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The Next Era of Manufacturing the Future: Making Things in a Changing World.

Haseeb Ahmad Khan, Abhinav Tiwari, Jalaj Kaushik, Manoj Yadav, Bhaskar Chandra Kandpal

Department of Mechanical Engineering
Inderprastha Engineering College, Ghaziabad, India

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Abstract: In recent year's advancement in technology acted as a driving force in changing all areas of society. Not only utilized in personal lives, but also giving prospective of improvement at our workplace. This transformation is known as the fourth industrial revolution.. Industry 4.0 will see many tasks that will ones perform by human, now being automated. In this paper, major pillar of industry 4.0 is discussed that have major impact in this technological revolution.

***Keywords* — Industry 4.0, Digital Manufacturing; Cloud Manufacturing, Additive Manufacturing, Digital Manufacturing**

I. INTRODUCTION

Manufacturing sector is considered as the major pillar for the economic productivity of any developing country. It provides a strong source for innovation which leads to a better industrialization. Throughout the last few decades, the manufacturing paradigm is continuously changing due to the improved utilization of data, enhanced communication and advancements in materials and using these factors developed countries transforms their finished goods to higher value from cheap raw materials. As each industrial revolution made a devastated change in conventionally running industry. So, industry 4.0 will also result in manufacturers to use methods other than traditional techniques . Today, the production process at most enterprises in India and throughout the world is mostly automated. At every stage, most of the work is done by mechanisms, machines, software for comprehensive data analysis. As Artificial Intelligence (AI) is one of the fastest growing innovative sectors of technological advancement [1], experts believe that not only Internet companies such as Google or Amazon are flagships for the implementation and development of AI solutions. All the sectors where AI is already being used are amongst the top market leaders. Contradictory to that banks and service market companies have also successfully implemented it in their operations .

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Corresponding Author: B.C.Kandpal (e-mail: bhaskar.kandpal@ ipec.org.in).

In the fourth era of industrial revolution the major focus is on the minimization of waste and on achieving mass personalization of products through intelligent manufacturing processes. The focus is on making the processes more efficient by specific reductions in variations . The dawn of industry 4.0 has led to rapid digitization. In fact, 76% of manufacturers expect their operations to be highly digitized for enterprises looking to deliver a secured and performance centric experience. If the advancement in technology grows with this pace it will change the job environment in the manufacturing sector. This review paper deals only with papers related to the second category of literature on energy-efficient production planning (EEPP) . Typically, the purpose of the EEPP model is to calculate a production plan that takes into account energy-related goals as well as traditional production planning (PP) goals, such as minimizing inventory storage costs, installation costs, or total completion time. There are energy-related constraints, such as limiting greenhouse gas GHG emissions or meeting established maximum demand, such as minimizing energy consumption, energy costs, or energy-related (GHG) emissions. Compared to approaches aimed at technologically improving the energy efficiency of production systems, the EEPP model is actually becoming more popular as it is not usually associated with large investments. So, we will further discuss some of the production technologies that are majorly contributing in the fourth industrial revolution i.e. Industry 4.0 are: Digital Manufacturing (DM) is the process of manufacturing of products from the point of design to the final delivery of products to the customers will all be highly automated and will follow the highly integrated approach of

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manufacturing. It will work on the block chain technology in which information will be replicated and propagated

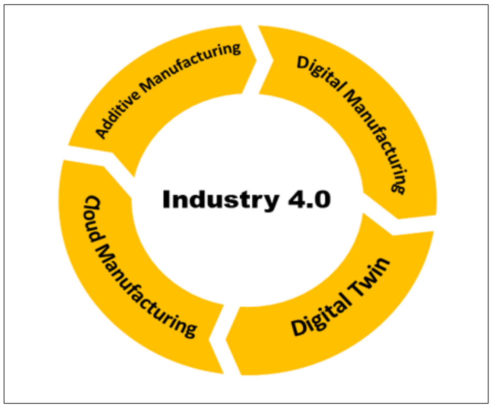

Figure 1: Major Pillars of Industry 4.0

throughout the computer system's overall network. So to manage the inventory and meet personalized customer demands, a service oriented concept known as Cloud Manufacturing (CM) will be used. It was submitted by a research team lead by Prof. Bo Hu Li and Prof. Lin Zhang in China in 2009.
Another pillar of industry 4.0 is the Digital Twin (DT) which bridges the gap between virtual copy and real asset by analyzing and simulating data in the most optimum manner. The term "Digital Twin" was coined by Dr. Michael Grieves in 2002.

The main advantage of using digital twin in industry is to skip the prototyping part in product lifecycle, but for developing countries the concept of digital twin is currently a standout trend, so for prototyping Additive Manufacturing (AD) is used. AD is creation of physical objects in a layer-by-layer format from 3D digital design data . 3D printers are most popularly used in prototyping of asset using additive manufacturing concepts.Fig.1 shows major pillars of industry 4.0.

II. LITERATURE REVIEW

Manufacturing has evolved a lot from the point of concept development to the methodologies available for the production of goods. Manufacturing is at the forefront of rising and developing nation's economic growth strategies. Manufacturing's percentage of GDP is thus a primary indicator of the sector's importance in a country's economy. Industry 4.0, is known as a new degree of organizational control over the whole value chain of a product's life cycle, focused toward increasing personalized client requirements.

Generally, the main aim is to determine how to put it into action for the advancements of industries and how the changes will contribute in maximizing resource utilization through minimization of waste. There are some of the domains in which the traditional manufacturing model lags due to the limitation of human operators' ability. So, to cope up with human error and increase the work precision, some of the methods is discussed and concluded their outcome as a whole. In this paper, various pillars that will lay the foundation of this fourth industrial revolution will be discussed and also discuss their scope and implementation in constructing optimum, accurate, highly precise assets in the real world.

The increased demand for the fine quality of product led to an increase in demand for different types of manufacturing technologies. Some manufacturing technologies, for instance, such as cloud manufacturing, Additive Manufacturing, Digital Twin was introduced. These processes also help to overcome the problem of sudden increase in customer demands. So, these processes have been reviewed and discussed further. These manufacturing processes can be interlinked with each other to play their part as a whole that can help to improve the productivity of that system.

DIGITAL MANUFACTURING

Companies are adopting several new technologies which forms the pillars of industry 4.0, of which Digital Manufacturing (DM) distinguishes itself by integrating traditional manufacturing techniques with digitalization. In traditional manufacturing processes the product is developed by first drawing its design, then is sent for manufacturing and production and finally marketing of the product takes place after which the product reaches to the final customers as shown in Fig.2. This requires a lot of time. There are probabilities of misinterpretation among several parties involved in the product conceptualization and manufacturing. Therefore, the advancement in the manufacturing process is necessary for manufacturing companies to sustain in the market and thereby also increasing the product quality which can further fulfil the consumer's requirement. In DM, different processes take place simultaneously which ultimately decreases the overall product life time. There is a dynamic shift in the market taking place every day which challenges the industry to overcome the problem of increase in customer demand. So, integration of design, manufacturing and other product operations can help the industry overcome the problem in the most efficient way by reducing the time for product development and by dealing with constantly increasing complexity which in turn can also increase the product quality .Fig.3 shows this digital way of manufacturing. intelligence, 3D printing, lean and agile manufacturing, cloud computing, digital twin and robotics along with the emergence of IOT in the field of technology and manufacturing. It is been quite obvious that every industrial revolution has bought a major change in the way different

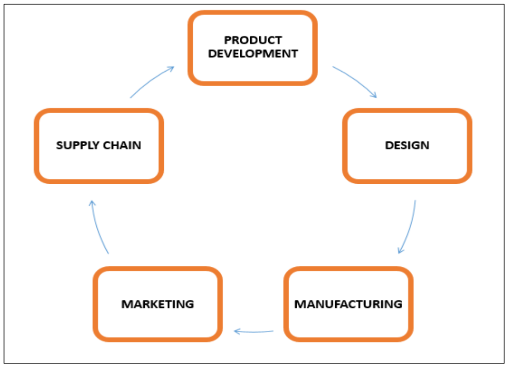

Figure 2: Traditional way of Manufacturing.

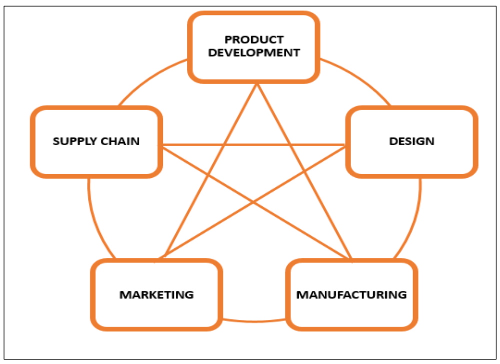

Figure 3: Digital way of Manufacturing

products are been manufactured traditionally. Introducing industry 4.0 can lead a drastic change in every sector of the operation. The digital revolution is in many ways driving industry transformations.

DIGITAL THREAD

Digital revolution in manufacturing is all about integrating different technologies together within a system. It allows a connected flow of data across the communication framework and integrates the view of assets over the course of its existence . The digital thread is a platform for a digital twin and a significant competency in model-based systems engineering. The main purpose of digital thread within DM is to merge the information throughout its value chain which consists of designing, manufacturing, testing and on to the final disposal of product. The pace of feedback can be much quicker in digital thread. It enhances the traceability so that decision making becomes easier. It can be seen how demands connect the product's effectiveness and ultimately how changes in those requirements will impact product performance.

INTELLIGENT MACHINING (IM)

Conventionally, tool manufacturing involves an operator controlling a machine like a cutting device or an additive process and then making decisions based on analogue or digital sensor readings. Automated manufacturing or intelligent machining requires a finer degree of data and computer algorithms. These are essentially mathematical expressions of the operator's activities. There are processes which can be classified as open loop systems or closed loop systems. Open loop system is those in which input is given in and output is given out and no feedback system is involved whereas in case of closed loop system feedback mechanism is involved. Sensors are attached and get feedback from output point and compare it with the required criteria and make changes to the input accordingly. So, IM use the closed loop approach which has self-monitoring and correction functions . To make the manufacturing process as efficient and transparent as possible, intelligent machining can be proven as of much more utility. The main purpose of intelligent machining is to enhance the quality of product manufactured. There have been some misconceptions about IM that it not to replace the role of humans in manufacturing units. IM helps in data monitoring so to make important adjustment which increases the efficiency of the process. The employee's safety can be improved by using data analysis from intelligent machining sensors.

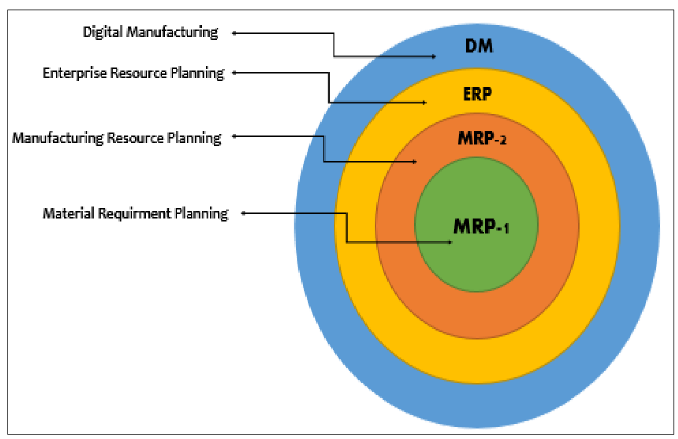

Figure 4: DM is the superset of all the manufacturing philosophies.

Time before when computers started dominating in industries, manufacturers used to plan production and manage purchasing activities manually. MRP, MRP II and ERP are PC-based systems which are used typically and targeted at assisting manufacturing facilities in effectively governing their production.Material requirements planning (MRP) refers to the quantity of parts, components, and materials required to make a product. Based on the information given by different experts MRP can be referred as a group of technologies that uses bill of material (BOM), inventory data and the master production schedule (MPS) to determine the inventory levels.

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MRPII (Manufacturing Resource Planning) is a computerized inventory management and production planning system which schedules component items as needed, track inventory and help a company in many other aspects of business.

CLOUD MANUFACTURING

When people, assets, and processes are out of sync then schedule, quality and cost performance of a manufacturing plant can suffer. Manufacturers are also constantly challenged by customer requirements for more personalized products, and shorter life cycles. Industry 4.0 addresses these challenges, but the digital transformation to intelligent connected products requires connecting a wide variety of equipment devices for processing, analyzing and sharing data throughout the organization to drive business value. So, a completely new manufacturing paradigm, namely, cloud manufacturing, is gaining attention in industry . Fig.5 shows cloud manufacturing ecosystem.

China has the most manufacturing industries in the world. These industries depends upon the inventory to satisfy customers' needs and to maintain these inventories, is a task. So having a service-oriented manufacturing network can provide a better way to meet the demand. E-commerce companies like Alibaba provided a better reach of products to people i.e., that people can visit a website to order their requisites, while the production is not limited to one company only. Cloud helped to create a system of manufacturing services to allow many industries to communicate their needs as shown in Fig. 5. So, service-oriented manufacturing provides enhanced efficiency of industries that can exponentially reduce the cost of production and creates optimum resource utilization. Chinese state council stated that the new advancement in manufacturing technologies has changed the past behavior of the supply chain, which also contributed to economic growth and the profit of the industries by not only meeting the demand but also by satisfying the ever-increasing demand of consumers .

Developing countries such as India should consider cloud manufacturing to improve the quality as well as the productivity of the manufacturing plant. After the Covid-19 pandemic, lot of MNCs are planning to relocate their manufacturing units from China to India .
There are many advantages to implementing a service-oriented approach in manufacturing. The most important is flexibility which provides a large capability under one roof. In this, there is less reliance on certain connections and companies are reduced, the manufactures with great expertise are assigned. As mentioned, the fixed reliance on inventories can be reduced which proves a flexible approach to get raw materials and in turn good quality. Since the rate of a service or a product is proportional to the quality of the product that’s why many manufacturing platforms set up considering the quality that they are going to provide. To attain flexibility and quality, the load should be allocated equitably among suppliers. So evenly distributed load is also one of the major factors for reducing the downtime caused by overload of work. For example, industry X has 800 orders to manufacture but the producing unit is full. So, the orders are distributed to other Y and Z industries using the information from the cloud. Thus, the order can be processed without waiting and overload of work for industry X to finish the order.

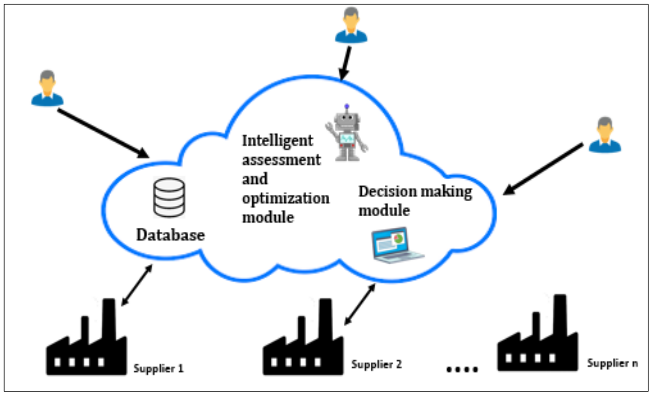

Figure 5: A Cloud Manufacturing Ecosystem.

APPLICATIONS

In the cloud, cloud design software can be rented to complete innovative designs through online collaboration and can realize remote control of manufacturing processing equipment like 3D printers through the cloud platform to complete more complex manufacturing tasks by establishing virtual factories and workshops in the cloud platform as shown in Fig.6.

DIGITAL TWIN

A Digital Twin (DT) is a virtual representation of real product or system. DT makes it easy to tackle the big challenge of integration between IoT and data analytics through by bridging the gap between virtual and physical asset . While there are slow advancements of technology in India, the DT concept within the industries remains as the standout trend currently. Digital twin represents the physical part of assets based on simulations and data collected by the IoT Devices as shown in Fig. 7. It depicts the representation and comparison of real car and its virtual model i.e. acts as a bridge between physical asset and real asset. Some of the steps help to optimize the performance of real assets with the help of data analysis of virtual twins. First of all, the real time data from sensors are collected and stored on the cloud. The data is then evaluated and simulated in a virtual copy of the assets. After receiving information from the simulation, the parameters are applied in real assets.

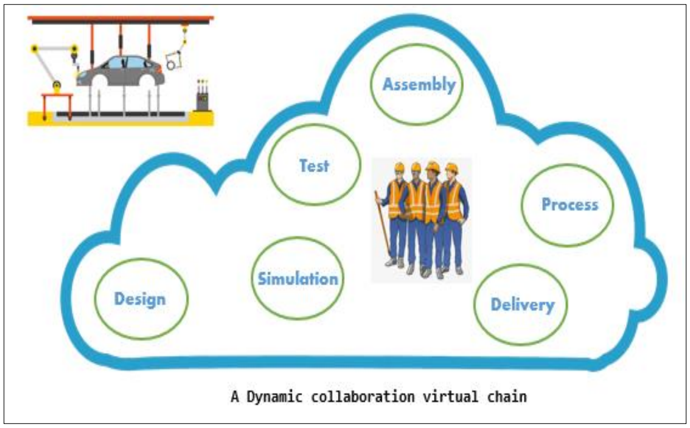

Figure 6: Cloud manufacturing system of car manufacturing unit.

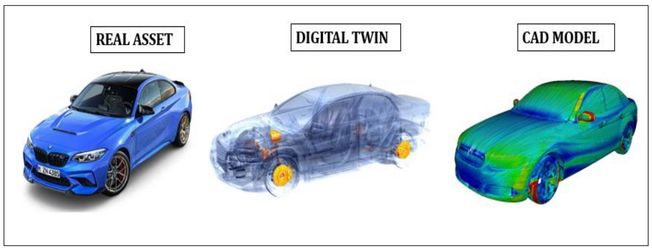

Figure 7: Comparison of digital twin with cad model and real asset.

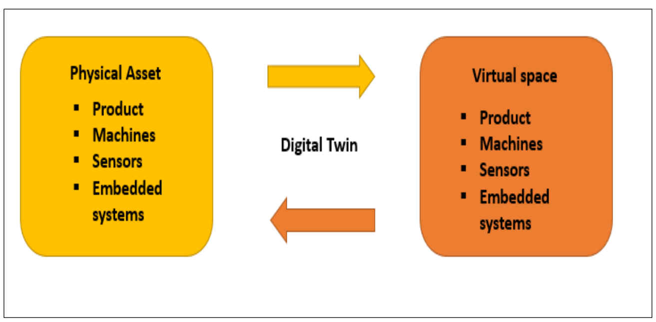

Figure 8: Digital twin acting as a bridge between physical asset and virtual space.

Due to digitalization of various processes, many big companies are now concerned in shortening the time of a processing by using DT. Now with the use DT, the task can be performed virtually which can help to reduce the overall processing time, It shortens the time that consumed in making and testing of a prototype . Surprisingly, it also helps in designing a product by considering various aspects as per the need. A DT also describes how the product can be manufactured. It defines the product behavior during operation and maintenance. The complete product lifecycle can be governed by the DT using simulations to get the optimal solution.Fig.8 shows the relation between physical asset and virtual world.

IMPLEMENTATION OF DIGITAL TWIN IN INDUSTRY

The Digital Twins play a major role in improving products without halting production. Conventionally, stopping a production line generated too much of a loss, so only essential maintenance was performed. DT gives companies warning in advance, as well as the ability to tune the results in the virtual world first, before risking any changes in real processes. Many big companies like SIEMENS and PTC are already using it . DT can be implemented for various level in industry ie for asset, full facility or for production purpose . It is classified into 3 parts- production process, individual products and performance of product

(a) Production process:

Digital Twins of certain elements can also be linked together to create larger twins of more complex systems supporting industrial plants. A DT has the ability of systematically analyzing big data sets. As the product is manufactured, the quality is ensured by identifying poor specifications of products or equipment, which can help in finding out design flaws and defects. With this technology one can quickly optimize the working on ground which enables to use in an efficient manner.

(b) Individual product:

Industrial IoT Digital Twins is a network of intelligent devices connected with each other. In this people, data, and assets help each other to communicate which in turn lower the service costs as well as improves customer satisfaction. If a physical engagement by technician is required, the problem can first be diagnosed remotely via the twin and then it informs all the equipment that are needed for the solution . Also, when different products are ordered by clients, configuration can be performed by service personnel remotely. New products can be developed with insights based upon the behavior of existing products in the real world .

(c) Performance of product:

Data collected by a DT can be used to train machine learning models to monitor and optimize performance. It can detect machines that have wear and tear issues that require regular changes or replacements. Having data about energy consumption and asset performance enables companies to identify key areas which can be improved or optimized which increases efficiency of industry by significantly reducing costs. Gestamp, a Spanish automotive supplier, is using DT technology to assess, refine and optimize performance.The most important goals for Gestamp is to reduce production costs as much as

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possible .

ADDITIVE MANUFACTURING (AM)

Additive manufacturing is the novel manufacturing technology which has the potential to change the traditional way of manufacturing. It has already started gaining the interests of not only the inventors and researchers but also many leading organizations are keeping their eye to know more about this technology. Moreover, this can be very well predicted that the 3D printing market will continue to outpace those conventional manufacturing technologies, such as injection molding and CNC machining. The reasons being very clear that 3D printing gives freedom of design . A single 3D printer can make many designs of different shapes and sizes. It has ability to manufacture complex structures and products. 3D printing is a process that gives us the freedom to build complex parts that can be made with ease as the process makes it possible to innovate beyond imagination. The cost of making a complex structure is same as that of making simpler ones on a 3D printer. It has a higher manufacturing capacity than a regular one and produces less waste. For both mass and personal customization, rapid prototyping is available which produces greater results in terms of quality and precision, as well as being more cost-effective due to the fact that it requires very little human intervention.

ADDITIVE MANUFACTURING SYSTEM

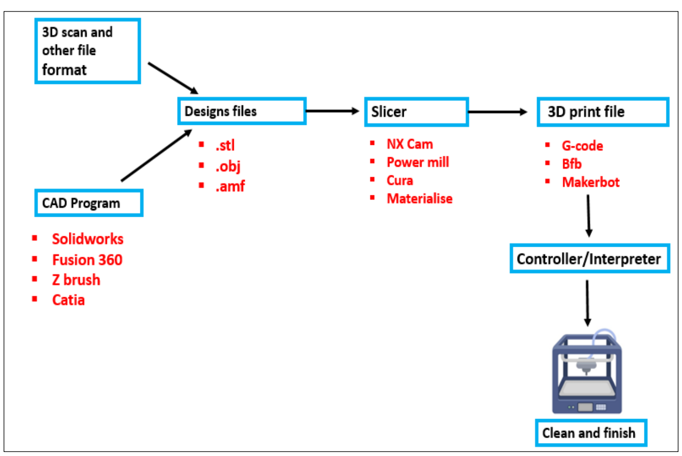

Figure 9: Additive Manufacturing System.

The first step in making an additive manufacturing system is CAD- model creation. The object which is to be made is first modelled from a computer aided design (CAD) software package. Solid modellers, such as Solid works or Catia, represent 3D objects more accurately than wire-frame modellers such as AutoCAD and therefore yield better results. (Fig. 10). The next step is Conversion to STL-format in which the CAD-file is converted to STL-format. STL file format represents a 3D surface as an assembly of planar triangles. Since STL files cannot represent curved faces and surfaces it uses planar elements which has a mesh shaped triangle. The approximations can be further improved by increasing the number of triangles . Next step is the slicing of STL-File followed by preparation of a pre-processing program for the STL-file. The pre-processing software slices the STL- model into a number of layers from 0.01mm to 0.7mm thick, depending on the build technique. The Auxiliary structure is created by the program which supports the model during the build. Overhangs, internal cavities and thin-walled sections are the delicate features and therefore these supports are required for them (Fig. 11) after that Layer-by-layer construction is done. Here the actual construction of the part takes place by building one layer at a time from polymer, paper or powdered metal. Generally machines are fairly autonomous, which needs only little human intervention. The last step is cleaning and finishing. In this all, the supports are detached from the prototype and then the prototype is removed from the machine . Then sanding, sealing, painting, minor cleaning & surface treatment improves its appearance and durability. (Fig. 12)

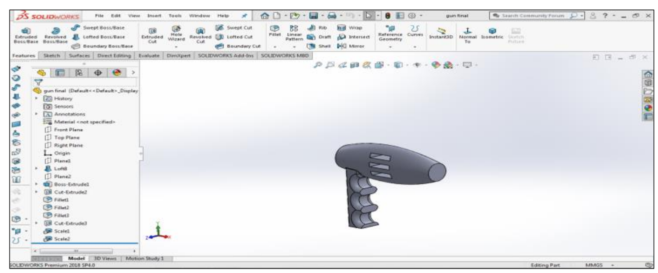

Figure: 10 CAD Model Creation.

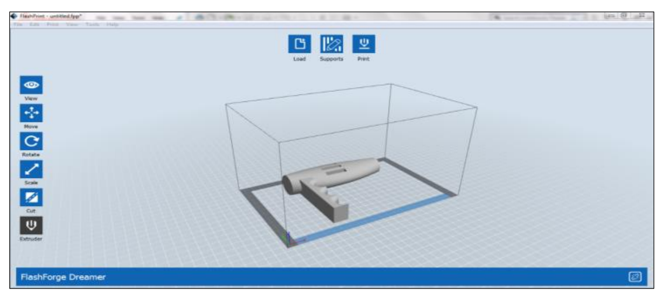

Figure 11: Slice the STL File.

Figure 12: Clean and Finish.

TYPES OF 3D PRINTINGS

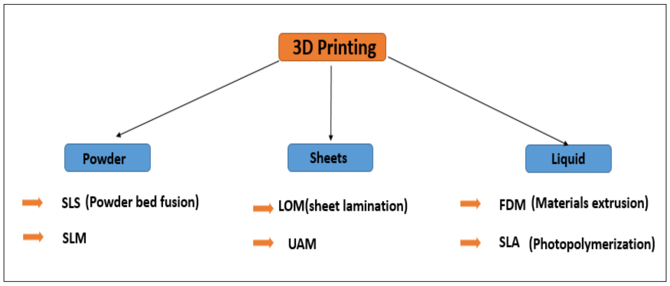

Figure 13: Types of 3D Printing

(a) Selective Elective Laser Sintering (SLS)

In the SLS method, a high-power laser and powdered materials are used. In these different types of materials can be used such as nylon, polystyrene and some metals.3D parts are produced by fusing a thin and fine slice of the powdered materials which are kept on depositing platform and are fused together with another layer with a laser beam supplied to the building area by a roller. For each particular level, a laser traces the path on the surface of the binding area. After that the power melts by the application of heat which fuses with the lower layer.

In manufacturing it is used to manufacture aerospace and automotive parts and have a diversity of materials. In casting industry, it is used to make patterns including mold inserts without the need for costly tooling Prosthetics – SLS is perfect for producing prosthetics as well as items such as cranial implants.

(b) Stereo lithography (SLA)

In SLA, a 3D model is built from liquid photosensitive polymers when exposed to UV-rays or electron beams.[30] It is one of the earliest and most frequently used 3D printing techniques. SLA works on the principle of vat photo polymerization technique. Initially the material is in the liquid state and then it hardens until the liquid is exposed to ultraviolet light. It gives true color3D printing. Some applications are: Finite element analysis, Concept molding, clothing designs, textures etc. .

(c) Fused Deposition Modelling (FDM)

In FDM a numerically controlled extruder head (nozzle) can move both vertically and horizontally over a table. Platform can be adjusted according to the level [33]. Thermoplastic is extruded using the same orifice of heated nozzle. Extruder head takes information from the file and moves in that path. After the first layer the table is lowered and following layers are formed. Parts are built from the base to the top in layer-by-layer manner, by heating and extruding thermoplastic filament. It works on the principle of materials extrusion technique. FDM is also known as FUSED FILAMENT FABRICATION (FFF).

(d) Laminated Object Manufacturing (LOM)

In LOM thin slices of materials (usually adhesive coated paper, plastic or metal) are consecutively sticked together to form a 3D-shape. The paper supply is controlled by two rollers which have preheated glue. This paper is then flattened and a new layer of paper is formed by a heated roller and desired shape is obtained by cutting it with blade or laser, after the end of the previous layer the platform descends and a new paper is supplied. When the paper is in position, the platform is moved back up so the new paper can be sticked together with the existing stack, and the cycle repeats. It is a relatively low-cost additive manufacturing technology.Fig.13 shows classification of 3D printing.

MATERIALS USED

Nowadays, the demand of complexed design and multi-functional products have increased and therefore many new materials, such as nanomaterials, biomaterials, smart materials or even metals and its alloys are used for 3D printing. Food, medicines and textiles can also be 3D printed nowadays and for that special kind of raw materials are required. Such material are as: -

Thermoplastic polymers such as Acrylonitrile butadiene styrene (ABS), poly-lactic acid (PLA) is the most popularly used materials in 3D printing because of their diverse applications. Some of the applications are as follows: -

a) They have a low melting point which results in smooth flow of material.
b) FDM makes use of different polymers like PLA and ABS for 3D printing complex geometries.
c) Using thermoplastic can be cost effective and it also gives the freedom to make complex designs and then 3D print them.
d) It is used for personal household use and is a go-to material for 3D printers.

Metals can also be used in 3D printings and its applications in the additive manufacturing world is growing exponentially. Through the use of metals and its alloys different components can be manufactured having good mechanical properties and complex geometries with higher accuracy and precision. Also, Ceramics and concrete are one of the materials that have come into use in 3D printing recently because they are more durable than metal and plastic. It can withstand extreme heat and pressure without even breaking or bending into another shape [34]. Affordable housing construction in low-income countries,building complex bridges across the cities can be the great practical examples of 3d printing applications.[35]. This technology will help in making the construction easy for space explorations

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III CONCLUSION

To be competitive on a global marketplace, meeting and satisfying dynamic customer demands, collaboration within critical and complex manufacturing activities such many businesses are interested in design and manufacturing. Computer processing speeds and storage capacities have grown astonishingly over the past 50 years. So, in the future, physical and virtual objects will start to merge with each other which in turn will elevate each other by its physical form or presence in the digital world. For example, using digital twins every real industry might have a complete digital replica right down to individual nuts and bolts, which can then be communicated with to access information about when they were installed, how often they've been used or what a typical failure rate might be.

In cloud manufacturing we saw how virtual objects will gain "real" identities—even personalities—while physical objects and environments will have digital personalized replicas. This will allow one to communicate with the help of a cloud which will trigger certain actions or events. Tiny factories of the future Modern manufacturing (and to some extent global capitalism) have been founded on the belief that large inputs are required and that economies of scale produce economic benefit. But this isn't necessarily the case in the future. The products can be manufactured at the nano level precisely using nanotechnology "factories". Moreover, in the fourth industrial revolution the products could be created only for the period in which they're needed and then be reverse-manufactured to get rid of them by using 3D printing technology. Using digital manufacturing concepts, we would be able to manufacture anything people wanted, in the most accurate and fastest way. By introducing the following ways, it will push us in a whole new economic system that is less reliant on physical resources and human labor, such as

1. By Providing (Online) Production/Inventory Management Strategies Proposal
2. By promoting energy-efficient production from the point of view of the utility that supplies energy from the manufacturer's point of view.
3. By Providing only general frameworks or software applications, not a quantitative model
4. By Focusing mainly on the system level, rather than machine level.

Industry 4.0 will be one of the most important and impactful industrial revolutions of all time.it will lead to large scale digitization of all the physical assets of the industry. At the economic end industries will generate profits like never before but also job opportunities will decrease. As the theory of Darwin states "survival of fittest" i.e., only the most skillful person and industry will survive after this revolution. As we said earlier, the main motive of industry is to satisfy customer personalized needs and to do this, they are having a continuous pursuit to improve quality of goods by decreasing waste. The fourth industrial revolution promises to overcome all the obstacles in a very optimum and sustainable way. "In 2008 a personal computer was able to handle around 10 billion instructions per second. Sounds a lot. But that's roughly the same as the brain of a small fish. By around 2040 machine brains should, in theory, be able to handle around 100 trillion instructions per second. That's about the same as a human brain"-Richards Watson.

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