Basics of Mechanical Engineering-2

Prof. J. Ramkumar

Prof. Amandeep Singh Oberoi

Department of Mechanical Engineering

Indian Institute of Technology, Kanpur

Week 05

Lecture 16

Basics of Forming (Part 1 of 5)

Welcome to the next section of the course. So, here in this section, we will focus on forming. In the first section, we were more focused on casting. Casting and forming fall under the category of constant volume processes. So, that means the starting material and the ending material will be approximately the same.

I use one liter of aluminum alloy, and when I convert it using volume, density, and other factors, I try to get approximately the same amount in the final product. I start with 1 kg, and I get approximately 1 kg. So, in metal forming, it is the same story. What is the difference?

The difference is, there we converted the state from solid to semi-solid to liquid, and then poured it into the mold, but here we are not going to change the state. We are going to use a solid as a solid and try to shape it. Friends, in manufacturing, there are only three parameters that are very important. One is pressure, the other is temperature, and the third is time.

When we did casting, we used only two of these parameters: temperature and time. We did not go deep into die casting. In die casting, we also use pressure. Whereas, when you come to metal forming, it is more focused on pressure and time, or pressure and temperature. These are the two things.

But the predominant parameter is going to be pressure. What is pressure? Pressure is nothing but force applied per unit area. If I have a solid, now I apply a huge load on top of it such that it deforms. Let us take a simple example in your kitchen.

You make a small ball out of atta. You roll it and make it out of atta and then what you do is you keep it on a flat plate, and you have a roller to roll on top of it. Now the ball shape item whatever was there which occupied a smaller area. Now you try to spread it. You increase the surface area but reduce its thickness.

The starting volume, whatever was there, and the ending volume will be the same. Where is the difference? It is the surface area. So, here you can clearly see when I apply pressure, I try to deform a raw material. So, those processes are called forming.

It is a very important process. If you see, forming plays a very important role, and several applications are there. For example, when you see doors which are there, which are made out of metal, they are made through the forming process. The door frames are made through the metal forming process. The car bonnet is made through the metal forming process.

The rocket casing is made through the metal forming process. The sharpener which you use for pencils, you see a small blade made through the metal forming process. If you see a scissor made through the metal forming process, a spanner made through the metal forming process, a stand which is used for taking videos, a tripod made through the metal forming process. So, almost everything is made through metal forming processes. It is a very important process. So, let us try to understand the fundamentals of the metal forming process.

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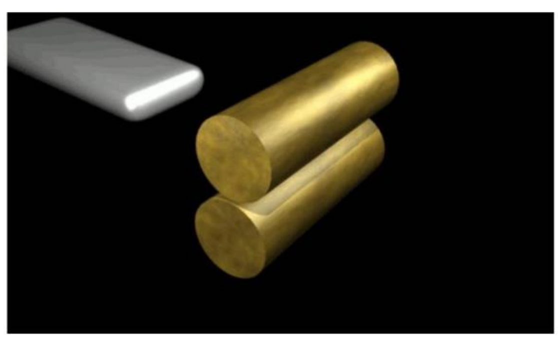

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In this process, we have two weeks exclusively dedicated to discussing metal forming. So, we will follow a flow like this: first, we will try to have an introduction, then we will try to have classifications. Like we had in casting classifications—expendable mould, non-expendable moulds, right? So, like that, here also we try to classify—classify how?

We will try to classify based on the raw material available to us. That is one way of doing it, then the shape that needs to be achieved. For example, whether it has to be continuous or discrete. So, we will see the classifications, then we will try to understand the forming mechanisms. That will be the third part of it. The temperature plays a very important role, as you also know.

Suppose you cannot bend it—for example, if you take a spoon or a rod and try to bend it—it becomes difficult. If we see that our force is not enough to bend it, naturally what we do is go to the kitchen, start the burner, heat the rod, and then it gets slightly softened and bends. So, the effect of temperature will be the next one we focus on, then we will try to see what the different types of processes are: cold working process, warm working process, and we will try to see the hot working process. So, then we will try to see various bulk forming processes, like rolling. Right from history, we will see rolling analysis, rolling analysis outcomes, rolling mills, operations, and defects.

Finally, we will try to recap with some references. If you look at the figure where the animation is playing, you see two rollers, and a thick plate is pushed inside. When it is pushed inside, the rollers rotate. When it rolls, it tries to drag the material inside, and when the load is applied, you see the width expands and the thickness reduces. So, basically, the surface area expands, but the volume remains the same. So, that is what is shown in this animation.

Introduction

- Metal forming includes a large group of manufacturing processes in which plastic deformation is used to change the shape of metal workpieces.
- In forming process, metal deforms to take a shape determined by the geometry of the die.
- In this process stresses applied to plastically deform the metal are usually compressive.
- Most desirable properties for forming include low yield strength and high ductility.
- Strain rate and friction are additional factors affecting metal forming performance.

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So, metal forming includes a large group of manufacturing processes in which plastic deformation is used to change the shape of the metal workpiece. When you look at the stress-strain diagram, We had for aluminum alloys; we had for aluminum alloys like this. So, you will have the elastic limit, then you will have the plastic region. So, when we are doing metal forming, we cross the elastic state, enter the plastic region, and then try to shape it.

If you go further down, it will try to break, so we do not enter that area. So, interestingly, when you get into it, there is a phenomenon called strain hardening. The strain hardening phenomenon occurs, and you can improve the mechanical properties, get a very hard output from the sheet, and then shape it. So, that is the metal forming phenomenon. So, in metal forming, we work in the plastic region.

It is very clear that you have to apply so much stress to get the strain. What is the strain? The strain can be elongation in one direction or in the cross direction. So, in this process, plastic deformation is used to change the shape of the metal piece. For example, if you want a spoon to be made, the basic material will be a flat plate.

And then, when a load is applied, you try to get the shape of a spoon, right? So, that is basically giving a shape to the metal piece. In the forming process, the metal deforms to take the shape determined by the geometry of the die. So, when I have a sheet and I apply pressure, wherever I apply pressure, the sheet tries to deform. So, irregular shapes can be achieved this way.

So, what I do is try to deform it into a geometry that is given to the die. So, this is called the die, and this is called the punch, where you apply the load, and this is the sheet that is getting deformed. So, plastically, I deform it into a given shape to get the output. The shape is given to the die. So, you can have the geometry here depending on your requirement.

In this process, the stress applied to plastically deform the metal is usually compressive. By and large, it is compressive. What is compressive? You have a workpiece. You try to hammer the workpiece to get the output.

That is compressive force. When you have a workpiece and you try to pull it, that is called tensile. When you push it, that is compressive. So, by and large, compressive stress is applied to the sheet, and then it tries to deform. So that is what we say: compressive load is applied. Even in the previous example, you can see between the two rollers, there is a compressive load which is applied, which when it tries to extract, gets converted into tensile.

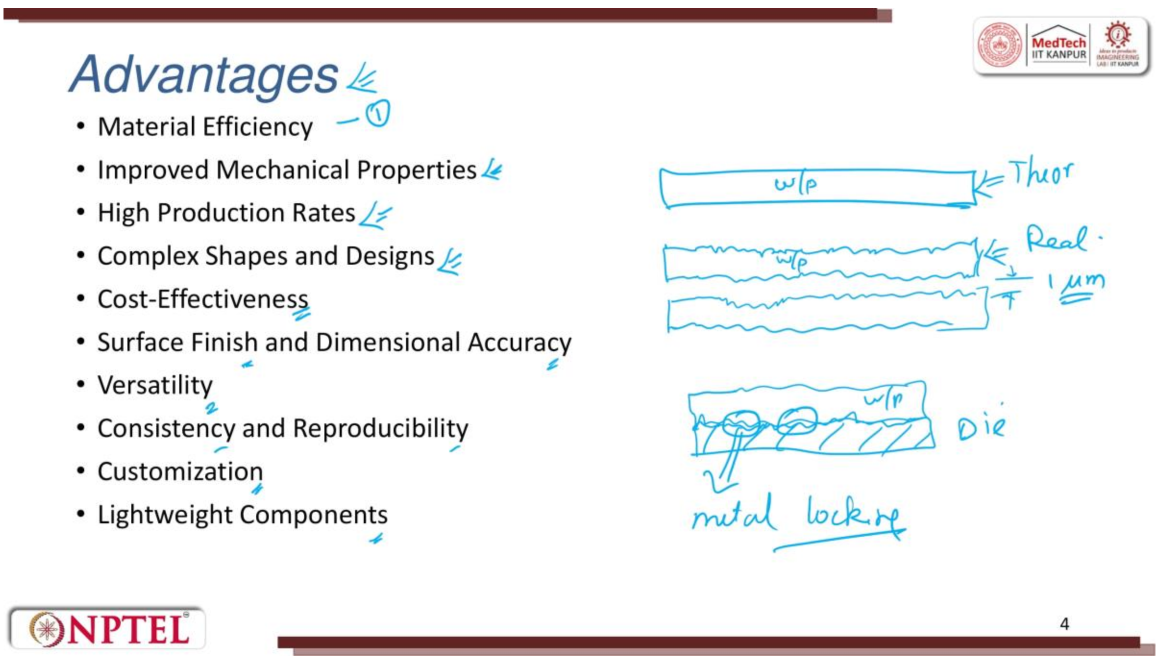
Because you are compressing it, you are allowing it to have a free end, so it expands. But friends, remember, what you input, the same volume only you will get. There can be a change in the dimensions. The most reliable properties for forming include low yield strength and high ductility, so the strains will be very high. That is why we try to choose all the ductile materials as the workpiece.

For example, we try to take aluminium, which is very ductile and has low yield strength, making it ideal for forming processes. Copper, titanium, magnesium, and steel, which you can easily deform. Cast iron cannot be deformed. So, there is not much ductility. Cast iron cannot be used, and it has a high yield strength. Strain rates and friction are additional factors affecting the metal forming process. What are strain rates?

I try to slowly stretch it. The straining is gradual. Strain divided by time is the strain rate. If I slowly move a metal, it is a slow strain rate. When I move it quickly or instantly, it is referred to as a high strain rate. For example, if you take an elastic rubber band and slowly stretch it, you can keep stretching it to a great extent.

When I move it quickly or instantly, it is referred to as a high strain rate. So, that is the strain rate. And the other thing you should understand, friends, is we keep the sheet metal between metals. So, this is a metal die, and this is a metal punch, right? So, the workpiece will have metal-to-metal contact. When there is metal-to-metal contact, there is always friction, right?

See, when you try to take even an elastic eraser or when you try to take atta and press it, there is contact between your finger and the workpiece volume. When I try to drag it, there will always be a friction component. If there is no friction, the deformation becomes easy, but it is not controllable. So why is that friction occurring? I will try to explain in the next slide.



Why is that friction? Because any metal—this is the theoretical metal you have—but if you look at it microscopically, you will have all sorts of undulations on the surface. This is theoretical; this is real—okay. Now, I have another surface, assuming this is the die surface, and this is the workpiece. You have a die surface which is there, and all these undulations I'm talking about are of the order of 1 micron.

Your hair is 100 microns, so this is one-hundredth of that, right. Typically, your hair is about 70 to 80 microns thick—assuming it's 100 microns, the undulation on the surface is about one-hundredth of that. When this is trying to move, and here I have something else—like this is the other workpiece, which is the die workpiece. This is the workpiece.

You can see at several places there is metal locking. This metal locking tries to restrict the material from flowing.

Now you are applying pressure, so it has to break the locking and then it has to move. This will create friction, and if the friction is very high, it can also generate heat. So, what does it mean, or what is the inference we get from it? So, when metal-forming operations are done, you will always look for lubricants. What is the function of the lubricant?

Lubricants will flow inside these undulations. It will form a thin layer. So, when two surfaces are present, one will try to slide over the other. So, in room-temperature metal forming, we always try to use a lubricant—it can be oil, it can be soap water. It can be molybdenum sulfide, whatever it is, depending on your requirements.

So, what is the advantage of the metal-forming process? It is highly efficient. Why? The starting material and the ending material are the same, and the starting material enters a plastic zone, undergoes strain hardening, and then you get the output. So, its hardness value improves to some extent, and mechanical properties also improve.

It improves the mechanical properties. Metal forming is always used for higher production rates. If I want to make any part or a product in numbers of a few thousand. Then we always look for metal forming processes. So, it has a very high production rate, and very complex shapes can be made.

When you do casting, what happens? We have already seen. If there are very small features, all these features have to be given to the mold when you pour the material. The liquid might not fill up all the small features. So, you will get a rounded-off shape. But in metal forming, since you apply pressure with a known volume, it always tries to take the complex shape under design.

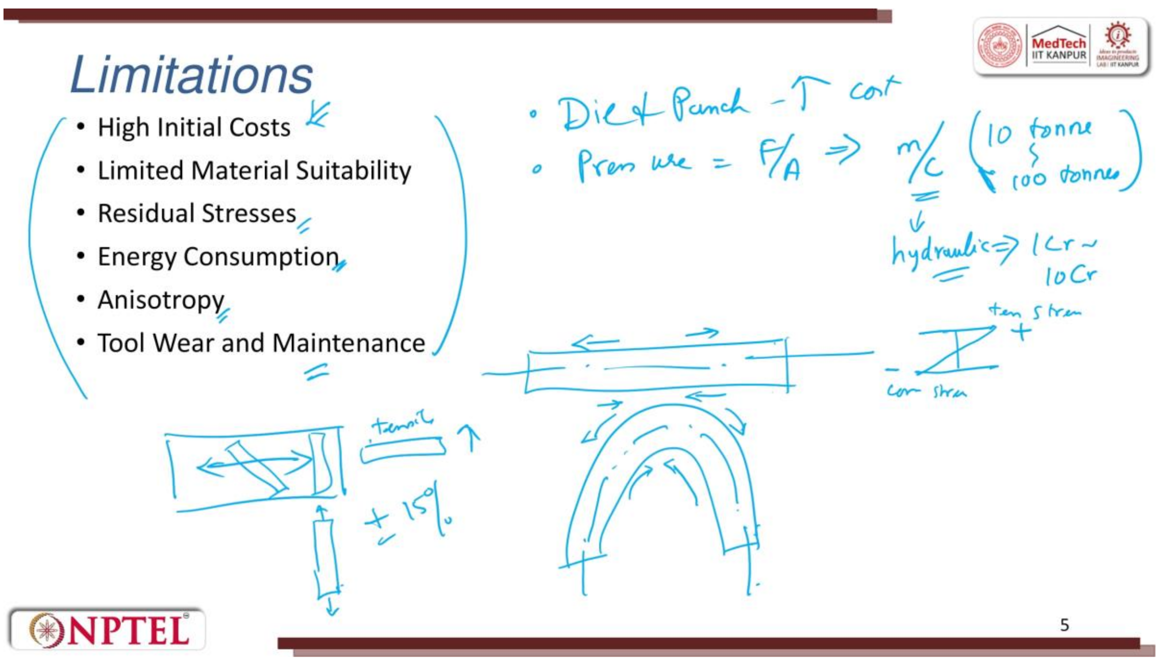
It is a very cost-effective process. Why? Because it is used for higher production rates. Almost all the sheet metal work which is done, be it a chair. Everything is made out of metal forming because the production rate is phenomenally high.

It has a very good surface finish and dimensional accuracy. It does not need to undergo a finishing stage. There can be excess material available which flows out. We will trim it off. That is called flash, and that flash can be removed.

But by and large, it gives you a good surface finish and dimensional accuracy. It is a versatile process, and whatever it produces is consistent and reproducible. Like in casting, what happens whenever there is an air bubble, right? There is an air bubble; it tries to produce a defect. Whenever there is erosion of the mould material, it gets affected, but here such things will not happen.

So, it has consistency and is also reproducible. It is customizable. That means you can try to play with the die or punch. Whatever it is, you can try to customize almost all the lightweight components. Wherein the sheet thickness is 1 millimeter or less than 1 millimeter.

We always go for metal-forming processes. If you look at an airplane where we all sit and travel, it has a structure. The structure is also made by metal-forming. The other thing, the cover of the plane is also made by metal-forming—the sheet metal, whatever is there, is made by metal-forming. So, metal-forming is a versatile process.



Saying this, it also has some disadvantages because it is used for higher production, repeatable, reliable processes. The initial cost is very high. That means the die and punch costs are high. The second thing is, if I have to apply huge pressure, what is pressure? Pressure is nothing, as I told you—it is force per unit area. I need a machine which is used for doing it.

So, typically, the machines we talk about in normal domestic applications— we talk about 10-ton machines; it can go up to 100 tons. So, this is the load created in the machine. So, the machine itself will have hydraulics; it will have electronics. So, all these things are expensive.

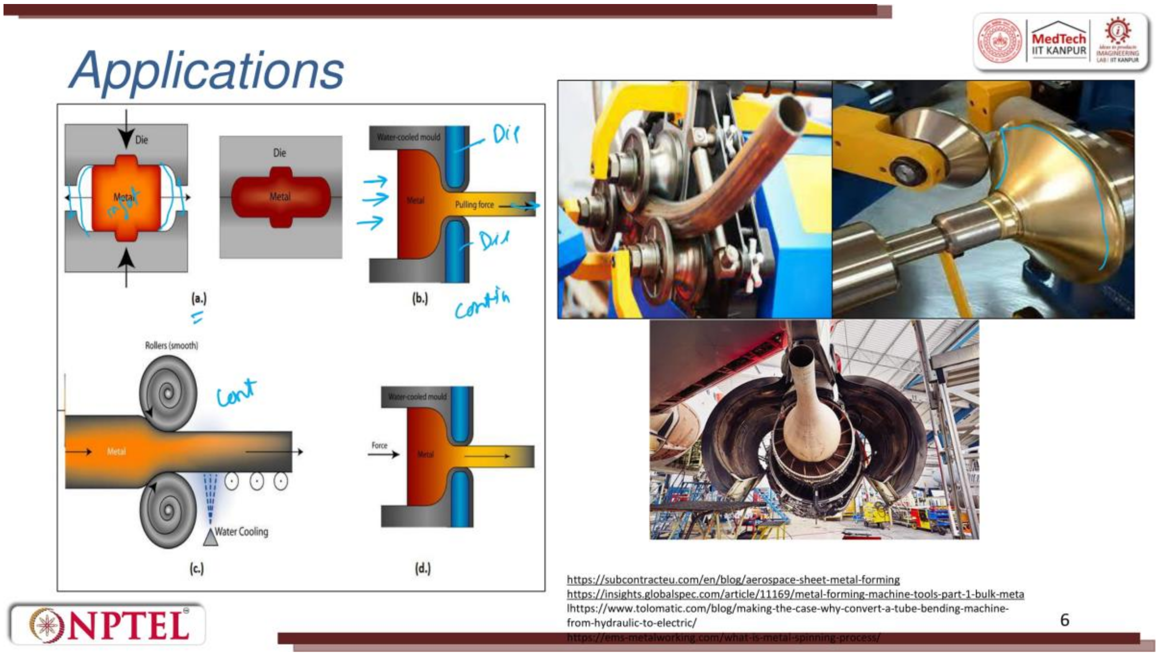
If there is a good machine, a very good controllable machine, it can go from a few 1 crore to a few 10 crores, right. It has residual stress because, what is residual stress? Residual stress is when you try to change the shape of your rod. When you try to change the surface, this is the, for example, this is a rod, you try to deform it into a U shape. So, here there are tensile stresses on the surface, and at the bottom, you will have compressive stress.

So, this will be compressive; on the top, you will have tensile. So, from here to here, if you try to draw, this is tensile and this is compressive. You see here it goes like this. This is, I am just drawing a cross section; this is tensile stress on the surface. This is compressive stress on the surface; this is the positive side, and this is the negative side. So, within this thickness, there is a transition happening.

This will try to introduce residual stresses in the material. Since you are working on 10 ton to 100 ton, the energy consumption is very high. And anisotropic is, if you have a sheet, if you are rolling the sheet in this direction. So, the tensile strength along this direction will be higher than cutting a piece in this direction. This is tensile running along the direction, and I draw perpendicular to it; again, I do here tensile.

I will see a different result here. So, it has different properties in varying directions, and suppose I cut at a 45-degree angle. Then, I will get a different response in the tensile test behavior. Of course, all these things will have a certain error of 10 to 15 percent. There will be differences, but they can be accommodated.

Tool wear and maintenance are also part and parcel of the limitations. So, these are a few limitations, but despite these limitations, you see a lot of advantages in metal forming.



So, if you look at it, these are some of the applications. So, you place a metal part there, which is called an ingot or a chunk of material. Now, I apply compressive force in both directions.

So, wherever there is compressive load, the material will try to bulge and expand. When it bulges and expands, wherever there is free space, it expands in that direction. And after some time, it keeps expanding, but I try to confine it by this dead end. So, it tries to get the shape I want, right? This is one application we can try, like stamping or a forced impact process.

So, the load can be continuously applied or the load can be impacted. It can be continuous, meaning you are trying to reduce it; impact means tuck. So, at regular intervals of time, you apply a heavy load. So, it tries to take the shape. The spanners you use in the automobile industry are made by the forging process.

It is an impact forging process. If it is a larger component, we use the drop forging process, right? The wheel axles are made out of a metal-forming process. The next one is the extrusion process, wherein we have material there. And then we try—this is a die—the die gets the shape of the output.

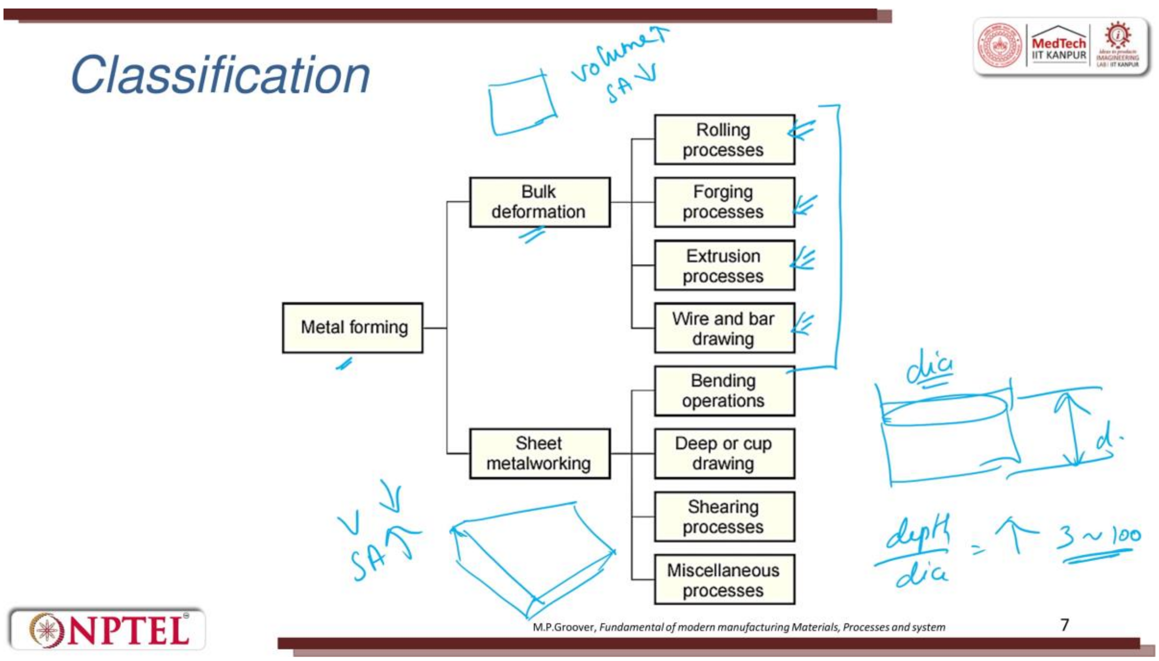
So, we try to pull material across the die and get the shape of it. So, the applications are the frames, the tubes, whatever you have—they are made out of this extrusion process.

So, you can pull here and also, parallelly, you can push it here. So, these are all extrusion processes. This is a rolling process wherein you have two rollers.

Or rolls. These rolls rotate, and they rotate in opposite directions with different speeds. So, what happens is the metal is dragged inside and thrown out. You try to get a flat plate sheet out of it. Here, the cross-section area will be uniform. Here also, it will be uniform.

So, this is used for a continuous process. Until the raw material is here, this is also called a continuous process. The moment it is exhausted, you put the next roll. But the output will be the same. In a die, it is discrete part manufacturing.

A tube—this is a tube. The tube can be made by an extrusion process. So, here we do a tube-bending process. Next, we try to make a curvature on the given object. So, this is also possible with a roller. So, this big structures are also made out of metal forming operations.



Now, let us see the classification of metal forming process. The metal forming process is classified based upon the raw material available. If the raw material is in an ingot form where the volume is high and surface area is low. They fall under the category called bulk.

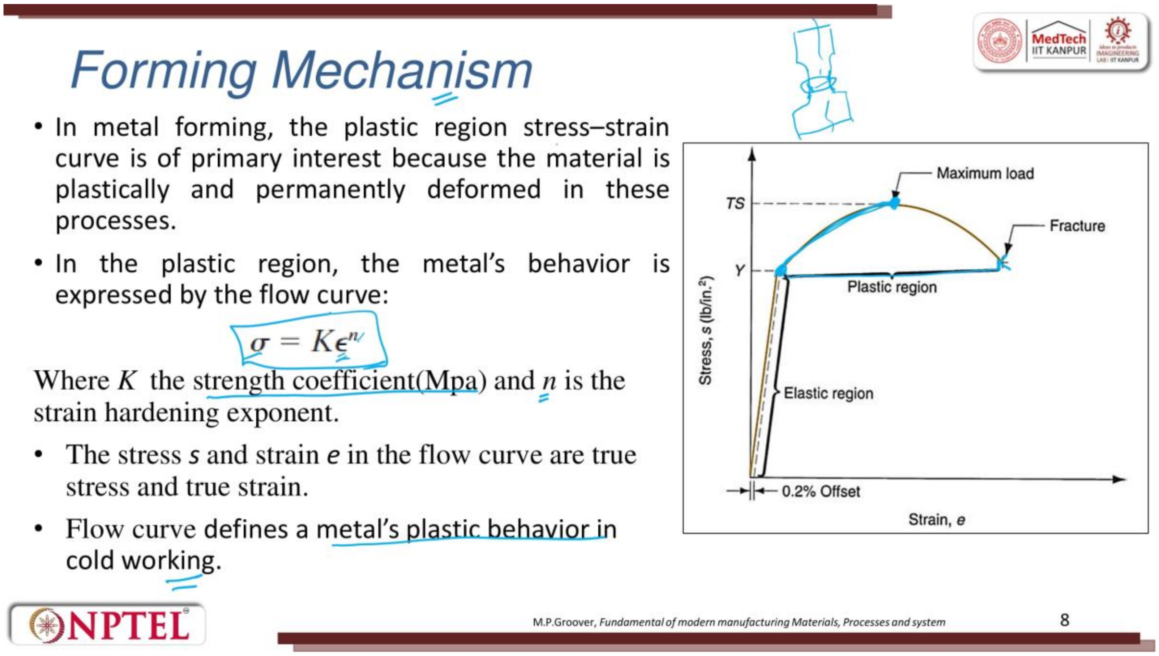
If the volume is less, If the volume is less, surface area is large, then it gets into sheet metal, metal forming operations. So, sheet metal, metal forming operations are used, are commercially used in a big way, right. Under the bulk, what we do is, we try to classify the process. So, first classification is a rolling process, we will see individual rolling process.

Then it is forging which I told you an example of impact forging, extrusion process. Wherein which I put material and pull, the wire drawing process. So, all these processes are bulk deformation process. The wire which we use in the electricity that is also made by metal forming process. So these are the four major process which form under bulk deformation process.

Sheet deformation processes can include bending and deep cup drawing. For example, the glass tumbler, the aluminum glass, or stainless steel glass tumbler is made through deep drawing. Wherever the aspect ratio, or the depth-to-diameter ratio, is high, we use the cup drawing process. The depth here can range from 3; the ratio can go up to 100, depending upon the requirements, right. Then, the shearing process is used in many sheet metal operations.

You can see sometimes there will be holes in it; those processes are called shearing processes. Then, you can have other miscellaneous processes. There can be a combination of bulk deformation and sheet deformation together. Those processes are variants or sometimes called hybrid processes. But these are the very basics.

In this course, it is good enough if you go through some of the basics to understand and appreciate the classifications of metal forming processes.



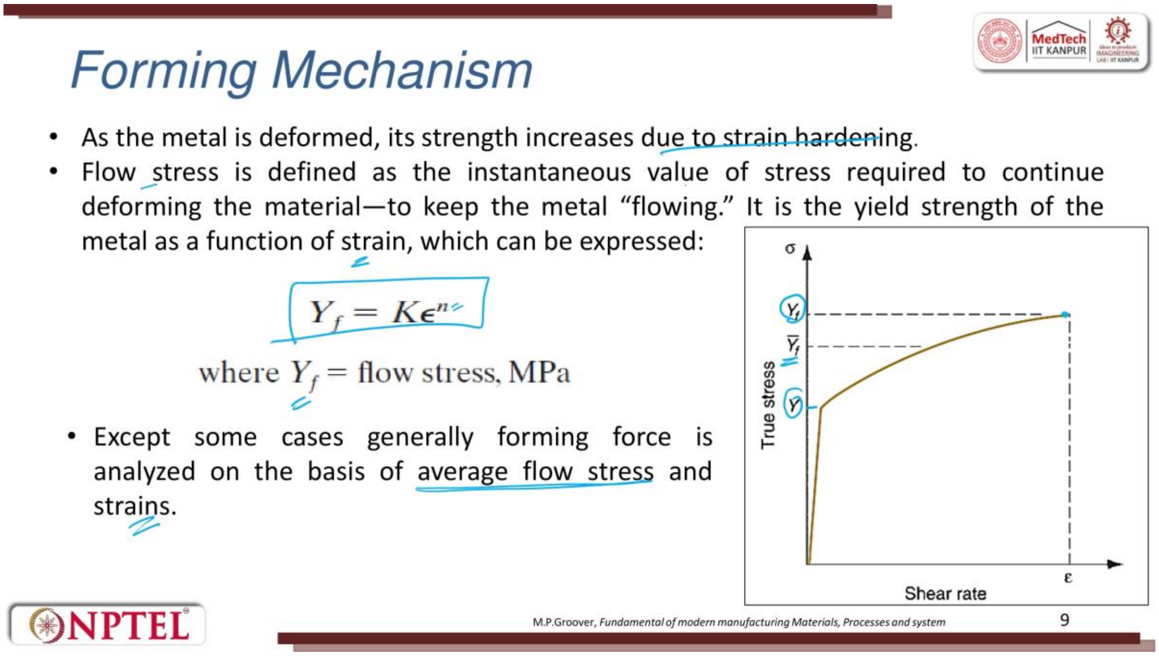
Now, let us get into a little bit of the mechanism of forming. In metal forming, the plastic region—the stress-strain—is of primary interest because the material is plastically deformed. This is what I said: plastically deformed. And it can go to any extent, right.

So, this is a fracture. We do not want to get into the fracture zone. We will always try to get from here to here. We will try to stop right in the plastic region. So, it is permanently deformed in these processes. So, in the plastic region, the material behavior is expressed by a flow curve. This is called the flow curve.

The $\sigma = K\epsilon^n$. The constant, when we remove the proportionality, there is a constant. So, that is called the strength coefficient of a given metal, where n is exponential hardness.

This depends on the material property. n is a material property. K is also a strength coefficient. The stress and strain in a flow curve are true stress and true strain. The flow curve defines the metal's plastic behavior in cold working only.

When the temperature increases, they undergo a change in it. So, this is already dealt with, so I do not have to go in depth.



As the metal is deformed, its strength increases due to strain hardening. That is why you see here, there is a phenomenon from here to here. There is strain hardening.

There are two phenomena of hardening. One, as and when you do a tensile test, when you keep on expanding. So you see the material also slowly gets necked. It gets slowly necked, and then you get something like this, right? So, there is a reduction in the area of the material plus an increase in load.

So, both these things contribute to the strain hardening behavior. So, the flow stress is defined as the instantaneous value of stress required to continue deforming the material. To keep the metal flowing is called flow stress. It is the yield strength of the metal as a function of strain, which is expressed.

$$Y_f = K\epsilon^n$$

Which is the exponential hardness coefficient, except in some cases. Generally, forming force is analyzed on the basis of average flow stress and strain. So, what is average flow stress? Plastic limit maximum, ultimate strength—we always try to take the mean. So, that is what we call average flow stress.

Forming Mechanism

Average flow stress (or mean flow stress)

- It is the average value of stress over the stress–strain curve from the beginning of strain to the final (maximum) value that occurs during deformation

$$\bar{Y}_f = \frac{K\epsilon^n}{1+n}$$

where $\bar{Y}_f$ = average flow stress, MPa (lb/in^2); and ϵ = maximum strain value during the deformation process.

So, the average flow stress or the mean flow stress is expressed in this way. So, it is the average value of the stress over the strain. Stress-strain curve from the beginning of strain to the final value that occurs during deformation. So, the mean can be expressed in this way.

So, $\bar{Y}_f$ is called the average flow stress, and maximum strain values are strain during the deformation process. Where n is the exponential strain hardening, n is the strain hardening exponent.

Role of Temperature

- In metal forming high temperature reduces strain hardening and strength both also it increases ductility which in turn reduces friction and power requirements.
- Effects of temperature in forming process are distinguished by following three types of working or forming-

Cold working	$\leq 0.3T_m$
Warm working	$0.3T_m$–$0.5T_m$
Hot working	$0.5T_m$–$0.75T_m$

Energy ↑ Force ↓

Where Tm is melting point of metal

Recrystallization of the metal in hot working involves atomic diffusion, which is a time-dependent process.

- The recrystallization temperature for a given metal is about one-half of its melting point on the absolute scale.

So, the role of temperature. If I have a machine where there is a restriction, I cannot apply a heavy load. So, the next thing we do is we try to heat the sheet so that we soften it. So, sheet metal operations can happen at room temperature.

It can happen slightly above room temperature and at hot temperatures, working on the higher side. So, it can be less than 30 percent of the melting point. It is called cold working between 30 to 50 percent of the melting point. If you heat it and work it, it is called warm working. If it is hot, within 50 to 75 percent of the melting point, you heat the material and then deform it; this is called hot working.

So, here, what happens is the more you try to go down, the energy you apply to the process increases, okay? So, the role of temperature energy increases, and the force you apply on deformation decreases. So, the role of temperature is very, very important. In metal forming, high temperature reduces strain hardening and strength both. Also, it increases ductility, which in turn reduces friction and power consumption.

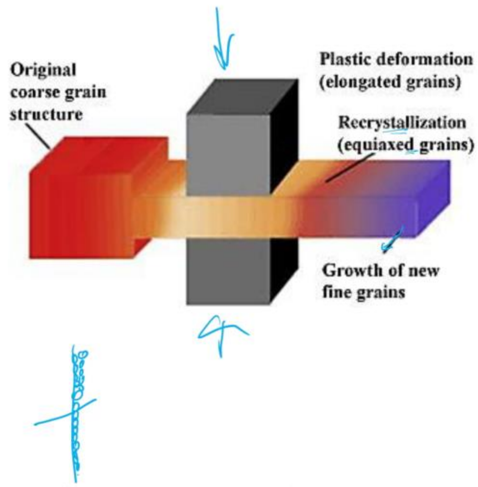
So, this point is very important. It does so many things. It reduces strain hardening and strength; it increases ductility, reduces friction, and lowers power requirements. Friction is reduced, and power requirement is reduced. How is friction reduced?

The metal locking, whatever is there, will not be so strong when we try to increase it because the material is soft. It will just drag and keep moving. The effect of temperature in the forming process is distinguished by following the three types of working or forming. Friends, this is a thumb rule. There can be up and down variations.

From book to book, variations can be there. But this, we will try to assume that there are three, and these are the ranges with which it is working. So, what happens is there is a phenomenon called recrystallization that happens when you are doing hot working. Recrystallization of metal in hot working involves atomic diffusion, which is a time-dependent process. The recrystallization temperature for a given metal is about one-half of its melting point on the absolute scale. So, we try to play around with the recrystallization temperature.

Isothermal Forming

- It refers to forming operations that are carried out in such a way as to eliminate surface cooling and the resulting thermal gradients in the work part.
- It is accomplished by preheating the tools that come in contact with the part to the same temperature as the work metal.
- Metals and alloys, having good hot hardness, property are formed by this method.



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Isothermal forming. So, thermal means you are using temperature; iso means uniform. It refers to forming operations that are carried out in such a way as to eliminate surface cooling and the resulting thermal gradient in the workpiece. So, you can see here the original coarse grain structure will be here.

Now you are making an impact. So now you can see the plastic deformation here. There is an elongation of grains. So recrystallized equiaxial grains are forming. There is grain-on-grain growth of new grains as you move in this direction.

So by temperature and force, you are trying to alter the grain. So if you go back to the The casting, you will see equiaxial grains formed close to the mold-metal interface. You can see that, right? Why are these grains?

Because there is a gradient. That is a similar thing happening here. So, plastic deformation and elongated grains are present. Then you have equiaxed grains on top because a thermal gradient is present. Then, because of it, when you try to push it further, there is growth.

So it refers to forming operations that are carried out in such a way. As to eliminate surface cooling and the resulting temperature gradient in the workpiece. It is accomplished by preheating the tools that come in contact with the part to the same temperature as the work metal. Okay. Preheating the tool or the workpiece. Metals and alloys having good hot hardness properties are formed by this method.

So, what is hot hardness? At high temperature, the hardness is still maintained. So, there we use this isothermal forming, iso uniform temperature thermal.

Cold Working Process

Cold Working (or cold forming) is metal forming performed at room temperature or slightly above.

Advantages

- Greater accuracy, results in closer tolerances.
- Better surface finish.
- Higher strength and hardness of the part due to strain hardening
- Better directional properties can be obtained in the resulting product due to better grain flow during deformation.
- No heating of the work is required it results in easy product handling.
- Low costs and higher production rates.

Disadvantages

- Higher forces and power are required to perform the operation.
- Surfaces of the starting workpiece must be free of scale and dirt.
- Ductility and strain hardening of the work metal limit the amount of forming that can be done to the part.
- In some cases, annealing of a surface is required before forming.

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Cold working process. Cold working process is a metal forming performed at room temperature or slightly higher than room temperature.

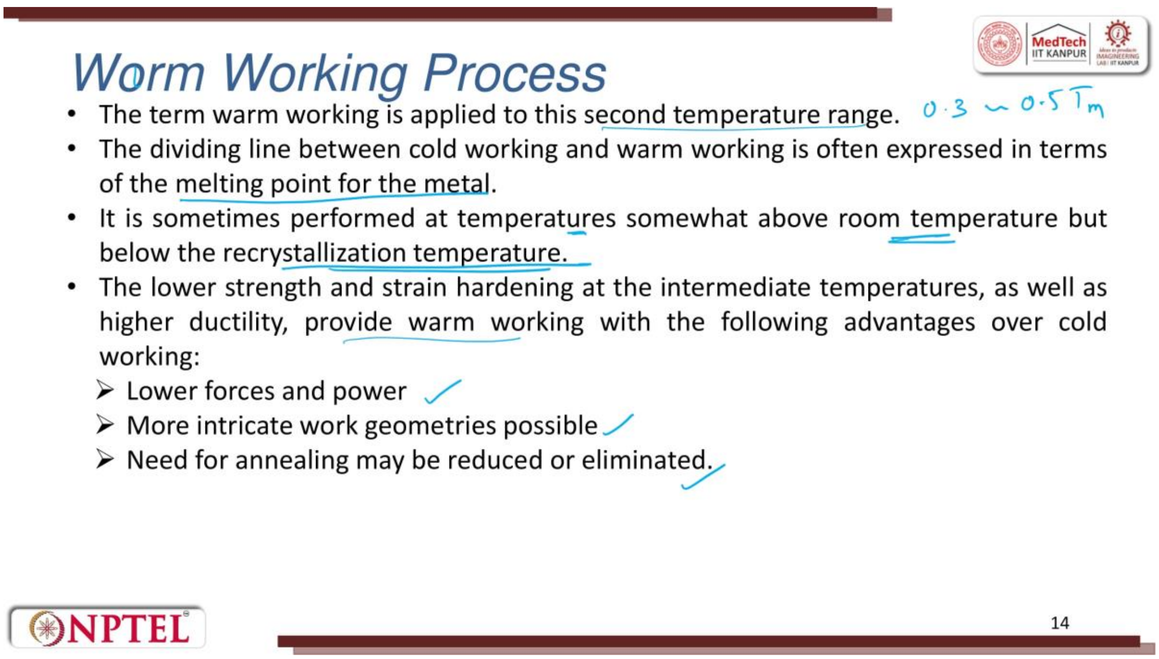
It gives you accurate results and close tolerance. It has a very good surface finish, high strength, and hardness of the part due to the strain hardening behavior. This is very good, right. In fact, heavy deformation occurs. If you have a machine, for example, rail wheels are made by forging.

So, high strength and hardness of the part due to strain hardening is achieved in cold working process. The directional property can be obtained in resulting product due to better grain growth during deformation. Low heating of the workpiece is required resulting in easy product handling. It is low cost and the production rate is also higher. So, what are the disadvantages?

The force and power required are very high. The surface sometimes might start to have scales. Scales are oxidation layers on that surface. You might have to do some removing operation. The surfaces of the starting workpiece must be free from scales.

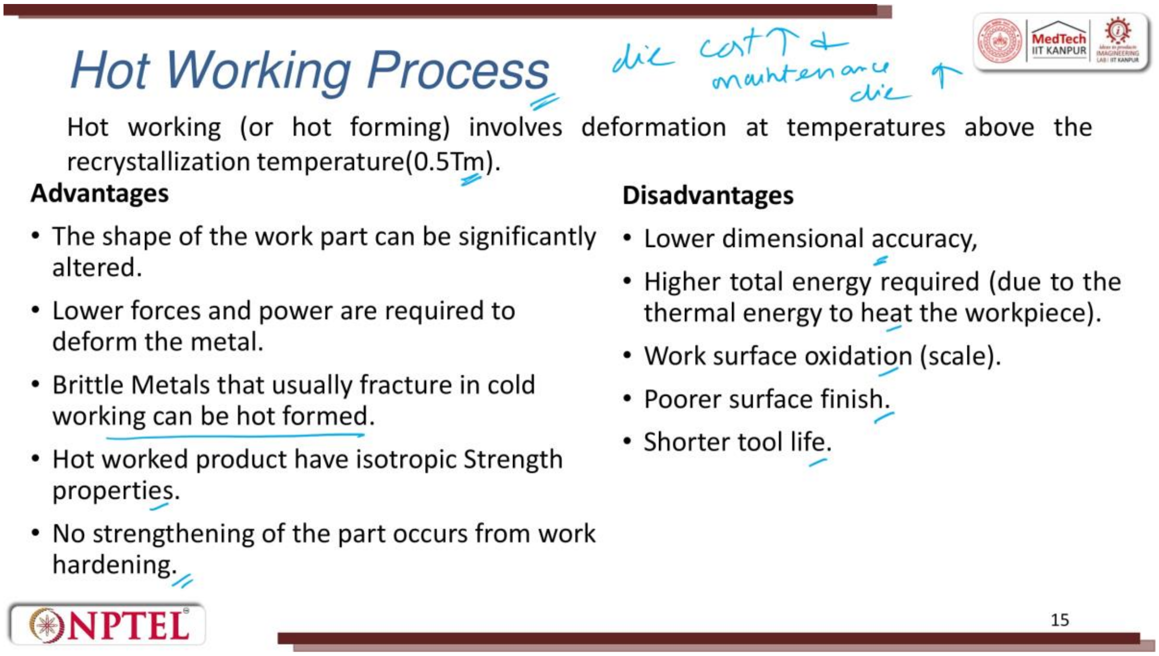
Otherwise what is happening, the oxide whatever is there. When it is trying to mix, the oxides try to dig into the workpiece and you have some undulation on the surface. Ductility and strain hardening of the work metal limit. Then the amount of forming can be done for a part. A annealing of the surface are required before forming.

So, you do that and then you get it done. So, now this talks about the advantages and disadvantages of the cold working process.



When we talk about the warm working process, the term warm working is applied to its second temperature range of 0.3. The dividing line between cold working and warm working is often expressed in terms of the melting point of the metal. It is sometimes performed at temperatures somewhat above room temperature but below the recrystallization temperature.

The low strength and strain hardening at the intermediate temperature as well as higher. Warm working provides the following advantages: lower force, lower power, and more intricate workpiece geometries can be achieved. The need for annealing may be reduced or eliminated, which is a prominent phenomenon for room temperature working processes.



Hot working occurs where the temperature goes above 0.5 pm, so it is the annealing temperature. The shape of the work part can be significantly altered by using hot working.

If you are trying to deform a large volume in a short time, you heat it. Low force and power are required. Brittle metals that usually fracture during cold working can be processed in hot working. For example, cast iron is a brittle material. If you want to deform it, try taking it to a higher temperature and then attempt to deform it.

Generally, cast iron is not done by the hot working process, right? You have to think of some other material. Hot-worked products have isotropic strength properties. Low strengthening of the part occurs from work hardening. So, low dimensional accuracy because you do it in cold or hot.

So, dimensional accuracies will be low. The energy applied is high. When you are heating, the oxidation phenomenon happens so fast. Once oxidation happens, there is a poor finish, and the tool life is shorter because here you heat and cool. So, it undergoes a thermal cycle, and because of the thermal cycle, there is a lot of wear, and it has to be replaced. So, in the hot working process, the die cost is high, and the maintenance of the die is also expensive.

Factor Affecting Forming

Friction

- In metal forming, It arises because of the close contact between the tool and work surfaces and the high pressures that drive the surfaces together in these operations.
- In most metal-forming processes, friction is undesirable for the following reasons:
  - Metal flow in the work is retarded, causing residual stresses and sometimes defects in the product.
  - Forces and power to operate are increased.
  - Tool wear can lead to loss of dimensional accuracy, resulting in defective parts and requiring replacement of the tooling.
- If the coefficient of friction becomes large enough, a condition known as sticking occurs.
- Sticking in metalworking (also called sticking friction) is the tendency for the two surfaces in relative motion to adhere to each other rather than slide. It means
- Sticking occurs in metal forming operations and is a prominent problem in rolling;

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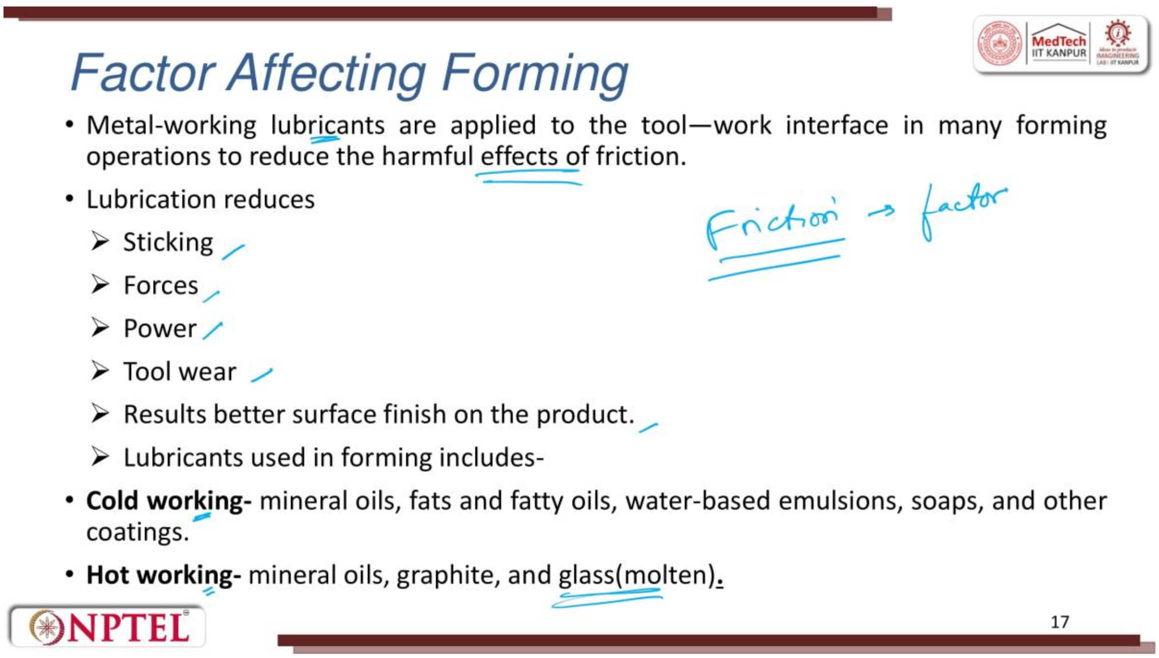
So, what are the factors which affect the forming process? In metal forming, friction arises because of the close contact between the tool and the workpiece surface. And the high pressures that drive the surface together in these operations. So, metal-to-metal contact with pressure leads to friction.

In most metal forming processes, friction is undesirable for the following reasons. Metal flow in the workpiece is restricted. Causing residual stresses and sometimes defects in the part. When there is friction there, what happens? Naturally, the flow of metal will not occur.

If the flow of metal does not occur, there will always be cracks in the workpiece. You will have cracks because there is improper flow. Metal flow in the workpiece is retarded, causing residual stresses and sometimes defects in the product. The forces and power required to operate are increased. Tool wear can lead to loss of dimensional accuracy, resulting in defective parts and requiring replacement of the tool.

If the coefficient of friction becomes large enough, A condition known as sticking occurs. So, like you have rubber band sticking, chewing gum sticking, then you have eraser sticking, right? Like that, you can also have a phenomenon called the sticking phenomenon between metal and metal. This is quite common when you try to do cold working processes.

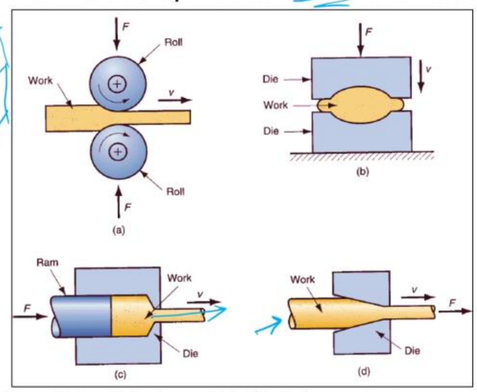
It is called a stick-slip phenomenon or sticking phenomenon. Sticking in metal forming is also called sticking friction. It is the tendency for two surfaces in relative motion to adhere to each other rather than slide. This means sticking occurs in metal forming operations and is a prominent problem in rolling. So, friction is one factor that affects the forming process.



So, we always try to use lubricants between the tool and the workpiece to reduce the harmful effects of friction. Lubrication reduces sticking phenomena, force, power, tool wear, and improves surface finish. Lubricants can include cold working and hot working. In cold working, we use mineral oil, fats, fatty oil, water-based emulsions, soaps, and other coatings. In hot working, we use mineral oil with a higher boiling point, and we also use graphite. Graphite is nothing but a form of charcoal, and we also use molten glass as a hot lubricant while deforming. So, friction is one of the major factors that affects the metal forming process.

Bulk Forming

- This process are generally characterized by significant deformations and massive shape changes, and the surface area–to–volume of the work is relatively small.
- Starting work shapes for these processes include cylindrical billets and rectangular bars.
- The bulk forming process are:
  - Rolling Process
  - Forging Process
  - Extrusion Process
  - Wire Drawing
  - Bar Drawing



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Now, let us get into the bulk forming process. These processes are generally characterized by significant deformation and massive shape changes. And the surface area-to-volume ratio of the workpiece is relatively small. Surface-to-volume.

The surface is smaller in size. So, the surface area will be less than the volume. You have to see the ratio. People also try to call it volume-to-surface area. So, you see and understand what it is.

The starting workpiece for these processes includes cylindrical billets and rectangular bars. Cylindrical billets are used because when you try to cast and pour, you form billets. Billets are cuboidal and go for long, heavy objects. From here, we try to apply force and reform to get the required output. So, billets and rectangular bars are the starting materials.

So, the bulk forming process is rolling. So, I can put it between the rolls and then try to deform it to get a flat plate. I can forge it to get a discrete part. I can use it for extrusion, as I said. We apply force from the back.

It is a die, and then the workpiece flows out. So, it has a uniform cross-section extrusion process. Wire drawing is also drawn. So, the difference between the extrusion process and the wire drawing processes is that here the input is continuously coming. Here we have a billet; we push the billet, and then again you have to load another billet to do the deformation.

Wire drawing, and when the diameter is large, we call it bar drawing. Thank you so much.