Fundamentals of Manufacturing Processes

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Lecture - 31
Metal working processes: Sheet Metal Operations (Shearing)

Hello, I welcome you all in this presentation, related with the subject fundamentals of the manufacturing processes and we are talking about the metal working process among which we have already talked about the bulk material processes, where the deformation of the material is used for shaping the material as per the requirement, but in case of the sheet metal instead of the bulk material, the sheet metals is used, which generally has the thickness less than 6 mm and you know.

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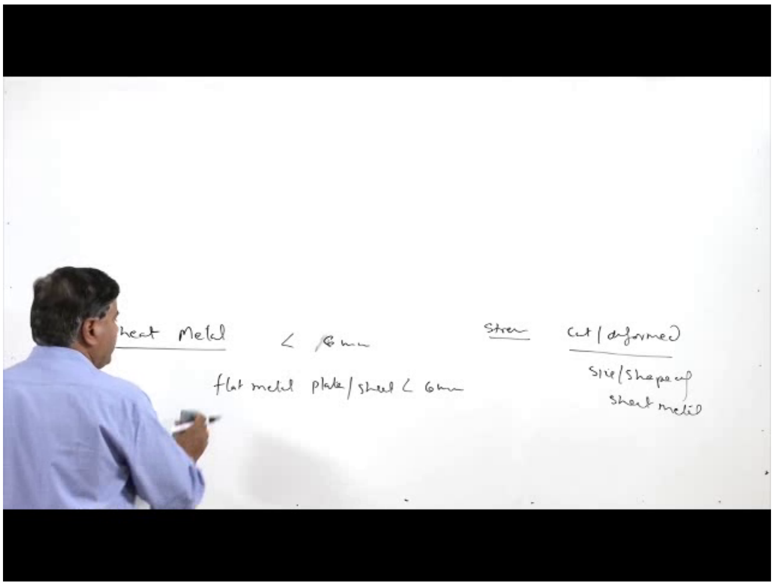

So, these are the flat metallic plates or the sheets having thickness less than 6 mm are applied with the pressure, to induce variety of the stresses. So, that the metal either can be cut or it can be deformed so that the desired size and shape of the sheet metal can be achieved. So, basically, for a shaping purpose and shaping and sizing purpose, the sheet metal is processed by application of the force, through the deformation and the cutting.

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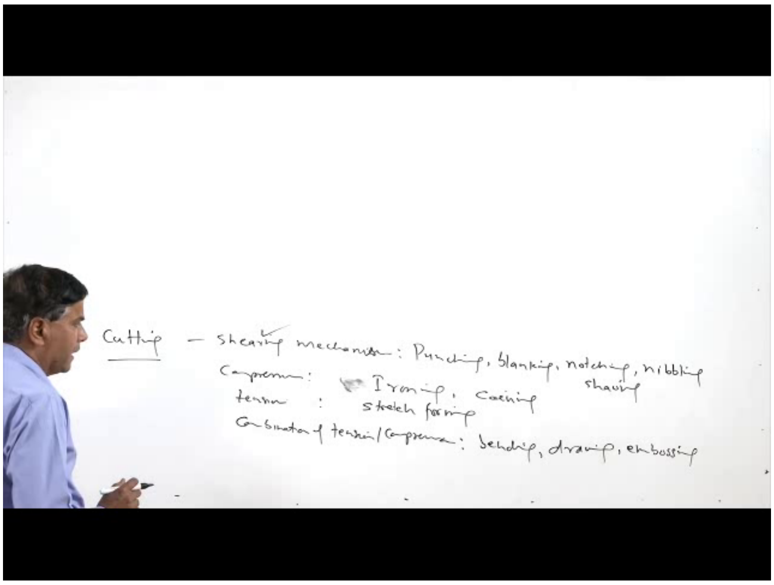

So, basically the cutting in case of the sheet metal is invariably achieved through the shearing mechanism, while the deformation is achieved by the application of the compression tension and the combination of the tension and compression both. So, there are a number of processes which fall in each of the categories. So, the shearing basically, involving the cutting in the number of processes like punching, which is primarily used for cutting the holes, of the different shapes, that blanking used for cutting the e metallic strips, which can be processed further for making the usable goods either by the deformation or by for the cutting, then notching, nibbling, shaving.

So, all these are the sheet metal operations, which will be involving the shearing or the cutting, then those operations, where sheet metal is subjected to the compressive stresses with the application of the force includes ironing. Ironing is the operation, where sheet metal is thin down, especially in case of the cup shaped products and then coining. Then tension is used in case of the stretch forming. A stretch forming to form the sheet metal in particular profile, a stretch forming is used using the tensile stresses, then combination of the tension and compression both is used in operations like bending, drawing, embossing etcetera. So, there are many processes in each of the categories.

So, in today's presentation, we will talk about the mechanism of the shearing and then other operations will be talking in the next lecture. So, the basic principle related with the shearing of the sheet metal, which is extensively used for cutting purpose. So, that the various operations can be performed sharing is carried out. So, for the sharing purpose, what we use the shearing is just like the use of scissor also. Whenever scissor is used for either cutting hair or papers or cloth, basically, the shearing is involved.

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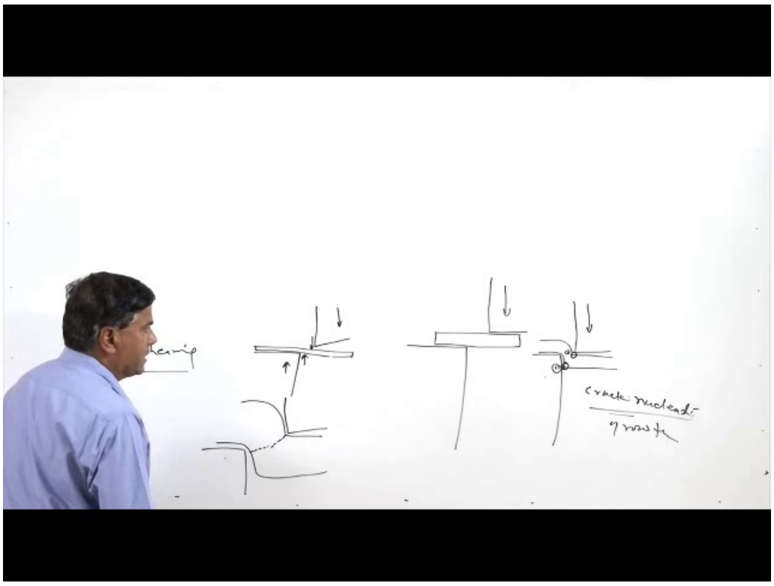

So, in a case of like scissor, like we, what we have; the two blades, one is upper blade sorry, lower blade, another is upper blade, like this and between these two plates, the strip or the item which is to be cut is placed. So, like we can move both the blades, in order to have the relative motion, but when this kind of the blades acts basically, the shear force acts on to the or on to the strip. So, what we use, if we see in the larger, in the bigger section, upper blade and the lower blade, when there is no cut, the strip is like flat. So, if the blade is moved in downward direction, in that case, the blade will be bending the strip in this manner. So, here this is the location of the upper blade. So, upper blade is moving down and trying to bend the strip at the two sides. This is one and this is another.

So, in this case the material is elongated, both these sides and here at these corners the deformation of the material at micro level happens to such an extent that cracks start to nucleate cracks, nucleate and then they grow. So, nucleation of the cracks and their growth subsequently leads to the fracture and the suppress. So, in this case are, this case. So, the cracks will be propagating both this from both the sides and they will be meeting at the center.

So, when the gap between the blades is optimum one, the cracks will be propagating from both the sides and it will be leading to the suppression by meeting of the cracks, growing cracks at the middle of the strips, under the optimum conditions of clearance. To see this more clearly, if we can see this diagram, here what we can see, here there is a one upper blade and there is a lower blade and this is the strip, which has been cut by the shearing.

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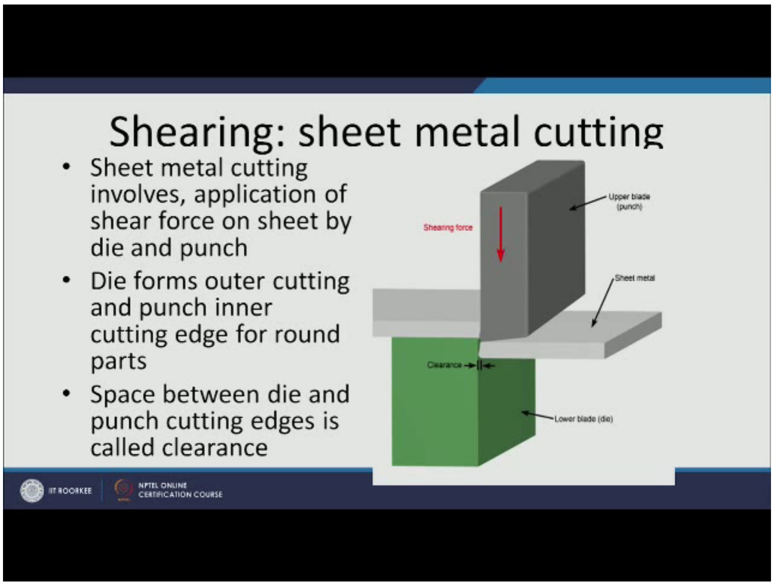

And there and if you see the upper blades and the lower blades will have some gap and that gap is termed as the clearance it is required that, there is an optimum clearance for having the clean cut. So, if you see the sheet metal cutting involves the application of the shear force on to the sheet, with the help of the die and punch. So, here in case this, there the upper one is called mostly punch and the lower one is called die. Die forms, the outer cutting edge and the punch forms the inner cutting edge of the round parts vocalized-noise. So, the space between the die and punch cutting edges is called clearance.

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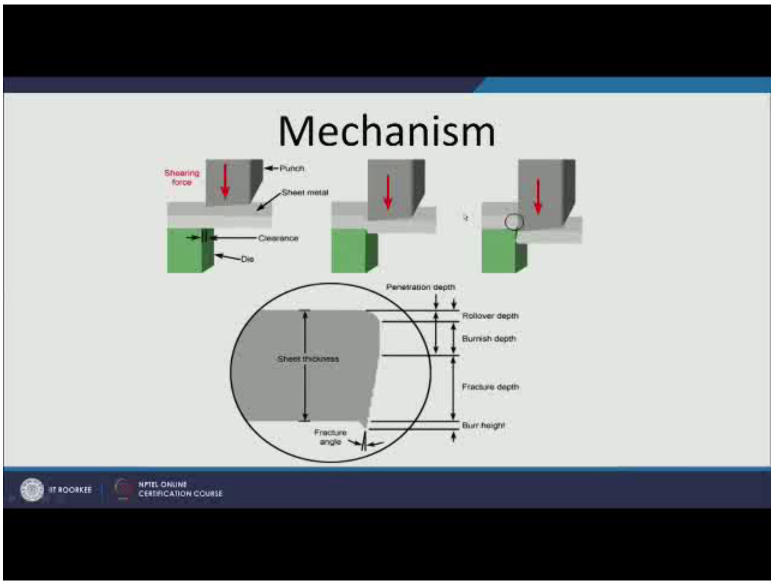

So, if we see it more closely, the sequentially, this is of stage one, where the punch is just in contact with the die and this is the clearance between the punch and die and the strip is flat, when the punch moves down. It causes the deformation in this strip. So, here the deformation of the strip at these corners leads to the excessive elongation of the material, which subsequently with the further progress of the punch in downward direction, causes the propagation of the crack and then ultimately, it results in the separation of the material.

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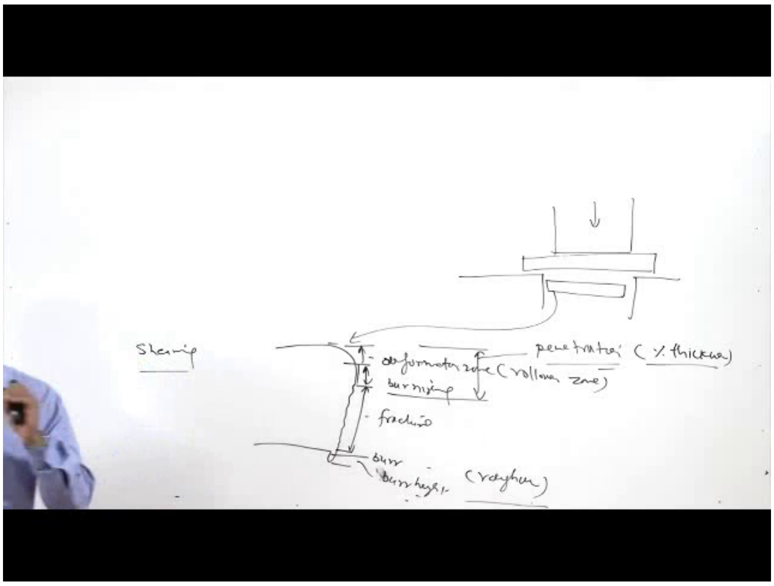

So, if we see whatever the cut edge which is produced, it has a particular configuration and which can be represented with the help of this diagram. So, whenever we apply the punch, which is moving in downward direction. It produces one deformation zone at the top. So, this deformation zone is also called Roll over zone.

Then another portion, this one which rubs with the surface of the punch, this is called Burnishing zone. So, burnishing zone is formed by rubbing of the metal, which has been penetrated metal of the sheet, which has been penetrated and rubbed by the punch in course of the movement then when the cracks start propagating from both the sides, they result in the fracture surface. So, this region is the fracture will be experiencing the fracture and due to the deformation of the material beyond. It is the lower edge, one burr is formed. So, this one is called burr height.

So, these are the four regions, which are formed in the cut strip, especially when we find that between the die and punch strip is placed like in the free conditions and this is die and this is punch. So, when the punch moves down. It produces a cut and the slug comes out in this form. So, this slug in the free conditions of this strip produces at these edges. This kind of the geometry, which has one deformation zone, then burnishing zone, then fracture region and then burr region.

So, if we sum up the deformation zone and the burnishing zone, sum of both these is called penetration. Penetration is the depth by which the punch must move inside the sheet metal. So, that the fracture can be facilitated and this penetration which is the sum of the deformation zone and the burnishing zone is expressed as a percentage of the sheet thickness. Percentage of the sheet thickness and this burr height is basically, indicating the kind of the roughness which is present in the cut edges. So, these are the five different constituents related with this. If during the punching, we have very proper holding of die strip then, it will not be causing this kind of the roughness.

So, this is what has been shown in this diagram, wherein, we have the first of the rollover depth, then the burnishing depth and some of the rollover depth. Plus burnishing depth is being termed as a penetration depth. Then we have fracture region, that is this zone and then burr is formed in the lower side. This one is called burr height, this called burr, which indicates the roughness of the cut edge

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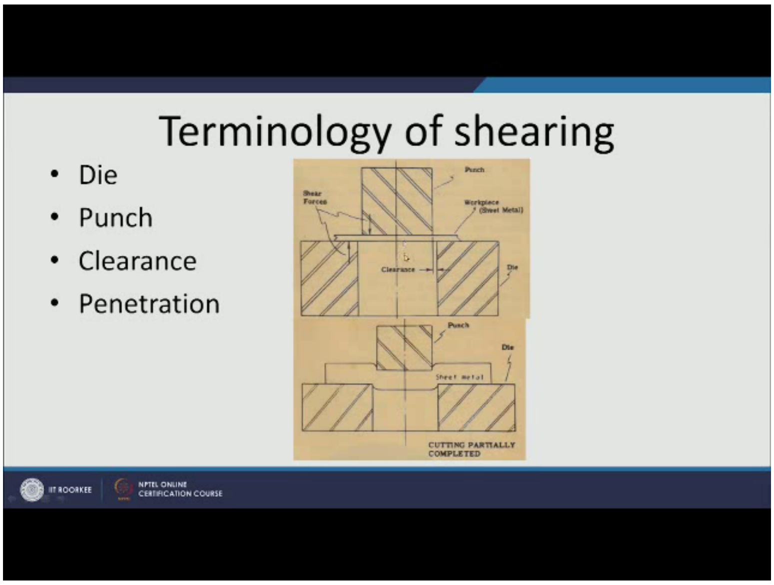

So, for punching purpose what kind of the configuration, which is used like I have mentioned at the top, we have punch and the lower side, we have one die and between these two strips are placed and there is always some gap between the punch and the die which is termed as a clearance. So, clearance has to be equal on all the sides. It all along the circumference and there is some distance by which punch must penetrate into the sheet metal which is defined as the penetration for ensuring the shearing of the material.

So, what happens when the punch move is down into the sheet metal? So, it causes the deformation of the sheet metal this is what we can seen and this deformation leads to the like development of the compressive strains all along the circumference of the punch and the similarly the compressive strains are also induced all along the lower edge of the die.

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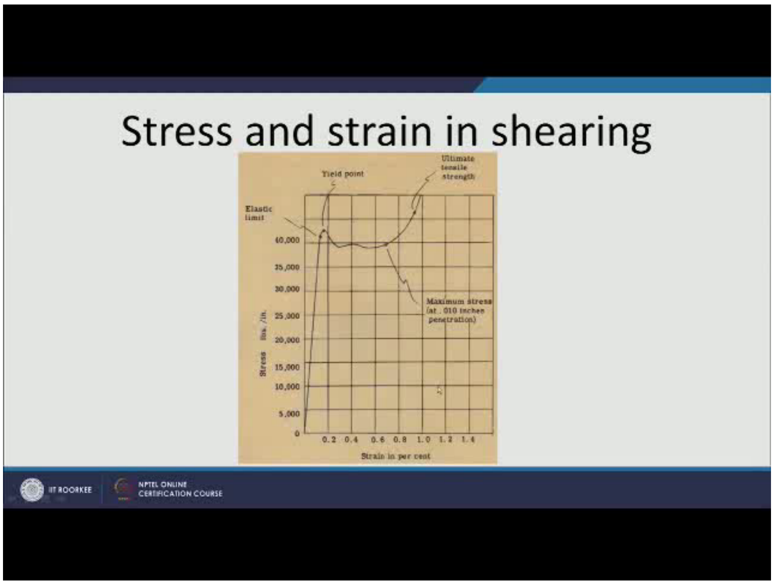

So, when what happens, when we see that the compressive stresses are applied on to the sheet metal during the shearing. We know that when the punch moves down, the stresses on to the sheet metal will be increasing continuously and which will be causing first the plastic deformation and then it will be leading to the penetration into the sheet metal. So, depending upon the kind of distance, which is being travelled by the punch inside the sheet, we get the different strains.

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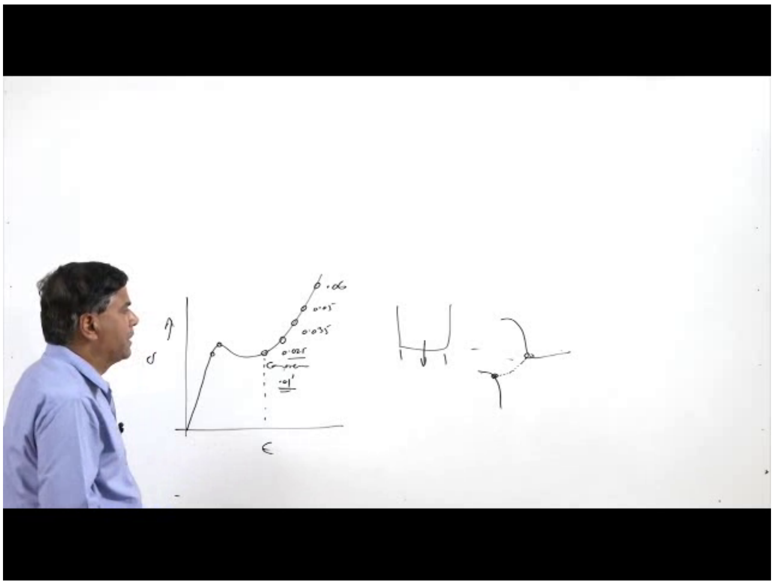

So, as the punch moves down, it will be leading to the increasing compressive strain into the sheet. So, this X axis is showing in the strain and the stress is on Y axis, then the diagram that is what we get, becomes like this. Here, this is the yield point. This is the elastic point and this is the like say plastic region, where say some compressive strain has been induced, that is of this much magnitude due to the entry of the punch into the sheet metal as the punch will go deep and deep into the sheet metal. This strain will keep on increasing at the same time. The stress is being induced will also keep on increasing and is stage, will arrived where the crack will start a nucleating and it's growth will continue. So, schematically, there is, this is say for one particular value of the strain or the penetration for one particular value of the penetration, say the punch is penetrating into the sheet by certain magnitude, say this is equal to the 0.001 inch.

So, for the smaller magnitudes it is a 0.01 inch so for the smaller magnitude initial entry causing the depth of the 0.01 inch. If, when the depth increases; obviously, the compressive strain and the stresses will keep on increasing. So, they will be causing more amount of the compressive strain. Say, this will keep on increasing like this and after reaching a particular value, say 0.05.

We will find that the crack nucleation will start from both the sides, from the lower side as well as from the upper side like this. So, from this end crack will start propagating and from this side crack will start propagating and both will meet at the center. So, with the increasing entry of the punch into the sheet metal the compressive strain as well as the stresses will keep on increasing and stage will arrive. When the cracks will nucleate both the sides and their growth will start.

So, that is what sequentially will be explained in the subsequent diagrams here. So, if we see this one, the Y axis is showing, the stress being induced and the X axis showing the strain being induced. So, for the entry of the punch into the sheet metal with the magnitude of the 0.01 inch, it results is this, a stress magnitude and this is the strain.

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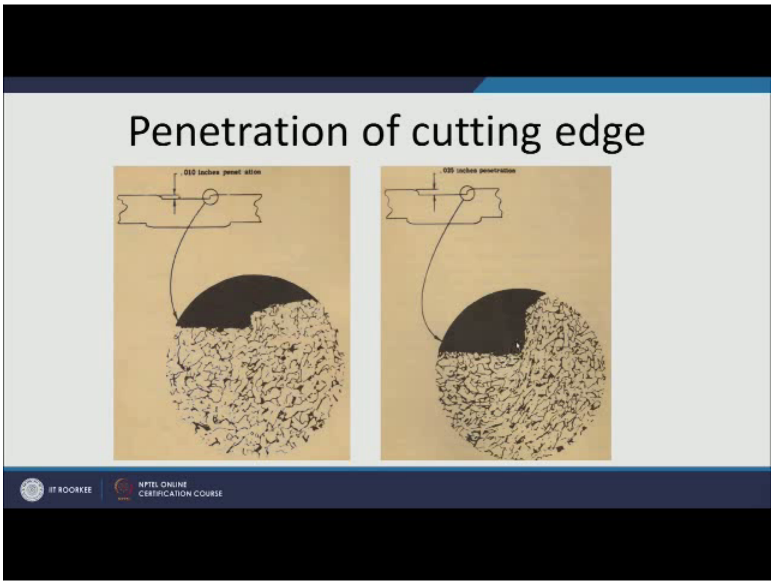

Then for the in, so, at this stage, what kind of the configuration is achieved, near the edge. Say, this is, this impression is being formed it to the entry of the punch into the sheet metal with the magnitude of the 0.01 inch that is the penetration. So, it causes little bit deformation of the grains in this area.

Similar, kind of the deformation will be occurring in the opposite way, in these two sides also and here, this side also. So, what happens, when we increase the depth of penetration increasing depth of penetration will be causing the more damage to the grains near the surface layers. If we further increase the depth of penetration like 0.035, then it will be increasing the elongation of the surface of the grains near the surface layer. So, all these are the grains, which have been elongated initially, if we see all these are equiaxed grains, but near surface layers having the grains, which are being elongated and with the increase of the depth of penetration, these elongation is increasing further. So, a stage will arrive when the cracks, when the grains, is start up fracturing and then that leads to the nucleation of the crack.

So, further increase in the point say with the 0.05 inch of the penetration, further increase in the grains. Grains have been elongated significantly and what happens when the penetration is increased.

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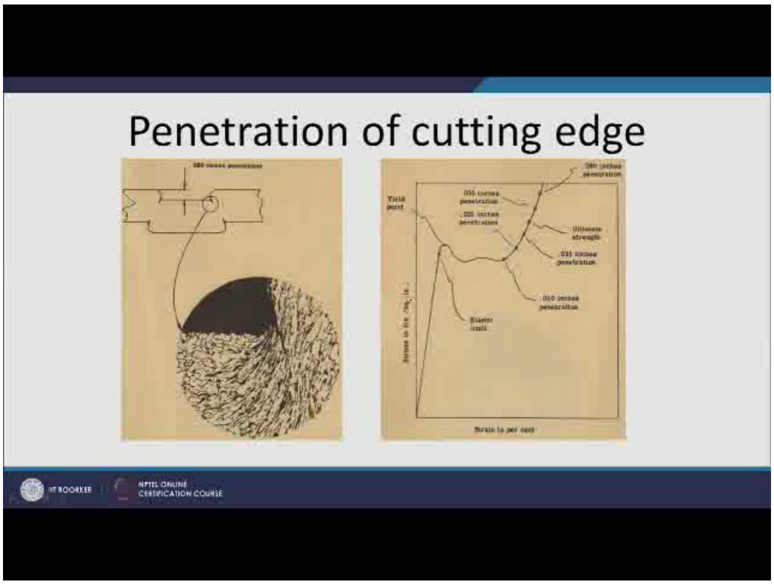

You will see that the grains have elongated to such an extent that some of the grains, near the surface have fractured and the crack growth has started. So, this process will continue, until the fractures coming from both the sides or cracks coming from both the sides meet at the center.

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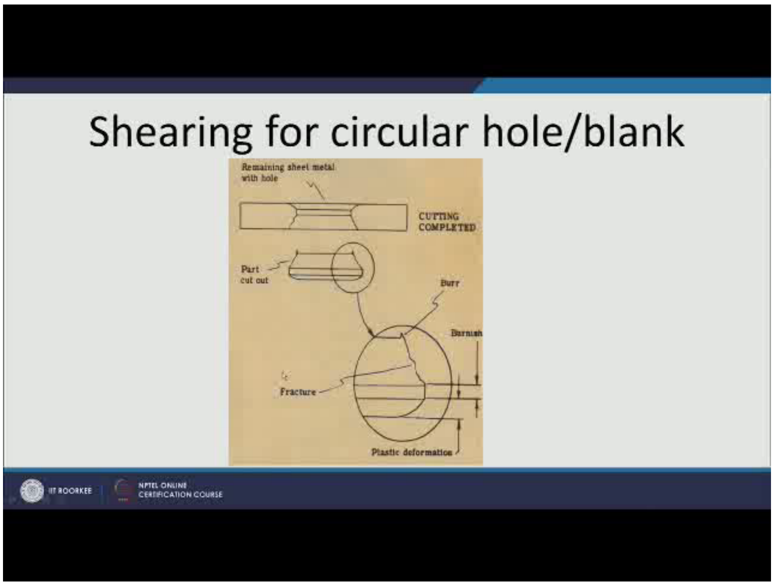

So, this is the kind of the geometry when the fracture completes. We get one, the part of the metal removed and this is the kind of the geometry of the hole, which is created. So, we will see that, this is not cylindrical hole, which is expected and similarly, the piece of the material, which is coming out of the sheet, which is like a scrap or the blank or the slug is also not very straight and square, but it has like disc shaped or the fracture surface and the burr, which we can see here in enlarged view, this is what I have already explained.

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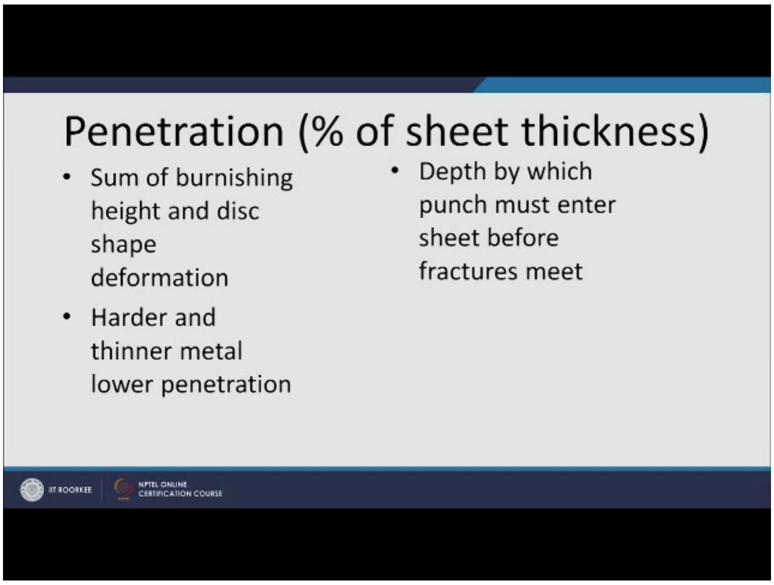

So, now we will see the penetration as I have said. So, what is the kind of penetration, which is needed for causing this shearing process. So, here, this is about the magnitude of the penetration like entry of the punch into the sheet metal by the 0.06 inches. Since, it is expressed in terms of the percentage of the sheet metal thickness. So, the penetration, which is normally required for shearing purpose into the sheet metal is expressed as a percentage of the thickness, of the sheet metal which as per the like softness or the hardness of the material and the thickness of the sheet.

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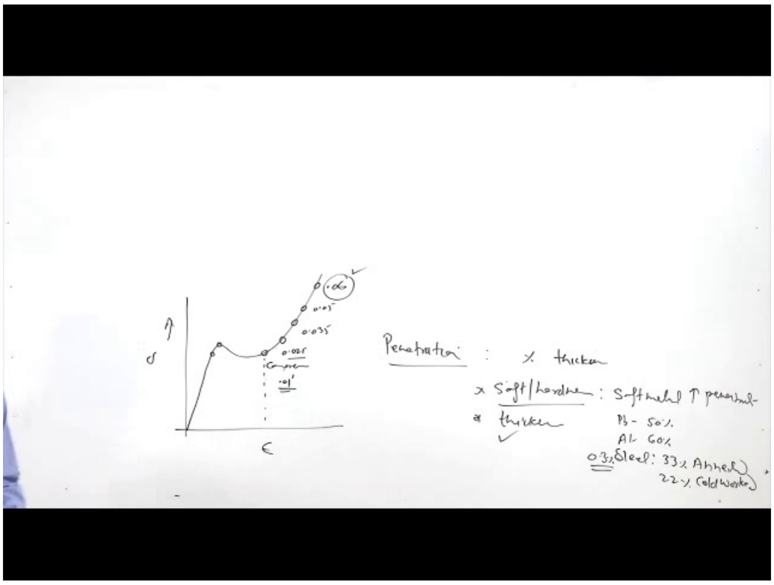

These are the factors which will be affecting the penetration. So, softer the metal, soft metals need high penetration for example, here if we consider the lead, the penetration required is 50 percent and for aluminum it is 60 percent and if we consider the steel having 0.03 percent carbon, then it will the required penetration is 33 percent, when it is soft and it is required like 22 percent, only when it is cold worked, means it is of the higher hardness and the higher and the lower ductility.

So, the strength or softness of the metal or the hardness of the metal, affects the sheet metal thickness. Similarly, for increase the thickness, greater the percentage of the penetration is required. So, this is what has been explained, the penetration is the sum of the burnishing height and the disk shape roll over zone or the deformation zone harder and the thinner metal requires, hard metal requires less penetration and the thin metals require less penetration and what is the penetration is the depth by which punchs, punch must penetrate the sheet before fractures meet. So, this is the monetary requirement for the shearing or for achieving the cut through the shearing process.

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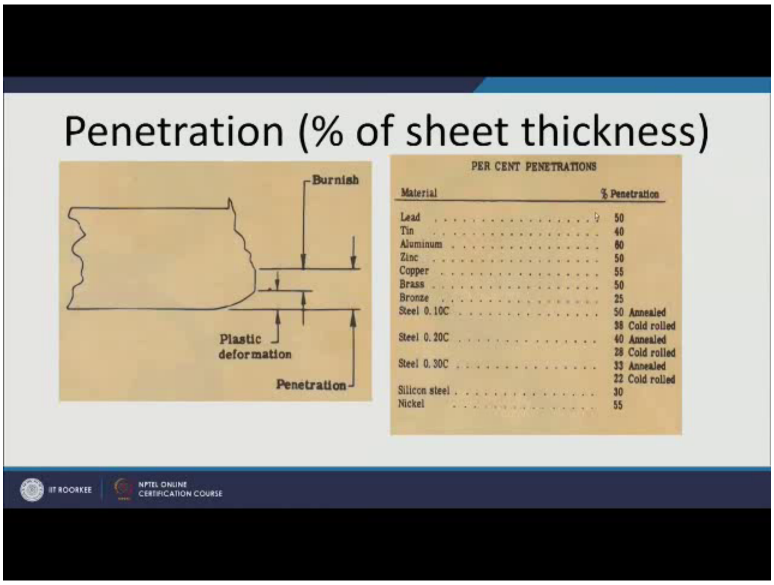

So, this list simply shows the kind of the penetration which is required for the different metals, like lead 50 percent, tin 40 percent, aluminum 60 percent, zinc 50 percent and say, for other high strength metals like silicon, steel 30 percent, nickel 55 percent and like a among the steels also low carbon steels will be requiring, higher penetration as compared to the high carbon steel.

For example, steel of the 0.1 percent carbon needs the 50 percent penetration, in anneal condition. While for 0.3 percent carbon in anneal conditioned. It needs 33 percent. So, similarly, if we compare the annealed and the cold rolled, we see 0.1 percent, carbon steel requires 50-50 percent. Penetration in annealed conditioned, while that is 38 percent in the cold rolled condition. So, depending upon the thickness and depending upon the hardness of the material, the different amount of the penetration is required.

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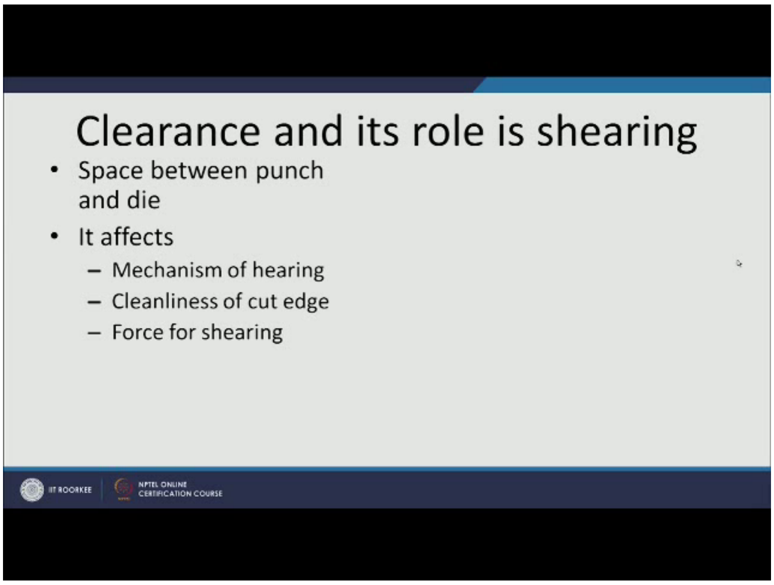

Now, come another important thing is the clearance, which facilitates the proper shearing of the metal.

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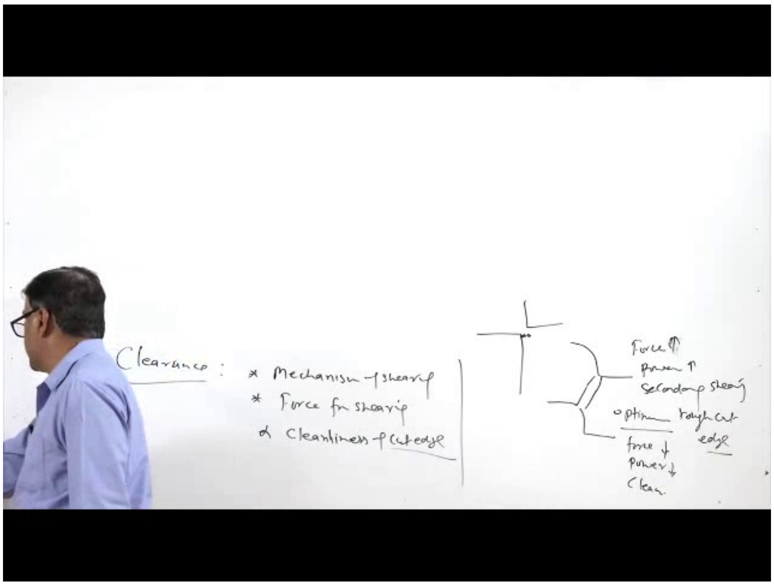

So, as I said the clearance is another important thing which significantly governs the kind of the cut edge. So, the role of the clearance is what it affects, the mechanism of the shearing. It affects the force required for shearing force or the power required for shearing and cleanliness of the cut edge is also affected by the clearance.

So, if we see the mechanism of the shearing, when like if the gap is gap between the punch and die is optimum then, it will be leading to the propagation of the crack from both the sides and which will be meeting at the center. So, this is what is called optimum. It will be leading to the optimum clear, is this will be achieved when the clearance is optimum and the force required is less power required is less and if the cut is very clean, while if the, if the gap is too less, when the gap is too less means the gap between the punch and die is too close, in that case we may find that these cracks coming from the two sides may not meet each other at the center.

So, they bypass each other and in that case our the force requirement, increases power requirement, increases as well as the secondary shear is takes place, like the shearing, which is due to the shearing the cracks coming from both the sides do not meet at the center. So, they will be leading to the, like the secondary shearing and this causes the rough cut edges.

So, the rough cut edges are produced when the clearance is less than the optimum 1 and when the gap is too close, then it will be leading to then, it will be leading to, then it all will also be leading to the secondary shearing and very rough kind of the cut edge even there may not be the shearing.

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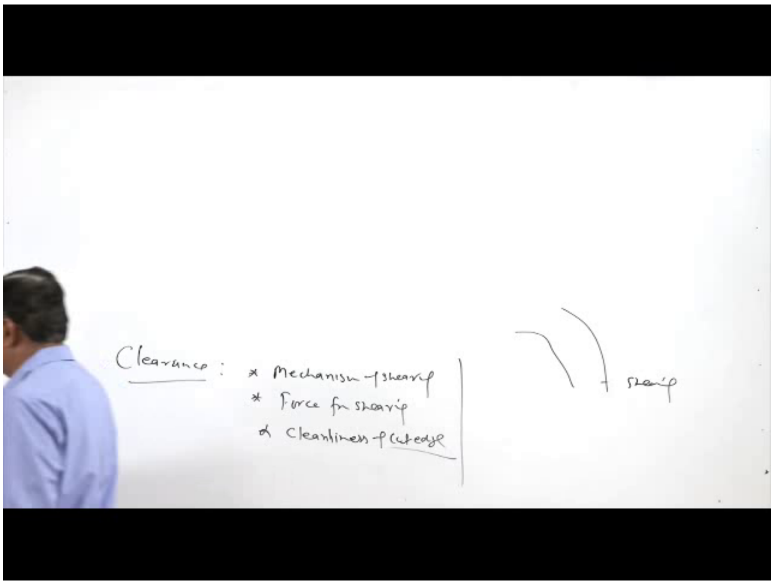

So, the control of the clearance is important for having the very clean cut edge and proper at growth and the propagation of the cracks, from both the sides. So, that they meet center and minimum force and power requirement for the shearing purpose.

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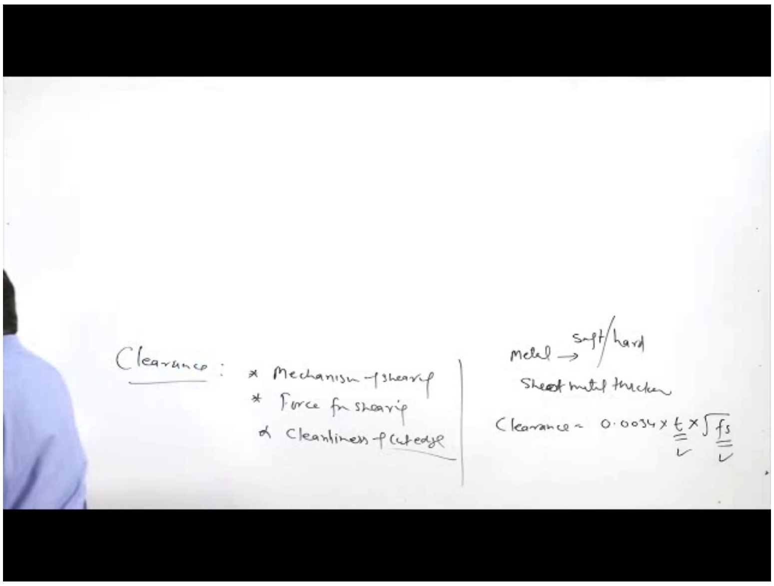

So, clearance depending upon the sheet metal, depending upon the metal, which is to be processed like whether it is soft or hard, the clearances is suitably selected. This is one and it also depends upon the sheet metal thickness. So, both of these factors are clubbed. So, clearance is given empirically using the equation like 0.0034 multiplied by t, t is the sheet metal thickness in mm and square root of the fs shear strength of the material. So, here the material shear strength thickness of the sheet, both are considered for calculation of the clearance which is needed.

If we go by the sum rule, then for soft metals and for hard metals, the different clearances are used and it is also expressed as a percentage of the sheet metal thickness.

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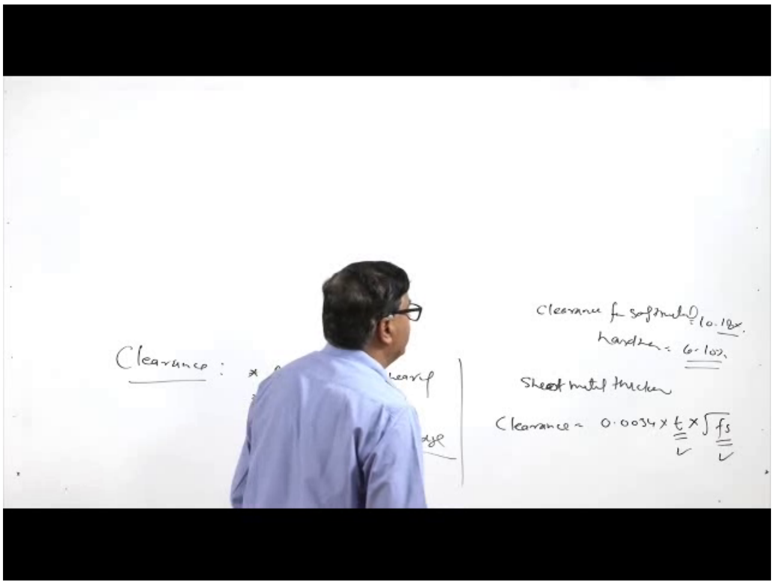

So, clearance for soft metals is found more, that is like say 10 to 18 percent and for hard metals; it is like 6 to 10 percent. So, lower clearances are used for the hard metals and more clearance for the soft metal and similarly, apart from the sheet metal thickness the metal shear strength also effects the selection of the clearance. So, optimum clearance is important for having the clean cut edge and minimum force requirement. The, now I will just plot the kind of the force like the force versus, the time curve which is achieved during the shearing.

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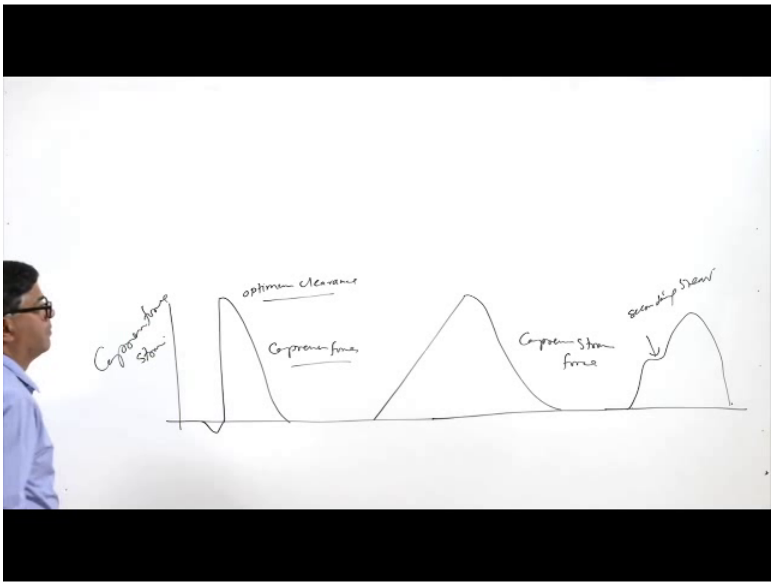

So, the curve comes out to be like this, when very optimum kind of the optimum clearance is used. Then a very clean vertical means continuously increasing compressive force. This indicates the compressive force variation and when very tight clearance is used, in that case it results in very inclined kind of the force variation and then . So, this also indicates the compressive strain or compressive force generation, as a function of the time during the shearing and when it is a, it is less not very less, but it is less than the, that is required, then it leads to the variation in this manner.

So, this kind of the deviation indicates the secondary shear and also. So, both. So, all these, this is a scale is like compressive force or the strain during the shearing process. So, now here, I will summarize this presentation. In this presentation, we have talked about the different kind of the stresses, which are induced in the sheet metals for performing the different sheet metal operations, shearing is one of the very commonly used mechanism for a sheet metal processing and. So, the mechanism of the shearing and the role of the penetration and the clearance has been talked in the shearing process.

Thank you for your attention.