Product Design and Manufacturing

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Lecture – 17
Manufacturing Process Selection (part 2 of 2)

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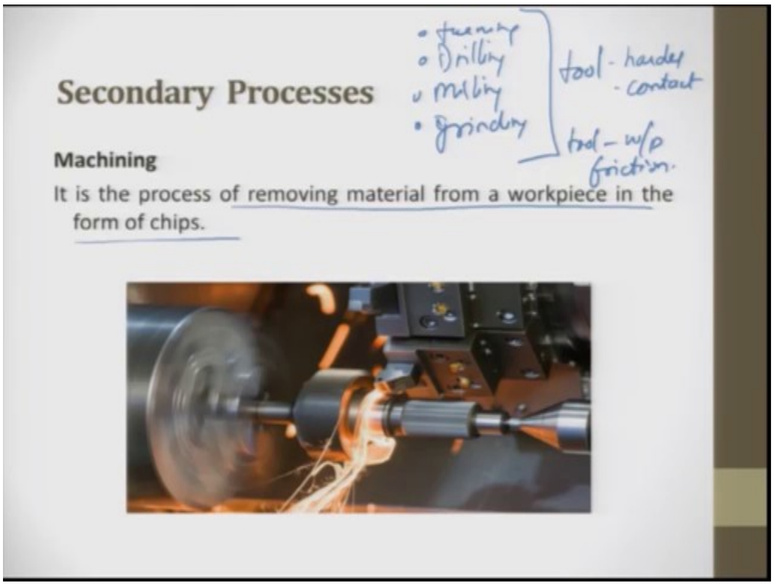

Next one is machining. Machining is a process, where, in which the material is removed from the work piece in the form of chip to produce the shape, whatever we want. So, here this is a turning process we do. So, you can do by turning, drilling and milling. There are so many processes; turning, drilling and milling, grinding, these are some other process; I am just listing it down. So, all these processes, what we do is, we try to use a tool, a tool which is harder than the work piece, harder and which is in contact with the work piece and then, it tries to remove material in the form of chip.

So, when this is getting done, as I told you, during the process, there is a temperature rise. A typical example is this, because here, when it is in contact, there is going to be friction. So, tool-work piece, you will have a friction. So, this friction increases the temperature and you tried to produce a chip. So, the temperature tries to dictate the material and the temperature has to negotiate. If the temperature is very high and if the material is deforming that the geometry, whatever we try to retain will not be accurate.

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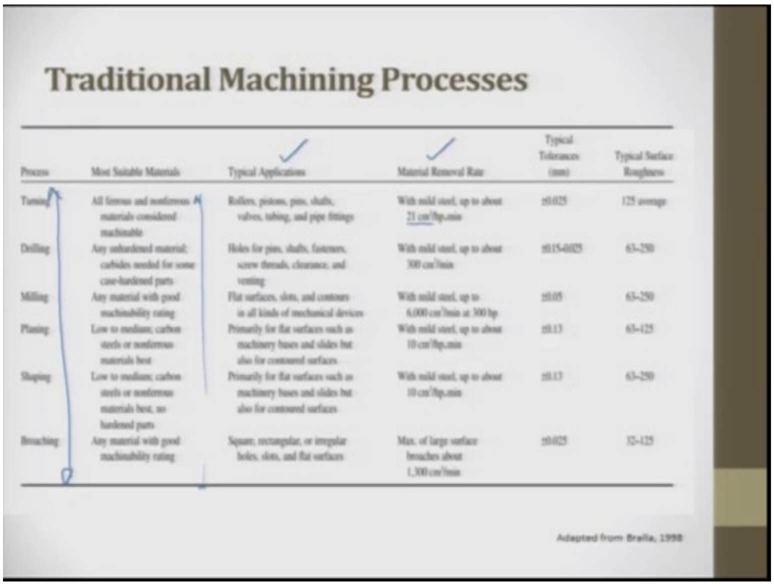

So, here are some of the processes which have told, I have just put in front of you. So, and then, I have also set what are all the different materials can be done, what are the different applications. These are just a glimpse than what is the material removal rate. So, you can see here, I have put it 21. Why is metal removal rate important, because it will try to dictate the time required for producing, the next test tolerances and the last one is roughness, as I told you earlier, roughness is very important when you are in contacting surfaces and tolerances, because you have to mate and then, so, these are the tolerances we can do.

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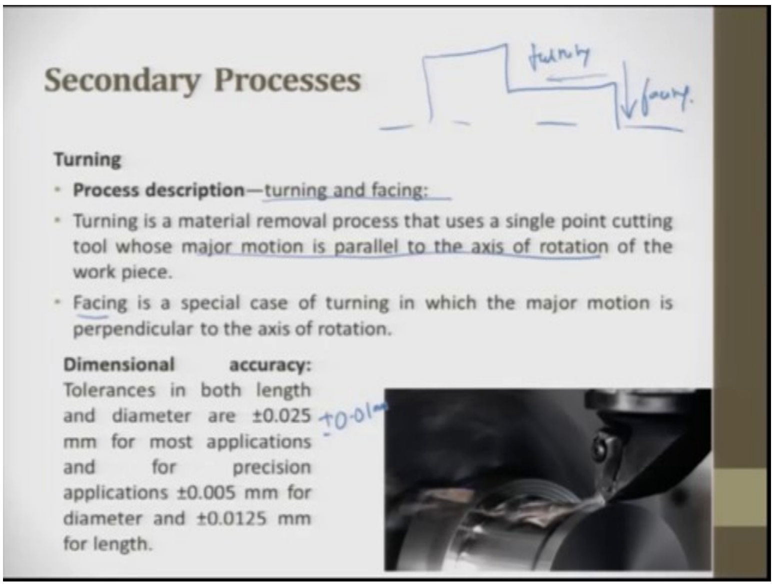

So, turning and facing have taken little bit. Turning is a material removal process where in which; we use a single point cutting tool. So, it moves whose major motion is parallel to the axis of rotation, of the work piece and facing, So, if I wanted to reduce a diameter. So, reduce a diameter. So, here this is, this is along the space parallel to the axis. The tool moves parallel to the axis. So, this is called Turning. If I move perpendicular to the axis, then it is called as Facing.

So, this is turning and this is facing ok. The dimensional accuracy, depending upon the machine, you have precision lathes, you have precision machines. So, you can try to go to very small dimensions possible. For example, you can even go today with 0.01 millimeters, it is possible today, because there is precision lathe which have come. So, the dimensions and accuracies, I have already talked, have just given in detail.

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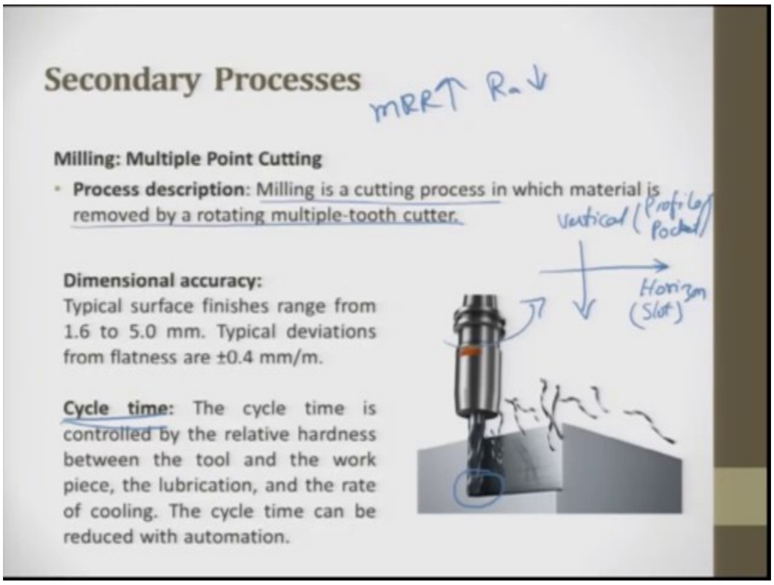

Next, when I talked about milling. So, milling I said, drilling is the 2.0 cutting or multi cut, two cutting edges will have in milling, what you will have as you will have multiple cutting edges. So, we will have multiple cutting edges. These multiple cutting edges, when it is rotated, it tries to remove material as chips. You can see how the chips flies and falls. Milling is a cutting operation in which, the material is removed by rotating a multiple tool cutter. So, again here, depending upon the axis, it can be vertical axis, it can be on horizontal axis. Horizontal axis, right, vertical axis, you try to cut a profile are you try to cut pockets. Profiles and pockets can be cut, or any other shape. It can be of three dimensions. Horizontal predominantly used for cutting of slots, grooves. Here, we talk about the cycle time; this cycle time is directly related to the material removal rate.

horizontal

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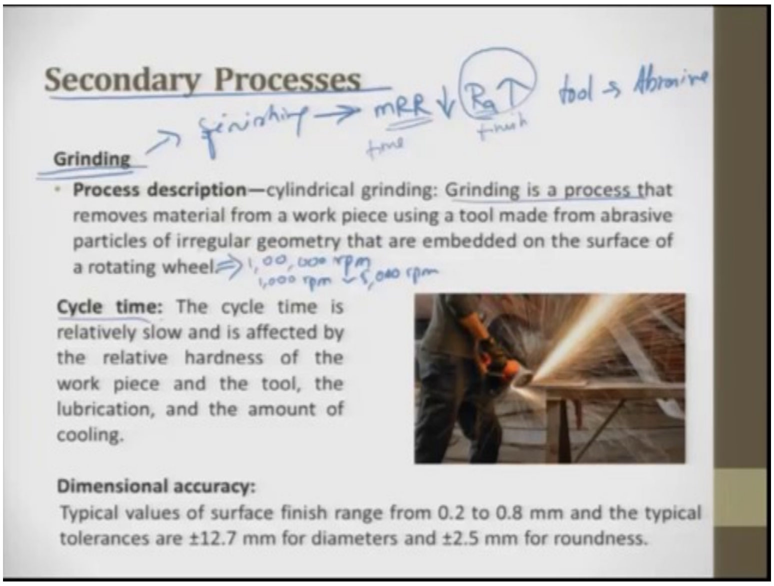

Next is grinding. Grinding falls under the category of secondary or process. So, grinding falls under the domain of finishing; that means, to say here; the material removal rate will be very less and the finished will be very high. In these two, material removals rate will be very high and RA will be very low. So, here we are not bothered about material removal rate to a large extent. We are more worried about surface finish. So, here we talked how accurate it can produce. So, you see; there is a paradigm shift. Here, time was talked about, here finishes talked about, here appearance is talked about, and here functional requirements are talked about. So, here we do not focus on material removal rate.

So, grinding is a process. The only difference between milling, turning and grinding is, here what happens is that, tool is nothing, but abrasive. So, they are random and by nature, several of these abrasives are put together, they are stuck to each other by a bond. There are several bonds: - vitrified bond, sulfide bond and other things. So, they are stuck to each other and then, you tried to give shape to the abrasive bonded. So, the bonds and it is called as an abrasive wheel. So, this wheel rotates at very high RPM and then, it tries to grind the surfaces. So, here the grinding as a process, that removes materials from the work piece using a tool made out of abrasive particles of irregular geometry that can be embedded on the surface of a rotating wheel.

So, the wheel speed, is generally, today we talk about 1 lakh RPM easily, but in general, what we talked about in lab scales, academic scales and there or in machines, whatever you get today is 1000 RPM to 5000 RPM, you can get like handheld. You can get of the 1000 - 5000 RPM. See 10 - 1 lakh RPM, it has to have a stable structure and rigid structure, and generally when you talk from the designers' perspective, we have hand hold grinders, which rotate with the speed between 1000 RPM to 5000 RPM. It is pretty high. So, that is why what we do is, when you try to grind, we try to hold it by two hands and then, start doing it.

The cycle time is relatively low as I said the material removal rate is less and the finishing is, size of the cycle time is pretty low. The dimensions whatever you can get are pretty high. So, if you are looking for very tight tolerances, then after the machining operation, we always try to do a grinding operation to get the required tolerance.

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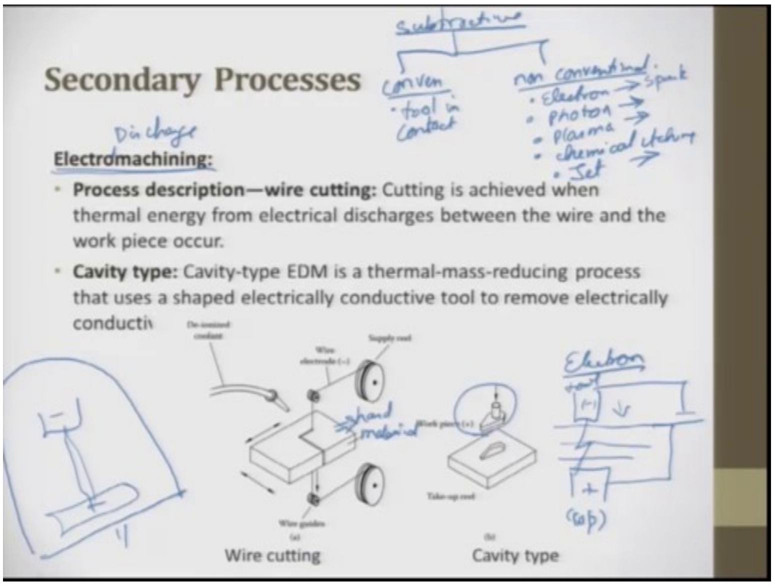

Now, I will just have to put a glimpse of the non – conventional, where the tool is not in. So, in subtractive two processes, as I said, subtractive process, as I said the one is conventional and the other one is non – conventional. Ok? Conventional means that tool is in contact. So, when the tool is contact, the material removal rate is high, the surface finish, what you get this good. So, when you talk about non - contact, the tool is not in contact. So, what are all the possible tools? We use electron as a tool, we use photon as a tool, we use electron, photon, we use plasma as tool, we use chemical etching as a tool.

So, electrons, what happens is it can lead to a spark or it can do and electron machining directly. So, it here, we use photon which is nothing, but laser. So, then we use here plasma, which is the four state of material and chemical etching. Ok? The next one, last one is going to be the jet. So, jet can be in water. So, all these things are subtractive to process. Since the material is not in contact the tool isn't contact with the material, naturally, the material removal rate is going to be extremely low and the power consumption is going to be high. You can never compare a non - conventional process with the conventional process. Ok? And all these non majority of the non -conventional processes are energy intensive. The photon; laser which is used today, the efficiency of a laser while machining is around about fifteen percent.

So, electron can be done in two ways. So, what we do is electron, we have electrodes. This is negative and this is positive. In between we have a dielectric. So, we bring this to as close as possible and then, we apply a potential. So, when it is brought very close to each other and when you apply a potential, there is going to be an ionization, going to happen between these two sides and once the ionization is mature, there is going to be a spark. The spark means; it is a sudden surge of electrons and it is going to move from one side to the other. The numbers of electrons are pretty large. The bunch of electrons have a pretty large, when they try to hit at the surface, that is going to create a spark. The ionization is matured, spark is created.

When it tries to hit at the work piece, through this is your work piece, this is your tool. So, now what happens, there is going to be a melt vaporization phenomenon, material is going to be removal. So, wherever you have a harder work piece, where the tool cannot be used for machining, then we go for electron as a tool and then, you do machining and if you do not want this electron this system So, what we do is, we try to have an electron. Ok? We try to have the tool; we try to have work piece. Ok? And then, I put it inside a vacuum and then, I start the electrons to hit at the work piece. So, here it is also again melt-vaporization, but it is happening inside a chamber.

So, this process is called as electron beam machining and here, it is called as electric discharge machining. So, the discharge happens. So, the melting happens and the material is removed. So, here the tool, whatever I said can be in terms of solid tool or the tool can also get into a wire form. So, with whatever is a basic principle, I use here and then, I start machining. Wherever you have a very hard material to machine, we generally go for this process. So, that is called as electro machining or electro discharge machining. So, here wire is used. I have explained all this, since a cavity cut or it is otherwise called as die shanking and people start machining it.

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When you move towards plastic, the most commonly used process is injection moulding process. Here, it is a secondary process. So, what happens is, you have a heated plastic which is extruded. An extruded process, your over extrusion, we saw extruded and there we saw about metal here, it is polymer extruded into a hollow tube. This is a tube and then, the mould is closed, hollow tube, it is extruded right and then, this portion is closed. Ok? And then, once it is closed, what we do is through this tube's bottom side, we try to push air or you can even, you try to crimp it here and push air from the top both sides are possible.

So, here in this example, we have used pushing air from the top. So, when the air is pushed from the top, this is a visco elastic material polymer. So, it tries to expand and the air is given enough or the volume of air is made sure, such that the volume of this container or slightly higher is there. So, then, what happens, all the visco elastic material gets expanded and touches the die surface, whatever is a die surface and impressions on the die surface, is getting transferred to the exterior of the polymer and after this, what we do is, we hold it for some time such that, the curing of the polymer happens and then, we open the die and then, what you get is the product out.

So, this is a process which is blow moulding process. Since, you see lot of pearl pet bottles around or lot of mineral water bottles around, I thought I should explain this process. The entire process takes hardly 5 seconds or 10 seconds depending upon it and you can have multiple dies at the same time. So, one shot you might get 3 or 4. So, this is a secondary process. I have just put because polymers are, they are also growing in a big way to make product today.

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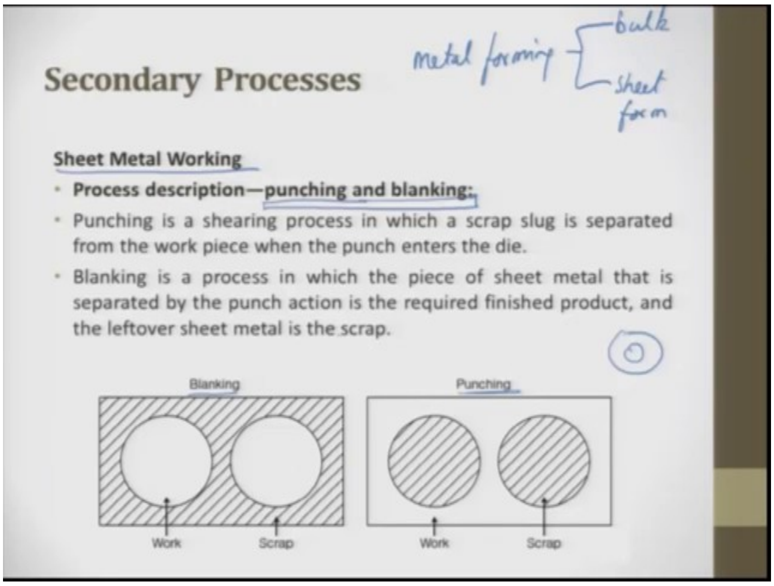

When you talk about sheet metal process, here is a process which frequently people try to get confused. One is called as punching and the other one is called as blanking. When you talk about metal forming, there are two categories. One is called as bulk forming and the other one is called as sheet forming. Wherever you have a larger surface area, it is sheet forming, where larger about the volumes, surface area is not very large then we call it is bulk forming. In bulk forming, we apply lot of a force to deform the materials. Here, comparatively it is slightly less. Ok? So, in sheet metal forming the most common thing which people always get confused is punching and blanking.

When I try to take a sheet, when I try to take a sheet, I tried to create impression for a use of punch. I create an impression and pear some material out. Whatever gets out of this ring, if I make it as a useful part, then that useful part is produced by a process called blanking. Whatever part I produce, which gets out and if it is a scrap, then that is called punching work scrap. Right? So, here punching is whatever comes out of it is not used. So, then it is called as punching. So, you can have progressive punching. So, you can also have washers. So, first outside is punched and then, next internal is punched possible. So, you get an over doughnuts structure like this, for sheet metal. Ok?

So, punching is a sharing process, in which the scrap slug is separated from the work piece, when the punch enters into the die, blanking is a process in which the piece of the sheet metal, that is separated from the punch action is required finished product and it is left over sheet metal is the scrap. Then, it is called as blanking. Ok? So, the coins, whatever we use the currency coins, all of them are done by blanking and then, it is done by stamping, you try to get the impression like one embossment, whatever they do it on the coin.

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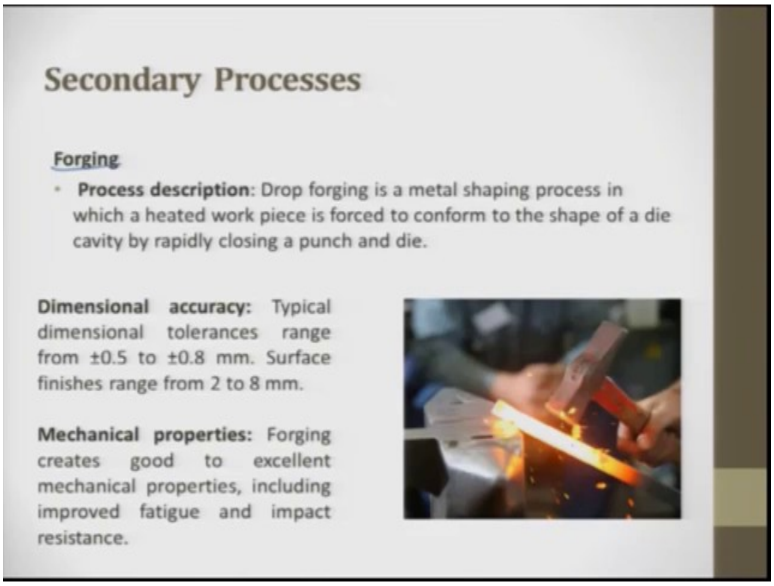

Next one is forging as I told you, if you have a bulk, if you have surface area, not so large. So then, it is called as volume surface to volume ratio, if you do and if the surface is area is very less, then the process, whatever we use is called as forging. So forging, what we do if we try to take a material and here, you should understand you try to take a material, you try to heat the material. So, the load, whatever you apply for deformation is less, if you do not heat the material, the load is very high. So, that is what I said. If you go back to the manufacturing process; pressure, temperature and time all are linked. So, in a process, you can have temperature and pressure. So, this is our example for it. So, depending upon the temperature, the force applied is less or more. Ok? So, you can do it at hot state, you can do it at warm state, you can do it at room temperature state.

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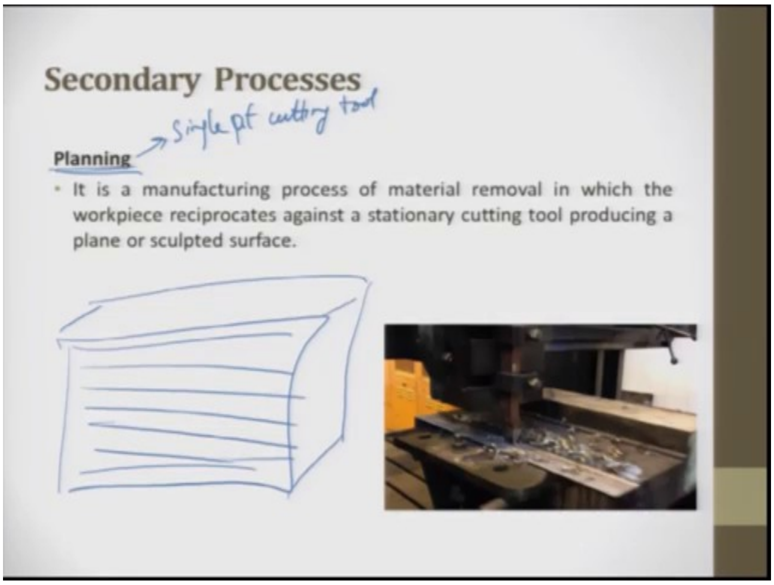

So, when you talk about a very large surface, the entire surface and it is a prismatic surface. If it has to be machined, prismatic surface has to be machine. We call and we call a process called as planing. So, planing is a process where in which, we use a single point cutting tool to produce a flat surface on a prismatic, very large area. We are not talking about the bed size will be very light. For example, the lathe complete bed will be planned. Ok? The saddle complete one-meter-long saddle will be plane. So, of those very large, where the bed size is, what is over the process, what to use is called a planning.

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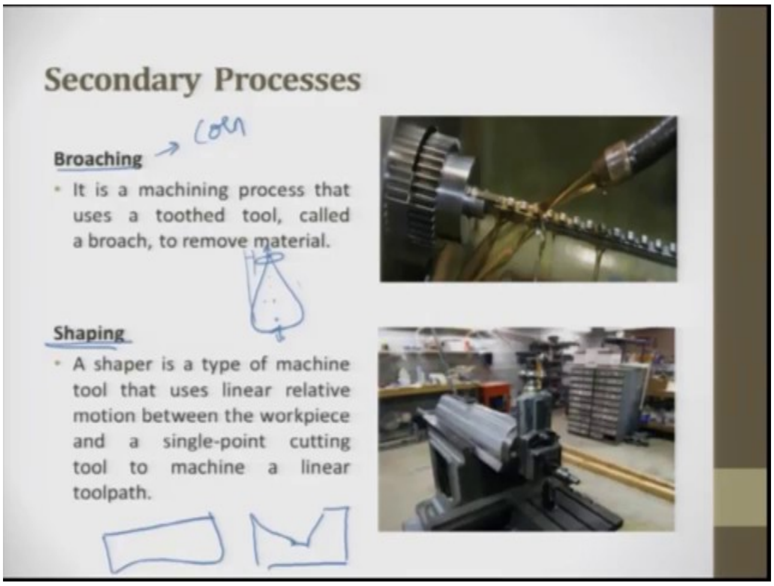

When the process area, when the work piece size is small, then we call it as shaping. So, the only difference is here, the bed moves, the tool is a single point cutting tool, which is almost a constant. Here, that tool moves and the bed is constant that's the difference and here, you can make flat surfaces, you can make V surfaces. So, all are possible by this process. The next interesting one is called as broaching, which very rarely, we use. Broaching, what happens is it, here we use multi - point cutting tool and it is a finishing process. Ok?

So, here the tool is like your corn. So, corn. So, it is something like this right. So, you try to pull, you try to pull the tool through your work piece. So, initially it is of a smaller diameter and then as and when it keeps going, it tries to expand the diameter and then finish. So, here the difference and diameter will be maximum of few millimeters or it will be less than millimeter.

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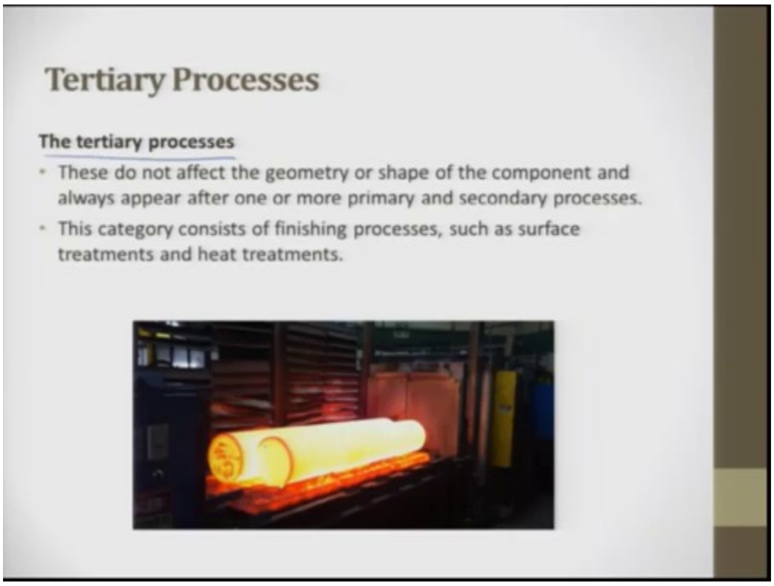

The last operation is heat treatment. So, heat treatment, as you have made a shape, you have made a size, but you wanted to play with a mechanical property alone. So, what we do is, we try to heat the work piece and then, after heating the work piece, we try to leave it in the atmosphere; furnace atmosphere or we try to bring it out and then, we try to go quenching. So, here what happens, only the mechanical properties keep changing.

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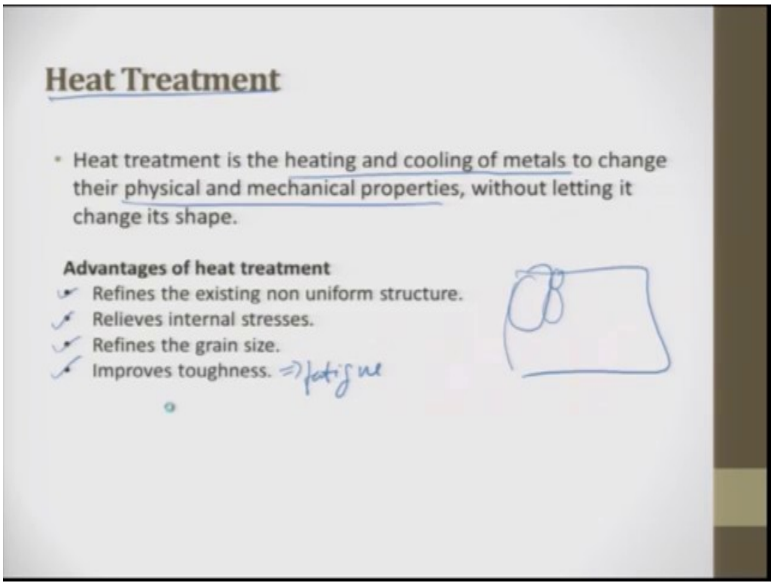

Heat treatment is a process, where in which it is heating and cooling of metal to change its physical and mechanical property, the shape does not change, and the size does not change. So, what is the advantage? It refines the existing non - uniform structure. So;

that means, to say a structure, means in say, microstructure, and the grains will be large grains will be small because of the machining operation. So, in there will be not non - uniform distribution of stresses mechanical or compressive stresses on top of the surface. So, if you want to refine them. So, that is possible by heat treatment, internal stresses can be relieved.

The grain size can be refined and the improvement of toughness can happen. Toughness is in turn required, because you want to enhance the fatigue behavior. Fatigue behavior you want to enhance. So, that is what we do. So, if you make a grain size smaller, than it is the work. The work piece is going to demonstrate a harder hardness is going to be high. So, if it is, the grains are large, then it is going to be toughness going to be large. So, this affects the mechanical property on the physical property of a material.

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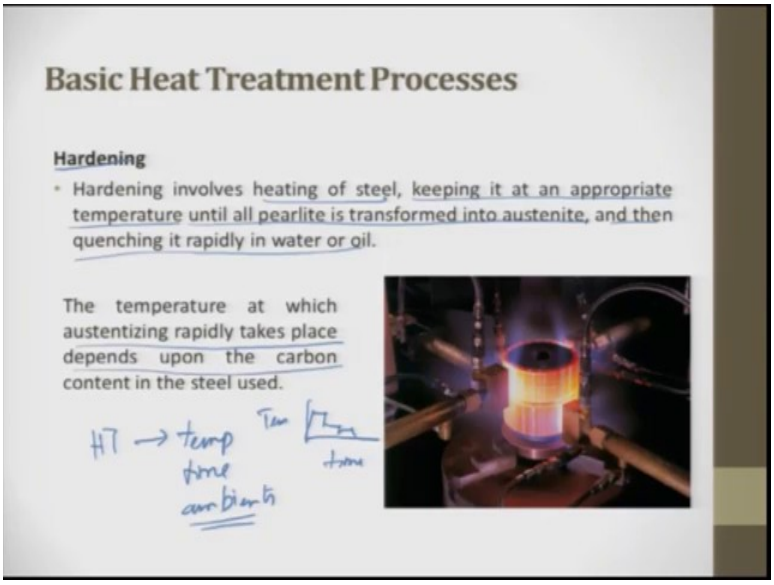

So, the hardening which involves heating of steel and keeping it at an appropriate temperature, until all the pearlite is transformed into austenite and then, quenching it rapidly in water or oil you can do it. So, basically here, what are we trying to demonstrate is, we are trying to demonstrate heat treatment wherein which; temperature, time and ambience are important. So, if you see that temperature, time cycle is there. So, something like this, you have cycles and when we try to do it, you can.

The ambience, it can be quenched oil quenched, you get a different profile, then you try to put it in the furnace, you get a different profile when you put it in an ambience, where it is full of nitrogen, you get a different response. So, that is what you are trying to say. So, the temperature at which the austenite rapidly takes place depends upon the carbon content in the steel.

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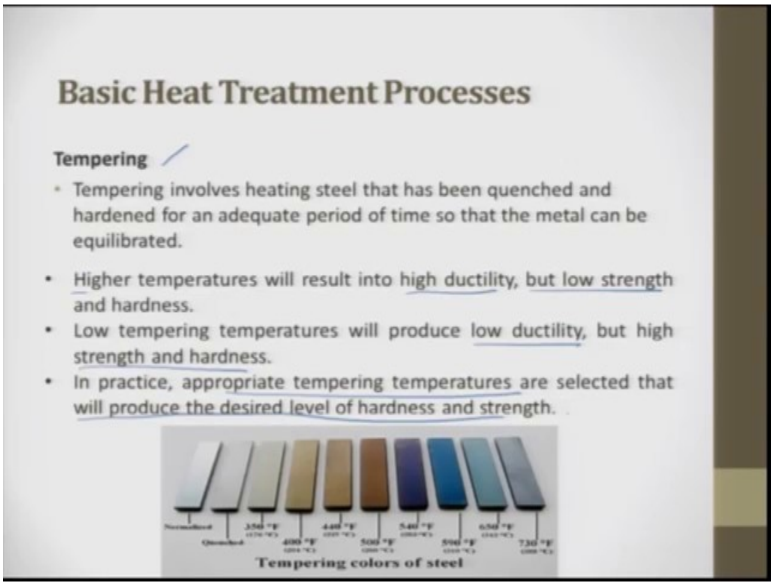

So, the next one is tempering is nothing, but I try to heat the steel and then, quench it and hardened to an adequate period of time so that, the metal can be equilibrated. So, you see their tempering color of steel. So, if you try to play with the heat treatment, now, you can try to play with the color. So, today what people are talking, trying to talk about is, I will make a shape then I will do heat treatment, when I do heat treatment, if tries to introduce a color, which tries to remove the painting operation. Ok? So, today just by playing, see you see the normalized play, quenched play at 350 degrees, then you do 400 degrees tempering and then, at 540 you see at different color is coming 590, you see a blue is color coming.

So, just by playing with the temperature, we are able to; you are able to change the color. So, this is good information, which people have started working from the designer’s perspective, you get the shape, put it inside and then, you try to play with the heat treatment, you get a color which is getting impregnated without any operations. Ok? The heat treatment, the higher temperature can result in higher ductility, but lower strength, a compromise, a lower tempering temperature will produce lower ductility, but the higher strength and hardness in practice appropriate tempering temperatures are selected, which will produce the desired level of hardness and strength.

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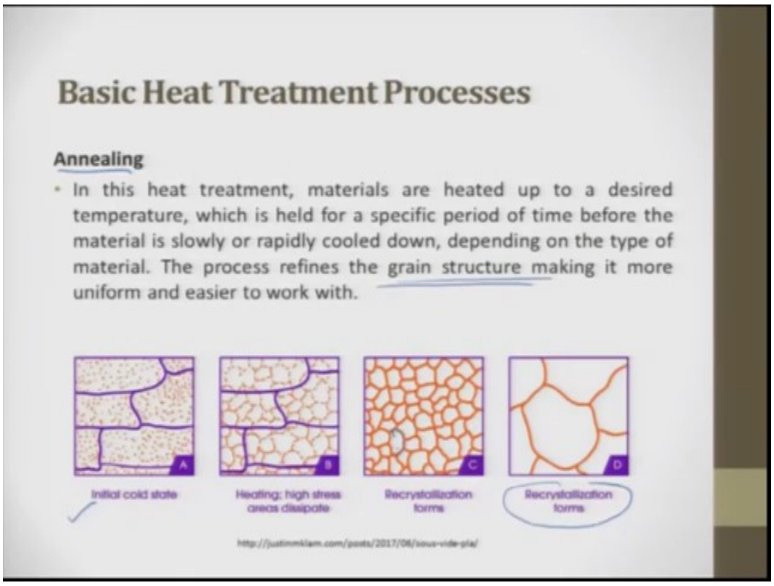

So, the other process is annealing. So, in annealing, it is the heat treatment material, in this heat treatment material are heated up to a desired temperature. Which is held for a specific period of time, before the material is slowly or rapidly cooled down, depending on the type of material, the process refines the grain size. So, if you look at it initially or cold state; that means, to say you have done a metal forming and then, you heat it what happens that the high stress areas are dissipated then, a recrystallization happens then, a recrystallization leads to grain growth happens.

So, you see here, the grain sizes are changed from one to the other, such that you tried to get a different mechanical property. So here, what did you do, you did not change the size you just changed with the grain structure and if you have carbon, which is in internal by just playing with the heat treatment, we can move the carbon all around to the grain boundary and it gets precipitated along the grain boundary.

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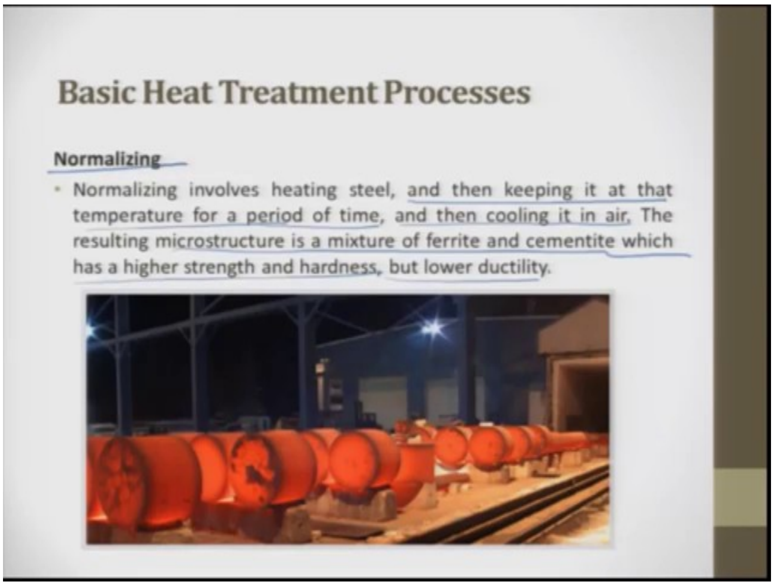

Normalizing involves a heat treatment. Here, heating steel here I have taken only an example of steel, you can also try to do with copper, aluminum, anything. Ok? For everything, there is a heat treatment cycle, you have to watch out for it and then, start doing it. I am walking through only steal, because steel is predominantly used material for primary structure load bearing area.

So, and then, keep it at a temperature for a period of time and then, cool it in air. So, these are discs, which are cut and that are undergoing normalizing structure. The resulting microstructure is a mixture of ferrite and cementite, which has a higher strength and hardness, but lower ductility. So, now, what you do is, after doing this you try to take it once again to heat treatment and then, you tried to change the grain structure and start converting these billets into flat rolls for coils possible.

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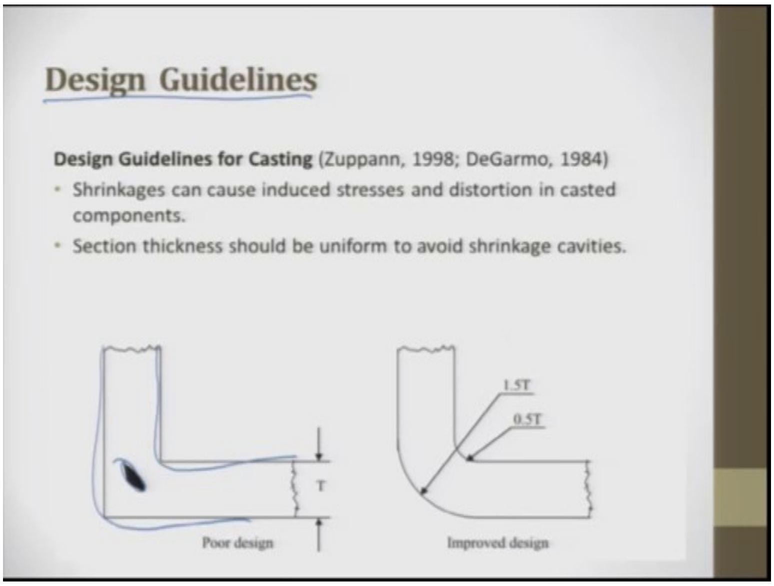

So, just play with the heat treatment. So, some of the design guidelines, forecasting the shrinkage can cause induced the stresses and distortion in casting components. So, the sections thickness, here, if you have abrupt change, it will always try to introduce, you will not have uniform cooling. So, there will be a possibility of defect might be caused. So, you and there, can be lot of internal stresses in order to avoid it, whenever you try to do casting, you try to give a radius and avoid the sharp edges. So, that you can try to get a better performance and shrinkage is also not there.

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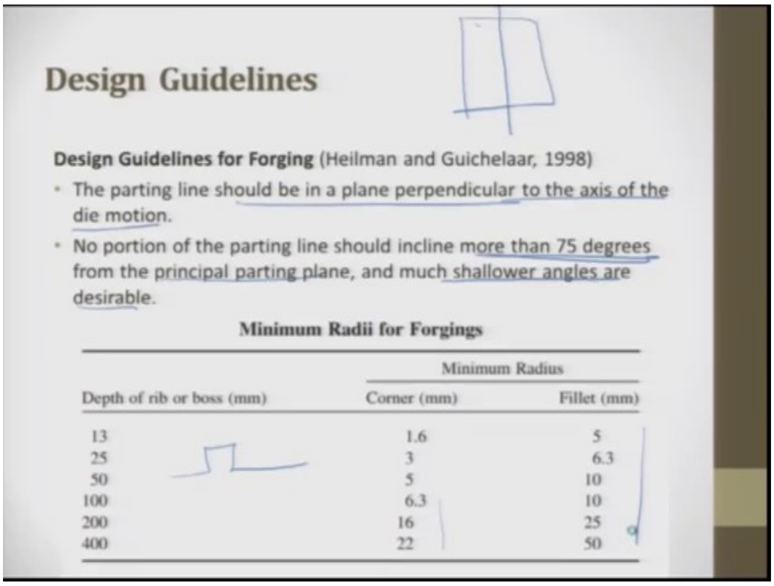

When you try to forge the parting line, what is a parting line? Parting line is when, you have two surfaces. When you have a product, the parting line surface, this is a parting line because you generally make with two dies. If you look at the bottle, for example, we have demonstrated. So here, if you see here, the parting line can be here or it can be on the other side, 90 degree rotated can be a parting line. This parting line is important because this parting line is decided, based upon the strength with gets or the load with gets applied on to the one on the product.

So, if you do a wrong choice of your parting line, the strength of the product falls down drastically and second thing, parting line is always decided because the die has to be separated. You cannot make through a single die. So, you always make it through split die. So, how should be the geometry on both the dies that will be decided by the parting line or moment? I know the parting line; I can take that decision.

So, parting line decision, as far as plastic parts are concerned is a big challenge. This is ok? Suppose you are trying to make a pencil box. So, the symmetry on the pencil box is very difficult. So, now, making a parting line is also a deciding a parting line, such that it can withstand lots, is a challenge. If you have bottle cylindrical part, it is a different and an easy job.

But if you have something like a skewed geometry, then it is very difficult. So, here that is what I was trying to talk about, the parting line should be in the plane perpendicular. So in the bottle, so, this is the bottle perpendicular, means 90 degrees to the axis of the die motion. So, no portion of the parting line should be inclined more than 75 degrees from the principal parting plane and much shallower angles are desirable.

So, this is what. So, here we have, this is very important. Let it be a metal part, let it be a polymer part, when you try to use die. So, parting line is very important. So, here, I have given the radius depth of the rib to boss. So, rib is nothing, but this is a rib. Ok? So, or a boss, so the corner radius and I have given the fillets.

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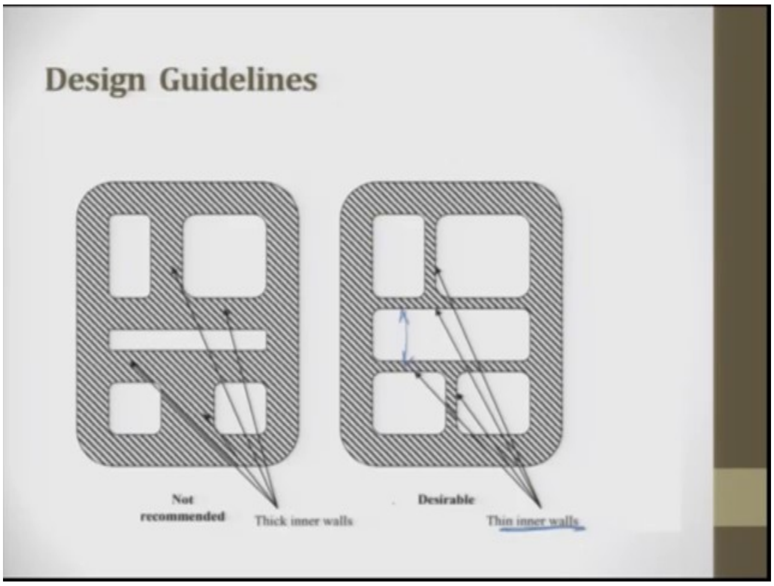

So, if you want to produce a part like this and then, you want to do a sheet metal just as an example, in the computer desktop computer, you have the server. So, there you have a sheet metal parts. So, you see various geometries like this appear, because the heat has to be exhausted and extracted.

So, here if you, instead of making this, it is always easy to make this. So, here what we do is, we just expanded the width and then, we made this thin. So, that we try to get the required output. So, this is not recommended, this is recommended; thin walls are recommended. Thick walls are not recommended, because these thick walls can try to distraught over a period of time.

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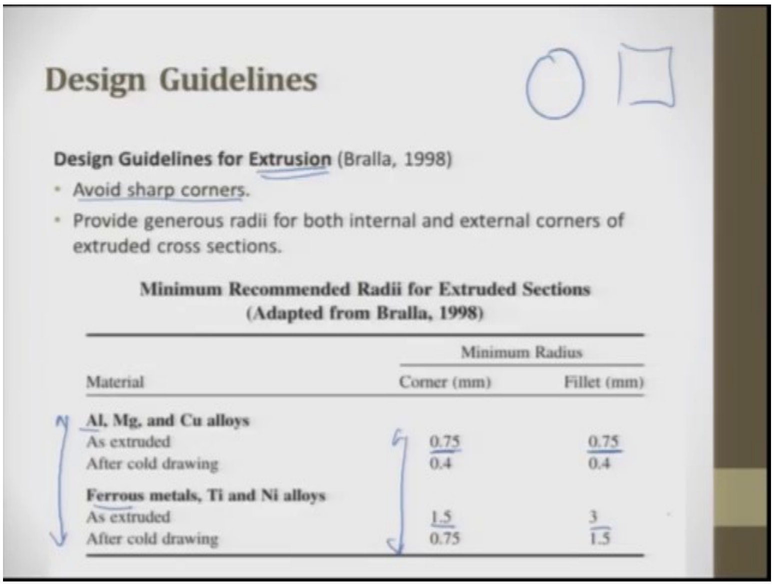

So, in extrusion what we studied about the pipe or the rod which is getting extruded in metal in polymer also extrusion is possible. So, avoid sharp edges; that mean, to say you always try to take cylindrical, never try to take a square extruded part, then the generous be generous, in giving the internal and the external geometry. Here are some materials which we are given and look at the corner radius for aluminum and all it is 0.75 fillet, radius is 0.75, for ferrous it is 1.5 and 3.

So, depending upon the material, the fillet radius is also done. So, all this information are available in books; in standard books, for example, you can look at data books where and which different process, these guidelines are given. So, you have to go through that while deciding the geometry for the die.

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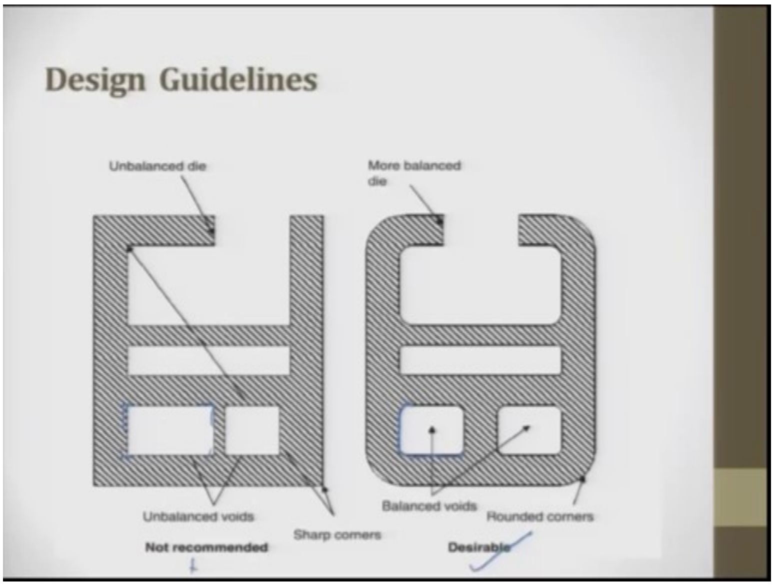

So, this is called as an unbalanced die. So, this is called as a balanced die. This is desirable, this is not desirable sharp edges are never desirable in punching operation, it is always good to have a fillet at radius, because sharp, when it is piercing, making a die is also a challenge because if it has to be punched. So, to have a punch which is square, making a square geometry is little difficult. So, if you have to, if you can make a filtered one. So, the sharp edges can be avoided.

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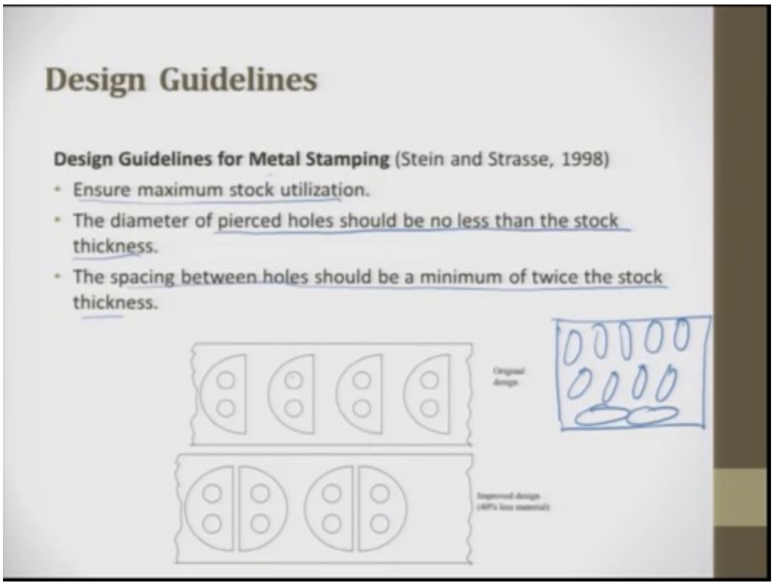

So, these are some more for stamping. So, ensure the maximum stock is utilized. For example, I do not know, how many of you have seen, when you walk out, you will also see rubber pad, where in which different foot wears are cut at varying angles. So, what they have done is, they have maximized the utilization in producing whatever product they want. Ok? This is called as nesting. So, nesting itself is a big algorithm. So, you have a sheet metal, you have a product, how many parts - parts can be made, what all orientation it is not necessary all has to be in one direction. You can do it anywhere, but you try to reduce the scrap.

So, ensure maximum stock utilization, the diameter of the pierced holes should not be less than the stock thickness, keep that in mind. The spacing between the holes should be minimum of twice the stock thickness. So, that is what is required. So, that you can try to do stamping operation, this also holds good for elastomers and plastics.

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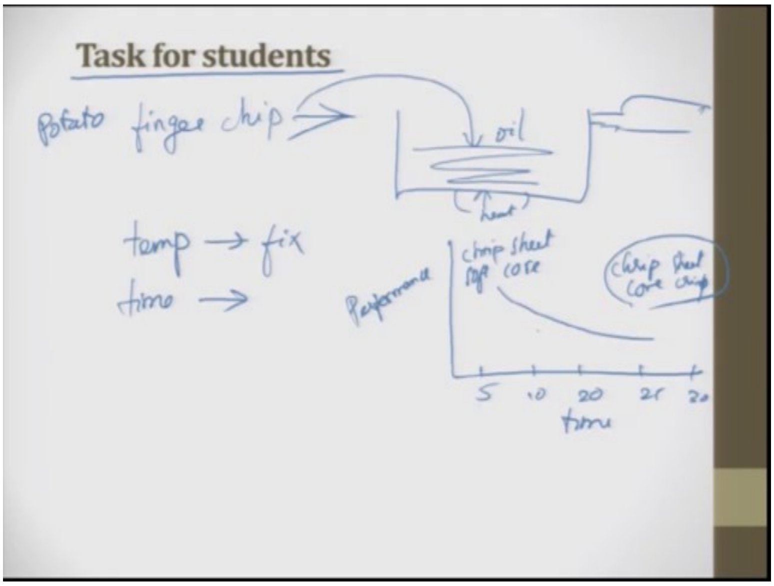

So, today’s task for the students is going to be a fun task. So, try to take the finger chips, which is readymade available. Try to put it in a pan, where it is with oil, right, try to drop it inside a pan. Ok? So, here what you do is the temperature of your pan oil pan is fixed. Ok? So, now, what you do is, you try to vary time so; that means, to say. So, you have time maybe 5 minutes, 10 minutes, 20 minutes, 25 minutes, 30 minutes, after the oil has come to a stable state. Ok? And then, what you do is, you try to take the performance. So, what you do is, you try to take a finger chips, which is already available or take a potato. So, this is a potato finger chips, take a finger chips right.

And it is readymade available. Today, drop it inside the oil pan, this is oil. The temperature has come to a stable state and then, what you do is, you try to and here, it is still burning right heat is away, heat is applied. So, it comes to a stable state, to a large extent and then, here is a time. So, you just try to put the chips at then, keep it for this. I have just put it as 5 - 10 magnitude of my own choice. It can be 1 minute, 2 minute, and 3 minute also and then try to see whether you get a crispy shell, soft core. Ok? When do you get at which temperature and then, as when you keep increasing the time and so, it is going to stay there for a more time. So, you will see a crispy sheet outside and the core also will become crispy.

So, try to do this exercise. So, what I am trying to demonstrate here is, just by taking the constant finger chips work piece material, dropping inside a heat treatment process, just by varying the time, you see different taste of the same material comes. So, it is crispy. So, it breaks or it taste nice and completely crispy is of a different taste and the performances different. So, this exercise, just try to do it for yourself. So, that you will try to appreciate the heat treatment effect on the work piece and its performance here, we talk in terms of taste, but you can also make it brittle. So, it is brittle another thing.

Thank you very much.