Theory of Production Processes
Dr. Pradeep Kumar Jha
Department of Mechanical Engineering
Indian Institute of Technology, Roorkee

Lecture - 40
Metal Forming Defects

Welcome to the lecture on Metal Forming Defects. So, far we discussed about different kinds of metal forming processes among that you had the bulk deforming processes, like forging or rolling or extrusion and then you had the sheet metal forming processes, in that you had we discussed about other sheet metal forming processes. Now, as we know that in the case of metal forming we apply the stresses and most probably it is the compressive stress in most of the cases we apply the compressive load and the object is or the specimen is subjected to mixed state of stresses, you have the boundaries on the sides of the specimen.

So, you have many parameters which are into action and if the proper way of you know applying load is not there or you have improper values of the operating parameters like temperature, you know pressure and all that. So, that may lead to you know defects as it happens in the case of casting if you have no proper control on the temperature or on the surface finish of the mold or so, or even during that process of the flow of metal. So, if there is no proper design of the gating system or rising system that may lead to defect. So, similarly here also the process starts by after heating the material in case of hot forming we heat the, you know billet or the stock material and then we are putting it in between the dice and then applying the pressure.

So, from there it starts you have many stages and there may be chances of different kinds of defects and in this lecture we are going to discuss about different kinds of defects which may arise in the case of forming processes which are normally encountered. And then accordingly if you know the you know cause of these defects then accordingly you can have the steps. So, that these defects can be minimized or their occurrence can be avoided so that is how the we have to analyse the different kind of metal forming defects. So, coming to the first process of forging and what are the different forging defects which occurred in the case of you know I mean what are the different defects which occur in the case of forging. Now, the first effect is the residual stresses.

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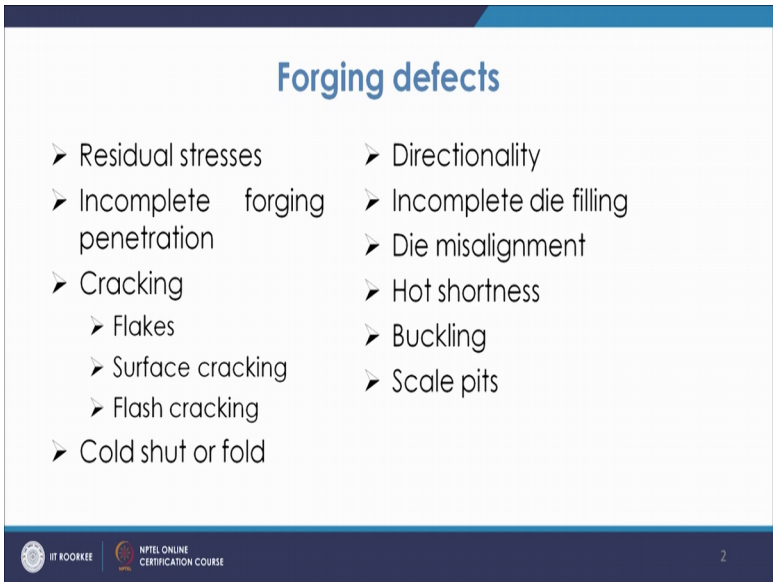

So, you know that we try to deform the material and we assume that there is homogeneous deformation, but if there is not homogeneous deformation in that case that may lead to the onset of or the generation of the residual stresses in the case of forged components. So, that is how the residual stresses come into picture.

Residual stresses also may come into picture if the force components you know when we are forging the component after that we are quenching and the temperature is higher in that case there may be the formation of residual stresses. So, that way these residual stresses are formed. Then comes the incomplete forging penetration. Now, in complete forging penetration means the forging is not completely going till the surface you know depth whole surface depth.

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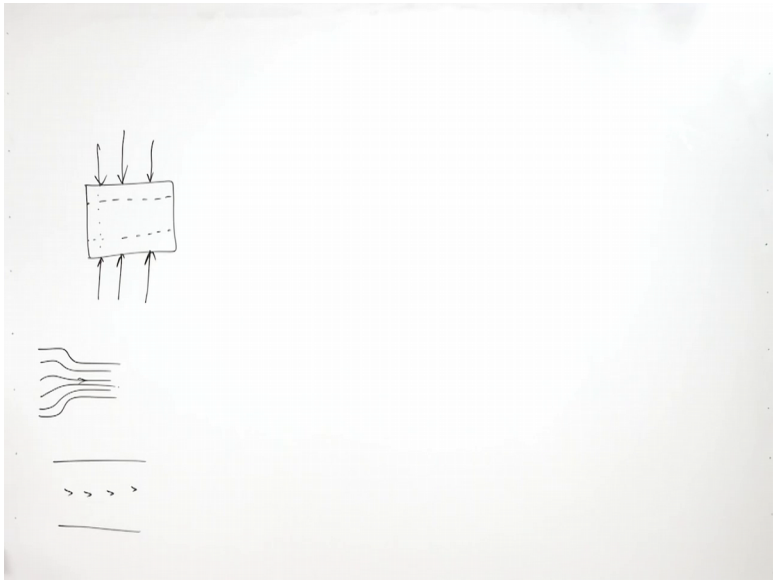

So, basically we have the, suppose you have the stock and we are basically forging from. So, we are applying the pressure from both the sides. Now, what we assume that once we forge then all the grains whatever grains are there at all these point the grains they are basically deformed. Now, if due to certain regions the grains only up to certain depth from top or from the bottom they are only deformed and your this the grains which are inside they are not affected that is known as incomplete forging penetration.

So, basically here the forging is limited to the surface layers. So, that is how it is defined incomplete forging penetration means the forcing is limited to the surface layers and this happens when you are you know when you have light and rapid hammering you do it. So, you have the hammer which is light although you do it rapidly, but then it is light you are not putting the adequate load I mean adequate you know load is not applied on the you know stock. So, in that case this incomplete forging penetration is encountered. Now, what happens that the main purpose many a times as you know if it is an alloy normally in the case of alloys we have already discussed that in the case of alloys the typical structure is the generating structure.

Now, what happens that during the forging these dendritic structure which is there inside they are broken sometimes dendritic structure that will be basically broken. So, once you heat it you go to higher temperature and then once you apply the compressive stresses in that case you are likely to break these dendritic you know arms you are like. So, that way

these dendritic structures basically you know will be broken. Now, in the case of improper load and light load (Refer Time: 06:58) rapid this generating structure which is there in towards the middle of disgusting that is not broken. So, all the purpose of the forging is not achieved, the advantage you cannot achieve because dendritic structure is still there. So, that is what is known as incomplete forging.

So, for that you need to see that the application which you are the load which you are applying that must be adequate enough. So, that the adequate compressive stresses are developed so that the effect is very much you know felt even during in the center of the casting not only it is limited to the surface layers. So, that is known as you know this incomplete forging penetration.

Now, we are coming to the cracking. So, as you know that you have cracks formed in the case of forging and these cracks are of different types. So, one of the crack is you know flakes. So, they are small cracks and that is known as flake. So, what happens is normally in the case of larger forgings these cracks are found and mainly towards the centre of the casting. So, what happens that it is normally because of the large hydrogen content in the large steel (Refer Time: 08:37) and also if the residual stresses are entrapped. So, in that case it is even the chances of having these type of flakes or internal ruptures that becomes higher. So, that you see towards the center portion towards the inside because of, reason is because of the hydrogen content and accordingly you will have to have the remedy so that this type of cracks are not you know encountered.

Then comes the surface cracking, surface cracking is you know the cracks are invisible at the surface. So, this is your surface cracking and this is because of the excessive working of surface at too low temperature or it may be because of the hot shortness. So, it may, it is because of the presence of sulphur environment. So, if the there is you know hot in the atmosphere is having sulphur. So, if the sulphur concentration in the furnaces is you know higher, then that leads to this hot shortness in the steel. So, that also leads to the surface cracking. So, you have two reasons basically you have excessive working of the surface at two low temperature, so that also leads to the fine cracks at the surface as well as the presence of sulphur and you will have to balance you know sort of control these parameters to avoid these surface cracking.

Now, many times we also see the cracks at the flashes. So, what we see that the crack which is there in the flash that basically has the chance to propagate into the host part. So, suppose we can see the chance of that that here.

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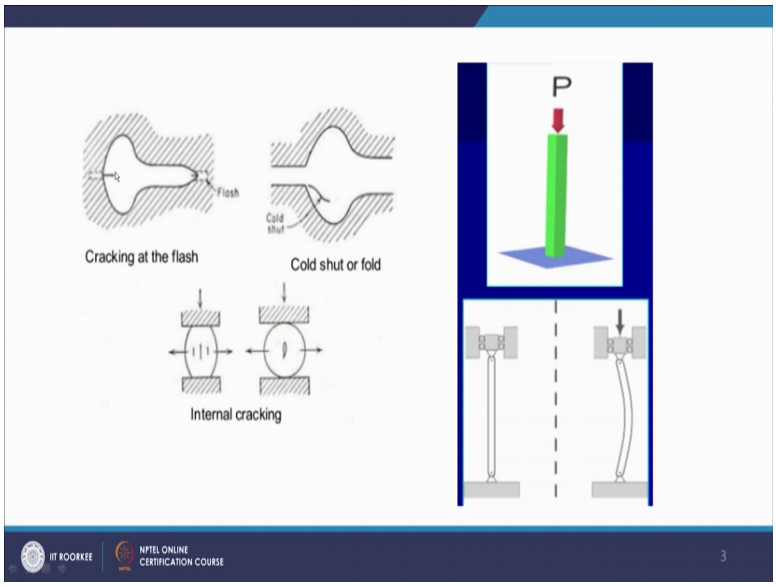

Now, this is the flash, if you look at, now what is happening is you have the this is a flash and in this case that is chance that this flash if it cracks if the whole crack is here along the length of the flash chances are there that this crack basically is extended into the forge component and if that extend is extending into the forge component then that becomes basically a kind of defect that is known as you know flash cracking.

So, normally it will be you know that will be seen because the flash needs to be trimmed off. So, trimming is another operation which is done to remove the flash as you know flash we have not discussed much about the flash because we assume that you know about it just like you have the extra material which is there in the case of risers in casting process. Here in the case of forging the extra material goes as flash and once it goes into it in ensures that most of the pockets of the forging is already you know filled. So, this is the function of flash once the flash you know goes out, now what we see is many a times you know if the thinner is the flash then the chances of the flash crack extending into the full surface becomes higher. So, you know you can avoid this flash cracking or this defect by you know increasing the thickness of the flash or you can also relocate this flash reason to a less critical reason so that even if small amount of crack is basically

seen in the you know protruding into the casting if it is less critical then you can still go with it. But the thing is that you can avoid it by increasing that thickness of the flash. So, that is how you have the different types of cracks which are basically you know seen in the case of the forged components.

Next type of the defect which is very common that is known as cold shut or fold. So, what is cold shut or folds? So, as we discussed the in the case of casting coals shut means when you have two metal streams that is liquid state and they are coming from the opposite ends and they are not able to fuse properly then you get the cold shut. So, basically it is not proper fusing, proper welding of the liquid metal or meeting of the liquid metal.

Now, in this case also in the forging also the cold shut means is it is a kind of discontinuity and here also this is also known as fold. So, fold means the you know two surfaces of metal here we talk about the two because we are in having the solid state. So, we are talking about the two surfaces and the two surfaces of the metal they are you know folding against each other without you know welding completely. So, they will have the folding, but they do not weld completely. So, that is how you will have a cold shut formed.

So, you know this you can happen when the metal has flown you know front passed part of the dye cavity that has already filled or that is only partially filled because metal failed to fill that cavity because of many other parameters like improper you know corner radius or fill it radius or so, so it has not been able to fill that and then further it has gone there. So, by that time it is going that may be because of the temperature gradient or temperature differential, they are not able to fold each other. So, there is excessive chilling occurring also that is also one of the reason then there may be you know large friction occurring that may also be the reason in all these cases you have the difference of temperature and then in that case they are not able to completely you know have the welding completely have a proper surface. So, basically the common cause which is attributed to the onset of this cold shut is having a very small dye radius, so that is also one of the cause.

So, now, we will discuss about the other defect that is directionality. So, what is that directionality? Now, this is because of the flow lines in the fibre structure. So, you have

this defect known as directionality. Now, what happens that when we apply the you know forging load then we know that you have the national properties attached in the force component your grains are you know having being deformed in a particular direction.

So, what happens that you have some of the properties like tensile ductility as well as the fatigue properties they become lesser in the transverse direction. So, in the direction normal to the direction where you apply the you know compressive stresses. So, what we do is and that is very much obvious because once we apply these five flow lines or fibre lines they are oriented in certain direction. Now, what happens that, once you have the, your this will flow lines will be you know moving in this direction. Now, what happens? That across the transverse direction some of the properties decreased like you have tensile ductility and fatigue properties. So, basically what we do is normally the degree of deformation or the amount of deformation or degree of reduction in cross section that normally will limit. So, that this type of directionality is not very much you know achieved which affects these specific properties.

Next is the incomplete dye filling. Now, many times the dye is not able to fill completely and that is basically because of many reasons and one of the reason is that if you have the lose scale or lubricant residue which is left in the you know in that you know portion. So, in the deep recess of the dye in that case what happens that basically you know forms these scale pockets and also that causes under fills. So, the forging material it is not able to go up to the whole depth of the dye in those cases.

So, because of these presence of these scales or because of the presence of this lubricant residue which is not completely driven off in that case this kind of defect may come. And you know it may also be that if you have the you know if you do not do the proper descaling of the forged work piece then that may also lead to something like the defect known as scale pits. So, scale pits are also formed because what happens that when we go for the operations of forging from one stage to other then what happens because of the high temperature you have the scales formed you must remove these scales and clean it when you are going for the next stage. Now, if you do not do that these scales are basically trapped and therefore, the depressions that is known as the scale pits. Then apart from that you have dye misalignment, so dyes misalignment may be there and because of that you may have the improper structure formed because of this

misalignment of the dye. So, you must have the proper alignment of the dye so that the material comes in between the dye and your parting plane is basically not disturbed.

Further you have other like hot soreness we have already discussed it is because of the higher sulphur content in the furnace mass sphere and that is basically normally you know more prominent in the case of steel castings larger steel castings. You have all the case also the case of buckling which is observed and buckling is seen in the case of you know when you apply the compressive load in that case you see this buckling kind of as you see yes. So, if you apply that to a very large extent and because depending upon the geometry you may have the buckling seen. So, also you need to be aware about the onset of this buckling and then you have to take proper remedy for that. So, this is about the defects normally which is encountered in the forged practices.

Now, we will come to the other kind of defects other I mean defects in other forming method other forming method which we have discussed is the rolling. Now, in the case of rolling as we discussed you have the roll, two rolls and the material is or the stock is basically allowed to pass in between the rolls. So, you have the velocity given to the roll and then you have the friction at the surface of the roll in between the roll and also the stock so that allows you to pass through that.

Now, what happens in the case of rolls that as there may be reason and defects because of the structure of the roll or the geometry of the roll. So, there is a wear and tear in the rolls also, because of that there may be associated defects. You know there may be you know there is a spread of the material across the width direction. So, you have you are spreading it. So, there is spread in the width direction and that also leads to some kind of defect because you know while spreading you have the frictional forces acting and that there is a friction hill generated from the side to the center of the you know billet or whichever is part is rolled and in that case because of that you will have and you may have an even kind of elongation or so, so that may lead to the different type of defects. So, we will discuss about the different kinds of you know defects in the case of rolling.

Now, in the case of rolling as we discussed we have the interaction of the plastically deforming work piece and elastically deforming rolls. So, the walls are elastically deformed they are assumed to and the work is basically plastically deformed. So, you have the interaction of these two and because of that there may be you know because of

the influence of very high rolling pressure or high very high rolling forces, the rolls many a times flatten and bend and then because of that you will have the difference or you will have the presence of the or the difference in the structure of the seat itself. So, that kind of you know structural difference may come in the you know output products.

Now, again you have the mill spring. So, you know because of the mill spring the thickness of the seat which is exiting from the roll mill. So, as we discussed you have the spring back. So, because of the mean spring the thickness which will go out of the after the roll exit that will become a little bit higher because of that elastic property. So, that will be you know greater than the roll gap which will be set under the normal conditions so that for that you need to know the elastic constants. So, that you can say that to maintain particular thickness what should be that thing because once the objects pass through it then with slight increase becomes depending upon the elastic constant and that is why you must know the elastic constant of the mill so that you get the adequate, in the very accurate dimension of the rolled specimen. So, basically the limiting thickness which you achieve also that is basically proportional to the coefficient of friction. So, and also they are all radius so that way that how much you can get you know minimum thickness that also is a limitation.

Now, what happens? Because of the elastic you know flattening of the rolls with increasing roll pressure ones who have you increase the roll pressure and because of the elastic flattening. What happens? That, results into a condition where rolls eventually deform and they deform more than the work piece. So, for a given material and the set of rolling condition there has to be a minimum thickness below which the rolls the seat cannot be reduced further. So, that is how you assign the minimum you know height or minimum thickness up to which can be basically rolled. So, that is how it is done.

Now, we will come to the different types of defects in the case of rolling. So, the first is the bowing of seat. So, you know if the roll gap is not perfectly parallel you know as we discussed that many a times when we apply the pressure on the rolls you have basically you apply the action force by the rolls on the substance or the you know stock and then there is action forces on acting in the opposite direction on the rolls.

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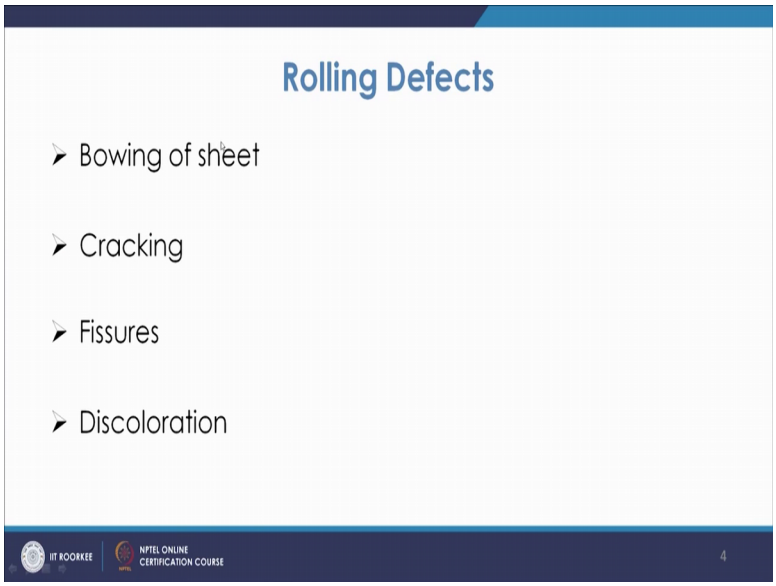

Now, if that is not perfectly parallel then one edge of the seat will be decreased more in thickness and then other than other part and that is how the bowing will start. So, I mean if you see that so, that way you know if there is there may be cases when the gap in the center part may be you know more or there may be chance when the gap in the center part may be less than the sides I mean the portion are the sides.

So, these situations basically lead to you know different kind of you know situations like if you try to see that if you have a different kind of dye structure and if you try to apply that. Now, what happens? That thus if it is concave type of you know you have dye and if you are applying on the you know material in that case what happens that you know the middle part middle part of the in that case. So, that will be compressed more, so use, you know once you leave them then the middle part will be under the tensile stresses. So, that is how it is seen that and then that may lead to the different kind of you know the sagging or bowing of the seat. So, that is actually encountered in the case of rolling.

Now, also it may lead to many at times it may lead to the formation of edge. So, cracking basically you have different way these cracks are formed and you have different varieties of cracks as you see you have you have the deeper cracks you have age cracks this alligatoring also in there when it is completely you know coming out. And you have waviness which is seen this is all because of the you know because of the poor you know gap role gaps and because of the improper you know change in elongation at different

portions you have the formation of this type of cracks which are formed in the case of forging.

Coming to the fissures. Now, these fissures are basically the internal defects which are because of the incomplete welding of pipe and blow holes. So, if these pipe and blow holes, as we know that in the case of rolling or any metal forming operations we try or we intend to basically weld that pipes or blow holes which is there in the product. So, if we are not able to do it completely then that may result to and you know defects known as fissures. So, that is Fischer then you have discoloration, so that discoloration basically what happens many a times. So, do you know that colours you know changes and so, this is because of the because happening of this heat treatment process, after the heat treatment process due to the lubricant removal many a times the colour you know changes that is this coloration. So, these are the normal defects which occur in the case of you know for rolling process.

The other defects which are occurring in the case of there is another process that is extrusion. In the extrusion way cases basically you have one of the difficulties commonly several cracks. So, there it occurs in the central portion if you have some cracks this type of cracks are formed. So, this is the crack that the several crack which is formed in the case of extrusion. Coming to the sheet metal parts you have different kinds of you know defects and that is you have local necking or thinning or buckling, then you have wrinkling, springback, cracks near the puncher region, tearing, earing, surface scratches, surface blemishes these are the different you know defects which encounter which we encounter in the case of you know sheet metal forming.

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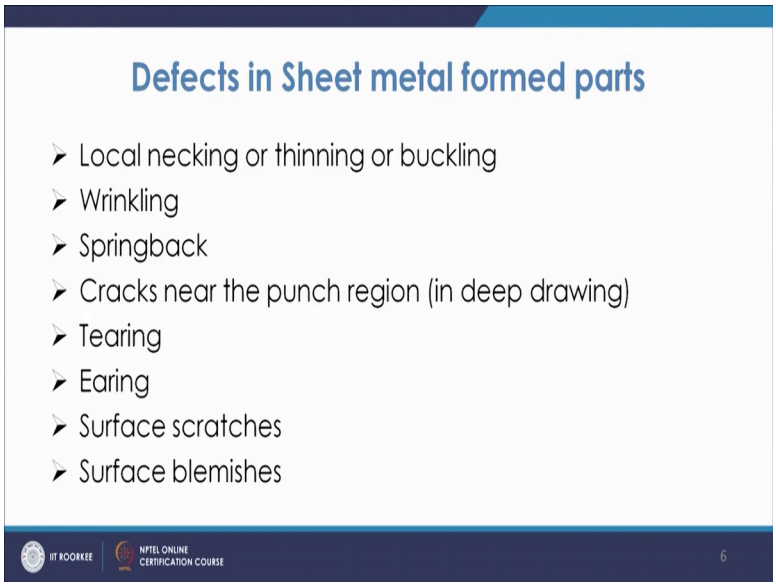

Now, local making or thinning or buckling, it is because of, so that occurs in the reason of the compressive stresses. So, as we know that we have discussed that normally we have avoid using compressive stresses because in the case of sheet metals you may have the chance of having this local necking or thinning or even buckling. So, that, you have to have the proper you know remedy the proper step taken. So that kind of stresses are not developed which results into this local necking or you know buckling then you have wrinkling.

So, wrinkling of friends or edges of cup is normally very a common defect and that results from the buckling of the seat, so because of again because of the large compressive circumferential stresses. So, because of that this wrinkling defect is found. Then you have spring back as we know that in case of spring back as we discussed when you try to bend it or when you try to deform it because of the elastic properties it tries to further go in the opposite direction because of the elastic effects that is when a spring back and that is also one kind of that gives you not that dimension which you desire. So, that has to be kept in mind.

Cracks near the punch reason. So, that is normally encountered in case of deep drawing that is seen and that basically you know you if the punch radius is very small then this occurs. So, if you increase the punch radius. So, because they are very various very sharp that it tries to cut it if you try to be give a crack. So, you will have to increase the punch

radius or lower the punch load. So, that these cracks are not formed. So, crack near the punch reason in deep drawing is another you know problem.

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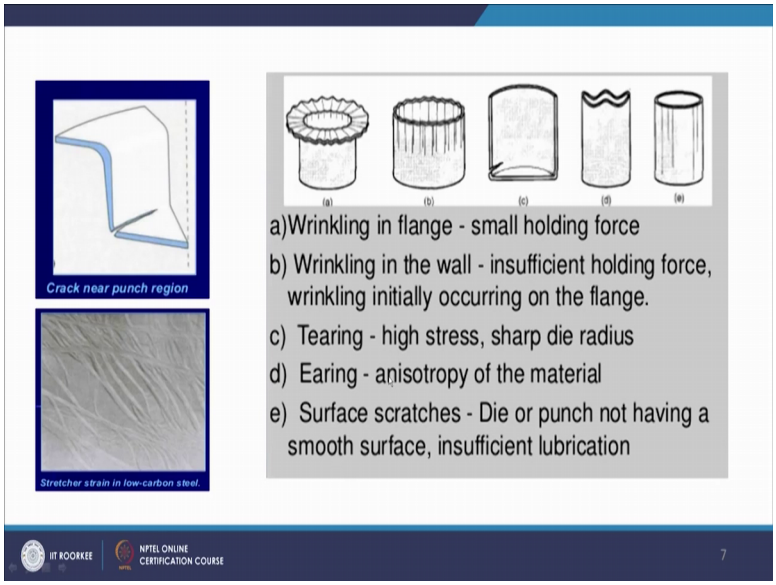

Then you have defects like tearing earing and surface scratches so that we can see here. So, as we see you have the crack near the punch reason and this is seen in the case of you know deep drawing where you have very small punch radius. So, you have to increase that person ages. So, that this crack which is formed is avoided.

Then you have the as you see that in this drawing of the components you have wrinkling in a flange your small holding force then you have the wrinkling in the wall as you see and this is because of the insufficient holding force. So, initially it occurs on the flange and then it goes around the surface. Then you have tearing here and tearing is because of the high stress and sharp dye radius that tearing is occurred earing is another defect that is because of the anisotropy of the material and the surfaces scratches you see. So, that the dye or punch is not having the smooth radius, a smooth surface or insufficient lubrication then in that case there may be surface scratches that may occur.

There is another thing that is surface blemishes. So, that is pronounced surface you know roughness in the reason of appreciable deformation so that basically you know that leads to basically you know surface blemishes and normally in the case of low carbon steel it has been seen that there are the presence of the stressor strains as you see here the this is known as stress or strain in the case of low carbon steel where you have a frame like

pattern of you know depressions on the surface that is you know; this is because of another you know result another reason that is the presence of yield points. So many a times while deforming the yield point is you know reached. So, in that case you have the non uniform deformation you know stars and that leads to such kind of strain marks that is treacherous strain marks.

So, these are the different kinds of defects which arise in the case of metal forming. So, you are advised, we advise you to go through these different kinds of defects in forging just analyse what are the reasons and so that you have more better understanding of the common type of defects and also their remedies.

Thank you very much.