Plastic Working of Metallic Materials

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Lecture – 28

Extrusion Process

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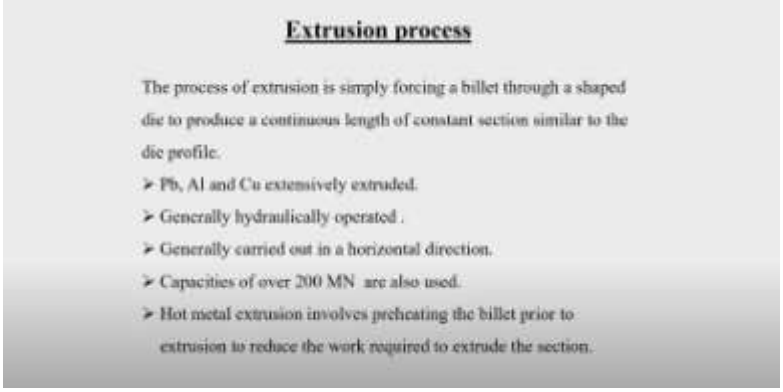

So in this module, we will be discussing about the extrusion process. The process of extrusion is simply forcing a billet through a shaped die to produce a continuous length of constant section similar to the die profile. If you really look into that the material which comes out of a toothpaste tube. That is a type of extrusion which we can tell. You are applying a compressive stress on one hand and then whatever in that semi-solid form, you know the material just comes out through that small opening, okay. So that is a simple example of an extrusion process, okay.

So in this case, the forces which are applied are purely compressive in nature and it will just be coming out through an orifice which you call as the die and depending upon the cross sectional area of the die or that orifice the shape can be obtained. So this is generally used for large scale production of structural parts okay and and normally it is being used for non-ferrous materials though for steels at higher temperature it is used but generally it is extensively used for low melting low melting temperature alloys. say lead, aluminum, copper, magnesium these things are being used.

Steels are also used but not in that big way. This extrusion generally they are hydraulically operated. In some case there are mechanical presses are there but normal case it is hydraulically operated because this is done at comparatively low strain rate. because you can get a very large length of the extruded part normally it is carried out in a

horizontal direction so that the length of the extruded can be very large. So that is one thing which is generally but vertical cases are also there but in that case the length is limited and extrusion process of over 200 mega Newton's are also used so very high press capacity high capacity process are also used.

In hot metal extrusion that involves preheating of the billet to the particular hot working condition, holding it there for some time that is called as a soaking and then you take it out of the furnace and then you keep it into the die and then proceed to get the required extruded shape. So that is what in extrusion you get it. Now let us look at what are the type of extrusions which are in practice.

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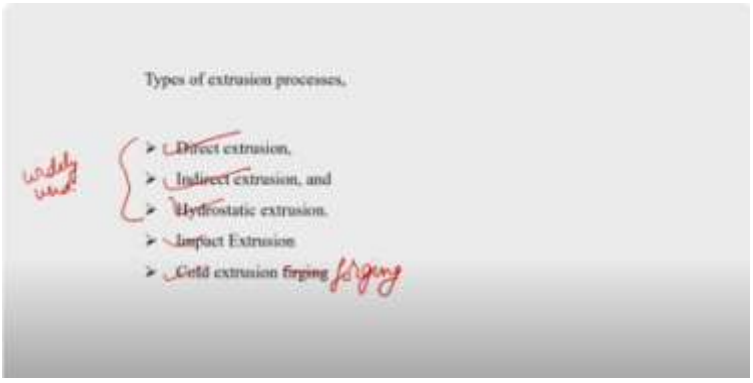

So the different type of extrusions are one is the direct extrusion we will come one by one next is the indirect extrusion then the hydrostatic extrusion and impact extrusion and cold extrusion forging it is cold extrusion forging. So in out of these these three are widely used. Impact extrusion though it was used but now it is not finding much but it is a very fast way of getting very thin components tubes basically. And this cold extrusion forging is also it is not used in that extensively but still it is used for some small pieces and other things under special conditions. So let us come to the direct extrusion.

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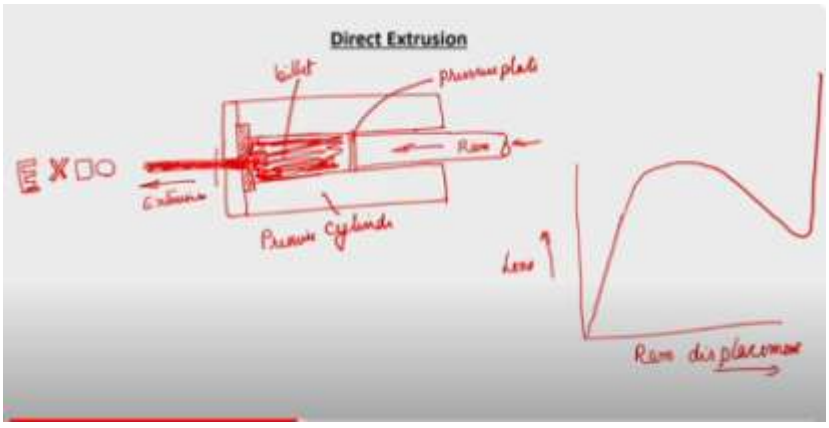

The direct extrusion when you look at it, it contains a chamber. This is the extrusion die into this, your material is filled up here This ram will be moving in this direction. This is called as the pressure plate. This is the cylinder, high pressure cylinder and this is the extrusion which comes out. So this, this is the basic die which is coming here. So in this die, the orifice, it can be, if it is circular, you can get a circular cross section. If it is a square, you get a square cross section.

If it is in the form of an X shape, you will get an X shape. Sometimes for aluminum doors and other things, you may see this type of shapes also. So, thin shapes you can get it. So, whatever type of shapes are there no you your die will have that die opening will have that type of a shape. So, you can have any type of shape.

So, whatever material comes through that that opening you will get that type of a shape. If you want a hollow part you can insert a mandrel into this and then proceed. What is the purpose of a pressure plate? The this pressure plate will have a diameter more or less which is equal to your insert diameter and the ram the ram which will be applying exerting the pressure or the high stresses into the ram may be, that may be through a hydraulic system or it can be through a screw press system any type of press system it can be there. So normally it is a hydraulic system so that you have a control of the speed. but the if the ram is diameter will be less than the ram diameter will be less than this pressure cylinder okay

So, in that case what happens is that if it is if there is no pressure plate and the ram diameter is equal to a pressure cylinder the metal may just flow backward and it will just chalk the ram there and then you will have all difficulties to prevent that the ram diameter is always kept slightly less than the pressure cylinder and it is only the pressure plate which is there you are just pressing forward, so here normally what happens is that this will be and then proper clamping will be there. So that after this ram moves forward and till it reaches this end when it reaches this end a small metal you will be leaving it for a cushioning effect 100 percent, otherwise the ram this pressure plate will come and touch the die and the die may get damaged to avoid that. You may allow some metal to be over and when say extrusion is over you will cut it from this side and then okay remove the cylinder backward and then so this will get ejected out. That is how that discard piece will be removed from that. And again you cross the cylinder insert the billet into this, this is the billet, into the cylinder and again press it. So if pressure plate is not put then if any chance of the metal back extruding into that is so and then ramming, the jamming the ram that can be avoided that is the main purpose of the pressure plate. Otherwise sometimes it gets jammed then you will have lot of problem. So this is the most widely used process. And in this direct extrusion, you will find that the frictional forces are very high because as the ram move forward, when the ram is moving in this direction, the billet is in touch with this entire die surface.

So, that will exert a very high amount of frictional forces the entire billet under the pressure it has to move forward. So, your frictional forces will be very large in that. So, sometimes that the amount of frictional forces is much higher, but as the ram displacement takes place in the forward direction. The frictional force will get reduced because the surface area of contact of the billet and the pressure cylinder this gets reduced hence the frictional force will get reduced. So if you look at a load versus displacement plot for this direct extrusion.

So if this is ram displacement and this is the load, initially like it will come like this, it will increase like this and then slowly it will start reducing and towards the end it will start shooting up like this. So this is the case. So here you may find that okay this this this is a very large amount of frictional forces are coming into picture compared to the other process. So in direct extrusion it is very simple in operation But the main problem is that high amount of energy is required high amount of forces are required for this extrusion process. Towards the end it will increase because as the thickness gets reduced we have discussed like even in flash also when the thickness gets reduced the forces which are necessary for further deformation will keep on increasing that is why it is moving in this direction.

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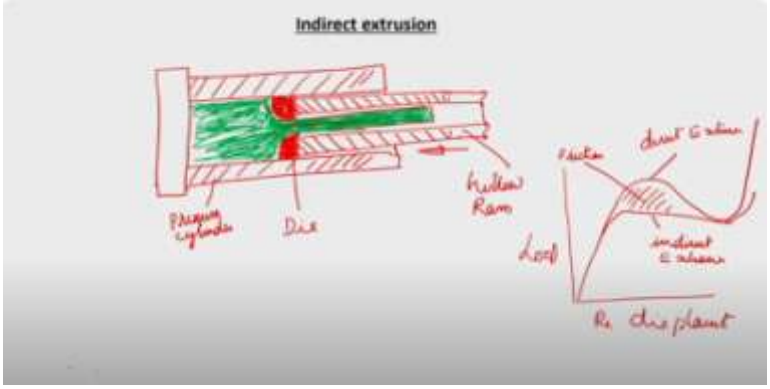

Now the second is the indirect extrusion. In the indirect extrusion, the frictional forces are get reduced considerably. See for example you are having it on a very rigid surface on a plate, a structure it is there and your pressure cylinder is like this. The only difference is that, in this a hollow cylinder is being used as the ram, hollow ram is used. So, if you look at that and the metal will be extruding in this direction, the ram will be moving in this direction. So, this is the billet and this is your ram, this is your die. See, if this is your billet, it gets extruded like this. So, this is the die, this is the hollow ram, this is the pressure cylinder. In this as the ram moves forward, the work piece is stationary. Work piece is not moving.

So the friction at the interface between the work piece or ingot and the cylinder is not coming into picture because there is no relative motion there. But rather what happens is that when it is pressing here the metal just moves outward in this direction, in this direction. So that is the biggest advantage. So friction is considerably reduced. You can say that most of the case it is like almost frictionless.

Only friction which is coming is where there is a relative motion at the die metal interface, not on the cylinder. So, there will be a small amount of frictional losses. So, compared to what you did it in the previous case no this is the load and the displacement ram displacement, in the other case in the case of direct extrusion it was like this, it went like this, but in the case of this is direct extrusion. But in this case you will find that it is coming and only very small difference is there and then it is going like this. So, this is indirect extrusion.

So, this area you will find that this is the frictional load. Load to overcome friction that is this area between these two. So overcome friction at the cylinder ingot interface, so that is the thing. So in this since relative motion between the ingot and the or the container and the billet is absent the frictional forces are considerably reduced and the power return for the extrusion is also reduced compared to the direct extrusion. But the biggest drawback with this is that you cannot it is very difficult to have a very long hollow ramp okay.

In the other case in the forward direction it may go to any length. But in this case the length is restricted because if it comes to more than the ram length then it will be a problem you will not be able to move further, so that difficulty is there. So here the restriction the length of the which can be achieved there is a limitation that is the thing. So but this is more efficient and it produces very high quality material because the frictional forces are reduced so the quality of the material which you obtain is much better than this.

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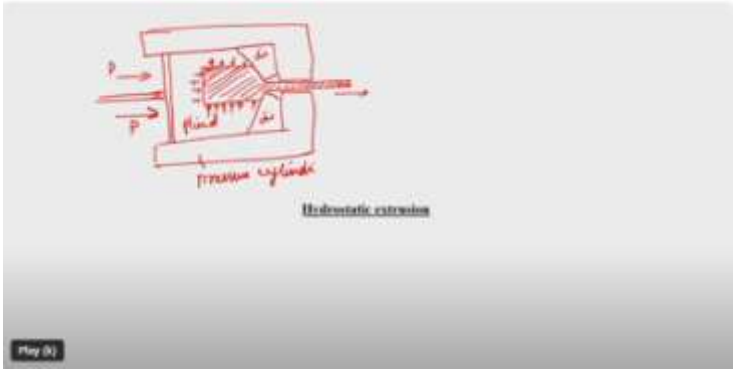

Third is the hydrostatic extrusion. In the hydrostatic extrusion, the hydrostatic stresses are being used in this case. So what happens is that you will have a pressure cylinder. So this is your die. It's a converging die type thing. And you will keep your work piece in this way so that inside the converging die, This is a closed chamber and the fluid is filled up inside this and you pressurize the fluid by applying some force maybe through a piston ram arrangement. So, this is a, this is a pressure cylinder and this is the die, and this is a fluid inside this. You have completely, so from all directions, we have a hydrostatic pressure which has been applied. So as per the Hooke's law, the pressure applied in any fluid is equally transmitted in all directions. So here that is the advantage which is coming on this. So in all the directions, when there is a hydrostatic pressure, the stresses required is very very less for the deformation. So, that is the biggest advantage in this and then you will find that even very brittle material, extremely brittle materials like ceramics also can be extruded in this form.

So, typical example is your molybdenum dies hillside which is a extremely brittle material which is used as heating elements for very high temperature application this can be extruded in this form. Even you can get a very high reduction by this hydrostatic extrusion. See, when the pressure is applied, it is transmitted in all directions. So not only in the lengthwise, also in the radial direction, also the material gets deformed. So you will find that both the length and the radial dimensions gets reduced and that will just flow out through this die opening.

You the precaution you need is that at the interface of the die this should be perfectly matching, the billet should be perfectly matching at the initial stage even if you seal it with a teflon tape also this fluid will not leak. So fluid should not leak that is one important condition which is required. If it leaks all the fluid only will come there, there will not be any extrusion. So, it has to be leak proof and then the drawback, another drawback is that it takes lot of time to open up and then make this arrangement and then cross it and again do the extrusion, it takes lot of time. So the processing time downtown is much higher in this case compared to other.

So on a continuous basis it is not that easy to get it, but the biggest advantage is that extremely brittle material also can be extruded by this hydrostatic extrusion and it requires not very high stresses, very high power is not required very low power only but it all depends upon how much pressure you can apply. And third limitation is that since you are going to fill up some fluid, the temperature at which it can be deformed is also limited. So, normally it is confined to at a room temperature or maybe up to something around 100, 150 degree because beyond that the fluid whatever you are using at a high pressure when you apply the high pressure, if the temperature is high, this will decompose and then you may not get what you require. So, but only thing is that this has to be carried out in a sealed container that is the biggest problem which people will be facing with the hydrostatic extrusion. So, in the hydrostatic extrusion because almost zero

frictional forces are there. Even if you look at the indirect extrusion or backward extrusion, there is going to be some amount of frictional force between the die and the workpiece.

Though and the cylinder and the ingot there is no friction but there is a friction at the die metal interface but in this hydrostatic extrusion that also is not there because there is no relative motion between the die and the work piece. It is compressed in all direction and then just rejects it out that is the biggest under the hydrostatic pressure this is this is coming out. Where at this region at the interface there is no restraint or there is no constraint so it metal moves through that region only. So that is one advantage. So you will find that the stresses which are required for a hydrostatic extrusion is much less than the other case.

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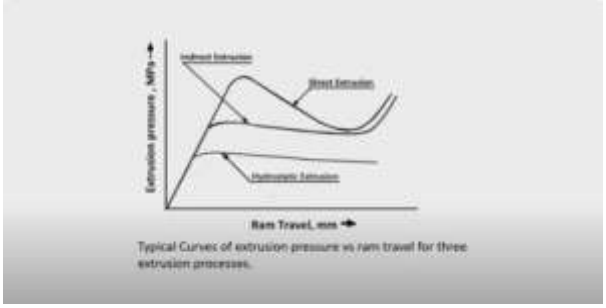

So these are the comparison for that. In an exaggerated way it is drawn but you will see that indirect extrusion you need higher and then reaches a maximum and then when the ram travel takes place. It comes down and then after some time it will start increasing. When it started increasing, you will have to stop it. The similar case also. Here in hydrostatic extrusion, even this increase will not be seen.

So you should have an idea how much length you will get. And when the necessary length is attained, you have to stop it. Or otherwise, because you cannot have a limit switch inside and other thing because it is a hydrostatic pressure you are applying. There is no movement of any ram or something. So, that is the only drawback. So you will find that here the stresses are load is very less for hydrostatic extrusion because there is no friction coming into picture.

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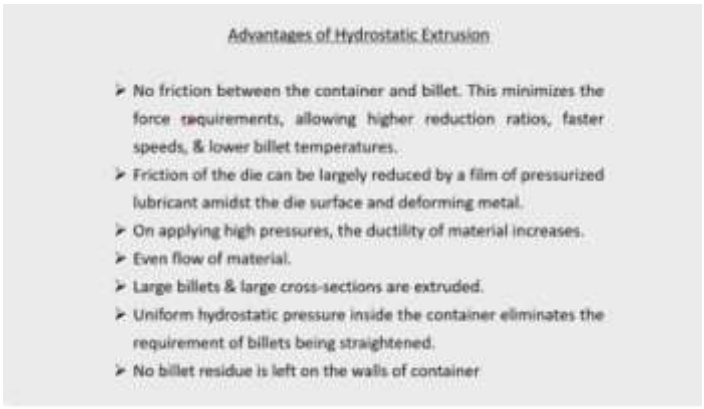

And the advantage of hydrostatic extrusion is that there is no friction between the container and the billet. This minimizes the force requirements allowing higher reduction ratios, faster speed and lower billet temperature. The deformation can be at a faster rate that depends upon what pressure you are applying and then lower billet temperature. Friction of the die can be largely reduced by a film of pressurized lubricant emits the die surface and deforming metal. When applying the high pressure the ductility of the material increases and even flow of the material take place, and large billets and large cross sections are can be extruded that is another advantage with this.

The limitation is what is the size of your pressure cylinder, so that way you can have it. And uniform hydrostatic pressure inside the container it eliminates the requirement of billets being straightened that is another advantage okay. So you do not need to machine the billet to get a uniform cross section across the length or billet length. So that is not required in this. So because of the hydrostatic pressure this eliminates that need and so that is one advantage.

No billet residue is left on the walls of the container. This is another advantage which you are getting with the hydrostatic explosion. The disadvantages are that the billets are to be prepared by tapering. one end where it is going to fix into your die. You have to taper it and then so that it perfectly fits and still you have to provide some facility for preventing the leakage.

Even a simple teflon tape will be sufficient for that. Once the deformation starts taking place, there won't be any gap. It will just fill up that die cavity. That is one another advantage. So this is essential for forming a seal at the starting of the cycle. Generally the complete billet is required to be machine it for the removal of the surface defect because if there is a surface defect that will come into picture.

So normally that is not that much of a problem but still people will prefer to deform it sorry machine it. It can be difficult to contain the fluid under the effect of high pressure the high pressure up to very high pressure up to 2 gigapascal or 290 kilo cycles per inch

and kilo pounds per square inch also it may be very difficult and other things. Then another limitation is that increased handling for injection and removal of the fluid for every extrusion cycle. So, that is one drawback which is there. Then decreased control of speed of the billet and stopping because of the potential stiff slip and enormous stored energy of the compressed fluid and enhanced complications and the extrusion is done at elevated temperature because the fluid may decompose.

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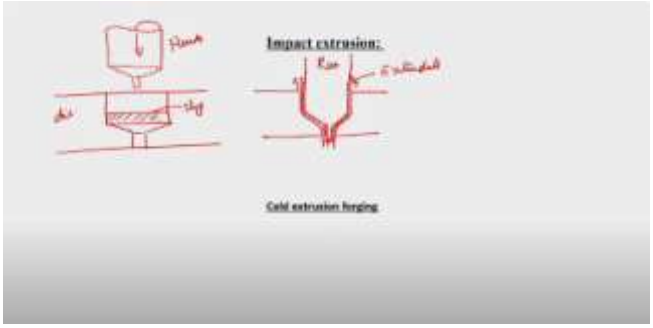

Another method is the impact extrusion which takes place. Say earlier some 15-20 years back now this toothpaste were coming in aluminum can tubes, aluminum tubes these were made by impact extrusion. So, in impact extrusion it is a very simple method whereby this is the die you may keep a billet here. and then a punch may come inside. So, this will come, so this is your punch and this is your die and this is your what you call it as a slug. It will be a very small disk this type is like a coin, it will be there and this punch will be coming under very high impact normally by means of a mechanical press a mechanical mechanism and it comes know that it will be coming and hitting with a very high impact and then what will happen because of the very high impact this metal will deform and then you will find that in this case. If this is the punch, a small thin layer, it will just flow along this.

This is your extruded. It will just move backward in this direction because of because once this is entering into that perfectly it is matching also metal will not extrude into this this portion. So that is the thing and it will rather it will extrude back, initially some extrusion will be there and this is that part where you will find that like the toothpaste opening, the mouth opening you know like that it will come. So if you do not want this if it, if it can be like a flat plate also that also can be there so there is no need of in that case. It can be like a can for your drinks and other things. Now you have a can like what is that soft drinks cans are there aluminum.

So that that is that can be made like this. So it is at a very fast rate this process takes place. So this is your RAM and this is the extruded. This can be fully automated with the proper indexing after this one it can be rejected out and then okay next slug is kept in and then you know automatically, it just keeps on moving, that is the biggest advantage with

the impact extrusion. So, normally this is held in a slider coming mechanism a mechanical procedure at a very fast rate maybe you may get it with a 60 pieces per minute or 120 pieces per minute you can always adjust it and get it in whatever way, very thin cans can be obtained by this. And another is the cold extrusion forging is there the only difference between these two are that in this case the like deep drawing type operation is not taking place.

But you are getting a thicker piece with some amount of height okay but the pieces are thick whereas in impact extrusion it is very thin and you are not going to have a very long length of extruded pieces some sort of disc shapes and other things only if they are using like car this wheel cap and other things you know these things are made by this cold extrusion forging with the complicated shapes and other things okay with that today it is over. Thank you.