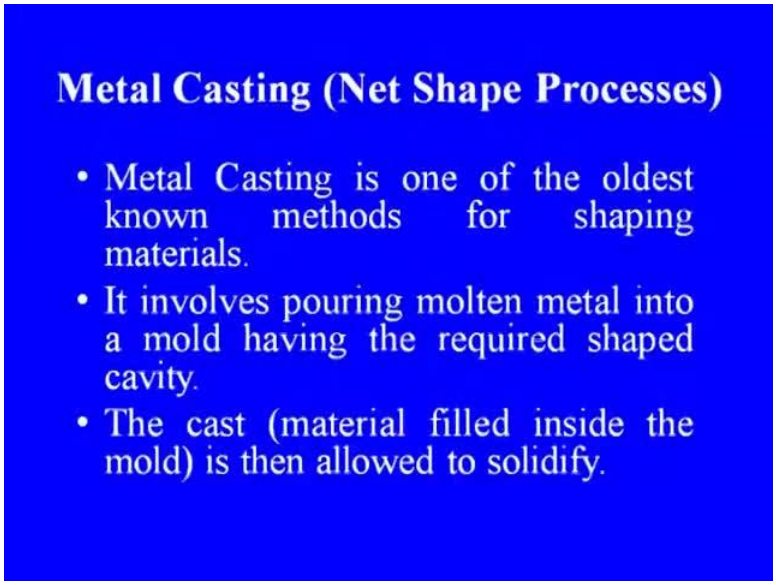
Advanced Manufacturing Processes
Prof. Apurbba Kumar Sharma
Department of Medical and Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 1
Introduction
Lecture - 4
Description and Taxonomy of the Mfg. Processes

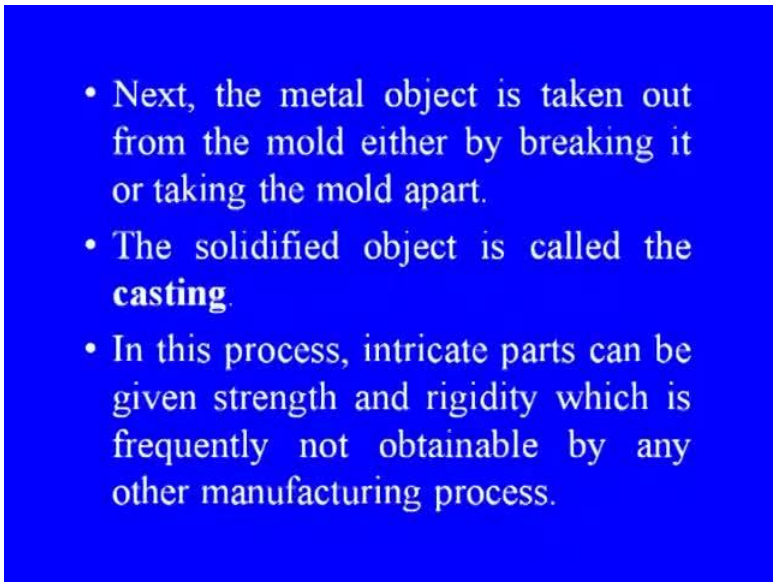
Dear students, in this session we will discuss briefly the most widely used manufacturing processes. First the metal casting which is also called neon net shape process.

(Refer Slide Time: 00:50)



Metal casting is one of the oldest known methods for shaping materials. It involves pouring molten metal into a mold having the required shaped cavity. The cast also called material filled inside the mold is then allowed to solidify.

(Refer Slide Time: 01:23)

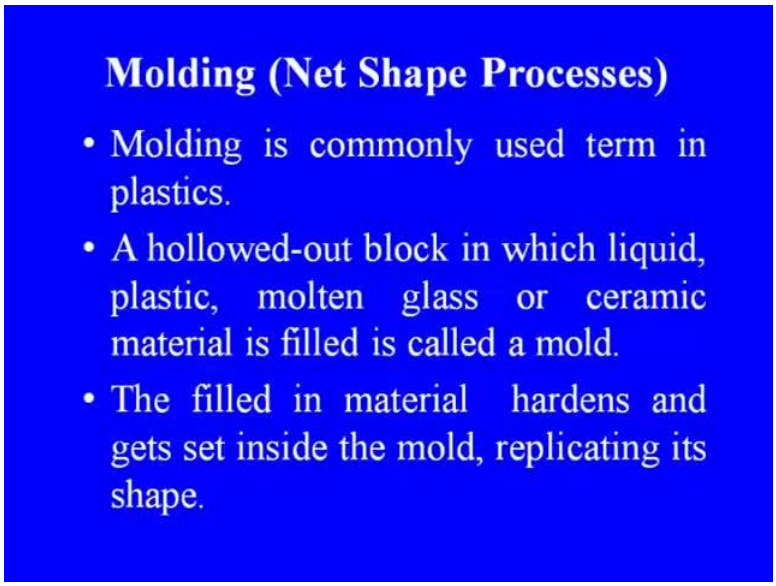


Next, the metal object is taken out from the mold either by breaking it or taking the mold apart. The solidified object is called the casting, in this process intricate parts can be given strength and rigidity which is frequently not obtainable by any other manufacturing process.

(Refer Slide Time: 02:06)

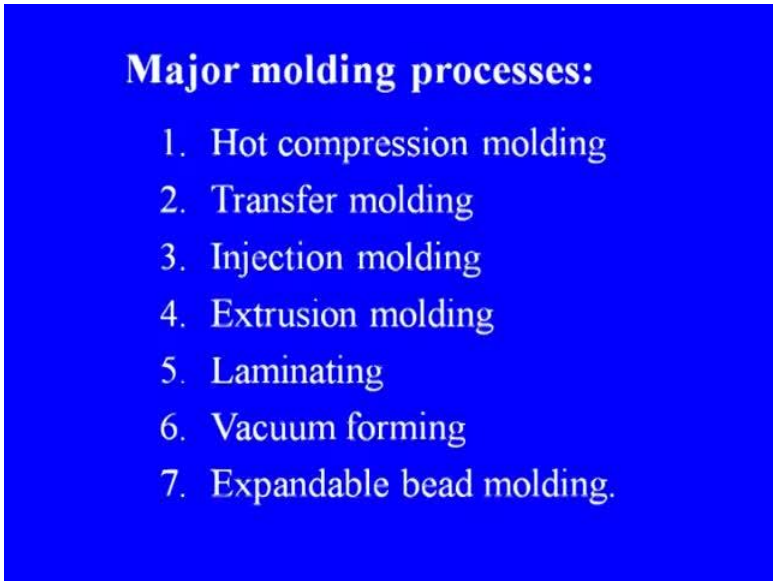
Major casting processes are sand casting, permanent mold casting, continuous casting, die casting, slush casting, centrifugal casting, evaporative-pattern casting, lost wax casting, shell molding, vacuum sealed molding, etcetera.

(Refer Slide Time: 02:48)



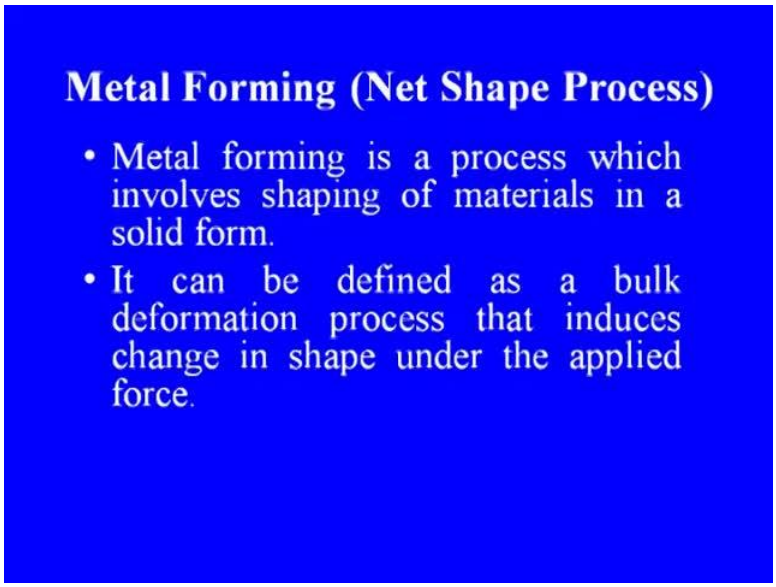
Molding, molding is commonly used term in plastics which is also a net shape process. A hollowed out block in which liquid, plastic, molten glass or ceramic material is filled is called a mold. The filled in material hardens and gets set inside the mold, replicating its shape, in order to remove the hardened substance a release assent is also used there are several molding processes. The major molding processes will be briefly introduced now.

(Refer Slide Time: 03:42)



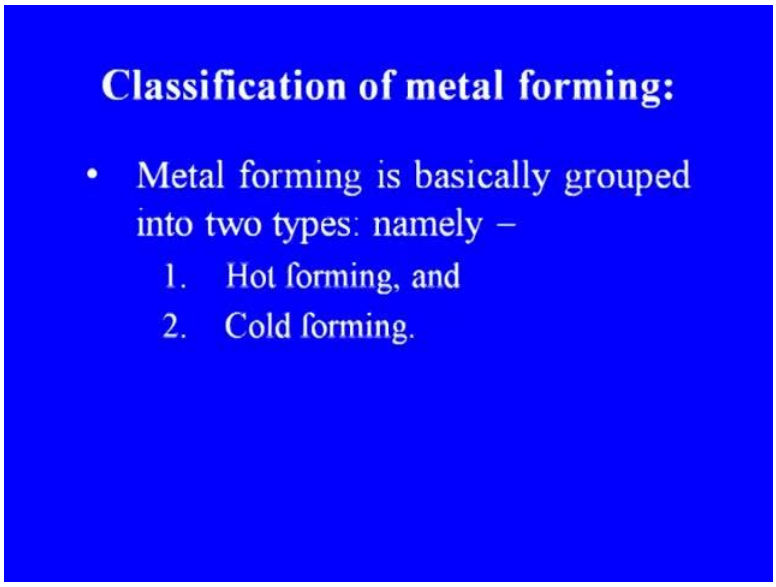
Hot compression molding, transfer molding, injection molding, extrusion molding, laminating, vacuum forming, expandable bead molding, then comes to metal forming, which is also a net shape process.

(Refer Slide Time: 04:15)



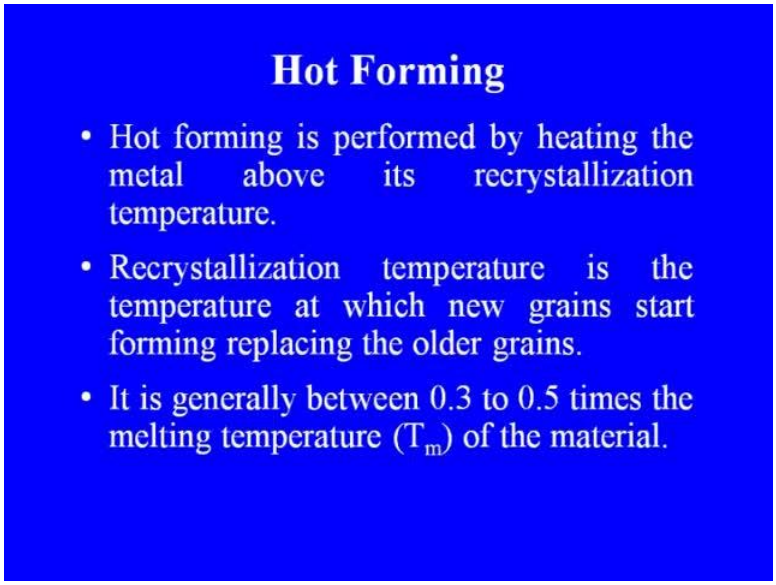
Metal forming is a process which involves shaping of materials in a solid form. It can be defined as a bulk deformation process that induces change in shape under the applied force.

(Refer Slide Time: 04:55)



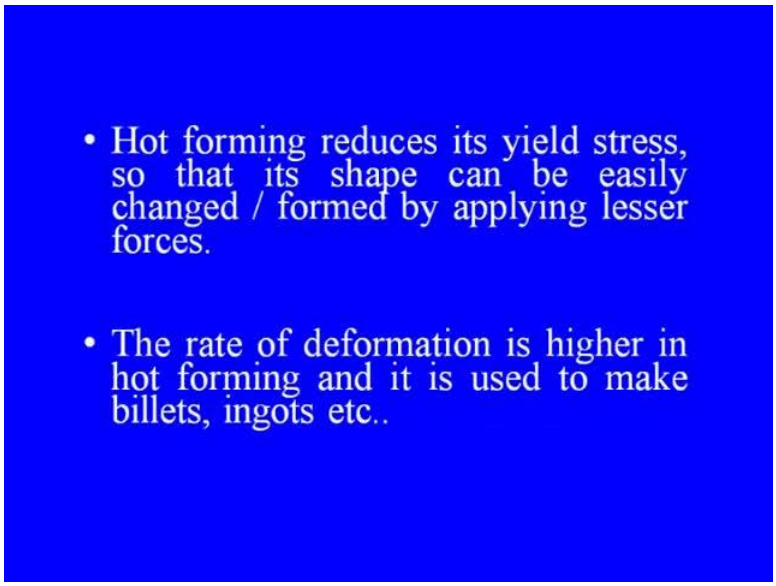
Classification of metal forming processes. Metal forming is basically grouped into two types namely hot forming and cold forming.

(Refer Slide Time: 05:07)



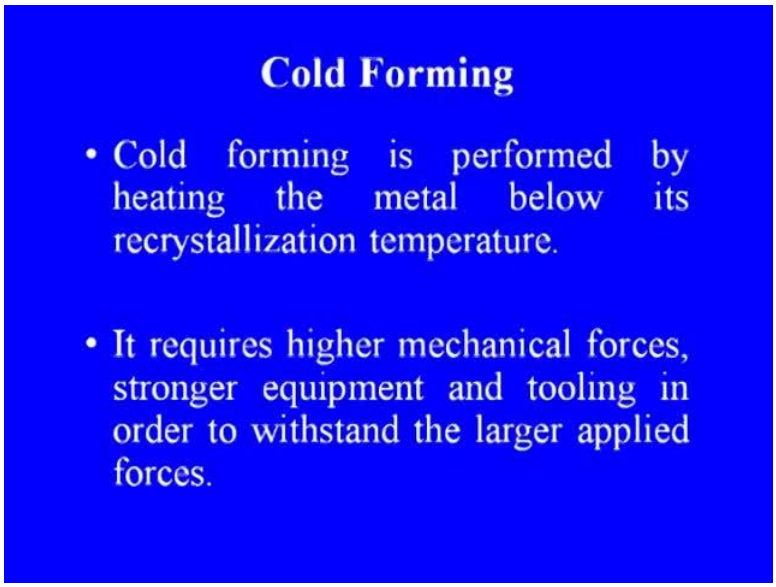
Hot forming is the process, which is performed by heating the metal above its re-crystallization temperature. The re-crystallization temperature is the temperature at which new grains start forming, replacing the older grains, it is generally between 0.3 to 0.5 times the melting temperature of any material.

(Refer Slide Time: 06:01)



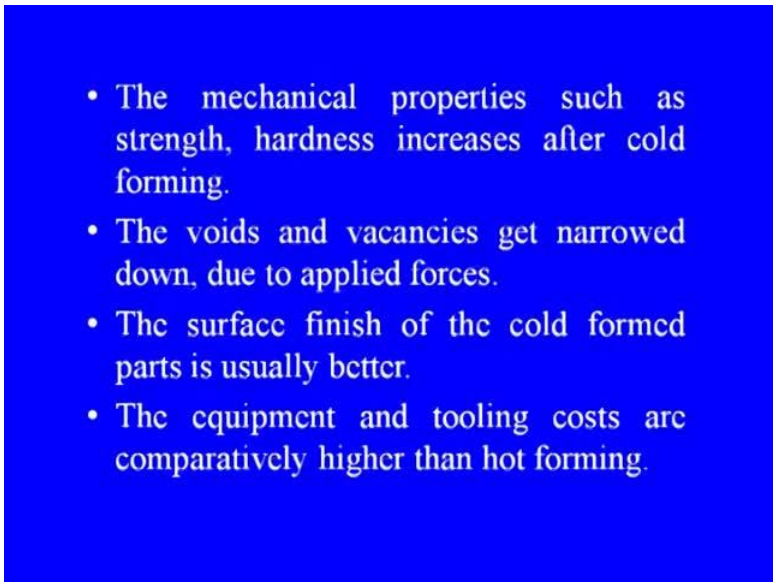
Hot forming reduces the materials yield stress, so that its shape can be easily changed or formed by applying lesser forces. The rate deformation is higher in hot forming and it is used to make billets, ingots, etcetera.

(Refer Slide Time: 06:32)



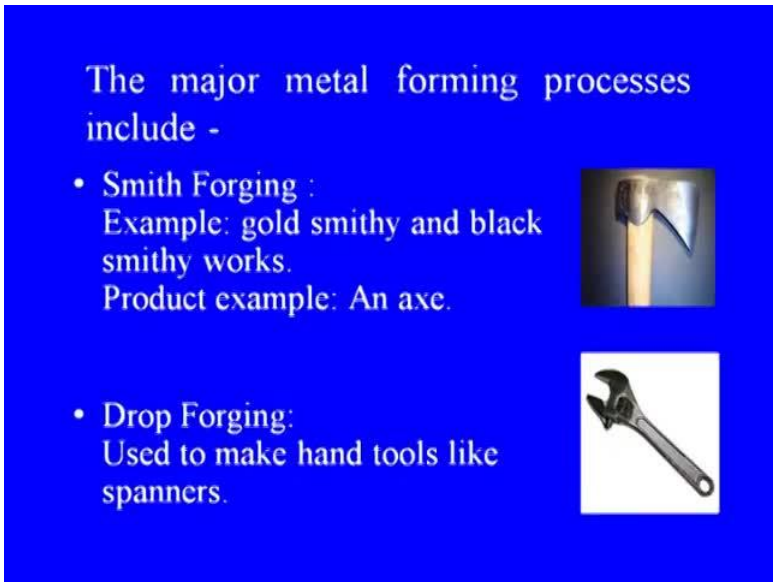
Cold forming, cold forming is performed by heating the metal below its re-crystallization temperature. It requires higher mechanical forces, stronger equipment and tooling in order to withstand the larger applied forces.

(Refer Slide Time: 07:02)



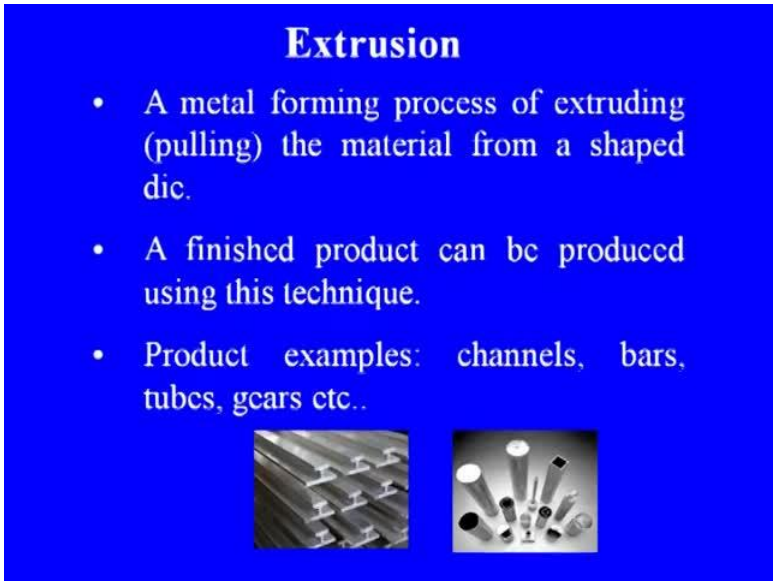
The mechanical properties such as strength, hardness etcetera increases after cold forming. The voids and vacancies get narrowed due to applied forces. The surface finish of the cold formed parts is usually better. The equipment and tooling cost in cold working are comparatively higher than hot forming.

(Refer Slide Time: 07:44)



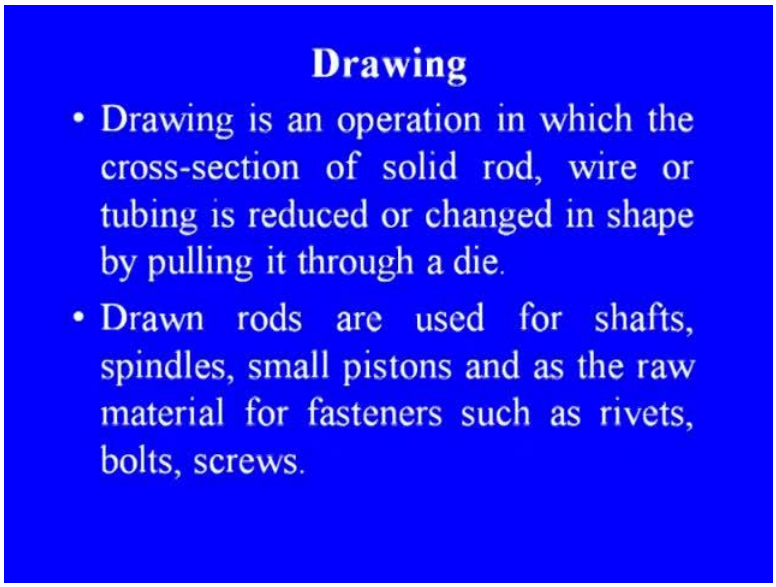
The major metal forming processes include Smith forging the example is gold smithy and black smithy works, and the product example can be an axe. Drop forging which is used to make hand tools like spanners.

(Refer Slide Time: 08:26)



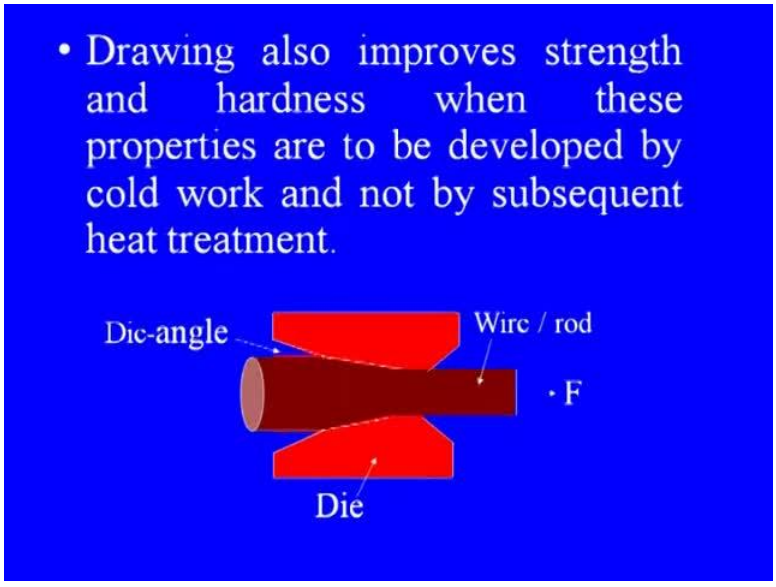
Next process is extrusion, it is a metal forming process of extruding the material from a shaped die. A finished product can be produced using this technique, the product examples include channels, bars, tubes, gears etcetera.

(Refer Slide Time: 08:52)



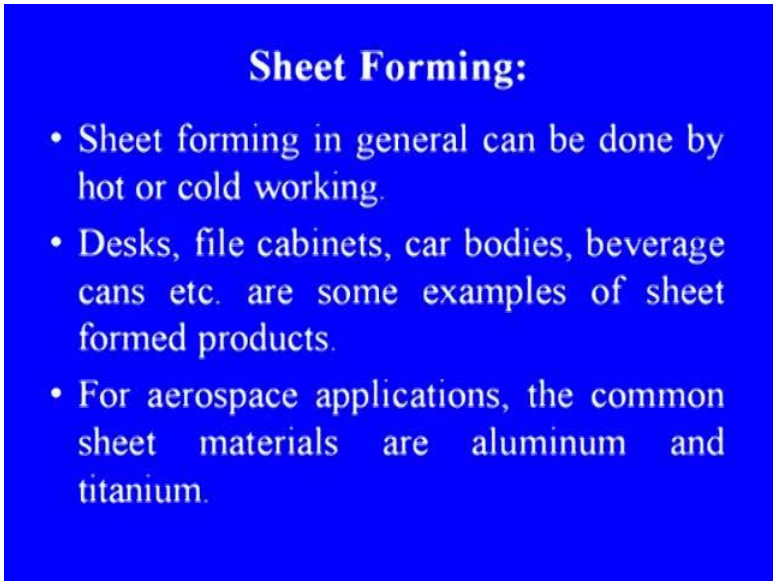
Drawing, drawing is an operation in which the cross section of solid rods, wire or tubing is reduced or changed in shape by pulling it through a die. Drawn rods are used for shafts spindles, small pistons and as the raw material for fasteners such as rivets, bolts and screws.

(Refer Slide Time: 09:53)



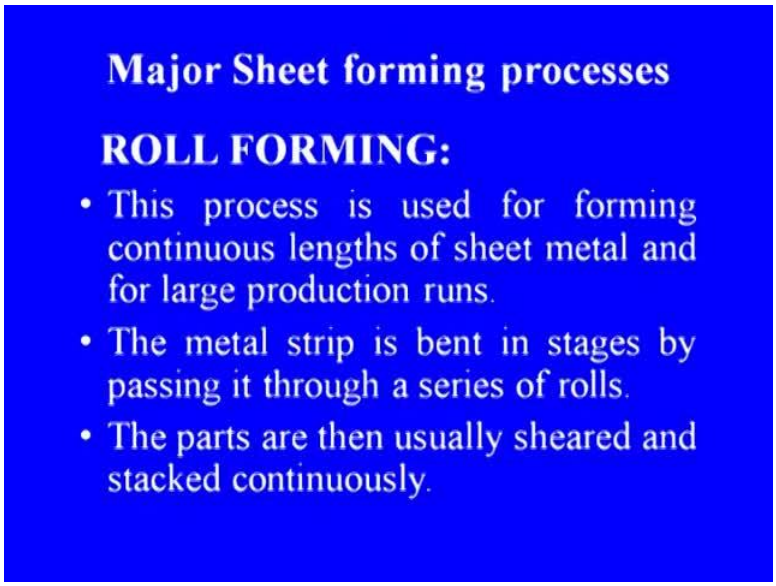
Drawing also improves strength and hardness, when these properties are to be developed by cold work and not by subsequent heat treatment. In this process a set of die is placed through which the material to be drawn or pulled through by applying certain force, this reduces the dimension of the input material and a wire or rod of different dimension is produced, this die angle forms a critical parameter in this process.

(Refer Slide Time: 10:47)



Sheet forming sheet forming in general can be done by hot or cold working. Desks, file cabinets, car bodies, beverage cans etcetera are some examples of sheet formed products. For aerospace applications, the common sheet materials are aluminum and titanium.

(Refer Slide Time: 11:32)



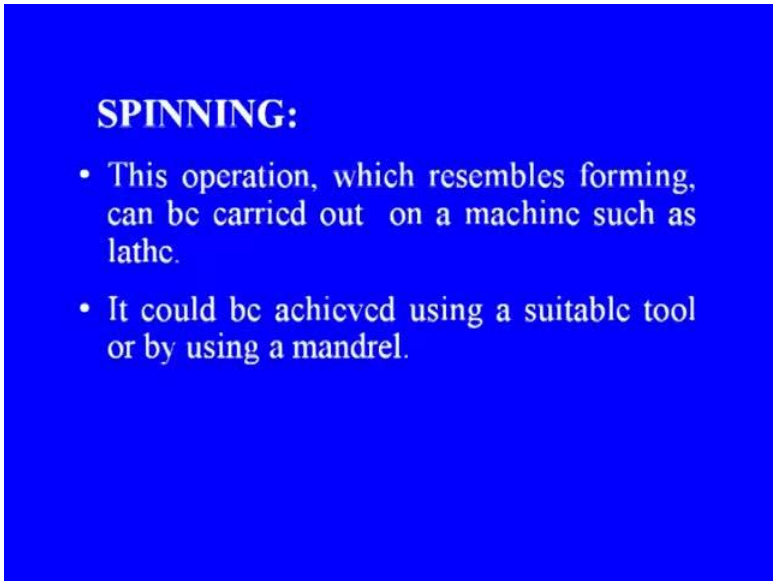
Major sheet forming processes. First Roll forming this process is used for forming continuous lengths of sheet metal and for large production runs. The metal strip is bent in stages by passing it through a series of rolls. The parts are then usually sheared and stacked continuously.

(Refer Slide Time: 12:13)

Stretch forming in this process, the sheet is clamped along its edges and hen stretched over a die or form block, which moves upward, downward, or sideways, depending on

the particular machine. Stretch forming is used primarily to make aircraft wing skin panels, automobile door panels, and window frames.

(Refer Slide Time: 12:58)

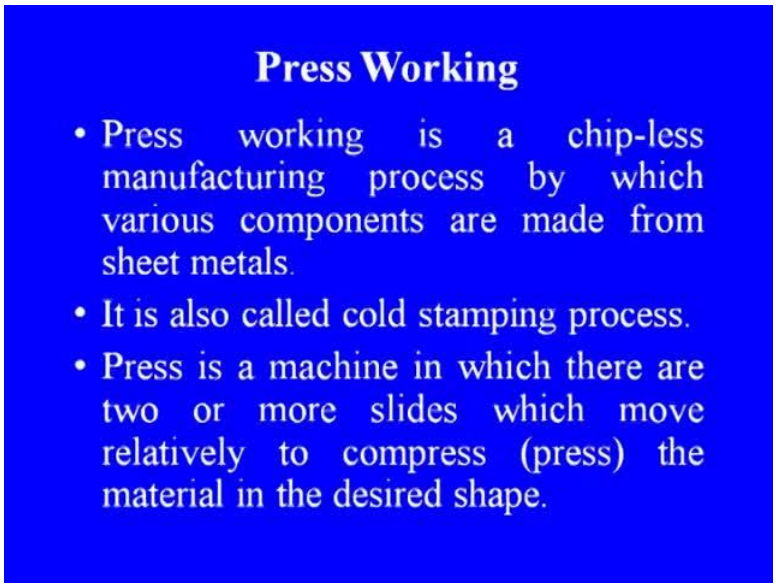


Next process is spinning this operation, which resembles forming, can be carried out on a machine such as lathe. It could be achieved using a suitable tool or by using a mandrel. Electro forming in this process electrical energy is used to execute large scale forming such as hydro forming.

(Refer Slide Time: 13:41)

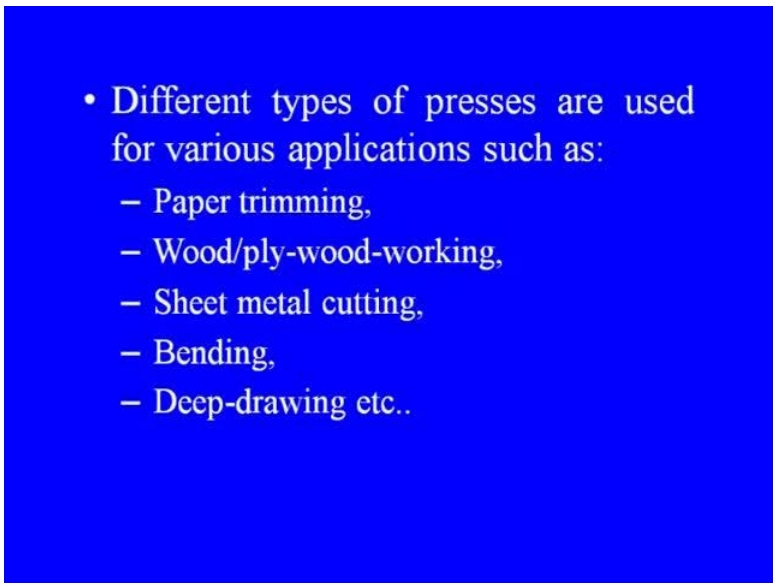
Explosive forming in explosive forming, controlled explosive reactions enable the forming in sheet metals and other metallic products, where the rate of deformation is high.

(Refer Slide Time: 14:11)



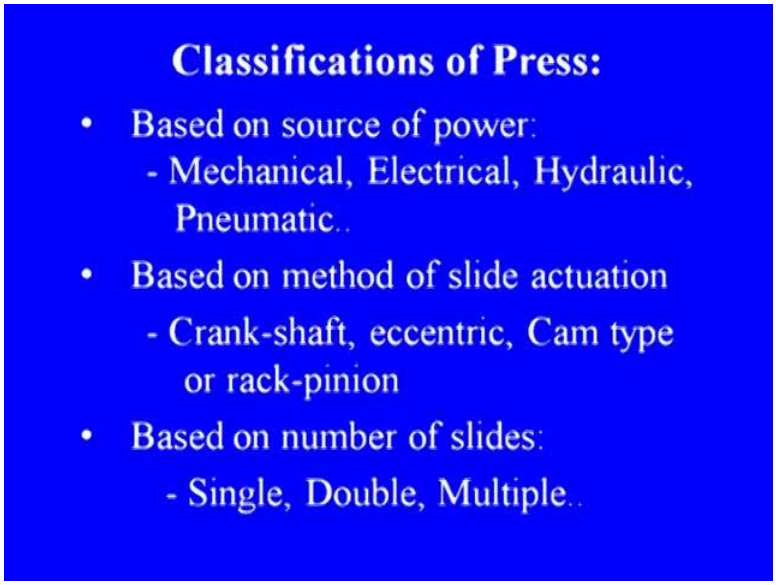
Press working, press working is a chip-less manufacturing process by which various components are made from sheet metals, it is also called cold stamping process. Press is a machine in which there are two or more slides, which move relatively to compress the material in the desired shape.

(Refer Slide Time: 14:55)



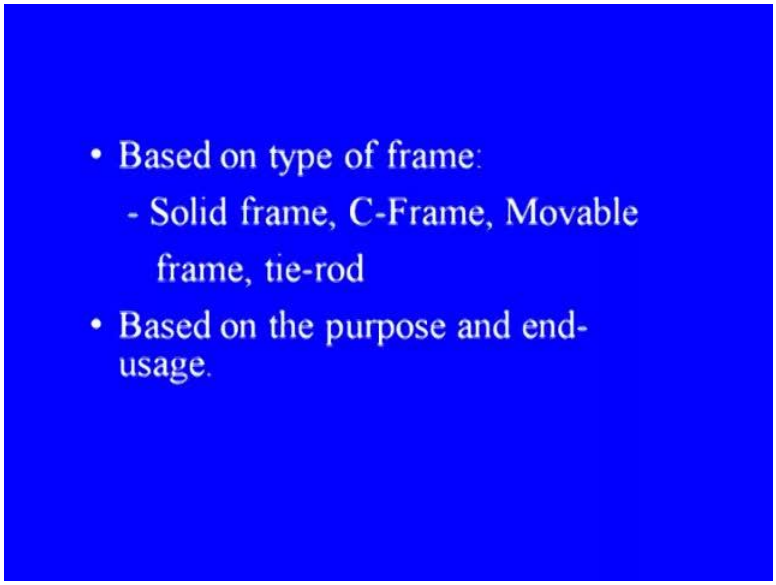
Different types of presses are used for various applications such as paper trimming, wood ply or wood working, sheet metal cutting, bending, deep-drawing etcetera.

(Refer Slide Time: 15:19)



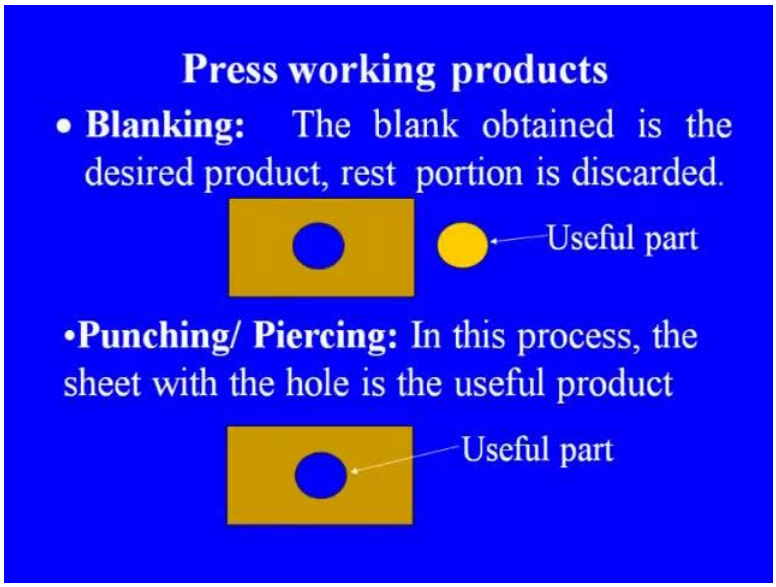
Then different types of presses are classified based on source of power for example, mechanical, electrical, hydraulic, pneumatic etcetera. Then can be also classified based on method of slide actuation for example, crank-shaft, eccentric, cam type or rack and pinion type. Presses can also be classified based on number of slides for example, single double, multiple.

(Refer Slide Time: 16:16)



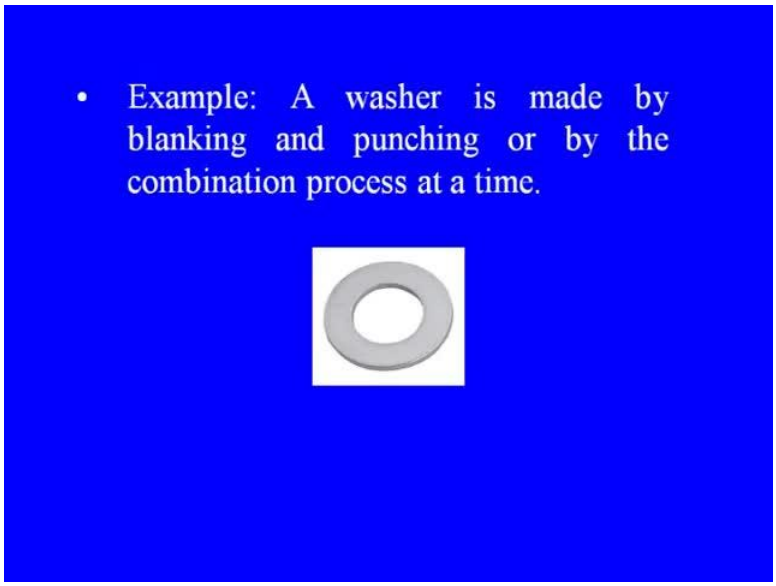
Then presses are also classified based on type of frame for example solid frame, C-Frame, movable frame, tie rod etcetera. They are also classified based on the purpose and end usage.

(Refer Slide Time: 16:48)



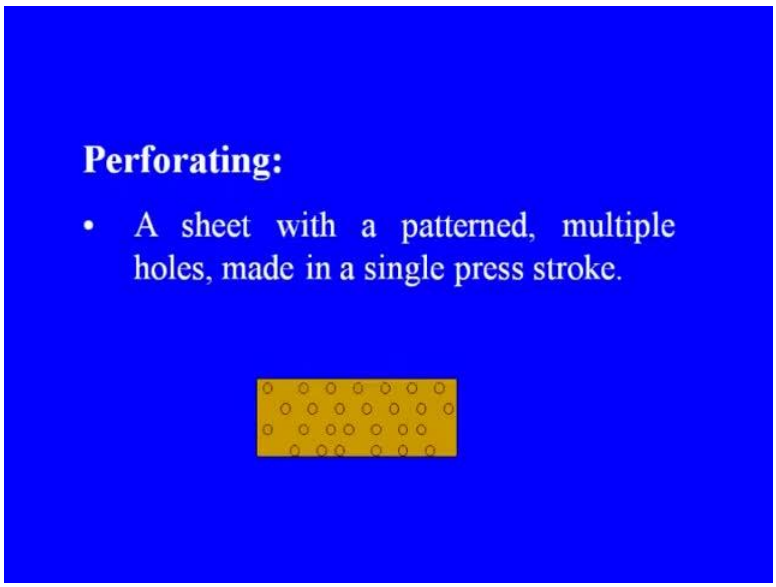
Then press working products blanking, blanking is an operation in which the blank obtained is the desired product, the rest portion is discarded. Here as showed in the figure the useful part of this entire sheet is the blank produced in contrast in piercing process, the sheet with the hole is considered as the useful product. The corresponding metallic part produce as result of producing this hole is now discarded, thus the sheet with the pierce hole becomes the useful part.

(Refer Slide Time: 17:55)



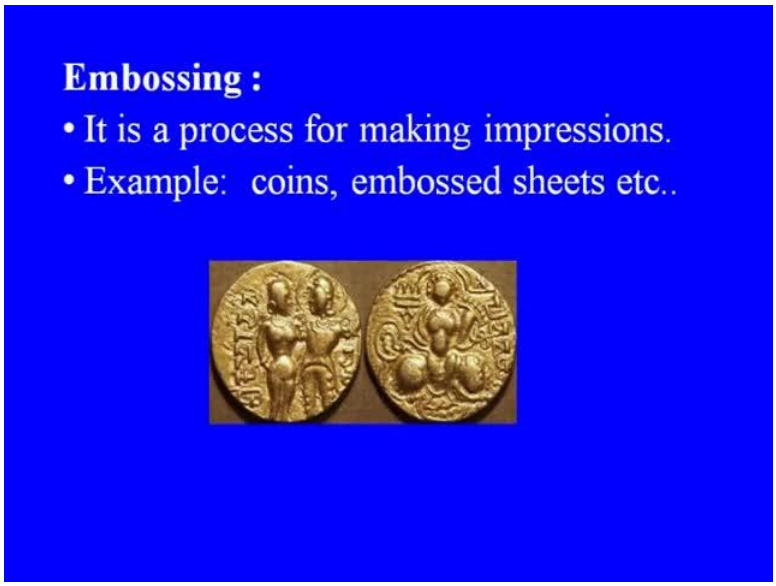
Example for this process is a washer is made by blanking and punching or by the combination of the processes at a time.

(Refer Slide Time: 18:17)



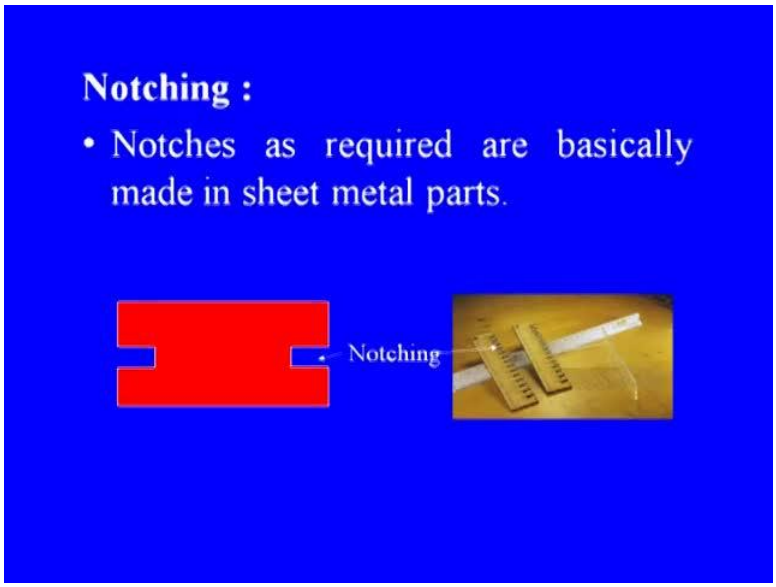
Perforating a sheet with a patterned, multiple holes, made in a single press stroke is as shown the sheet is perforated in a particular pattern.

(Refer Slide Time: 18:46)



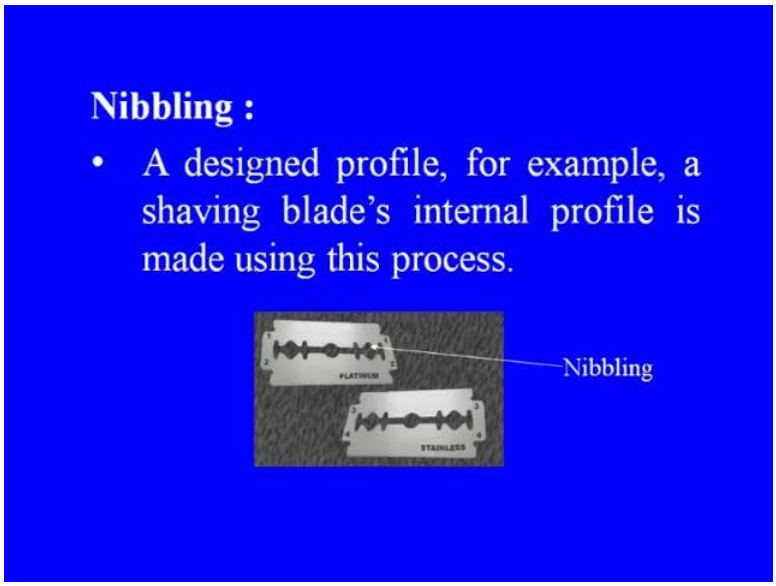
Next process is embossing, it is a process for making impressions. For example coins or embossed sheets. Bending this process is used for making bends in sheet metal rods, channels etcetera as per the requirement on a press.

(Refer Slide Time: 19:14)



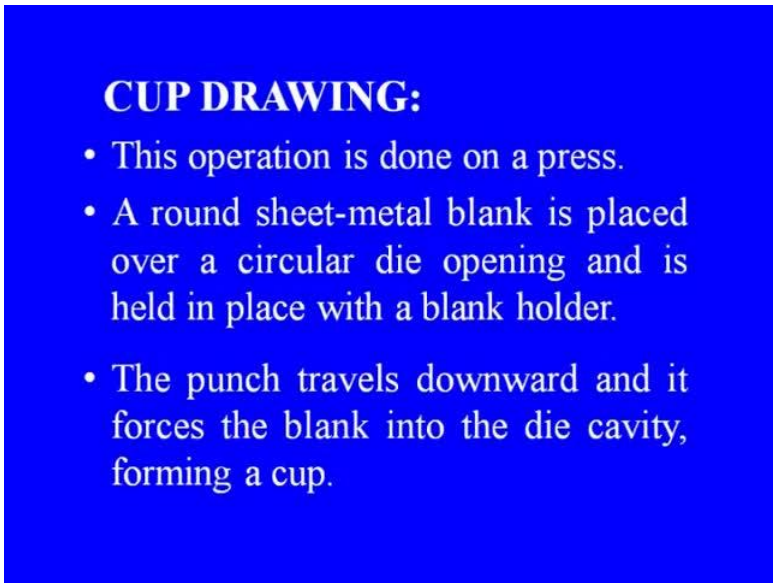
Notching, notches are made as required basically in a sheet metal. So, here this is the sheet metal in which notches of desired dimension are made.

(Refer Slide Time: 19:50)



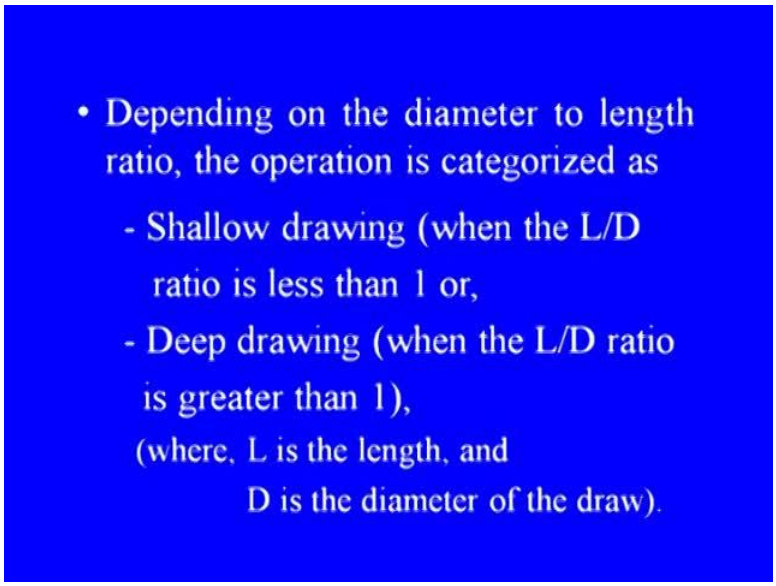
Another process is nibbling a designed profile, for example, a shaving blad's internal profile is made using this process. This profile is tiny at the same time bit complex, this is the process which is more suitable to carry out this manufacturing.

(Refer Slide Time: 20:29)



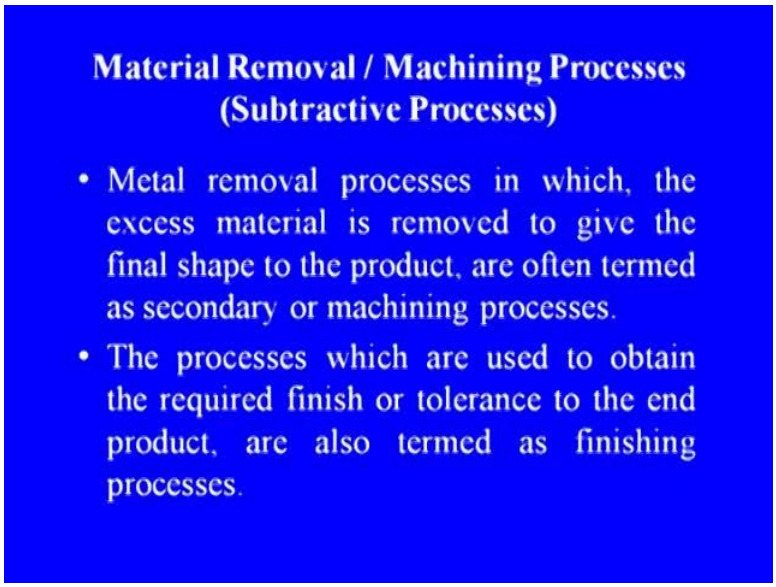
Cup drawing this operation is done on a press. A round sheet metal blank is placed over a circular die opening and held in place with a blank holder. The punch travels downward and it forces the blank into the die cavity, forming a cup.

(Refer Slide Time: 21:04)



Depending on the diameter to length ratio, the operation is categorized as shallow drawing, when the L by D ratio is less than 1 or deep drawing in which length to diameter ratio is greater than 1, where L is the length and D is the diameter of the draw.

(Refer Slide Time: 21:59)

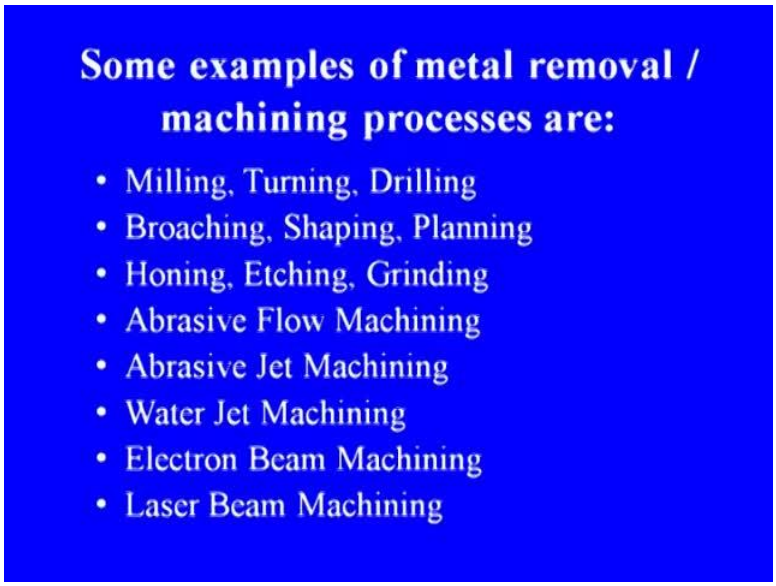


Let us move on to material removal processes also known as subtractive processes, or we call as machining processes. Material removal or machining processes are called subtractive processes, in this process the excess material is removed to give the final shape to the product, and are often termed as secondary or machining processes. The

processes which are used to obtain the required finish or tolerance to the end product are also termed as finishing processes.

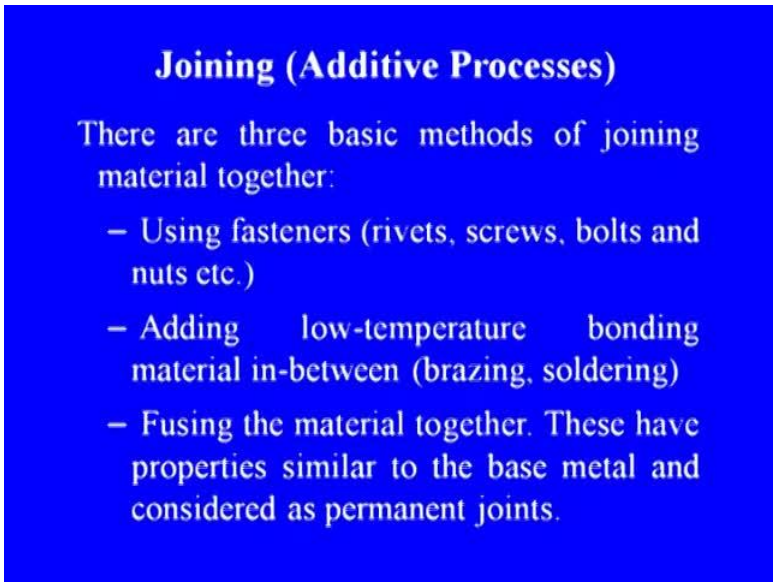
This means, that in both the cases that is in the removal of material or finishing of part the product to be cut or finished is made by some other processes described earlier at instances, if the product geometry is very complex, a combination of different processes are used to make, the final part.

(Refer Slide Time: 23:18)



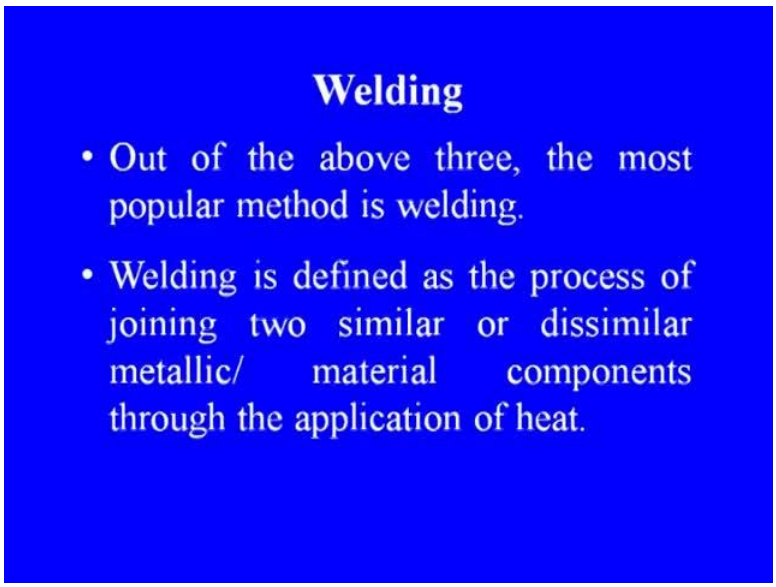
Some examples of metal removal or machining processes are milling, turning, drilling, broaching, shaping, planning, honing, etching, grinding, abrasive flow machining, abrasive jet machining, water jet machining, electron beam machining, laser beam machining etcetera. Let us move on to joining processes which are also called additive processes.

(Refer Slide Time: 24:04)



There are three basic methods of joining material together. Number 1 using fasteners like rivets, screws, bolts and nuts etcetera. Number 2 adding low temperature bonding material in between like in brazing and soldering, and number 3 fusing the material together. These have properties similar to the base metal and considered as permanent joints.

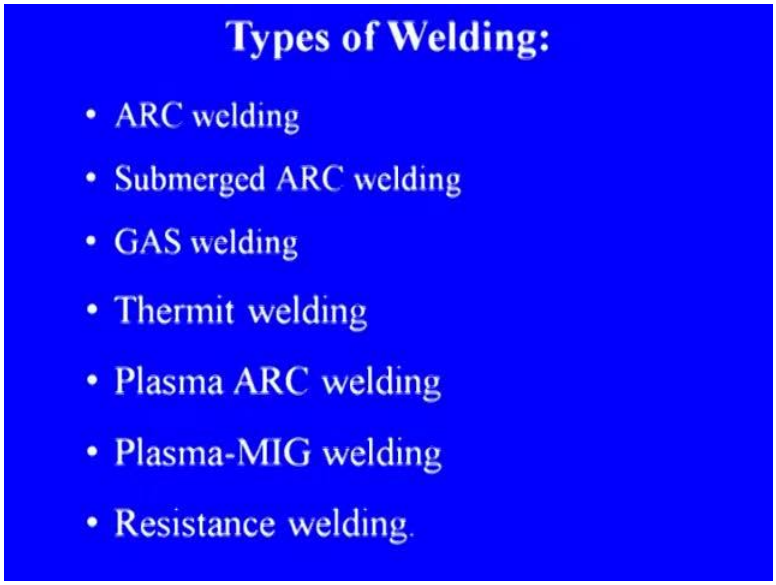
(Refer Slide Time: 25:08)



Welding out of the above three categories, the most popular method is welding in which materials are jointed permanently. Welding is defined as the process of joining two

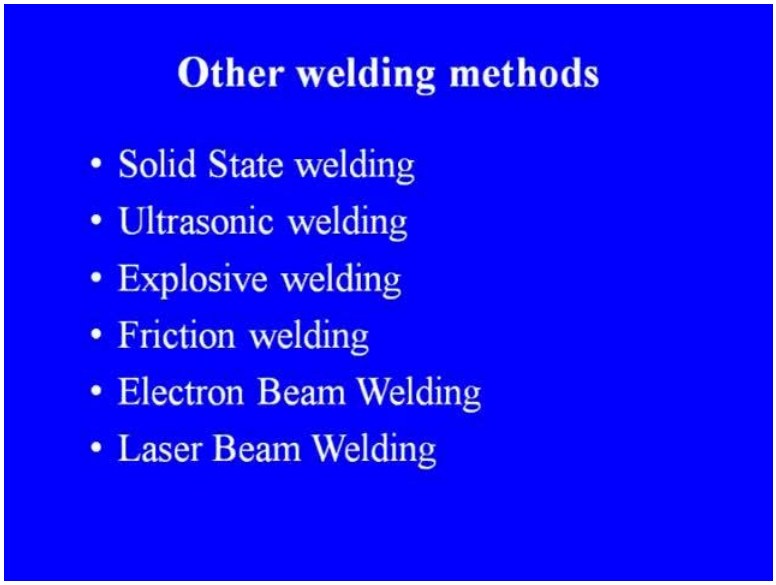
similar or dissimilar metallic or material components, through the application of heat. In welding filler material can be used and pressure may be applied as per the necessity.

(Refer Slide Time: 25:40)



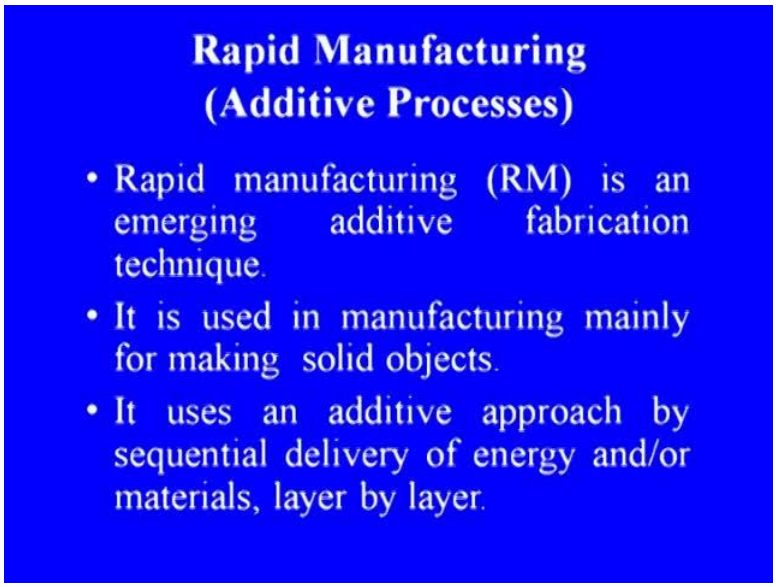
Different types of welding include ARC welding, submerged ARC welding, GAS welding, thermit welding, plasma ARC welding, plasma-MIG welding, resistance welding etcetera.

(Refer Slide Time: 26:07)



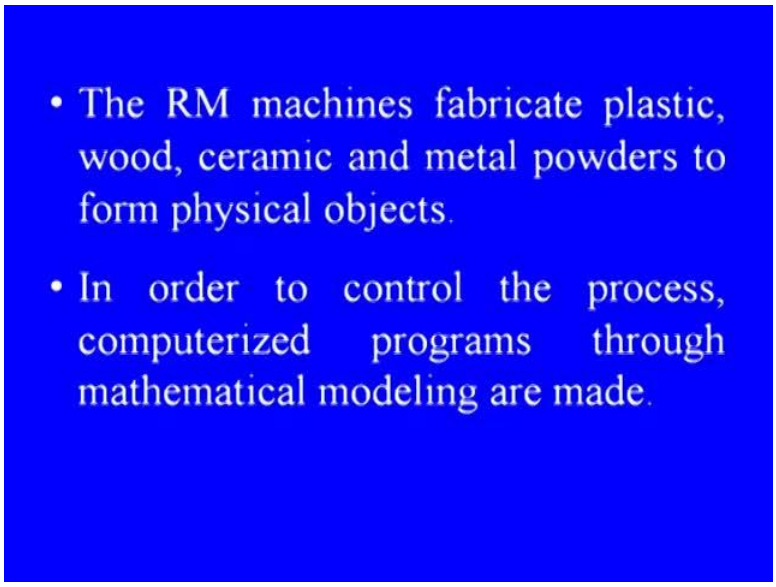
Other welding methods are solid state welding, ultrasonic welding, explosive welding, friction welding, electron beam welding, laser beam welding etcetera. Let us move on to rapid manufacturing, which is also additive process.

(Refer Slide Time: 26:36)



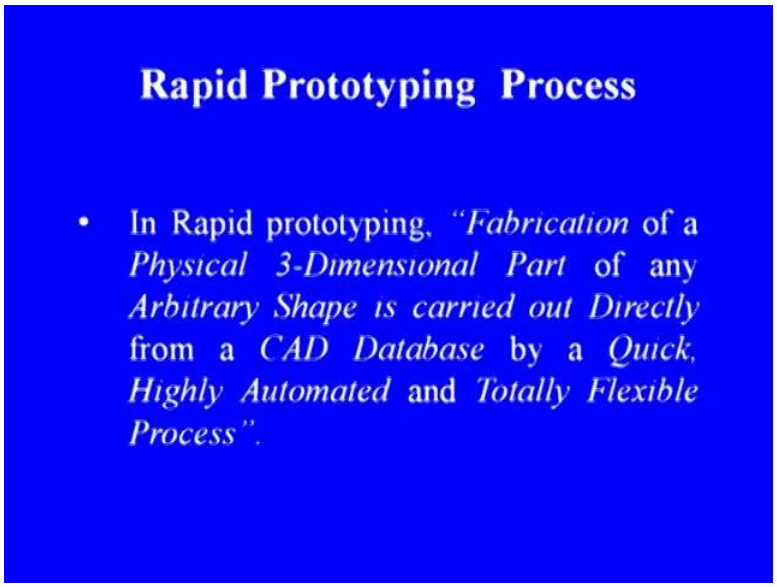
Rapid manufacturing is an emerging additive fabrication technique. It is used in manufacturing mainly for making solid objects. It uses an additive approach by sequential delivery of energy and or materials, layer by layer.

(Refer Slide Time: 27:09)



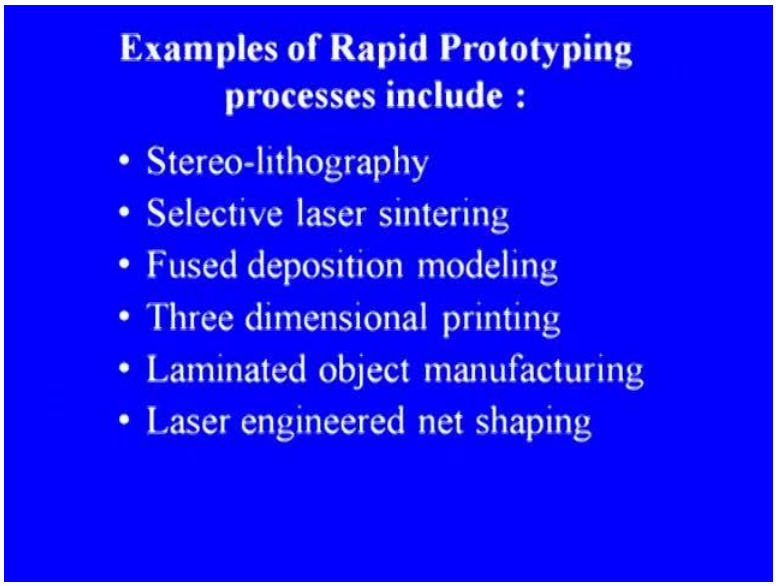
The rapid manufacturing machines fabricate plastic, wood, ceramic and metal powders to form physical objects. In order to control the process, computerized programs through mathematical modeling are made.

(Refer Slide Time: 27:42)



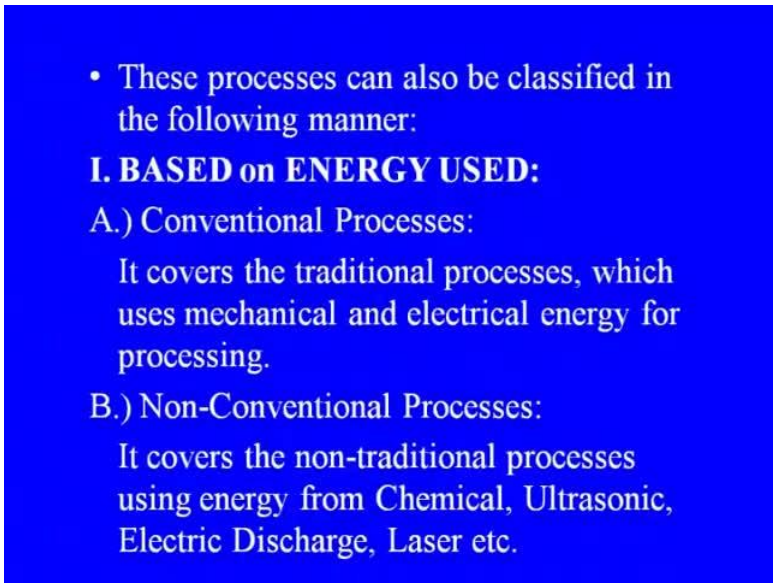
Rapid prototyping processes, in rapid prototyping fabrication of a physical 3-dimensional part of any arbitrary shape is carried out directly from a CAD database by a quick highly automated and totally flexible process. This is a relatively new material additive manufacturing process, in which a part is produced by depositing layers or by joining particles of raw materials.

(Refer Slide Time: 28:38)



Examples of rapid prototyping processes include stereo-lithography, selective laser sintering, fused deposition modeling, Three-dimensional printing, laminated object manufacturing, laser engineered net shaping etcetera.

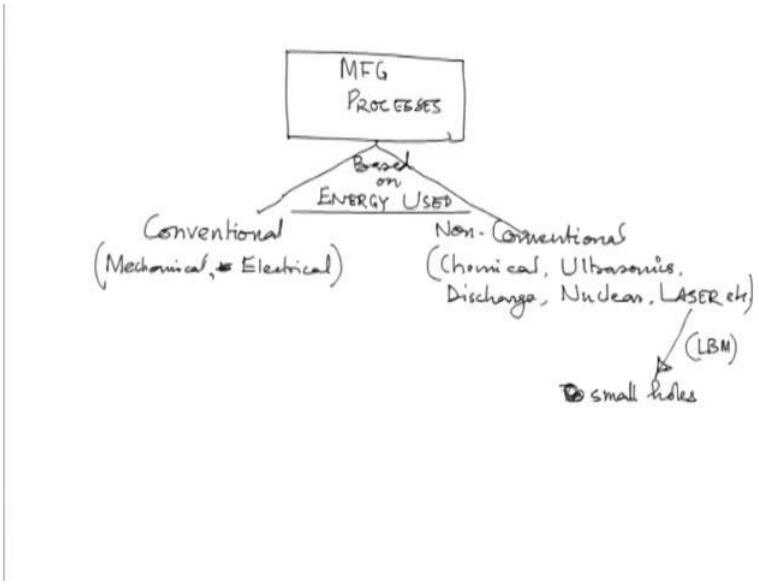
(Refer Slide Time: 29:08)



The manufacturing processes can also be classified in the following manner that is based on energy used. Based on energy used the processes can be divided like conventional processes and non conventional processes. In these conventional processes, mechanical and electrical energy are used for processing. However, in the non conventional

processes, the energy from chemical, ultrasonic, electrical discharge, laser etcetera are used. So, this can be like categorized something like this.

(Refer Slide Time: 29:55)

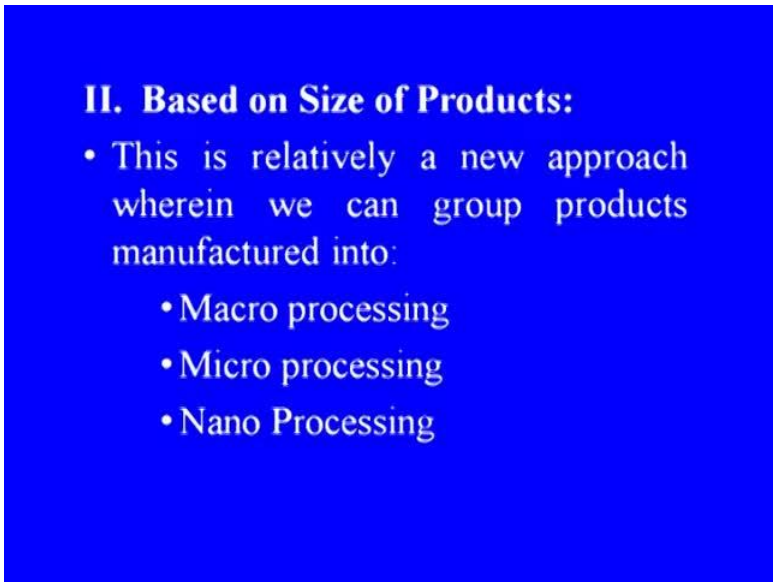


Another classification of manufacturing processes. So, this is conventional and this is non conventional. So, this is based on we can say energy used now, in this conventional basically the energy, form of energy used is mechanical and electrical, which are most common in almost all processing material, processing techniques. However, in this the non conventional methods so here something like chemical energy or the chemical processes, or it can be ultrasonic, ultrasonic or it can be discharge energy like is used in E D M etcetera or it can be nuclear energy or it can be like laser energy etcetera.

That means, the processes say for example, now a days laser machining is very popular. So, laser machining so for making to make small holes, small holes, small diameter holes this laser beam machining or also call L B M laser beam machining is very frequently used. So, this falls under the category of this, which is not a very conventional mode of energy.

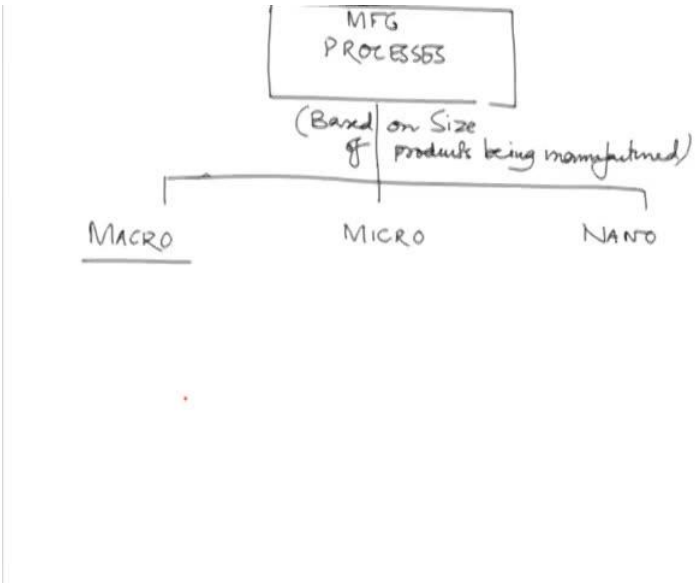
This requires a special device, we use electrical energy no doubt for these processes, but not as it is we use electrical energy to produce laser and this laser is directly used now for metal processing. That means, the work done is through laser heating not by the conventional electrical and chip. So, this is the difference between this conventional mechanical or electrical form of energy used or the non conventional energy used.

(Refer Slide Time: 33:13)



Then another classification could be based on the size of products. So, this relatively a new approach in which we can group products by their size, which are manufactured in the domain of macro processing, micro processing or nano processing.

(Refer Slide Time: 33:48)



So, generally this also can be let us see in this way by so manufacturing processes again manufacturing processes. So, this is this can be as say macro then micro and then nano. So, this is based on based on size of products being manufactured. Now, the most of the

products we see or we use in general are in macro domain, but micro domains there are certain products like powder most of the powder materials.

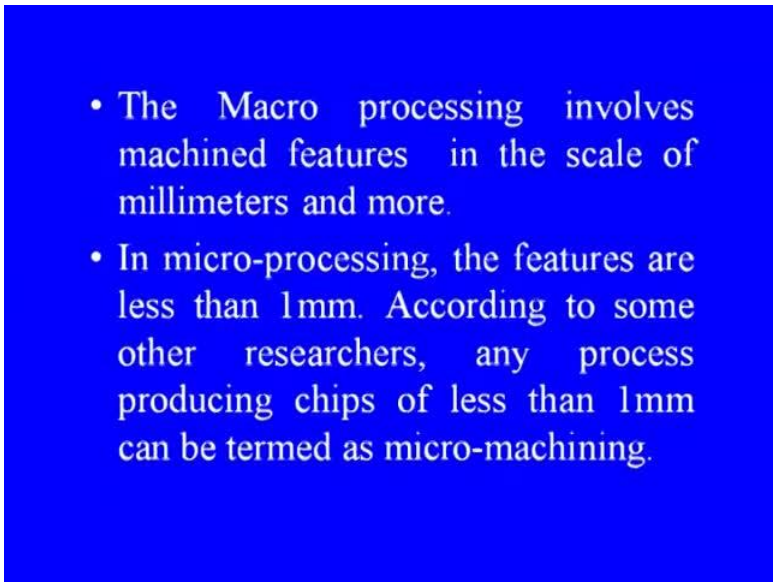
So, this and now a days the even the electronic components so those are manufactured in micro domain like say for example, the components needed for I C or integrated circuits or most of the electronic gadgets they use components, which are very small and in the micro level so these are also being produced. Now, if someone says where is the exact demarcation line between this macro and the micro it is not very clear cut, but from our experience we can generally say, the micro is in the domain or where the size is in on around 1 micron or some researchers say that if the machining produces, the chip which is produced or which is in the size of 1 micron so that can we called as micro machining.

So, is the case with which is the micro component so a clear cut definition is yet to be evolved. However like MEMS micro electro mechanical systems so there are number of components, mechanical components are also there say gears may be there. Some channels may be there so the sizes of these may not be very clearly defined, but in a relatively very small domain, which we can comfortably call as micro domain so is the case with this nano.

Generally, in the nano scale the sizes or the size or the components or the products that fall in the nano or nano size, nano scale can be considered as the nano domain, but again to arrive at a particular number that defines, micro and nano as a product or micro manufacturing and nano manufacturing as a domain is practically difficult. However, the concept is the approach that is needed for macro manufacturing, micro manufacturing and nano manufacturing may differ substantially. The same equipment, same machine may not used very widely for micro sorry macro products to be produced, may not be useful for micro products to be produced.

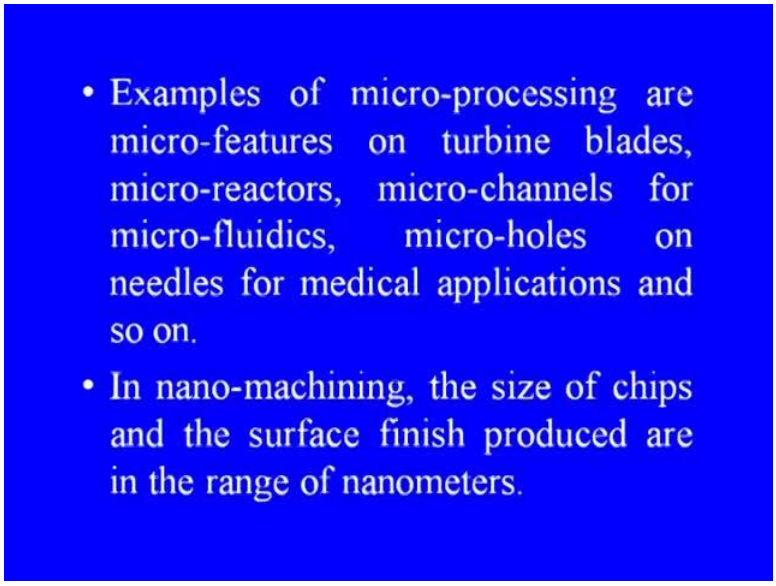
Similarly, they may quite different they may be quite different for producing the nano products. herefore, it is always better to define these domains as a different manufacturing domains, like the precession we need for micro machining, the tools we need for micro machining or substantially different from those used in macro machining so is the case with nano manufacturing. In which even the environment can be or should be controlled apart from the machines different, tools different and so on. That means the total approach is different significantly from that of macro and micro domains.

(Refer Slide Time: 39:25)



The macro processing involves machined features in the scale of millimeters and more. In micro-processing, the features are less than 1 millimeter. Generally as I have already indicated some researchers say, any process that produces chips of less than 1 millimeter can be termed as micro machining.

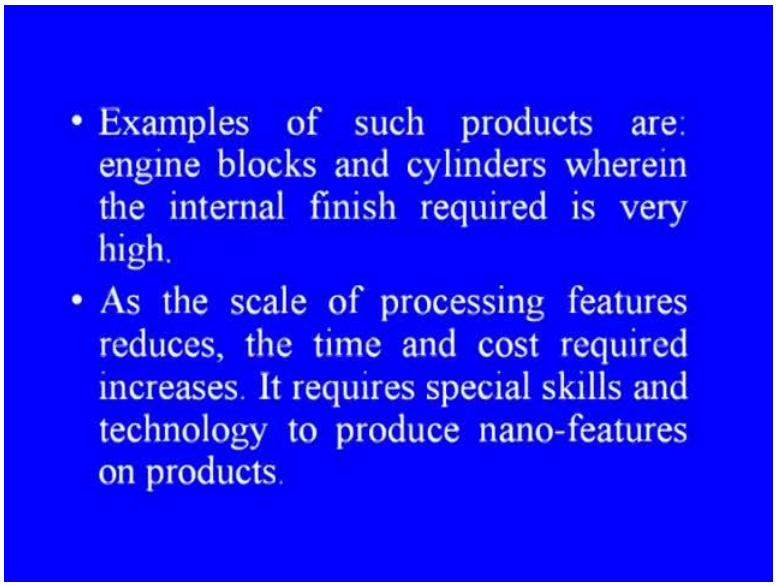
(Refer Slide Time: 39:55)



Examples of micro-processing are micro features on turbine blades, micro-reactors, micro channels for micro fluidics, micro holes on needles for medical applications, lab on chip then heat exchangers, micro channels for heat exchangers and so on. In nano

manufacturing on the other hand, the size of chips and the surface finish produced are in the range of nanometers. Therefore, as the chip size we can say is in the nano meters therefore, the techniques to be used also accordingly should be suitable. That means, it will be in terms of few atoms.

(Refer Slide Time: 40:50)



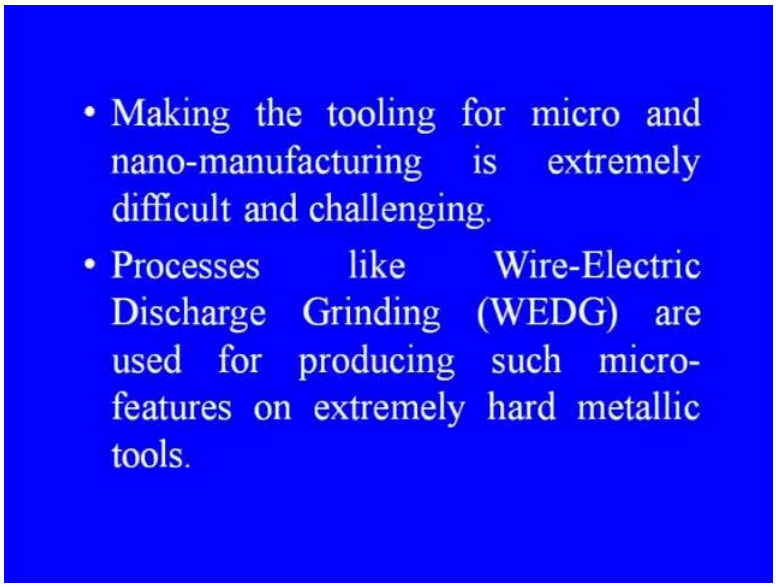
Examples of such products are engine blocks and cylinders, wherein the internal finish required is very high. As the scale of processing features reduces, the time and cost required increases. It requires special skills as well as special technology to produce nano features on products. As I have already indicated as you go on nano level even at particular, which may have several micron diameter can affect the entire manufacturing itself. Therefore, the environment control in nano manufacturing is also an important aspect, we have to have special environment, then the surface produced or the machining generally, machining is a production of new surface.

At a nano level, may get immediately oxidized and form a different substance say for example, if it is oxidized then instead of a metal, the surface will become metal oxide. Then removing down metal oxide instead of metal may require a different amount of force and accordingly a different equipment as a whole. Therefore, the control of the environment is also an important aspect in case of nano manufacturing.

Thus what we understand from this discussion is macro, micro, and the nano manufacturing that needs, different conditions right from the machine tools used, the

cutting tools used and the environment used. So, therefore, we have some logic to differentiate them or categorize them in three different categories like macro, micro, and nano manufacturing.

(Refer Slide Time: 43:28)



Making the tooling for micro and nano-manufacturing is extremely difficult and challenging. This is what I was telling, say for example processes like wire-electric discharge, grinding are used for producing such micro features on extremely hard metallic tools. Thus for nano manufacturing again the production of tool is itself is a big issue. Therefore, it is logical to separate them out which may require say for example, chemical processing for making the tool itself, where as in most of the macro manufacturing cases, we go for mechanical processing of the or shaping of the tool or we we can say from tools etcetera for the macro level manufacturing.

In the end let us summarize, what we have discussed in this session. In this session we have discussed about different categorization of manufacturing processes, different approaches towards categorization we have seen based on different aspects, based on energy used and based on the size of the products and so on. We hope this session was informative and interesting.

Thank you.