Plastic Working of Metallic Materials
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Lecture 18
Rolling of Metals

Today we will be discussing about the rolling of metals. This is theory Module six, Lecture number one.

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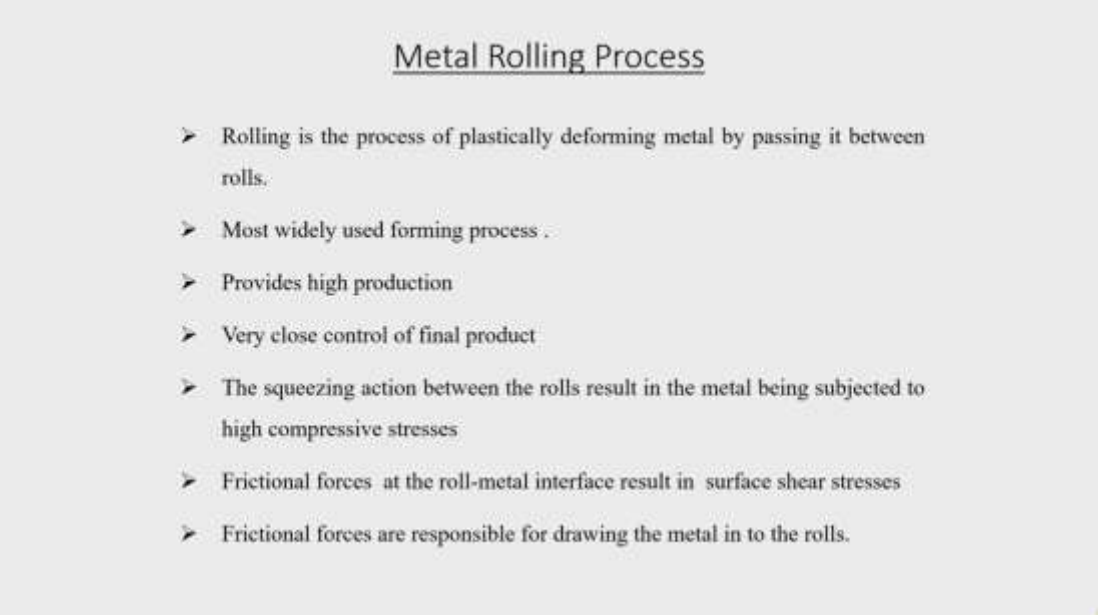

And when you come to this rolling, metal rolling is rolling is a very extensively and widely used metal forming process especially in metal industries and this is a process of plastically deforming metal by passing it between two rolls. Okay. So, if you look at any industry where the manufacture this strips or sheets or ah plates or even foils, these are most of them are manufactured by rolling process in a continuous way or sometimes in a batch wise also it is manufactured.

So, almost all types of sections are made by rolling. So, you talk about the square section, cylindrical section, the channel section, the I section, the X section and even say non-ferrous metal the door frames the door frames know they have a very complicated sections also. So, that also to some extent can be, not all, to some extent can be made. But in general for structural application where you want certain sections, standard sections then rolling is the solution for that.

So, that is why you will find the rolling as a very big industry in metal industries. So, this rolling has the advantages of advantages of other metal deformation processing, like say it has very high production rate on a continuous basis continuous rolling mills, continuously it will give if you

want a very thin sheet from a from a billet or a bloom, then you continuously get, it is coiled into in say in a coiler and then get it in a roll form.

If you want to say a certain specific length also of different sections that also you can have it. So, it provides very high production rate and it also gives very close control of the final product. So, dimensional tolerances are very good, the mechanical properties are being enhanced because of the rolling depending upon safe it is cold rolling. The mechanical properties get increased, due to work hardening behavior during the deformation.

So, and you get more or less uniform thickness for each section. So, that is the biggest advantage in metal rolling and on a continuous basis on a continuous way you are going to get it in a continuous process. So, when this metal the initial material is introduced into the metal into this the gap between the two rolls. The metal is being squeezed bit by the roll or by the rolls by the two rolls a pair of rolls. These are counter rotating rolls I think.

And when it is squeezed, it results in compressive stresses at the inside the material. So, the chance of having metal defect is very less, because under compression it is very difficult to have defect forms like a holes and other things form, but in under tensile stresses definitely the holes can form. But under compression in, we can say that the general theory, belief is that you cannot fail any material under compression.

But it is not hundred percentage isostatic compression is not there, but still the compressive stresses are developed and then when the metal passes between the rolls there are because there is a relative motion between the work piece and the rolls. So, you will find that at the interface the roll and the work piece interface, there are frictional forces are being developed and this and frictional forces are developed, this results in surface sheer stresses. Okay.

So, the frictional forces are responsible for drawing the metal into the rolls, if there is no friction, it is very difficult to mm do the rolling operation. Because, otherwise you may have to give external force. So, that the billet is just forced into that in between the rolls. So, but if there are friction then automatically it can be rolled above the friction, the friction friction here more than certain limiting value, then the roll itself will draw the metal inside into the roll gap itself. So, those are the main advantages of metal rolling process.

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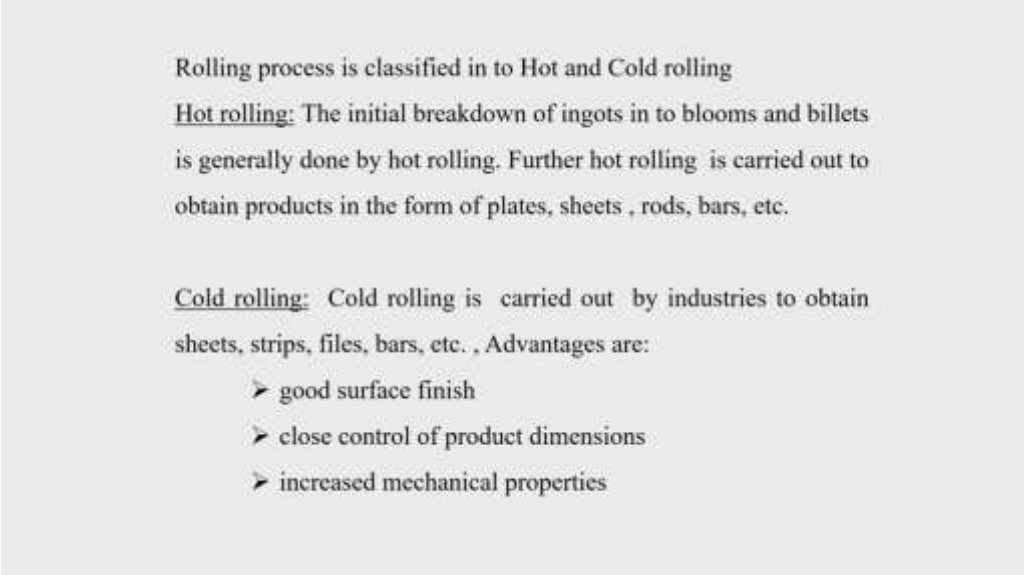

We can classify this rolling process into say hot rolling and cold rolling. The hot rolling is the basically referred to as the initial breakdown of ingots in to blooms and billets and is generally done by the hot rolling process. Because we look at specially steel industries non-ferrous may not be that much but steel industries if you look at it, you get the metal in the cast form, ingot form you get it and these diameters are very less. It maybe some around even 1 meter also or even more and with a height of almost L by D ratio is more than 1.5 also.

So, you may get that cast very big billets sorry ingots are obtained and these because size is so large, it will contains all sorts of microstructure, maybe at the surface, you may find an oxidise mm a very thin layer of oxdise structure on the surface you will find because of the rapid cooling, when the molten metal comes into contact with the metallic die in when you are making a big ingots. Then you will find there are columnar grains are there.

And after some time towards the center when you move the columnar grains may enter into the columnar generic structure and finally generic structure you will find at the center depending upon the alloy, you may also find the aqueous generoidic structure also, all these sorts of. So, from the surface to the center, you will find the micro structure. So is changing this the micro structure of the material is changing at the level of an optical microscope if you look at it not.

I am not talking about the under transmission electron microscope. And at the same time, because of these conditions of cooling and depending upon the thermo physical properties of the metal, you may find large amount of segregation and cooling also. So, the micro structure from the center from the surface of the ingot to the center of the structure, if you look ingot, if you look at it, it is a very complicated structure, it is not a homogeneous structure. So, this has to be broken down.

So the for that purpose with a very higher diameter and other things if you wanted to do cold rolling you may need, the power requirement will be very high because of the work hardening. So, what you do is that you go for hot rolling, so that the initial breakdown of the ingot into blooms and billets, this is run by the hot rolling operation, even hot rolling operation the subsequent operation also will be done by hot rolling, but it is not necessary.

So, further hot rolling also is carried out to obtain products in the form of plates, sheets, rods, bars and other thing, that also is done. The advantage is that when you are going for a hot rolling operation, your power requirement will be very less that is the biggest advantage because the rolling mill itself consume large amount of electricity. So, when you are doing the hot rolling operation, the power requirement for the rolls that is can be reduced considerably.

So, generally people prefer the hot rolling to obtain say even plates or sheets or rods and bars, but maybe the final structure before use, people that may go for cold rolling. So cold rolling the advantage is that this difference is the temperature. The temperature hot rolling is that process which is carried about above the recrystallization temperature of the rolling. And if that is done below the recrystallization temperature then you referred to as cold rolling and it is carried out by industries to obtain thin sheets, strips, foils, this is foils, not files and bars etc.

The advantages are they have good, very good surface finish when you are doing in the cold condition good surface finish is obtained. Whereas when you are doing the hot rolling the metal many times the surface may get oxidized at higher temperature and this is too much with the non-ferrous materials, steel also gets oxidized. So, oxide layer comes into picture. Sometimes if you do not remove it, then okay, built up scales will form into that and then thin defects, but whereas these problems are eliminated in cold rolling.

Because, at room temperature the extent of getting oxidized is very less. So, you and then you have a better dimensional control. So, you get a very good surface finish, the cross control of pro the dimension. So, the product can be obtained the because of this because other operations can be eliminated to because you are getting the very good surface finish, with a very precise dimension also you are getting. Whereas in hot rolling, the temperature may vary when the temperature varies, your dimensions also may vary.

So, because that is of practical difficulties are there. And in cold rolling, because the metal is being drastically deformed in the cold condition the metal is not softened. Okay. So the temperature dependent mm phenomena metallurgical phenomena are eliminated, such like dynamic recrystallization, dynamic recovery these things are eliminated under the metal gets work hardened. So, there is an increase in the mechanical properties like strength and the hardness.

But at the same time there will be a decrease in the ductility, when the strength is increased by plastic deformation or hardness is increased by plastic deformation, then the toughness of the material gets decreased, the ductility of the material gets decreased, the malleability of the material which decrease, the brittleness increase all these things that happens. But to some extent, as per the requirement of the use you can have the material with a specified mechanical properties like strength and hardness and ductility, which is acceptable by the industries.

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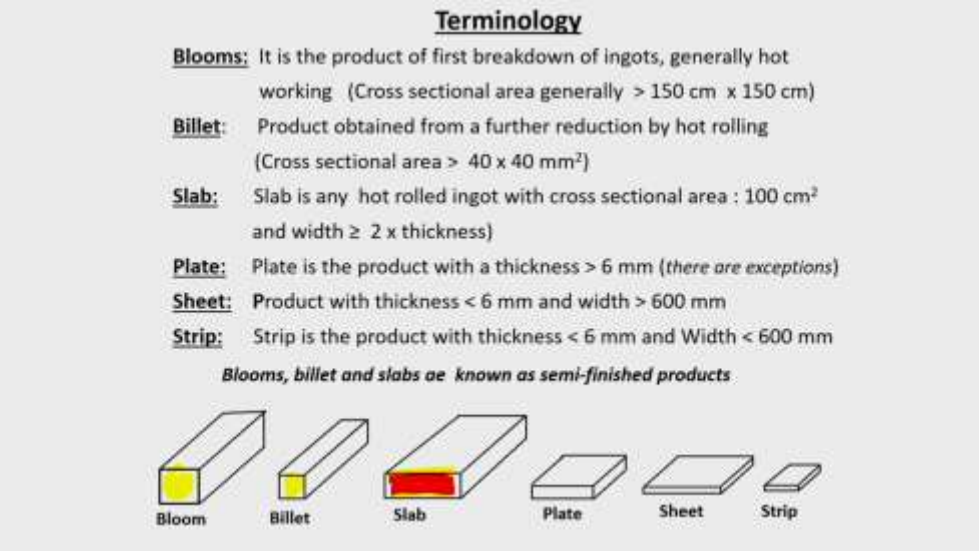

Before we go further, I was talking about this billets, blooms, slabs and other things. So, one should know what are the or what are these terminologies. Okay, what it refers to. So, for example, when you talk about blooms, bloom is the product of the first breakdown of the ingot. Okay. And generally it is done by, not generally almost it is done by a hot working. All of them are very hot working.

So, in this blooms has a speciality the cross sectional area is very large you anywhere between say one fifty centimetre by one fifty centimetre per square section is there. So, you will have a cross sectional area of one fifty by one fifty cross sectionally, your length will increase. So, these are referred to as blooms and these are obtained by the by the hot deformation hot working process and the initial. It can be by forging, it can be by rolling, but normally people may go for forging also and get the blooms and other things. Okay.

Because for our rolling mill this the size will be, the weight will be very large. So, but generally people, if there is a facility for forging then you get it by blooms. The next term is the billet. The billet is the product obtained from further reduction of the blooms, Okay. So, there by subsequent reduction by maybe by a cross sectional area gets reduced from one fifty centimeter one fifty centimeter by one fifty centimeter, you end up with the forty by forty millimeter square area when you are getting it then, that is called as the billet.

So, cross sectional area is again the square cross sectional area. Now, slab is any hot rolled ingot with the cross sectional area almost hundred millimeter square and with the width greater than twice the thickness. So, that is called a slab, you will find that the width is higher than the thickness. Okay. So, this is a width which you will find it is higher than the thickness. And then you have the plate right is the product with the thickness generally referred to a thickness which is greater than 6 mm.

Although there are certain cases the exceptions are there, but depending upon the thickness and the width, but normally it is referred to the products which having a thickness greater than six mm. And next the sheet where the thickness is less than six mm is called a sheet and width will be normally greater than six hundred, sometimes it may be eight hundred, sometimes it may be

six hundred depending upon the rod length. Okay. So, this so, that is referred to by this.
Sheets are generally sheets and plates are made by rolling, not by not by any other methods. Okay. So, here the as long as the thickness is less than six mm you call it as either sheet or strip. Okay. So, if the width only difference is in the width. The width is greater than six hundred mm then you call it a sheet with a strip is the width is less than six hundred mm it is called as the strip that is the difference between this. And if you look at this blooms, billets and slabs, they are known as semi-finished product.
Because these blooms, billets and slabs may be further subjected to plastic deformation to get some specific shape and not only shape, size as well as specific properties. Okay. Mechanical properties, but whereas sheet and other things like before the final operation like oven, operation is done by rolling then it is not given any semi-finished product only final, if it is sheet metal working, only those type things are there, but the thickness is going to remain constant.
So, further subsequent ah processing to reduce the size or dimensions will not be there. So, that is already. So, this blooms, billets and slabs maybe further reduced in cross section or reduction may be given to obtain plates, sheets, strips and various sections.
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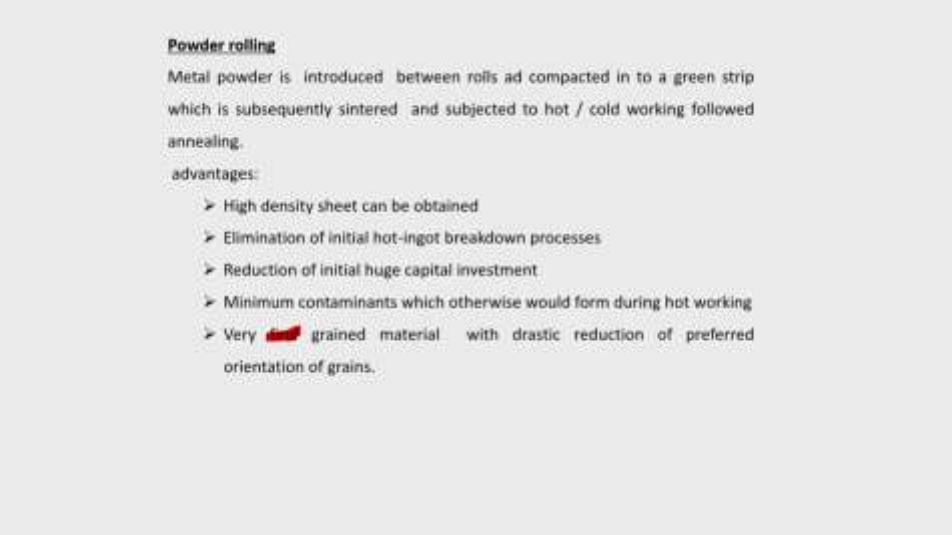

There is another when you called about rolling, there is also something called as powder rolling. In this the metal powder maybe metal means even it can be pure metal or it can be alloy powder. They are introduced between the roll and then, okay, it is compact and when it passes through between the roll and gets compressed. So, here it gets compacted into strips you will get green compact or green strips.
Green means it has just not very high strength is there are, just able to hold it by metal mechanical interlocking between this individual powder particles by cold welding they are just getting in this. But it is having some strength it is not there and then once it comes out, you will find it is having a very good strength. So that but not for structural application to obtain the structural application these are subjected to sintering, means heating it at a higher temperature.
Normally if it is on a continuous process from the rolling mill it will pass through a continuous

heater. Okay. And after a certain distance you know it gets sintered, whereby the chemical bonding between the individual grains are obtained, by which is assisted by diffusion of elements from one grain to the other and then you get a very strong material and then it is again subjected to either cold or hot working.

Once because, once you will get sufficient strength by sintering process it may be subjected to a hot or cold working for further reduction. And during this reduction process you will find that, okay, lot of residual stresses and other things have developed. So, to remove that the final ah the product will be finally given an annealing heat treatment. Okay. So, that is one. So directly from the from the metal powder you are getting it.

Thus the advantages of this powder rolling are, you can have a very high density sheet. Because there will not be any porosity ingot whereas in ingot, there may be a shrinkage porosity there may be gas porosity like blow holes or pinholes and other things all those things may be there. There may be metallic in portions, which is formed during the casting process. So, these things are there is always a possibility of these types of defects in cast ingot.

Whereas in powder metallic powder the chance is very less. You have very fine sized powder metal powders with a homogeneous chemical composition or chemical homogeneity it will be there. Because of the powder size is very small at the level of around maybe twenty, thirty micrometre or even five to fifty micrometre not beyond that. So, and these are the powders which are being compacted by powder rolling.

So, you get a very high density of the sheet, elimination of initial hot ingot breakdown process, elimination of defects which has been formed during the initial hot ingot breakdown process. So, in the ingot as I said the segregation in the dendrite segregation, scoring all these things and then dendrite structure, columnar structure everything has to be broken down to obtain aqueous more or less aqueous structure.

But here that type of breakdown of the structure is not required because you are almost having a very good fine structure with homogeneous composition chemical homogeneity is also there. And then for a rolling mill as I mentioned at every stage, it is not in one stage process, it is different stages are there, there are different strands are there, we will come to that soon. And for each case, the initial capital investment is very huge, because when you are having several stages of rolling process initial capital investment will be very high.

That is 1 part, the power requirements will be very high for it because you may have different stages all those things are there. So, minimum contaminants are there in the powder rolling because your powder you are getting a homogeneous composition for the powder, metal powder. So, there is no chance of getting any other contaminants of course, it depends upon certain material also if you are having something like magnesium and titanium, you have to take an extra precaution so that it is does not get oxidized.

These type things are there, but in general when you say that contamination is very less. So, otherwise when during hot working know and there is every chance at the higher temperature normal metals also will get oxidized and the like in steel what happens is that the oxide layer which is called a scale, that also will come, it may just get embedded inside the material during

the rolling process, so that you end up with the defect.

So, these type things are eliminated or are not there during the powder rolling. And then very fine very fine grains the material with the drastic reduction of preferred orientation, because in metallic material continuously you do rolling operation along certain particular direction. At the end you may find there is a preferred orientation, that mean grains the specific to crystallographic, crystal planes and will get aligned along some particular direction, that is called the preferred orientation.

That will result in directional properties for the metal but whereas in this case that they extend of forming the preferred orientation is very less. Okay. So, that these are the advantages of powder rolling, anyway we are not going for this powder rolling but I was just discussing about the advantages.

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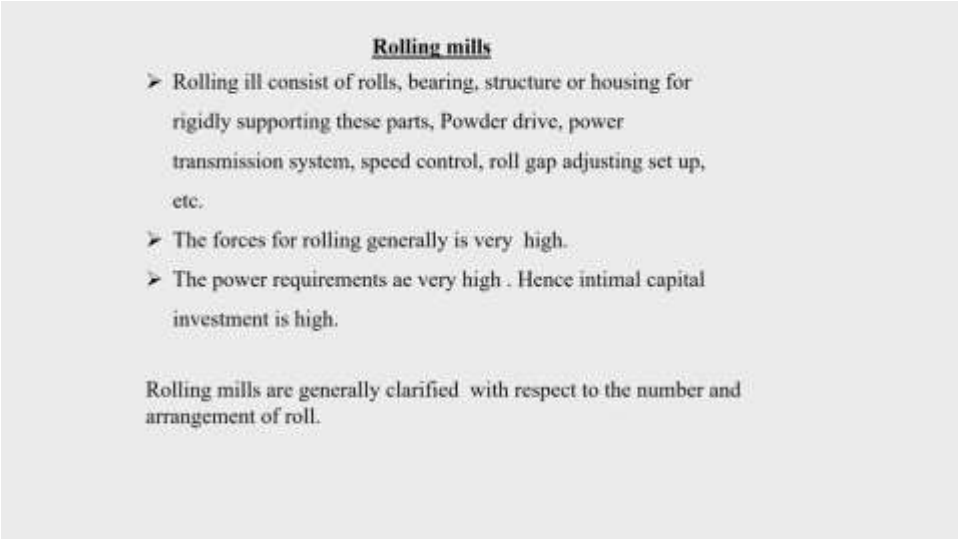

Now, the rolling process is generally done in rolling mills. So, the rolling mill consist of minimum 1 pair of rolls or more it can be more, but minimum two rolls should be there, which are counter-rotating. There should be bearings very good quality bearings, so, that the rolls can be fixed inside the bearings with the help of the bearings with the, with the less dimensional variation. Okay.

And there should be a structure or a housing for supporting these parts in a very rigid way. So, because the amount of forces and the torque which are required for the rolling process is very, very high. So, the structure should be able to hold it rigidly. So, you should have a very rigid structure or housing for supporting all these parts. Then there should be power power drive in the electricity. So, you need that power source is there high amount of power is required.

And there will be your power drive like in the mainly the high capacity motor, high powered motors are required no very very very high power motors are required. Then from the motor to the rolls there should be a proper power transmission system. So, this should be there. There should be speed control, so, that depending upon the material you should be able to adjust the speed of the rolls not late depending upon the material also depending upon the reduction which

is required also you should be able to adjust the speed of the rolls.

And in addition to this, you should have the facility for wrong gap adjustment, very often you may have to keep on changing and for roll gap adjustment setup also is required. So, rolling mill consist of all these things. So, it is not a very simple case as you feel. The forces for require for the rolling are very very high, the power requirement is also very high. So, initial capital investment is high. So, generally the rolling mills are classified with respect to a number of the rolls and the arrangement of the rolls.

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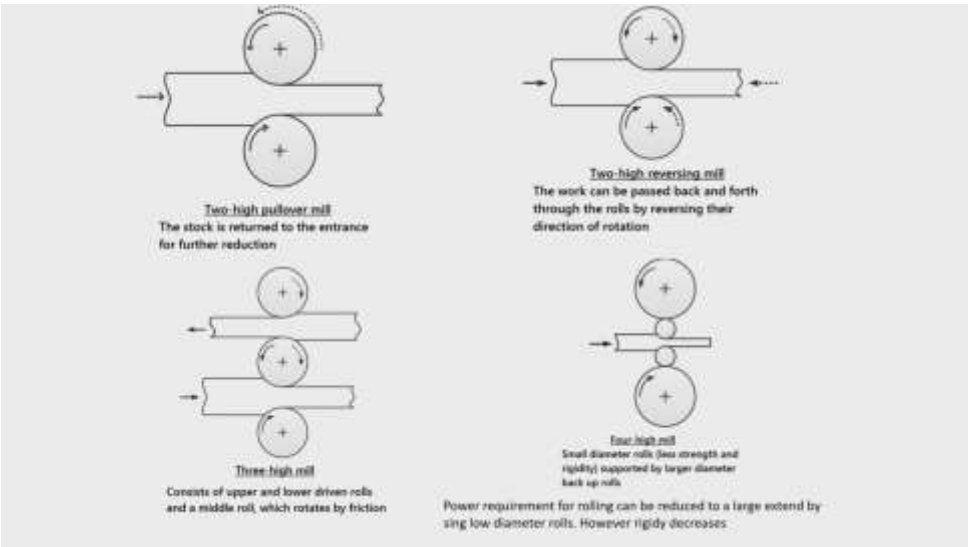

So, let us come to the type of rolling mills, when you say the most simplest material is the two-high pullover mill, rolling mill, two-high pullover mill is what you are getting here. Okay. So, in this two counter rotating rolls are there with a proper roll gap between them. Okay, and then what happened to them the strip enters from one end and then, Okay, you will find that with the initial thickness the initial thickness is here the final thickness is something something around here.

So, as it enters the metal is compressed and that the same time because of the frictional interface surface, the shear forces are developed, the metal gets elongated its grain says gets increased all those things happens. But finally, when it exits the roll gap that the part which is there in contact with the roll is called roll gap, when it accept the roll gap you will have a reduced thickness.

So, the stock once you roll it if a mill is there with the two-high pullover mill what happened you first to do rolling operation and then once it comes out, it is again taken back and then again adjust the roll gap and again so maybe reduce roll gap and again just a pass through that. So, this is generally a type of manual type of done at small level industries they go for this high pull-over mills.

The next is that because this is very difficult because one operator has to stand at one end and another operator at the other end and sometimes not depending upon the weight of this you may need to have more than one operator at each end and then somebody has to bring it back also. Okay. Some device for material handling should be there. So, if it is done in the hot condition it

will get cold all those difficulties are there. So, to overcome that, the three high mill is being there. So, in this three high mill you have only three rolls.

So, if you look at this part, which is here, these are counter-rotating and if you look at this two, this is also counter-rotating but in opposite direction. So, here the initial stage is you allow the metal to pass through this here in the one stage and an operator is here, once it goes into the through the conveyor, when it comes it just picks it up and put it into here. So, the material goes like this, okay. So, that is the advantage of this pullover. So, you need only one operator here, one operator here, once it moves into this area that edge, the final edges just made and put it into here.

So, as per the requirement, the roll gaps are always adjusted and fixed. So, you have a particular reduction in this process which is possible. So, and these rotates well. So, these are all rotating at the same speed, but depending upon the roll gap your reduction will vary. So, simultaneously you can do this also, that that is another advantage. So it may need not be sheet it can be even rolls also you can reduce by this. So that is the biggest advantage with this.

Next is the two-high reversing mill. Okay. So, in this the work piece can be passed back and forth through the rolls by reversing the direction of rotation. So, at one instance these two rolls will be rotating in one direction maybe, let it say for this particular configuration, which is shown, it will be moving velocity will be in this direction. And once the metal passes through the other end, then your roll gap adjustment is done and then maybe the roll gap is reduced.

And then from that end here the rotation of the rolls are reversed in this case. Second step and then it can come into the it can move into this direction. So, this is the two high reversing mill which is here. Now another case in the four high mill, in the four high mill you will find that later when you come to the analysis of this rolling mill rolling operation or mechanics of this rolling, you will find that the power requirement for rolling operation can be reduced considerably if you are using a lower diameter roll.

So that advantage but when you are using a lower diameter roll, because they are all length is very large, there is every chance that roll deflection may take place. Okay. So, for that purpose, what we will do is that this is your actual working rolls and then this is supported in the backside back by backing roll. So, this will be the backing rolls, these two are the backing rolls. So, you have this working roll and backing roll.

So, the backing roll will give sufficient rigidity because the working roll diameter is very less, but by that you can reduce the power requirement. But as I said the roll deflection will take place and the diameter is very less, especially the tenderness ratios of the roll is very high. So, you may find the uniformity in the thickness across the width may not be there. So, to avoid that only you are going to give the backing rolls, for larger diameter backing rolls are there as a support roll.

So, in that case, your power consumption is reduced considerably and the roll it will give more or less uniform dimensional dimensions and with the ends third with a very fine dimension of with a smaller diameter roll your surface finish can be very good. So, in this case for cold rolling this is generally preferred. Because cold ordering is done towards the final stages and and then you have you can get a good surface finish as well as at the same time you have reductions are

possible to thin sections and other things.

And for this power requirement will be very low. So that that is why this four high mills are there, you can have very higher cluster mills are also there.

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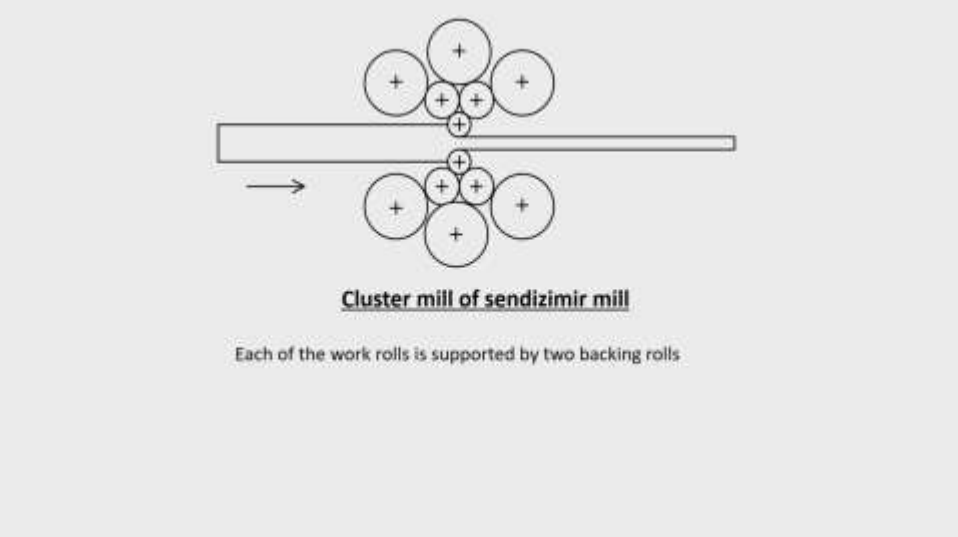

So, in that case, so you have a large number of rolls. So, each roll is supported by two back end rolls. So, when you look at this working roll is supported by two back end roll here, whose diameter is larger. Because if it is, in the previous case know, only one support roll is there. So it may shift this side, the other way. So whereas in this particular case between these two backing rolls you know, that gap is there.

So, that is held here but when here diameter is very less when you wanted two rolls in you you cannot have a very large the two rolls and then this small one that is not possible because it may touch the biller. so that you do not want So, for that purpose the first backing rolls is having aa a diameter, which is higher than the working roll and then you have a very large backing roll of them say one two three backing rolls you can support this two backing rolls the intermediate backing rolls can be supported by this very large backing rolls.

So, here rigidity will be well maintained and for that parcel and then this is generally done for very high speed rolling process when it is high speed rolling process the rigidity should be very high, your surface finish should be very high more or less these are the towards the end of the rolling up up process. Now, you have one stage, second stage, third stage, 4 stage and when it comes to the final stage, the speed ah or the billet or the work piece, which comes out of the roll be very very high. Okay.

So, for that purpose this is done. So, you get a good surface finish and normally at the towards the end the final finishing operation the deformation the reduction will be very less.

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Sendzimir mill

This is one case of cluster rolls called as sendzimir mill which is taken this photo is taken from the internet only. So, you can see that these are the two working rolls each other this is supported by two backing rolls, these two backing rolls are supported by three backing rolls with the slightly bigger diameter and finally, you have a larger the diameter backing roll. So, this is the case this rack and pinion arrangement is a case for roll gap adjustment when it rotates the whole thing the whole system will move upward here also you can adjust it.

So, your roll gap can be reduced by this um by this this adjustment. So, you have all those things and here you will see that before each or all know there are bearings and what you are see is bearings Okay, not the roaring. So, no, because this is a side view which is founded. So, it is a very complicated thing set up. So, in the rolling mill, all these things will be there at one strand itself.

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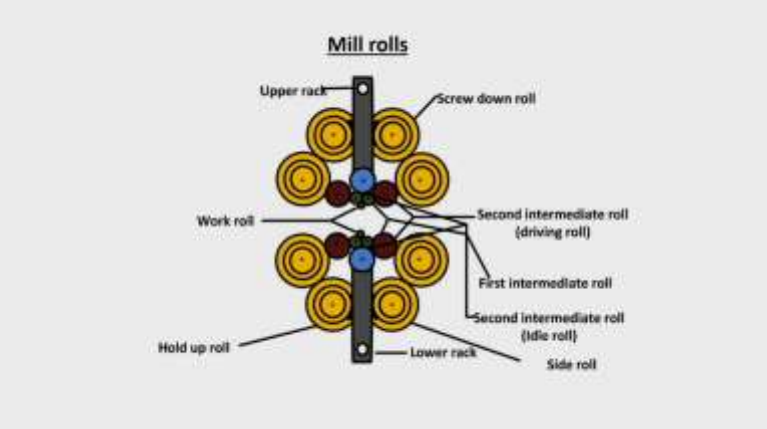

So, this is another larger number of mills are there. So, here now the lower rack, upper rack you can adjust to these two into that this can be brought down this can be brought up so that your roll gap can be adjusted in this case okay. So, you will see that secondary intermediate rolls are their first intermediate rolls are the secondary or idle rolls are the driving rolls of the screw down roll or so, all those from a very simple rolling mill setup a very complicated rolling mill setup is there.

But for large scale production, this cluster mills are generally used. Now, if you look at the

typical arrangement of rolling in a rolling mill rolling mill if you look at in certain cases when you wanted to have ten sheets, suppose you take the case for sheet metal industry where you wanted the thickness of the two mm three mm or one mm like that sheets if you wanted or even foils if you wanted then you will find that the number of stations are very less.

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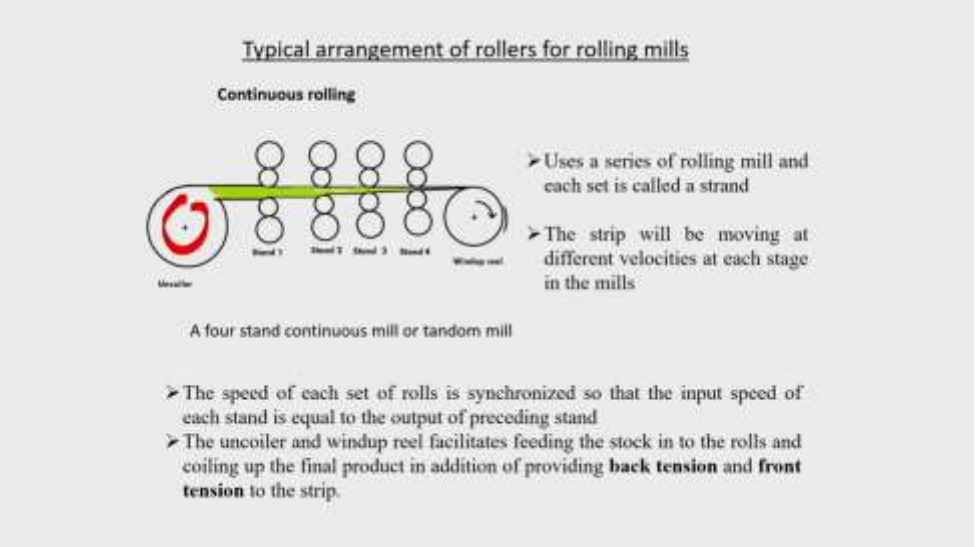

So, here the initial material may be there from un coiler region you are having and then from there it is just put it in to what do you call it as the first strand the or the first stage of rolling So, when it enters into that, you will find that the velocity of the material which comes out will be higher than what was the initial before it enter. Because there is a reduction. So, when you are when the height is getting reduced the corresponding is the length get increase for maintaining the constant volume of the material.

And then it will come to the it will be the exit of the first station will be the inlet to the second strand strand. Okay. And there is a spelling mistake instead of stand it will be strand. ard for restraint and under And the exit of the second strand should be the inlet the third strand and so on it was there may be a large number of rolling stations and strand will be there. In this case and finally, you get the very thin maybe foil or very thin sheet and other things and if it is a continuous process.

It will be just a winding upon a reel and then finally well get this. This sheet metal which is wound around a reel we can very often see when you strand on the outside itself and trucks now carrying thing like a big bobbin only one will be there in a truck because the quantity is very large. So, you can see that is obtained by this wind up reel and other things and you are getting it wind up because it is in it a continuous form.

So, the whole process sometimes there may be more than ten, twelve rolling stations will be there. So, in that case what happened after each stage the total rolling mill if you look at length may come to something around might be five hundred meter or more. Five hundred meter is around half a kilometer or even more also it will come because not only the rolling to adjust the velocity between the exit of one strand and inlet of the other strand,

Sometimes you may have to have pits so that otherwise know the velocity if there is a small variation in that when you will have problem okay, at one strand maybe back stresses maybe low or high and all those things can happen. So, for that purpose the total rolling mill the total line length will be very loud. So, one thing is how to reduce this is one thing which people look at it what are the technology which can be developed to reduce the total length of rolling mill.

So, there are now various methods which comes. So, the it uses the continuous rolling uses a series of rolling mill and each set is called as a strand. Here as I said there is a small spelling mistake in that here it should be a strand the strip will be moving at different velocities at each stage in the mill. So, what is the velocity here is different than the velocity or was this part it will be higher and here it will be still higher here it will be still higher and it will be still higher.

This is ah the velocity will change like that in this case. The speed of each set of rolls is synchronized. So that is what but that very accurately it may be difficult that is why I said sometimes there may be pits maybe there that will go into depth and then okay come into it. So, but in normal case, it is synchronized. So that the input speed of each strand is equal to the output of the preceding strand.

Uncoiler and windup reel facilitates feeding the stock in to the rolls and coiling up the final product in addition to providing back tension and front tension of the strip. So, if you pull it from here you call it as a front tension, if here it is less than the velocity of the speed then you call it as back tension is given. So front in one station itself, if you look there may be back there may be front and depending upon that you can move ah you can reduce or increase your power requirement.

But when you are adjusting for power requirement some other drawbacks also come so, it has to be finally optimized. Another case, because to reduce these total length of the rolling mill is just using a planetary mill that is also has come in to the force. So, in this it consists of a pair of heavy backend roll also there is a backend roll here there is a backend roll here and this in contact with your live rolls a large number of planetary rolls are there. These are the small.

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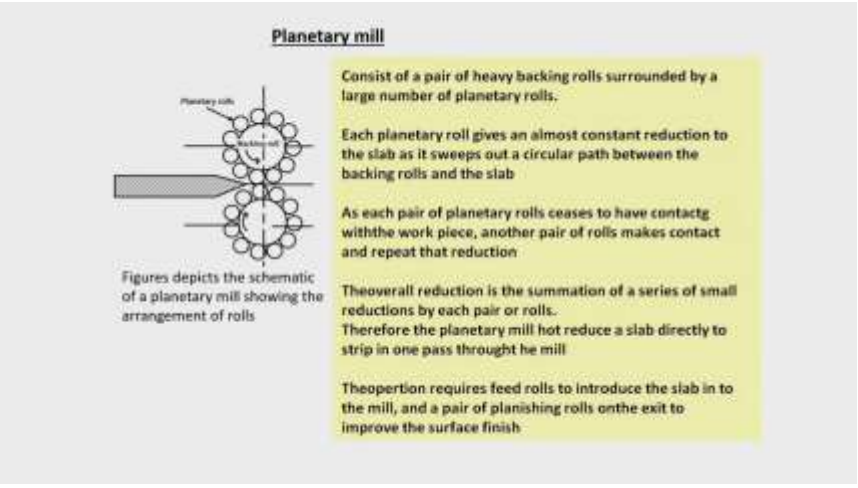

So, the billet entering into this region and then what happens is that each planetary roll gives an

almost constant reduction to the slab as it as it sweeps out a circular path you will find that is it just sweeping out a circular path. So, here when it enters you know, it gives a constant reduction for between each rolls, but when it comes through here it is very less. So, it is not in line also. So, that way you can find that there is the raw gap continuously keeps on adjusting.

So, this entire thing will be rotating like this. And if you really visualize you will find that okay, this this minimum distance is not along the central line. So, that is also there. So, it can be adjusted to whatever way you want. So, as each pair of planetary roll ceases to have contact with the work piece another pair of rolls contact and repeat the production. So, when it is coming out from here, you will find the next set of things will be coming in contact.

And as it is moving, the height keeps on continuously decreasing that is the biggest advantage for this when this is this is moving downwards the overall reduction is the summation of a series of small reductions by each pair of rolls. Therefore, the planetary mill hot mill reduces slab directly to a strip in one pass through the mill. So, you this way you can save large number of rolling strands. This is one advantage but it cannot be used for very large reduction that is another case.

So with an intermediate or smaller reduction, this is a very useful method, but there is a problem because you may find that the surface which comes out the surface of the material which comes out there may not be it may not be smooth, okay. Because there may be roll marking and defects okay for that you may have a use of panishing rolls, it once it comes out of that you it will be passed to through a panishing roll where it is made of planes throughout simple final finishing, rolling mill have to be perfect.

But large number of rolling strands can be eliminated and at one station. So, you can save a lot of space in this. So, that will improve that panishing rolls. No, but it will improve the surface finish of the rolls.

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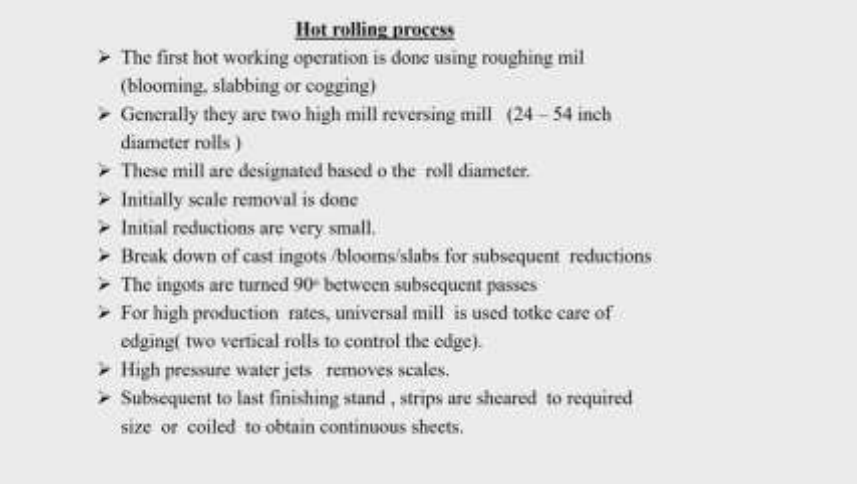

Now, as I mentioned, let us look at what are the advantages with the hot rolling process compared to the cold rolling process. The first hot working operation is done using a roughing mill the in the hot rolling process from you call it as blooming or slabbing or cogging so where

as the size of the billet or the ingot is very large and then you are just first breakdown passing through the roll.

So that either you called us bloom when you are getting a bloom you get blowing if you are get into a slab called it slabbing or otherwise know with the whether the size is very large you are called it cogging so that is called as by that is done by a roughing tool surface, surface roughness will be very high okay not very smooth surface roughness will be very high. So, that extensive deformation can be taken place.

Generally these are the first row hardworking operation they are done by to high reversing mill or even symbol pullover also they will be doing it depending upon the size of that and in this case the the mill diameter of the roll is very important normally now, you will find that the diameter of the rolls are between say twenty four to fifty four inch diameter rolls and the this this 2 reversing will know they will be characterized by the diameter of that okay.

So, that is what these meals are designated based on the roll diameter. But before that see you are keeping this bill at or ingot in a furnace and digging for hot working operation you have to keep it in a furnace and then you have to take it out. So, when you are keeping it in a furnace, you had to soak it there for sufficient time. So that homogeneity in the temperature across the section is obtained. So for larger size you have to keep it for a large number of larger time. okay.

As a thumb rule is called as the time required half an hour plus half an hour per inch thickness. So, the thickness is very large then you have to keep it for extremely large stream because heat has to be conduct and that the center and the surface that temperature should be more or less same. So, for that temperature homogeneity or thermal homogeneity obtain you may have to keep it for for longer time at that height temperature in the furnace of. So, when you are keeping it the high temperature in the furnace.

What happens is that most of the metallic materials will start getting oxidized at the surface. So, there will be an oxide layer if it is steel this steel there will scale formation it gets oxidized and it will get separated. So, there will be scale formation will be there. Whereas, if it is aluminous scale formation may not be there aluminum will get oxidized very thin layer only. It will not increase further. If it is magnesium the PV ratio is very high.

So, it will become porous and then okay this will just diffuse inside and inside and finally, you will lose the material. Titanium also the oxygen will penetrate through the grain boundary regions. So, depending upon the material if it is steel there will be oxide scales. So, you have to remove the scales. So, for that you give a very small amount of deformation very small more initial cases very small. So that during that process, the scales are get removed.

You call it as de scaling. Okay and after that rolling for this only small reduction is done once the scales are removed then it is passed to the next stage where the large amount of deformation takes place okay. And so, the breakdown of the cast ingots or blooms or slabs for subsequent reductions is done subsequently. But after each one, as I said, it may be somewhere around one fifty ah more than one fifty mm diameter and in the next stage, but it may be fifty or something when it comes like that know.

You will find the most of the case it is done as a square itself cross sectional area. So, once one

default ah reduction is given the width the thickness is lower compared to the strength. So, what we will do the next step this will be rotated by ninety degree and then passed it. So, you will have on the width reduction first is the thickness reduces but the width remains the same the next step, because it is rotated ninety degree the height gets reduced and then finally you get the same size.

So a square section you can get it. So, um the ingots are turned ninety degree between subsequent passes to get the a square cross section, but for high production range, generally universal mil will be used to take care of this, because when you are reducing the height, there may be a break for especially at what working condition side where it is not in contact, then there the deformation may be lower.

So to avoid that, ah so that this rotation by ninety degree can be avoid to taking care of the edges for that what they are doing is that the universal mill after it passes through that you will find it passes through another set of rolls which are vertically placed. So that uniform width is obtained okay, and now with the subsequent rolling see if the material is still hot, and that hot temperatures are just coming in contact directly in contact with the atmospheric air which contains the large amount of oxygen so again, there is a tendency to get to oxidise and form the scale.

So, with the after one or two operation you have to remove it otherwise that scales will get tempered. So, for that that is removed by high pressure water jets. So, after some one or two stages of rolling you pass this high pressure water jets then this um scales will be removed. Okay. Then, so, that way at different stages, the rolling operation takes place and the last finishing strand, once it passes the last of the finishing rolling operation were minimum reduction will be given.

But that time the concentration will be to get a very high surface finish and the dimension um minimum dimension tolerance. So, that is what they will be looking at it. So, at that time, once it comes out of that there might be either so you just sheared to some specific length, so you will have the facility for that or if it is very thin you will it will be passed into the coiler where it will get coiled under. So, these are the cases with obtained in a continuous sheet by rolling number.

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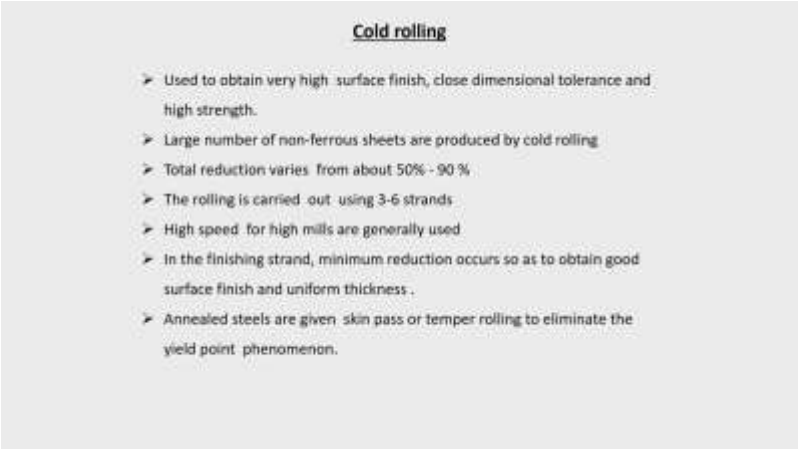

But though you are getting you are breaking down the micro structure and other things and getting homogeneity it in composition, the mechanical properties and the surface finish of the hot rolled material will not be that good because operation is done at high temperature. So any type of hard work hardening is taking place because of the higher temperature target soft and also so many structural materials which we wanted to use that is done by cold rolling maybe after us certain stage the final stages know it will be by cold rolling.

So for this is mainly to obtain very good surface finish cross dimensional tolerance and high strength. High strength, by means of work hardening because it is done at the room temperature. So work hardening takes place and you will find that the strength increases. So a large number of non-ferrous sheets are produced by the cold rolling process. Most of the case non-ferrous sheets are generally in because one thing is that the temperature is very less also unless it is something like nickel base or titanium base other case know.

Most of the non-ferrous material that operation temperature is less and in this cold rolling because I say that the initial things are done in the hot condition, but towards the final you wanted to have a control of their microstructure you have to have a control of your dimension you have to have a control of the mechanical properties. So, considering all these things, the cold rolling generally it may have three or four strands only have three to six strands only not more.

So at the three to six strands only. So, high speed for high mill are generally used for high reductions have generally used the cold rolling is not the high speed normally and then the finishing strand the minimum reduction occurs to obtain good surface finish anyone from thickness annealed steels are given see sometimes when you get annealed material when you are given know.

You will find that okay specially steels having um some amount of industrialised impurities carbon and nitrogen sorry nitrogen and some other elements you will find in steels there is a yield point phenomena with the strictness that means, when you are just doing a tensile test you will find that it reaches a maximum value and then suddenly there is a drop in the stress it remains there constant for some time and further with work hardening takes place. This is called as yield point phenomena.

So, when yield point phenomena is taking place your material may during the deformation may not be good because structure lines and other things comes so that may result in um material which is defective okay, because subsequently some other phenomena will take place. So, you So, in that case to avoid this yield point phenomena annealed steels are given as only at the surface or you call it as temper rolling to eliminate the input from in that case know some amount of information takes place.

And so, once that yield drop has taken place, then it will know go to the upper yield point will remain the lower yield point and then once the yield point elongation is complete, then you will find that the work hardening is taking place. So, that yield point phenomena can be eliminated by giving temper rolling or a skin pass rolling also these are some of the photographs which has been taken from the internet here this is for the sheet metal we can see that the sheet metal is being rolled.

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And then it is passing into that here it will be passing into pit only okay and then this is rolled strip which has been coiled into the coiler form and then okay you are coiling it properly. So, if you look at the roll forming machine now you see what is the length a very huge length is taking very amount of space also.

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This is the whole crowd hot rolling condition, the coiler form this is the temperature is very high that is why the color is there but if you look at the length, this is a person standing here compared to the size you can look at what is the length is coming. So, it is very very very large amount of length is there.

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And you can get a special type of cold rolling in which flat slab progressively bent into complex shapes by passing it through a series of driven rolls are also you can get different shapes also see like this step shapes. Now you will find that the roof tops thin sheets roofs are also there. Corrugated shape these are all obtained by this section rolling strands. So you can get different shapes.

So, here you can see that the angle sections are there general sections are there these wheel sections are there three may be different shapes we can get it. So no appreciable change in the thickness of the metal during this for this for sheet metal are working roll forming you call it as suitable for producing moderate sections such as irregular shaped channels and then finally it will be trimmed off. So those other things okay, thank you