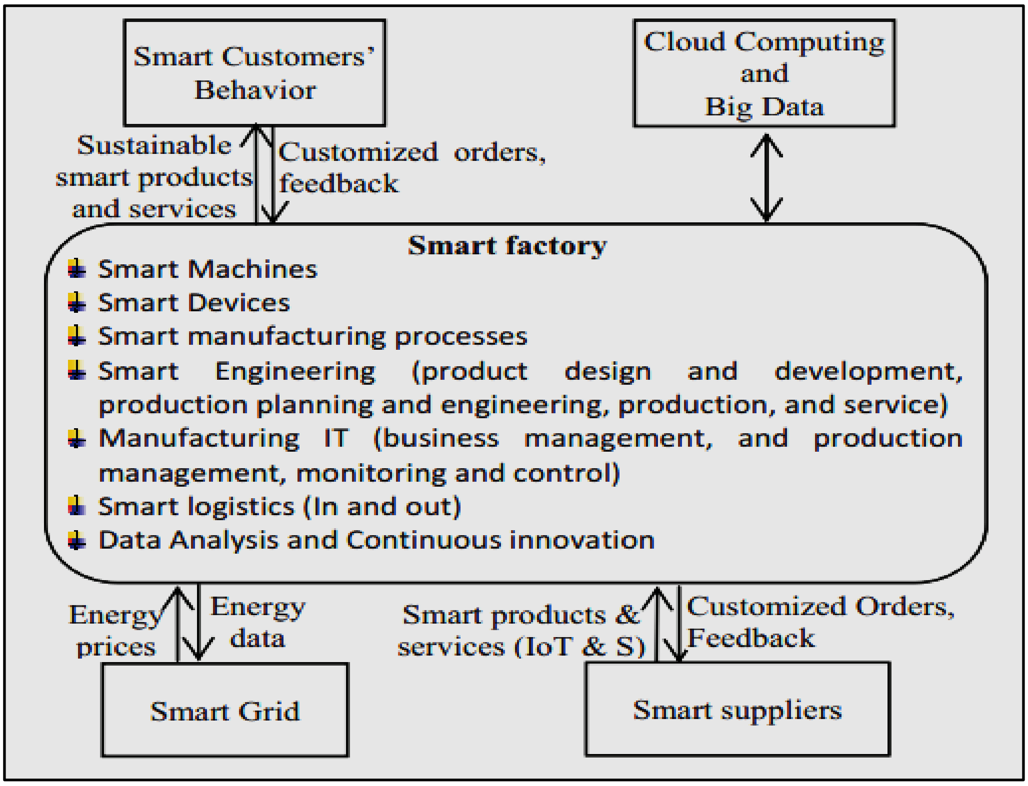

Figure 5.1: Reference architecture for IoT-based smart factory

Smart Machines: Encompass M2M connectivity and machine-to-machine and human-to-machine communication.

Smart devices: Comprises factory equipment that is connected, such as field equipment, mobile equipment, operating equipment, etc.

Smart manufacturing processes: Incorporate dynamic, effective, automated, and real-time process communication for the administration and control of a highly dynamic industrial environment made possible by IoT.

Smart Engineering: Encompasses the development of products, product engineering, manufacturing, and after-sales support. The planning process may need to use the data gathered during production (mechanical, electrical, etc.).

Manufacturing IT: Begins with software programs used by one or more companies to support value networks; continues with intelligent monitoring and control using sensors, smart meters, and smart mobile devices; and concludes with intelligent production management, which incorporates data from IoT into production management logic.

Smart logistics: Incorporate sophisticated logistical equipment and procedures. Intelligent internal logistics, like self-organized logistics, can respond to unforeseen production changes like bottlenecks and supply shortages.

Big Data and Cloud computing Data: Comprise software for analysis, algorithms, etc. As demonstrated in Fig. 1, big data analytics will open up tremendous prospects for enhancing factories and manufacturing processes and enabling companies to produce new goods.

Smart suppliers: Entail developing long-term relationships with suppliers. For example, by increasing real-time information sharing and choosing the best supplier based on industrial requirements boost flexibility.

Smart Grid: The smart factory's energy supply infrastructure is included. Demand-side management is vital for responding to changes in energy prices.

5.4 Smart Factories:

All industrial buildings were changed into smart factories, and all physical production systems acquired more intelligent traits when sophisticated technologies like big data, intelligent robotics, and virtual personal assistants were considered. Industrial processes, the machinery employed in manufacturing processes, and factories have all become more intelligent due to the integration of the real and virtual worlds. Modern industrial operations are more automated, developing new production systems with high technologies' highest degree of autonomy. The coordination and interaction between all operations from the supplier to the customer are today's most crucial smart factory principles. The cyber-physical systems serve as the Framework for smart industries. In other words, the smart factories' brains might be called cyber-physical systems.

These technologies can resolve incredibly challenging manufacturing and supply chain management issues. Thanks to digitization, virtual environments can simulate real-world industrial situations. All production procedures can be developed in the virtual world before practical production. The good and bad circumstances that could emerge during the physical production process might be identified in this way. Finally, it may be possible to choose the measures based on anticipated risks and issues.

Additionally, because all elements, such as machinery, labor, tools, and industrial processes, can be optimized, idle capacity cannot exist in production operations. As a result, all industrial processes can attain the highest levels of productivity and efficiency.

The more intelligent manufacturing systems framework should be used to redesign new production processes. As a result, the most crucial requirement for smart factories is real-time information. As a result, businesses are working to develop a new information flow infrastructure. Real-time data must be gathered using sensors and identification systems and analyzed concurrently. In addition, physical products may contain digital qualities. It allows for the direct collection of real-time data from items. A product in the manufacturing process can also communicate with its environment and take its digital memory with it throughout its life cycle by establishing a digital identity. As a result, real-time data collection and processing may be feasible, and as a result, the information flow system may become more efficient and valuable.

Manufacturing and logistics processes will alter as a result of smart factories. First, a flawless material flow system can be built at first. Second, every procedure between a supplier and a client may be reorganized to increase production. Furthermore, smart factories will provide a safer working environment. Depending on technological developments, manufacturing systems may become intelligent. The fundamental components of the smart factory are intelligent machines that can automatically make the best decisions. Additionally, several significant technological developments that enable interaction between machines and humans, such as robotics technologies, automation systems, identification systems, and communication systems, can present a chance to develop a more intelligent production system. The most crucial components of smart production systems are automation, robotics, and machine autonomy.

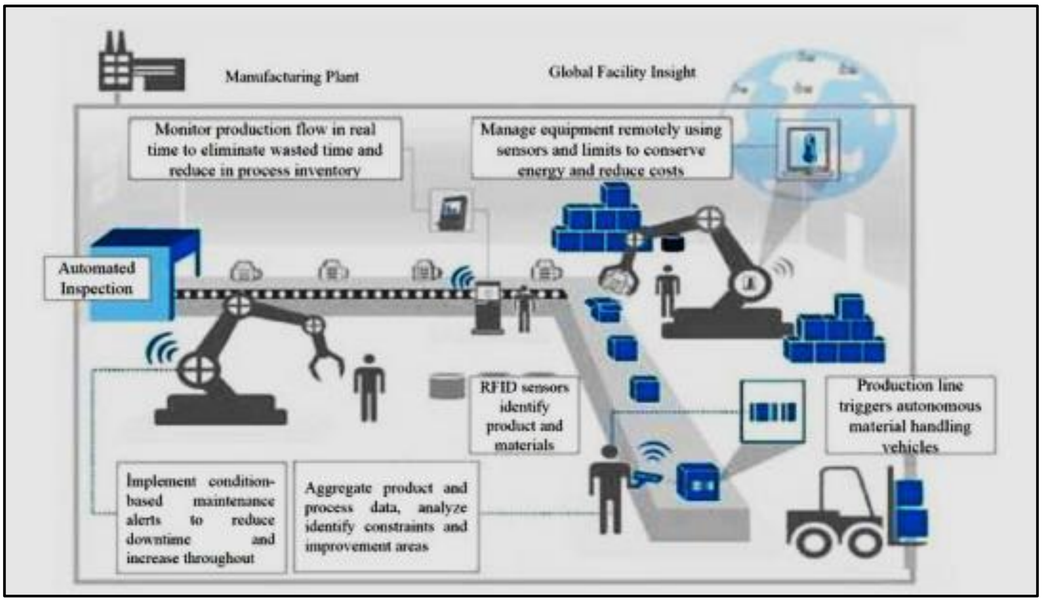

Figure 5.2: Smart Factory and operations, Source: Microsoft IoT in manufacturing infographic, 2015

5.5 Characteristics of Smart Factories:

This section discusses the main potential characteristics of smart factories in industry 4.0, highlighting how these characteristics can improve the sustainability of smart factories.

5.5.1 Mass customization:

Production procedures must adapt to the various demands of production orders. Individuals can participate in the design process, and it facilitates last-minute revisions. Furthermore, low production volumes (such as a batch size of 1) are feasible and profitable (W. Wahlster). Therefore, mass customization (MC) can be used to manage the imbalance between economies of scale and scope. This idea has been extensively discussed in the literature, including in (F. S. Fogliatto, G. J. C. da Silveira, and D. Borenstein, 2012), and the current focus of research is on how an MC business model performs in terms of environmental sustainability.

5.5.2 Factory visibility and optimized decision-making:

Making the proper decisions at all times is essential for market success. IoT enables optimization across industrial locations in the production field, consequently increasing factory productivity. It also provides end-to-end transparency virtually instantly (e.g., production status).

For instance, minimizing waste can be achieved by giving decision-makers access to real-time information on the production's status, enabling them to act quickly when issues arise. In such circumstances, it is possible to stop the machine from producing defective goods. Additionally, transparency encompasses knowledge about how production processes behave in terms of their energy use. To reduce energy waste and consumption costs, production management decisions, in this case, can take energy data into account.

5.5.3 Flexibility:

Various factors, including time, quality, price, and ecological considerations, must be considered in intelligent production processes and self-configuration [D. Zuehlke, 2010]. (e.g., avoid peak time, etc.).

5.5.4 New planning methods for factories:

"The application of abstract planning methods based on digital models, with a stronger parallelization taking into account the planning of mechanical and electronic systems" (D. Zuehlke). Furthermore, it is essential for smart factories to improve production processes at multiple levels in real time and on a case-by-case basis to increase resource productivity and enhance energy efficiency. Additionally, the availability of energy consumption data from IoT can be taken into consideration to reduce the expenses associated with energy consumption of production schedules by specifying the launch time for job processing (F. Shrouf, 2014).

5.5.5 Creating new services:

IoT will create new opportunities for providing clients with services and value before and after a purchase (e.g., through smart devices and mobile applications).

5.5.6 Remote monitoring:

IoT technology will enable third parties (like suppliers) to get involved in factories' operation, maintenance, and monitoring via new services.

5.5.7 Automation and change role of man:

Production processes can be improved with the least amount of human involvement. This might increase productivity, decrease errors, and reduce resource and energy waste.

5.5.8 Proactive maintenance:

Proactive maintenance is improved by tracking production systems and gathering performance data in real-time. For instance, by utilizing sensors to monitor temperature, it is possible to take preventative measures before a breakdown occurs. Preemptive measures can also be done when energy use spikes above average for an extended period. It will conserve energy, reduce defective product waste, and prevent machine breakdown. Describe an IoT-enabled future in which machines detect the failure and initiate maintenance procedures on their own

5.5.9 Connected Supply Chain:

IoT will assist producers in better comprehending the information that may be supplied in real-time about the supply chain. All parties may comprehend interdependencies, the flow of materials, and manufacturing cycle durations by linking the machines and equipment to suppliers.

5.5.10 Energy management (HVAC and production):

Energy consumption behavior on production lines and in individual machines must be understood in order to increase energy efficiency (K. Vikhorev, R. Greenough, and N. Brown, 2012). Smart meters can offer real-time data, make decisions based on capabilities, and work with outside services (S. Karnouskos, and C. Schroth, 2009).

According to (G. Miragliotta and F. Shrouf), implementing IoT technology to increase production-level energy efficiency allows for adopting several sustainable practices (e.g., avoiding peak time, integrating energy data in the production schedule, etc.).

Additionally, it makes it possible for factory HVAC and other environmental controls to be automated.

5.5.11 Evolution of textile manufacturing:

India's textile industry has an illustrious background that dates back to the Indus Valley civilization circa 3500 BC. One of the biggest textile industries in the world, India is credited with producing some of the best textiles, including angora, cotton, wool, and black and white silk.

There has been a textile industry in India for more than 5000 years. However, despite traditionally playing a significant role in commercial activity in ancient and medieval India, the modern Indian textile industry wasn't founded until the British enterprises did so in the early 19th century.

While India is a country whose territory is revered by many, it also has a proud origin tale in which all its citizens take great pleasure. The textile sector in India is fascinating. Midway through the 1800s, a single spinning wheel was all needed to start the enterprise. The development of textiles in India began with this wheel in conjunction with manual labor.

Since it has existed for thousands of years, the textile sector has developed into one of the most significant in the nation. Early Indian textile manufacturing was dominated by cotton and hurries. Still, during the past 150 years, the sector has experienced rapid diversification due to adopting equipment, improved production techniques, and other processing technologies.

One of the main forces behind the development of India's economy, society, and culture has been the textile industry. This has made it possible for the profession to grow significantly. However, from 1750 to 1850, India's textile industry saw a significant change.

5.5.12 The Future of Manufacturing:

Intelligent automation is the key to the success of the production. In fact, according to IDC, 20% of G2000 manufacturers will have switched to intelligent manufacturing by 2021, resulting in execution times up to 25% faster. Because of this, these manufacturers will continuously see annual efficiency improvements that let them reduce costs and raise margins.

A journey, not an overnight transformation, is required to become a smart factory. If you haven't already, starting your journey toward digital transformation is crucial. Smart manufacturing will dominate the industry because it offers several advantages, such as higher production and improved throughput, without compromising product quality.

In addition, it is simpler and more convenient to begin and continue your trip because of the obvious benefits and the numerous resources available to offer understanding and direction.

5.6 The four levels of Smart factory evolution:

5.6.1 Connected Data:

Connecting your data and integrating many sources into a single source of truth that continuously collects and tracks production data are the first steps in establishing a smart factory. When all the information is in one place and always accessible, solving problems is essentially frictionless. Operators and engineers can use data visualizations and dashboards to retrieve the system's data when a problem arises, effectively employing the system as a query engine. In addition, engineers can swiftly respond to inquiries because easy access to all the data increases plant productivity and adaptability in the face of shifting environmental conditions.

A connected data infrastructure also makes it possible to remotely and in real-time monitor the production floor. Enables engineers to concentrate their efforts on high-value problems like process improvement, waste minimization, or quality enhancements. Engineers must devote a lot of time, energy, and involvement to predictive analysis, which enables firms to make adjustments before problems arise. Manufacturers must use machine learning technologies that provide predictive and prescriptive analytics to advance.

5.6.2 Predictive Analytics:

At level two, proactive analysis and changes are implemented in production processes instead of reactive problem-solving. With the help of predictive analytics, engineers and operators may take proactive measures to stop costly downtime or poor quality.

Manufacturers can forecast and prevent issues on the production floor by expanding the data architecture from the previous level and integrating new capabilities like machine learning and artificial intelligence. For example, machine learning systems usually need three to six months of historical data for reliable forecasts. Still, depending on your product mix, they enable you to generate insights instantly.

Predictive analytics produces an intelligent system that can identify insights rapidly and predict errors more precisely when combined with a connected data infrastructure that gathers all your production data. In addition, real-time notifications provide the right person with important information so they can act promptly. Predictive analytics' key advantage is that factory staff no longer need to manually analyze processes or query the system to identify solutions to production-related problems.

5.6.3 Prescriptive Analytics:

A Smart factory's third level further improves production optimization. Machine learning technologies offer settings using prescriptive analytics that enables you to maximize production rather than forecasting when failures might happen. These configuration suggestions help you duplicate your most effective runs more reliably and translate decades of tried-and-true best practices from seasoned veterans into steps that novice operators may easily take.

Prescriptive analytics separates the factors and production settings that contribute to your most and least lucrative runs by examining past production data. The engineers who can review the insights and alter the processes to increase throughput without compromising product quality are given these suggestions. Likewise, manufacturers can improve contribution margins and cut waste and inefficiencies from their manufacturing processes by using the suggested settings.

5.6.4 AI-Driven Automation:

At stage four, automation powered by AI implements the suggestions found by studying factory data. As an illustration, a machine learning model will recognize an optimization, then create and communicate the suggested settings in real-time to the device, where they are automatically carried out.

The time it takes to put an insight that the system has discovered into action becomes extremely short in a closed-loop artificial intelligence-controlled production line.

At level 4, datasets must be sufficiently large and contain a sufficient number of validated cases to give the system the data it needs to "know" the effects of a production change. The time required to advance from level three to level four varies depending on how long it takes to collect the required datasets. The technology of the future is still true AI-driven automation.

Having a human review and accepting machine recommendations will always have advantages. But when it comes to risky operations, it has excellent advantages. Automating hazardous operations or production components that formerly required an operator and supervising from a distance dramatically lowers the possibility of a safety event.

5.7 Conclusion:

Despite the world constantly changing, the winds of change we see today are more substantial and affect practically every part of our life. Only recently have the effects of the fourth industrial revolution been apparent. In the manufacturing sectors, these effects are especially pronounced. Only recently have the effects of the fourth industrial revolution been apparent.

Many manufacturing industrialists believe that shortly, they will be even more dominant than they are now. Therefore, many large-scale businesses would lose their competitive edge if they don't pay attention to these trends. The apparel and textile sectors need to be aware of the brand-new paradigms that the fourth industrial revolution is bringing forth. As a result of the precarious market conditions, becoming a smart factory will be one option to satisfy client demands in the upcoming years.

Thus, the textile industry can address the structural issues brought on by high labor costs, energy expenses, and market uncertainty. In addition, they can boost industrial processes' productivity and efficiency, allowing for high-quality performance of logistics operations.

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