Basics of Mechanical Engineering-2

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Week 05

Lecture 19

Basics of Forming (Part 4 of 5)

Welcome to the next lecture under the topic of basics of forming. As we know very clearly forming is a constant volume process. We have already seen rolling process and forging process. Rolling process to produce sheet, a sheet which is used in covering the door frames, sheet which is used in making railway bogies. A sheet which is made when you in the lifts when you are trying to travel you can see there will be a sheet which is kept there.

Forging is a discrete part manufacturing process where in which we try to make screwdriver, spanner, rods, etc. The next one in the series is extrusion. Before going deep into the process, I would like to present analogy for extrusion process. Let us take two examples, one is medicine ointment tube, the other one is your toothpaste tube. Toothpaste tube will have the toothpaste inside it, it has an orifice then you cover the orifice.

So that the material inside will not get dried or contaminated. You open up the lid and then you have an orifice. Now you pressurize from the other end and make sure the toothpaste or the ointment exits through the orifice. Now if the orifice size is cylindrical what comes out is a tube form. If the orifice has some variation correspondingly those variations will be seen out when the exit happens to the orifice.

The toothpaste and ointment you can keep on extruding till the content inside the tube gets completed with the same analogy. Let us get into extrusion. Extrusion is also a process wherein which the material is filled inside a die. And you push the material from the back side or from the front side. And the material has to exit out through the die orifice.

If the process continues till the material is there inside. You can either do it from the back side or you can push it from the firm side and then you can exit out. So, this is what is the basics of extrusion process. Now, let us get into the process so that you can understand more in detail.

First, we will try to see the introduction of extrusion process. Then naturally, there are advantage and limitation. You should also understand the history so that you try to extrapolate where all you can use it in the near future. Then there classification as we saw in the basics of metal forming, cold working, warm working and hot working. Here you also have cold extrusion, hot extrusion. Then as I told you have forward extrusion reverse or backward extrusion.

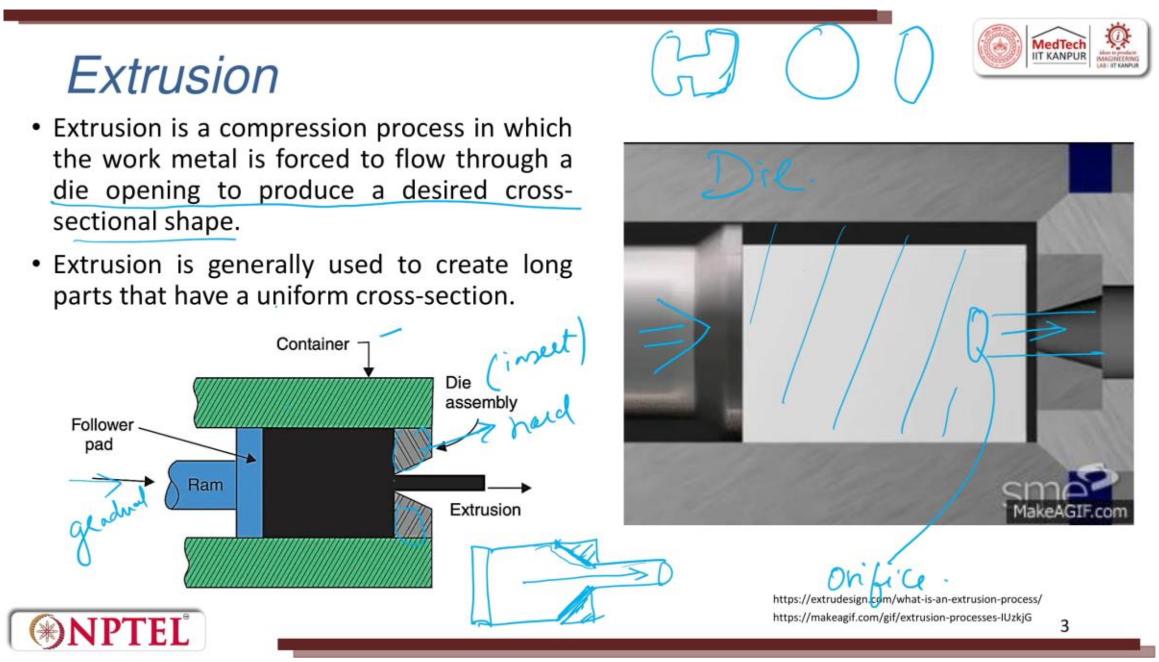
The other analogy given is direct extrusion and indirect extrusion. The moment there is metal, you immediately think about the force you should apply. So, we will try to analyze some extrusion processes and, finally, the defects. If the same process continues for a longer time, we move into wire and bar drawing. The only difference between these two is the amount of material left in the cylinder.

So, you can do it, or instead of keeping a cylinder, you can continuously feed material and get an output. For example, wire and bar are part of it, then a little history of wire extrusion. We will do a small analysis, then tube drawing. Finally, we will recap with some examples you can do yourself and see the references. The extrusion process, as I told you, involves material kept inside the tube I mentioned.

So, here it is not a tube; it is a die. I gave you an analogy of pressing a hand from one side. Here, you use a punch and apply force. Why? Because metal compression requires a lot of energy.

The second thing is, there is a metal-to-metal contact, so the friction is going to be very high. It is a constant-volume process; when you keep compressing, it gets buckled or bulged. Now, the bulging has to be restricted. It is restricted, and there is an exit. Through this exit, you try to get the output you want. This portion is called the RE phase.

This portion is called the orifice. Depending on the cross-section of the orifice, you can get the output material or the geometry you want.



Extrusion is a compression process. Forging is also a compression process. A compression process in which the work metal is forced to flow through a die opening to produce the desired cross-sectional shape.

You can have a cylinder, or you can have a cross-section like this also, right? Whichever is there, you can also have cylindrical, or sometimes elliptical—whatever you want, you can try to do. So, generally, what people do is extrude and then chop off to the required length to meet the requirements. For example, door frames are made by the extrusion process; aluminum door frames are made by the extrusion process. You extrude—it can be a box, a rectangle, or a tapered box.

So, it depends on the orifice. And as long as the material is there, you can keep pushing it and extruding it. Friends, you should also keep in mind, as I told you, the analogy of the toothpaste and the ointment. You will see this is the dead-end orifice, and this is a tube, right? So, here, what happens is the material will start flowing.

There is always a taper given here. Why is this taper given? If the taper is not given, then if it is a square one, this portion becomes the dead zone. What is a dead zone? The material gets accumulated here, and it is always wasted. So, we always try to have some taper so that all the material gets extruded out, okay?

So, extrusion is generally used to create long parts that have a uniform cross-section. So, you have a container, you have a ram—the punch is called the ram. So, it is pushed from there. It is generally operated hydraulically or, yeah, it is operated hydraulically. And it is a gradually applied load. It is not like forging impact; it is a gradually applied load, and there is an extrusion. The die, whatever is there, this material will be hard.

For example, it can be made out of tungsten or stainless steel, which has very high hardness. Here, you need not have ductility; it has to be very high hardness and machinable. So, this material container material and die material need not be the same. The die can be the orifice. I am talking about the die; it can be an insert. So, that means this and this material will be the same because it is a cylinder, and the insert material will be different. The orifice can be given there. You can also extrude gears, and then you can chop them off to your requirements.

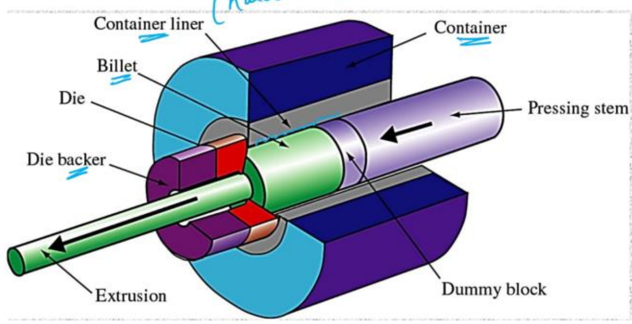
Extrusion

Advantages

- A wide range of shapes can be produced, particularly through the hot extrusion.
- Better Grain structure and strength properties of the product.
- Fairly close tolerances are possible.
- Little or no wasted of material.

Limitation

- The part fabricated should be uniform in cross-section throughout its length.



Kalpakjian • Schmid

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The advantages: a wide range of shapes can be produced, particularly through the hot extrusion process. Better grain structure and strength properties of the product are achieved through extrusion. In any of the metal forming processes, better grain structure and strength properties will be achieved. Very close tolerances are possible.

So, that means whatever comes out is directly a near-net shape; you do not have to do any machining or something. And the last one is there is little or no wastage of material. So, the workpiece, whatever I was talking to you about, is nothing but the billet. So, now you remember ingot billet, which we have gone through in the previous lectures. So, you can see here this is the liner container and a liner container.

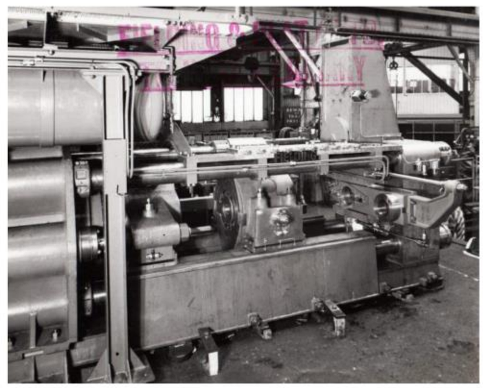
It is almost the same analogy like in automobile. Why there is a liner because there is lot of friction moment there is lot of friction there will be wear and tear. So, this wear and tear every time replacing the container is going to be expensive. So, I put a thin liner this thin liner will have high hardness properties. And I can replace it without changing the entire container.

So, this is the function of a liner billet Then I talked about the die ok. So, then it is the die backer. okay. Through this the cross section gets reduced. Now when it is exiting out there can be a possibility that there is bulging happening.

So, in order to restrict it we also have a backer, but the diameter of the backer will be slightly larger than the die diameter. So, in it make sure that it gets the retains the same cross section for a longer time. Once it exits out for maybe few inches, then the shape will not change. So, they do it. The limitation is the part fabrication should be uniform in the cross section throughout the length. If you want to have any variation like in forging you had, it is not possible.

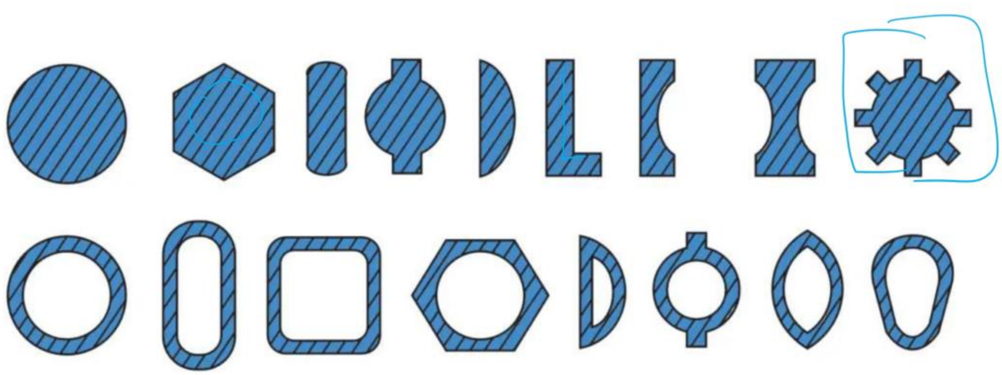
History

- Extrusion as an industrial process was invented around 1800 in England.
- The Industrial Revolution when that country was leading the world in technological innovations.
- The invention consisted of the first hydraulic press for extruding lead pipes.
- An important step forward was made in Germany around 1890 when the first horizontal extrusion press was built for extruding metals with higher melting points than lead.
- The feature that made this possible was the use of a dummy block that separated the ram from the work billet.



https://www.fieldingandplatthistory.org.uk

Shape Produced



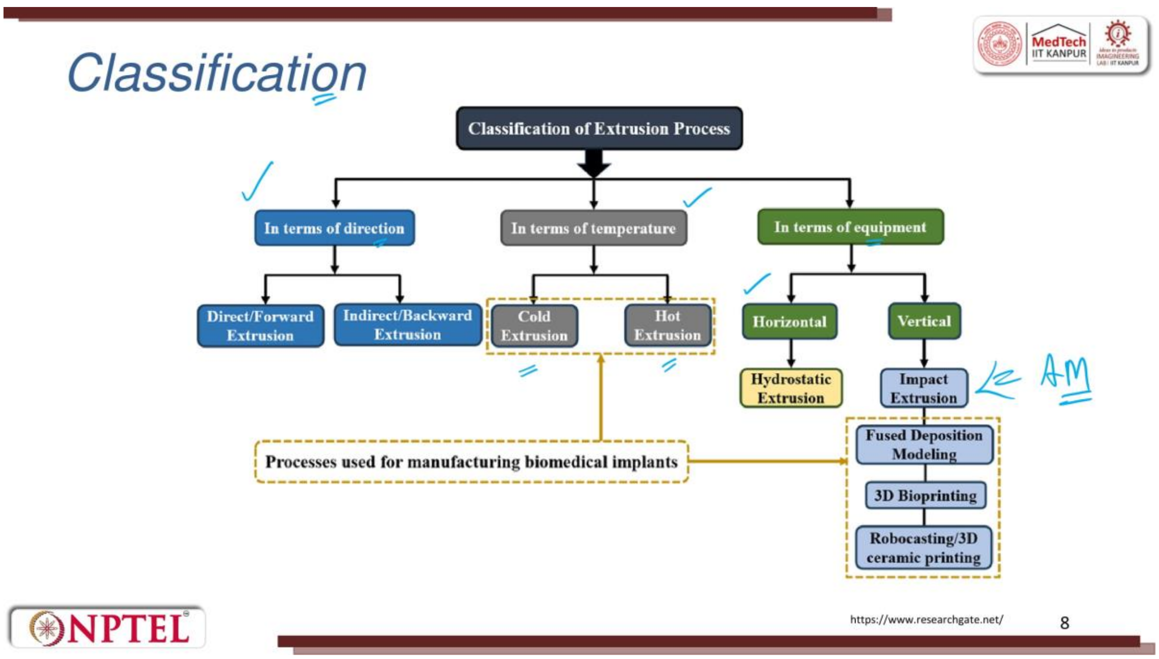
https://extrudesign.com/what-is-an-extrusion-process/

Let us look at the history these processes exclusion process is not very long or it does not have a big history. The exclusion as an industrial process was invented in 1800 in England whereas, if you look at forging and rolling it had BCE and other things. The industrial revolution is when the country was leading the world in technological innovation England played a very important role. The invention consists of the first hydraulic press for extruding lead pipes.

An important step forward was made in Germany around 1890 when the first historical extrusion press was built for extruding metal with higher melting point than lead. Lead is a soft material. So, it was first extruded then hard materials. The feature that made this possible was the use of a dummy block that separated from the ramp from the wooden block. So, this is how the history went and people started using it then.

And today it is a very stable process wonderful outputs are made and various of these shapes are made through extrusion. You can see from cylinder hexagon whatever it is, but it has to be all throughout the same geometry. You can have a square, you can have a cylinder hollow cylinder, you can have a hexagon shape hollow hexagon shape gear. All these things are made out of extrusion process. You can have even L spacers for your requirements.

These are almost all the parts that are made through the extrusion process. If you look at your computer, there are heat sinks. These heat sinks are made through the extrusion process.

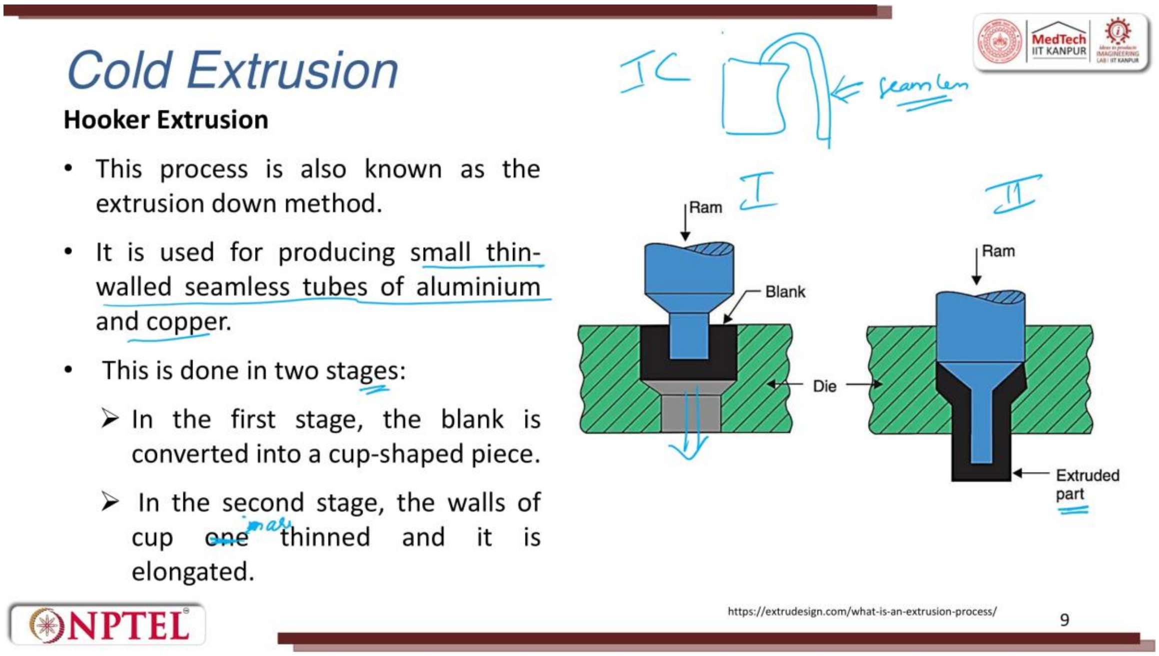


So now, let us look into the classification of the extrusion process. The classification in terms of direction can be forward extrusion or backward extrusion.

The other way of referring to it is direct extrusion and indirect extrusion. This is based on the direction. Next, it is based on the temperature. You have cold extrusion and hot extrusion. In terms of equipment, you have horizontal or vertical.

Vertical is this way; horizontal is this way. Generally, horizontal is preferred because long tubes can be obtained horizontally. So, under horizontal, you have hydrostatic extrusion. When we have it in vertical, we have impact extrusion. So, the examples of impact extrusion will be fused deposition modeling.

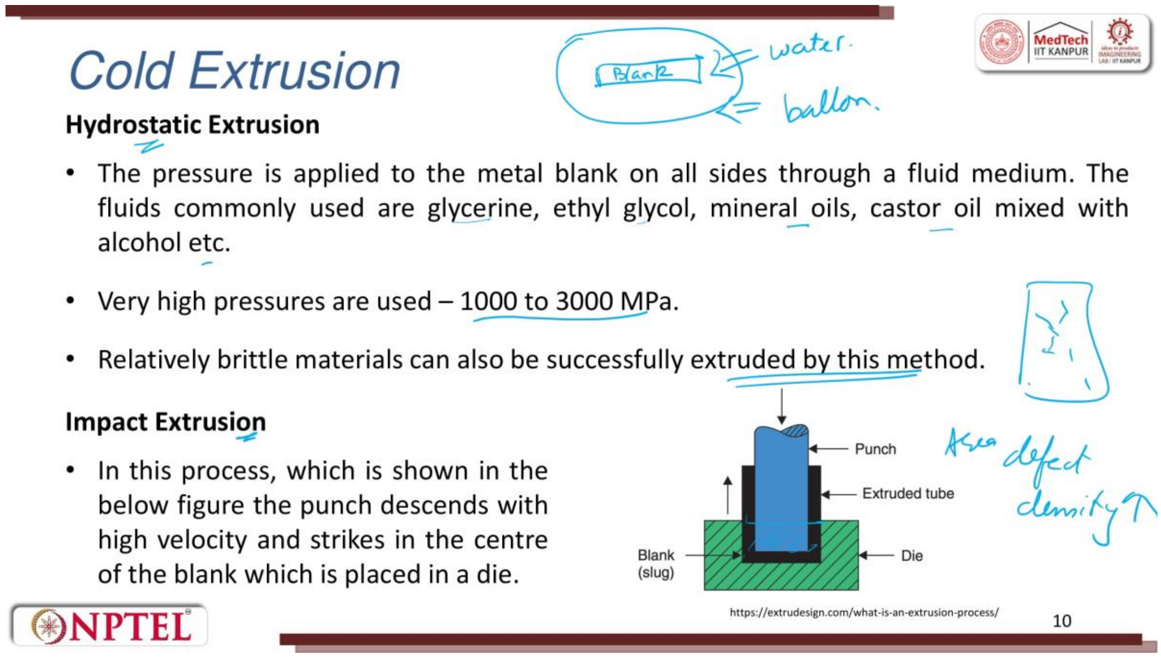
3D bioprinting, Robocasting, and 3D ceramic printing. So, these are all additive manufacturing techniques in which we also try to use the extrusion process. So, the process used for manufacturing bio-implants can come from here or it can come from here, okay? So, this classification and this classification are very important for hard, heavy engineering materials. We always go for the horizontal type, cold extrusion, okay.



This process is also known as the extrusion down method. So, you have a blank which is kept, and there is a ram which pushes it, and then you try to get it through the orifice. So, this will be the extruded part. The process is also known as the extrusion down method. It is used for producing small, thin-walled, seamless tubes of aluminum and copper.

So, what is so special about these seamless tubes? When you have very high pressure to be moved inside, if you see your IC engine, you will always see there will be an engine, and there will be a pipe which goes like this. These pipes are seamless pipes. And these pipes try to take very high pressure, and seamless pipes are very much used for heat exchangers.

So, small thin walled seamless tubes of aluminium and copper. This is done in two stages. In the first stage, this is first stage, the blank is converted into a cup shaped piece. In the second stage, the wall of the cup are thinned and it is elongated. So, this is stage 1, this is stage 2.



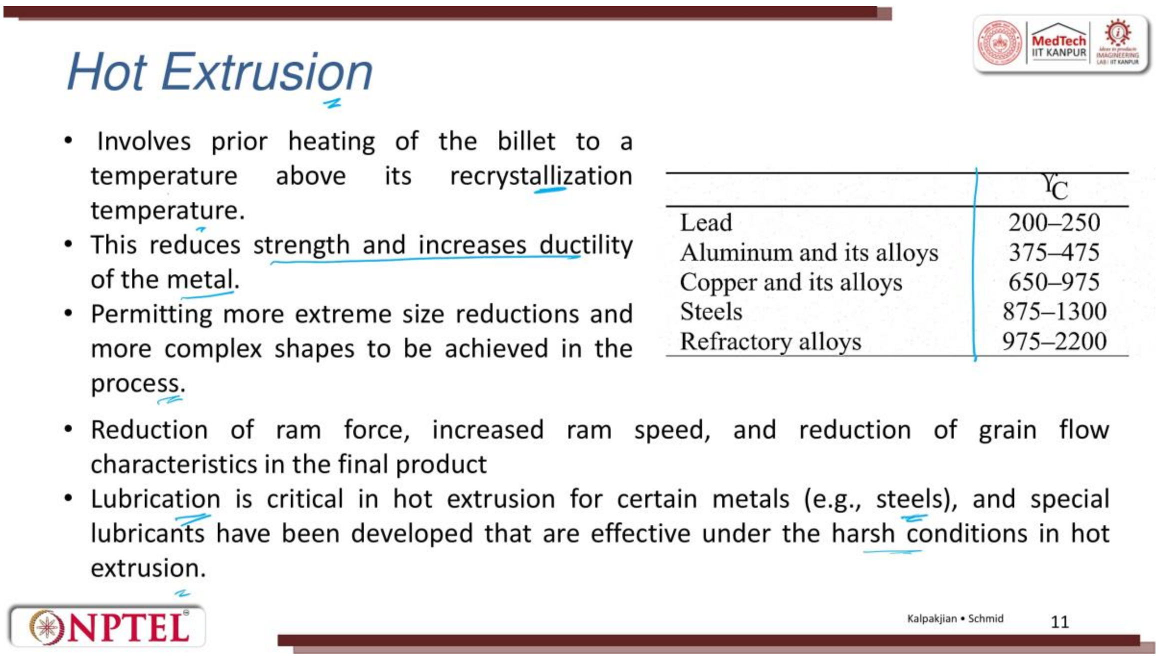
Hydrostatic extrusion is the pressure is applied to the metal blank on all sides through a fluid film. Assume that you have you have a balloon, you are keeping an object inside the balloon. The balloon is filled with water. This is a balloon. So, now, the pressure exerted all around the blank will be uniform.

So, when this is uniform, so then the defects can be reduced in a large way. So, pressure is applied to the metal blank on all sides through a fluid media. The fluid commonly used is glycerin, ethylene glycol, mineral oil, castor oil mixed with alcohol. Very high pressures of 1000 to 3000 mega pascals are applied. Relatively brittle materials can be successfully extruded by this method.

Because of the hydrostatic pressure which is there, the cracks which are seen on the surface of the brittle material. Brittle materials always have high defect density, high defect density. What is defect density or area defect density? In a given unit area, the amount of defects or the number of defects is more. Now, these defects, when you try to extrude, they try to grow fast and will try to crack, breaking the material.

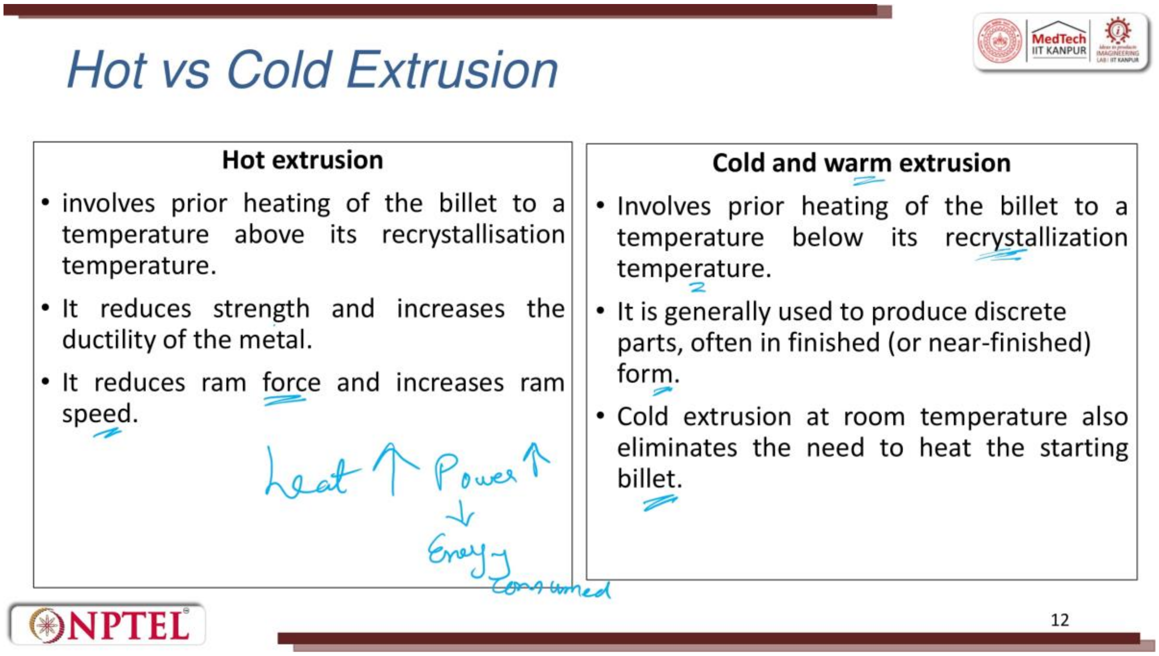
Now, what is happening once you apply hydrostatic pressure? These cracks are compressed. So, the moment it is compressed, it cannot grow. If it cannot grow, then you try to deform and get the output. So, that is called the hydrostatic extrusion process. There is another process called impact extrusion.

In this process, which is shown in the figure, The punch descends with high velocity and strikes the center of the blank, which is placed in the die. So, there is an impact which hits. So, the material is filled here; the blank is filled here. When the punch hits just around the clearance between the punch and the die, the thin metal extrudes. So, this process is called impact extrusion.



Hot extrusion. It involves heating the billet to a temperature above the recrystallization temperature. This reduces the strength and increases the ductility of the metal, which permits more extreme size reduction. And more complex shapes to be achieved in the process. The same process wherein you heat and impact.

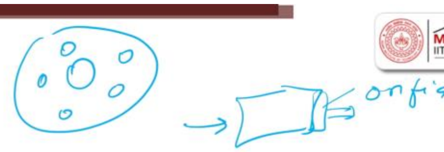
The reduction of the ram force, increased ram speed, and reduction of grain flow characteristics in the final product are seen. And just around the process or around the blank, lubrication plays a very critical role, and we generally do not use a water or soap solution. We try to use slightly high-temperature lubricant such that it can function at higher temperatures. Lubricant is critical in hot extrusion for certain materials like steel, and special lubricants are developed that are effective under harsh conditions in hot extrusion. These are the yield points for various materials.



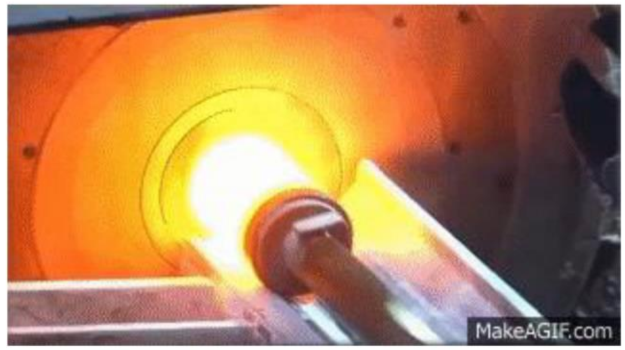
To compare hot extrusion and cold and warm extrusion, hot extrusion involves prior heating of the blank to a temperature above the recrystallization temperature. It reduces the strength and increases the ductility; it reduces the ram force and increases the ram speed. So, the production rate can be higher. Cold and warm working involves prior heating of the billet to a temperature below the recrystallization temperature because there is warm. It is generally used to produce discrete parts, often in finished form.

So, here there is a possibility of oxide getting formed, here you get it almost finished. The cold extrusion at room temperature also eliminates the need to heat the starting billet. Heating of the starting billet is expensive, heating increasing temperature increases power or increases the power. So, power means I am talking about the energy consumed. It is a energy costly process, hot extrusion.

Direction Extrusion



- Direct extrusion is also known as **forward extrusion**.
- A metal billet is loaded into a container, and a ram compresses the material, forcing it to flow through one or more openings in a die at the opposite end of the container.
- A small portion of the billet that cannot be forced through the die opening, is called the **butt.**



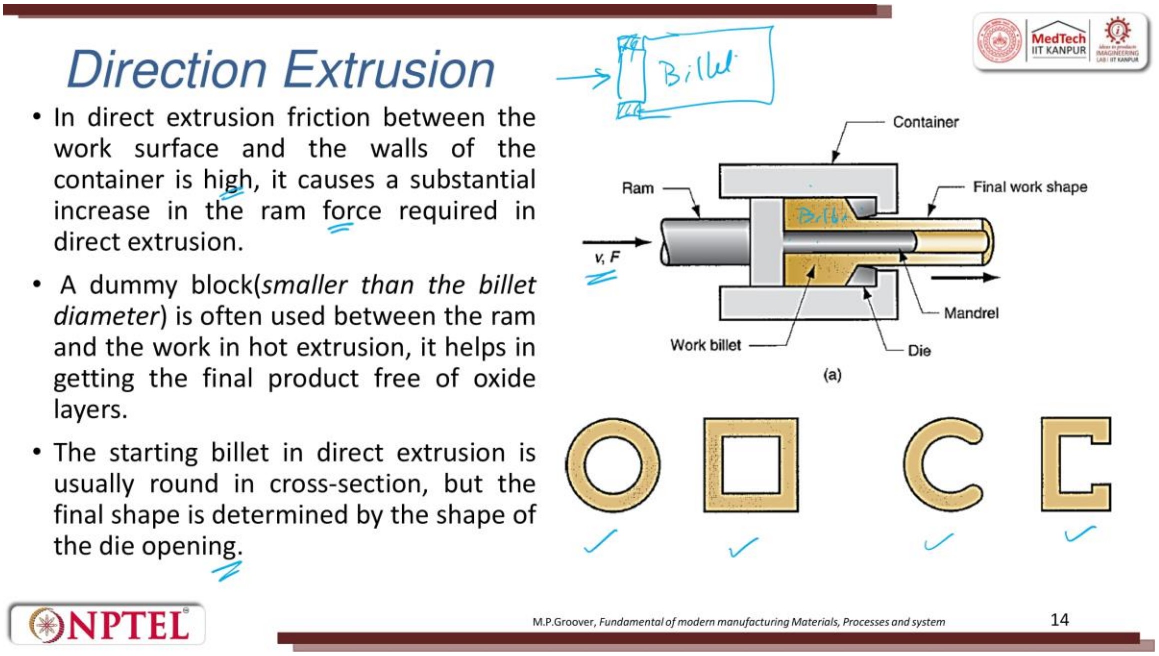
https://makeagif.com/gif/hot-extrusion-production-

Direct extrusion is also known as forward extrusion. So, the billet is loaded into the container and a ramp compresses the material. Forcing it to flow through one or more opening in a die at the opposite end of the container. So, you can see there is a billet which is kept in a container. So, this is a container and a ram is compressed.

So, this is a ram which moves the material forcing it to flow through one or more opening. So, what we are trying to say is you try to take a container and then you try to take a die. Suppose you have several orifices like this, then through all of these orifice you can try to extrude the material. Forces it to flow through one or more opening in a die at the opposite side of the container. So, container so, this is so, you have a container this is the punch which is there and here is the orifice and here is the output.

A small portion of the billet that cannot be forced through the billet opening is called the butt. So, here you can see the container in much more detail. So, this is the die, these are inserts, and as I told you, the backer plate. So, this container itself can have some small backer plates. So, here you put the billet, and the force is applied with a feed rate.

So, you can see an extrusion happening here. You can get a hollow tube or a thick full cylinder tube. So, here there is a mandrel. So, it is restricting the material in the center portion. So, you are trying to get a hollow tube cross-section.

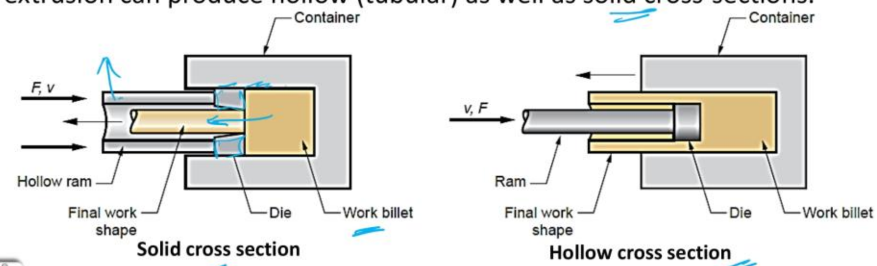


So, in direct extrusion, friction between the work surface and the wall of the container is very high. It causes a substantial increase in the ram force in direct extrusion. A dummy block smaller than the billet diameter is often used between the ram and the work in hot extrusion. It helps in getting the final product free of an oxide layer. So, what we are trying to say is, a dummy block is often used between the ram and the extrusion billet.

It helps sometimes; the diameter can be low, sometimes it can be high, or also equal to the diameter of the billet, right. It is often used between the ram and the work in hot extrusion, which helps in getting the final product free from oxide layers. The starting billet in extrusion is usually round in cross-section, and the final shape depends upon the die or a face. Whatever you choose, you can get a hollow cylinder, a square tube, a C-section, or you can get an engineered regular C-section. All these things are possible by direct extrusion. So, it need not be only solid; it can also be hollow.

Indirection Extrusion

- Indirect extrusion is also known as backward extrusion and reverse extrusion.
- In this process the die is mounted to the ram, as the ram penetrates the work, the metal is forced to flow through the clearance in a direction opposite to the motion of the ram.
- As the billet is not forced to move (relative to the container)there is no friction at the container walls, it causes lower ram force than indirect extrusion.
- Indirect extrusion can produce hollow (tubular) as well as solid cross-sections.



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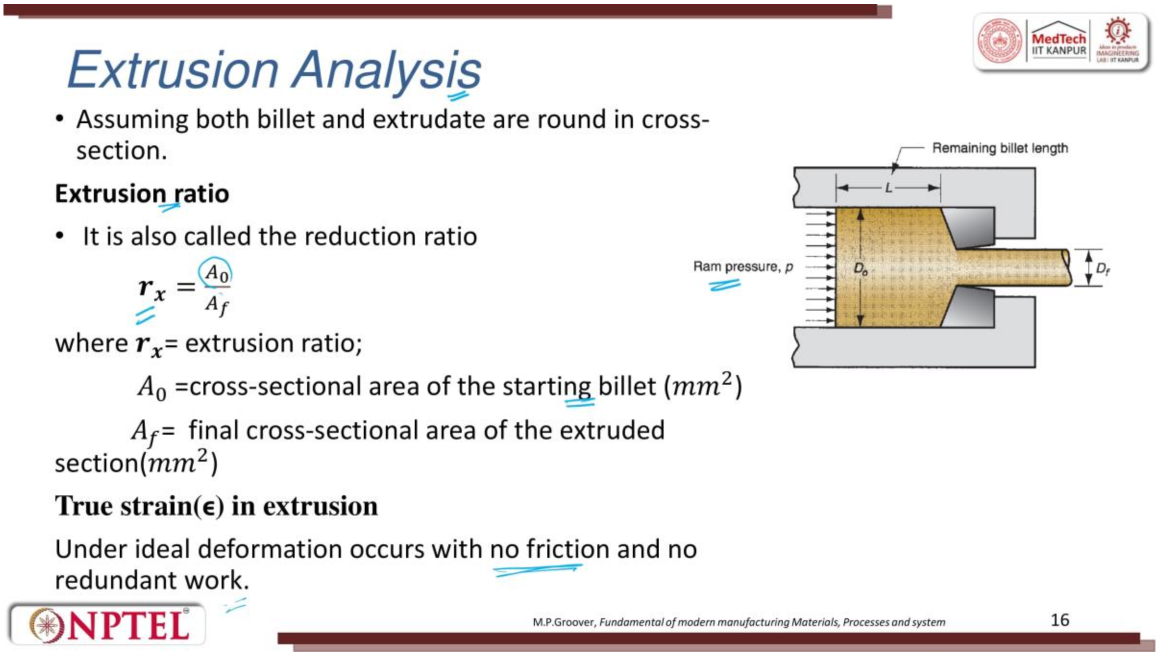
M.P.Groover, *Fundamental of modern manufacturing Materials, Processes and system*

Let us now look into indirect extrusion. Indirect extrusion is otherwise called backward extrusion. Or reverse extrusion, forward-reverse, forward-backward, direct-indirect, okay. Please understand the analogy of these process names.

In this process, the die is mounted to the ram. This is the ram; the die is mounted to the ram. This is very important in this process: the die is mounted to the ram, and the ram penetrates the work. The metal is forced to flow through the clearance in the direction opposite to the ram's motion. So, here you have a billet, and you have a ram. The ram has the orifice cross-section, final diameter, or whatever you want.

The die is attached to the ram and it is forced against the billet. So, you can try to produce solid cross section, you can also try to produce hollow cross section. As the billet is not forced to move is not forced to move there is no friction at the container wall. So, here there is no friction. So, it causes the ram force to be lesser in indirect.

So, this process is much better than the direct process because the friction is reduced, moment friction is reduced, the energy consumed is reduced. So, indirect extrusion can also produce hollow tubes as well as solid cross section. But what is the restriction? The restriction is the amount of material what you have. It is the same for direct also, but here it is much more restricted as compared to that of direct. Now, let us try to find out the force what is required for extruding.



So, extrusion analysis will be the next discussion. So, we put a billet. This billet is kept inside a container. The billet is pushed by a ram to a length called L and the diameter which gets out to the RE phase is called as D.

Assuming both the billet and the extrudent are round in cross section. So, the extrusion ratio is

$$r_x = \frac{A_0}{A_f}$$

A0 is the cross section area of the starting billet, Af is the final cross section of the work piece which comes out through the orifice or the die. So, the reduction ratio rx is found out by this ratio. So, now let us go back to the true strain what we have seen in the initial stages of this course.

True strain in extrusion under ideal deformation occurrence with no friction and no redundancy of work.

Extrusion Analysis

Ram pressure(P)

Under ideal deformation, the ram pressure required to extrude the billet through die hole is given by,

$$p = \overline{Y}_f \ln(r_e) = \overline{Y}_f \ln\left(\frac{A_0}{A_f}\right) \quad \text{where} \quad \overline{Y}_f = \frac{K\varepsilon^n}{1+n}$$

Note: The average flow stress is found out by integrating the flow curve equation between zero and the final strain defining the range of forming

Where Y_f is average flow stress, and ε is maximum strain value during the extrusion process.

The actual pressure for extrusion will be greater than in ideal case, because of the friction between billet and die and billet and container wall.

- Ram pressure to perform indirect extrusion (based on Johnson's Extrusion strain formula)

$$p = \overline{Y}_f \epsilon_x$$

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You try to calculate the ram pressure. Under ideal deformation, the ram pressure requires to extrude the billet through the die hole is given by

$$p = \overline{Y}_f \ln(r_e) = \overline{Y}_f \ln\left(\frac{A_0}{A_f}\right)$$

Now, how do you find out the average flow stress? The average flow stress is found out by

$$\overline{Y}_f = \frac{K\varepsilon^n}{1+n}$$

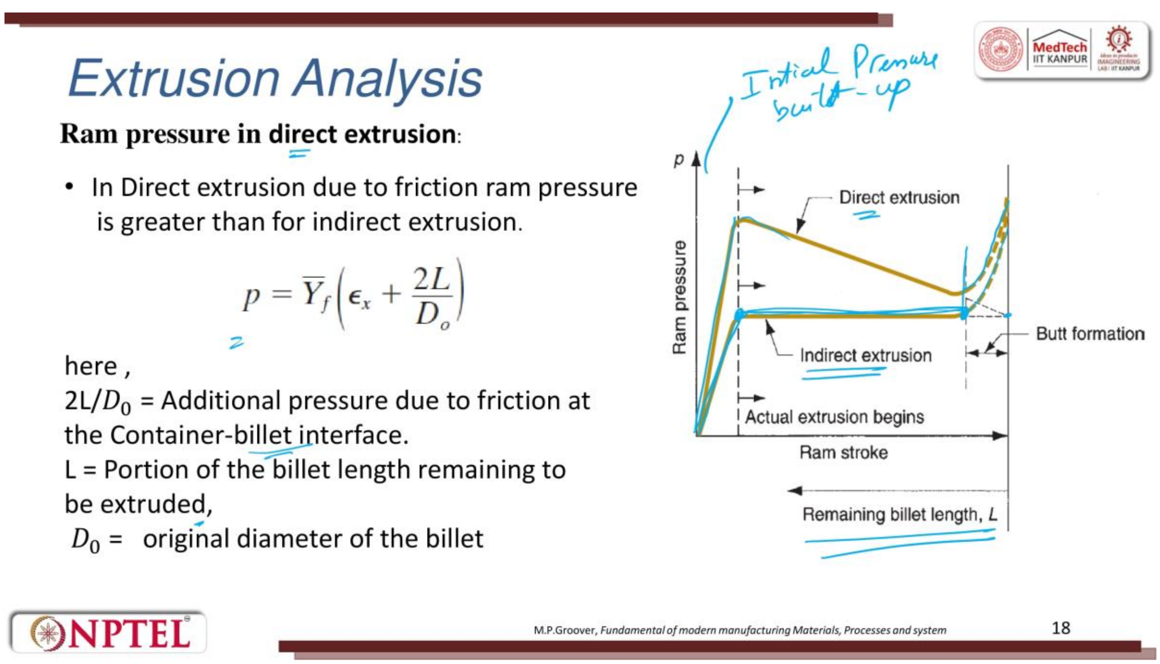
Where ε is the maximum shear strain during the extrusion process, n is a strain hardening coefficient. The average flow stress is found out to be integrating the flow curve equation. Between 0 to the final strain defining the range of forming process.

So, through this we try to calculate the load, but this load also we assume that there is no redundancy of work there is no friction. The actual pressure of extrusion will be greater than the ideal because the friction between the die the billet. And the die and billet and the container are pretty high. So, the ram pressure to perform indirect extrusion based upon Johnson's extrusion strain formula is defined by this. So, if we want to plot the ram pressure with the ram stroke which is the billet length L, you can see two different curves.

One is you see indirect. Indirect what happens initially it tries to increase the pressure after certain point. There is a uniform pressure getting applied and then you see there is a increase in pressure. So, in the stable region you will see that actual extrusion begins from here and it ends later. But it around about half of it or three-fourth of it the plateau is the same.

So, there you see it in indirect pressure. Whereas, in direct pressure what happens you there is a increase in ram pressure. And then there is a decrease in ram pressure because the friction is the work piece is moving.

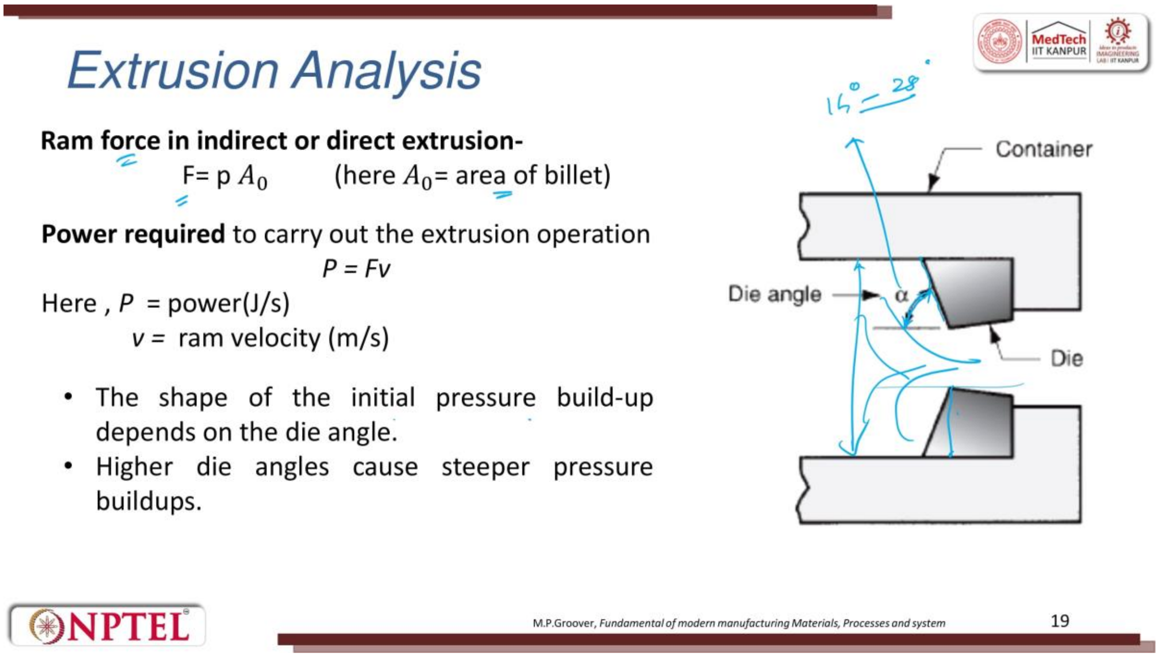
So, you have a reduction in the pressure. And when the butt formation starts there you can see once again there is a increase in ram pressure. So, indirect extrusion is always preferred as compared to that of direct extrusion because you can operate it at a lower ram pressure.



In indirect extrusion due to the friction ram pressure is greater than the direct extrusion. So, P is found out by

$$p = \overline{Y}_f\left(\epsilon_x + \frac{2L}{D_o}\right)$$

L is the length remain for to be extruded, D0 is the original diameter. Through this we try to find out the ram pressure for direct extrusion.



So, ram pressure for indirect extrusion F = P A0, A0 is the This is the area of the billet. So, the power consumption P = F v. What is F? F is the ram force, v is the velocity with which it is pushed.

So, if you look at the die, so there is an angle which is very important for the material to flow. So, this is called as the die angle. So, it can be it is with reference you can try to take and this can vary from maybe 14 degrees to 25 degrees depending upon your need. The shape of the initial pressure built up depends on the die angle.

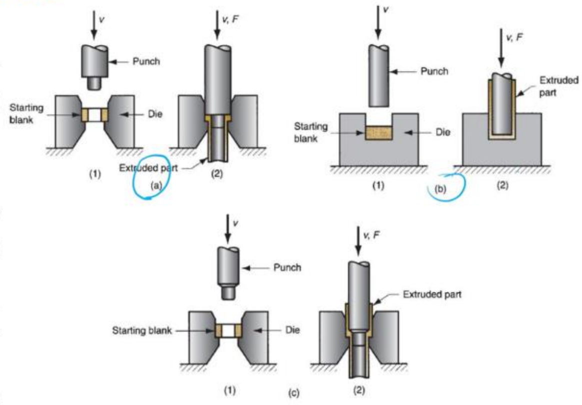
If you have a die angle more and more and more. So, what happens is there is a smooth flow of material. If it is a sharp one, then there is a sudden cross-section variation. So, it tries to hamper the pressure. So, the shape of the initial pressure buildup.

So, where is the initial pressure buildup? This is the initial pressure buildup, initial pressure buildup. The higher the angle, the steeper the pressure buildup.

Other Extrusion Process

Impact Extrusion

- Impact extrusion is performed at higher speeds and shorter strokes than conventional extrusion.
- It is used to make individual components.
- The billet is extruded through the die by impact pressure and not just by applying pressure.
- Impact extrusion is carried out as cold forming.
- large reductions and high production rates.



combinations

- Very thin walls are possible by the backward impact extrusion method. Eg: making toothpaste tubes, and battery cases.

So, impact extrusion—all your tubes—when we started, we started with an analogy of a tube. All these tubes are made by impact extrusion. Impact extrusion is performed at higher speed and shorter strokes than conventional extrusion.

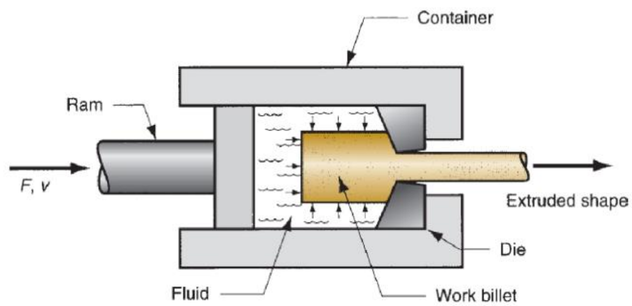
It is used for making individual components; very small pins can be made. If you see, the majority of the copper pins used in ICs are made through impact extrusion. The billet is extruded through a die. So, this is the die. So, the punch comes extruded through a die by impact pressure and not just by applying pressure.

Impact extrusion is carried out in cold form. So, this is one. You can also have an impact extrusion like this, and you can have a combination of this plus this. So, you try to get an extruded portion on the top. Impact extrusion is carried out in cold forms.

Larger reductions and higher production rates can be achieved by this process. Very thin walls are possible with backward impact extrusion. For example, making toothpaste tubes and battery casings is done by impact forging.

Hydrostatic Extrusion

- In this, the metal billet is compressed from all sides by a liquid rather than the ram.
- The presence of liquid inside the container eliminates the need for any lubricant and also, the material is more uniformly compressed from all sides throughout the deformation zone.



- Highly brittle materials such as grey cast iron can also be extruded.
- Pressure-transmitting fluids used are castor oil with 10% alcohol, SAE 30 mineral lubricating oil, glycerine, ethyl glycol and iso pentane etc.

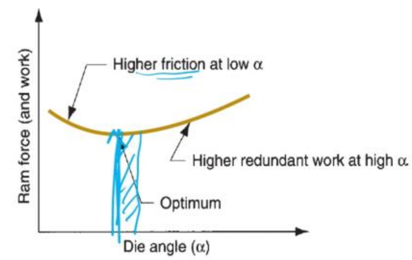
Hydrostatic, which we have already seen, has uniform pressure. So, there is not much friction here. So, you put in a liquid, then fluid, and then you insert a ram. This ram pushes, gets pressurized, and applies load on the billet, which then gets extruded. Here, the metal billet is compressed from all sides by a liquid rather than a ram. The presence of liquid inside the container eliminates friction and the need for lubricant. It is very good, but the process itself is very difficult.

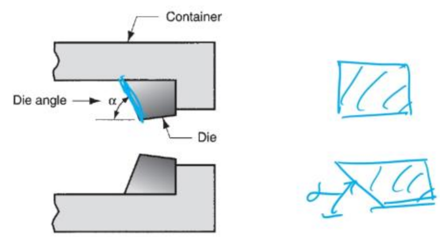
Why? Because when you start pushing the ram, there will be pressures that build up. So, there has to be a container that must be leak-proof, which is difficult. So, the presence of liquid inside the container eliminates the need for any lubricant. And also, the material is uniformly compressed from all sides throughout the deformation zone.

So, brittle materials like gray cast iron can be extruded. The pressure-transmitting fluid used is castor oil with 10 percent alcohol in it, so that it can uniformly apply pressure.

Die Angle: Importance

- Die angle and orifice shape are two important factor in die design.
- Low die angles results,
  - ➢ large surface area of the die it increases friction at the die-billet interface.
  - ➢ Higher friction results in higher ram force.
- Large die angle results,
  - ➢ More turbulence in the metal flow during reduction,
  - ➢ It increases the ram force.





NPTEL

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The die angle, which we saw, we just went through it superficially. And then we came here, but now let us see the importance of this die angle. The die angle and the orifice shape are two important factors in a die.

So, when we look at the ram pressure and the die angle, there is an optimum that exists. The force reduces and after some point, it tries to increase. Maybe this zone is called the safe zone. So, you can have a single point or a range. So, when higher friction occurs at a lower angle, the low die angle results in a large surface area of the billet, increasing friction at the billet-die interface. So, this one, the large surface area, increases the friction at the die-billet interface.

The higher friction results in higher ram. The large die angle results in more turbulence in the metal flow during reduction. So, it also increases the flow. So, basically what we are trying to say is you can have a block like this, you can have a block like this. So, we are talking about the angle right; this is nothing but the die.

So, when the surface area is large, it increases friction at the die-billet interface when the die angle is large. So, when it is a low die angle and when it is a large die angle, that more turbulence in the metal flow reduces the friction. And it also increases the ram flow.

Die Angle: Importance

- The shape of the die orifice affects the ram pressure required to perform an extrusion operation , its denoted by die shape factor (k_x).

Die shape factor

- It is defined as the ratio of the pressure required to extrude a cross section of a given shape relative to the extrusion pressure for a round cross section of the same area.

Here, k_x =die shape factor

C_x =perimeter of the extruded cross section(mm)

C_c = perimeter of a circle of the same area as the extruded shape(mm)

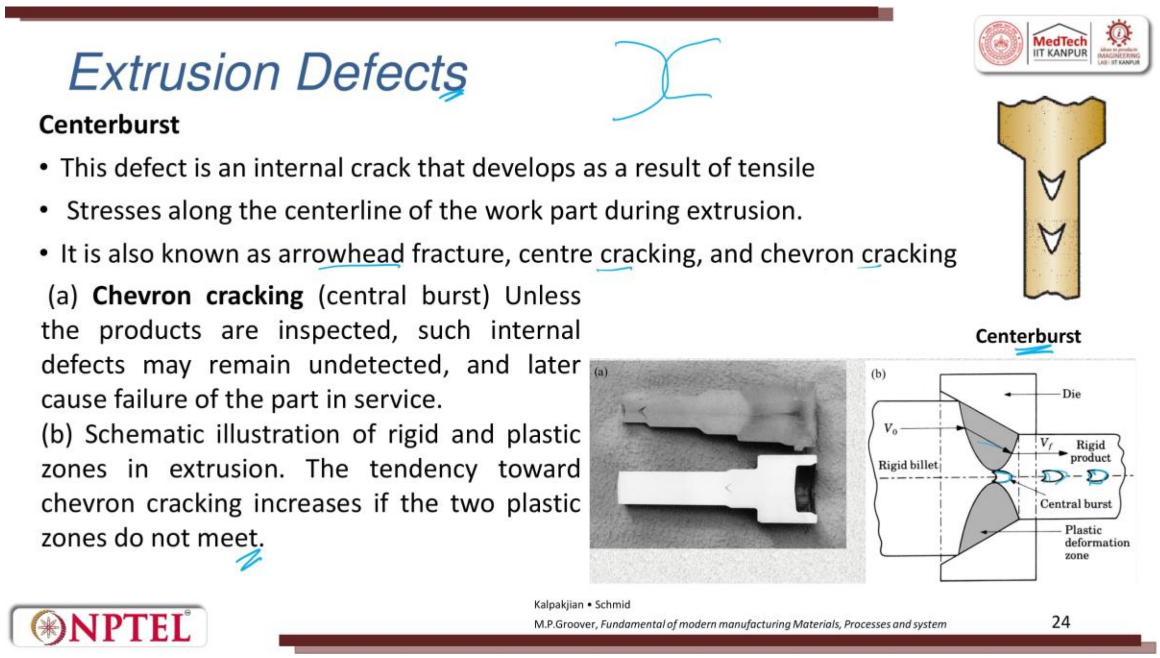
Die materials

- For hot extrusion - tool and alloy steels.
- For cold extrusion - tool steels and cemented carbides. Carbides are used when high production rates, long die life, and good dimensional control are expected.

NPTEL 23

The shape of the die orifice affects the ram pressure required to perform an extrusion operation; the shape factor plays an important role, which is kx. Die shape factor is defined as the ratio of the pressure required to extrude a cross-section of a given shape.

So, kx is nothing but Cx by Cc: perimeter of the extruded cross-section divided by the perimeter of a circle of the same area as the extruded shape. So, this is a very important factor called Kx, the die material. For hot extrusion, tool and die alloy steels are used, whereas in cold extrusion, tool steels and cemented carbide are used. So, now let us look into the defects.



The most common defect is called a center burst. You can see here there is a burst which is happening center burst. This defect is an internal crack that develops as a result of tensile force which is coming. This stresses along the center line of the work part during extrusion. It is also known as arrowhead fracture, center cracking or chevron's cracking. Chevron's cracking unless the products are inspected such internal defects remains undetected.

And when you put in service condition it fails and later causes a failure of the parts in service. So, this is very important and this can happen because of this. So, you have a die angle. So, when the material is getting extruded because cross section area reduction. So, you can see here this is a center bust which is getting formed ok.

So, the schematic illustration of rigid and plastic zone in extrusion is seen here. The tendency towards chevron cracking increases if two plastic zones do not meet. It is almost like your in casting also we saw right when they do not meet they have this chevrons cracking.

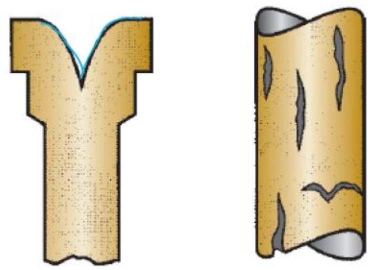
Extrusion Defects

Piping

- Piping is a defect associated with direct extrusion.
- It is the formation of a sink hole in the end of the billet.
- It is also known as tailpipe and fishtailing.

Surface cracking

- This defect results from high work part temperatures that cause cracks to develop at the surface.
- They often occur when extrusion speed is too high, leading to high strain rates and associated heat generation

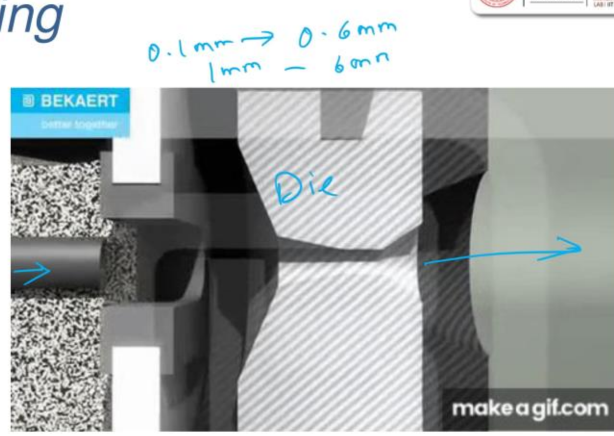


Piping Surface cracking

Piping is the other defect which is quite common. Piping if a defect associated with the direct extrusion. So, you can see here on the top; you can see it is the formation of a sinkhole at the end of the billet. It is also known as a tail pipe or fish tailing. There are surface cracks. These defects result in a high workpiece temperature that causes cracks on the surface. They often occur when the extrusion speed is too high, leading to high strain rates and associated heat generation. These are all cracks that are there on the surface.

Wire and Bar Drawing

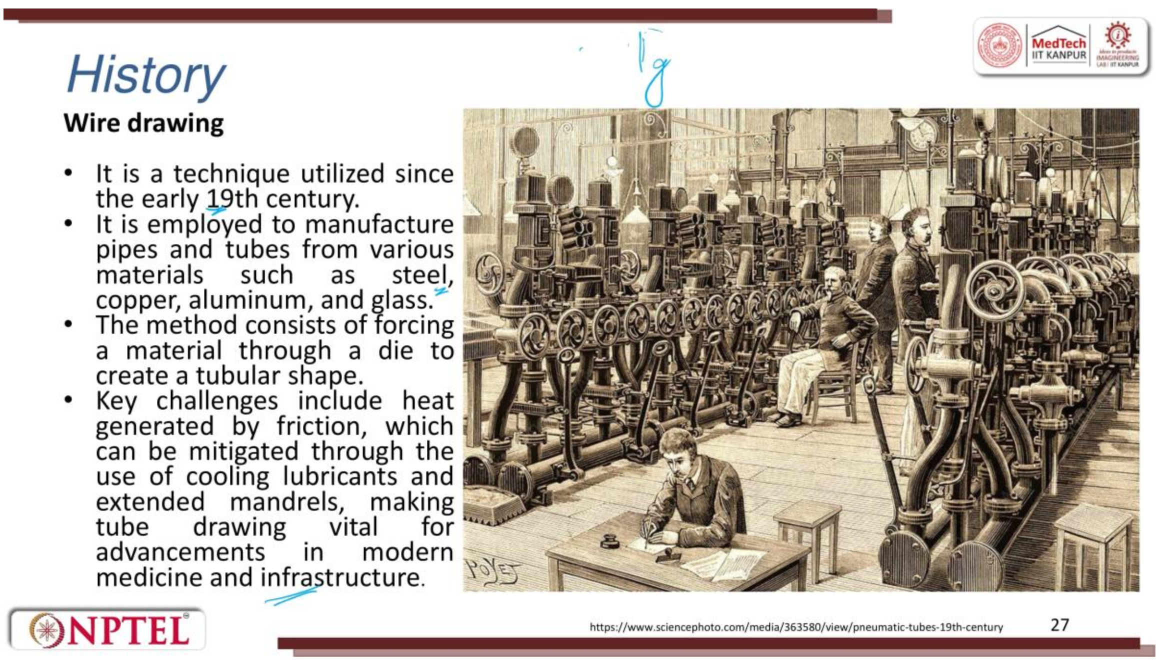
- Drawing is an operation in which the cross-section of a bar, rod, or wire is reduced by pulling it through a die opening.
- Work is pulled through the die in drawing, whereas it is pushed through the die in extrusion.
- The basic difference between bar drawing and wire drawing is the stock size that is processed.
- Bar drawing is the term used for large diameter bar and rod stock , while wire drawing applies to small diameter stock.



Now, a small variation from the extrusion process is the wire drawing process. The difference between extrusion and wire drawing is that in wire drawing, the wire is continuously fed from one side, and the reduction happens on the other side. You can also have a bar or a wire. Drawing is an operation in which the cross-section of the rod, bar, or wire is reduced by pulling it through a die opening.

So, here we pull it through a die opening, right? So, there it is all compression; here it is pulling. The work is pulled through the die in drawing, whereas it is pushed through the die in extrusion—a big difference: compression versus tensile. The basic difference between bar drawing and wire drawing is the stock size cross-section: bars are of larger diameter, and wires are of thinner diameter. You can get from 0.1 millimeter up to 0.6 millimeter.

You can get a bar from 1 millimeter to 6 millimeters depending upon your requirements. The bar drawing is the term used for large diameter bars and rod stocks, while wire drawing is for smaller diameters.

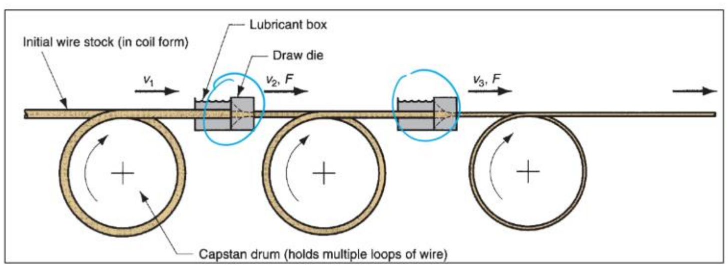


It is a technique that started in the 19th century. It is employed to manufacture pipes and tubes from various materials such as steel, copper, aluminium, and glass.

So, you can also have steel wire, copper wire, aluminium wire, and glass. At the glass transition temperature (Tg), you can get optical fiber wires. The method consists of forcing a material through a die and creating a tubular shape. The key challenge is the heat generated by friction. This can be mitigated through the use of cooling lubricants. And an extended mandrel makes tube drawing vital for advancements in modern medicine and other infrastructure. So, you can have a continuous reduction of wire passing through several of these dies.

Wire Drawing

- Wire drawing from coils consisting of several hundred meters of wire and is drawn through a series of dies.
- The number of dies varies between 4 and 12.
- It is '**continuous drawing**' because of the long production runs that are achieved with the wire coils.
- The segments can be butt-welded to the next to make the operation truly continuous



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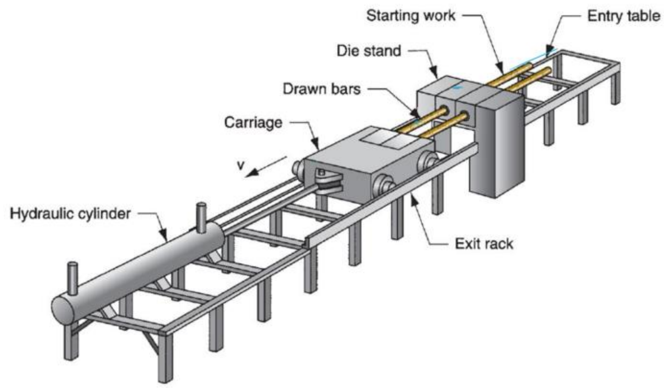
A coil consists of several hundred meters of wire. And it is drawn through a series of dies (1, 2, etc.), with a reduction happening at each die. The number of dies varies from 4 to 12; it is a continuous drawing process. It produces a long run that is achieved through the wire getting coiled.

So, you can get a long one, but you coil it so you get it. So, that is why when you buy wire, you always get a coiled wire. The segment can be butt-welded to the next to make the operation truly continuous.

Bar Drawing

- Done as a single stage operation, in which stock is pulled through one die opening.
- The inlet bars are straight and not in the form of coil, which limits the length of the work that can be drawn.
- It is a batch type operation.



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This is for wire, and in the same way for bar also, you can try to have it done as a single-stage operation in which the stock is pulled through one die opening. The inlet bars are straight and not in the form of a coil, which limits the length of the work that can be drawn. So, you see here, bar—this is a hydraulic. So, here it passes—this is a carriage. So, you have drawn bar—this is a die through which the bar is getting extruded. It is a batch-type process.

Bar and Wire Drawing Analysis

Area reduction(r) in drawing- change in shape of work.

Here, A_0= initial area of work (mm^2)

A_f= final area of work (mm^2)

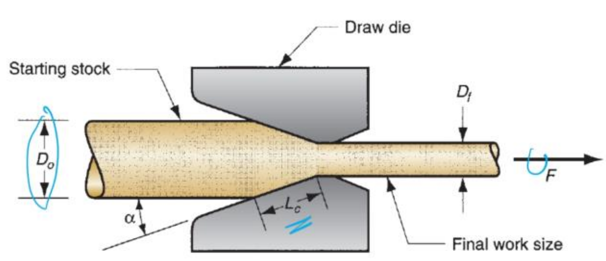
Draft is the difference between original and final stock diameters.

$$d = D_0 - D_f$$

Here d= draft

D_0= initial diameter of work

D_f= final diameter of work



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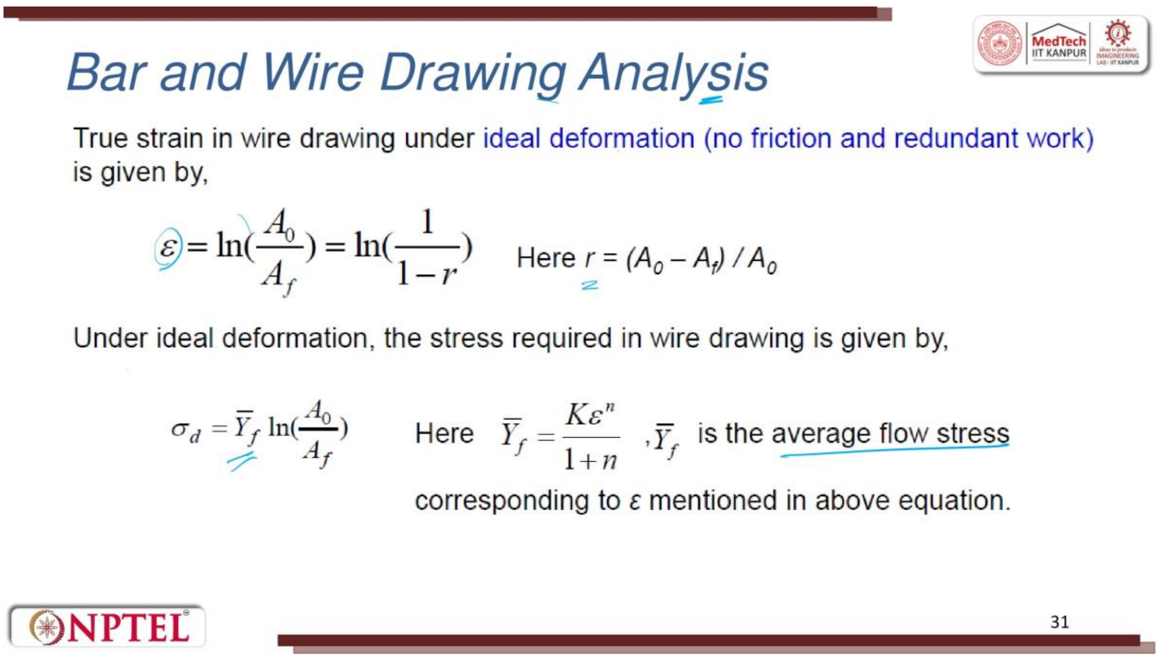
The area reduction is called A. So, A is nothing but A_0/A_f. The draft is the difference between D_0 and Df. So, this is called the draft. So, area reduction and draft reduction are also very important. Here, the contact length Lc plays a very important role because that also dictates the pressure—the ram pressure or the pulling pressure.



Bar and wire drawing analysis: the true strain in the wire drawing under ideal conditions. No friction and redundancy work. This strain is written as

$$\varepsilon = \ln(\frac{A_0}{A_f}) = \ln(\frac{1}{1-r})$$

Under ideal conditions, the stress required in wire drawing is given by the formula YF. The flow stress is calculated. The average flow stress is calculated, and this gets fit into the formula. We try to get the strain, two strains which are there. A typical draw die consists of four regions.

Draw Dies

A typical draw die consist of four regions:

Entry

- Entry region is usually a bell-shaped mouth that does
- Not contact the work.
- Its purpose is to funnel the lubricant into the die and prevent Scoring of work and die surfaces.

Approach angle

- It is region where the drawing process occurs.
- It is cone-shaped with an angle (half-angle) normally ranging from about 6° to 20°.

Bearing surface(land)

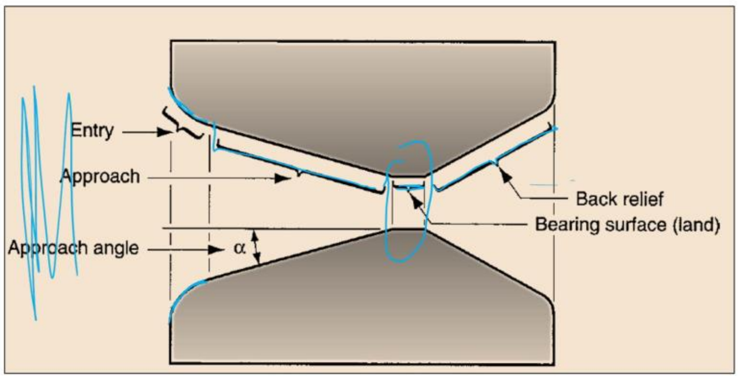
This region determines the size of the final drawn stock.

Back relief

- It is exit zone
- It is provided with a back relief angle (half-angle) of about 30°.

Draw Dies

- **Draw dies are made** of tool steels or cemented carbides.
- **Dies for high-speed wire drawing** operations uses inserts made of diamond for the wear surfaces.



The typical draw die consists of four regions. So, the first one is called the entry. This is almost like an ellipse, right? So, it is in my entry. So, if at all there is any vibration or variation, that gets streamlined through the entry. Then it has an approach, the second segment. The third segment is the bearing surface area, and the fourth one is the ideal relief. There are four zones. So, if the wire comes with vibration, the entry gets taken care of. Then from there, the approach tries to drag it toward a small cross-section. And at that cross-section, it maintains the geometry for some time.

And then it is released because here there will be a lot of friction. You cannot have it continuous. Once it is maintained for some time, then what you do is when it exits out, it should not be free to bulge out again. So, we try to restrict it for some time. So, these are the four zones. Now, let us see it in more detail. There are four regions: entry.

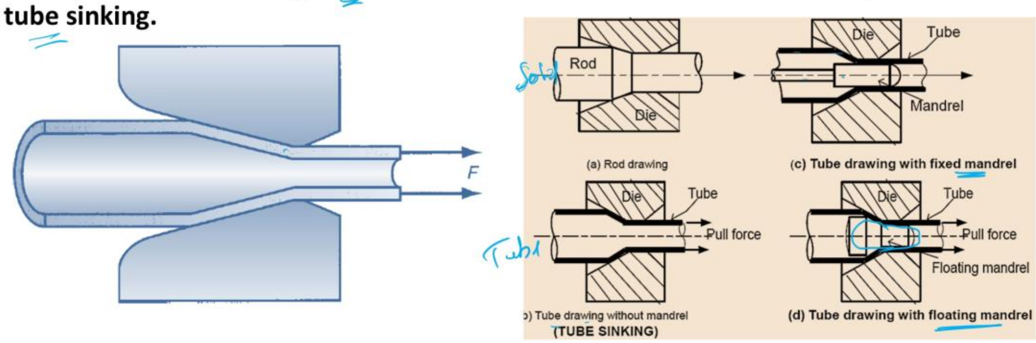
The entry region usually is a bell shaped mouth that does not come in contact with the work piece. But the purpose is to funnel the lubricant into the dye and prevent scoring of the work on the dye surface vibration and liquid also. The approach angle it is the region where the drawing process occurs. It is a cone shaped with an angle half angle normally ranging between 6 to 20 degrees. Then comes the bearing surface this region determines the size of the final drawn stock and the back relief.

It is the exit zone which it is provided with a back relief angle of about 30 degrees. So, that it tries to when you when it comes out. From there it is getting focused and then it is coil. So, the approach angle bearing surface and back relief is all important. Entry is for lubrication and also to reduce the vibration.

The draw die are made out of tool steel and cemented carbide. The die for high speed wire operation uses insert made out of diamond for wear resistance. In wire drawing and in bar drawing. It is not only the hollow, it is not only the solid cross section, it can also produce tube cross section right. That means, to say a hollow can be done.

Tube Drawing

- Drawing is used to reduce the diameter or wall thickness of seamless tubes and pipes.
- Tube drawing can be carried out either with or without a mandrel.
- Inside diameter and wall thickness of tube and pipe can be controlled by mandrel.
- In simple form of drawing no mandrel and is used for diameter reduction, its also called as **tube sinking.**



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Tube drawing is used to reduce the diameter or the wall thickness of a seamless tube or pipe. This is a tube where the pipe diameter is reduced. The tube draw can be carried out either with or without a mandrel. So, this is a rod. So, there is a die.

So, now, what you do is you put a mandrel and then you try to make it a tube drawing with a fixed mandrel. So, here it is a solid cross-section. This is where you put a mandrel and then you create the tube-like structure. The other one is you start with the tube-like structure and then you try to reduce it. The last one is going to be a floating mandrel.

The floating mandrel is used for making long tubes; they have a floating mandrel. So, rod tube drawing with a fixed mandrel, tube drawing without a mandrel, tube drawing with a floating mandrel. In the simple form of drawing, no mandrel is used for diameter reduction; it is also called tube sinking. No mandrel is called tube sinking. So, a tubular structure can also be produced by drawing. Suppose you want to have a 10-meter-long pipe; it is done by a floating mandrel.

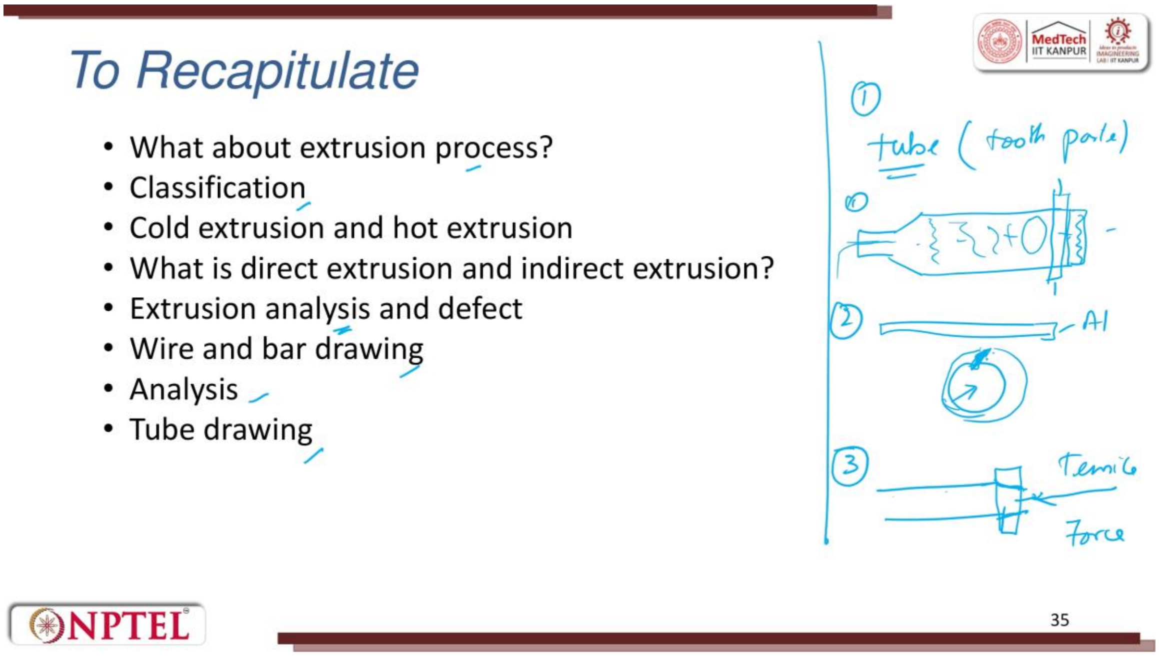
So, before we recap some of the exercises which you can try at home. The first thing is to take a tube, such as a toothpaste tube, and try to squeeze it. Try to squeeze from this portion, okay? And try to push out all the material through the orifice, right? Only at this point will you see that once a major portion is done, you will have a lot of residue here.

And then, what do you do? You try to roll or put your roller here and then try to squeeze it out. So, when you put a roller here and squeeze, what happens is a small amount of material comes out. This clearly states that there will be residue, and this residue has to be pressurized and pushed out. If you do not do this, there will be some residue left, which is wasted.

The second thing I would like you to do is Take a thin sheet—very thin—of aluminum or whatever, and try to make a hollow cylinder. And then, on top of this cylinder, try to stick or place something heavy, like a stake or similar. So, you try to do this, and then through this, try to pressurize water. You will see that at some point, this weld will yield or there will be a water leak through it.

This will try to explain the importance of seamless pipes. The third thing I want to do is, take a wire—copper wire or a metal wire, whatever it is. And then you put a die here, OK? You put a die here. Now, try to pull the wire from the opposite side and observe the force you experience. These are some experiments you can do at home.

This will help you understand the importance of extrusion, the formation of dead zones in materials, and seamless tube pipes. And the tensile force required for drawing a wire. So, when you do this, you will appreciate and enjoy this lecture.



So, what did we cover in this lecture? We discussed the extrusion process, then classifications. We covered cold and hot extrusion, direct and indirect extrusion, extrusion analysis with defects. Then we discussed wire drawing analysis and different types of tube drawing. Friends, with this, we are coming to the end of the bulk deformation processes. So, through this, you will understand and appreciate constant volume processes and bulk processes.

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These are the books we used as references for making the slides.

Thank you very much.