

Basics of Mechanical Engineering-2

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Week 01

Lecture 01

Introduction to Manufacturing Engineering

Welcome to the course on Introduction to Basic Mechanical Engineering-2. We are now going to get into the second part of this course. In this course, our primary focus will be manufacturing. Manufacturing is a wonderful area in which what you feel and what you think can be converted into a physical part—nothing is better than that. You get so much satisfaction when you try to manufacture on your own and see a product, which can be a small functional or aesthetic product. So, manufacturing is the focus of this course for the next 30 hours.

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- Introduction
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- History
- Constant Volume Method
- Materials Shape Deformation
- Materials Subtraction
- Materials Joining
- Polymer Moulding Method
- Materials Addition
- To Recapitulate

The content of this lecture is going to be a basic introduction, then manufacturing, how manufacturing evolved over time, what are the classifications of manufacturing—that is, Constant Volume Methods, Material Shaping Deformation, Material Subtraction, Material Joining, Polymer Molding Methods, Material Addition, and finally, we will try

Manufacturing



- Manufacturing refers to the process of producing goods through the utilization of
 - equipment,
 - labor,
 - machinery,
 - tools, and
 - various chemical or biological methods of processing or formulation.
- Manufacturing is the field of engineering focused on the design and optimization of manufacturing processes, which involve transforming raw materials into finished products.
- This process initiates with the design of the product and the specification of materials.
- Subsequently, these materials undergo modifications during manufacturing to achieve the intended final product.



to see a recap.

Manufacturing refers to a process of producing goods through the utilization of equipment, labor, machinery, tools, and various other

chemical or biological methods of processing or formulation. So, it's a process of producing goods. These goods are useful for humankind. We are not asking you to produce it only by manpower. We are also trying to involve equipment, machinery, and tools.

So, manufacturing is not exactly focused only on mechanical manufacturing. You can try to produce any output. For example, cooking. Cooking is also manufacturing, in which you try to produce food using utensils, a spoon, and raw materials. There is a temperature, a pressure, or a shearing action.

You convert it into another form and present it in such a way that it is more attractive. Manufacturing is the process of producing goods. Manufacturing is the field of engineering that is focused on the design and optimization of the manufacturing process. You can produce a particular product through various outputs and various processes. So,

trying to choose the best process in terms of energy and quality is what the optimization of the manufacturing process is about.

It involves the transformation of raw materials into finished goods. Taking one kilo of material and trying to produce one piece is not manufacturing. Trying to produce the maximum output with minimum waste is the optimization of the manufacturing process. The process begins with the design of the product and the specification of the material. In the next lecture, we will try to understand materials so that you can properly choose the manufacturing process.

Subsequently, the material undergoes modifications in terms of shape, size, heat treatment, and all these things. For example, with finger chips, whatever you do, you quench them in oil and take them out. That's the modification of the surface. The surface becomes crispy, and the core becomes soft. So, materials undergo modifications during manufacturing to achieve the intended physical product.

So, manufacturing is producing goods from raw materials in an optimized fashion using minimum energy, manpower, and materials.

Applications



Today, when we look into the automobile industry, we see a lot of automation happening, and we use many robots. These are the bottom ones. These are fixtures to hold, and these

are robots that can help in welding, assembly, or whatever it is. You can see here another type of robot that is used for pick-and-place and welding.

So these are nothing but machineries which are used, equipment which is used for holding but producing the output which is consistent, reliable, and repeatable.

History of Manufacturing



- Human ancestors created tools from stone and other materials well before the appearance of Homo sapiens approximately **200,000 years ago**.
- The oldest techniques for producing stone tools, referred to as the Oldowan "industry," can be traced back to at least **2.3 million years ago**.

- With the earliest concrete evidence of tool use discovered in Ethiopia's Great Rift Valley, dating to around **2.5 million years ago**.
- To manufacture a stone tool, a "core" of hard stone with specific flaking properties (such as flint) was struck with a hammerstone.



The manufacturing did not start just now. It has a history. The human ancestors created tools from stone and other materials well before the appearance of Homo sapiens approximately 200,000 years ago. They realized that the tool which is used for sharpening a stick or a softer material should be harder, and there has to be a geometry given to the tool.

So, they created a tool from stone and other materials. The oldest technique for producing stone tools, referred to as the Oldowan industry, traces back to 2.3 million years ago, with the earliest concrete evidence of tool use discovered in the Ethiopian Great Rift Valley, dated 2.5 million years ago. To manufacture a stone tool, a core of hard stone with specific flaking properties was struck with a hammer stone. So, shaping the tool to produce the required output. See, in the early days, the part was the product.

They made a part, a product. Today, what we do is we do a lot of automation. We do a lot of mechanisms. So, we try to give energy on one side and try to do multiple things. So, in those days when they were trying to focus towards manufacturing, they were more

focused on a part to be made as a product which would be made from a single tool. The tool in earlier days was stone, and subsequently, other metals came into existence.

Examples of Ancient Manufacturing



Flint stone core for making blade in Negev Israel



A late Bronze Age sword or dagger blade now on display at the National Archaeological Museum in France



So, examples of ancient manufacturing include a flint stone core for making blades in Negev, Israel, and a large Bronze Age sword dagger blade now on display at the National Archaeological Museum in France; you can say this is a tool which is used.

Manufacturing Process



- On the basis of materials, application, etc, these are classified in number of ways.
- Manufacturing processes if generally divided into six major groups.
 - **Constant Volume Method**
 - **Materials Shape Deformation**
 - **Materials Subtraction**
 - **Materials Joining**
 - **Polymer Moulding Method**
 - **Materials Addition**



So, when we try to look into manufacturing, the manufacturing process is generally classified into six different types. The Constant Volume Method means that the starting material and the ending material, the starting raw material and the ending product, should be almost the same. So, those things are called Constant Volume Methods.

Material Shaping Deformation, wherein the raw material shape is changed from one shape, one dimension to another. The volume of the material used at this stage is also constant. For example, when we try to make chapati, we make a roll, a ball of atta. Then we try to smear it or spread it and make it flat. The shape and size are changed into a different shape and size.

Here it is again a constant volume process. The raw material, which is in a ball form, is now converted into a flat, smeared chapati. So, that is a constant volume where the material shape is deformed. Subtractive process wherein we try to carve out the unnecessary part from the raw material and try to make an output. For example, you are trying to chisel a statue from a stone.

You have a big, huge chunk of stone. You try to chisel it by using a tool. We start removing. So it is a material subtraction process. Material joining process is when you make small, small pieces.

You assemble them to get an output. For example, you want to make a building. So what you do is you try to have a small amount of bricks which are placed one after the other above each other. A unit block is replicated and assembled. You try to make a structure.

So that is Material Joining. Then, polymer is a process where it is extensively used for blowing or injection molding. You look at a plastic chair or you look at a water bottle. You look at a syringe tank. It is all made out of polymer material.

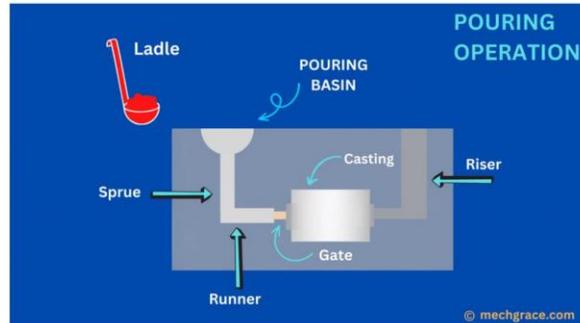
So predominantly here, we use the injection molding process. So molding methods. And the last one is the Additive Manufacturing process. The Additive Manufacturing process and the joining process look to be the same. But here, the material which is added layer by layer to make an output is Material Addition.

So basically, the manufacturing process can be classified as one among the six. For making an output, you can use a combination or you can use a hybrid also.

Constant Volume Method



- Casting is formally known as the Constant volume manufacturing method.
- The raw materials are heated up to the melting point so that the raw material changes to its shapes and became in molten state.
- The molten form of the materials are filled in to mould cavities so that molten metal is solidify in the mould cavity and shape fabricated according to mould cavity.
- The low melting point materials like Aluminium, Copper, Brass, Cast iron, etc.



So the best example for the Constant Volume process is Casting. So Casting is nothing but you think of a die or an ice cube tray where you pour water in it and keep it inside the freezer. So what happens?

The liquid is converted into a solid. Because of the temperature difference which is there, the temperature is extracted, and then the water is converted into a solid. A liquid gets

into a solid shape. This is Casting. So when we try to do it for a metal, what happens is we try to take it to a higher temperature.

So very high temperatures like 500 degrees, 600 degrees, 800 degrees. So we try to melt the metal and take it to that temperature. Now pour it into a die or into a mould. When you pour it into a mould, you can directly pour it, but there can be choking. So we have to allow it to flow uniformly and then go to the mould.

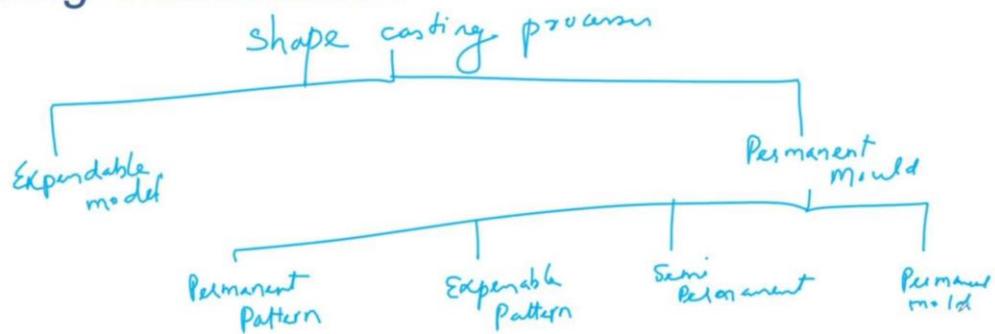
So what we do is use the ladle to pour. The liquid metal gets into the gating system. So they have a sprue, which is used to make the flow uniform. Then there is a runner. This runner leads to the mould area.

And when you pour the required material, there can sometimes be an irregular flow. To avoid this, they always try to pour excess material. The excess material they pour is now taken away through this riser, or the solidification happens because liquid turns into solid. Solidification happens maybe because the flow of material is not sufficient enough to cover the entire area. So we try to pour some excess from this riser, which gets into the mould and fills it up.

So this is a process where it is a constant volume process. What you pour and what gets solidified will be almost the same. So the process is called casting. The raw material is heated up to the melting point so that the raw material changes its shape and phase becomes a molten state. The molten form of the material is filled into the mould cavity so that the molten metal solidifies in the mould cavity and the shape fabricates onto the mould cavity.

So aluminum can be done, copper can be done, brass can be done, cast iron can be done, and steel can be done. There are several things that can be done.

Casting Classification



So if you try to see the classification of casting, Shape casting processes include expendable molds and permanent molds. What are they?

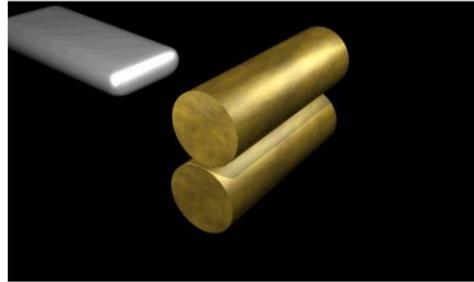
The mold, whatever you try to make, When taking the product out, you break it. For example, if you try to pour something inside pottery, it gets solidified, and once you want to take the component out, you break it open. So that is called expendable. If you do not want to, the ice cube tray is a permanent mold.

So here, you can have a permanent pattern. We will see what a pattern is later. So, permanent pattern. Expendable pattern, semi-permanent pattern, and then you will see this is permanent mold. So, these are the ways they are classified.

Material Shape Deformation Manufacturing



- In shape deformation manufacturing, the shape of the raw materials is deformed by applying compression, and tensile force beyond the elastic limit.
- The materials plastically deform due to the action of shear stress induced in the materials.
- This process is generally known as the forming process
- Some of the examples are
 - Bending
 - Rolling
 - Drawing
 - Deep drawing, etc



<https://commons.wikimedia.org/wiki/File:Rolling.gif>

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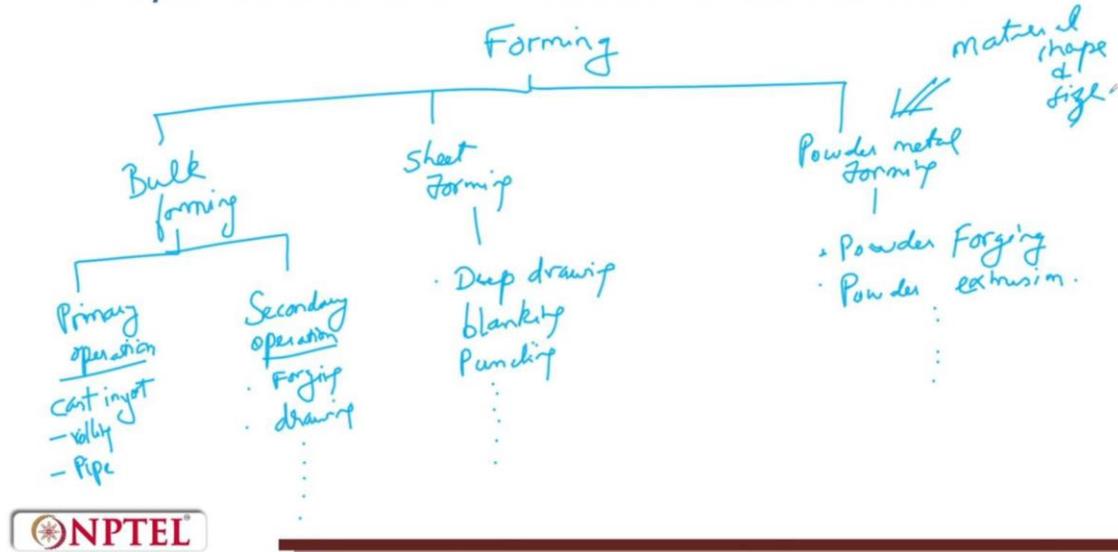


When we look at the shaping process, as I told you, I gave you an example of chapati. The chapati, you make a ball, and then you split the ball and flatten it through a bale or a roller. So, you can see there, the volume is constant, but the shape and size are changed. So here, in material shaping deformation manufacturing, In shape deformation manufacturing, the shape of the raw material is deformed by applying compressive force, tensile force, or shear force beyond the elastic limits.

I hope you remember in the first series, we presented a stress-strain graph for each of the materials, and we talked about the elastic region and plastic region. So, it has to cross the elastic limit. The material plastically deforms due to the action of shear stress induced in the material. So, this process is called forming. If it happens for a metal, it is called the metal forming process.

There are several examples of metal forming processes. They are nothing but bending of a pipe, then rolling of a sheet, drawing of a wire, deep drawing of a cup or a tumbler, which you use for drinking water, a deep-drawn cup. So, these are some of the processes which fall under Material Shaping Deformation Manufacturing.

Shape Deformation Process Classification



So, the classifications under shape deformation manufacturing process are: you can have forming. This forming can be bulk forming, this can be sheet forming, and this can be powder metal forming.

Here, in bulk forming, we will have primary operations and we can have secondary operations. In sheet metal, we can have, we will write down the processes exactly: deep drawing, blanking, punching; these are some of the processes. We have many more processes. In primary operations, you have cast ingots, such as rolling, pipe manufacturing, etc.

Secondary operations are forging, next is drawing, and many more, etc. So, when you go to powder, it is powder forging, it is powder extrusion, etc. Right? So, if you look at it, the bulk forming, sheet forming, these are basically talking about the material, shape, and size. If the volume is large and the area is small, it becomes bulk. If the surface area is large and the volume is less or the width or the thickness is less, then it forms under sheet. So, if you take various shape deformation processes, they are classified as the following.

Material Subtraction Manufacturing



- In materials subtraction techniques, the materials are removed from the raw material in the form of chips, powders, etc.
- The material is removed by rotating cutter, single/multi-point cutting tool, evaporation, chemical reaction, etc.
- Some examples are
 - Milling
 - Drilling
 - Honing
 - Facing
 - Turning, etc.



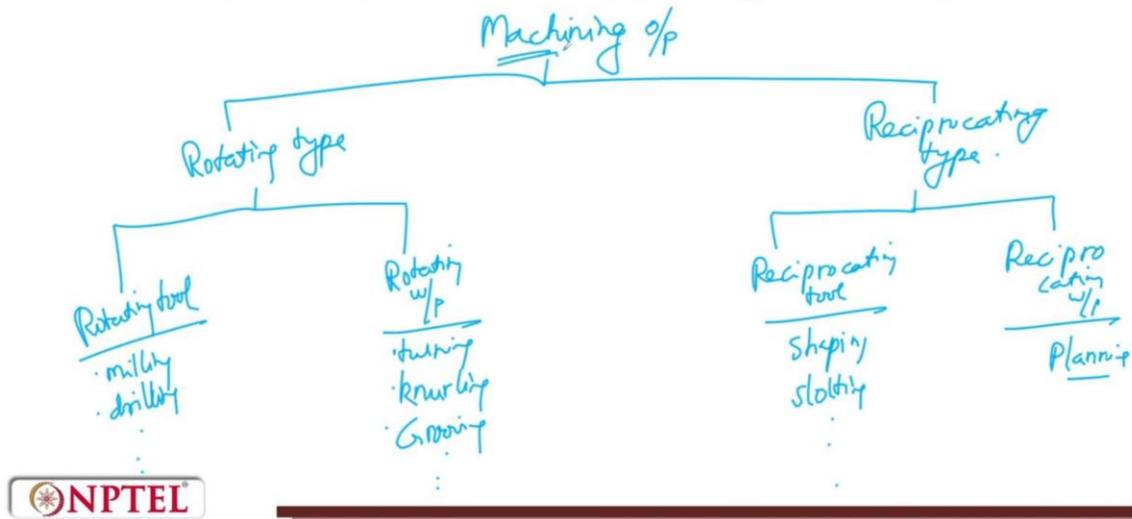
<https://giphy.com/explore/cnc-milling> 12

Then, let us look into the subtractive process. In the subtractive process, the material is removed from the starting material. In the material subtraction technique, the materials are removed from the raw material in the form of chips or powder. The workpiece can be rotated, or the tool can be stationary.

The workpiece can be rotated. It is basically the relative motion between the two that plays a very important role. And in the tool, we can have a single-point or a multiple-point cutting tool to remove material. And apart from this, you can also have a laser that, when it hits a surface, evaporates the material, or you can chemically etch and remove the material. So, all these processes are material subtraction manufacturing processes.

The names given are milling; which is a multi-point cutting tool process, drilling; which is a two-point cutting tool process, facing; which uses a single-point cutting tool to make a flat surface, and turning; which reduces the diameter using a single-point cutting tool. So, all these things are different manufacturing processes.

Material Subtraction Manufacturing Classification



When we talk about material subtraction manufacturing processes, you will have machining. This is a machining operation. So, this is the rotating type, and this one is the reciprocating type.

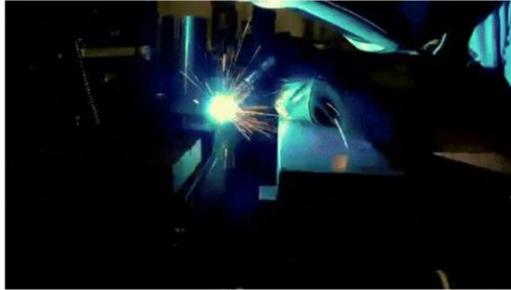
In the rotating type, you have two things. One is the rotating tool. The other one is the rotating workpiece. In reciprocating, you can have a reciprocating tool and a reciprocating workpiece. Okay. The processes are milling, drilling, etc.

Rotating workpiece, turning, knurling, grooving, etc. When we talk about reciprocating, we talk about shaping and slotting, etc. In reciprocating tools, we talk about planing. Here, if you look into it, depending upon the mechanism, like depending upon the relative motion, rotary type or reciprocating type, you classify the machining process or machining operation.

Material Joining Manufacturing



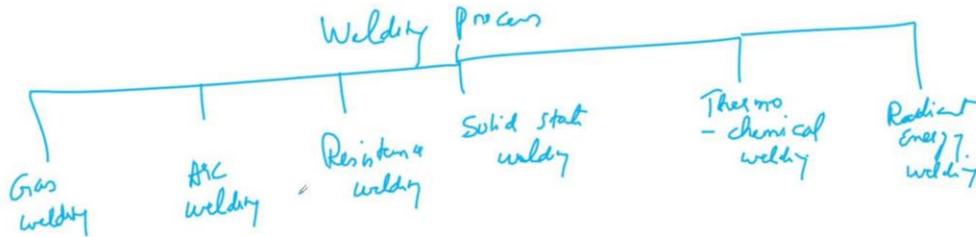
- In materials joining process, the two similar or dissimilar materials are joined with or without filler materials.
- The material is joined by in such a way that it may or may not destroyed the base materials.
- Some examples are
 - Arc Welding
 - Gas welding
 - Soldering
 - Brazing
 - Friction Welding, etc.



Next is joining. So, in material joining processes, there can be a joining between two similar materials or dissimilar materials. They can join without a filler or with a filler. That means to say a filler can be deposited, and two pieces can be joined. A filler can be deposited, or this is A, B, or you can join A and B directly without a filler. The material is joined in such a way that they may or may not destroy the base material.

There are several processes, some of which are listed here: arc welding, gas welding, soldering, brazing, and friction welding. These are some of the processes. So, where there is a high temperature used, then two base materials are joined. If they cannot join, we melt a filler and then join. So, these are some of the material joining processes.

Material Joining Manufacturing Classification

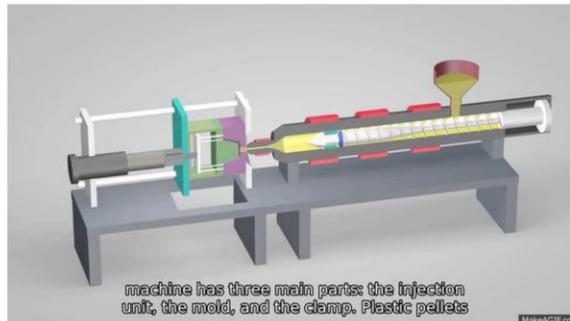


So, if you want to look at their classification, we have welding processes. Gas welding, arc welding, resistance welding, solid-state welding, then we have thermo-chemical welding, and then we have radiant energy welding. These are the different types of welding processes. So, we will see them when we go through the course.

We will try to see many of them and understand the process parameters, their advantages, difficulties, and all those things.

Polymer Moulding Manufacturing

- In this manufacturing process, the polymer materials in small granular/pellet form are heated in the injection barrels with heaters.
- After sufficient heating, the pellets/ granular are converted in to molten state.
- This molten form of the materials are flow in the mould cavity so that material is solidify in the mould.
- Some examples are
 - Injection Moulding
 - Blow Moulding, etc

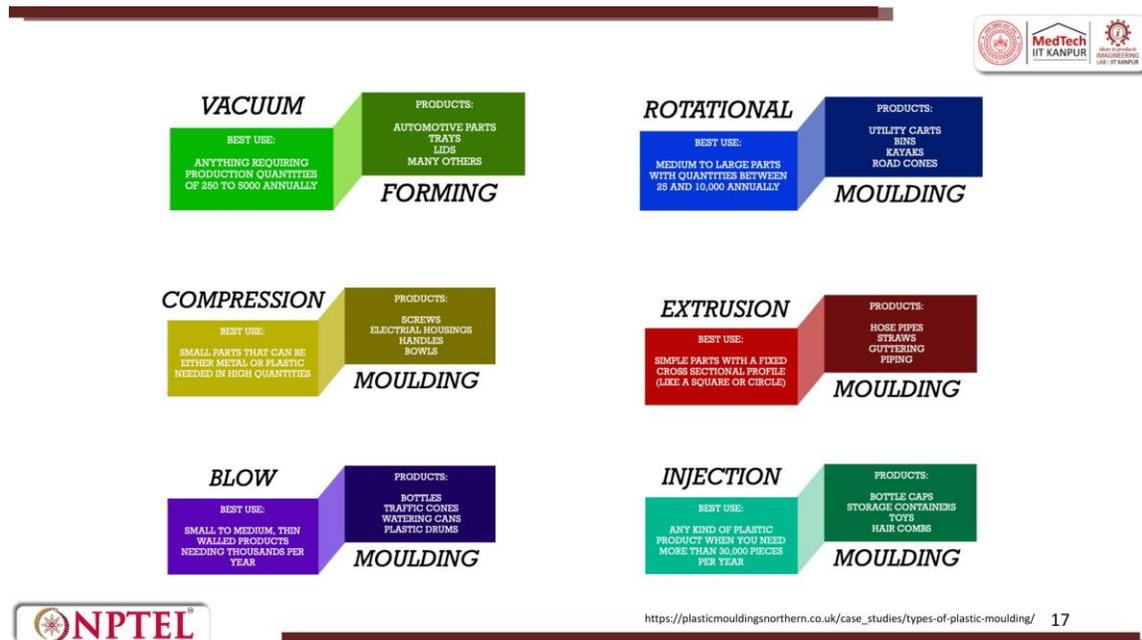


The next one is polymer-based. Polymer-based is the polymer molding process. Here, we have demonstrated an injection molding process. There are polymer pellets.

It can be in a solid or powder form. It is passed through a barrel where there is three-stage heating. So the polymer, when it passes through these heaters, will get converted from a solid state to a semi-solid state, and then, because of the screw which is moving inward, the polymer is pressurized and injected into the mold to get the required feature. In this kind of manufacturing process, this is the mold. So here, what you see is the mold.

So in this kind of manufacturing process, the polymer material, small granules, or pellets are put in a hopper and then moved forward through the barrel in the presence of a heater. It is moved inside. And then, the polymer comes here. It is injected. After sufficient heating, the pellets or granules are converted into a molten state.

And then, the molten form is injected into the mold. So there are several processes which fall under this. Two such processes which we have taken are injection molding. This process, which is displayed here, is injection molding.



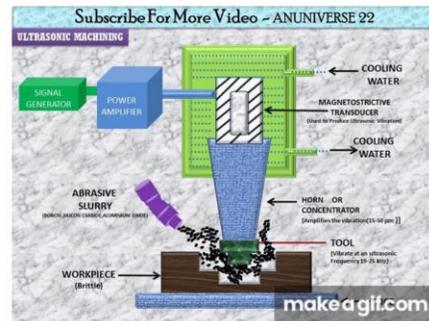
So when we try to look at classifications, we can have vacuum forming. Rotational molding, compression molding, extrusion molding, blow molding, and injection molding. These are some of the classifications of polymer processes. Vacuum forming means a vacuum is used to form a shape given on the polymer. Rotational molding means you put

the polymer into a cylinder, rotate it, and get an output. Compression is when you put it between two flat plates, the polymer melts, and then it is made into a shape.

Extrusion is like you push it through a die, extrude it, and get a wire form. Blow molding is when a bottle is made; the raw material is kept, and then air is blown to get the required output. Injection molding is the example which we saw till now.

Advanced Manufacturing Process

- In some applications where higher precision and accuracy are prime requirements advanced manufacturing processes are used
- These processes are also called unconventional manufacturing processes.
- These processes utilize high energy sources like frequency, intensity, power, etc to machine the object.
- These operation produces the highest quality of surface finishing with great accuracy.
- Some examples are
 - ECM
 - EDM
 - Ultrasonic Machine, etc

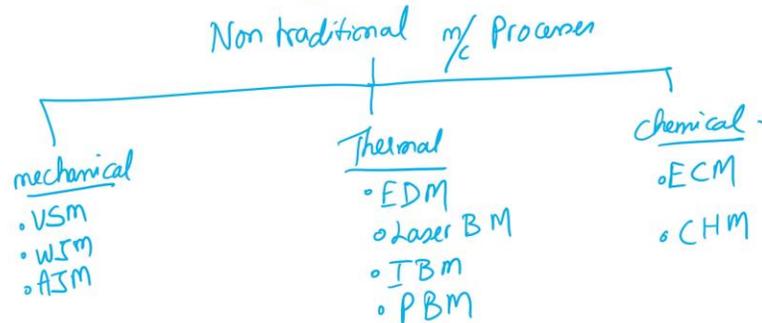


The advanced manufacturing process. In some applications where high precision and accuracy are primarily required, advanced manufacturing processes also come into existence.

In Advanced Manufacturing Processes, we also call them unconventional machining processes. Here we use a high-energy source. It can be ultrasonic vibration, it can be light heating a source, and then it can be a chemical used for machining, or between two electrodes, there can be a spark happening. So, in all these processes, the tool is no way harder than the workpiece. In normal conventional processes, the tool should be harder than the workpiece.

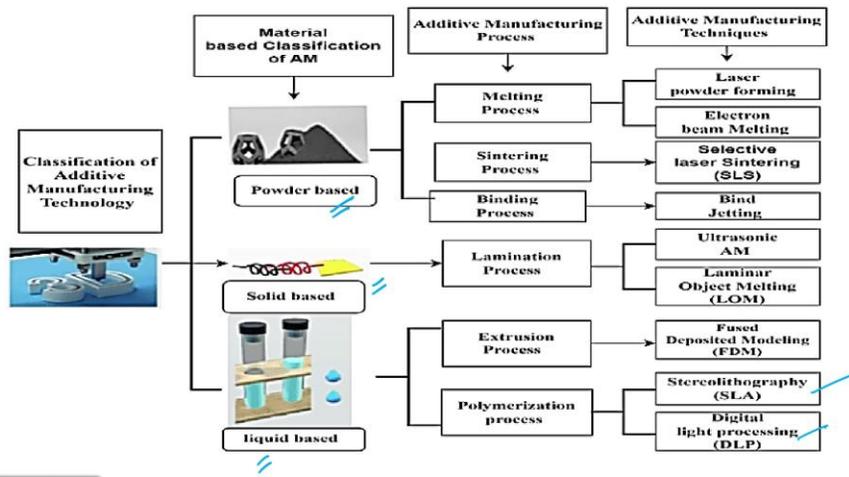
So, in advanced manufacturing processes, some examples are electrochemical machining, electric discharge machining, and ultrasonic machining.

Advanced Manufacturing Process Classification



So, we can focus on this. So, non-traditional machining processes, here you can have mechanical-based, thermal-based, and chemical-based processes. In mechanical, you have USM. These are the processes. You will see them in detail: Ultrasonic Machining process, Water Jet Machining process, Abrasive Jet Machining process. In thermal, you can see EDM, Ion Beam Machining process, Laser Beam Machining process, and Photon Beam Machining. In chemical, we have Electro-Chemical Machining and Chemical Machining. So, these are some of the classifications in Advanced Manufacturing Processes.

Material Addition Manufacturing



https://www.researchgate.net/figure/Classification-of-AM-techniques-supported-the-sort-of-base-materials-used_fig1_381737440

The last process is Material Addition Manufacturing. So, here it predominantly talks about Additive Manufacturing. So, here the starting material can be powder-based, solid-based, or liquid-based. When there is a powder base, we will use melt processing, sintering, or binding processes to convert the powder form into a finished product in the presence of an energy source.

So, a laser power can be used, an electron beam can be used, or binder jetting can be used. When we take a solid as a base, you can try to have a laminated process. So, you can have ultrasonic additive lamination or laminated object molding. So, when we are talking about the extrusion process, if it is in wire form, it is a fused deposition process. If it is in liquid form, it is a polymerization process, SLA, and DLP.

Material Addition Manufacturing

- In material addition manufacturing, the material is added layer by layer arrangement where the CAD model generated through modelling software is sliced into layers by slicing the software's
- The slicing files (STL) are ready to print with 3D printing machines.
- Refer to the NPTEL courses “Rapid Manufacturing”, and “Metal Additive Manufacturing” for more details.



So, what are the different steps involved in the Material Addition process? In Material Addition Manufacturing, the material is added layer by layer, wherein the data of the layer is captured from a CAD model generated through solid modeling software. So, the steps involved are: you design an object, then you slice and create an STL file, then you print them layer by layer using a machine or an energy source, then you do post-processing to get the shape of the product you want. So, these are the classifications of the Material Additive Manufacturing process.

To Recapitulate



- What is the Manufacturing?
- Applications of manufacturing.
- What are the type of Manufacturing?
- What are the Metal addition, Subtraction, Constant volume, metal joining etc?
- What are the different classification of manufacturing process.?



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To recap what we have studied till now, we have understood what manufacturing is, the excellence of manufacturing, the application of manufacturing, what the six different types of manufacturing are, and in each of them, what the major classifications are.

We will try to study in-depth during the course. But before getting into different kinds of manufacturing processes, first, let us have a small understanding of material and then jump into manufacturing processes.

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These are the reference materials we have used.

Thank you very much.