Principles of Metal Forming Technology
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Lecture - 02
Classification of Metal Working Processes

Welcome to the lecture on Classification of Metal Working Processes. So in this lecture we will talk about the different types of metal working processes the different ways by which they are classified. So, the metal working process creates useful shapes by plastic forming processes and control mechanical properties.

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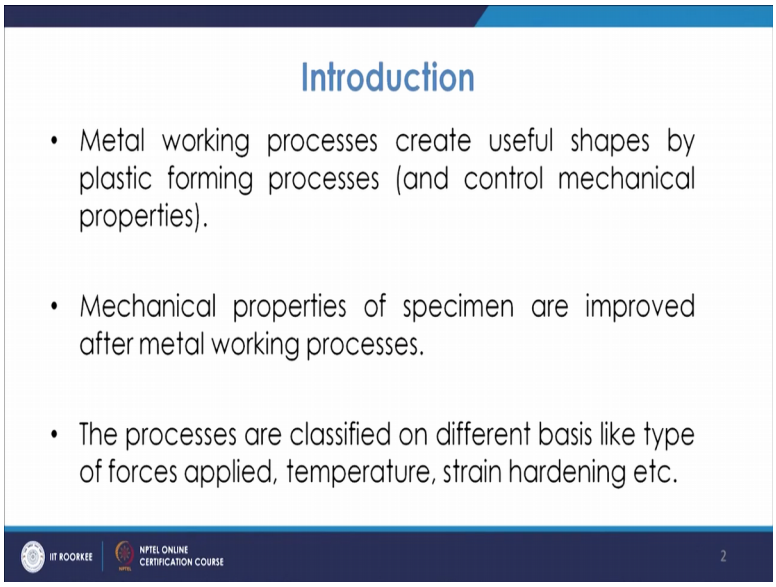

So, we have already you know studied about it that we use the plastic forming, we go the forming in the plastic state and then do the forming. So, mechanical property of the specimen are improved and certainly they are classified on different bases like type of forces applied temperature strain hardening etc.

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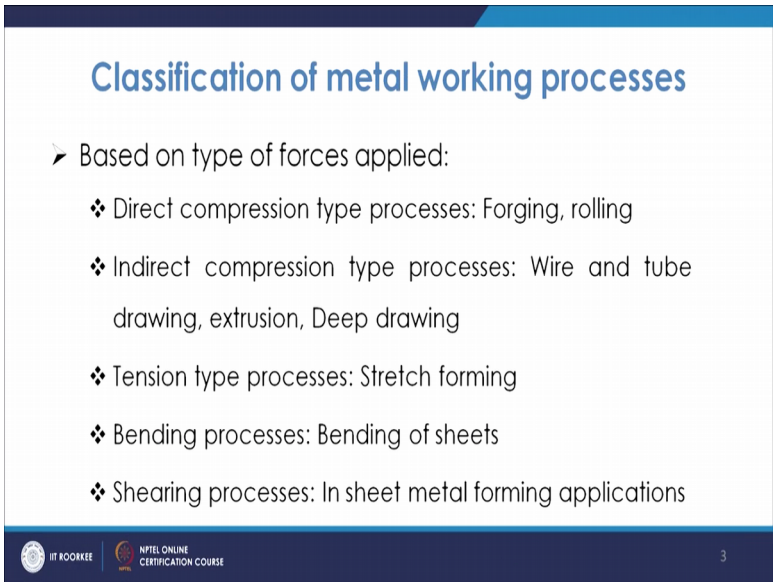

So, let us see that how they are classified? Now as we know that in the case of metal forming there are many things like the force we apply, the force may be applied in different way and it is basically working on the specimen in different way, different in the different ways the stresses are generated and because of that the deformation takes place, So depending upon the type of forces which are applied you have one is direct compression type processes. So, under that basically you are applying the compressive forces because of the direct compression type stresses developed you have the deformation of the material taking place and forging and rolling is its example.

Similarly, indirect compression type process, so in this case normally what we do is we apply the force normally in a tensile way and what happens that at the point where you have suppose, die and the work piece it has certain you know reason where the interact. So, at its interface so they are basically indirectly compressive type of stress develop and then that basically does the failure of the material at that particular point and the deformation takes place.

So, basically we are not directly applying the compressive force we are indirectly basically the compressive force is applied and that basically creates the deformation and its example is wire drawing or tube drawing. So, as you know that in wire drawing you are pulling and then at the die exit you know and there when where the bar or the fillet

which is in contact at that point the compressive stresses are developed, compressive forces are developed.

And because of that the local failure takes place and then the material comes out, so that is your in direct compression type. Similarly tube drawing extrusion also the same thing and deep drawing, so will discuss about them. Then tension type processes where normally because of the tension force this deformation takes place an example is stress forming, where you form block and you are applying you are you are stretching a sheet in that case so it will due to the tensile stress is developed that deformation takes place, so that is stretch forming.

Bending processes where we apply the bending moment to bend the specimen and in that case the material bends, so that is bending process. Similarly shearing process an shearing process you will have blades, so you will have the from the top and bottom you have two blades and they will be shearing or cutting. So, because of that the failure takes place and then the deformation takes place, so that these are basically the different types of forces, because of which the deformation takes place and we will talk about them one by one.

So, first is the direct compression type forces, now in this the force is applied to surface of work piece and then and metal show takes place at right angles to the direction of compression. So, in this case the example is as we discussed it is forging and rolling so if you see this is forging and this is the rolling.

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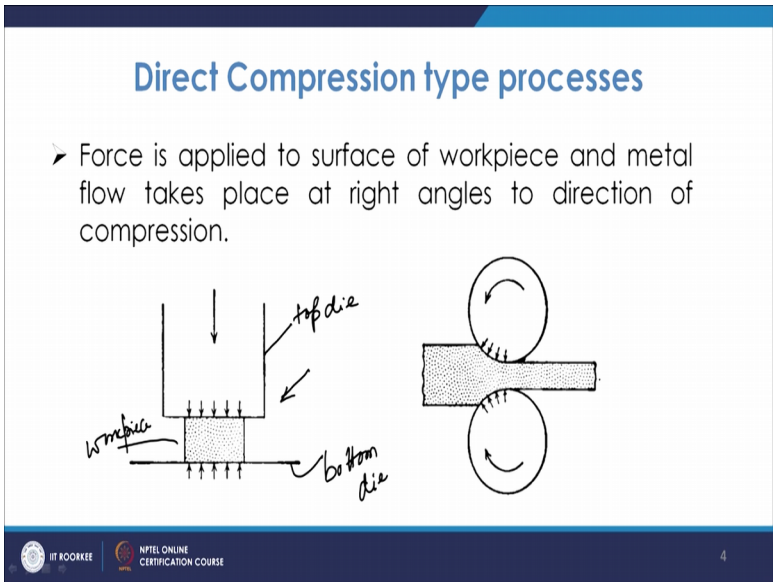

Now, in this case as you see in forging you this is the top die and this is the bottom die. So, you apply the pressure from here you apply the compressive force as you see and this job is subjected to the compressive load and then because of the compressive load the material deforms and it goes. So you are applying the you know force in the vertical direction or z direction and the material if you are keeping one of the dimension constant from both the sides then the material will be flow in x direction. So this way the flow will take place perpendicular to the direction of the applied compressive force so this is the normally case in the case of direct compression type process.

So, coming to the direct compression type processes, now as we discussed that we apply the force to the surface of the workpiece and metal flow takes place at right angles to the direction of compression. So the example is forging and rolling, so what we see this is this is the forging process and this is the forging process and this is the rolling process. So what we see is that in this process is this forging process this is the top die and this is bottom die and the workpiece is kept in between and so this will be your workpiece, so this is your workpiece. Now, the workpiece basically will be subjected to this compressive force from the top from the top so you have the reaction, so you will have this is subjected to the compressive stress.

Now, because of that what happens that this material will deform, now the thing is that it with since it is it is constant from both these sides. So, it cannot expand in the vertical

direction. Now, the further thing is that it will be expanding either in the x direction or the y direction, if it is the z direction in that case it will be changing in x or in the y direction. So, that way basically you are applying the compressive force in the z direction and it is able to flow in x or y directions is perpendicular to z direction. So this is because of the direct compression type of forces and these deformation takes place here.

Similarly, direct compression type force is also applied in the case of rolling, so in the this rolling process is very common in the case of industries where you are trying to decrease the cross section of the larger you know your products like you have (Refer Time: 08:43) or plumes or so. So in that case you are passing it through the two rolls, the rolls are extremely hard and they will be rotating in opposite direction. So, what happens when they come in contact with this job then they are applying the compressive stress and in that the material will be compressed and then they try to flow through the exit.

So, if you look at the compression here so it will be compressor in the vertical direction and then material flows in the in horizontal direction or so. So basically these are the examples of the direct compression type of forces and the forging and rolling is the example of such process. Then you have indirect compression type of forces, now in the case of indirect compression type forces normally you primarily apply the forces which are tensile, but then in the direct compressive forces are developed because of the reaction of the workpiece with the die and there is very very high value.

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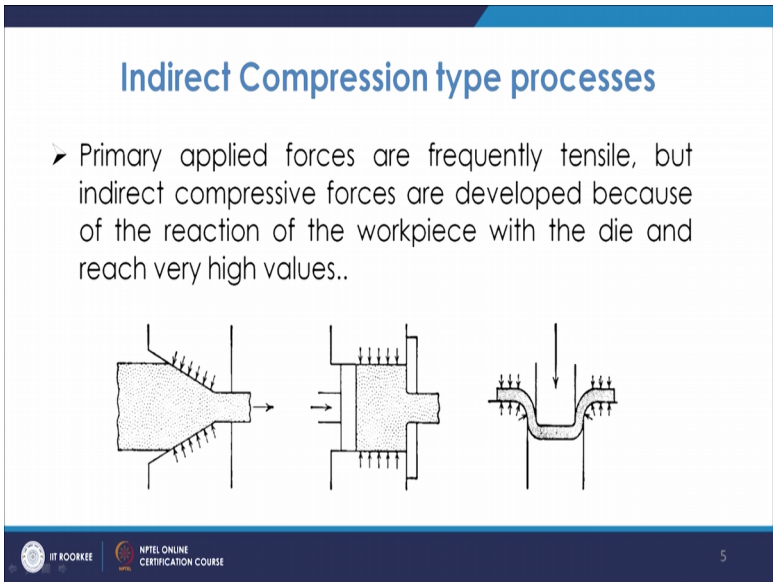

Now what will be happens in these cases like this is your tube drawing I mean this is wire drawing, so in the case of wire drawing what we see is you apply the force in this direction you are basically pulling. So, you are primarily you are taking the tensile type of primary primarily you are applying the force.

But then what happens this is the die, so this material billet or so. Now, it is in touch here, so once you pull here from here once there in touch there will be reaction forces generated. Now, the reaction force which is generated at the workpiece and the die interface here so because of the basically what happens that force is normally compressive in nature and because of that when the stresses reach more than the yield limit in that case the material deform starts deforming and then the material will flow through this orifice, so that you can draw this rod.

So this way where you can where you can draw, so wire driving is an example of indirect so ultimately you are pulling like this, but then the stress because of which the failure is taking place is basically compressive stress, so that is why we are indirectly basically able to generate such stress because by the tensile forces, so that is why it is indirect compression type. Another example is also the you know extrusion, so in the extrusion as you are applying the force like this and then because of this reaction here you have compressive type of stress developed and then it material fails and goes to this direction.

So this is also example of indirect compression type of process the other example you may be looking at the that is the drawing of the cup and if you look at here, here also you are applying the force like this. And then you see that here you have the reaction forces acting and this is basically compressive in nature and because of that the deformation is taking place and it moves towards the bottom. So these are the example of indirect compression type processes. Moving further you have tension type.

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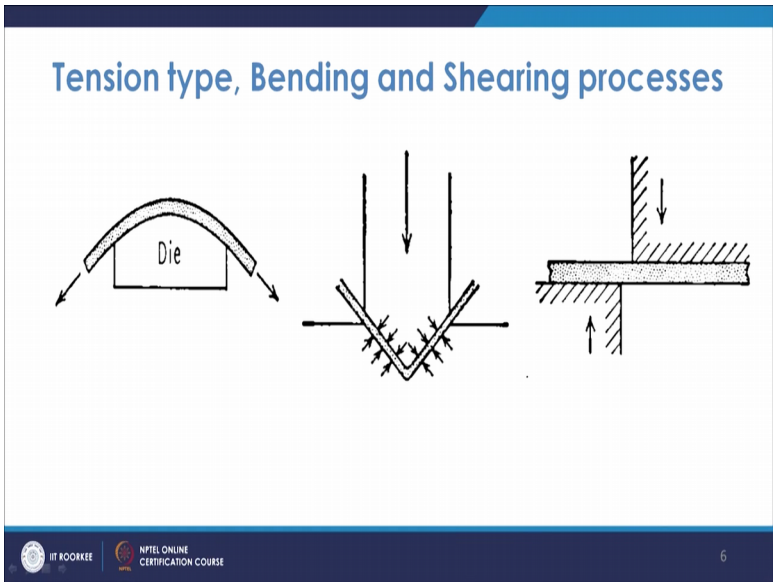

So, the stress forming is the example of tension type of forming process, where are you have these being stressed from both the sides and you have form block die. So, it will be stressed because of the tensile type of force which is there primarily and then that is why it is tension type of forming process. Similarly where you apply the bending moment in these cases and you see that with the help of this punch you induce these bending at these two places because of the bending moment created and so this is under the bending type of forces.

Similarly, you have the shearing process where you have these blades so top and bottom and once they will move in the bottom end the reaction will be there at the top. So at this point there will be shearing taking place are shearing taking place and cutting. So basically bending and shearing process normally they are applied in the case of the sheet metal forming processes and in the case of sheet metal forming processes typically you

go for such process like you have punching, you have blanking, that that bending of the seats and all that so they are these processes are basically utilized more and more.

So then another classification is based on you know what kind of you are doing, so what happens is that sometimes you are reducing the larger dimension to smaller dimension not the final dimension you are achieving final step you are achieving. So when you are reducing the larger dimension product like ingot or billet to standard mill product of simple shape such as sheet, plate and bar so that is basically the primary metal working processes.

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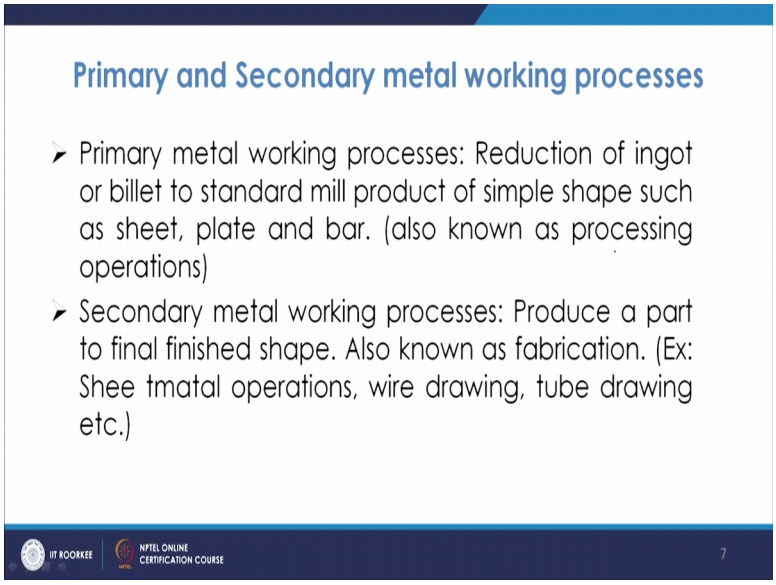

So, you are you have just like you do the rolling, forging or so intermediate one rolling basically. So those processes are where you are basically reducing the largest dimension of the product to the smaller dimension simple shapes than that is your primary metal working process and then when you are going for the final finished product, so they are known as secondary metal working processes.

So, in this case what you do is you have to finally, get the final shape so the finishing is there like the sheet metal operations, wire drawing, tube drawing all these are the one which are the example of such processes. So in such case you see that finally, you get the final shape and the example is like wire drawing, tube drawing etcetera also these primary metal working processes where are you reduce the ingot or billet to simple shapes they are known as processing operations and this is known as the fabrication

operations. So, normally it will be done on the largest size products largest size you know sample like billiards or the ingots and here it will be done on the sheet metals, so that is known as fabrication. So, we talk about fabrication operations that is secondary metal working operation.

Then we already discussed that you have the classification also based on the temperature of deformation and the temperature on the basis of temperature it is defined as either hot working or cold working. So, as you know that there are two main purpose of doing the deformation one is the reduction in dimension as well as the improvement in mechanical properties and many a times the improvement in the strength. So, the deformation when we do at high temperature for getting larger deformation then it is known at as hard working or hot forming processes and it is done at sufficiently high temperature.

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Deformation Temperature	Typical Processes
1. Hot Working Processes	Done at a sufficiently high temperature such that continued deformation does not result in increased hardness. Example: Hot rolled steel. Surface finish and tolerances are inferior to cold working processes because of surface reactions (oxidation scale etc). Deformation forces are low.
2. Cold Working Processes	Strain hardening effects predominate over thermal recovery effects. With continued deformation, the hardness and strength increase and the ductility decrease. It results in an elongated grain structure and can be used to harden metals and alloys that do not respond to heat treatment. Example: Cold rolled steel. Excellent surface finish and tolerances. Deformation forces are high.

So, in that the deformation will be more, but the hardness will not be more hardness will not be increased, so also the surface finish and the tolerances are inferior. So we have discuss that in the case of hot working since we are dealing with high temperature, so that will be at high temperature and our chances of the scale formation and you cannot control the surface finish and also the dimension to a very precise value. So, basically in that your surface finish and tolerances are inferior as compared to cold working because in cold working it is done at lower temperature, so they are the finishes better also there are surface reactions like oxidation scale and all that, so that is that.

Another hot working is that, the deformation forces are low in such cases when you increase the temperature the material becomes its strength becomes less. So, the force which is required to deform the workpiece is low so you can go for larger degree of deformation. Whereas, when you go for the cold working at as the temperature comes down the strength becomes higher. So in that case the requirement of the load becomes larger, so that there is a limitation up to what degree of cold work you can go for. So in the case of cold working process the strain hardening effects predominate over thermal recovery facts.

So, as we discussed that the main difference between the hot working and the cold working is that is this recovery effect. So what we see so this is the this recovery effect, now this recovery effect is dominant in the case of hot working. What is this recovery effect, because what happens that when you are applying the forces on the body or on the sample then the grains are started the grains will experience the strain and then there will be a strain crystals. Now, when you are heating when you are heating to higher temperature and when you are forming, now at that particular high temperature the those any amount of you know strain field which is generated or the stress which is generated so that is relieved basically and that is why the crystals are strain free.

So, that is nothing, but the recovery fact so the recovery will be there in the case of hot working and in the case of cold working this recovery does not take place. So the thing is that when you do the cold working the material gets strained every further you grow a cold working it will be further strained, so the stress which is generated in the material hardness will go on increasing. Whereas, in the case hot working that does not increase because it is done at higher temperature, so that there you have strain free crystals every time as the temperature is higher than that recrystallization temperature, so this is main deform I mean difference between the hot working and cold working.

So, with continued deformation the hardness and strength increase and the ductility decrease. So in case of cold working when you are going for the cold work every time the strength will increase, hardness will increase, but that will cost the ductility to certain extent. So ductility will be decreasing so it results in an elongated grain structure and can be used to harden metals and alloys that do not respond to heat treatment. So many a times those materials which do not respond to heat treatment you can go for such

treatment to such metals such materials and get their properties improved, example cold rolled steel or so.

Excellent surface finish and tolerances and deformation forces are high, so as we discussed that when we are dealing with the material at higher temperature as well as at low temperature at lower temperature the yield strength is higher. So, for deforming you require larger and larger forces and as you go on cold working every time you do the cold working the strength will be increased.

So, you require larger stress further to deform so deformation force will go on increasing you know as we go continuously deforming the material. So, there is a limit of the degree of the formation in the case of cold work because you need very very high powered equipment. Also if you try to do the you know cold forming cold working beyond certain degree then the material may be broken, it may be it may result into fracture, because the brittleness is induced in the material.

So this is the basically difference between the hot working and the cold working, now that is basically depending upon the temperature and this temperature is a recrystallization temperature as we discussed and this recrystallization temperature is normally 0.5 to 0.6 times the melting temperature of the material in Kelvin. So if you take about the iron or so about 1000 degree or so in case of steel and low carbon and medium carbon steel, in case if it is the formed above that that it is the hot forming and below that it is a low which will low I mean hot working or it is below that it is cold working.

Now, the thing is that many for many metals if you look at the recrystallization temperature it is not very high value. So, even the room temperature may be the hot working temperature, so you have to keep in mind that so in those cases that is cold working itself or hot working itself if you do at the room temperature. Whereas, in the case of iron you have to go for very high temperature and even if you go at 600 degrees centigrade it is type of cold working, so that depends upon the material properties. Now, we need to know about the deformation processing system.

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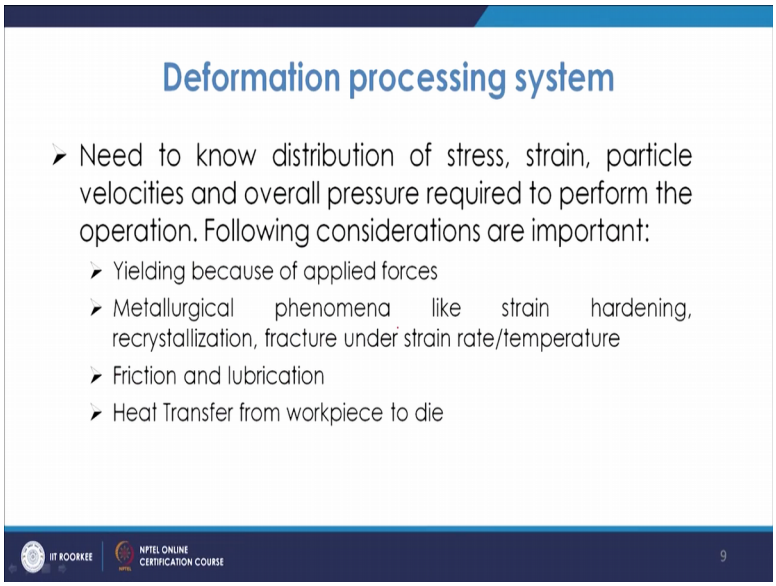

So, what is the deformation processing system? So when we talk about the deformation processing system I mean it is a domain where your you have to pin point that what you have to study. Now when we talk about any deformation process what is typically there in a typical deformation process.

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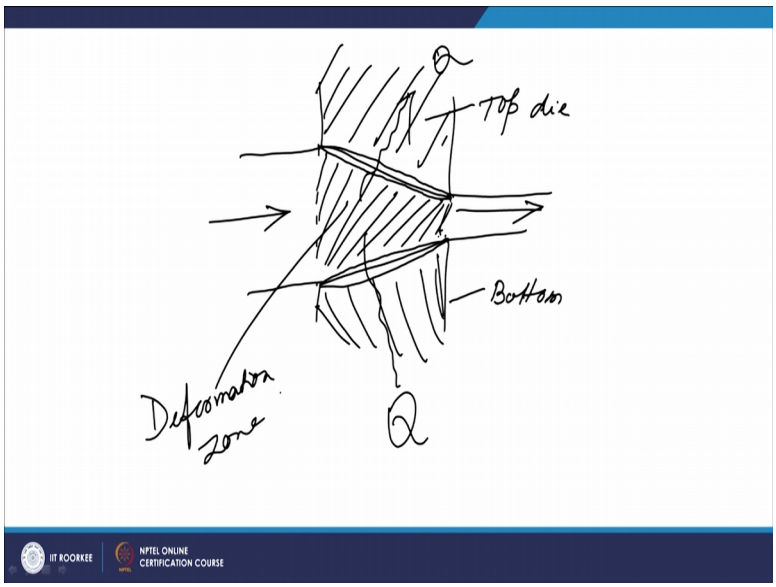

So what happens that you have suppose such is the material such that this is the die, so this is your top die and this is your bottom die and you are allowing some material to suppose go there and then it will go through it.

So, the thing is that what happens that this is the die and surface workpiece, so basically this zone is the lubrication zone, lubrication zone is developed here and similarly you will have lubrication working here itself. Similarly you have you know if you look at this zone this is this zone is basically the deformation zones. So this zone is known as the formation zone.

So this is the zone known as the deformation zone and this is your top die, similarly this is your top die and from here is a material is pushed and it comes like this. Now, the thing is that you need to concentrate on this zone and you want to find what is the stress, strain value velocity, what is the pressure required to deform all that you need to know.

Now, the thing is that when the material which you put is heated here so what it will do it will be releasing the work heat to this side. So basically there are many things happening in this zone and this zone is known as deformation zone.

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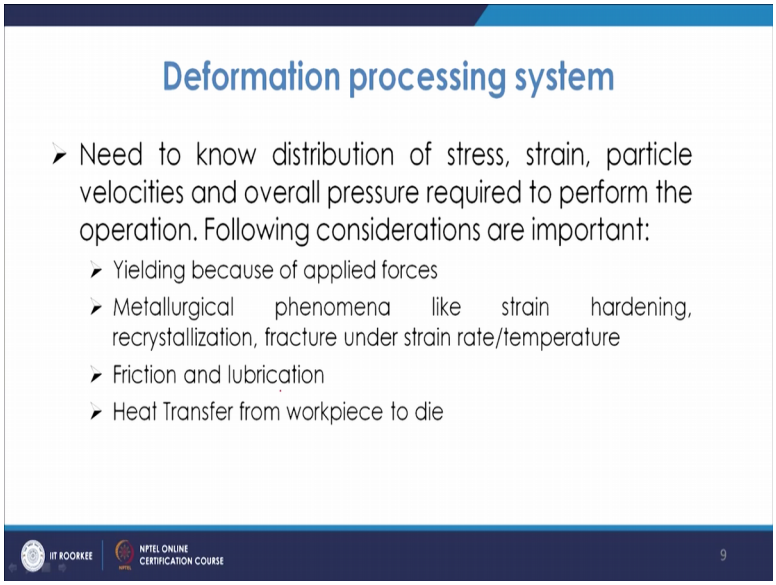

So, in this is what we do in the case of deformation processing system, we need to know the distribution of stress strain particle velocity and overall pressure required to perform the operations. So, that is what we need we need to find the stress strain velocity and also the what is the pressure required to perform the operation, so based on that you can design the equipment so that you will be doing the successful forming operation.

Now, for that there are many things many consideration which are important there will be yielding, because of the applied forces in the deformation zone. When you are applying the forces then the materials in the stress value will reach beyond or equal to the yield point value then the material will yield. Similarly there are many metallurgical phenomena like you have strain hardening recrystallization fracture under strain rate and temperature.

So you have there are many parameters which are to be taken into account like depending upon the temperature condition you may have these strain hardening effects, you may have the recrystallization effects, also the fracture will be there under the strain and strain rate and temperature. So, they are strain is there, strain rate is there and temperature these parameters affect basically the fractured behavior in one sense. So, you need to have a I mean concentration of all these effects you have friction and lubrication going on so as we discussed that at this place when it enters into it, there will be friction forces and then you are applying the lubrication system here.

So, this also need to be and tackled when we talk about the deformation processing system, we need to see that how much friction is generated friction forces are required so that the material goes into this and then the slowly it will come at and then it comes out here. So, basically when we talk about the different type of processor we will see that how this friction forces play the role in pushing the system into in between the rolls and between the dies and then how the friction is you know generated. What will be the frictional forces amount because depending upon the reaction amount you can have the frictional amount, what is will be the maximum friction or minimum friction which is required. So, that is another consideration which has to be kept in mind in such cases.

Then there will be heat transfer from the workpiece to the die, so that is what we have seen that your heat will be transferred from this side and it will going into the die. So from the workpiece it will go because it is in increment contact with this, so heat will be transferred so all these considerations are required to study about the deformation processing system.

So, as we discussed about the different processes we will see that how the deformation goes, which zone you have to confined yourself to study about the processes and to find further the value of pressure or stresses required to deform, velocities at different points,

strain or stress at different points or so. So this is how we analyze the different type of forming processes that we will do in our coming lectures.

Thank you very much.