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Industry 4.0 & its Role in Quality Control: A Review

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ABSTRACT: With the advent of information technologies (IT), there has been an increase in the economy of all countries around the world. Companies are competing globally to grab opportunities that comes on their way. So, these companies have to operate in a way without sacrificing for the quality of their product, process and services in order to meet customer needs and requirements. The solution for this is implementation of Industry 4.0, which is one of the major and most discussed topics. The objective of this review paper is to provide with a brief overview of Industry 4.0, its nine pillars and their role in quality control.

KEYWORDS: Industry 4.0, Big data analytics, IIoT, Cloud computing, Autonomous robots, Additive manufacturing, Augmented reality, Simulation, System integration, Cyber security & cyber physical system (CPS), Quality control.

I. INTRODUCTION

In recent times due to technical advances there is a change in the way things are getting produced. There has been a shift in industry from manual work towards the use of Industry 4.0. These changes have a profound effect on the industrial processes, products and even the lifestyle of people. The four main phases of industrial development are shown in Figure 1.

The first industrial revolution marked its onset from the 18th century with the use of steam power. This change brought a major breakthrough in industrial processes which increased productivity and also improved the quality of life and hence became a driver of the change. There was a transition in the textile industries where steam powered engines were used instead of weaving looms powered by muscles [1].

The Second Industrial Revolution started in 19th century with the introduction of electricity and assembly line production also known as mass production. The idea of mass production was developed by Henry Ford (1863-1947) in Chicago. He saw pigs that were hung from conveyor belts and each butcher will perform his individual task. So, he decided to adopt the same principle into automobile production which brought a drastic change in production processes. Earlier assembly of one entire automobile was done by one single station whereas now the automobiles are manufactured and assembled in sequence on a conveyor belt which resulted in quick production at minimum cost.

The Third Industrial Revolution started in 20th century where there was use of partial automation with the use of memory programmable control and computer. This kind of manufacturing facilitates flexibility in producing variety of products [1].

Industries are currently implementing the Fourth Industrial Revolution also known as "Industry 4.0" where there is application of information and communication technologies in industry and is a development of Third Industrial Revolution. Computer technology has been extensively used in production systems and are expanded with the help of networks and they now have a digital twin on the internet. This allows communication with one another and the output can be obtained easily. Thus, this industrial revolution is called the next step of automation.

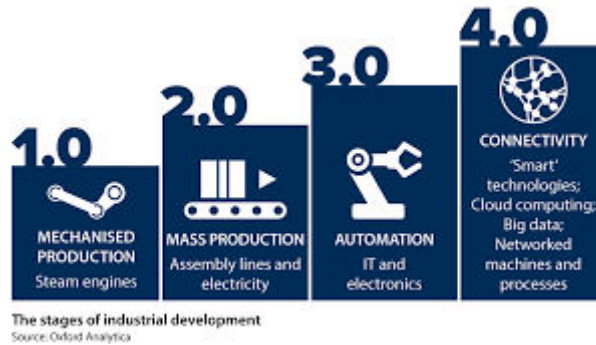


Figure.1. Evolution of Industry 4.0

Ever since there was an introduction of First Industrial Revolution and all the subsequent revolutions have reorganized the traditional automation systems to more intelligent self-organizing systems which makes production processes automatic, robust and sustainable allowing people to operate machines with ease, more efficiently and consistently [1].

Origin Of Industry 4.0

Industry 4.0 began in Germany. We know that Germany is a global leader in manufacturing sector and has been one of the best and most competitive manufacturing industries in the world. German government took an initiative and considered Industry 4.0 as a strategy to bring development in industrial sectors. Because of Industry 4.0 Germany has become the most influencing country in machinery and automotive manufacturing. This topic was first introduced in 2011 and since then it has become a frequent topic of discussion in academic, research and also in industries.

The main objective of Industry 4.0 is the use of newly emerged technologies and concepts such as [1]:

- Virtualization of the real-world digital mapping
- Increase in Smart Factories where smart methods are used to develop smart products.
- Integrating technical and business in industries
- Use of internet and Internet of Things (IoT)

Adoption of Industry 4.0 has resulted in reduction of costs such as[2]:

- Cost of production was decreased by 10% to 30%,
- logistic costs by 10% to 30% and
- quality management costs by 10% to 20%

II. INDUSTRY 4.0

According to the German Federal Government, Industry 4.0 is an evolving structure in which manufacturing and logistics systems, known as Cyber Physical Production Systems (CPPS). In order to match manufacturing and business processes, it makes use of globally available information and communication network for automated exchange of information [3].

A definition for Industry 4.0 was made by the Siegfried Dais of Robert Bosch GmbH and Henning Kagermann of Acatech, the communication Promoter Group of the Industry-Science research Alliance in 2011 as the latest level of control for the value chain of the product life cycle. Its main focus is on customer needs and their requirements. This cycle of product development starts from the product idea where the order is placed, developed and manufactured. Then the product is out for delivery to reach the end customer. And the last phase of this cycle is the recycling phase.



Industry 4.0 is built on the availability of pertinent real time information by linking all value chain operations. Systems, things, and people are interconnected to produce self-organizing, interactive and actual optimized real-world connections across industries. They are further improved based on various criteria such as resource availability, manufacturing costs and their consumption.

As we can see the above definition seems to be a bit complex, hence the more accurate one was given by Acatech in 2013. It defines Industry 4.0 as combination of Internet of Things (IoT) in industrial processes and Cyber Physical System in manufacturing, as well as logistics. They majorly impact value creation, downstream services, business models and work organization.

From the above definitions, it is seen that obtaining a perfect definition for Industry 4.0 can be complex and misleading. In simple terms industry 4.0 defines the entire life cycle of product and manufacturing and also Cyber Physical Systems (CPS) which is a factor of Industry 4.0. Because of this reason coming up with one perfect definition is quite difficult [4].

There are nine pillars that are the main foundation for Industry 4.0 which leads to transformation of isolated and optimized production cell into a fully integrated, automated, and optimized production flow, which leads to greater efficiency [5][6].

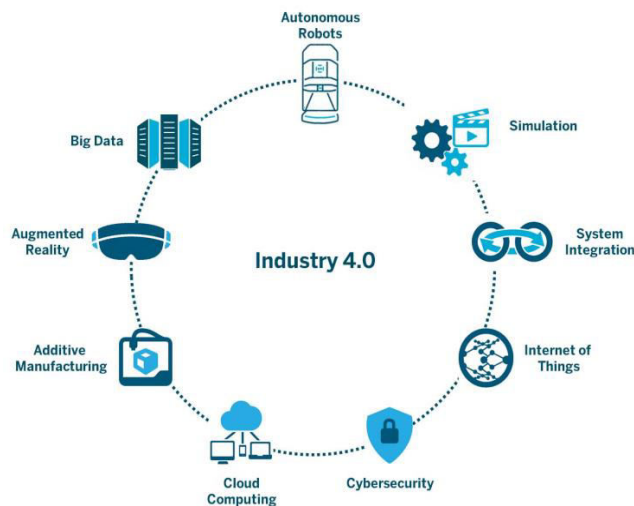


Figure.2. The nine pillars of Industry 4.0

Big Data Analytics

IoT devices generate large and complex data sets, which are referred to as Big data. This data is collected in a variety of different formats and protocols from a variety of applications, sensors, websites, computers, and cameras etc. There are huge amounts of data of various varieties generated in the industries i.e., data from sensors on production equipment and databases from Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), and Manufacturing Execution Systems (MES). Manufacturers use data analysis to convert recorded data into useful business insights and obtain real benefits by looking for useful correlations, trends, patterns, and preferences in large data sets to help them make better decisions [10]. Such sets of data are used to forecast potential threats, repair and maintenance activities that are required in production processes, as well as predict any new issues or problems that may arise, and suggest wide range of solutions to avoid them from recurring in the industry [7]. As a result, production efficiency is improved indirectly, and we can better understand real-time data through self-service systems, production management automation, and predictive maintenance optimization [10].



Industrial Internet Of Things (IIOT)

The Internet of Things (IoT) is defined as a network of physical devices which are digitally connected that facilitates data communication and exchange over the Internet. Smartphones, household appliances, buildings, and even cars may be among the smart devices. Integration of Radio Frequency Identification (RFID) tags, sensors, electronics and software makes industrial IoT unique and it allows various systems and machines in industries to gather information regarding their condition and performance.

Cloud Computing

From many years, manufacturers are gathering and storing data in order to improve operations. With increase in use of IoT and Industry 4.0, huge amount of data is being produced and handling this data manually becomes a cumbersome process. As a result, this led to the creation of technology called cloud computing. It is a platform where users store data in "cloud" and further process large datasets over the Internet on remote servers. Hence, it becomes easy for companies to access computer resource data without any investment on computer infrastructure in premise. With the help of cloud computing, companies collect and implement business intelligence through big data analytics, thus, simplifying the manufacturing and business operations.

Autonomous Robots

As a result of recent technological advancements, robots are extensively being used in industries to perform all the complex tasks that occurs. In today's manufacturing industry, robots play a vital role. Production areas which use autonomous robots are capable of handling complex task precisely and intelligently focusing on versatility, flexibility and safety are an essential aspect of Industry 4.0. They can work in areas where human workers are not permitted [7], collaborate and learn from humans because they can understand, act exactly the same way as information obtained and finally analyse it. Their integration becomes more economical and efficient without having to isolate their working area, that expands many potential applications in industries. Robots are being used in manufacturing areas, logistics and even in office management for distribution of documents and control them.

Additive Manufacturing

Industry 4.0 is driven by additive manufacturing, also known as 3D printing. It works by creating components with a 3D printer layer by layer, using digital 3D models. Additive manufacturing is commonly used for small batch size production with complex and lightweight designs. Technologies like selective laser melting (SLM), fused deposition method (FDM) and selective laser sintering (SLS) has helped in faster production and at a cheaper rate [7]. Parts are stored in virtual inventories and are manufactured at the point of need. This type of decentralized manufacturing approach can reduce distance of transportation and reduce inventory control costs since digital files are stored instead of physical parts.

Augmented Reality (AR)

Augmented reality forms a connection between the physical and digital worlds, with the help AR devices like smart glasses, smartphones and tablets by superimposing virtual images or data into a physical object. AR-based systems can be used for various purposes such as to send repair details and instruction to devices like mobiles and to select parts in warehouses. Industries uses augmented reality to help workers and provide them with real time information so that they can make better decisions and work efficiently [7].

Simulation

The computer model that mimics the operation of any real or suggested system is called simulation. It is representation of the physical world or the real world as a virtual model which is used in development of product and manufacturing operations supporting actual data accurately. Using these virtual models, test can be done more efficiently and it allows optimization of processes prior to production begins thereby minimizing the downtime and improving quality. With the help of 2D and 3D simulations, we can create virtual machine model to design, install, run test and control the software



before it is connected to the real system. These simulations not only cut down on downtime, but they also minimize the production failures during the initial phase. Simulations help in improving the quality of decision-making in a simple and quick manner [7].

System Integration

Despite the fact that Industry 4.0 enhances connectivity, it is seen that many production industries are still not been integrated. As the system integration improves industries becomes integrated both internal as well as externally thus, resulting in flexible manufacturing system by allowing correction in real time that occurs in production area. Horizontal integration is a process of companies increasing their production rate of goods or services in the same part of the supply chain via acquisition which may result in increase of market share. On the other hand, vertical integration is a strategy used by businesses to bring new methods to reduce cost of production, ensure safe access to important supplies and quick response to new opportunities that occurs [8]. Integration of horizontal and vertical system in business, in various functions they perform, in different departments results in far more consistency, ultimately helps in growth in value chain.

Cyber Security And Cyber Physical System

With Industry 4.0's improved connectivity and use of communication standards, there is always a need to protect systems that work in industries and production facility from cyber threats. Cyber Physical System is one of the most significant developments in information technology and computer science. With the help of these technologies physical and virtual models can be combined, controlled, integrated and organize industries' operations along with delivery, access of data and processes [9]. To conclude CPS is referred to as a system which exchanges data through intelligent network. Thus, resulting in smart production. CPS connected with Internet is referred to as "Internet of Things". The integration of CPS with the manufacturing environment will allow the vertical and horizontal integration of IT systems and the interconnection between the whole supply chain, potentially transforming today's factories into Industry 4.0 factories.

III. QUALITY

Quality means designing a product that meets the customer requirements which involves establishing right measurement standards, selecting suitable manufacturing process, using proper material etc., quality is usually refereed to the end use of the product. A modern definition of quality derives from Dr. Joseph M. Juran who is a founding father of many of the key quality management programs. According to him quality means "fitness for intended use." which simply means meeting customer expectations. In order to define quality David A. Garvin (specialist in the area of quality control) in 1984 came up with eight dimensions of quality: Performance, durability, serviceability, reliability, features, aesthetics, perceived quality and conformance to standard [9]. Quality works on satisfying customer needs and requirements and retain their loyalty. Companies that offer Quality goods and products will result in long-term revenue and profitability [9].

Quality Management

It is important to direct and regulate an organization in a systematic and transparent manner in order to effectively lead and manage it. Implementing and operating a management system that is intended to continuously enhance performance while meeting the needs of all stakeholders will lead to success. Quality management, among other management disciplines, is part of managing an organization. Quality management is the process of coordinating activities to control and direct organization pertaining quality and it includes four main components which are: quality planning, quality control, quality assurance and improvement. Quality planning is a part of quality management that focuses on defining quality standards and identifying the resources and operational processes required to achieve these objectives. Quality control is a component of quality management whose main focus is on meeting quality standards. Quality improvement is a component of quality management that aims to increase the ability to meet quality standards. Quality Assurance is a component of quality management where it focuses mainly on whether the quality criteria are met.



Quality Control

Quality has always been an essential part of almost all products and services. However, recognition of its importance and the implementation of formal techniques for quality control and improvement have been a gradual process. Quality control ensures that the items manufactured are of the highest possible quality. Manufacturing companies use a variety of QC tools to reduce process variability and increase process quality. To control product or process quality, a variety of strategies are available. Quality control is ensuring whether the manufactured product is fulfilling all the requirements with the highest possible quality. Many industries try improving the quality of their processes by reducing variability using quality control techniques. There are multiple techniques that are available to control the quality of process and products. Some of them are statistical process control (SPC), acceptance sampling, six sigma, and design of experiments (DoE), etc., Statistical process Control is a quality control system that inspects, tests, and analyses each product to determine if it meets the established quality standards. Because of the wide variety of customer needs, competency, and faster-evolving technology, manufacturing processes are becoming more flexible, and production must be done in small batches, with a lot of variety, unequal product sizes, and different levels of accuracy. As a result, using statistical process control tools like control charts to oversee the overall manufacturing process becomes difficult. There are many challenges that arise in the field of quality control and rapid growth in industries for which industry 4.0 becomes a solution.

IV. QUALITY CONTROL IN THE CONTEXT OF INDUSTRY 4.0

Any production process needs to be enhanced with the introduction of today's new technological innovations and in quality control where traditional approaches are being used, it becomes very important to bring the new technological changes in order to make the product more safe, reliable, and provide confidence in production [10]. In today's world, everyone values for quality be it at any cost, people are more quality conscious. This becomes a major pain point for the industries and their responsibility increases in making products that are complicated in both manufacturing as well as to ensure the economic competitiveness and sustainability. And to do so, any company should have a list of protocols that need to be followed which will guarantee the organization's internal processes. Smart factory works on the same principle too. With machines, sensors and robots, the factories are supervised in the same way as people do and it also uses tools with high accuracy and precision that assure better inspection and are capable of controlling all the processes during production. And yet, quality is being compromised when manufacturing customized products in small batch sizes as there will be more chances to cause errors and flaws due to lack of data. Therefore, it is important for the industries to apply the Industry 4.0 tools to quality control. However, precise measurement of a product to improve the quality might not be the only one contribution by the Industry 4.0 tools. They also help in quality of information such as optimizing, planning, operation and quality of forecast by Big Data analytics to analyze the data provided beforehand and utilize that data to detect problems that occur in future and find the solution for the predicted problems through simulation and even contribute towards effective workers participation [11].

Big Data

Big data is one of the most important and much required technology to make quality control and testing more effective and efficient. It is an intelligent tool that helps in improving the quality of products, reduce flaws during processing, and most importantly it saves both time and money. It helps to reduce the number of tests to be conducted by 70% through predictive analytics where historical data is collected and patterns are found and significantly reduce testing time and thus speeding up the time to markets. Big data includes customer-driven production by giving compiled insights to improve product design and testing. Thus, increasing the quality in customer service. Big data collects the opinions or the feedback from the social media and it keeps a track on how people use products and their choices of collection and also those things that might not add any value to the customer. Big data helps us solve unexpected problems in products and allows the manufacturer to see the different causes for failure through HALT (highly accelerated life testing). This helps to target the problems before proceeding with the development phase. Thus, big data will see a huge development in the coming years as innovation progress along with the development of business's new ways to deliver products with great value and quality within reasonable time frames. Big data not only helps the industry sectors where they can reduce the time and money spent on irrelevant testing. Customers can also benefit from the enhanced products.



Internet Of Things

For manufacturers, IoT technologies present the next step in process automation, real-time monitoring and data analytics. By employing IoT sensors, plant managers can monitor the environmental conditions, equipment performance and more. This enables manufacturers to pinpoint the source of quality control problems and take appropriate action. In terms of specific applications, IoT is assisting manufacturing companies:

- To perform predictive maintenance: Manufacturers are beginning to use IoT sensors that forecast when specific internal parts may malfunction without having to wait for a piece of machinery to fail. Uncalibrated machinery can introduce defects and irregularities in finished products, so equipment maintenance plays a very important role in quality control. Manufacturers can simultaneously decrease their overhead costs and minimize rejection rates while being proactive towards maintenance and repair.
- To monitor production with no physical contact: with the help of IoT technology system production can be monitored and can also be controlled by off-site employees remotely. Without any human intervention all the task that is related to quality control can be performed using vision inspection.
- To automate the production processes: automated systems detects if there are any variations in the output and send the data that is varied to the downstream equipment. Further this equipment takes corrective actions and adjust itself spontaneously. Thus, resulting in premium quality product.

For most of the firms, one of the major priorities is quality control. Benefits relating to process development and innovation is provided in IoT. Plant managers using these IoT technologies locate those activities that waste money and time. And this information can help the manufacturers in ensuring consistent outputs in multiple production sites. In a recent research from Intel, it was found out that 40% of all active IoT devices will be used in industry and manufacturing over the next 10 years.

System Integration

System integration can be further classified into horizontal and vertical system integration. With the help of system integration runtime can be recorded and quality data from local or external cloud that helps in optimizing the production. Availability of the plant can be increased with the help of predictive maintenance; unexpected and operational downtimes can be avoided. As the name suggests integration, which means networking of all the components enabling complete and automatic documentation helping in reduction of changeover time when quality issues occur. Also, it helps in reducing the units in callback by tracking the assembled parts and inspection results as an evidence to product quality. In addition, the automation processes can be directly connected with business processes in vertical integration i.e., connecting an enterprise resource planning (ERP) system and manufacturing execution system (MES) directly with the line.

V. CONCLUSION

The main focus of this paper is on the concept of industry 4.0 and its role in quality which provides efficient, smart and effective customized products at lesser and reasonable cost. By employing the nine pillars of Industry 4.0 in the manufacturing environment, many issues are resolved and it promises better safety, reduced cost of quality, higher efficiency thus leading to profitability of the industry. In customer point of view, customer is benefited by giving them a better experience and satisfaction towards the product. This paper also presents a brief introduction about quality control followed by an overview of main concepts (i.e., big data, internet of things, system integration) of Industry 4.0 with respect to quality control. Companies adapting industrial 4.0 not only helps in the quality control sector as discussed above but also helps them to stand out in this competitive market. Thus, becoming a key driver to innovation.

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