Fundamentals of Manufacturing Processes
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Lecture - 25
Metal Working Processes: Hot & Cold Working

Hello. I welcome you all in this presentation related with the subject Fundaments of the Manufacturing Processes. We have talked about the casting based processes. And today onwards we will be talking about the Metal Working Processes for manufacturing of the metallic components.

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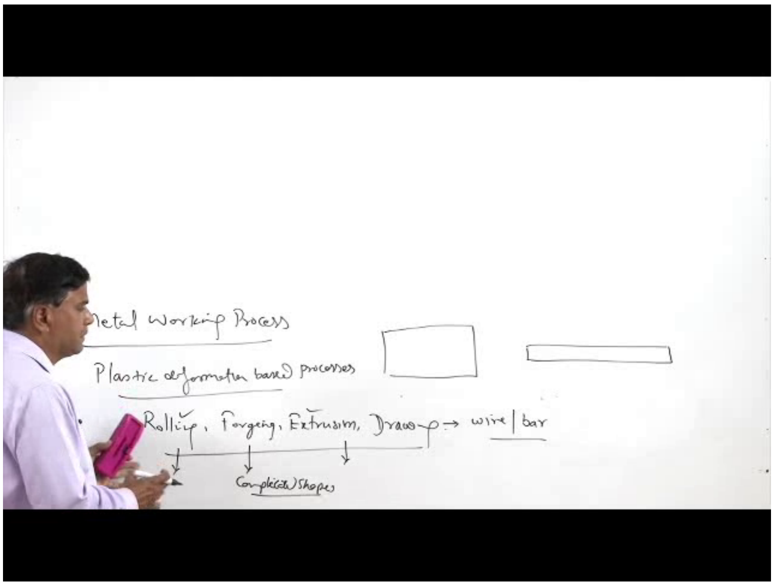

So, here these are basically the plastic deformation based processes. Means, in this group of the processes basically the desired size and a shape is achieved by applying the force to the metal or the bulk material so that required deformation is achieved and that plastic deformation of the material results in the shape which is desired. Like say this is the strip and if you want the strip of the smaller thickness, but of the greater length then by applying the processes like rolling or extrusion this kind of shape can be changed, but this will primarily be based on the plastic deformation.

So, for achieving the plastic deformation we need to apply the force so that the stresses acting on the metal are greater than the yield stress of the metal which is being processed. So, using the external forces basically the metal is plastically deformed so that the desired size and shape is achieved in metal working based processes.

So, here the common names of the processes which fall in this category are like a rolling, forging, extrusion, drawing; so these are the most common a plastic deformation based processes which are used for the different purposes. For example, the drawing is used for making the wires and the bars while others these are used for making the a complicated shapes. For uniform cross section components of the uniform cross section along the length both rolling and the extrusion based processes are used. So, rolling is used primarily for the simpler shapes as compared to that of the extrusion.

As I said the plastic deformation is needed in these processes in order to achieve the desired size and shape. So, the factors which will be affecting the plastic deformation will eventually be affecting the efficiency of the processes.

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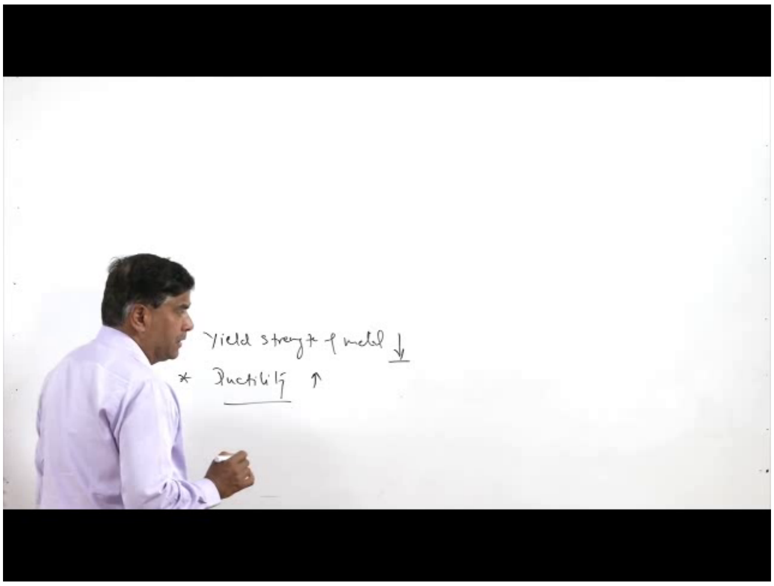

So, like ease of the deformation for the metal in these processes is influenced by the yield strength of the metal and the ductility. For ensuring that metal is deformed plastically by application of the external force in these processes the yield strength of the metal it is good to have the lower yield strength of the metal and the high ductility.

So, if we have to deform the metal of the high yield strength and the low ductility then the high a forces will be needed, high power consumption will be there in order to achieve the deformation. And if the ductility is very limited then it may not be possible also to achieve the plastic deformation.

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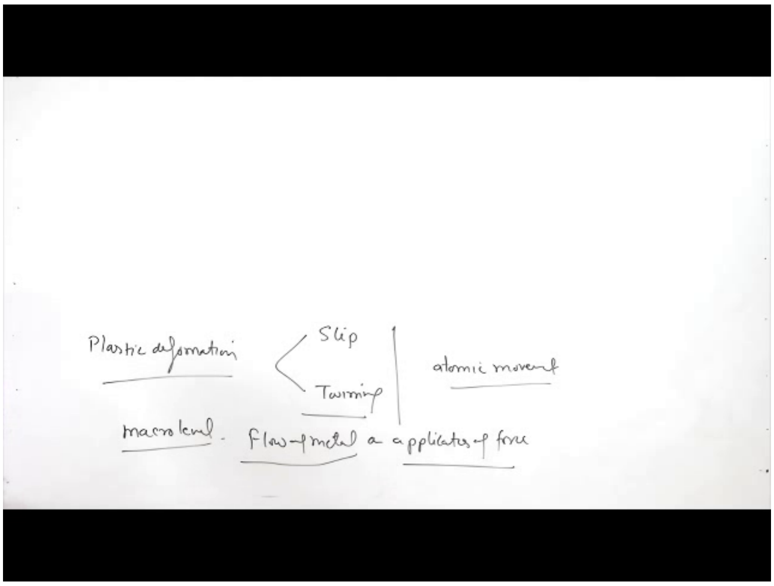

Now, microscopically the plastic deformation; plastic deformation microscopically is achieved through the two mechanisms these are called slip and the twinning. So, these are based on the atomic movement under the application of the external forces. So, this is what is there at micro level. But, at macro level the plastic deformation basically involves the flow of the metal. So, flow of the metal as per the direction of the force or application of the force.

So, the force is applied to cause the plastic deformation. So, as per the direction in which force is being applied the metal will be flowing to facilitate the plastic deformation. So, when the metal flows during the plastic deformation the crystals will be orienting in a particular direction.

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Say in a simple ingot which has been made by the casting the structure will primarily be equest, but when it is subjected to the plastic deformation in that case say this is rolled down to the smaller thickness. This large thickness is rolled down by passing through these two rollers. And so thickness is reduced and length is increased. So, in that case the grains will be elongated like this in the direction of the rolling or the direction in which the flow of the metal will be taking place. So, this is called the orientation or the flow of the grains in one particular direction.

So, this will be leading to the certain favorable as well as unfavorable effects. For example, like if the metal in initially had some inclusions and the porosities. So, then these inclusions will be broken down. So, due to the extensive plastic deformation in the direction of the flow of the material the inclusions get broken down into the small pieces. So, the inclusions will be present in very discrete manner and they will be present in the entire mass of the metal. So, that intern will be reducing the severity of the effect of the inclusions.

So, one thing which happens is that the inclusions and impurities are broken down and they are well distributed. So, when it happens we find the improvement in properties. If there are porosities in the metal which has been produced by the castings then these porosities will be collapsed. So, pores will collapse and increase the density of the metal. So, this is another favorable thing which is achieved that the pores and the gas pockets are closed when the metal is plastically deformed and allowed to flow in particular direction as per the method of manufacturing, so this intern increases the density of the material.

Additionally, whenever material is plastically deformed depending upon the temperature strength is increased. So, this is increase in a strength is achieved by the different mechanisms say in case of the hot working conditions the fine grain structure which is developed due to the deformation leads to the improvement in mechanical properties. While in case of the cold conditions if the deformation is carried out then strain hardening leads to the improvement in mechanical properties of the material.

So, these are the advantages which are achieved that a strength is improved porosities are collapsed and which intern increases the density. Inclusions and impurities are broken down and they get well distributed in the mass, so which intern reduces their severity on the effect on the mechanical properties. And so the properties are improved further. These processes help to achieve the desired size and a shape without any loss of the metal. Because, in this case mostly the shifting of the metal from one region to another takes place and actually there is no loss of the metal during the processing using the deformation based processes.

So, the metal wise it is the metal efficiency of the process in terms of the metal consumption is very good, because the losses are extremely less. Especially, little bit losses may occur in case of the hot working based processes where oxidation and scaling of the metal will be taking place at the high temperature and which may get removed. So, in order to facilitate the plastic deformation in metal working based processes normally the heating of the metal is carried out so that the deformation can be achieved easily.

We know that at the room temperature yield strength of the metal is high and the ductility is low.

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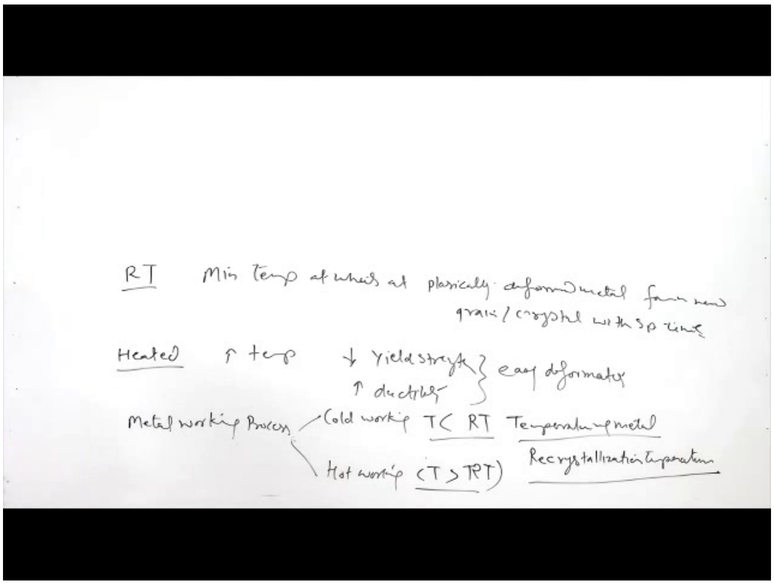

So, when a metal which is to be deformed plastically is heated. So, application of the heat increases the temperature which intern lowers the yield strength of the metal and increases the ductility. A combination of these two facilitates the easy plastic deformation. And therefore, the entire plastic deformation processes fall in the two categories. Means the metal working based processes fall in two categories: one is the cold working and another is hot working; and in between people sometimes say that warm working processes.

So, basically there are two big groups one is hot working and another is cold working and this distinction is based on the temperature at which the deformation is carried out. So, the temperature of the metal at which the deformation is carried out in the distinction between the hot and the cold working. And this distinction is based on the particular temperature which is called Recrystallisation temperature.

So, if the metal is deformed plastically above the recrystallisation temperature then, so here the temperature is greater than the recrystallisation temperature of the metal. While in case of the cold working temperature of the metal is less than the recrystallisation temperature. So, what is the recrystallisation temperature? To define this recrystallisation temperature it is the minimum temperature at which a plastically deformed metal deformed metal forms new grains or crystals within specified time.

So, this minimum temperature at which the new grains are formed within the certain specified limit that is called the recrystallisation temperature. And for most of the metal this recrystallisation temperature is found between one-third to one-half to the half of the melting point of the metals.

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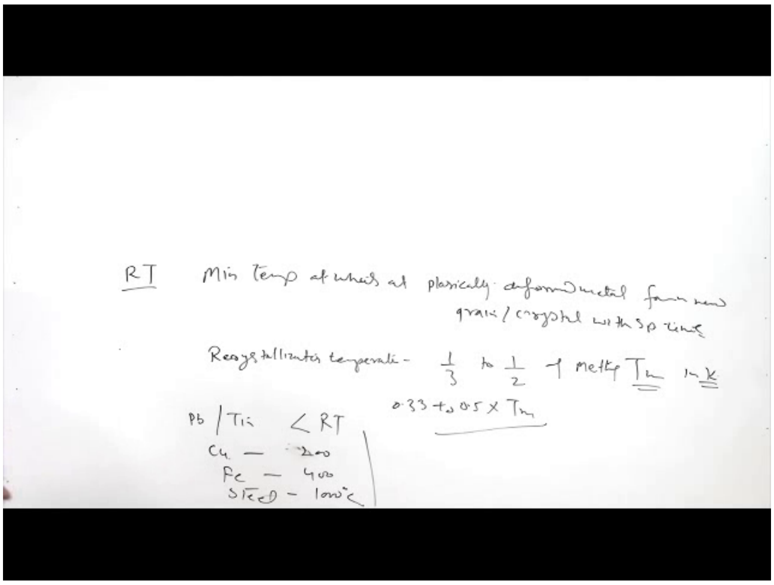

So, mostly this recrystallisation temperature crystallization temperature is found one-third to the one-half of the melting temperature of the metal in Kelvin. So, basically it is 0.33 to 0.5 times of the melting point temperature of the metal in Kelvin. For example, this temperature like for the metals like lead and tin is found even at the room temperature while for many other metals like copper may be 400 degree, for copper 200 degree centigrade, for pure iron 400 degree centigrade, but for the steels it may be like 1000 degree centigrade.

So, for the depending upon the metal the recrystallisation temperature is found to be that different. So, if the metal is worked above the recrystallisation temperature then it is called hot working otherwise it is called cold working; if the metal is worked at the lower temperature. So, the recrystallisation temperature how where is influenced by the extent of the deformation which has been carried out in the metal.

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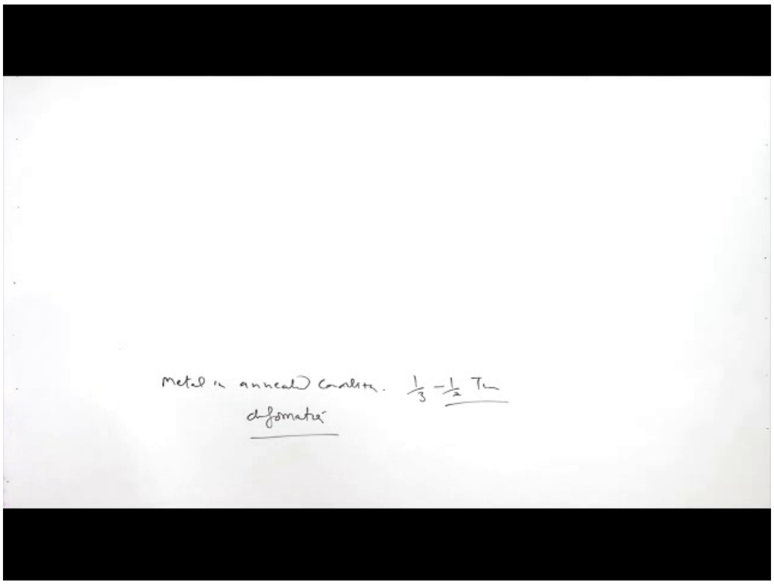

Mannered metal in metal in an yield condition is found in this range one-third to one-half of the melting point, but if it is deformed plastically. So, depending upon the extent of the deformation this temperature can be lower down. So, increase in the deformation basically reduces the recrystallisation temperature.

So, when a combination of the high temperature and the plastic deformation rate is applied to the metals then it leads to the very fine grain structure. So, here now we will see that the how the grain structure of the metal is effected when the metal is heated.

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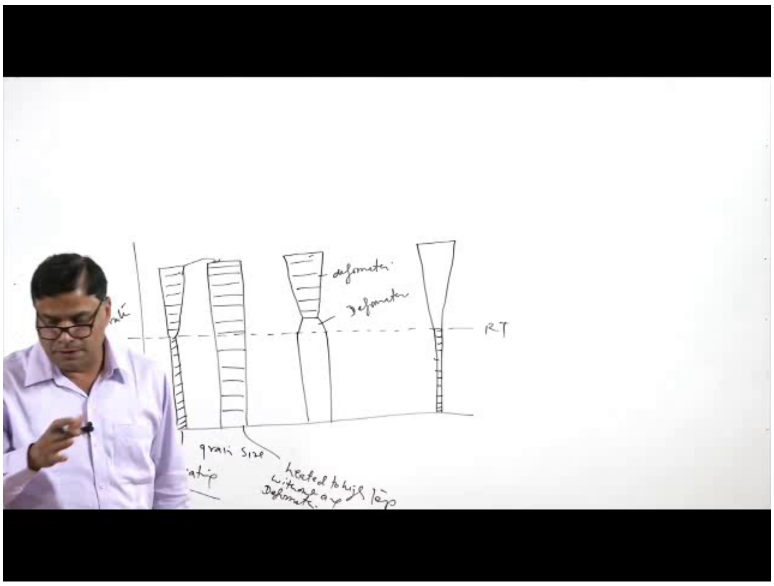

So, this is what we will see is schematically here this width will be showing the grain size and here this is the temperature during the heating what happens to the grain size. And say this is the recrystallisation temperature for the metal this is RT- recrystallisation temperature.

So, when the metal system is heated say the grain structure is fine initially. So, the grain structure is fine is this is the grain size. As soon as it is heated above the recrystallisation temperature the grain size is starts increasing. So, this is what we can see. Just above the recrystallisation temperature grains are fine, but they start getting cores and with the increase in temperature. So, this is what happens during the heating above the recrystallisation temperature.

And when the metal is heated up to the high temperature and then it is allowed to cool without any deformation. Say from this stage it is allowed to cool then it will be leading to the no change in the grain structure and it will remain coarse up to the room temperature. So, this is the case when heated to high temperature with and then allowed to cool without any deformation. So, if this is the case the grain structure will remain coarse.

The second case when we heat it to the high temperature. So, it is like this it is coarse then it is subjected to the deformation, so the grain structure is refined, but the deformation is stopped here. So, say material is due to the deformation and heating combination the grain structure gets refined, but the deformation is stopped above the recrystallisation temperature. So, once the deformation is stopped mechanical working is stopped above the recrystallisation temperature then again its coarsening begins. So, the grain structure gets core sand and then we find at the end again the cores grain structures.

So, the deformation of the metal must not be stopped above the recrystallisation temperature, but if the metal is being deformed at the high temperature during the hot working then the deformation should end just at the recrystallisation temperature, because there after they will not be any refinement or there will not be any coarsening. Since in this case the deformation was stopped above the recrystallisation temperature that is why it has got core sand.

Now we will see the third case when the deformation is stopped just at the recrystallisation temperature like this; so in this case we will be having very fine grain structure and thereafter it is allowed to cool so that there is no change in the grain size. So, this is the best situation. And efforts are made to deform the metal system after heating in such way that the deformation is stopped not above the recrystallisation temperature, but just take the recrystallisation temperature. And if the deformation is continued below this recrystallisation temperature then due to the lower ductility and higher strength metal may get cracked. So, that possibility is also to be avoided.

So, this is what we can see. What happens when the metal is heated to the high temperature with and the without plastic deformation.

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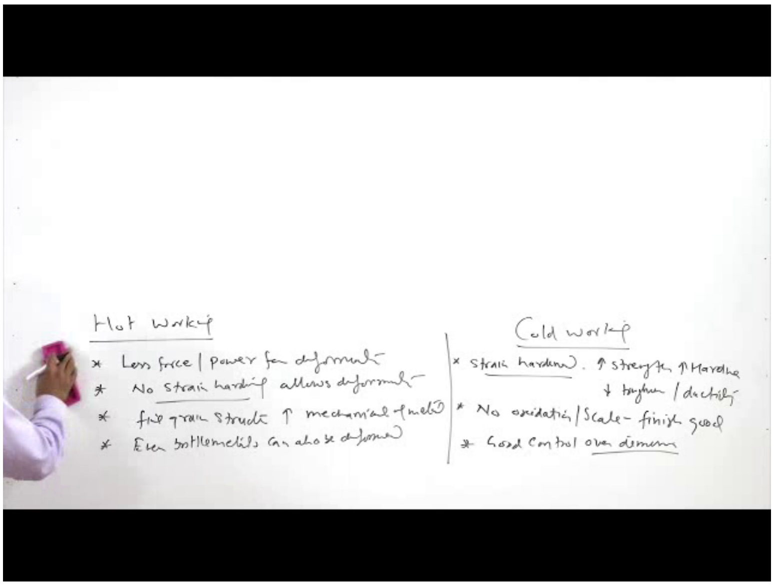

Now, if we will see the hot working and the cold working processes need to be compared hot working and the cold working processes. Cold working processes are those which will be carried out at the below the recrystallisation temperature, while the hot working processes will be carried out above the recrystallisation temperature. Now, first of all we see the advantages of both the processes. Advantage of the hot working process is what that the metals low yield strength is reduced and the ductility is improved. So, that it requires the less force and the power for deformation.

So, the desired shape and size can be achieved using the less power and the less force. So, this is the one advantage and when the metal is deformed at a high temperature above the recrystallisation temperature there is no strain hardening effect. So, we can continue to deform the metal up to any extent it will not get cracked and it will not allow show any the strain hardening effect. So, the no strain hardening effect allows deformation up to any extent.

The third one is a very controlled deformation at the high temperature leads to the fine grain structure. So, the fine grain structure basically helps in improving the mechanical properties of the metals. Another thing when the metal is heated to the high temperature we find that even the brittle metals even the brittle metals having the low ductility can also be deformed using the hot working processes or using the deformation based processes. So, these are the four advantages related with the hot working processes.

Now we will talk about the advantages of the cold working processes. In case of the cold working processes when the metal is deformed plastically at the temperature below the recrystallisation temperature it has the effect of the a deformation; it has the effect of the deformation on the strain hardening. So, basically the metal gets strained hardened because of the strain hardening the strength increases hardness increases. However, toughness decreases and also the ductility decrease. So, we get the much better and improved strength.

In case of the cold working when the cold working is carried out there is no oxidation, there is no scale formation so the finish which is achieved is very good, so good finish is achieved. And in the cold working since there is no application of the external heat, so there is no dimensional change due to the thermal expansion. And therefore, good control over the dimensions is achieved. So, the dimensional accuracy of the product which are made by the cold working processes is good.

And then so these are the advantages on the cold working site. Now we will coming we will be comparing these in respect of the limitations of the hot working processes. So, the many advantages of the cold working processes are basically the limitations of the hot working processes.

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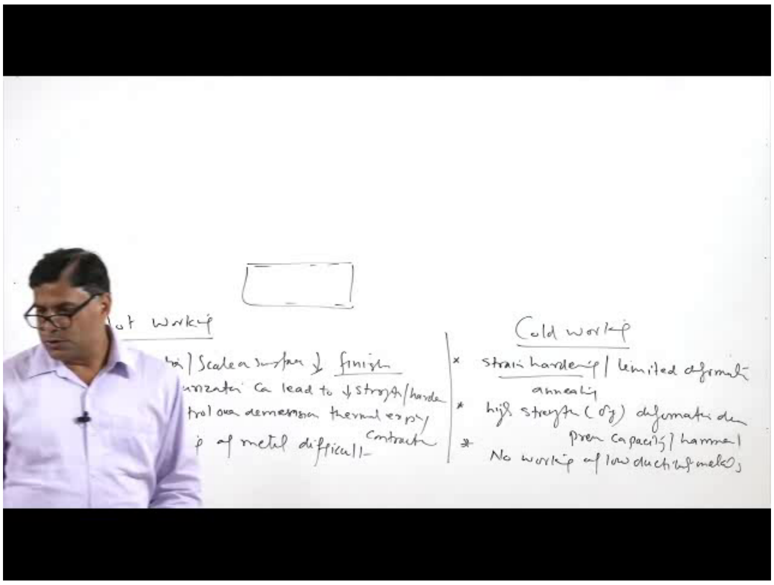

We know that in case of the hot working processes we have to heat the metals to the high temperature above the recrystallisation temperature.

So, this leads to the oxidation and scale formation on the surface of the metal which reduces the finish of the hot worked component. Finish is reduced of the hot worked components. Sometimes heating to the high temperature during the hot working also leads to the decarburization which means the loss of the carbon from the surface of the steels. So, if this is steel is a hot worked at a high temperature, so the loss of carbon from the near surface layers can lead to the loss of the strength. So, the decarburization can lead to the reduction in a strength and the hardness; so the loss of the mechanical properties in terms of the strength and the hardness.

Third one since the metal is heated during the hot working. So, the thermal expansion will be leading to the less control over the dimensions. So, basically the poor control over the dimensions primarily due to the thermal expansion and contraction of the metal during the hot working conditions.

So, this is another limitation related with the hot working. Processes one more thing the handling is difficult because the metal system is hot. So, you need to use the special equipments to handle the metal during the hot working which makes the handling of the metal during the hot working; handling of the metal becomes difficult. So, these are the limitations related with the hot working.

Now we will see the limitations of the cold working. We know that the cold working is carried out below the recrystallisation temperature which will be leading to the strain hardening. So, excessive strain hardening of the metal eventually leads to the cracking. So, due to the strain hardening limited deformation is possible in one go. And therefore, we need to carry out the annealing to induce the softness so that it can be further processed through the deformation. Limited deformation is possible in one go we need to apply the annealing or softening base possesses. These are called process annealing so that the softness can be induced and the further processing through the deformation can be achieved.

And another one is limited deformation is also achieved due to the high strength or high yield strength, high sigma y value limits the deformation which can be achieved; deformation due to the press capacity or the hammer capacity, because we need very high capacity pressers and the hammers for a causing the deformation in the metal at the low temperature.

And the next one is the deformation of the metal cannot be carried out for the low ductility metals. So, no working of the low ductility metals at the room temperature is possible. So, here what we have seen that hot working is easier to carry out, but it leads to the poor surface poor control over the dimensions while the cold working makes the deformation difficult it requires more forces and a more power consumption.

Now, we will summarize this presentation. In this presentation we have talked that the plastic deformation based processes help in improving the mechanical properties of the component by refining the grain structure, and using the strain hardening effect, and breaking the a regularities and impurities, and the collapsing the porosity. But they are two categories related with this process: one is a hot working another is cold working and this distinction is based on the recrystallisation temperature; the temperature at which the metal is processed.

Thank you for your attention.