# Manufacturing Engineering: Basics of Manufacturing Engineering

**Manufacturing** can be defined as *the conversion of raw materials into useful articles by means of physical labour or the use of power driven machinery.*

In prehistoric times, cave dwellers found that if a piece of flint stone was struck with another stone the flint could be turned into a sharp spear head or arrow head. They took the flint as their raw material and, by means of physical labour, converted it into something useful. They were manufacturing. By converting a useless piece of flint into a useful tool, they made it easier to defend themselves and to hunt for food in order to provide the tribe with its next meal.

Manufacturing has come a long way since then. Today, although there are still many skilled craftsmen who make things by hand, the manufacturing industries that are of significant economic importance to the nation are usually large concerns employing hundreds and in some cases thousands of people. They need large buildings, complex machinery and major investments of capital. They increasingly market and sell their products not just in one country but around the world.

Manufacturing as we understand it today began in what is called the *industrial revolution. The UK was the first nation to undergo the change from a largely agricultural economy to full-scale industrialization*. The foundations for this industrial revolution were laid in the seventeenth century by the expansion of trade, the accumulation of wealth and social and political change. This was followed in the eighteenth century by a period of great discoveries and inventions in the fields of materials, transportation (better roads, canals and railways), power sources (steam), and in the mechanization of production.

Manufacturing is a commercial activity and exists for two purposes:

• *To create wealth.* There is no point in investing your money or other people's money in a manufacturing plant unless the return on the investment is substantially better than the interest that your money could earn in a savings account.
• *To satisfy a demand.* There is no point in manufacturing a product for which there is no market. Even if there is a market (*a demand*), there is no point in manufacturing a product to satisfy that demand unless that product can be sold at a profit.

- We have already defined manufacturing as the conversion of raw materials into useful articles by means of physical labour or the use of power driven machinery. When this conversion takes place there is *value added* to the raw materials.
- This increase in value represents the creation of wealth both for the owners of the manufacturing enterprise itself and the nation as a whole.

After Second World War the rapid development of industrial economies in Asia and the Far East where labour is plentiful and cheap, also manufacturing and the marketing of manufactured goods has become global.

## Classification of Manufacturing Processes:

Manufacturing processes can be classified into six groups. They are:

### 1. Primary Shaping or Forming Processes

Primary shaping or forming is manufacturing of a solid body from a molten or gaseous state or form an amorphous material. Amorphous materials are gases, liquids, powders, fibres, chips, melts and like. A primary shaping or forming tool contains a hollow space, which, with the allowance for contraction usually corresponds to the form of the product. Here, cohesion is normally created among particles. Some of the important primary shaping processes are;

1. Casting. 2. Powder Metallurgy. 3. Plastic technology.

### 2. Deforming Processes

Deforming processes make use of suitable stresses like compression, tension, shear or combined stress to cause plastic deformation of the materials to produce required shapes without changing its mass or material composition. In forming, no material is removed, they are deformed and displaced. Some of the forming processes are;

1. Forging 2. Extrusion 3. Rolling.4. Sheet metal working. 5. Rotary swaging. 6. Thread rolling. 7. Explosive forming. 8. Electromagnetic forming.

### 3. Machining/Removing Processes

The principle used in all machining processes is to generate the surface required by providing suitable relative motions between the work piece and the tool. In these processes material removed from the unwanted regions of the input material. In this, work material is subjected to a lower stress as compared to forming processes. Some of the machining processes are;

1. Turning. 2. Drilling. 3. Milling. 4. EDM. 5. Grinding. 6. ECM. 7. Shaping and planning. 8. Ultrasonic machining.

### 4. Joining Processes

In this process two or more pieces of metal parts are united together to make sub-assembly or final product. The joining process can be carried out by fusing, pressing, rubbing, riveting or any other means of assembling. Some of the important joining processes are;

1. Pressure welding. 2. Diffusion welding. 3. Brazing. 4. Resistance welding. 5. Explosive welding

6. Soldering.

**5. Surface Finishing Processes**

These processes are utilized to provide intended surface finish on the metal surface of a job. By imparting a surface finishing process, dimension of the part is not changed functionally either a very negligible amount of metal is removed from or certain material is added to the surface of the job. Surface cleaning process is also accepted as a surface finishing process. Some of the surface processes are;

1. Plastic coating. 2. Metallic coating. 3. Organic finishes. 4. Inorganic finishes. 5. Anodizing. 6. Buffing. 7. Honing. 8. Tumbling. 9. Electro-plating. 10. Lapping. 11. Sanding

**6. Material Properties Modification Processes**

In this type of process, material properties of a work piece is changed in order to achieve desirable characteristics without changing the shape. Some of the processes are;

1. Heat and surface treatment. 2. Annealing 3. Stress relieving

## Scales of Production:

## Introduction:

- Popular makes of motor cars are mass-produced in large quantities by increasingly automated manufacturing techniques because of the large demand for such products.
- On the other hand large structures, such as bridges, are usually built on a 'one-off' basis mainly by hand.
- However some components, such as nuts and bolts, used in the construction of a bridge may well be mass-produced on automatic machines because of the quantity required.

**Extra Info** (Top restaurants will generally employ chefs to cook meals to order to a very high standard for a limited number of customers who are able and willing to pay the high cost of such labour-intensive service. On the other hand, fast food outlets are more likely to use processed foods that require the minimum of preparation. This increases the volume of meals that can be served and reduces the time and cost involved.)

Therefore the *scale of production* will depend upon the type of product and the demand for that product.

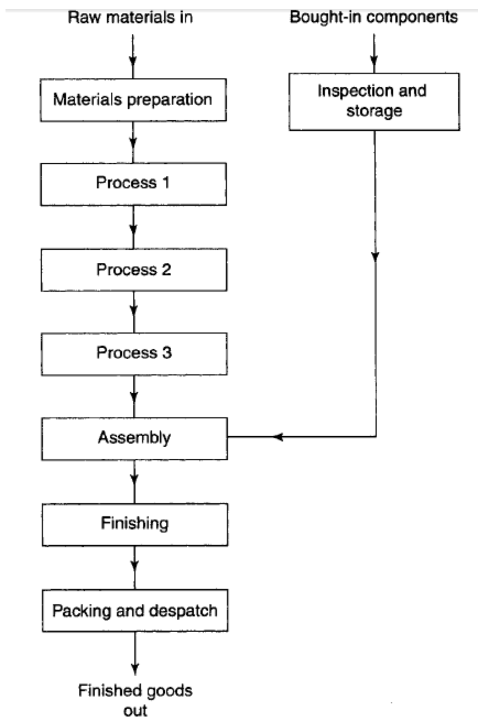
The broad groupings are as follows:

- Continuous flow and line production;
- Repetitive batch production;
- Small batch, jobbing and prototype production.

Let's now look at some typical applications of each category.
i.) **Continuous flow and line production:**


In *continuous flow production* the plant resembles one huge machine in which materials are taken in at one end of the plant and the finished products are continuously despatched from the other end of the plant. The plant runs for 24 hours a day and never stops. Plastic and glass sheet and plasterboard is produced in such a manner.

In *line* or *mass production* plants the manufacturing system plant is laid out to produce a single product (and limited variations on that product) with the minimum of handling. The product is moved from one operation and/or assembly station to the next in a continuous, predetermined sequence by means of a conveyor system. Individual operations are frequently automated. Such plants usually manufacture consumer goods such as cars and household appliances in large quantities in anticipation of orders. The layout of a typical flow or line production plant is shown below.




Layout for a flow production plant.

Extra Info

(The characteristics of *continuous flow* and *line production* can be summarized as:

- High capital investment costs.
- Long production runs of the same or similar product type. In some cases production never ceases until the plant requires refurbishment or the product changes.
- Highly specialized plant resulting in inflexibility and difficulty in accepting changes in product specifications.
- Rigid product design and manufacturing specifications.
- The processing equipment is laid out to suit the operation sequence.
- Stoppages occurring in any of the production units needs to be rectified immediately or the whole production line is brought quickly to a halt.
- Components, products and subassemblies move from one work-station to the next by means of pipelines in the case of fluids, gases and powders or by mechanical conveyors in the case of solid goods.)

**Batch Production:**

As its name implies, this involves the production of batches of the same or similar products in quantities ranging from, say, hundreds of units to several thousand units. These may be to specific order or in anticipation of future orders. If the batches of components are repeated from time to time, this method of manufacture is called *repetitive batch production.* General purpose rather than special purpose machines are used and these are usually grouped according to process.

Nowadays, the machines are often arranged to form *flexible manufacturing cells* in which the machines may be computer numerically controlled (CNC)and linked with a robot to load and unload them.

- To change the product, the computers are reprogrammed. The computer programsare kept on discs and are available for repetitive batches thus savinglead-time in setting up the cell.

Extra Info

(The characteristics of batch production can be summarized as:

• Flexibility. A wide range of similar products can be produced with the same plant.
• Batch sizes vary widely.
• Production is relatively slow as one set of operations are usually completed before the next are commenced.
• Work in progress has to be stored between operations. This ties up space and working capital. It also has to be transported from one group of machines to the next.
• General purpose machines are used. These have a lower productivity than the special purpose machines used in line and flow production.
• It is unlikely that all the machines in any particular plant are required for every product batch. Therefore work loading will tend to be intermittent with some machines remaining idle from time to time, whilst others are overloaded resulting in production bottlenecks.

• For the reasons stated above, unit production costs are very much higher than for flow and line production. Process efficiency is lower since variations will exist between the rate of production and consumer demand.)

**<u>Small batch, Prototype and Jobbing Production:</u>**


This refers to the manufacture of products in small quantities or even single items. The techniques involved will depend upon the size and type of the product. For very large products such as ships, oil rigs, bridges and the steel frames of large modern buildings, the workers and equipment are brought to the job. At the other end of the scale, a small drilling jig built in the toolroom will have parts manufacture on the various specialist machining sections and will be brought to and assembled by a specialist toolroom bench-hand (fitter). Prototypes for new products are made prior to bulk manufacture to test the design specification and ensure that it functions correctly.

Modifications frequently have to be made to the prototype before manufacture commences.

Workshops for small batch (100 or less) and single products such as jigs, fixtures, press tools and prototypes, are referred to as *jobbing shops*. That is, they exist to manufacture specific 'jobs' to order and do not manufacture on a speculative basis.

So far we have only considered an engineering example, but the same arguments apply elsewhere. For example when you order a suit from a *bespoke tailor* it will be manufactured as a 'one-off' specifically to your measurements and requirements. It will be unique and made mainly by hand in the tailor's workroom. The tailor will not manufacture on a speculative basis. However, the suit you buy from a clothing store will be one of a *batch* produced in a factory in a range of standard sizes and a range of
standard styles. The various parts of the suit will be cut out and made up by specialist machinists. The characteristics of small batch, prototype and prototype production can be summarized as:

Extra Info

- Work is quoted for job by job. Nothing is manufactured for stock.
- A wide range of general-purpose machines and associated processing equipment (for example heat treatment equipment for a tool room) is required.
- Highly skilled and versatile operators are required.
- Economical loading of the plant and personnel is difficult.
- Often, only outline specifications are provided, therefore design facilities are required.

## Advances in Manufacturing: CNC machines:

CNC stands for ***computer numeric controlled***. It refers to any machine tool (i.e. mill, lathe, drill press, etc.) which uses a computer to electronically control the motion of one or more axes on the machine.

The development of NC machine tools started from a task supported by the US Air Force in the early 1950's, involving MIT and several machine-tool manufacturing companies. The need was recognized for machines to be able to manufacture complex jet aircraft parts.

As computer technology evolved, computers replaced the more inflexible controllers found on the NC machines; hence the dawn of the CNC era.

CNC machine tools use software programs to provide the instructions necessary to control the axis motions, spindle speeds, tool changes and so on.

CNC machine tools allow multiple axes of motion simultaneously, resulting in 2D and 3D contouring ability.

CNC technology also increases productivity and quality control by allowing multiple parts to be produced using the same program and tooling.

## <u>Definition of CNC Machine</u>:

Computer Numerical Control (CNC) is one in which the functions and motions of a machine tool are controlled by means of a prepared program containing coded alphanumeric data.

CNC can control the motions of the work piece or tool, the input parameters such as feed, depth of cut, speed, and the functions such as turning spindle on/off, turning coolant on/off.

### <u>Applications</u>:

The applications of CNC include both for <u>machine tool</u> as well as <u>non-machine tool</u> areas.

- In the machine tool category, CNC is widely used for lathe, drill press, milling machine, grinding unit, laser, sheet-metal press working machine, tube bending machine etc.
- Highly automated machine tools such as turning center and machining center which change the cutting tools automatically under CNC control have been developed. In the non-machine tool category.
- CNC applications include welding machines (arc and resistance), coordinate measuring machine, electronic assembly, tape laying and filament winding machines for composites etc.

### <u>Advantages and Limitations</u>:

CNC machines offer the following advantages in manufacturing:

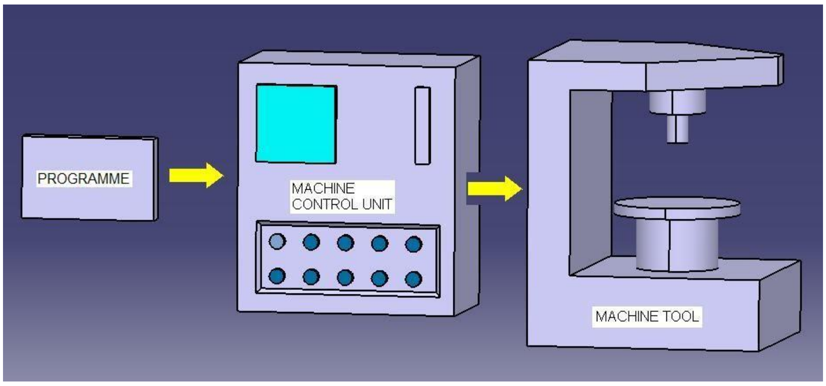
- *Higher flexibility*: This is essentially because of programmability, programmed control and facilities for multiple operations in one machining centre,
- *Increased productivity*: Due to low cycle time achieved through higher material removal rates and low set up times achieved by faster tool positioning, changing, automated material handling etc.
- *Improved quality*: Due to accurate part dimensions and excellent surface finish that can be achieved due to precision motion control and improved thermal control by automatic control of coolant flow.
- *Reduced scrap rate*: Use of Part programs that are developed using optimization procedures
- *Reliable and Safe operation*: Advanced engineering practices for design and manufacturing, automated monitoring, improved maintenance and low human interaction
- *Smaller footprint*: Due to the fact that several machines are fused into one.

On the other hand, the main disadvantages of NC systems are:

- Relatively higher cost compared to manual versions
- More complicated maintenance due to the complex nature of the technologies
- Need for skilled part programmers.

## Elements of a CNC:

A CNC system consists of three basic components:
1 . Part program
2 . Machine Control Unit (MCU)
3 . Machine tool (lathe, drill press, milling machine etc)




**Part Program:**

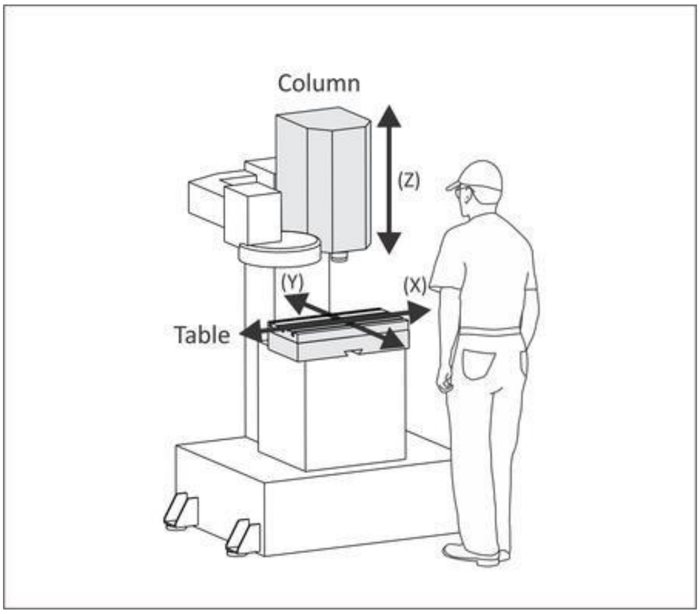
The part program is a detailed set of commands to be followed by the machine tool. Each command specifies a position in the Cartesian coordinate system (x,y,z) or motion (workpiece travel or cutting tool travel), machining parameters and on/off function. Part programmers should be well versed with machine tools, machining processes, effects of process variables, and limitations of CNC controls. The part program is written manually or by using computer assisted language such as APT (Automated Programming Tool).

**Machine Control Unit**

The machine control unit (MCU) is a microcomputer that stores the program and executes the commands into actions by the machine tool. The MCU consists of two main units: the data processing unit (DPU) and the control loops unit (CLU). The DPU software includes control system software, calculation algorithms, translation software that converts the part program into a usable format for the MCU, interpolation algorithm to achieve smooth motion of the cutter, editing of part program (in case of errors and changes). The DPU processes the data from the part program and provides it to the CLU which operates the drives attached to the machine leadscrews and receives feedback signals on the actual position and velocity of each one of the axes. A driver (dc motor) and a feedback device are attached to the leadscrew. The CLU consists of the circuits for position and velocity control loops, deceleration and backlash take up, function controls such as spindle on/off.

**Machine Tool:**

The machine tool could be one of the following: lathe, milling machine, laser, plasma, coordinate measuring machine.
i.) Milling Centre




Machine having three axis system. Ex: CNC Milling Machine (x, y & z)

ii.) Lathe Centre


Machine having two axis system. Ex: CNC Lathe Machine (x & z)

**<u>Advantages of CNC machines when compared to Conventional Machines:</u>**

- Once the program has been written and proved, parts can be consistently machined to a high degree of accuracy and consistency.
- Production time can also be reduced due the fact that the tool can be feed at a rapid feed rate to the work.
- Also complex form tools are not required as the CNC machine can generate the required profile.
- Safety has also been improved as most CNC machines have safety features such as guards.