Mechanics of Sheet Metal Forming

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Week- 08
Lecture- 21
Demonstration of Sheet Forming Experiments

So, this small section we are going to briefly demonstrate some sheet forming experiment. These experiments were done in some of our labs with very simple setup which will be easy for anybody to do it in their labs and we can evaluate certain outputs from that. So, the first one the video will be there you can look into this. This is the V bending of sheet initially sheet was shown and here you can see a setup we have with a simple punch. So, this is your actually a punch ok. It is a V bending punch and this is the die you can see the channel here which is of V shape and if you look into this punch here this particular punch ok can be replaced and there is a fastener above that you can see here this fastener can be removed and the punch can be replaced.

So, that you can make a different dimensions of punch with the different corner radius maybe and you can see that the person is showing that you have to keep it like this and punch will be clamped in the machine now die will also be clamped you will see yes. So, the clamping is done you can see a simple setup here ok. It is simple though easy to install it in an UTM this is a simple hydraulic UTM you can see and the punch is actually tightened. This punch can be replaced you can see that there is a T slot which is used to clamp the punch and which can be replaced you can install a new punch with that and the punch is adjusted you can see yes.

So, and you will see that now this die is kept on the UTM. So, this setup is little heavy ok. So, that you may not need to actually clamp the tool rather you can just keep it, it can lie on a place with its own weight. So, but only thing is you have to adjust it in such that when the punch comes down it should match with the groove. So, you can see that slowly the punch is giving vertical displacement it the ram is coming down.

So, a hydraulic is adjusted you can see and a punch is coming down and slowly because it is a screw driven. So, it is a coming down slowly and once it reaches the die level then you have to be careful you have to little bit adjust it. So, that the punch is in line with the channel V channel or V groove. So, it is nearing the die position and we may have to locate the sheet properly here and you can just see that yeah. So, you have to just check whether it is reached that level or not ok.

Once it is reached you can remove the sheet and you can just see now that it will be adjusted. So, it has come down and then you have to adjust it. So, final one should be clamped properly until then you have to little bit adjust it so that. So, now it is adjusted so after this die should not be moved. So, you have to little bit careful die should not be moved after this yes now it is moved up it is located properly and now the sheet is kept located on the die.

We are not going to use any lubricant or anything in this it is a simple bending operation V bending operation and you will see that here there is no holding. So, it is just moment only sheet moment is given to the sheet for it to bend. So, there is no applied tension here. So, you are going to give only moment to that and you will see that now vertical displacement is given to the ramp and punch is also moving down the sheet is bending. So, it is a further bend.

So, now you have to bend the sheet to such an extent that it takes almost the shape of the this V group. So, you can see that on the die surface the sheet is moving up right. So, which means that it is not held in that location it is just you know bending with moment. So, it is bent. So, now depending on this angle it may little bit slide in and important point that one should look right now is after a particular stage you know the displacement will be stopped and the ramp will be taken away at that time you will see that the sheet will try to relax you can see spring back it will try to relax the angle is going to change now you can see.

So, it has gone down and maybe even if you stop it now and if you try to displace in the upward direction slowly you will see some relaxation you see that it is relaxed now. So, sheet is relaxing you see that the angle included angle is now which is not the same as that of the die it has increased now and now it is it is like experiment is over now. So, you can take the sheet out and the sheet is bent this must be some aluminum alloy the sheet must be an aluminum alloy and you can see whether is there any necking happened on the outside region ok. On the tensile surface you can see on the bottom one yeah. So, there is no neck no crack is developed it is still fine ok, but you can measure the included angle and you can compare it with the die angle.

So, you can get some idea of what is the spring back the angle change. So, like this one can compare materials of different strength and agility to check how bending happens. So, this is a simple V bending setup which you can make it in a lab itself and you can do this kind of experiments. Theoretically we did some analysis to evaluate spring back and to evaluate you can also get load displacement graph from the machine itself ok there will be a computer interface. In the next experiment we will see in different experiment there will be computer interface in that you can get load displacement graph which will give you some idea of what kind of load it is going to have during deformation.

So, this is about your V bending of sheet and simple tools are there one die is required and there is a corresponding punch that is required. So, punch can be replaced so you can change the punch corner radius to see you know is there any change in the deformation in spring back all those studies can be made ok. So, you can also do some materials processing on the sheet to change the deformation pattern say for example you can do some sort of heat treatment you can do some processing like friction stir processing and you can study the bending behavior these are all possible now. Let us go to the next one which is on deep drawing. So, you will see that here this is the blank holder the first one which is shown which has got lot of holes there to clamp it onto the die and this is the die the central hole is actually the die hole ok into which the sheet is going to be pushed inside ok.

The inward movement will happen radial movement will happen inside that and the column which is shown which is just below that ring region is actually will be used to clamp the die onto the machine and there are two windows on this vertical column you can see here ok here also you can see some so with that can be used to see whether the sheet is actually drawing in or not or you want to check something you can do that you can put a camera inside and you can just see the deformation level if you want. So, again this is a bit heavy setup but then you can make it with simple hardwares in your lab itself this must be a I think a stainless steel sheet which must be having good deep draw ability and you can apply little lubricant on that which is what is shown here you can see lot of fasteners are there aligned key, spanners are required. So, it is a simple setup there is a blank holder and there is a die so and you can apply on the die surface so the sheet diameter is taken such a way that it is diameter is less than the location where fastening is going to happen. So, I am just going to place a sheet here right so it is placed coaxially ok it should be at the exactly at the center but one difficulty in this we cannot see the deformation so the sheet can slide in it may not be axisymmetric while it is deforming so one has to be careful. So, you are going to place a blank holder like a ring so here blank holding is done with mechanical fastening ok instead of hydraulic gripping here you are going to do mechanical fastening and you can put fasteners like this and you can tighten it so you can give a full tightening so that you have some blank holding force on the sheet so that it can avoid wrinkling.

So, there are probably 8 fasteners required so all may not be required maybe you can have maybe 4, 4 also would be sufficient. So, the cup that will be formed in this will have about 50 mm diameter ok so accordingly the setup has been made. So, now the second fastener is tightened the fastener can be kept upside down also so that there is no disturbance for the punch movement in the vertical direction. So, the third fastener is located now so while doing it one should be very careful that the sheet is not displaced from its position that is very important. So, if you so this is just a demonstration class so if you are going to do some experiments which will be useful for your project research work type of thing where data is very important for you practical data and you want to verify it with some you know theoretical calculations estimation then you have to do it meticulously you have to check couple of times whether the sheet is displaced after locking all these things or after locking it should not get displaced or while locking it should not get displaced one should look into all these things.

The steps are very important here and you also put lubricant so there is there are chances that it may slide from its position so one should be careful. So and you can see that the entire setup is going to be clamped in the same machine we have used a simple machine UTM but this can also be installed in a dynamic testing mission as well so wherein you can get you know accurate data and you can see the punch is already installed onto the upper ram ok. The punch is already installed you can see that this fellow ok is already installed into the upper ram it is a cylindrical punch ok which is going to match with the die hole it is a simple setup. So and like in the V bending operations here also you have to locate your punch appropriately so that you have to adjust the die and then you have to clamp the die. And now you allow vertical displacement by using your machine you can see that it is a UTM and hydraulic can be controlled and there is a computer interface on your right ok so and all the details can be mentioned here ok and when you start the test because of vertical moment you know your sheet will be pushed inside the die hole because of radial inward moment on the die surface.

So now the test is started I think and you will see the load displacement graph can be obtained like this so you can start the mission and you can open hydraulic so that deformation happens at a normal rate, slow rate slowly. So now yes you can see that some data we are obtaining load versus displacement some data we are having you can see that the load gives on increasing with respect to displacement about 1.5 mm, 1.6 mm displacement has been done now just about 9 kilo Newton is going to reach ok so you can look into it and then now I think the test is almost done now so it will take only may be few minutes one can complete it so you can remove the punch take it out and take the entire setup unlock it and take the entire setup out yes and then unlock your blank holding ring blank holder ring and you can see that a cup is formed but here you can see that actually the sheet is little bit displaced and a cup is not a axis symmetric you can see if some flange region is there on one side and flange region is totally gone on the other side you can see that that is why I was telling you that you have to be very very careful when you do this if you want to take real data which will be useful for some calculations then you have to locate it properly. So this is how cup is formed and you can see in this final cup there is some small you know waviness in the wall region ok wherever you have the cup that is fully drawn on the on the left side you can see there is small you know wrinkling on the walls that should not be there ok and one good thing is that there is no wrinkling on the flange region which you can visibly which is visible ok and one can get a full low displacement graph and you can do any analysis you want or you can do you know you can validate it with experimental results if you have some analytical modeling done.

So in the previous video we have seen deep drawing of sheet now I am going to show you another demonstration of same deep drawing ok to get an axis symmetric cup in the previous one it was not axis symmetric isn't it so I am just going to show you a demonstration so for same deep drawing and you will see that again the same die is used ok I am just you know you will see that it is the same die I am little fast forwarding it ok and it is a 50 mm cup that is formed so now you will see that the sheet will be a circular sheet the same sheet is taken. So if you want to measure strains on the sheet surface then you may have to put circle grids on that you may have to print circle grids so that you can measure strains at different locations of the deep drawn cup so you have a flange region cup wall and cup bottom like that so you put lubricant so that you have some nice cup that is formed grease would be better and you need to put fasteners also so you place it it should be symmetric otherwise you will get a distorted cup so you have to locate it properly see moment you put lubricant you have to be careful yeah so what you do is either you can keep the die on the machine and then you can place the sheet and blank holder all those things all you can arrange everything outside and then place the die you know entire assemble set up on the machine both ways you can do ok. But this way you know doing it you know assembly outside the machine is actually safe ok so that you don't need to you know see whether ram is moving or not of course you stop the machine and do but then this is the safest way to do so you are putting fasteners and it should be tightened such that appropriate blank holding force is given mechanically it is a mechanical blank holding force only not the hydraulic one and it has to be tightened well and so you have to adjust it and then you can see that all the fasteners are now assembled yes and it has been put on the UTM same UTM which I used for the previous experiment. Now this rigid punch is held on the you know upper platen and you allow hydraulic to come down but when you do it you have to do it little bit slowly so that you can so that the punch and the die are coaxial become coaxial so when you try to insert the punch you have to be little bit careful so that they slide very nicely yes and then you can tighten the dice so that does not get displaced. So now once your assembly is done in the machine you can see you can you know start the displacement of the you know ram and punch will move down so that the cup is actually pushed inside the die hole to form the cup okay and you can see that so this is your graphic interface you can see load versus displacement hydraulic is controlled and you can see that Y axis is load X axis is displacement and you can see the data and we know that there will be a typical load displacement graph for any material and you can see that it is continuing now.

So load keeps on increasing you will see that it goes on okay so there is about 3.5 mm displacement and load is about you have about 14 to 15 kN is there okay so you continue that until you get a full cup okay so now only issue here is so you may have to fabricate a setup through which you can see the cup that is formed okay there are several ways to do okay one way is you can make a window just below the die so that you can see it or you can have a video you know a camera sensors type of thing arrangement which can be kept below the you know the cup that is formed and you can see you know in your computer or in mobile also you can see whether it is drawn fully or not there are several ways one can do it. So otherwise you have to get you know a sense from your load displacement graph okay so that is the only way otherwise so visual thing you may have to make a separate camera arrangement for that see it is almost like 8 mm displacement 8 mm cup height is formed now and depending on the material and thickness you will get the load okay so otherwise it will keep on increasing so we are just basically repeating the experiment and it is going to be like this so we keep on increasing it so you can see the slope is slightly changed so it is you can see that it is almost saturating now which means that there are chances of you know cup is already formed because there is less material to get deformed you can see that load is coming down actually so you have to be a little bit careful you can stop the machine yes stop the ram movement and you may have to take it out slowly and then disassemble the setup and you will see that this time at least let us see a nice circular cup is formed which looks like an axisymmetric one yes this is better than the previous one you can see there is a small flange we did not draw it fully so that you can see what is the status there is a cup bottom that is formed is not it there is a cup bottom is there okay and you have a you know you have a flange region so you can see that this is your flange region okay and you have a cup bottom and there is a you know cup wall region so all three regions are formed and now the cup is almost you know axisymmetric so this is the way deep drawing has to be done okay. So now the next video which I am going to show you is basically you know you can see it is nothing but a stretch forming of sheets so in the stretch forming of sheet okay you will see that the main aim here is to basically deform the sheet okay and then through a punch you know an experimental setup punch die blank holder setup and then deform the sheet so that at the end of the experiment you can actually construct a forming limit curve that is the whole idea okay. So we are not going to do deep drawing rather what we are going to do is a stretching operation where the sheet is actually not going to draw in that is the whole idea here and as I told you previously you want to measure strains on the sheet surface which is mandatory okay when you construct a forming limit curve because forming limit curve is between major strain and minor strain that we already studied so you want to get the necking strains or fracture strains then you need to put circle grids on the surface a simpler way to do it is through electrochemical etching.

You can see that the person is doing electrochemical etching this is the setup and you can see that okay it is nicely formed okay you can see the circle grids are printed on the sheet surface right very nice ones are made so circle grids or particular diameter one should know the diameter initial diameter now this is another sheet with a different strain path and as you know for doing for evaluating this forming limit curve okay through this kind of stretching operations limiting dome height test is generally followed okay. Limiting dome height test is generally followed we have elaborately discussed about it in one of the chapters this is just a demonstration and in this case you will know that there are several strain paths to which the material has to be deformed. The first one that was deformed is like for example in the negative minor strain in the negative minor strain of the forming limit diagram okay that is why you have width which is you know like of the order of 20 mm or something but here the one which is now printed is in the plane strain path that is why width is slightly larger you can see at the mid region the width is slightly larger than the previous sheet right here also circle grids are formed you see that. So you have to put the circle grids on the outer surface of the sheet when it is kept on the die punch setup that you will see later on in this video. Now this is the third strain path so I am going to show you only three strain paths okay so this is the third one this is circular sheet you can see so this if you deform the sheet this will deform in balanced biaxial stretching okay where $\alpha = \beta = 1$ the previous one is basically $\beta = 0$ okay and you also know it is going to be there for negative minor strain for tensile strain path and here you will see that the circle grids are made at the center of the sample you can put for the whole sample does not matter because half of the sample will be in the clamping zone so it is not going to deform okay.

So here nicely you see that the circle grid is formed here you see so this tensile you have to make the circle grid tensile the green color one that layer plastic sheet you can make it okay and this electrochemical setup can be you know etching setup can be made it is available in practice okay. So this is the hydraulic press which we are going to use this 100 ton hydraulic press which we are going to use for stretching operation and you will see that the bottom one is basically you know you can see the die and there is a projection that is a draw bead and punch is coming out you can see punch will come from bottom. The upper most one is actually the blank holder okay so there are two actions here okay one the blank holder will come and hold the sheet and then inside that you know your die punch will come from bottom okay. See now this is the main difference between deep drawing and stretching with respect to the usage of machine. So in deep drawing operation you will see the sheet is mechanically clamped with fasteners right so but here you can see the sheet is clamped with a hydraulic pressure so it is a first action is done now second action will is nothing but the punch moving in upward direction so naturally you cannot see that okay the punch is deformed you know the punch is moved up and it is deformed the sheet you can see that see you have to deform it up to fracture okay and of course if you have ability to stop it at making that is good because some materials undergo making and then fracture okay so if you can stop it at making that is good actually one should do that but here is actually since it is a demonstration so it is actually fracture.

Now you see that circular grids are deformed into ellipses so you can find strains from that right so you can find strains from that near the fracture and that becomes your you know your making strains or limit strains of one particular strain path while developing the forming limit curve so you have to do like that for several strain paths several α and β right so one is done this is a second one you can see this is a second this is for plane strain path so now it is clamped so that the sheet does not move in now punch must be deforming the sheet so deformation is going on yes it is still going on. And you may have to you have to fracture it you have to or you have to stop it at making so now you can see that the sheet is again you know fracture you can take it out now you can see that they know the the draw bead has created an impression you can see that the bend region draw bead has created an impression isn't it that is why you need a draw bead so that the sheet does not actually draw in actually okay it is going to undergo only stretching now you can see you can measure strain grids on the near the fracture location to get the limit strains in this particular strain path now this is a third one this is a third one balanced biaxial stretching or equi-biaxial stretching you can say or equi-biaxial tension $\beta = 1, \alpha = 1$ is that region it will come so now again it is clamping the sheet so you can adjust the blank holder pressure actually okay you can adjust the blank holder pressure if the sheet is not clamped well you can easily find out and on the left side of the machine there is a you know arrangement for increasing the blank holding pressure so once that is done so your sheet will be clamped fully and here also you can see that this is again fractured but then it is too much of fracture okay so one should not go ahead like this actually but you should be able to stop it just at fracture one should try for that we do that regularly okay so now you here also you can see that the circular grids are deformed into ellipses okay so all the three you know sheets are deformed now isn't it so now similarly you can have few strain paths between the left and middle and middle and right so basically you have to increase the width of the sheet which is going to simulate some predefined strain paths okay so once that is done you allow it to fracture then you can measure the circular grids on the you know near the fracture location that will give you the fracture strains near the to construct the forming limit curve so you know how to develop forming limit curve which you already you know taught so all the fracture strains major strain and minor strain can be plotted in one graph and then you have to draw a locus okay and at several situations we have discussed how to develop how to evaluate major strain and minor strain right so it is going to be pretty simple in the case of circle grids because it is going to be converted into ellipses only right so now here you will see that initial diameter is known to you let us say 2.5 mm and now the major axis dimension is measured you see microscope you can measure and minor axis dimension is measured so from that you can get major strain and minor strain so you have to plot all this fracture data fracture strains in one plot okay in one graph okay and then you draw a forming limit curve okay such that all the fracture strains are going to go above the curve. So otherwise what you need to do is basically you need to measure the fracture strains near the fracture region and you should also measure some safe strains away from the fracture region okay the region away from the fracture region say for example couple of grids away from the fracture location so you plot all the strains in one graph and separate safe strains from fracture strains okay like the way we discussed in the actual lecture okay so that locus is nothing but your forming limit curve okay. So if you plot it along with all the strains so it is forming limit diagram so this way this limiting dome height test can be conducted okay in a hydraulic press in which the sheet is clamped first that is in the first action and second action is punches going to deform the sheet up to fracture.

So in deep drawing we have demonstrated that it can be done in a simple UTM but here we have shown that this demonstration is done stretching as demonstration is done in a hydraulic press. So only difference is there in the UTM you need a mechanical clamping method and here it is hydraulically clamped okay. So this way one can develop forming limit curve and you can do deep drawing and previously we have also demonstrated about sheet bending operations. Tensile test you know what to do you know many of you have understood that. So with this we stop this video demonstration. Thank you. .