Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology-Part-2

Module-41
Metal forming Processes Edit Lesson

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Hello and welcome to this manufacturing process technology part 2 module 41. And we are beginning a new section today or metal forming and you all know forming is one of the primary manufacturing processes which is able to give the overall shape and size to the material just like casting dance, but here the basic principle is quite different, you basically operate in a range particularly in hot working operations where the temperature, operational temperature is just below the solidus temperature.

And then basically, you know provide we can get energy to the material to take it into its flow stress region, so that it can flow and take various shapes, you know and that is how the overall forming strategy works out to be.

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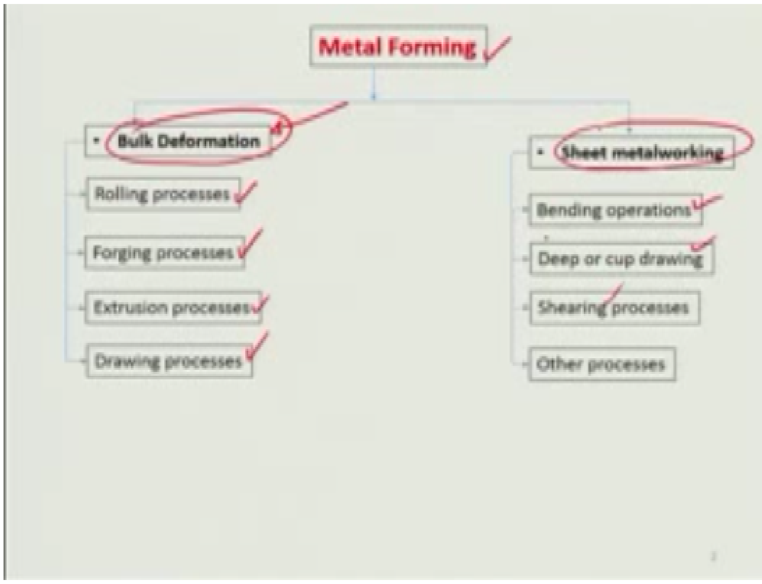

So if you look at the basic categories classifications of the broad term metal forming really can be classified into two different domains, one is all the processes are related to bulk deformation where there is a deformation along the bulk of the material, some processes may represent bulk deformation as a rolling processes, forging processes, extrusion processes, drawing processes so on so forth.

Then there are again, you know different set of or group of processes called sheet metal working processes which again come into metal forming domain for example, bending operations or deep or cup drawing, shearing processes some, you know associated processes like this. So they are classified into the sheet metal working processes. So you have categorized the whole forming domain into either the bulk deformation processes or the sheet metal working kind of processes. If we looked at what are going to be the terminologies associated with metal forming.

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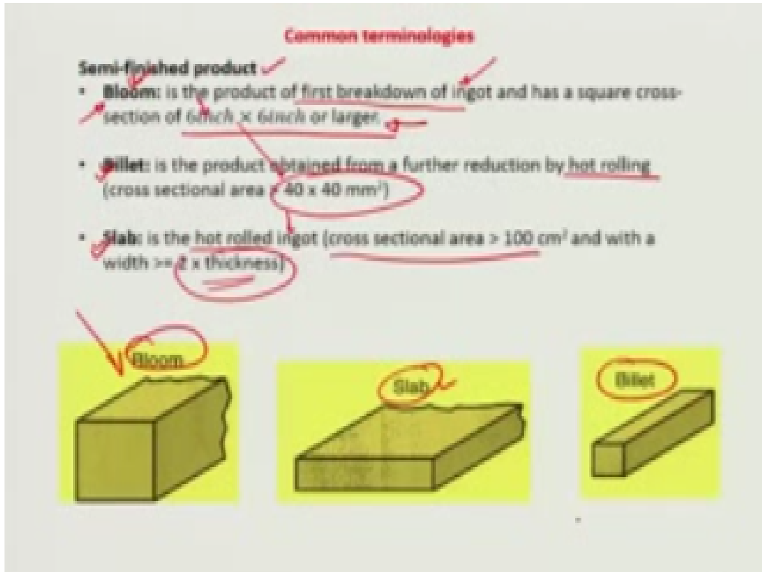

The first thing that comes to our mind is, you know what we know as a bloom in a slab okay. So these are some semi-finished products. In fact from a casting or a steel industry what is produced as an output is either ingot or maybe a first we put down of the ingot which is known as a bloom. Here for example, you know it shows a cross-sectional area of probably 6 inch x 6 inch or larger. So this is really now the raw metal comes out, you know as ingot or a breakdown of an ingot which is a bloom.

Also, you know if I what to further reduce the bloom into a billet through what for hot rolling process, you could typically have the areas of the range of again from 6inches which is about close to 150 mm all the way to one fourth of the value, so 40x40 mm sections. So it is categorized as billets. So these are again another finished product coming out of forming processes okay.

So over and above what the casting does you have to now give material as reluding material to the industry, so that it can be commonly shaped or size or can participate into assembly processes. Then you have another kind of semi-finished product called slab which we generate again by hot rolled, you know hot rolling processes over the input from the casting industry ingot.

In fact the term bloom here is really out of the very commonly used furnace, very primitive commonly used furnace called bloomer. And in fact it shows how the output of, you know such a skilled industry can be, or wherever the resting processing how the output would really shape into which is handle the bale it can be translated into various you know manufacturing process subsequent manufacturing process so also therefore these sections forms very important in terms of the inputs to the other manufacturing process okay so a slate is typically one where the cross section area is greater than 100cm and have width of almost either greater or equal to twice the thickness.

So at least you know that is how at least two thickness is twice the thickness is whatever it should be for material to be for a shape to be called as slap so you can have these various products blame blatant slap out of forming processes as the first shaping you know which happens to the casting in gods.

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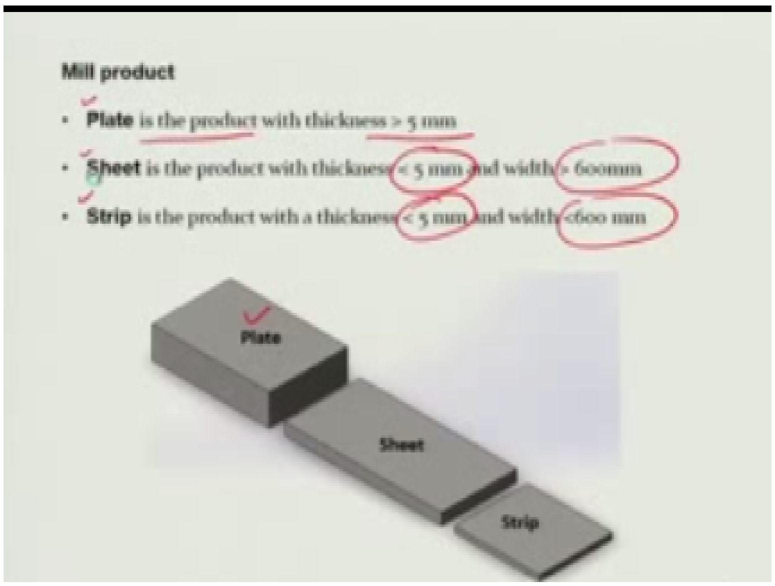

There are some other associated process which are of importance one is a plate so this is a product with thickness of greater than 5 mm of there is a sheet which is again a product classified by a thickness at least less than 5mm but a width of over 600mm and the finally a step which is again a product of metal forming class which can have less than 5 mm thickness and almost less than 5mm 600mm width.

Therefore you can further categories the finished products of million process is plates sheets and steps so you have the first end process hot rolling applied to in got from the casting creating bill it is and blooms and slaps and then you can also further reduce a bound size to plate sheets and steps, so that is how the various steps can be part of this steel industry to produce rough steel.

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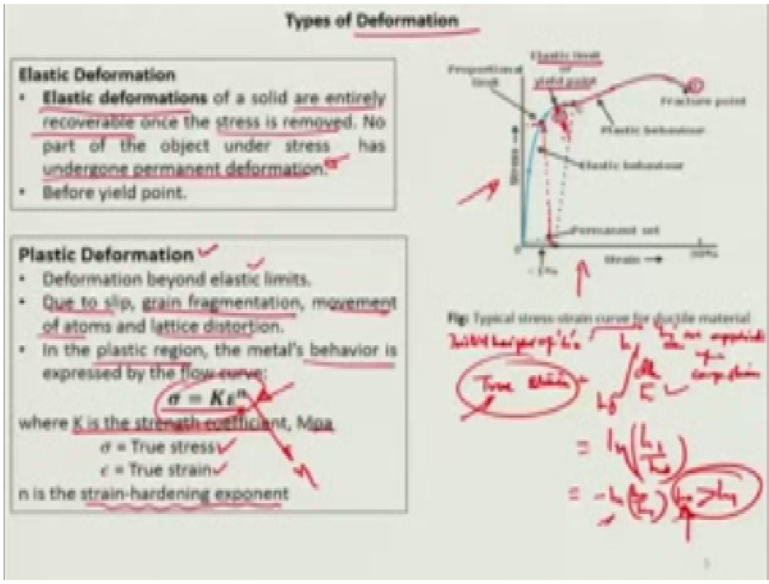

Which can be give for the various later on you know machining or assembly processes now having said that important term which is associated with all this deformation and as we all know you know is a very famous trust in for any duck title material as the printed here it indicates range which is actually where the special strainer proportional to each other also known as the proportional limit if the elastic range beyond which there is a you know some kind of maximum point up to which this sort of elastic behavior can be observed beyond which there is something called a permanent set or a deformation.

So here for example this is the yield point of the elastic limit up to which you can find out the deformation to be primary elastic you know as we all recall from basic solid machines knowledge elastic deformations are entirely recoverable once the acting streets monitors removed on the material is removed and on part of the object under stress may have under go any kind of permanent set permanent deformation beyond this point d there is obviously going to be point where any further increase in the stress level would result in some kind of permanent set okay form dislocations induced within the crystal structure.

So that the overall size and shape changes so this point d then is known as the yield point or the plastic limit and deformation beyond this elastic limit typically the curve from b to b region is also known as the plastic deformation the plastic flow and when essentially the that due to slip to the grain fragmentation or movement of atoms and lattice of phenomena, the metal kind of move the head and does not come back so you cannot recover the stress into the system once we system is in the plastic deformation range of plastic definition is so in a plastic region the metal's behavior would be expressed by the flow curve equation which is basically about the relationship of the two states and two stress in strength.

As we all may be called then the value of the true strain is actually divided by the integral of dH/ h between two different thickness is let so there is a initial block of height h is 0 this is your height of 0 and we are applying a compressive stress so that this goes to h1 flow on a equation of compressive stress so basically the two strain in this case can be recorded as integral is 0+ 1 vdh. H okay so we can actually get this by ln h1 by h0 and basically can also be recorded as – of ln0 / h1 where 0 obviously more than h1.

In this case initial high in this compressive specific heat that you apply initial height is more in comparison to the final height so that is the situation the two strain can be defined by this level of ratio between initial and find out direction the axes of the stress so between such two stress and two strain and it is basically represented as σ = KH power and this I mean basically gain very commonly known as strain I mean exponent, okay and case also known as restrict co efficient typically a specific heat of Pascal's.

Particularly in case of these etc. or other that high materials so we are really interested in looking at this end of the curve we are interested in looking at this from beyond words all the way in order to say the point d fracture point and here is when we have to do down al the forming process and typically we will have to in step by step manner arrive at certain type area and which are useful to estimate the kind of forces which would be aided for the material to flow into a range here it can happen.

Or the ultimately instant can be crossed so that from process start happening on mean starts getting formed so there are certain initially the rules are relationships which are important in context of making forming one of them is, is that.

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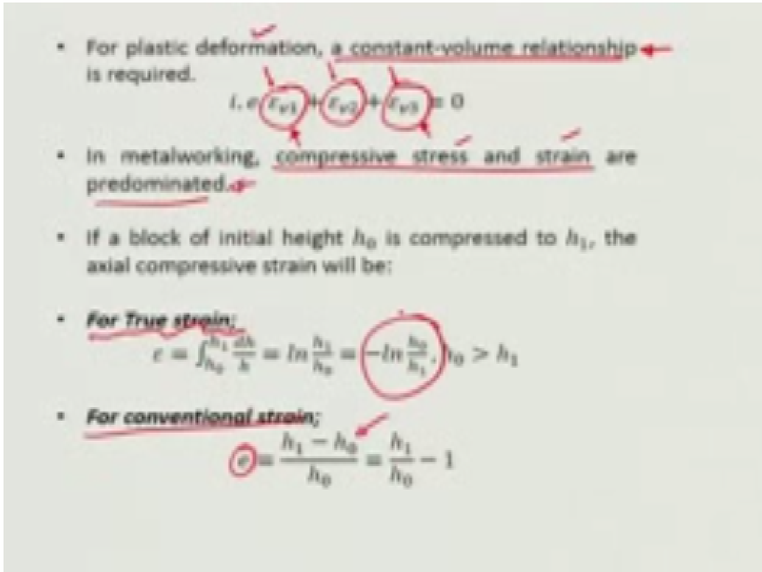

For plastic deformation and there is always a constant volume relationship okay which is needed so if let say strains and axial directions 1 2 and 3 or x y z axis are represented by epsilon v1 epsilon v2 and v3, so the constant volume criteria or constant volume relationship requires that if one of them has positive the other one should be negative so that the overall volume of the bulk of the material or the bulk definition bulk or the material which is being deformed that volume does not change, okay. And so that is how you know the first sort of premise would be when we are talking about plastic deformation.

And the other one is that in metal working processes then only the compressive stress and strain is our predominant so we would be mostly concerned with the compressive stress or strain otherwise so order less we are otherwise time to model the process like wide drawing where there is a combination of both the compressive visualize axial stress intension which are happening come virtually.

So for conventional is the system restrain is generally we call it as the change in length per unit origin length the true strain as a I will be illustrated is call it as –natural log of the initial height by the final height or the initial dimension by the final dimension. So these are some useful tips for studying metal forming processes.

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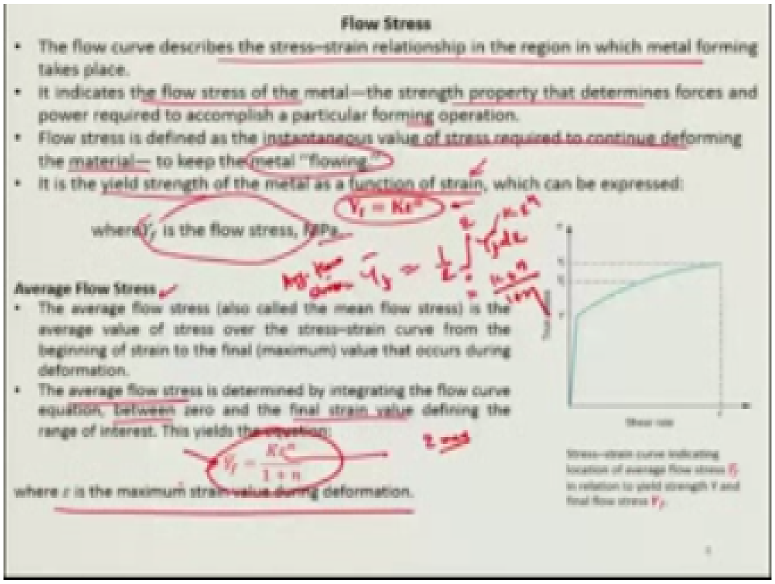

The other issue about really investigating the flow specific region is the flow arc if and as I mentioned earlier the flow curve is macro description for the specifying behavior in the metal forming regain okay, the region where the metal forming really happens so we are all concerned with what is the function relationship between the flow stress along the curve indicated here you know at the elastic limit has been exceeded.

So basically indicates the strength property that determines whether the forces and the power which required to accomplish a particular forming operation whenever you designing a formal process you need to estimate what is going to be the power needed for formulating certain plan shape and size of the metal one to the constant volume deformation criteria so the few stress in this case is defined as the instantaneous value of the stress required to continue the deformation of the material.

And keep the metal flowing okay so that is why we call it flow stress so it goes in 2D flow region and the metal can be flowed into various shapes and sizes okay so which is basic assumption of all the forming processes. So the healed strength of the metal if we really want to look at the healed strength of the function if the strain it can be expressed by this relationship here YF = K ε^m I think we had this detailed this relationship earlier.

Only thing this YF is the flow stress in the flow region particularly NNPA make it a Pascal's and ε is basically the strain so if you where to look at the average flow stress it can also be written down in 1/ε integral of this YF b ε where this ε is actually the maximum stress so you know initially we can assume this to go between 0 strain okay all the way to ε is the maximum strain I am sorry.

You can assume it to go between 0 to the maximum strain and that is how the average flow stress which can be recorded as YF average space represented, so now this can also be then just substituting this value $k\ \varepsilon^{n}$ represented as k εn/ 1+ n okay so this is how the average flow stress is sort of determine by integrating the flow curve equation between 0 and final stream values okay, defining the range of interest. So in this particular equation one has to remember that this ε is actually the maximum strain value that happens during the whole information process, so that is how the average flow stress Y_f' is recorded.

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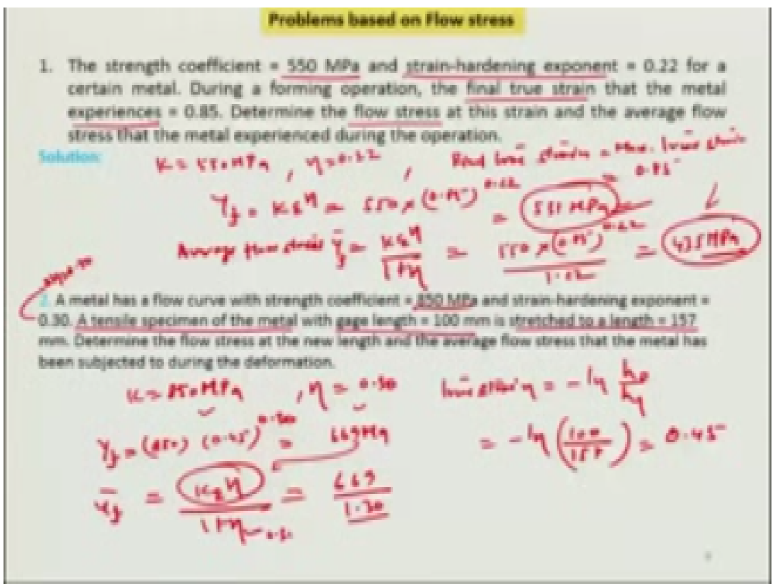

Let us actually look at some numerical example problems for calculating all these average flow stresses etcetera. Let us so the first problem is that the strength coefficient is about 550MPa so that is how the k value is 550MPa and we are looking at a strain handling exponent n value of 0.22 okay, for a certain metal and during forming operation the final true strain that the metal experiences is actually 0.85 so we are talking about the final true strain is also the maximum true strain you can say in a increasing curve as shown before in the flow region, okay.

So this is the maximum true strain and this is shown as 0.85 so obviously the Y_f value the flow stress at this particular strain can be recorded as $k\varepsilon^{n}$ k is 550 $MPa\text{x}0.85^{0.22}$ that comes out to be about 531MPa and if we look at the average flow stress again we use the same formulation that is integrating the in curve equation over the hole strain domain substituting the maximum strain value we get the average flow stress Yf′ is $k\varepsilon^n/1+n$ so in this case we have 550 as kε is 0.85 n is 0.22/1.22.

So this comes out to be equal to about 435MPa so you can see that where as the maximum you know it strain it is just comes out to be about 531MPa because I wanted to average this over the hole force you know over the whole stress strain curve area and divide that by the maximum strain to final true strain this comes out to be only 435MPa, so the average lower in comparison to the flow stress at the maximum strain point so which happens more or less in all the cases.

So let us also look at this another problem example so there is metal which has a flow curve a strength coefficient in this case is given as 850MPa so the k is 850MPa and this case the strain harming coefficient n is recorded as 0.30 we have again a tensile specimen of the metal and this has a gage length of 100mm and this is stretched to a length of 157mm so we actually know the true strain value here, true strain as we may be call is also represented by the relationship $–l_n$ initial gage by the final gage okay, so in this case it is $–l_n$ initial gage by final gage and this true strain and this exponent the strain hard being and the strength coefficient values.

We can determine he flows stress at the new length. So basically at this particular strain value met some stress strain value a flow stress yf could be represented as 850time of this value we have to strain the power of 0.030 so the new value comes out to be so this becomes equal to 0.45 and if you wanted to calculate the two stress value or the in this yield region of the flow region yf so the yf becomes equal to the k value which is 850 mega Pascal's time of this 0.45 the true strain and silent to the power of the strain hardening coefficient which is 0.30 I this case.

N here and you can see c = 0.30 so this becomes equal to 669 mega Pascal's similarly if you wanted to find out the average flow stress is actually represented as k f n / 1 + n we already know what is the kf silent from the last test a n from the last test kf summarize 69 mega Pascal's so which is divide that by 1.30 you remember this n is 0.30, so this happens to be 514 mega Pascal.

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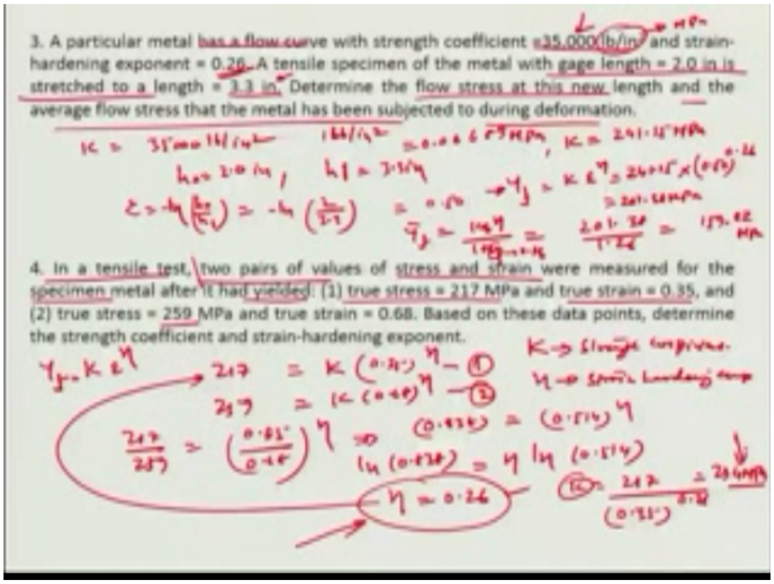

If few question which I would like to do in this particular example the metal has a flow curve with distance coefficient given by 53000 pounds per^2 so we will have to convert this in to mega Pascal's and that the strain hardening exponent in this case is given to be 0.26 you have metal with a initial gates given this about 2.0 inches and this is stretched to a find a length of 3.3 inches of obviously there has to be two strain value is saturate with it.

And we have to determine what is flow stress at this new length and also the average close to us to middle has been subjected to during the deformation so let us first recall all the value the strength coefficient k for this curve happens to be 35000 pounds per square range we already know the conversion one pound per square inch you know I can actually written down as 0.00689 mega Pascal's so having set that the k vale can be recorded as 241.15 mp in this particular case.

We already know that there is a initial gage length x0 2.0 inches which gets in to a final gage length h1 of 3.3 inches so the true strain value in this particular case ε can be recorded as – ln of h0 / h1 as for formulation there I have earlier so –ln 2/3.3 in this particular case it happens to be 0.50 so having set that now the ultimate you know the in strength or let us say the flow stress yf which is needed to be found at this new length can be written down is kf silent to the power of n so 241 .15 times of 0.50 the power of n which is in this case 0.26 it has been given as 0.26.

So this happens to be about close to 201 .38 mp similarly if I want to find out what is the average flow stress is represented by kf silent to power of n / 1 + n. So in this case it happens to be 201.38/1.26 remember and is equal to 0.26 so this comes out to be 159.82 mega Pascal's similarly we have this other question here in which there is a tensile conductor and where there are two pairs of values of stress and strain which are recorded for the specimen metal after it was yielded so now the metal has gone into the flow stress region and it can actually obey the relationship.

You know the flow stress equals to K ε^n so we have a you know clear of too stress and strain values in one place you know 217 ampere the yf you know this is actually represented as K times of 0.35^n suppose that K is strength option to this particular case and let us also suppose that n is be still hardening exponent these two have to determine so the other case or the other value or corresponding to 259 and the true strain is recorded as 0.6^n
So this relationships are obey because both of them are in you know the flow region and this stress to end characteristics follows the focal so we can actually have a ratio between one and two so 217/259 comes out to be 0.35/ 0.68^n if I take a you know so this is becomes 0.838 equals 0.514 to the power n so taking natural log on both sides Ln 0.838equalsn times of Ln 0.514 and in other words L becomes equal to 0.26 okay.

So with this new and values if I wanted to record by substituting that one of these equations what is the K value the K value comes out to be equal to 217/0.3 ^{n} the n value which has been recorded and this comes out to be about 294 mega Pascal so as you can observe here that this strain hardening coefficient happens to be about .26 and these strength coefficient happens to be 294 mega Pascal.

So this how you basically try to calculate the various parameters and the focal flow region and in other very important property if you because you know metal all metal forming typically happen beyond this last equilibrium and whatever we are going to do in the following lectures about forming processes are really going to be concerned with this flow region of the particular lecture.

So I know in the interest of time close this particular module but in the next module we will look at some of the criteria which are used for you know the point where yield starts really so these are known as the yield criteria and you will derive some of them with energy principles and another first principle there are two different criteria which is very commonly used one is called the worm verses criteria and another is cluster criteria.

So we will derived all that from first principles and then start applying to the metal forming processes and we are going to do modeling of one or two processes in the waves like rolling or any be even some grinding causes and the whole goal here is to operate in the flow region and we are able to identify when the flow region starts really so that you could get the exact power or exact flow source which are to applied for the metal to be yield and to able to follow the flow behavior. So with this we will like to close this module thank you very much for being with me thank you.

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