The New Approach towards Digitalized Manufacturing: Industry 4.0 - A Review

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Abstract

The manufacturing industry is a sector of our society which constantly faces challenges with the variation in demand and supply. Optimization in such a dynamic environment becomes difficult for any industry. Advanced approaches constantly attempt to balance the profit of the supplier as well as contentment level of the customer. Automation in the industry assures that mass production will maintain the supply proportional to the demand. In order to take the automation to the next level, Industry 4.0 allows for a more flexible production environment by introducing the concept of digitalization through a cyber-physical system or CPS. It also becomes an attempt to keep the manufacturing sector updated with the advances in technology of this 21st Cy.

This article attempts to list out the concepts of this next generation approach towards a more sustainable model of the manufacturing industry. Moreover, the research will also investigate the advantages and limitations of such a concept in any developing country while considering the initial investments and the undermined benefits.

Keywords:*Industry 4.0, digitalization, smart factories, big data, advanced analysis, data science*

1. Introduction

Man has been making objects since the stone age from the hunting equipments to boats and ships for travelling across the oceans. In order to understand the changes that took place with respect to the production of objects and industrialization, we must go back to the 18th Cy.

In the middle of the 18th Cy, many innovative solutions to everyday activities led to major changes in the human behavior. The majorly affected industry in this era was the textile industry. John Kay's flying shuttle and James Watt's condenser can be considered as the few of many major breakthroughs for the same. During this century, the cottage industries started to emerge as factories. This was the stepping stone for the first industrial boom of the history. The factories provided more job opportunities for the common man and people started to relocate to a more urban environment. The lifestyle was slowly changing along with the mentality of the people.

In the latter half of the 19th Cy, a new era began when Andrew Carnegie introduced the revolutionary steel making process. This opened doors to a lot of opportunities in the manufacturing industry as the prices of steel dropped drastically. According to Drath and Horch, "The second industrial revolution started about 100 years later in the slaughterhouses in Cincinnati and found its climax with the production of the Ford T in the US." (2014). The assembly line for this specific car was modified by Henry Ford for the increase in productivity and profitability of the process. This led to a huge decrease in the cost of the car and an increase in supply to match the steep demand.

The third industrial revolution started in 2011 and can be divided into two parts. The first main topic that was brought into focus was the concept of additive manufacturing. Even though, this concept was introduced in the middle of 20th Cy., it was a major breakthrough in many sectors after 2011. 3D printing technology is now used for creating prototypes and models as well as in medical applications like generating skin cells and, even, organs.

The second topic that was sought after during this time period was the green technology. The need of alternative fuel sources due to depletion of non-renewable resources was highlighted. Hence, many researchers were seeking different ways of using the energy from the elements of the earth itself in order to produce concentrated energy. The latest source of energy for electricity generation is the kinetic energy from the waves.

The first of the third industrial revolution was mentioned in Germany in the year 2013. This revolution takes the automation of a system to the next level. The robots that are already being used will be provided with increased level of artificial intelligence. The human-machine interactions will increase due to this rise in AI which will allow for a more flexible and sustainable manufacturing environment. The industries will adopt to a cyber-physical system in order to increase the AI. Cyber-physical (CPS) is a complex engineering system that integrates physical, computation and networking or communication processes.

The main aim of this revolution will be to increase the flexibility of the lean manufacturing system and also, provide sustainability to the processes. This will be achieved with the help of integration of Internet of Things with the current systems.

2. Manufacturing Industry

The manufacturing industry is one such sector which constantly faces challenges with the variation in demand and supply. Balancing the two while maintaining the profit levels of the organization becomes a tedious task. Various productivity techniques try to improve the work environment in order motivate and maintain a level of satisfaction for the workers. But they fail to address the process-specific problems that are faced. Industry 4.0 is an attempt to shape the process according to the requirement and add to the flexibility of the system. It also keeps up with the advances in technology of this 21st Cy by introducing the concept of a smart factory.

2.1 Need of a new approach

With the rise in the number of legs travelling the earth, there is an increasing demand of goods, products and services. This creates a need for mass production. Various industries have emerged to compete in the global market with their own choice of products produced in large numbers. As more industries emerge, the competition between them becomes tough and quality of the product becomes a key factor to increase the sales. Hence, the quality as well as the quantity come into consideration while optimizing a process of production. For this, a new approach becomes necessary which will monitor all the criteria at once. Hence, a next level of automation comes into picture.

2.2 Objective of Industry 4.0

For increasing the efficiency of any process, the number of mistakes made should be kept minimum. This can be achieved through by reducing the human intervention in any system in most of the cases. This new approach allows stability on the production floor by introducing the concept of integrated automated systems which are able to collaborate in order to produce the best of the best.

Many a times, the phrase "Old is gold" is visualized through the scene of the constant use of the age-old manufacturing processes like casting and forging. The second objective of this new approach is to update the production floor with respect to the technological boom that is introduced in other sectors. With this update, the number of products produced in a certain amount of time will be increased while maintaining the standards of the same. It does not attempt to completely banish the earlier processes but aims at modifying them such that they become more reliable and flexible.

3. What is Industry 4.0?

Industry 4.0 can be considered as an approach towards automated manufacturing systems. It introduces the concept of digitalization. Automation in a system includes the use of robots in order to replace humans in order to minimize the errors in the final products. Hence, automation can be defined as a task to improve the efficiency of any existing or new process. The concept of digitalization takes automation to the next level and allows the parameter of customer satisfaction to be considered. It emphasizes the concept of value addition in the overall process. It implements digitized systems on larger scales in order to allow a more flexible production environment.

The basic characteristics of Industry 4.0 include rise in data volume, computational power and connectivity, wide area networks, the emergence of new analytics and business-intelligence capabilities, new forums of human-machine interactions such as touch interfaces, improvement in digital instruction transfer to physical world such as advanced robotics, etc. Industry 4.0 w.r.t industrial production will be characterized by a higher degree of customization of products, supported by increasingly "flexible and agile manufacturing operations " (Lee, *et al,* 2015).

3.1Fundamentals of Industry 4.0

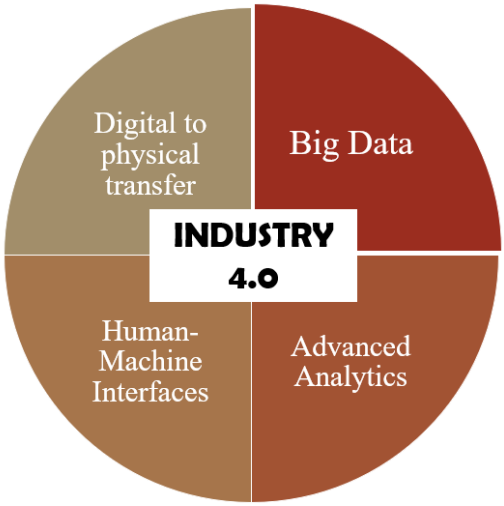

Fig. 1:Fundamentals of Industry 4.0

The four fundamentals of this concept are as follows:

3.1.1 Big Data

Statistical studies require data sets for predictive analysis. From a data set, the curve can be plotted from which points can be extrapolated. It is evident that the more data there is, the better the curve will fit. And a better fit curve allows the statisticians to predict the rest of the data sets more accurately. Hence, we realize that the more data you acquire from a system, the better control you will have over it. The better control

over any process allows for a decrease in the unplanned downtimes. In turn, this increases the end results or the "yield." For this concept, real-time data is collected at small intervals. This generates huge amounts of data and hence, the concept of storing and handling this big data comes into picture.

3.1.2 Advanced Analytics

Data, in its raw form, is of almost no use. Accumulated data becomes stale and can be considered as a waste by-product in the terms of Lean Manufacturing. In order to eliminate this type of waste, it becomes essential to process this data and utilize it to improve the on-going processes. To handle such type of a larger data set, advanced analytics becomes necessary. After the data has been thoroughly analyzed, the data points can be extrapolated for further research. Different softwares like MATLAB and python can be used to program and run analysis on the big data collected. This analysis will help to improve the product development sector.

3.1.3 Human-Machine Interface

To reduce random errors, automation becomes the key factor. For automation, a special communication system must be designed to allow the communication between not only a human and a robot but also, between two robots. This can be termed as "interoperability" between the robots. This will help in keeping the processes in continuous flow with as less disturbances as possible.

3.1.4 Digital to Physical Transfer

This transfer can be done with the help of 3D printing technology. The advantage of this transfer is that the cost of marketing the products reduce. For example, a company is to manufacture large household equipments like furniture. They can market their products by using 3D printed scaled down models of their products. Hence, the products that are to be sold are larger in size can be easily visualized in the real world instead of the 2D images that are currently used for marketing purposes. A full 3D model helps the customer get the actual feel of the product.

3.2 CRITERIA FOR INDUSTRY 4.0

In order for any organization to be considered as one of those using this concept, it has to satisfy the following criteria:

3.2.1 Interoperability

The machines that are collaborating on the production floor should have a well-established communication system. This will allow efficient functioning of the robots on the shop floor. The interoperability will also come in handy when one of the robot is shut down. In case of such a mishap, either a replacement of the failed components should be arranged immediately or a spare robot could replace the one that is idle. For this cause, interoperability between the robots as well as between humans becomes necessary.

3.2.2 Information Transparency

The input that is acquired from the system or process under control should be presented in such a form that the proceeding actions can take place in a simple and effective way. For example, if a ship is to be loaded with cargo, a sample modelling should be done based on the different weights that are to be mounted and their placements. The arrangement of this cargo has an effect on the complete travel time and efficiency of the ship. Hence, a pre-determined model can help in the process.This model will allow the user to view the orientation of the cargo to be placed as well as direct the crane after taking the inputs in order to place the cargos in a balanced manner. This automated pick and drop of the cargo will balance the ship in an accurate manner. This emphasizes the need of the information transparency between the robots and humans as well as clients and customers.

3.2.3 Technical Assistance

In an unfortunate case that a machine encounters an unexpected breakdown, due to information transparency, the problem will be detected almost immediately. The corrective action that has to be taken on this problem can be of two types: manual and automated. If the artificial intelligence of the robots is increased to that level, the robots itself can handle the job of maintenance. Otherwise, human operators should be readily available to fix the blinking red light.

3.2.4 Decentralized Decision Making

In a fully automated process, the decision that is to be made at every step is restricted to the CPU. According to the program that is fed, the system will decide whether it is OK to proceed or not. When interoperability between the robots come into picture, it is necessary to decentralize the decision-making process. In other words, the robots should be able to function independently and in collaboration. In case one of the robots is down, it should not shut the whole process down. Instead, the others should be working in their spot while another robot attends to the problem.On the other hand, they should also be working with respective other robots such that there is no hindrance in any on-going process.

3.2.5 Customer Involvement

The main aim of Industry 4.0 is to introduce flexibility in the system such that it reduces the rigidity of the Lean Manufacturing approach. In order to do this, real-time monitoring of data is required which is already

discussed previously. Once this is achieved, the customer will be able to change the inputs that he/she has already given before from the ability to check the status of their order from real-time monitoring system.

For example, Phil has already ordered a medium size pan pizza with onion and capsicum toppings. Say for example, he changes his mind and decided to remove the onion and add the olive toppings and change the size to a large instead of a medium. As of today, he cannot change the same order in an automated process. He will have to cancel the whole order and place a new one. If the concept of Industry 4.0 was to be implemented in an automated pizza parlor, then Phil will be able to check the status of his pizza on his phone directly. He can then change the upcoming parameters as he pleases. For example, if the pizza is already at the toppings station, he will not be able to change to a large pizza but he will be able to alter his toppings as he pleases.

Keeping the customers involved in the complete process is a key to increase the customer satisfaction due to its transparency of data.

4. WHY INDUSTRY 4.0?

- ✓ Interoperability between robots allows for various operations to take place, simultaneously.
- ✓ Lesser unplanned machine downtimes lead to more productive time and higher efficiency of the machines and robots.
- ✓ Safety at workplace is increased as the robots can be programmed to maintain a certain level of discipline in the workplace.
- ✓ Digitized optimization in every process helps to reduce the unnecessary operations and/or motions. On-spot decision making allows for a morepractical and efficient use of the robots and their intelligence in the process.
- ✓ The approach achieves more by doing less.
- ✓ This approach creates a simplified working experience.
- ✓ The automated process guarantees improved quality.
- ✓ Use of robots and machines lead to higher production.
- ✓ Due to the information transparency between the manufacturer and customer, more flexibility is involved.
- ✓ As the decisions are real-time, small mishaps or accidents do not hamper the process, drastically. This results in better stability in the overall system.

5. Drawbacks of Industry 4.0

- ✓ Increase use of automation means less human jobs on the production floor.
- ✓ Using cloud servers and Internet of Things leads to a requirement of high level cyber security.
- ✓ High initial costs due to the use of next generation softwares and machinery with increased intelligence.
- ✓ High replacement costs.
- ✓ Machine downtime results in higher losses.

6. Case Study: Optimization of the Pizza Delivery Service

This concept of Industry 4.0 can be implemented in our day to day lives. One of the example is in our pizza parlors. The main aim of the pizza parlor is to deliver a hot pizza at your doorstep, no matter where you live.

In today's world of pizza parlors, it seems that the customer requirement is often neglected and traffic jams often lead to couch potatoes eating cold food. This can cause a problem for the reputation of the business leading to a decrease in sales. To parry this problem, the pizza parlor can take measures that will help them in managing their pizza parlor locations and help to optimize the delivery process.

For this, the new approach will come in handy for collecting a large set of customer data. The customer can also stay in touch with the system through their smart phones that will link them to the servers and allow the access to the exact location of their delicious dinner. This case study discusses only the first step of the whole process i.e. the collection of the data set and one feasible solution.

To start off with, the company will need a main server where they will store and analyze the data points. A sample set of data is shown in the table below.

Pick up Location	Dist. (kms)	Time (mins)	Ambient Temp (°C)	Temp at Pick up (°C)	Temp at Delivery (°C)	Drop in Temp (°C)
Kothrud	1.6	26	24.2	56.5	40.2	**16.3**
Kothrud	3	32	24.2	54.2	37.8	**17.4**
Kothrud	1.6	17	22.3	53.7	39.9	**13.8**
Kothrud	3	35	22.3	54.6	36.6	**18.0**
Kothrud	4.5	39	22.3	57.0	32.5	**25.5**

Table 1: A Sample set of Acquired Customer Data

The pizza boxes will be fitted with some temperature measuring devices which will constantly track the changes in temperature from when the pizza is packed to when the pizza is delivered. This drop in temperature will be recorded and sent to the server. The pizza delivery man will possess a hand-held device which will keep the record of the location and the duration of travel which will, also, be sent to the server. This server then will tabulate the results of various deliveries and sort them according to location, time, requirement or any other criteria, as pertinent. This data will then be analyzed for the optimization of the delivery procedure.

The optimization can be carried out in different ways. One of the possible solution to the problem of the large drop in temperature due to increased travel time, environmental conditions, etc. is to introduce different

sets of pizza boxes. Refer Fig 2. According to the delivery locations and their popularity, the pizza centers will be allotted a boundary in which it must serve the orders, take, for example, the locations A, B, C, and D in a city. Each have a predefined radius of delivery. This will help in reducing the time travel. Now, when the pizzas are delivered and the data inputs are analyzed, the traffic conditions and the average distance travelled by the vehicles in a single block will tell exactly which parlor needs to improve their delivery process. The solution for the temperature drop in the pizza can be: to improve the insulation facilities for the boxes.

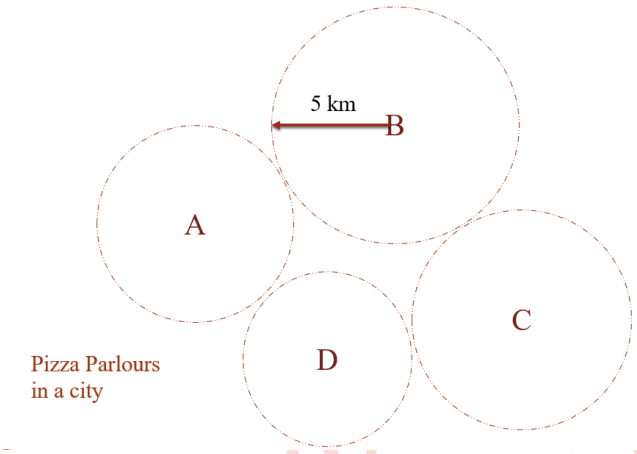

Fig. 2: Allocation of Pizza Delivery Centers in a city.

The problem with increasing the insulation for *all* boxes is that, the deliveries that are just minutes away and do not require such type of highly insulated environment, will still use it. This will increase the unnecessary overhead costs. Hence, different types of boxes with different types of insulations can be assigned as per the requirement. Refer Table 2.

Box Type	Suitable for Temperature Drop of:
Box P (lowest insulation)	upto 7°C
Box Q (low insulation)	7°C to 15°C
Box R (med insulation)	15°C to 22°C
Box S (high insulation)	22°C above

Table 2: Sample set of Box Types

If the location A and C have, approximately, 20°C drop in temperature between the starting point to delivery, a box type of P, Q and R can be stored at these locations. At location B, if the average temperature drop seems to be a little larger, then all box types can be stored at this location.

This stored data will be simulated to help in the improvement process of the delivery system. In the future, when an order is placed, at say location B, it will be analyzed from all the required parameters, like what time it was placed (for optimizing the traffic routes), what the current ambient weather is and so on. Based on the parameters, the server will give a direct output as of which box type will be best suited for the same.

This will satisfy the main aim of keeping the temperature drop constant irrespective of the distance that is to be travelled.

7. Conclusion

Manufacturing Industry was one of the only sectors which was using the age-old processes. In order to keep this sector in the race of the technological boom, the factories are implementing the concepts of this new approach. This will not only open doors to various different fields like data science and data analytics but also, allow a more work-friendly atmosphere in the organization with increased safety and lower workloads.

Industry 4.0 is definitely one of the industrial revolutions which has a profound effect on all of the world, as a whole. The limits of manufacturing are pushed by using the intelligence of the pre-programmed robots. Once this approach becomes the heart of the organizations, it will open up the market to a whole new set of opportunities. The increased flexibility will allow the customers to be satisfied with what they receive. On the other hand, the clients will also reach the level of satisfaction of providing the best quality products and services to their clients. The quality improvement will, also, help the organization to gain a certain reputation in the market.

Even though Industry 4.0 requires a huge amount of initial investments including the programming softwares, data collection, storage and handling devices, adept programmers, the next generation machinery and complex circuits inside the system, it will definitely prove to be beneficial for the organization in the long run.

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