**Design of Machine Elements – I**

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Lecture No - 08

Design for Strength

good day ah today as you have seen that we are going to discuss about the design for strength

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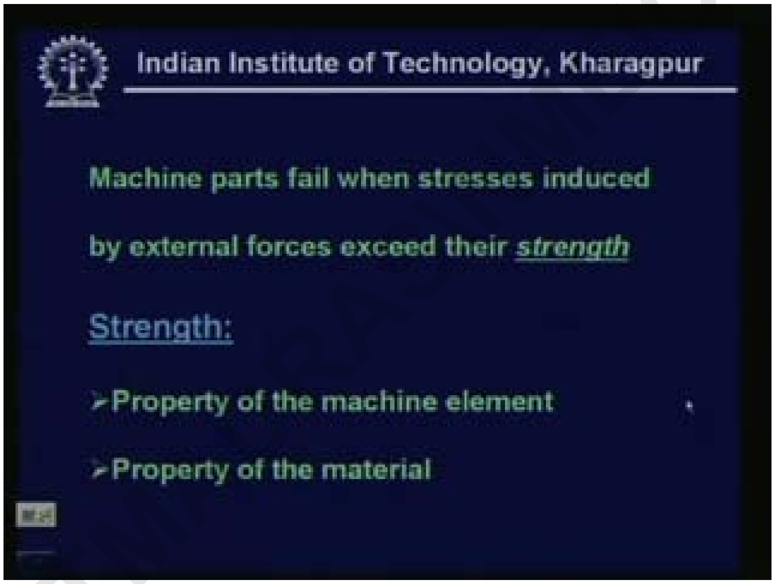


now we understand that when a machine part fails when stresses induced by external forces exceed their strength so this is very quite understandable now the only thing is that that we have to look that the meaning by the word strength

the strength means one we have can notice is that the property of the machine element now what we understand by the property of the machine element in suppose ah this is an machine element and which has been designed to take up some external loading on to it

so once it has been designed that whether it is put on to a machine member or it is simply lying on the table or somewhere else it is always going to have that strength for which it has been designed so that's the reason we call the property of that machine element strength is some sort of the property of that machine element

similarly property of the material is quite understandable because the strength of an aluminum bar won't be the same as a strength of a say mild steel bar or say for wood for any other material for example

so obviously one of the important role is being played by the property of the material or the selection of the material ah for a design of a machine component

so what we understand broadly by design

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that means the design is something like that this selection of optimum materials and dimensions to withstand failure due to applied load

see i have underlined two cases one is a failure and another is an applied load so obviously ah some question comes at what you understand by the failure well so obviously if we think of a failure then failure comes into two situations

one is the mechanical failure in materials another is due to the type of applied loads so that indicates the applied load

let us have a look into these two aspects a little closer that what we understand by the failure in materials

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so these failure in materials is normally designated as that mechanical failure in materials so you can see there are two criteria's one criteria it is been written as yielding so what we understand by yielding yielding or permanent deformation is a sliding along certain angular planes in the materials

so another one we understand is a fracture fracture is a failure by separation that occurs on a cross section normal to the tension directions that means always if there is an failure of the material then the failure of the material can take place as we understand either by yielding or by fracture

now whether it will be a yielding or it will be a fracture it largely depends upon the type of material you choose for the design

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so in that way we classify the materials as you know you have read earlier that one is called the ductile material and we will take up shortly another is a brittle material

now once we consider a material called ductile material then what it is its definition comes out to be the ductile material definition is that it's resistance to sliding is smaller than it's resistance to separation

so what we understand is that ah this particular situation we can just briefly explain over here

suppose we take a specimen

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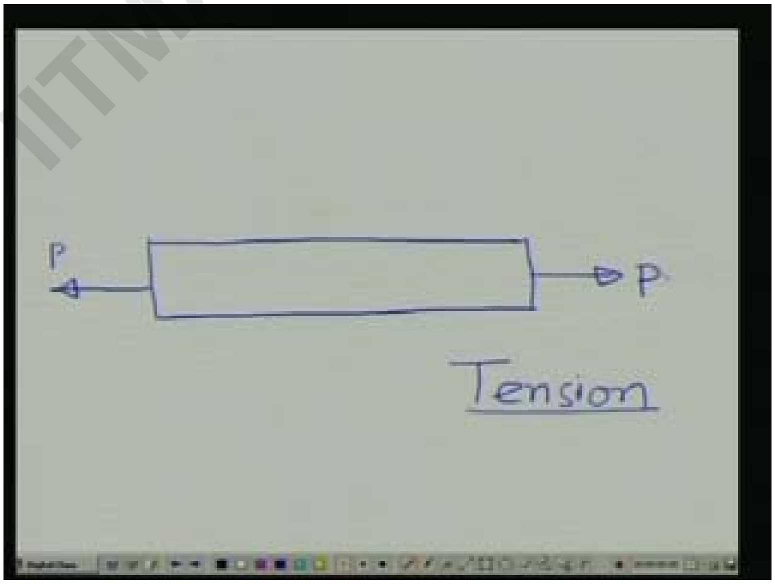

and we just put some applied load P alone its axial deduction so you understand the material is subjected to what you called a tension

now once we put the material in tension then in this particular case what will happen that if you have seen this type of material testing then you must have notice that this particular material if it follows to the category of ductile material then it under goes ah some sort of reduction in area cross sectional area at this particular zone so what we materialize if we can see this particular figure then i think it will be more clear that you must have seen that something like this

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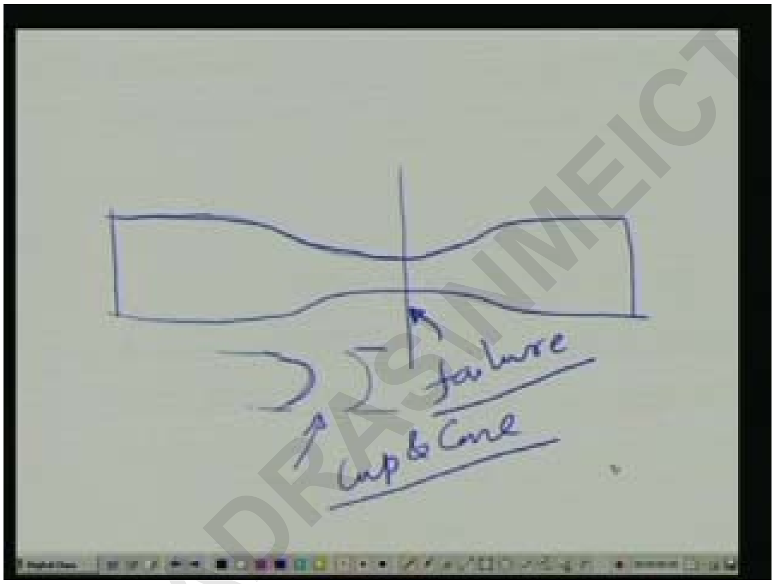


it comes down to something like this one and well some sort of situation comes and ultimately ah this particular failure takes place in this zone so this is the line where it failure takes place

now as a matter of fact although i have drawn a straight line over to show the failure the failure is not exactly the in a straight line it forms in a some sort of what is very conventionally called as this has an cup and another is a some sort of a cone failure that means this is a cup and cone failure that takes place in this particular case

so when it is going like this basically before this failure takes place this particular shape comes out by sliding of the planes more or less at an angle of around forty-five degree and then gradually this elongates and when it crosses the yield point it goes to the plastic state and then this fracture takes place so this is a peculiarity [Noise] of a ductile material and uh this ductile material failures and cup and cone shape and as we have discussed earlier this particular type of failure what we have just shown you is called is that failure purely by yielding

now in this cases what happens that the characteristics is this this materials can have same yield point value for both tension and compression

that means what is happening that what we have shown you ah just right now ah our tension the particular material was in tension suppose it has gone under gone some compression also then the experiments have shown that the ductile materials can have both the yielding i mean further yield points both same value for tension and compression

so this is that what we understand by a material ductile materials and a structural steels and most of the machine members ah ah well may not be a very precise but still most of the machine members which under goes shock vibrations etcetera or anywhere in everyday life we see the material of the designs are made by this ductile materials

now if we consider the next one the brittle material

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then what is the brittle material the brittle material is its resistance to separation is smaller than it’s {resista} (00:09:48) resistance to sliding is just opposite to that what we consider for the ductile material and here the failure takes place by fracture now what we understand that means there is no sliding of this particular to as the sliding what we have seen earlier for the case of ductile material where the two layers of materials can have a relative sliding around around forty-five degree but here it will have a short fracture separation and uh this is considered to be an brittle material

now ah i mean we can see one situation is that if we consider again a bar

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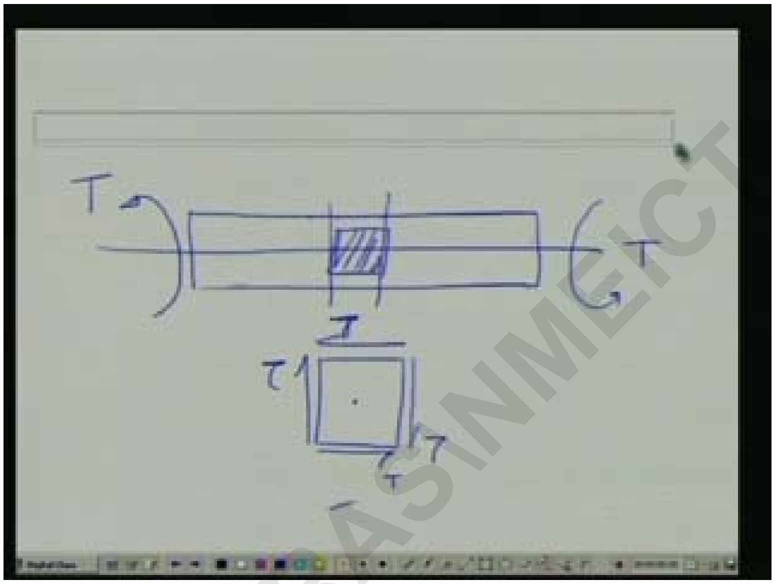

suppose we are having a bar it is acted upon by a tension i am i am sorry by an torsion suppose that T we see that (( )) (00:10:58) is giving an simple torsion to an material has i have shown you in this particular figure

so if we apply a torsion in this manner then what we understand that if we consider a small elemental section from this material then we know that this particular material is acted upon by an shear stress tau shear stress tau we know that shear stress are complimentary that means we will have a shear stress like this and we have a shear stress like this

you remember that this shear stress we consider to be a positive because it is at with respect to a point inside the body it is creating a clock wise rotation so this shear stress is a positive

now ah what happens that if we try to find out a situation of this particular state of stress through a Mohr circle so what is that we would like to just have a look at that one that if we consider

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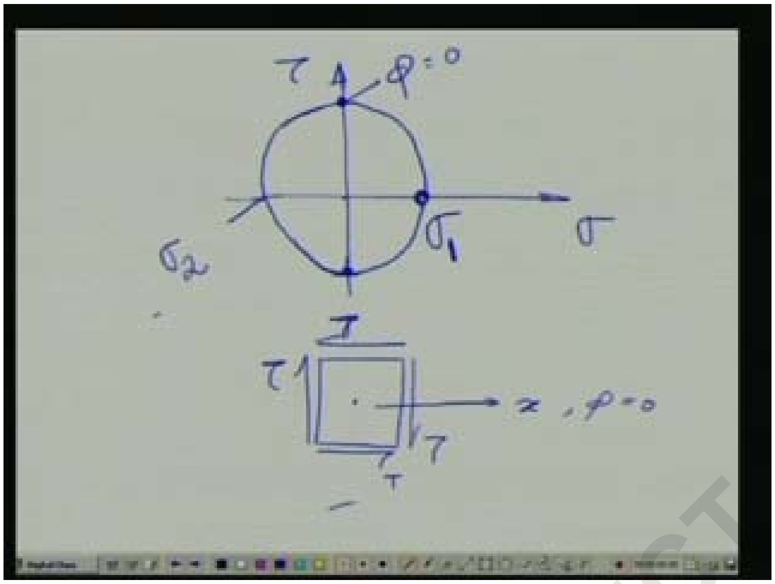


a Mohr circle i suppose you remember the Mohr circle we discussed in the last class or may be one or two classes earlier so we plot a sigma we plot a tau are the two axis for the Mohr circle and what is the state of stress this we understand this is an x plane or what we consider the phi equals to zero so here we see only shear stress so if we plot a shear stress now what is the other information on the other information on to this point is an shear stress at this point

so if we construct a circle this points we join so this is a centre of the circle than we find that this comes out to be the Mohr circle

now what is this one this is five equals to zero what is this one this is principles stress sigma one and this is principle stress i mean the {ma} (00:13:19) minimum one and the maximum one and these comes out to be sigma two what is the magnitude of this one we understand this is purely nothing but the tau and plus tau and minus tau that comes out to be this one

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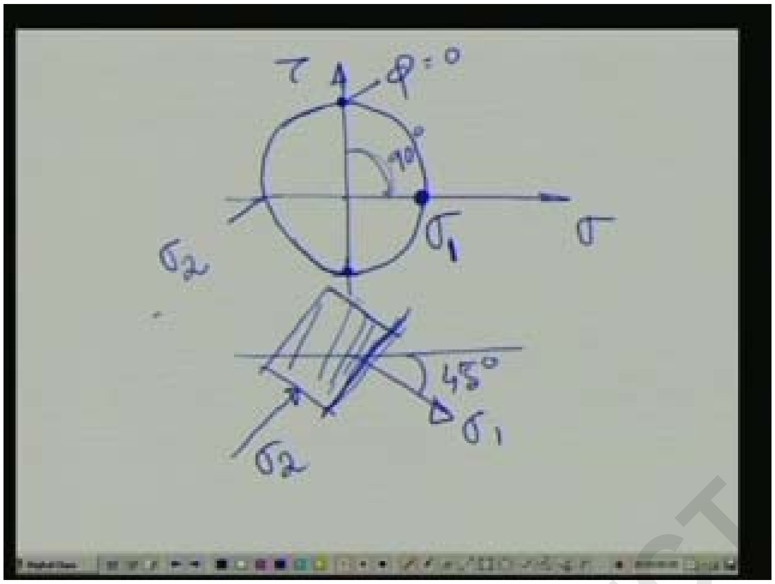


now ah what is the interest is that where at what plane this particular stress is occurring you can see this angle is ninety degree okay this angle is ninety degree we understand

so obviously what is happening that if we try to construct the orientation of the plane how we do it is ninety degree so on to the element it moves out by an angle forty-five degree okay so this is the plane so this is we consider as sigma two this is sigma one and this is the orientation of the plane where you get this particular feature

that means this is the plane which is perpendicular to the plane is at sigma one active now if we look into a situation ah say

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i have chosen a material chalk a simple chalk has been chosen and which apply a pio torsion onto the chalk

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just you can see that if i apply pio torsion then it's little hard so just see it has broken can you see the broken portion how it as failed so it as just failed in the situation of this forty-five degree line i mean i mean this both way this is a forty-five degree line so what is happening if you consider this forty-five degree line can we not see it is resembling the same forty-five degree line what we have drawn on to this particular plate over here okay

so this is what is one small model i wanted to show you now i just have an explanation just see once again this particular plane okay this is the plane you can see on to this is the plane where you can see ah ah failure and corresponding this is the plane where you can see the failure and this is all at forty-five degree as i have drawn on to this ah particular board

now see what is test actually indicated the test indicated nothing chalk is a brittle material so what is happening it's resistance to separation is smaller then what its registration ah i mean it's ah excuse me uh it's resistance to separation is smaller than it's resistance to sliding

so obviously ah what happened all though it was acted upon by pio torsion in some plane ah forty-five degree as i have shown you earlier that the uh it was ah maximum principle stress that means it is just failing ah what it is failing just perpendicular to the ah tension a tension direction that uh actually we have just earlier uh defined defined that fracture is a failure by separation that occurs on a cross section normal to the tension direction so as because it happens to be the ah it happen to be a brittle material the failure took place in that manner

now ah this is what we understand by a brittle material where failure takes place by fracture and i have shown you what is a fracture

this materials mostly have higher ultimate strength values in compression than in tension what is the ductile one the ductile had more or less the same intension and compression but normally for the brittle material it has got a more strength in compression than in ah tension

anyway ah if we want to see ah the failure i mean how the yielding takes place in cases of ductile material uh one has to obviously go to and find out from the universal testing machine how the failure takes place well ah

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which is a brittle material which is the ductile material then you can see ah ah rough guideline if percentage elongation at fracture is less than five percent the we consider this to be a brittle material and ductile material what we understand is that percentage elongation at fracture is more than five percent

now ah one of the situation that happens that uh uh that what has been mentioned over here the ductile materials may fail by fracture if there is cyclic loading long term static loading at elevated temperature impact loading work hardening severe {quen} (00:18:24) quenching so what are this ah concepts ah suppose what is cyclic loading cyclic loading is an fatigue loading what will be learning little i mean after some time that means content continuously if we consider a material member suppose this way and you just put a ah just you just bend it like that again you bend it on the other like bend it like this again on to the reverse direction so what is happening suppose at the top fiber if you consider then continuously you are having in one cycle it is undergoing an tension and in the next cycle what is undergoing it is undergoing an compression so that is what we understand by a cyclic loading

what is an long term static loading at elevated temperature that conventionally we call as an quick loading okay another one is called a impact loading impact loading you understand by this words that is if you are suddenly you are having an impact on to a machine member then this is called impact loading and due to that one also the ductile materials {fay} (00:19:29) may fail by fracture

what is understand this ductile material may fail by fracture means something like that ductile materials may just behave like an brittle material

now for the impact loading ah the one of the uh situations that can be coming into picture as a matter of this happens it happened rather uh that suppose a ship build up ship haul is build up by ship metals by welding and as normal temperature it is fine now you that should goes to an very cold temperature suppose at the ah at at the ah the cold zones in the ocean sides and then if you if it goes over there then what happens just due to that particular temperature effect what happens the brittle this that particular simple {miy} (00:20:19) this mild steel which was behaving like an ductile material may just behave like an brittle material and fail and this sort of incidence had occurred daily in world war two when the ships from say Germen side or like that it goes to the ah uh arctic oceans i mean arctic sides

so the if it obtain temperature is also of severe situations combined to the that impact where the brittle material uh where the brittle material failure behavior can be executed in a ductile material too

work hardening and severe quenching are some sort of situations that uh occurs you know it is a metallographic i mean the metallographic changes that takes place and the behavior of the ductile material could be a like an brittle material well ah

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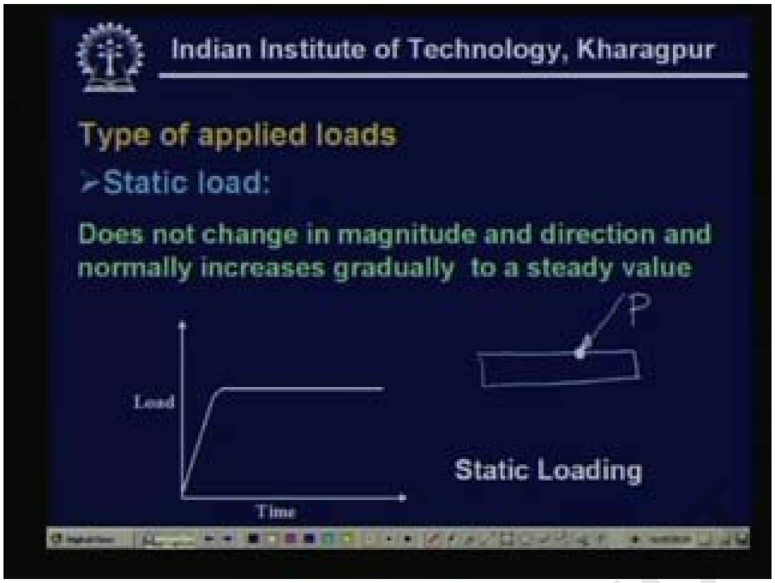


so that we have considered what is the type of failures normally uh due to this applied now come down to a another situation that type of applied loads

so what we gather ah

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if we just go through one step that is a failure mechanical failure and materials that we have just discussed and then we just have a look brief look at the type of applied load that can come into picture

see obviously first one what we called as an static load where the load does not change in magnitude and direction and normally increases gradually to a steady value even ah it's not mentioned here i think ah if you can consider a situation that point of application of the loads are also not changing means what i mean to say is that if uh if there is a material and a load is acted upon by the this way so these are the point of application and with time this point of application of the load P is also not changing

but anyway ah sometimes we understand a very small way are changes in the either in the point of application on the magnitude of the loads coming into picture we also called those situations as Cauchy's static and there also the design could be consider just as an the way we consider the design for the ah static load

so here ah we understand what we understand by the word static loading

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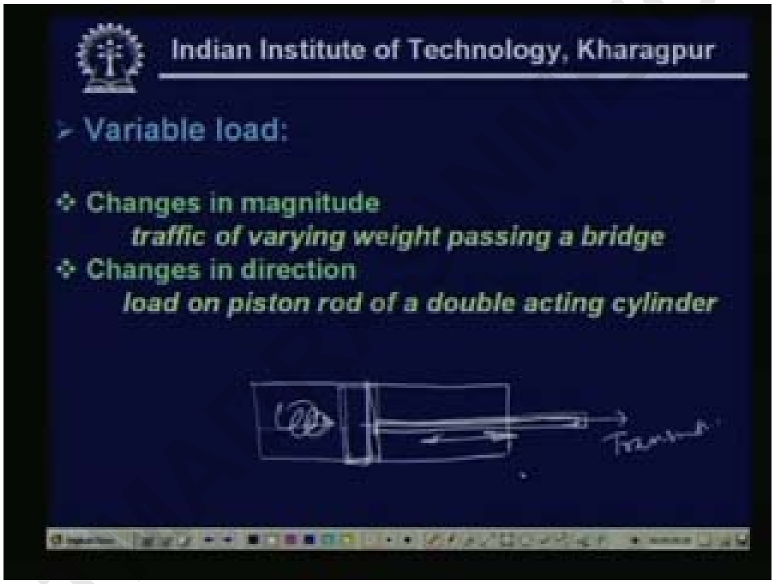


now we consider other situation that is the variable load what is the variable load variable load we understand is a change is in magnitude it change is in direction too

so we have given an example that traffic or varying weight passing a bridge that means you understand that on to the bridge continuously the changes is taking place that means one curve is passing like that again another curve is passing like that so obviously the bridge is not acted upon by a single magnitude the point of application of the load is changing the amount of magnitude of the load is changing because the different vehicles have got their different weights

so this is what we understand in the change in magnitude now what is an change in direction the change in direction is ah an example what we can see as a load on piston rod of a double acting cylinder so you understand that means if is a double acting cylinder ah then ah is then then on to that particular one once the so what we can understand is something like this ah it is ah some sort of well consider one so on to this one suppose something is there to force and then it is it is there on the transmission and you have to design this rod so what is happening it is just pressing this one again the transmitting is keeping it back so there is an continuous movement in these directions okay so the load on to this rod is gradually changing so this particular changing pattern what we call as a change in direction

so both together we consider the changes in magnitude changes in direction and that what it is causing ah the variable load

however ah once we go for designing then uh what we can see is that is a situation something like this what we have considered is say

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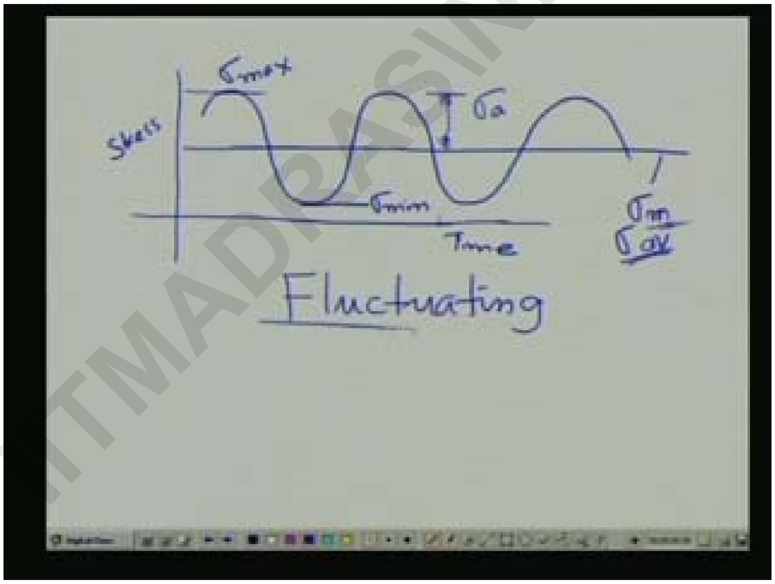


this is a this is a time axis and this is your stress then what you can have ((see the sinusoidal)) (00:26:18) load pattern is going like this

now in this case what we understand is that this we denote as the maximum load this we denote as the minimum load

so what we get we get somewhere a load line which we consider as sigma mean or sometimes it is also denoted as sigma average or sigma mean sigma mean means ah in we can we can denote is also something like this uh something like that sigma m also that is also {denot} (00:27:23) denoted as an sigma m

this is the mean stress and then what is it we call consider this is an sigma a what is a stress amplitude okay that means this is ah stress amplitude that means whatever this is coming out to be and this is the sigma mean line from here it is an sigma mean line

so some definitions are given for the sigma mean that is a summation of this one by two this is average and difference and divided by two is the this particular as stress amplitude

we will coming down to this ah derivations and the design aspects after in a short while from now or may be in the one or two lectures of this this will be decided

now these type of stresses we all as a fluctuating stress or fluctuating load

now once this is what we understand is a fluctuating load as we have seen time by stress if it is going a sinusoidal wave in the similar manner if we consider also another situation

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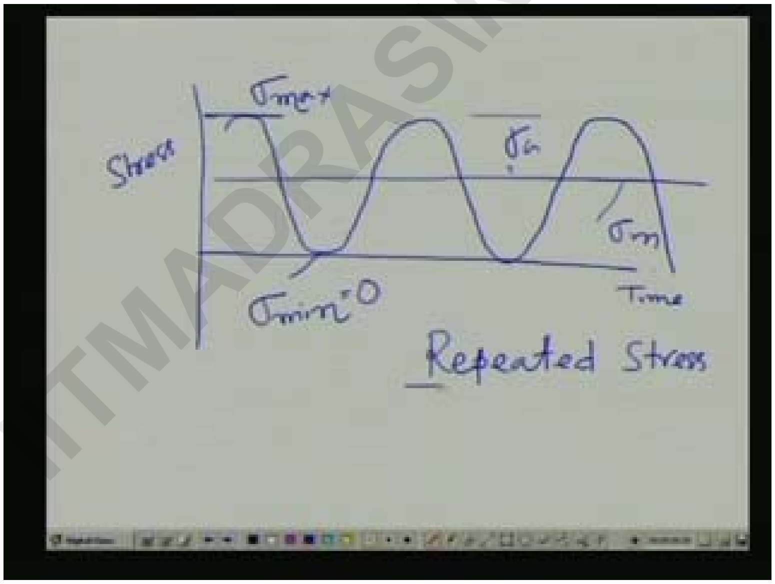


say this is your time this is your stress and it is going like this what we see we find that this is sigma maximum this as usual it is sigma minimum and once we see this is an sigma minimum that is comes out to be equal to zero and again we can have a mean stress line and as usual {stre} (00:29:46) ah what you call is an stress amplitude sigma a and this type of stresses is we call as repeated stress so this is also a repeated stress or repeated load and other one we can think of a situation

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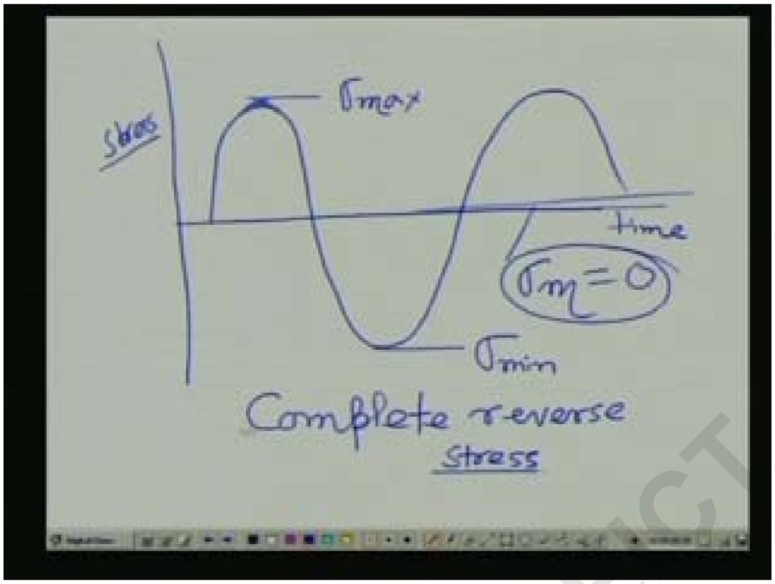


that comes out to be something like this this is a time axis and this is an stress axis and we have a some loading situation something like this

this is sigma max this we consider to be [Noise] sigma mean so the magnitude of the {stre} (00:31:00) sigma max and sigma mean is happens to be the same that means this is coming out to be sigma mean which comes out to be zero so average stress in this particular case coming out to be equals to zero

so this is called as complete reverse stress so this is an complete reverse stress situation so what you having ah situation like this so normally uh these are the three types of stresses that ah taken care of while ah doing the designs ah however there could be other {ther} (00:31:59) there are other various types of stresses that also we come across now before coming down to this particular idea of what are the other type of stresses let us be clear into one thing is that the basic concept is that

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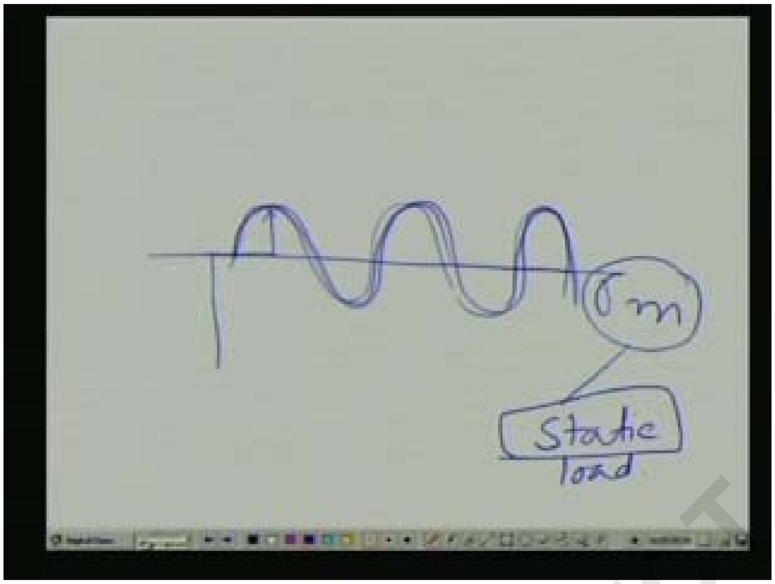


if you are having a mean stress line than stress amplitude something over that one so if we consider the mean stress then we consider the design to be a static because mean stress is somewhat resembling an static load so this is an static load and over which your super posing superimposing this the idea of a this type of what you call this fluctuating stresses or the repeated stresses or the complete revisal stresses that means this is the mean stress over which sigma a that means stress fluctuation or the that is being superimposed that is the basic idea of the design however we will come down to this situation later on when we the considering the typical idea of the now this is the variable load already we have discussed

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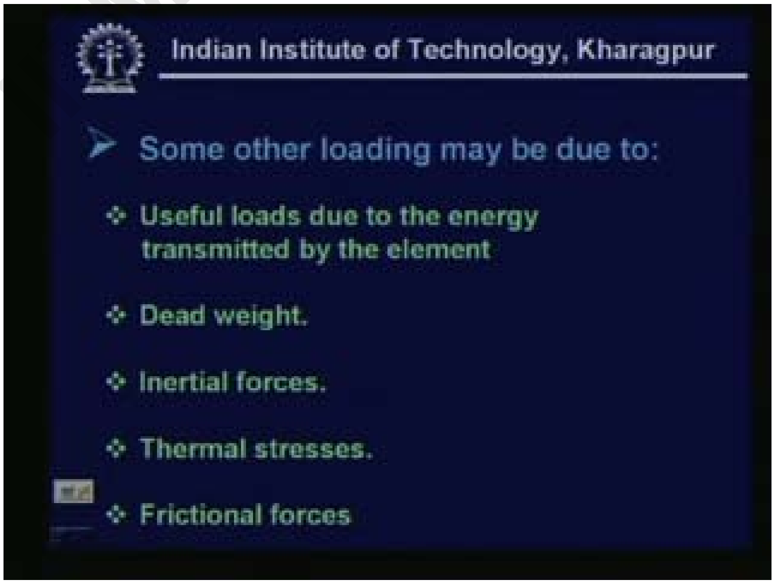

and then we come down to the conditions that some other loading which are the loads this is useful loads due to the energy transmitted by the element dead weight also taken up as an load initial forces thermal stresses here thermal stresses is one thing that comes into picture ah due to the thermal ah expansion and contraction of the machine member ah the temperature is causing a stress and that stress sometimes if we consider in the analogy of load that what we call as an thermal stress also a type of loading and also we consider the frictional forces to be the some sort of loading that we consider while designing a machine member

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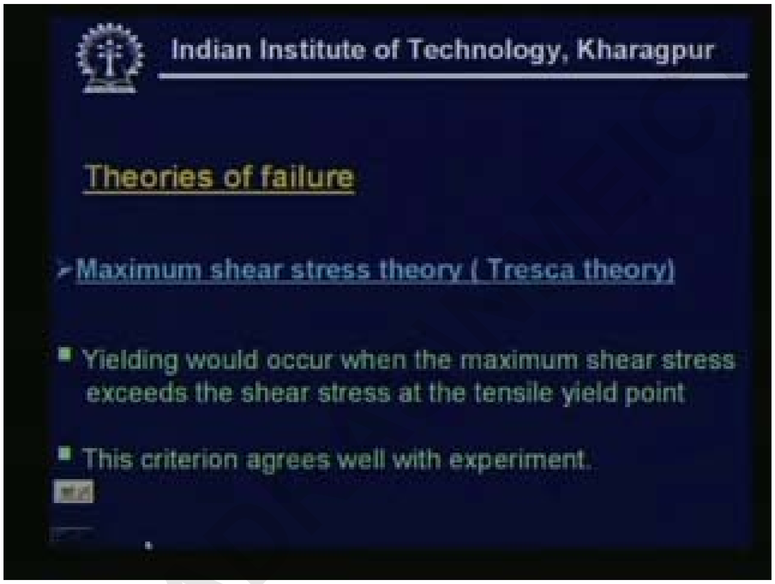


now ah this is one thing you can see the slides that is the theories of failure now what is this theory of theories of failure let us have some idea what we understand by the design theories of failure

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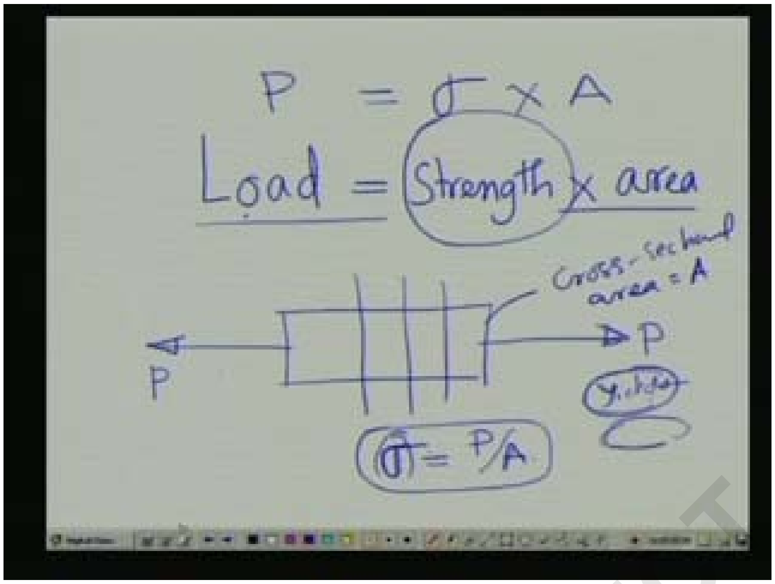


look if we see into this one basically what is design load equals to stress into area that we have learned isn't as a way roughly we understand that's a load means a certain amount of stress into area

now this stress if we remove the word stress by an another word i think you won't be having any objection strength into area what is the difference let us have this two words that {onc} (00:35:19) once i used a stress another i used an strength

see if we are having a material a machine member acted upon by a load P you know at any section what is a stress any section one two three if you consider the stress sigma will be equals to P by A what is A A is the cross sectional area equals to A

so you understand the P sigma equals to P divided by A so what are other way if we write out in this direction or this manner than this comes out to be sigma multiplied by A

this is okay it is acted upon by the load this is okay cross sectional area that is the area now we come down to this particular idea of the stress

now here we have written first earlier it is a stress fine when i write a strength then what it implies that if you go on increasing this load P okay then what will happen at certain time the material will fail where it will fail you can consider the failure to be yield yield failure at the yield strength of the material it fails next what is happening and another case it is what I mean to by yield failure because any ah way once if the machine member comes out to be an yielding zone then it goes to a permanent deformation or it goes to a plastic state so that also we can consider to be a failure basically it is at failure because it won't come back to its original position so yield point is also a failure and ultimate point is also another failure we consider so so yield stress point ultimate stress points these are the certain characteristics and those characteristics are nothing as we discussed as the strength of the material

once the material fails that whenever it crosses the strength of that material that is the property of the material is the strength and that is defined by yield point or the ultimate point

so those that that's the reason what i am trying to say indicate that here you can see the stress generated will have a maximum limit and that will be that is our consideration where we will be considering say we consider to be yield strength

so yield strength of the material multiplied by area is a maximum amount of load in other words the stress what is generated could can go maximum up to the value of this material why because we can see this material was in pure tension so the stress generated and the strength of the material could be put one is to one

what i mean to say the maximum stress that can come into the material and the strength of the material can be well related because we are only having a stress in one direction and that stress can have a maximum value which is equal to the strength of that material

so you understand that means stress is at a point and that stress at a point some times that stress at a point when it reaches a maximum that we can say it is the strength of the material and this analogy or putting the stress directly {equat} (00:39:09) equating to the strength as as a yield point of the material or the ultimate stress of the material is very easy means {ieve} (00:39:19) it is understandable suppose in addition to that

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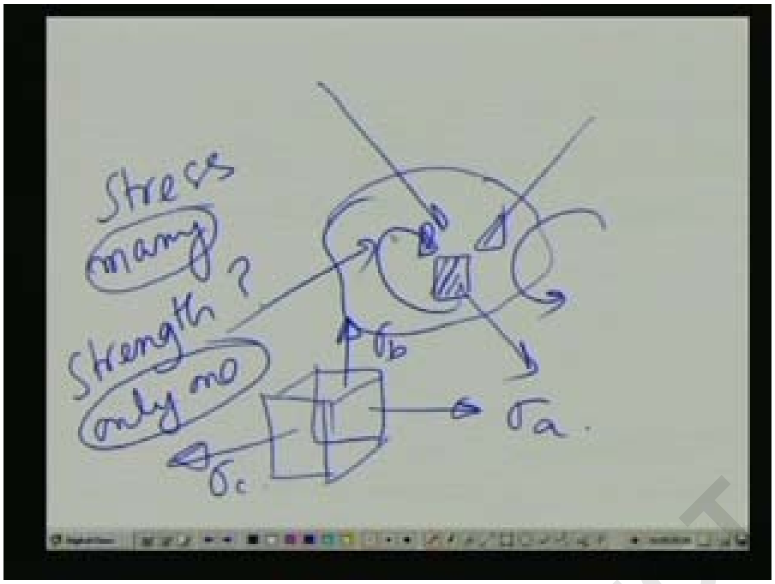


we have a member acted upon by various loads various loads like that ah well various loads of the torque then loading applied like these some loads act like this then if we take up a stress element somewhere over here a small element we have seen earlier that this particular element can have a say sigma a sigma b if you consider the three dimensional aspect than it can have also a sigma c something like that that means acted upon by stresses at various directions

so if it is so then we understand that stresses we are having multitude of stresses but what is the strength that means stress many okay that what is understand by strength strength is only one sailed point so there are many stresses at different points and that that is only one strength of that material so unlike the simpler situation here what we have to find out we have to find out the stress at typical point or the different points or the critical i mean the what we primarily talk about as an critical points and then and then only we can equate it with a strength of the material which primarily is a once the material can either i mean either you can consider the yield strength of the material or the ultimate strength of the material so the strength of the material is basically coming out to be one

so that’s the reason we are having the concept of theories of failure that means the people or the engineers they have derived many conditions that is what are the {cons} (00:41:41) suitable conditions for which ah you define the material will fail

so ah while considering the theories of failure we considering two aspects one aspect is a theory failure theories that are ah i will discuss about failure theories which will be primarily used for the design of ah you know maximum shears i mean ah design of ductile materials machine components built of ductile materials and ah we consider some theories which are quite appropriate for consideration of the brittle materials

now one of such theories for the design of ductile material comes out to be maximum shear stress theory it is also known as Tresca theory

its states that yielding would occur when the maximum shear stress exceeds the shear stress at the tensile yield point as it is written below this criteria agrees well with a experiment

now what you understand that yielding would occur when the maximum shear stress exceeds the shear stress at the tensile yield point

now uh let us have a brief discussion on this particular aspect

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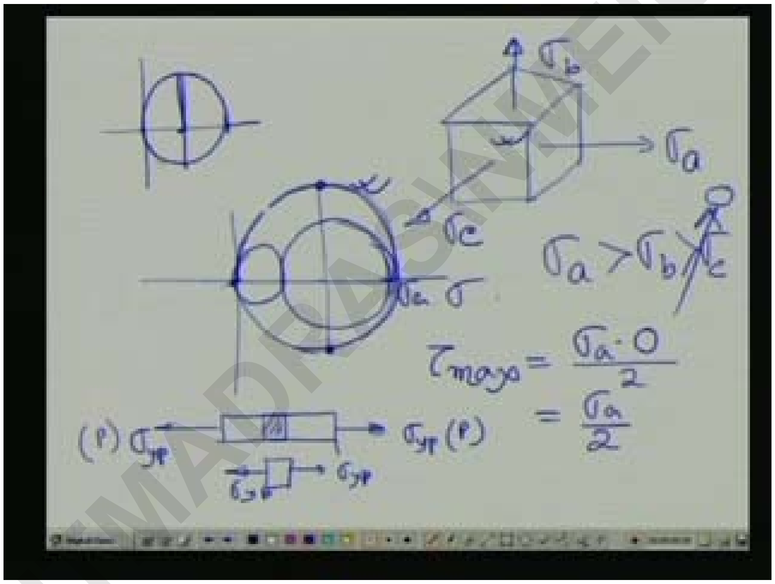


suppose a material as i told you earlier can have say the stresses sigma a something like that it is sigma b what is an this is an sigma c ah i am sorry this is sigma c and let us write it clearly this is sigma a

now consider a situation ah uh something like this a sigma a greater than sigma b greater than sigma c and to consider into two dimensional aspects say let us put the sigma c to b seen

now in that aspect if we draw a Mohr circle for this situation than we can we can see a situation it is Mohr circles between sigma suppose we consider the view from the top sigma c and sigma a so we get a Mohr circle like that suppose we consider ah situation between sigma a and sigma b suppose sigma a and sigma b are the same sine that means it is like this and between b and c we can find out these are the stresses

what is this one this are the Mohr circles i think i need not again describe the Mohr circle so this are the Mohr circles for situations suppose this sigma a let us consider this is sigma a and sigma c comes out to be zero

now as for the criteria what it says that is at this position for the outer most circle what is the value of this tau max this tau max is nothing but the radios of the more circle so tau max equals to sigma a minus sigma c by two and this now i write as zero that means it is just come now to be sigma a by two

now if you consider a material made of the same material for which we the machine component has been built it is acted upon by stresses by loads and ah in this case when the load comes out to be yield point load then we get a this corresponding to the load which is creating an yield point okay you understand this is a yield point corresponding to a load P

so this stress element will be something like sigma yield point sigma yield point okay then what is representation on to this particular ah ah you know okay i require this much position only ah so that will be in a Mohr circle this is what sigma yield point this is zero so this is what we are getting now correct this comes out to be tau max so that equals to what if the criteria that you wanted to know the yielding would occur when the maximum shear stress exceeds the shear stress at the tensile yield point so you remember so what we get

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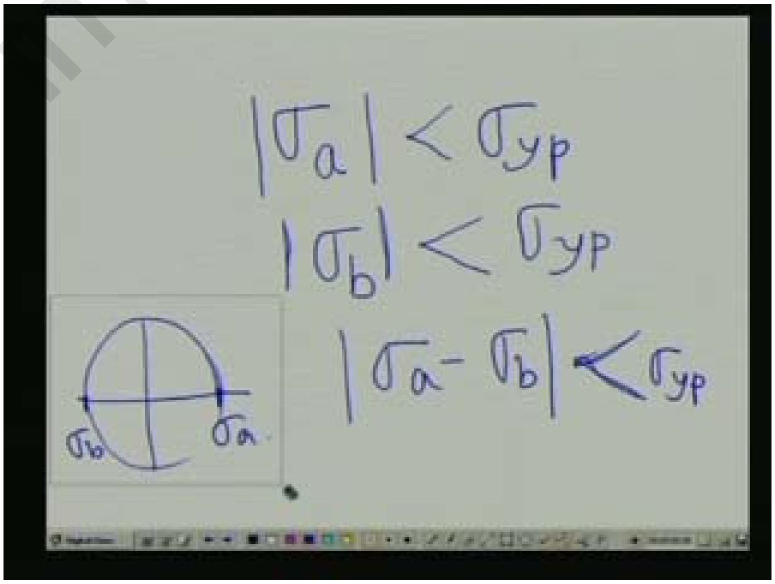

so what we get that sigma a by two should be less than sigma yield point by two or sigma a is something less than sigma yield point

now we we we consider to be more generalize ah by a situation ah by a situation i think that will be much more better and that is what we consider to be as something like this

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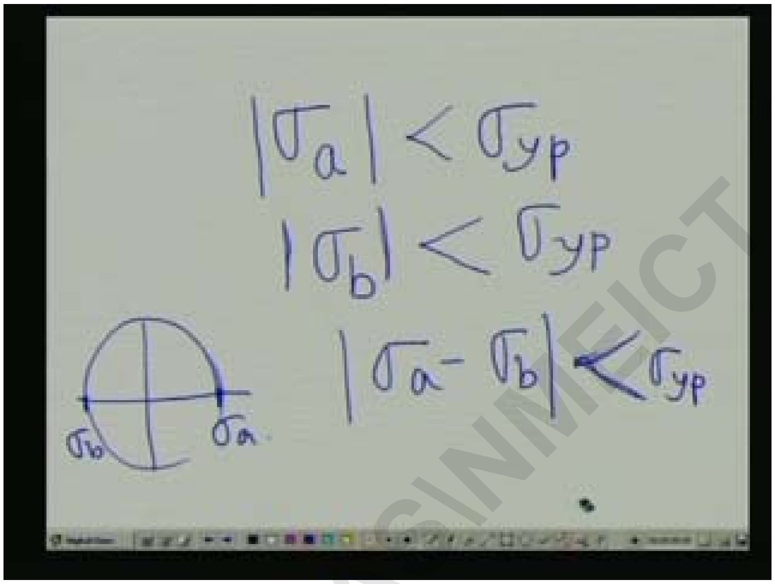


that sigma a sigma yield point the two two cancels out sigma b less than sigma yield point that could be possibly that sigma b is more and what i did not shown you suppose sigma a is a positive magnitude and sigma b is of the negative means of the reverse than what is happening you can understand than tau max sigma a minus sigma b so in that case the modules of sigma a minus sigma b should be ah sorry sorry sigma yield point

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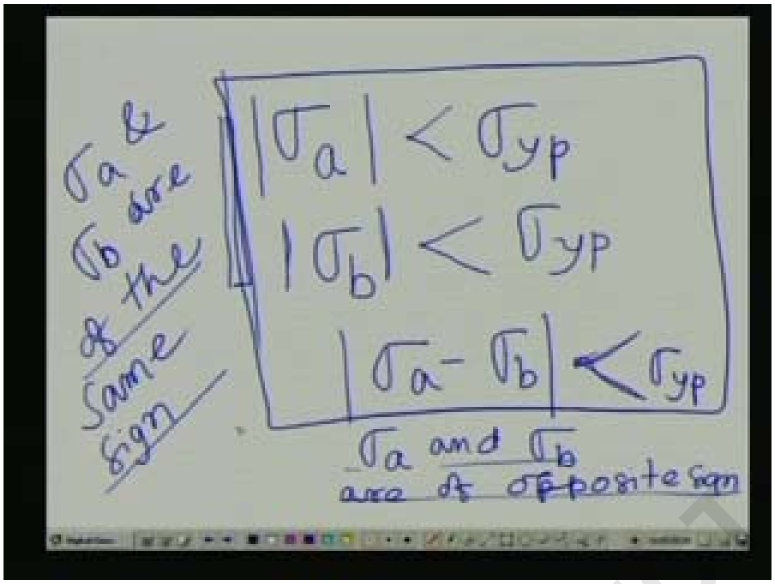


so we understand that what is the meaning is that if we consider this equations than this is when sigma a and sigma b are of the same sign and this denotes that sigma a and sigma b are of opposite sign

so these are the situations what is being expressed so the ultimately what we get we get the maximum shear stress theory as outlined over here that means how you design it that means once you find out the ah that particular one what we find out this particular stress at this level and this stress should be not less than this one you you remember this particular sigma yield point how it has come basically it tau max and that has come out to be sigma yield point by two so two two cancel so we are writing a sigma yield point

so that means this is ah this is ah now i am just erasing out so what it is this this is a material property material strength that means a stress at a point is now can be related to be this particular situation so it is a by actual state of stress so depending upon the designer he will be finding out critical sections and thereby he can represents the theory in this manner

now if we put these results if we put these results

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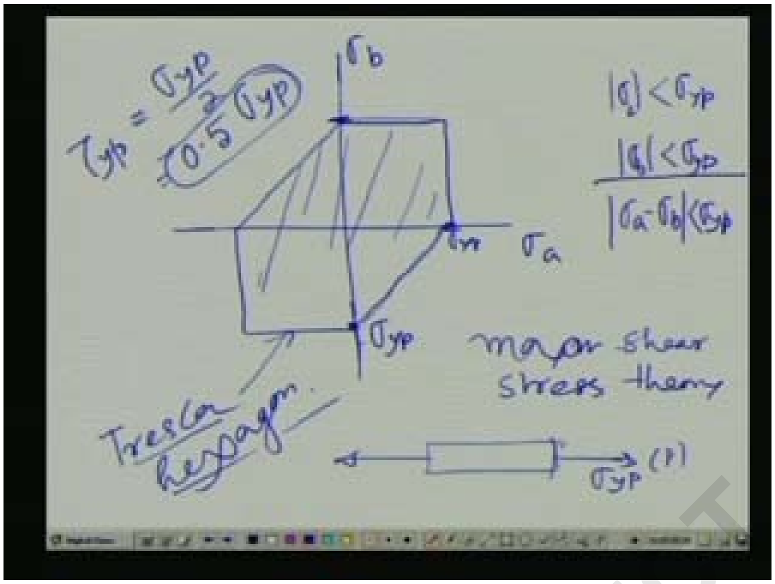


then you can see the three conditions if i write down this sigma a sigma yield point sigma b less than sigma yield point you understand same sign and sigma a minus sigma b modulus less than sigma yield point than what is happening if we plot this all the situations than this axis is sigma a this axis is sigma b than you will get something like this

anyway this is your sigma yield point this point is this bounded by or is a sigma yield point points like this okay

so any stress values bounded with this zone is a same stress so this is what what we called is a maximum shear stress theory

what is this is called this is sometimes is called Tresca hexagon

now this is a very useful tool in designing and uh if you you can see that by the simple tension test what you can find that sigma yield point we can find from the simple {tenn} (00:53:37) tension test so by this theory what is what it is being predicted that tau yield point should be how much if you consider this one tau yield point should be sigma yield point by two or that is equals to point five sigma yield point it is not exactly but it is quite close to the experiment

well we have other theories which i think we can continue in the next class thank you

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good day we continue our lecture on the design for strength from the earlier class so ah we have just very quick re-capsulation of what

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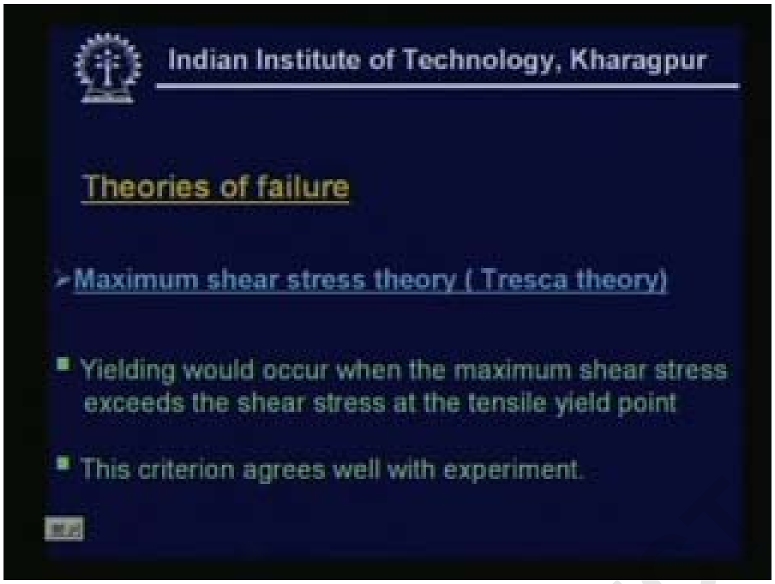


we {diad} (00:54:40) discussed last class ah we had discussed about the maximum shear stress theory which also is called has an ah Tresca theory and uh what we have seen that yielding would occur when maximum shear stress exceeds the shear stress at the tensile yield point and ah in the ah ah on this regard we found out ah what we did we have seen that you know we got some relations

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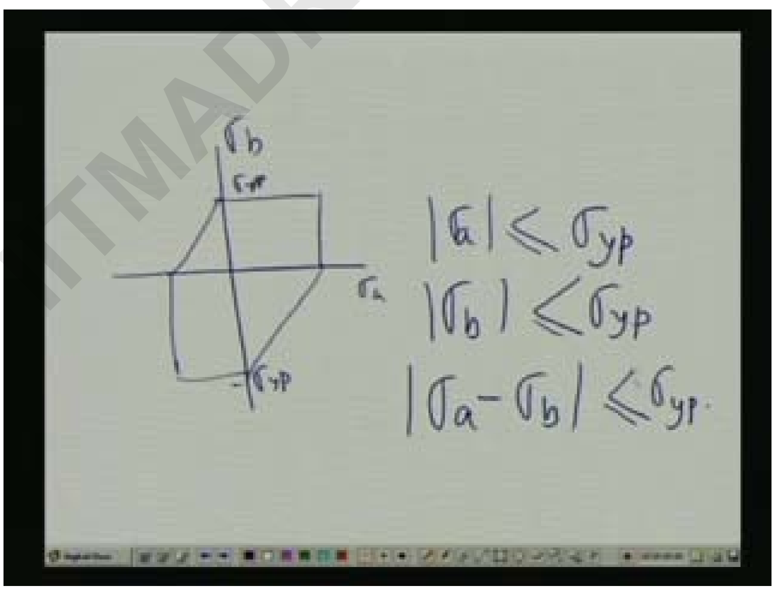


that if this is sigma a sigma b the envelope was something like this and having these values of yield point sigma yield point any way you can give also minus sign over here and these are also bounded by these things and we ah got the equations of the form sigma a for a shape design sigma b modulus for the shape design and sigma a minus sigma b for the shape design again comes out to be yield point [Noise]

well sometimes we can also use an equality to get the extreme value in the simple tension test and in simple compression tests is a same but uh it is normally it is not because what happens when was the brittle materials then the flows or the some other material defects will be more pronounced if it is acted upon by a uh you know tensile test but uh if it is acted upon by a compressive test of the compressive test ah on the other hand than what we will be finding out that the material can take up more and more load so ah in general at it as been earlier ah you know last lecture when we have discussed about that materials we have we have told something that the brittle materials normally have the more values in the compressive stress compare to what we get in the ah tensile test

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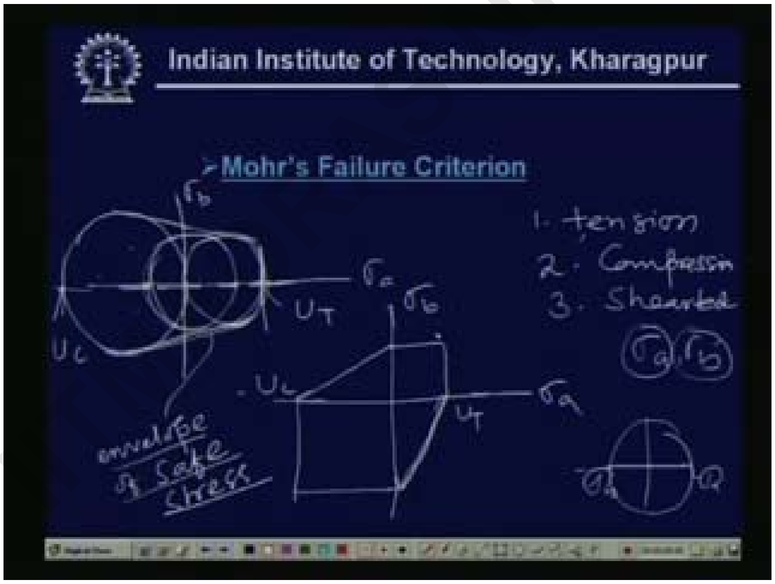


so ah just to overcome this ah situation the drawbacks of the maximum principle stress theory then what has been suggested is that ah another idea that is called Mohr's failure criterion

now one thing i would like to say that is in the Mohr's failure also the ah the material {wha} (00:57:29) what the people considers is a brittle material

so now by now what we have learnt we have learnt two situations that means two situations means one for the brittle material and another for the ductile material we discussed about the ductile material the two popular theories are what the maximum shear stress theory and the distortion energy theory and for the brittle material we consider the situation which is called the Mohr's failure criteria and maximum normal stress theory

so ah these are very important situations that means this four theories maximum shear stress theory Tresca theory the distortion energy theory this is for the both are for the ductile material than next comes to the maximum principal stress theory and then we find out the Mohr's failure criterion now with