Plastic Working of Metallic Materials

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Lecture – 30

Sheet Metal Forming : Introduction

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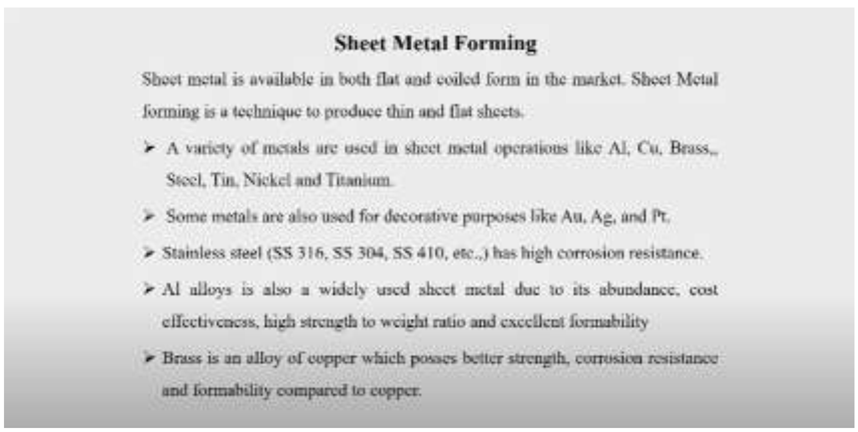

We will come to this module 8 which is basically the sheet metal forming and today I will start with sheet metal forming introduction. In all industrial processing you will see that this sheet metal is available in both flat and coiled form in the market. So, either it may be in the coil form like a big roll you can see that. Or you may get it in different shapes sizes like 6 feet by 8 feet or 6 feet by 6 feet like that standard sizes also you may get it in the cut form. But when it is very thin now generally people prefer and when they wanted to buy in bulk they buy in big roll form itself so that it is easy to unwind from that use it. So, so either in flat form or coil form it is available in the market and these sheets are basically it is subjected to various processing sheet metal operations to produce the shapes which you require actually okay.

And you will see that the type of materials which are available are normally say aluminum, steel, copper, brass, tin. Then say materials which are for high temperatures like nickel or even medium temperatures like titanium, depending upon the use, it is available. So most of the commercially available materials are available, aluminum alloys and copper and brass and steel, these are extensively used. Now the in addition to this there are some metals which are also used for decorative purposes like with the help of say maybe which are made out of gold or silver or platinum which are purely for decorative purpose or ornamental purpose these are also being used. Say steels are extensively used as a sheet metal operation both for automobile applications and say defense applications and many other commercial applications, steels are extensively used.

Stainless steels are used even in household purposes, domestic purposes, all these domestic vessels, glass plates. Like that now you will find a variety of things. Most of them domestic application, domestic purpose it is generally is a 316 or 304 aluminum alloys. But there are other martensitic alloys also, stainless steel also. So different varieties are there depending for industrial purpose it is being used.

But this stainless steel the advantages are it is having very high corrosion resistance, hence it is extensively used for domestic purpose. Aluminum alloy is also widely used sheet metal due to its abundance, cost effectiveness, it is very light and high strength to weight ratio and it is having a excellent formability. So that it can be easily deformed to any shape without much of without much difficulty. So that is why aluminum stands on that. And say maybe for the last 20-25 years, aluminum has picked up in a very heavy way in the domestic sector for most of the case for kitchen utensils, pressure cookers and many a variety of applications it is being used.

Then similarly brass which was used right from say maybe for several centuries itself it is being used as household utensils. Now also there are many clusters at grass root level in India where maybe a whole village is making this brass vessels and other things ok and these are also made by from the sheet blast sheets only they are doing just by hammering on a grass root level you know they do it by just by hammering and getting it into the particular shape. Whereas in industrial purpose okay there are so automatic automated machines and other things are and so machines are being done as well as automation also is there so that in a large scale these things can be done. So in sheet material forming say for example when you look at the automobile parts body parts then these are all by sheet material forming okay.

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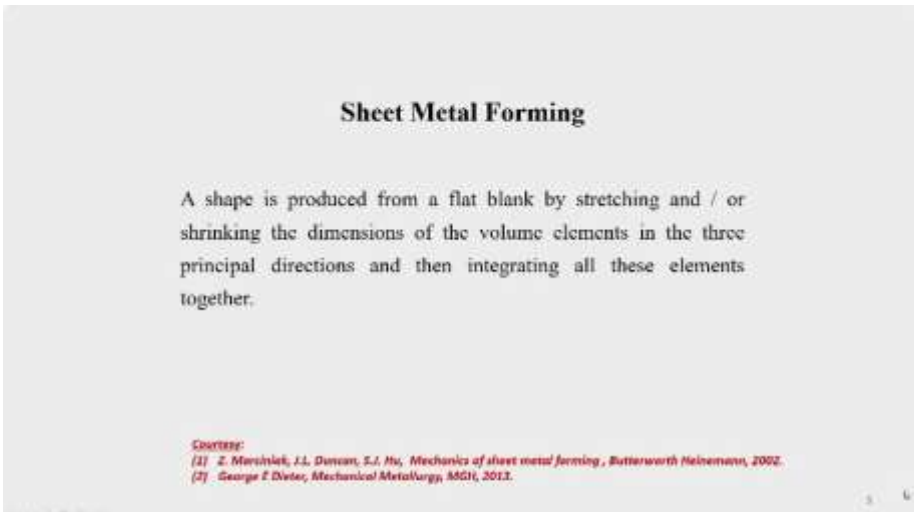

So with this today's lecture I will be referring with respect to the figures which has been reproduced from say Marcenek, Duncan and Hu, the mechanics of sheet metal forming as well as some part from Georgi Dieter. So that is what, so many of the pictures have been reproduced also okay from these books. So the sheet metal forming operation, what is it? That means any shape which is produced from the flat blank by stretching and or shrinking the dimensions, of the volume elements in three principle directions and then integrating all these elements together. So you may be sometimes know you may be just doing the part by part and finally you may just join together to get the final shape that also either sometimes a single shape single process itself you will get the final shape. But in this case it is a sheet metal which you are taking, you are allowing there for some stretching at some places and or maybe shrinking at some places and then okay getting the shape.

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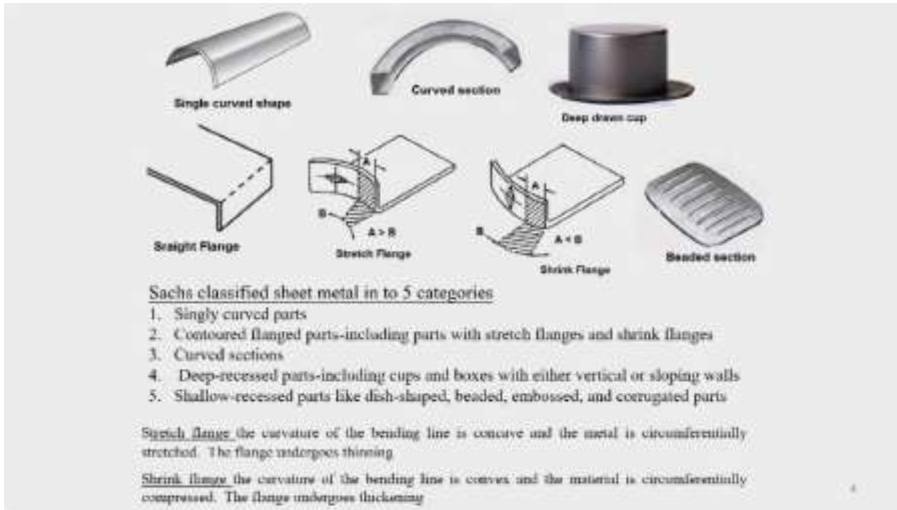

Sometimes for the final shape you may have to join it also. See some of the, so when you look at a large number of shapes are there okay. So, it becomes very difficult to put under which category. So, that is a very difficult job. But however, the SACS has classified sheet metal into five major categories.

So, like singly curved part so that is this part which is the very simple shape a curved shape which you can easily get it maybe a sheet metal you can just roll it and get this shape or pass it through some particular channels and other things you get the shape. So, these are all this single curved shape then contour flanged parts there are parts you are going to get it, with the say maybe this straight flange is there this should be straight flange you can have stretch flange you can have shrink flange okay that means you are just by bending you are getting a flange part okay so in a stretch flange what happens is that the curvature of the bending line is concave and the metal is circumferentially stretched. If you look at this when doing this it is circumferentially stretched. Initially the size was maybe like this only before but after bending there is a stretching taking place so that you get this this area where A is greater than the B.

That is after after the stretch flanging operation you find that this width has increased that means it has just stretched that part that flange part. In and in this case the flange undergoes thinning because when it is stretched there is going to be a thinning effect to maintain the constant volume relationship. Whereas in shrink flange it is a different way there the curvature of the bending line is convex see you see that it is convex and the material is circumstantially, circumferentially compressed into that. So what was B, this length has now become as A where B is greater than A in this case. So there is going to be a shrinking.

The flange undergoes thinning, sorry thickening. So that is a shrinking. But whereas straight flange you are just bending it, okay, there is no stretching or shrinking. It is the same thing. Then you have say deep recessed part like this, curved sections with a vertical or slopping walls and other things. So, deep, such a part is like a deep-drawn cup. So, like this you can get it. Many in the household items now you will find these things, okay. Even industrial purpose also you will see that, okay.

So, either with a vertical or slopping walls, what is shown here is a vertical wall, okay. And then you have the flange here. Then there are the curved sections which are there. Maybe like a channel you are getting it curved and other things. So some part will be stretched, some part maybe shrunk, shrunk and other things.

So those type things will happen to that. So curved section also is there. And then there are shallow recessed parts like dish shaped or beaded section or embossed or corrugated sections even in railways you know you will find that many of these things are there earlier in toilets and other things you know you will get these parts. So, many of the parts in railways you will find that this beaded sections are there. So, he the major categories classification he has made is into these 5 parts and let us look at some of that.

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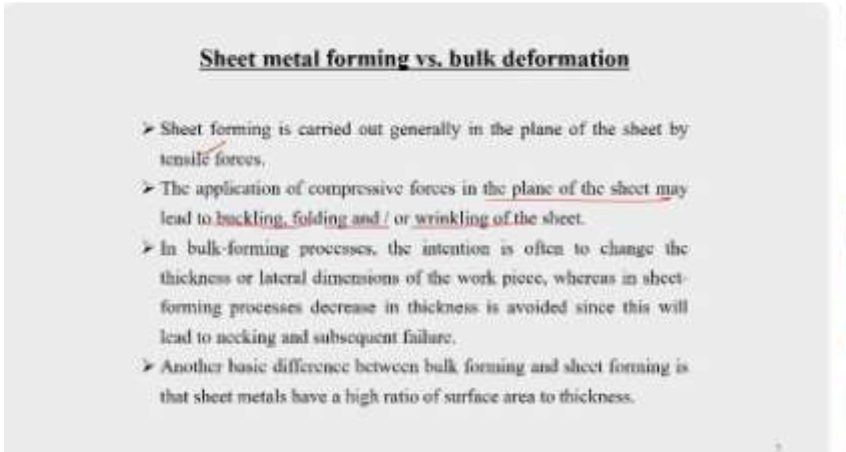

But before we go proceed further let us make a distinction between the sheet metal forming and bulk deformation. Say in bulk deformation, you will find that most of the time the material is deformed in all the three directions okay. So and most of them most of the case it is by compressive stresses maybe direct compressive stress or indirect compressive stress as a result of the reaction you may get compressive stress so any of these things are there. So normally bulk deformation is carried about by compressive stresses whereas sheet forming sheet metal forming is carried out generally in the plane of the sheet because these are thin sheet in the plane of the sheet and they are carried out by tensile forces. Most of the case there are cases where it is compressive.

The majority of them is by tensile forces. The application of compressive forces in the plane of the sheet may lead to buckling, folding or and or wrinkling of the sheet. So that, that is also there. If you are if the sheet material if you are applying compressive stresses in the plane of the sheet naturally it will bend okay or it may fold off or it may just there may be wrinkling and all those things can happen. So in whereas in bulk forming process the intention is often to change the thickness or the lateral dimensions of the workpiece whereas in sheet forming operation the decrease in thickness is avoided because all this bulk deformation process either you have to extend the width or length and other thing and reduce the thickness okay.

So for that metal may flow laterally and other things or perpendicular to a direction of the your load which has been a compressive stresses whereas in the sheet forming process thickness further reduction is not possible. So thickness reduction is avoided because when any process now when you lead to say thickness reduction it may result in necking okay and then subsequent failure of that. So in sheet material your aim will be to have the particular shape with more or less the same thickness throughout that is one thing which people will be looking at it. Another basic difference between bulk forming and sheet forming is that in sheet metal they have a very high ratio surface to thickness that is the one specialty whereas in bulk forming the surface area to thickness is very less okay.

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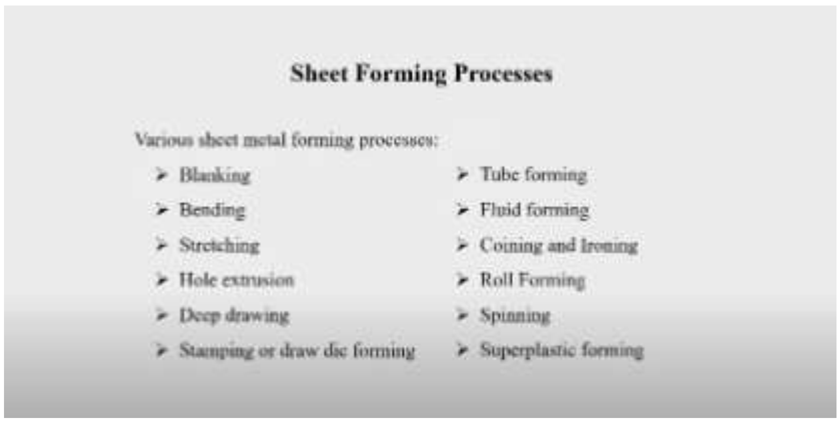

So let us look at what are these sheet forming various sheet forming processes. There are a large number of sheet forming process some of this only because if you wanted to write all those things it will be a very extensive processes because many of the case depending upon the need also people suddenly develop it. So that way we cannot include all those things. But normal or generally used to sheet forming operations we can say that one is a blanking bending, stretching, hole extrusion, deep drawing, stamping or draw die forming, tube forming, fluid forming, coining and ironing, roll forming, spinning and super to some extent super plastic forming okay.

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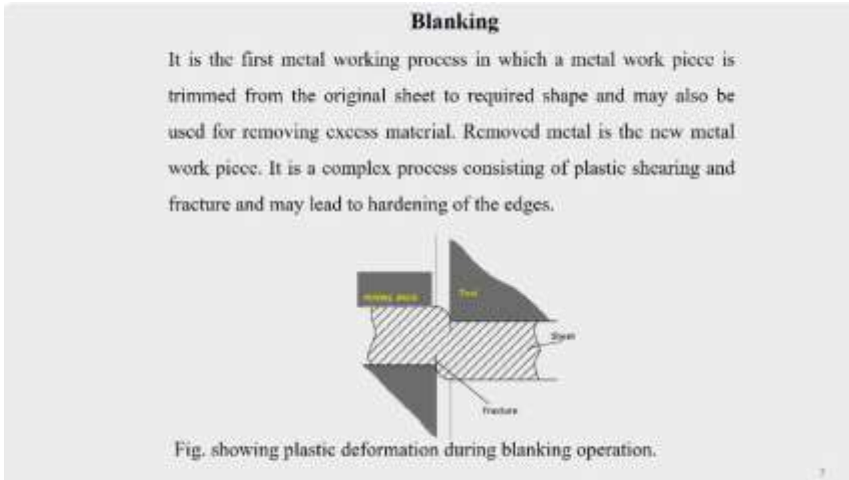

Fig. showing plastic deformation during blanking operation.

So let us look one by one. In blanking this is the first sheet metal working process because if you are getting it from a coil in a coiled form. As per your requirement, you have to cut it, cut the material as per the size and other things. So for that, this blanking operation is being done. Blanking means there is only a small difference between shearing and piercing. Blanking is the case after cutting whatever has been removed from the base basic form from the sheet. So if you are going to use that then you call it as blanking that is the only difference it is only a terminology difference okay. So here you may have to say even if you are if it is not from coil also if it is from sheet size like as I was telling 6 feet by 6 feet or 6 feet by 8 feet size standard size is there from that also you may have to cut your cut the material as per your requirement. okay so for that this blanking operation is used okay and whatever metal is removed from the from the initial material raw material that is that will be the new metal work piece which you will be using for subsequent operation okay. But this blanking it is not that easy. It is not that very simple also. You see that it is a complex process.

This is the diagonal of a blanking operation. There is a on this the sheet metal is kept here and maybe it is held by a block, by applying some pressure and then it is like a projecting outside and a tool just shears it off like this. So, a tool moves down causing this failure. So, maybe from this tip the fracture starts and from here also fracture starts and maybe it may move like this and then join together and then you get it separated.

So, here the process is very complex because consisting of plastic shearing and fracture and when this is happening when there is a plastic shearing it may lead to a hardening of the edges. So when the edge gets hardened and you try to do it in a subsequent operation because the non-uniform properties will be there and there it may start forming the defects that that chance is also there. So you have to optimize it so that it is not getting hardened basically decided by this, the clearance between these two tools. So that is one thing and that depends upon your thickness of your sheet metal. The clearance will be decided based on the thickness of your sheet metal also. So that is also there. So this is a simple blanking operation. This will move here and this will be there. So this is held there. So it will just shear off. A very simple operation.

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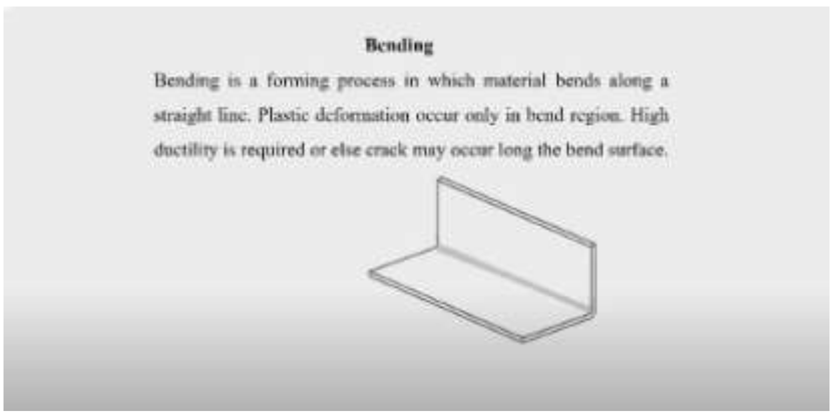

Another which is mostly used is the bending operation. Bending is a metal forming of process in which the material bends along a straight line. See for example, it was a single sheet but we just kept on bending. So now you are getting maybe 90 degree or whatever degree you can get it, so for that purpose. So in this during the bending there is going to be a plastic deformation only at the bend region other places it is there is no plastic deformation that is why this is shown slightly shaded here. So at this part at this part plastic deformation is there so that part may be slightly over cordoned okay so that it will have a high strength at this region okay. So high for this bending operation you need very high ductility. If the ductility is poor, you may not be able to bend it to that much level. Suppose you want a 90 degree, you may not be able to bend it to 90 degree, okay.

So, so if the ductility is poor, the material is brittle, even with a small angle itself now it may crack, crack may develop. So what is important is that for bending, you need to have a high ductility and so that cracks will not develop during the bending stage.

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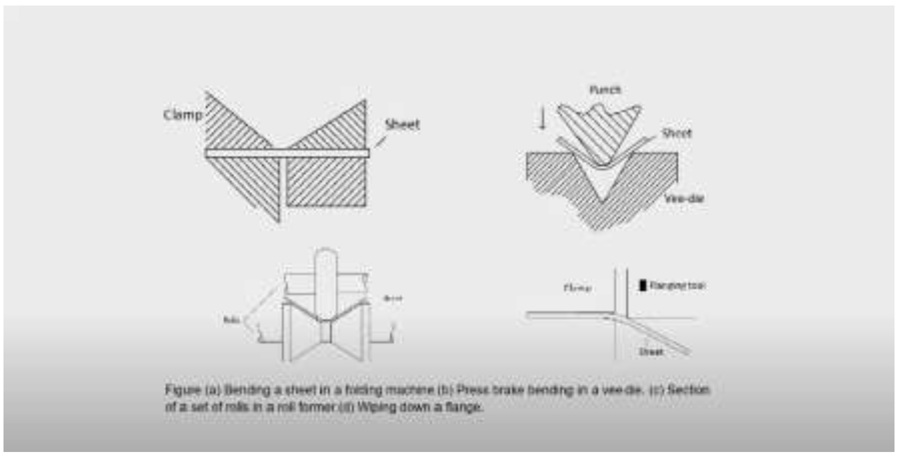

So bending operations as I said I have taken from the book already these are by different processes like bending a sheet in a folding machine. So you are holding this sheet metal here this is your sheet metal you are you are holding it here and so this is it is being clamped here. So between two pieces you are just inserting it and then clamped there there is a mechanical by mechanical means now you are clamping it and this side also it is clamped but this is fixed this is stationary here this part you may just rotate it like this up to whatever angle you want so this you may just rotate like this and once it is bent so it will be rotated about an axis so once it is rotated this part this part will get bent okay and get the shape.

But remember it also depends upon your mechanical properties if you are just bending by 90 degree you may not get a 90 degree bend because there is going to be what is called as a spring back effect because of the models of velocity there is going to be a spring back effect. So you have to do a little bit of trial and error and find out how much it has to be bend but then by this machine it becomes very simple. Another easy method is a suppress brake for bending in a V die. So this is a V die, maybe if you want 60 degree you can make 60 degree, if you want 90 degree you can make 90 degree here in this. You keep the sheet in this V die and then using a punch you press it so that finally you know what will happen it will come like this okay whatever shape you want it will come like this.

So the final case it will be it will go like this you will get the sheet bent okay. So that is that using a wheel die and a punch arrangement you can do this is very very fast process. Suppose you can also use say a roll former if you want a sheet which is continuously coming and you wanted to bend it then it is only this between 2 rolls you pass it so that it will get bent when you enter it. And by a sequence, a series of these rolls you can get whatever shape you want.

Maybe at the first step it may not be there. This is how one of the technique of making this corrugated sheets. So maybe you can have these rolls, a set of rolls at one place arranged in a way and then pass the sheet along that rolls and other things and then you get it corrugated sheets tin sheets and other things which is aware or galvanized sheets you will get it. So that is by this method. So the advantage is that even if it is a very long process when you are taking it from a coiled form you can just have it in a continuous way and later after this bending operation you cut it okay.

So that is one thing. And another is wiping down a flange here you are just similar to this here you are clamping it and then there is a flanging tool which moves inside this okay. So whatever you wanted a flange to make so that much the projection will be there the sheet metal and then okay you just pass it through this because it is clamped here it will bend and get the shape. So that is by means of a wiping down a flange okay so that way you can get it without much of a difficulty.

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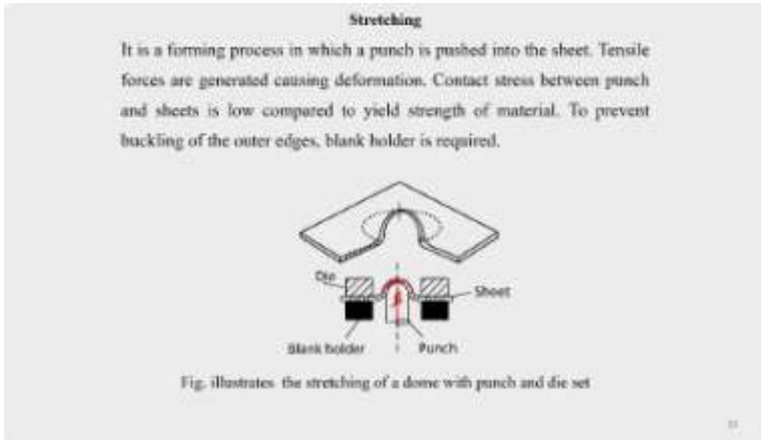

Another is the stretching. The stretching is the forming process in which as you see that here in this figure itself you can see a punch it is the work piece is held between the sheet is held between a die and a blank holder. And then a punch is allowed to move upward or downward depending upon which way you wanted it either it is moving upward or downward so that it will cause this the tensile forces will be generated inside the material and then it will get the shape change. The inside shape will be decided by the shape of your punch okay so that way you can get it. Tensile faults are generated causing the deformation, plastic deformation also it take place to some extent.

Contact stresses between punch and sheet is very low compared to yield strength of the material that is one thing okay. So contact stresses are not very high. Now prevent see sometimes when you are just it is like a stretching operation because of the tensile force of stretching operation is taking place. So this should be held by very rigidly by means of a blank holder. So, otherwise what happens is that if there is no blank holder the buckling of the outer edges will take place because it is drawn.

So, outer edge may get buckling and other things and you may not get the shape. So, to prevent that a blank holder is required. Okay then only you can have a stretching force okay tensile forces are can be generated and causing the deformation. So this is much easier to get a simple shapes axisymmetric shapes and other things this process is much simpler and you can get

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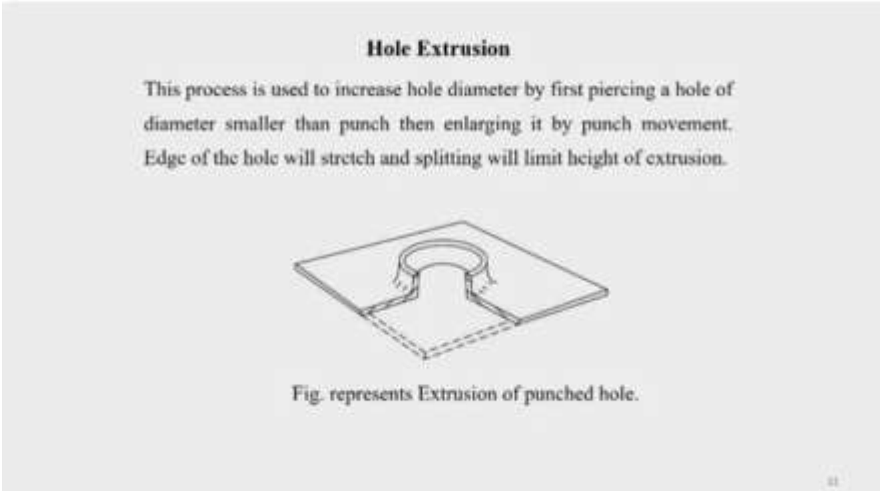

Fig. represents Extrusion of punched hole.

Another method is a hole extrusion you want a hole but it has to be like a extruded part also ok. So, in this it is used to first you know by you have to pierce a hole a hole is pierced first and that size of that first that piercing hole will be less than the final size what you wanted the diameter will be less than that. So, you first pierce a hole then then you allow a punch to move through that if you allow a punch to move through this a punch having a slightly bigger diameter than the piercing hole the diameter of the hole then it get expanded here and the edge of the hole will stretch in this case you know because the diameter is larger it will again stretch, But if it is too much then there may be splitting which may take place. So you one should know about the formability behavior of the material and the ductility and say other r ratios and other r values and other things you should know. Once you know that you know you will be able to tell how much it can stretch and how much this hole can be extruded. If it is too much there will be cracks. So hole will stretch and splitting will limit the height of extrusion.

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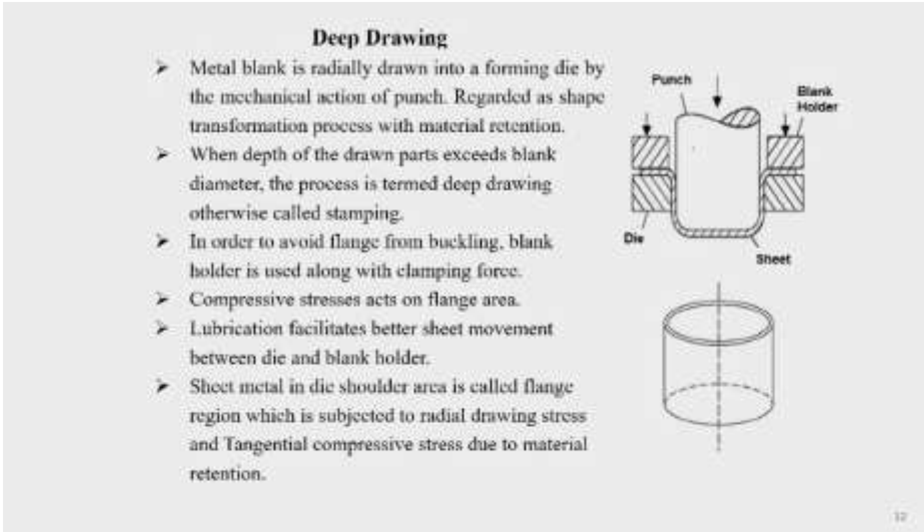

Another sheet metal operation which is extensively used is the deep drawing. See if you look at most of the household items, tumblers, glass, steel, glasses and other things you know they are made by deep drawing operation. So with the deep recessed parts any part can is made by deep drawing operation.

Basically a metal blank is radially drawn into a forming die. So you are you are going to keep a metal blank here and it is held by means of a blank holder and the punch moves down it moves too much down. So what happened is that here it stretches okay and then you get that shape. Now deep drawing is, and stamping though it looks similar the term terminology deep drawing is used when the depth of the drawn part that means from this here to here this depth, this h is greater than your blank diameter h is greater than your diameter okay. So, maybe if I say that this is your d So in this case you call it as deep drawing but if this depth is less than your diameter then you call it as stamping operation that is the only difference. These are processes same maybe the same machine may be used but just by this dimensional terminology gets changed.

So in order to avoid flange from buckling the blank holder is used along with the clamping force. So, if you do not have this blank holder naturally now you will say it may be drawn inside and you may end up with the lots of wrinkles and other things all those problem will come. So, to avoid that you need a blank holder which has to be which has to hold the sheet on the die so that now you are going to get this stretching forces on the sidewalls. So in this case the compressive stresses act on this when you are holding this in this region now you will see that it is compressive forces which are acting and if you give some good lubrication and other things now it facilitates better sheet movement in this deep drawing operation lubricants are generally used. So that it gives a better sheet movement between the die and the blank holder otherwise now even not lay here even in the between the punch and the blank also you should know that.

So, these things are there ok. Now when you are drawing when this deep drawing operation is going on stretching the metal will slowly move inside also see from the blank holder side it will move radially and then cause that so in if it is not there the thickening will take place but in this case no only in a controlled way it will go there and the thickness will remain more or less same. And the sheet metal in this die shoulder region is called as a flange region which is subjected to radial drawing stress and tangential compressive stress due to material retention. So, it will be drawn inside material just to flow into this it will start flowing into that and then that will be taken care of by extending the increase in the depth of this okay.

So, that is what happens. So, radial drawing stresses will be there on this the part in the shoulder area where it is held by the blank holder okay and there are also tangential compressive stresses due to material retention. So deep drawing is extensively used for getting some specific shapes and other things deep recessed parts.

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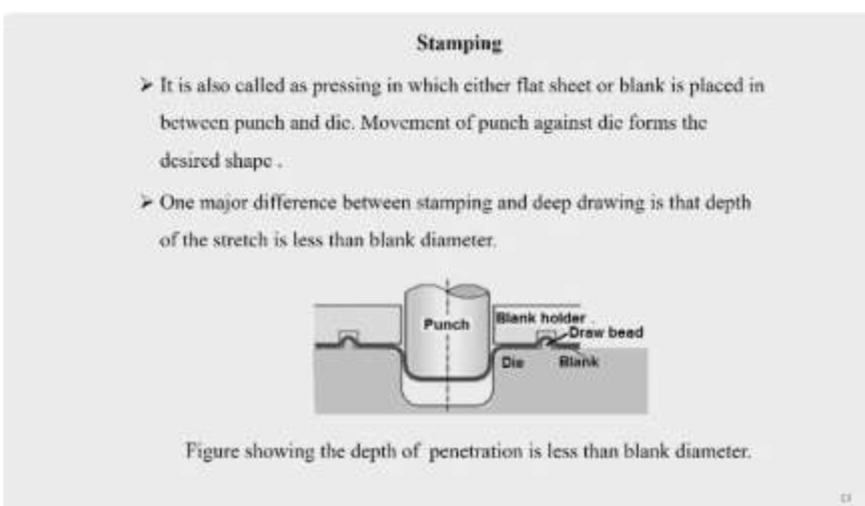

So when you look at stamping there is only one difference in this case your the depth the height at which this side wall movement is there no that is much less compared to the diameter of the punch. So it is also called as pressing in which either flat sheet or blank is placed between the punch and the die and movement of the punch against the die forms the desired shape.

One major difference between that as I said that the depth of the stretch is less than the blank diameter that then you call it as stamping. Otherwise it is the same process is same machine will be the same only the terminology is different.

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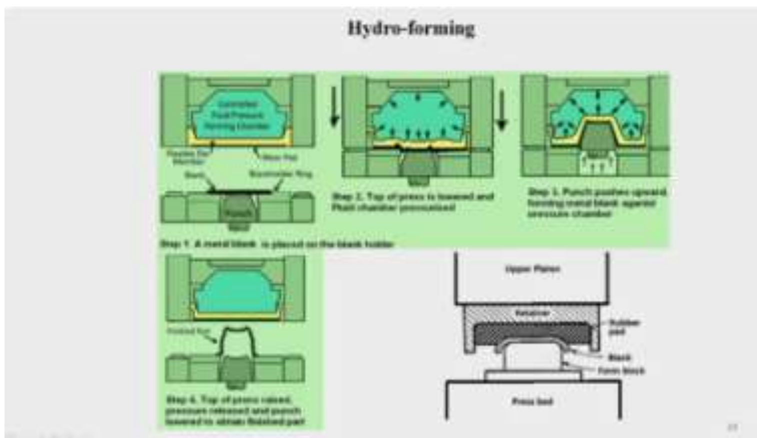

Now when you wanted some specific with the high precision and accuracy some specific shapes and other things if you are wondered then hydroforming is extensively used and this is extensively used for automobile body parts where you get a very good surface finish and the production rate is much higher and the defect or rejection in the process is very minimum in this case. Once you standardize it for a particular component, the rejection is almost nil, That is one biggest advantage with this. So hydrofoaming, it is nothing but you are going to have a hydrostatic pressure on the sheet metal, okay. So equally in all directions, you are going to have, wherever it is going stretch and other things. So in the process, you will get a uniform section thickness.

So that is what this hydroforming. So the process is very simple. You have a control fluid pressure forming chamber. So this will be a flexible die member, something like it may be synthetic rubber, okay. This is made of synthetic rubber. This flexible die member is a synthetic rubber. There is a wear pad also so that now this rubber also will not get worn off. So those type things are there. And your blank is kept on a die and maybe inside a blank holder ring. Inside the blank holder ring you are keeping it. and then the whole arrangement this whole arrangement it will move up and then press against to this the top part about this fluid pressure forming chamber. So you remember that here there is fluid so this is rubber so that also will act like a hydrostatic type of stress so you can get this very flexible and then where once it comes and touches here this, this punch moves upward this is the punch pushes upward.

So now once it comes and presses here what will happen is that you will pressurize this fluid chamber okay with a high pressure you are filling it it will be under high pressure and now what happens is that this punch you will see that the punch shape is there. So whatever shape you wanted it is that shape the punch will have that similar shape here. So this punch moves up, and when it is moving see this this flexible pad is there now which is rubber that will elongate no problem but the fluid pressure which is there it will exert a hydrostatic stress in this equal in all directions. So you will find that whatever is happening the thickness remains almost the same and and once that shape has come then you just or retract the punch backward and then you will get this finished part and lower it you get the finished part you take it.

The biggest advantage in this is the thickness remains almost same in this case because it is uniformly deforming throughout the part. So that is one thing. The defects are reduced and consistency in the quality is also maintained in this. Drawback is that this rubber padding it may get worn off very fast you may have to remove so that will increase your cost of the component because rubber rubber material itself is costly so that is another simple method using a simple press and other thing is that okay you have this a form block is there on which whatever shape you want and the metal blank is kept there it is pressed against a rubber pad itself there is no hydraulic pressure here this is a retainer on with the rubber pad is there you just proceed this is for simple shapes and other things this works out okay.

Because this because of the rubber pad itself that itself will act as a give a sort of to some extent a hydrostatic stresses it will give and due to that you can get the shape. So on the foam box whatever the form shape is there that you will get it. So that is what is hydrofoaming. So hydrofoaming is that way very convenient thing. Only thing initial investment may be high but compared to the production rate that will be balanced off.

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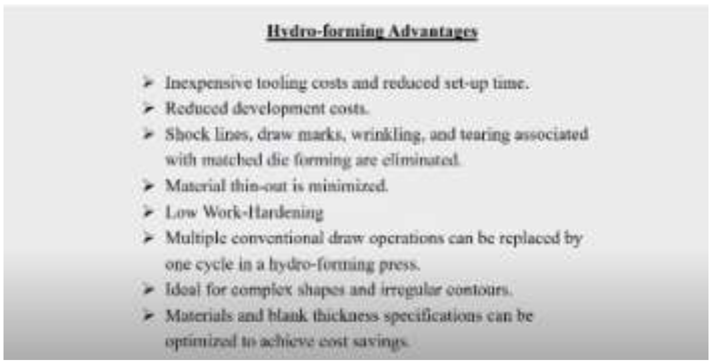

The advantages of hydro forming are inexpensive tooling cost and reduced setup time. This is one biggest advantage. Once you fix it, then you can start making in large number. So that is the so inexpensive tooling cost. But machine cost is high. It is not very high also. But the tooling costs are not high, okay. It is very cheap and due to that not only that the setup time is also very much reduced it is a very simple thing only to fix it. There is nothing like exactly arranging these parts and matching and other things so that is not coming into picture. Then reduced development cost. So, once you have the machine then any type of component can be like you can have a variety of components made into that not any shape it cannot be made, but you can have a variety of shapes. So, component also for that you know the development cost will not be very high. Then the shock lines, draw mark, wrinkling and tearing associated with the matched dye forming, these are all eliminated, these are not going to happen because of the hydrostatic stress, okay.

Wrinkling will not be there, draw mark will not be there, shock lines will not be there and maybe some tearing also because of the hydrostatic pressure, so that way the tearing also may be eliminated. The thinning of the material, because it is a hydrostatic stress and it is deforming uniformly in all directions whatever thinning is taking place it is uniform. So localized thinning is not there okay so that is minimized that is one advantage and low work hardening. Then multiple conventional draw operations can be replaced by one cycle in a hydroforming press, this is the biggest advantage.

So, instead of 2-3 operations, this you can do it in a single operation just by your pressurizing the chamber, pressure chamber and other thing and then having a proper shape on the punch and other things. So, that that is one biggest advantage with this thing. And this is ideal thing for complex and blank complex shape and irregular contour this is the answer to that. Other shape you know it becomes very difficult by other methods it may not be possible but by hydroforming you can have that in a complex shape also and irregular contour also you can have it. And the materials and the blank thickness specification can be optimized to achieve cost saving.

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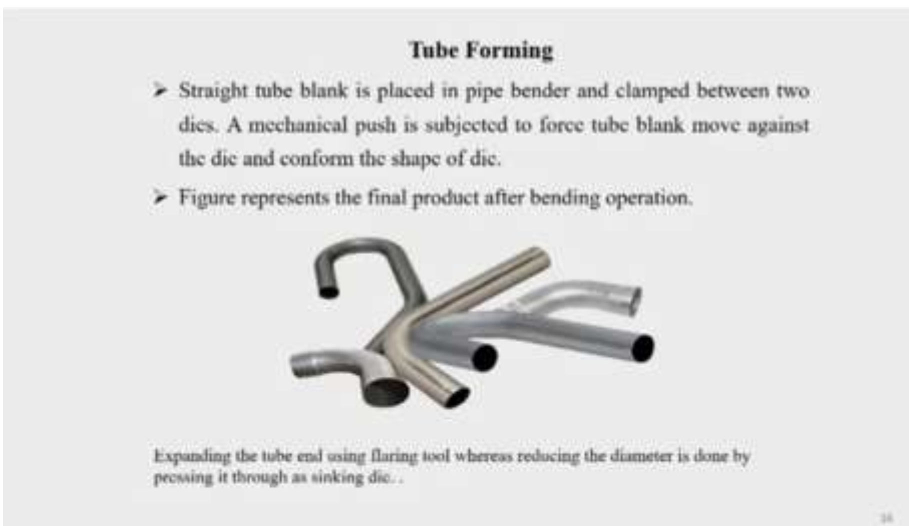

So, these are some of the advantages. So next method is your tube forming. In the tube forming, say you have tube and then you have to give it different shapes. Maybe you may have to bend it. You may have to say enlarge the one end you may have to reduce the diameter at one end of this pipe these are all done by tube forming operations okay. So you can see that say here there is a particular dimension this this was a pipe and then okay or a tube was there here the dimension is different here dimension is different. So you may get all you may it was a straight pipe now you are getting this type of shapes but remember when you are bending the tube there is every chance that it may collapse at the bend.

So you have to do it effectively so that that it is uniformly bend without collapsing okay if it is collapsing it will not serve the purpose and your efficiency of the performance of the component or the machine will be affected so you do not want that. So in this case see instead of just bending say bending may be done between a pipe bender Okay the tube blank will be placed in a pipe bender and clamped between two dies and then okay a mechanical by means of mechanical means you are pushing it and subjected to force the tube blank move against the die and come to the required shape and this is what is generally done. A tube when you are just bending it may cross as I said it may cross so you may have to do something some people then fill it up with the sand and then bend it so that it is cylindrical in shape itself or some people may just fill it up with water and refrigeration they do it so that it becomes to ice and then both the ends are closed and you bend it so that this circular cross section is maintained, that depending upon those people who are using it, they will come out with their own ways and means of bending without this collapsing of the tube at the bend. Now, in case if you wanted to expand the tube end, say like here, here from the tube, you wanted to expand this then use a flaring tool so you just a flaring tool you insert it and rotate it and then finally get that shape you press it into that and then you get that shape so that is a flaring tool. But if you wanted the diameter to be reduced then you press it through a sinking die okay die sinking you know so through that you know you just pull it and then get it. So there also you can rotate and get there in that case you know the metal it will thin whereas in this case of flaring tool when you are using to increase the diameter the sidewall will get thinned off. Whereas in the sinking using the sinking die you will find that okay it may be slightly increased only. So this tube bending, so lot of shapes are used in tube bending.

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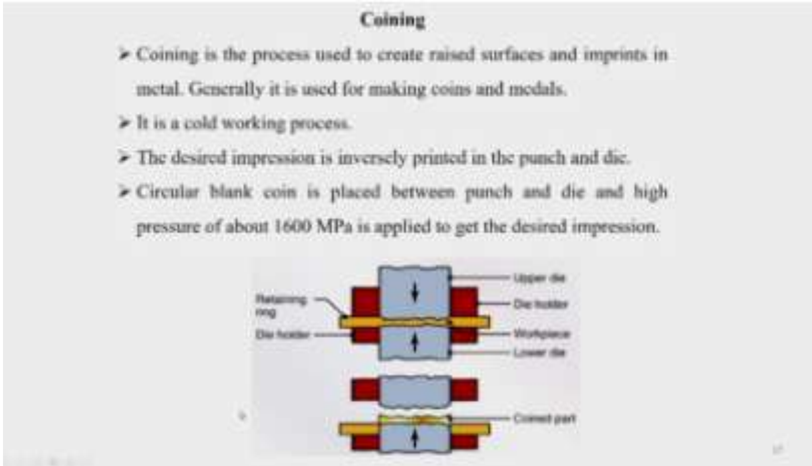

Another method is the coining. See coining is like how you make a coin, okay. So metallic coins are there in almost every country there are coins. We have you know 10 rupee coin, 5 rupee coin, 1 rupee coin, 2 rupee coins and other things are there. These are done by coining process. So what you do is that you are going to have a piece which is kept here. The work piece is kept here and then between upper die and the lower die now you just press it. So, depending upon what is the shape here what are the features you wanted here on the coin. So, the reverse of that will be reverse impression will be there on the on your die and punch like if you take a coin on one side it is head and the other is tail you call it as you know. So, on one side that impression the reverse impression we can say that like it is you know we cannot call it as mirror image, but what is that male and female joint type thing.

So, that impression should be there on the upper die and similarly on the other side whatever will be there you wanted it on the lower die and then the metal is there and then you are pressing it when you are pressing it some plastic deformation takes place and metal will flow into this all this contours and then fill it up okay and then finally it is taken and then it is what is that shade okay. Blanking is done sorry okay and this coining is always a cold working process okay and these are used for making coins and medals and many of these type things. The pressure which is acting on this during the coining will be very high okay it may be of the order of 1600 or 1000 mega Pascal to get the desired impression on that apply a higher pressure on this.

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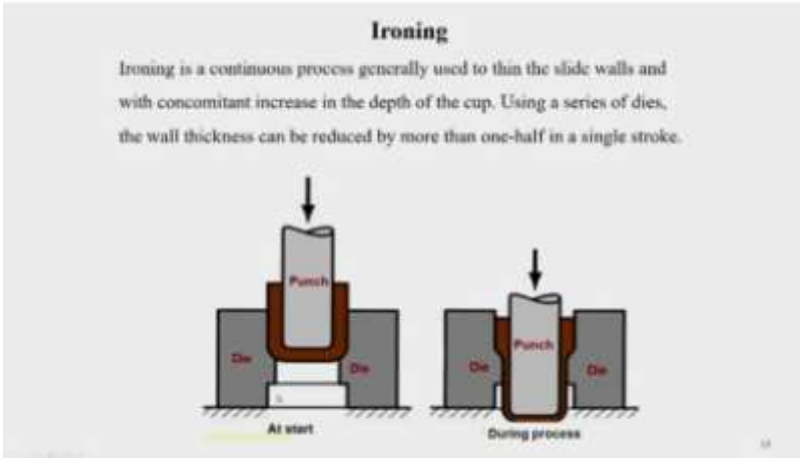

Another method is ironing. So ironing is a continuous process which is used to thin the sidewalls and when you may get with the concomitant increase in the depth of the cup. So that is the thing. These are all sectional views which are shown. So here you will keep the blank here and the punch you will through with the help of the punch you are just moving it and then so maybe depending upon the clearance between the punch and the die your thickness will get reduced.

So, that is the main method of ironing. So, at the start it will be like this maybe when you see that on this die itself there is initially it may be like this but somewhere below that you will find the die shape is like that there is provision for thinning. So, in that case metal will flow along here and so till the complete punch traverses downwards the full extent if it is there till that time it will just keep on. So, but you have to be very careful otherwise sometimes now the still the full metal may not be enough so that punch stroke adjustment you have to do it properly. So, in this case if you look at it you see that here it is like a deep drawing operation but when it comes here there is a thinning which is taking place the side walls gets thinner.

So, but you can have this arrangement in a by using a series of dice one after the other you can do it. So, that in one stroke itself you can get a large reduction from the initial thickness to final thickness in one stroke itself we can we can just arrange this die next part there is a die here when it moves here where the still clearance is less and other things. So so that is one advantage so more than one one half the thickness can be reduced to almost half that is 50 percent reduction you can have it in a single stroke by this one so by means of ironing so that also is a extensively used to process.

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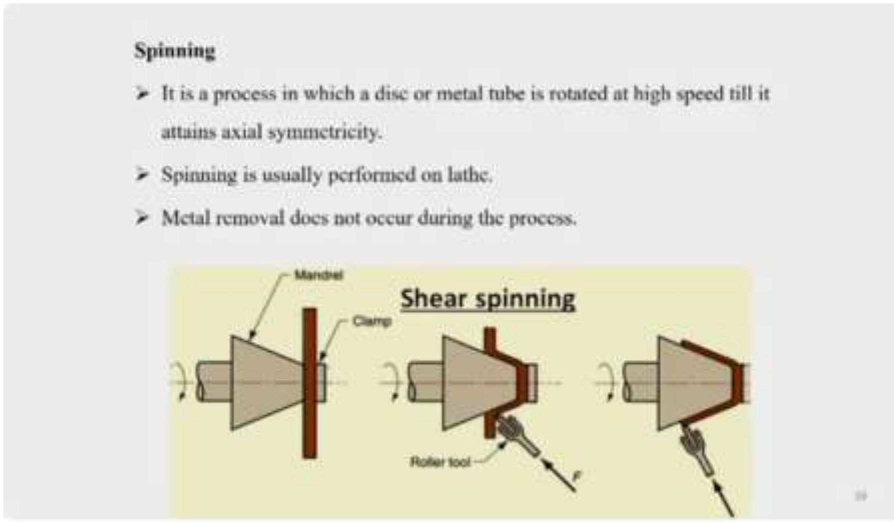

Another method is the spinning operation see one is simple metal spinning and another is the shear spinning. So you have a mandrel say like this mandrel is here and then this is held on a lathe and by means of the your tail stroke and head stroke now you just keep it on this and this is the mandrel and your work piece is this is a work piece okay.

This is your work piece and then it is rotated and a tool is allowed to move along in this direction okay. So you will get this particular shape, so it will get the shape, so you will get a cup type thing, so inside will be corresponding the outside of this mandrel, so that is what you are doing. So that is a simple spinning operation. So it is a process in which a disc or metal tube is rotated at high speed till it attains axial symmetry, and then by means of a roller tool you are just allowing to deform it and then get this particular shape. Whereas in shear spinning not only that shape is obtained you may the clearance between this roller and this your mandrel is very less so that you may have to either there is there will be a thinning effect in this.

So lot of plastic deformation takes place by means of the roller tool, its thickness gets reduced, so that is the thing. And till this part when it comes here, now you are getting this shape. This is the intermediate shape, this is the starting, this is the starting shape, this is the intermediate shape and final shape. So initially your blank thickness was this much but when you are getting the sidewall thickness is much less than that, so that is.

what is called as shear spinning. So here plastic deformation, shear spinning plastic deformation is taking place and you can have a correlation between what is this angle and what is the thickness you are going to get it. So that we will discuss about it later. So by shear spinning also we can have it.

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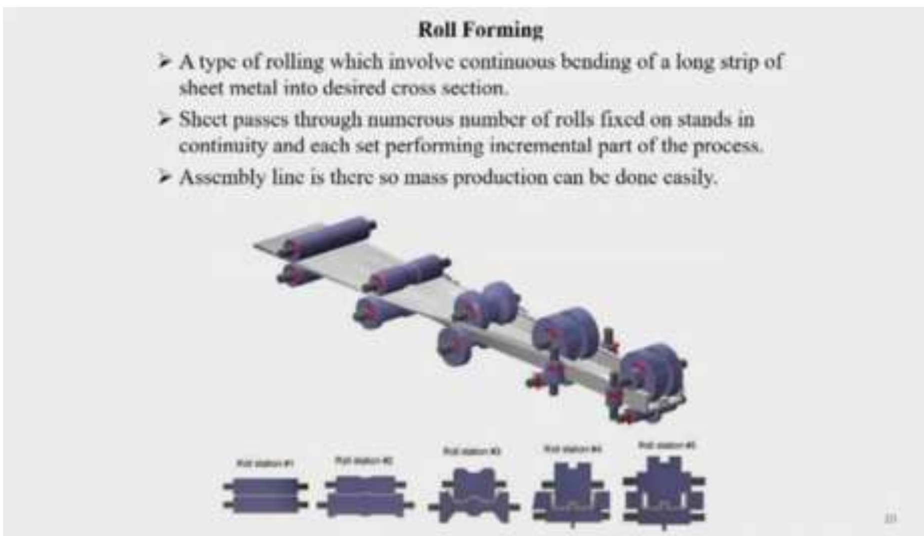

Now this roll forming is there, you want a particular shape and on a continuous long sheet if it is rare you wanted to see you have a simple plain sheet like this and maybe your final shape is something like this if you want it is not that only one you can have multiple also.

You see that it is passed through a series of rolls. See this is the first roll where it is plain and other things and the second roll comes now you see the size of the roller is different. So there is going to be a small amount of deformation when it comes to the third one okay the sheet metal get bent deformed in this form in this particular shape and the fourth one you are getting this shape and finally the fifth one also you are going to get it. So by a sequence of passage through by the passing it through a series of rolls with the different contours finally you get the final shape what you want and if that is on a single sheet on a continuous sheet then you go for this roll forming. So because it is passed through between pairs of rolls okay. So, like each each stage there is some amount of deformation to get so that straight in one go you are not going to get the final shape okay. So, in a in a progressive way you are going to change the shape and finally you get it. The assembly line is the no mass production can be done easily okay. So, that is one thing with roll forming.

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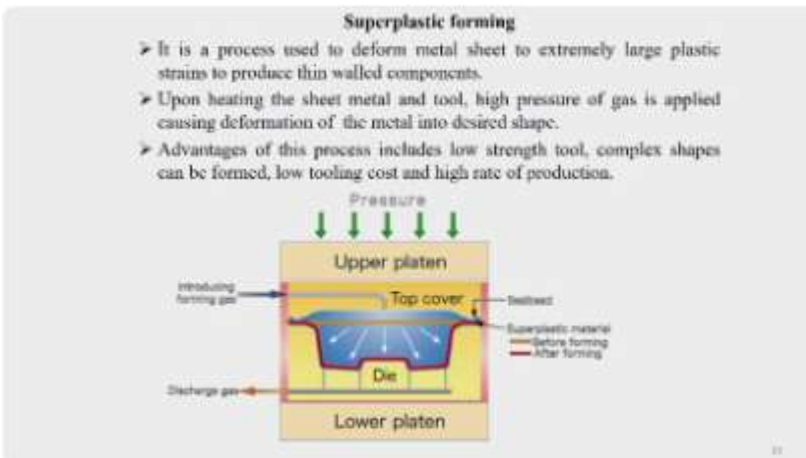

Another is the super plastic forming only drawback with the super plastic forming is that it is a slow process ok, it takes some time but you can get deep recessed parts say for example if you want that shell for your granite and other things ok or grenade and other things when you wanted then this bomb what is that that casing ok So all those things you know you can have for that the superplastic forming is known. See superplastic forming is that you when you are deforming the material there is no necking taking place. The material exhibits superplasticity when you say that there is no necking with this thing when in our tensile strength after reaching the ultimate tensile strength, then you will see that the load drops that is because of the necking takes place at localized region which we have mentioned in our first class or second class first lecture or second lecture of the module 1. So that so under certain specific conditions any material most of the materials will exhibit super plastic deformation. So once it exhibits super plastic deformation your percentage elongation can go up to say maybe 600 or 1000 or 2000 percentage okay. So you start with a very small piece and then you are you are able to along it into a very fine rod. See simple example is you take a glass rod heat it under just heat it and when the temperature crosses around 700 800 you can just pull it like a and then it gets reduced into a very fine form. So small area so it will get extended to say more than 1000 percentage okay. So that is what is called as super plastic super plasticity and the process of deforming under super plastic condition to get a shape where we can have a large amount of strain so that is called as super plastic forming, to and by this process you can get very thin walled component to a very high accuracy and good surface finish all is possible by this okay. Advantage of this process is the low strength the tool and then complex shape can be formed and low cooling cost tooling cost and high rate of production high rate of production is not that very high okay. So other other things are fine you can get a very complex shape with very high intricate shapes you can get it that is one advantage and cost is not very high. The principle behind this see when you wanted a material to have super plastic deformation the general metallurgical reasons which they give is that it should have very fine grain size, something between 5 to 10 or 5 to 15 micrometer diameter, not higher than that, very fine.

The structure should contain two phases. The continuous phase should be ductile and the discontinuous phase should be brittle and this should be uniformly distributed. These are the conditions which is difficult but not impossible okay. So and in that case and then you are deforming it under very slow strain rate okay. So strain rate is very low that is why it takes lot of time in this process.

So, what you do is that you just have a super plastic material is kept here first okay. This figure is showing at the end and then it there is a seal bead which is there. So, that will just separate out from the region above this sheet and below that sheet. It will be completely isolated okay. So for that you need to have a seal bead and other things and then the whole setup if you wanted to do it at a higher temperature you keep it at a higher temperature and when the temperature is reached, so entire thing that temperature particular temperature once it is reached then you just introduce some forming gas into this, into this top chamber. So what happens at that high temperature and this will be generally be done at a low strain rate. So this will just keep on moving like this okay and once it see because necking is not taking place so fracture will not take place and but only thing is that this has to be carried out at that particular conditions okay. But the biggest advantage is that if a material say for example Titanium, Aluminium, Vanadium is a extensively used super plastic material and it is used for space application and defense applications in a big way. So that sheet when you are keeping it and then you are going to apply this pressure at a very slow rate okay. So but that sheet should have all these conditions that microstructure it should satisfy two phase and one should be the brittle one should be discontinuous okay and then it should be deformed at that particular strain rate which is generally very slow strain rate that is of the order of 10 to the power minus 3 per second and other things, all those things. So here once you seal it you pass this gas at that particular temperature and so it exerts the pressure on this so that will allow this metal to deform superplastically. So it will not result in necking. It will just deform and then okay it will come and touch this formed die on this walls and then stop it okay. So that is how this it is done but this strain rate is very very low.

So it takes lot of time but you will get it with a very good surface finish and very close dimensional accuracy. Now coming to this other parts like when you go for this for the analysis we will have to think about various points like what are the properties the material should have. It is not that okay you cannot take a brittle material and do a sheet metal operation, it is not possible. It will just crack. So material should be ductile. So you need to have certain knowledge about these material properties. So this part was mentioned earlier, the very important criteria for selecting a material depends upon its functionality that is there.

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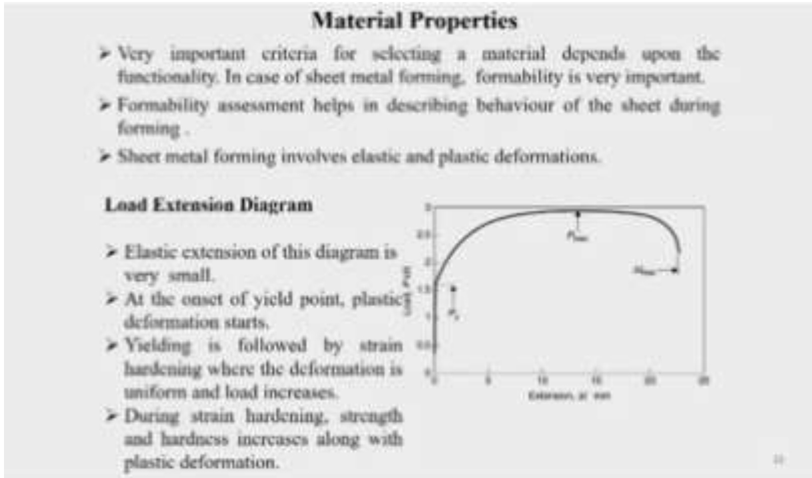

And in case of sheet metal forming, the most important criteria is the formability that means the relative is with which we can deform the material that is called as a formability. So you should have an idea about the formability of the work piece material which you are going to deform it that is very essential. Once you have this formability assessment, once it has been done, this helps in describing the behavior of the sheet during forming.

So under what conditions it will deform. So and whether you can go deform the material up to this particular limit or it can go to infinitely or what is the limit beyond which if you try to deform, it will result in the cracks formation and then subsequently it will fail. So, you should have an idea what is the limit activity and if you want still wanted to go further what you will do. So, for that this formality assessment if it is there that is very good. And you will see that sheet metal forming involves both elastic and plastic deformation. So this is a typical load extension curve which we have done and from this we can get your stress strain curve also and then if you know the dimensions then you can find out the true stress true strain curves and other things.

Now at the onset initially when you load it, it will deform but after certain time it will start deforming and that load at which it will start deforming is called as a yield point okay. So at the onset of this yielding the plastic deformation starts and from there till it reaches your ultimate insertion the material undergoes work hardening. Initial work hardening will be higher but when you move towards the later stage with the increase in the extension the work hardening rate will decrease and finally it will saturate saturate out okay. During the strain hardening the strength and hardness that means from this region from yield point to your ultimate tensile strength. The strength and the hardness of the material increases along with the increase as the plastic deformation increases. So that is one thing. So maybe after this deformation you may get a material having higher strength and hardness.

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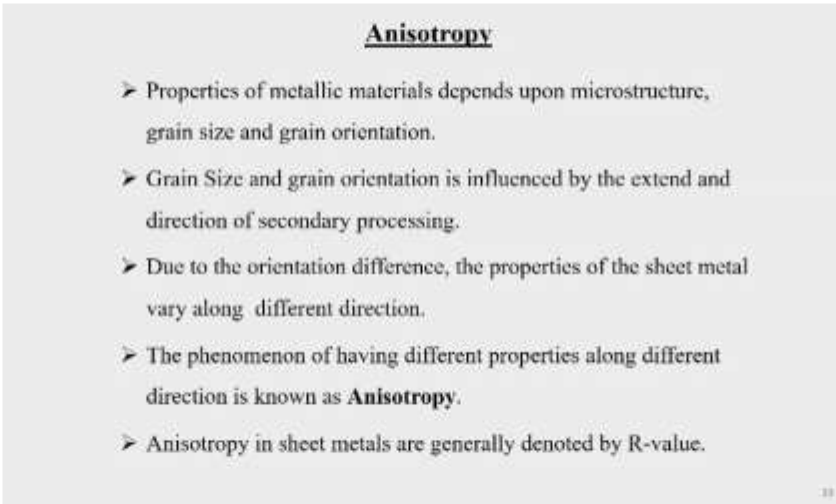

If if that is required we can use it if that hardness and strength at that region is not required we can give a heat treatment annealing heat treatment so that it will be nullified okay. So but one term which we have not discussed so far compared to a bulk deformation we could have discussed there also but purposefully I did not discuss it there so so that we can go into depth here that is the anisotropy of the material. Any sheet metal, especially if they have been cold deformed, you can easily find out in which direction this has deformed because when you look at the light reflection of the light we can make it out in which direction it was deformed okay.

So that is one floor test to find out which is the direction at which the sheet was rolled okay so that is there. So all these materials you know you will see that its properties of this metallic material depends upon the microstructure and in microstructure what is that what are the phases what is the grain size of these phases and what is their orientation because almost all sheet metal comes in the after secondary process maybe by rolling or forging or drawing whatever it be it comes after the secondary processing operation. So that large amount of strain has been there in this case what happens is that grain size with the extent of deformation which you have imparted on to that the grain size will get reduced. If the deformation was less grain size will be large but if you have given extensively deformed grain size will be less. But at the same time if you have given a after this one if you have given a heat treatment then it may become very soft also.

So all these things are possible. But ultimately when you look at the structure you will find that what decides the properties of the material below the equi-hocosy temperature that is the grain size and the grain orientation. So higher the deformation which you have given, the lower, finer will be the grain size. Finer means smaller size, okay. Coarser grain means bigger size, that is what. So finer will be the grain size. And you will find that the grains are oriented along certain directions. A phenomenon which people abundantly use now is the texture. So most of the case after large number of deformation, you will find that a particular crystallographic, the crystallographic planes of one grain it is arranged in a particular direction, along a particular direction. Similarly, you will find for most of the grains, it is arranged in that particular direction, along that particular direction.

So, that is called as the preferred orientation. After this extensive deformation, the grains will orient it in a particular fashion, in a particular direction, which you call it as preferred orientation, ok. So, the grain size and grain orientation, so they are influenced by the extent of the the direction of the secondary processing the extent and the direction of secondary processing and based on that only your properties will change. So due to the orientation difference the properties of the sheet metal vary along different direction because if the grains are elongated along one direction and then in other direction if you apply maybe the properties will be poor whereas when you have applied along one direction along that direction property mechanical properties will be better.

So that is one thing the phenomena of having different properties along different direction. So suppose I have a sheet like this and this was the rolled direction if I if I just take a sample like this and then okay study the properties. But if I take at this 90 degree to this and then study the mechanical property, here now grain orientation was like this. So here the transfer's properties will be very poor. Similarly, here it will be the maximum.

Similarly, if you are having something like this orientation like this, then it may be intermediate between these two. So in this case, when you look the properties along this direction and the properties along this direction and the properties along these directions, these are different. So if they are different, then you say that the material exhibits an isotropic, okay. So in a single sheet, from that you cut it cut your tensile samples along different directions and then study you will find that they are not same but along the same direction if you just take it and conduct a large number of tests along a particular direction then you will find that okay it is a reliable result if it is a larger than 5 or 10 then you consider it as a reliable result okay and take the statistical values and to find out these properties. But if they are different then you call it as this is exhibiting anisotropy. So anisotropy in sheet metals are quantified by this term R value.

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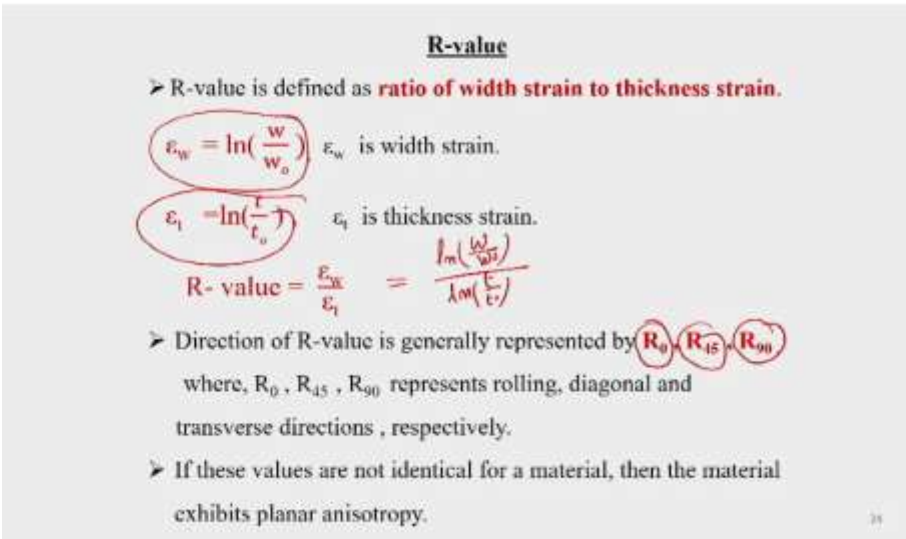

Let us see what is this R value. The R value of a metal sheet is defined as the ratio of width strain to thickness strain in whichever direction you are taking but along the axis of the tensile stress if that is taken as a length, then the width and thickness is there. So, the strain along the width and the strain along the thickness, the ratio between these two is called as the r value. That means the strain along the width, width strain is this and this is the thickness strain. So, r value when you just do that is E w by E t. So, that is equal to say you can say log w by w 0 by log thickness T by T0 in this ratio when you take it what is that value you are going to get it is called as R value. Now this R value depends upon different directions also as I said maybe you are you are just cutting the sample along the direction of rolling another you are cutting along the direction transfers to the direction of rolling another you are cutting a sample from which is equally inclined to both this length and the width direction okay. So in those cases you know your properties will be different.

$$\epsilon_w = \ln\left(\frac{w_1}{w_0}\right)$$

$$\epsilon_t = \ln\left(\frac{t}{t_0}\right)$$

$$R - value = \frac{\epsilon_w}{\epsilon_t} = \frac{\ln\left(\frac{w_1}{w_0}\right)}{\ln\left(\frac{t}{t_0}\right)}$$

So when it is along the direction of rolling then you call it as R0. When it is transverse to that, then you call it as 90, R90. And if it is taken at 45 degree inclined to this direction of rolling, then you call it as R45. So that is the only difference, okay. So this R0, R45 and R90 represent rolling, diagonal and transverse directions respectively. If these values are not identical for a material, then the material exhibits planar anisotropy.

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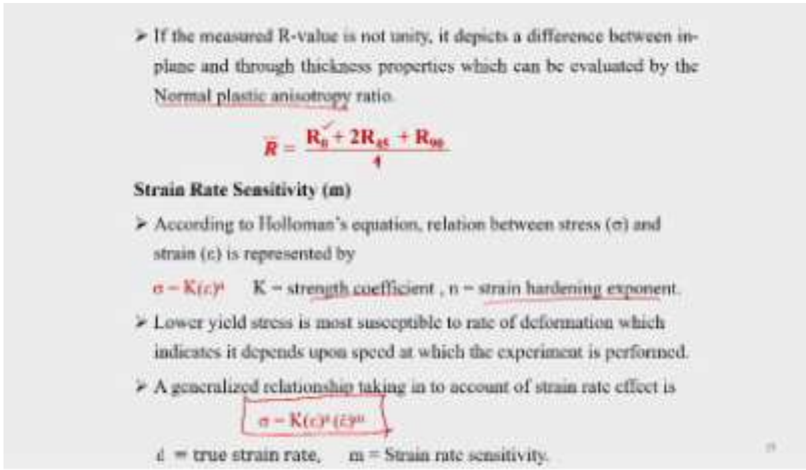

So, what is this planar anisotropy let us see and if the measured R value is not unity, if it is not unity, it depicts a difference in plane between the in plane and through thickness properties of the material. So if it is not unity because the strain along the width and the strain along the thickness it is different. So you will find that okay there is a difference between the in plane and thorough thickness through thickness properties of the material. and which can be evaluated by the term normal plastic anisotropy. The normal plastic anisotropy R bar is defined as one by fourth of sum of R0 plus 2 R45 plus R90 this we can easily get it from your matrix tensor this one now you can easily get it into this okay. So this is much easier so and then that divided by 4 so that is what you called as normal plastic anisotropy.

$$\bar{R} = \frac{R_0 + 2R_{45} + R_{90}}{4}$$

Another thing which you have to consider is the strain rate sensitivity M. See, we have earlier discussed the Holloman equation between the stress and strain at room temperature. But when you go to a higher temperature, it is entirely a different thing. So, where k is the sigma is equal to k epsilon raise to n, where k is the strength coefficient and n is the strain hardening exponent. Now, in this case, you will find that lower the yield strength, if the material is having lower yield strength, then it is susceptible to rate of deformation which indicates it depends upon the speed at which the experiment is performed.

$$\sigma = K(\epsilon)^n$$

So this is the case at the particular speed but if you are doing it at a very high speed then you will find that there is a difference in the the flow stress. So at a higher strain rate when you are doing you may find a you will end up with a higher flow stress okay so that is there and then that will be different for each material. So we can say generalized relationship taking into account the strain rate effect you can write in this form sigma is equal to k into epsilon raise to n into epsilon dot raise to n where epsilon dot is a true strain rate and M is a strain rate sensitivity of the material okay. So that way you can find out this process.

$$\sigma = K(\epsilon)^n(\dot{\epsilon})^m$$

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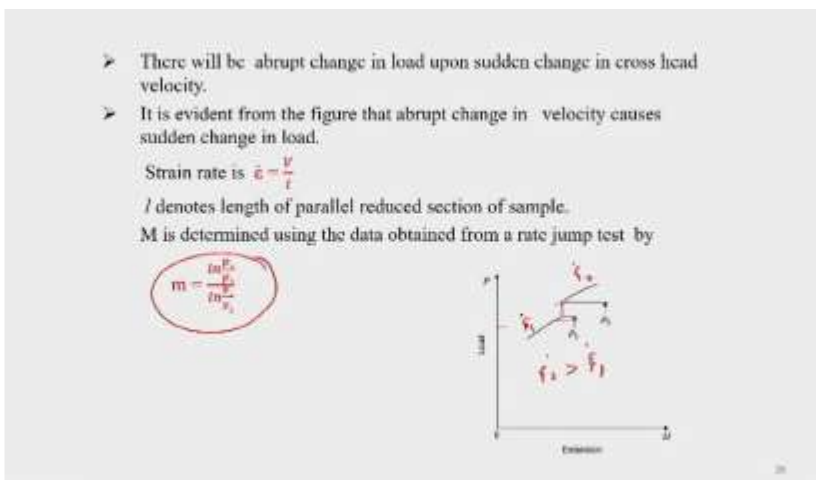

Now there will be an abrupt change in the load upon sudden change in crosshead velocity that also will be there. It is evident from the figure that the abrupt change in velocity causes sudden change in the load but this we cannot help it actually. So strain rate is epsilon dot that is equal to V by L where V is the velocity of the material the constant velocity or maybe velocity depending upon say your work piece material okay and L is the length of parallel reduced section of the sample. So by that relationship we can get this strain rate. The strain rate sensitivity M is determined using the data obtained from a rate jump test which we have discussed in our initial lectures.

$$\dot{\epsilon} = \frac{V}{l}$$

I think second or third lecture we have discussed about you do it at a particular strain rate. So epsilon dot epsilon dot 1 and this is epsilon dot 2. So when this is done, so epsilon dot 2 is greater than epsilon dot 1. In that case, you will find that maybe at this point it was epsilon dot 1 but suddenly you change to strain rate of epsilon dot 2. So there is a difference in the load. So from here to here, you will find that there is a big difference in the load. that load you take it and then you can just substitute here in this equation the derivation we have earlier mentioned also M is equal to log P1 by P2 P is the load and by log V1 by V2 that is the velocity this one this is the it will give you a strain rate sensitivity index okay. So I think with this I will stop today. Thank you.

$$m = \frac{\ln \frac{P_1}{P_2}}{\ln \frac{V_1}{V_2}}$$