Design of Machine Elements – I

Prof. B. Maiti

Department of Mechanical Engineering

IIT Kharagpur

Lecture No - 38

Design of Cylinders and

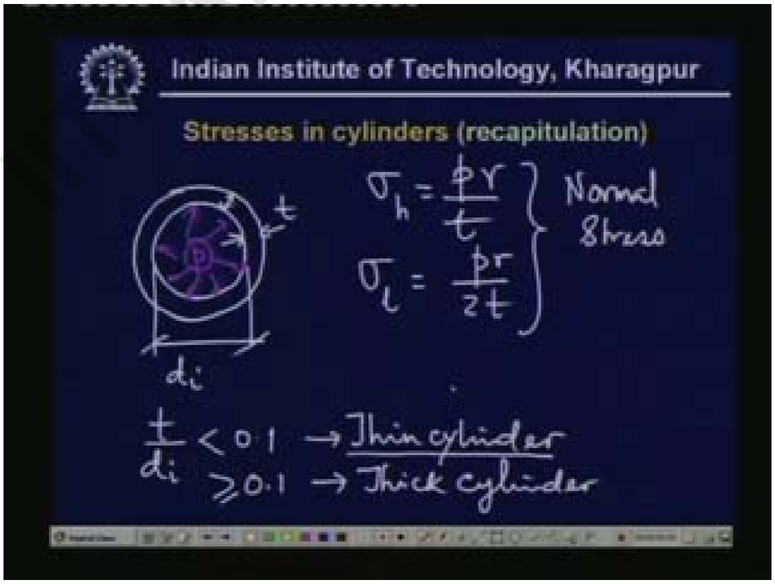
Pressure Vessels – III

let us begin lectures on machine design part one this is lecture number thirty-eight and the topic is design of cylinders and pressure vessels this is the part three and the concluding part of the lectures on the same topic

now in last two lectures we have discussed how to design a cylinder when the cylinder is modeled to be a thick one or a thin one and also we have discussed how to take care of the effect where ah when the cylinder rotates also the temperature distributions

just before going further let us recapitulate once again what we have learnt so far in a very brief file

(Refer Time Slide: 00:01:26 min)



so ah let us for this time being let us again go back to the earlier discussions and ah just um refresh our memories about the stresses in cylinders

now the discussion started with the different kinds of cylinders see the cylinders are classified according to the thickness

and the so this is the thickness and the inner diameter d i so it is divided if this is d t by d i if this is less than ah um point one then we call it a thin cylinder [Noise]

and if it is greater than point one or equal to we model this to be a thick cylinder [Noise]

now for a thin cylinder we have two kinds of stress

so now let us discuss ah about thin cylinders so for thin cylinders we have two stresses one is Hooke's stress which is p

p is the internal pressure that is [Noise] we are designing a vessel which is subjected to pressure from inside

so this is now pr divided by t where r is the mean radius because now the inner radius and the outer radius they are ah very close so they are fully modeled to be ah the same as the mean radius

so this is the Hooke's stress and we have another stress which is longitudinal stress and this is p r by two t

so these are the two stresses and those are now the normal stress [Noise]

why normal because there is no shear stress involved and the ah the assumption is that the stress distributions stress ah along the thickness of it

so sigma r if you remember when we applied for the thick cylinder here for the thin pressure vessels sigma r is equal to zero

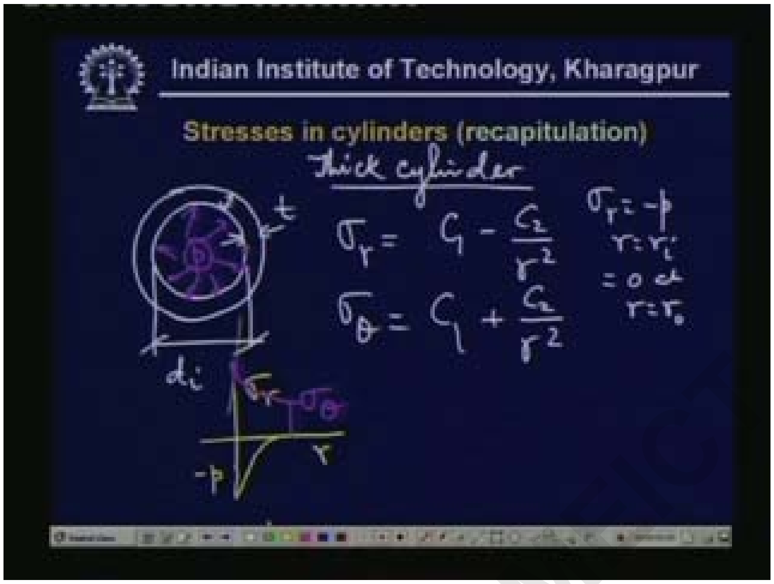
so with this assumptions we have this two kinds of stresses

now with this stress we can design the pressure vessels or the cylinder for various ah design ah for failure criteria's

for example the pressure vessel if it fails for shear then we'll have to calculate the maximum shear stress ah that is very easily calculated knowing the Hooke's stress and the longitudinal stress

so these are two major formulae used for the thin cylinder now for the thick cylinder we have a number of ah design criteria which we use

(Refer Time Slide: 00:04:32 min)



now this is for the thick cylinder now if it is subjected to internal pressure then of course ah whether this is ah plain strain problem or plain stress problem the results are similar

ah but if it is ah um rotating or if it is ah um subjected to thermal stresses that is there is a temperature distributions then of course you'll have to differentiate between the ah plain stress problem and the plain strain problem

plain stress problem appears for a short disk or for a short cylinder where as plain strain problem is normally taken when the cylinder is too long because then the normal strength is neglected

now for the thick cylinder when it is subjected to internal pressures as i said the thick cylinder ah um that is the ah um these stress distributions is ah um independent of the whether the problem is a plain stress problem or plain strain problem now ah um

when we have any such kind of ah situations then sigma r is equal to that is sigma is the radial stress and this will be equal to c one minus c two by r square

that is sigma r varies within the thickness suppose within this thickness sigma r varies from minus p to zero

so this is ah with r this is r and this is sigma r and sigma theta is again taken to be this is sigma theta is c one plus c two divided by r square now c one and c two are constants and they are to be obtained from the boundary conditions ah now if it is subjected to internal pressure then of course sigma r equal to minus p

at r equal to r i and equal to zero at r equal to r zero

so these are the boundary conditions with which we can find out the stress distributions

and once you are on c two ((are known)) ((00:06:55 min)) then we can plug the same into the expressions for sigma theta to find out the ah again this stress distributions in the circumferential directions and their stress distribution is some what like this

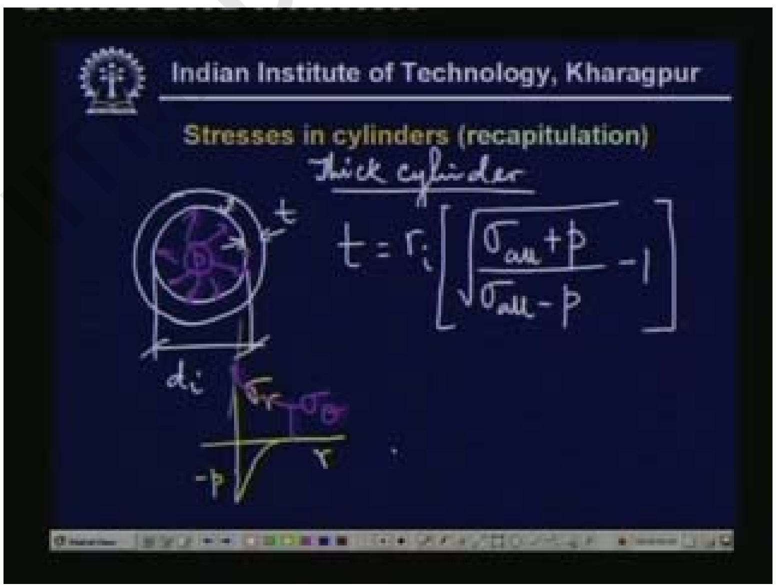
so this is the sigma theta which again gets a maximum ((volume)) ((00:07:17 min)) of the inner radius when it is subjected to internal pressures

and the minimum the outer radius and the {mick} (00:07:24 min) and the maximum compressive stress for {sig} (00:07:27 min) in radial directions is ah in the inner radius and zero are the outer radius

so these are roughly the stress distribution

now ah this is for the plain stress as well as plain strain problem now once we select the design criteria that is if it feels under normal ah um the maximum normal force then of course the design

(Refer Time Slide: 00:07:59 min)



thickness as we have seen in the last class that is t that is design one is equal to r i times under root sigma allowable plus pressure that is internal pressure sigma allowable minus pressure minus one and so

so this is the thickness to be designed

here we see that if p is greater than sigma allowable then of course ah no t can exist which will ah which can be designed that is no t axis for which this cylinder can sustain this force

so therefore if we want to increase the capacity of this cylinder that is the maximum pressure that the cylinder can withstand then with this material it is not possible

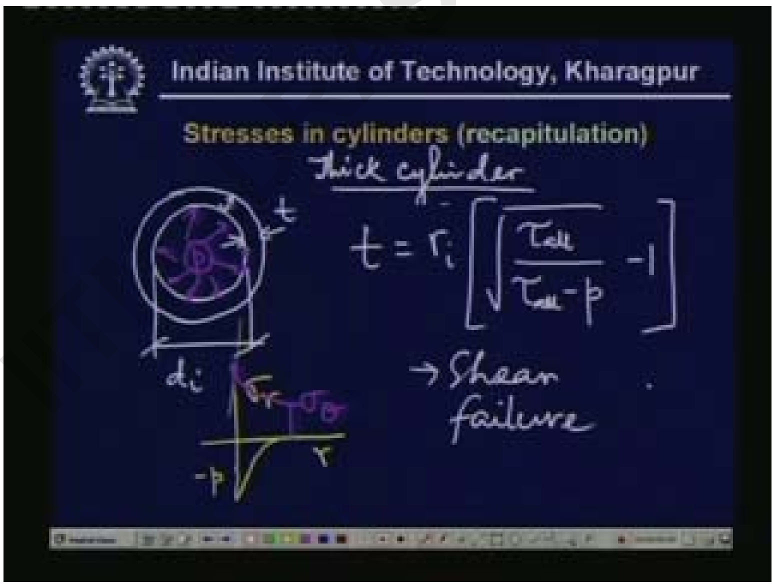
therefore we have to do some other technique we have to resort to some other techniques in order to achieve the higher strength that is ah

if you want to design a cylinder such that a stress ah a internal force internal pressure more than this particular value is is {applicable}((00:09:09 min)) then we'll have to think of other means and that what we are going to discuss today

but this is the case where the material fails in normal stress

now if it fails in shear then of course the situation is different and

(Refer Time Slide: 00:09:30 min)



the formula is {c}((00:09:28 min)) if this fail in shear then this is

so tau allowable divided by tau allowable minus p minus one

so this is the design ah thickness

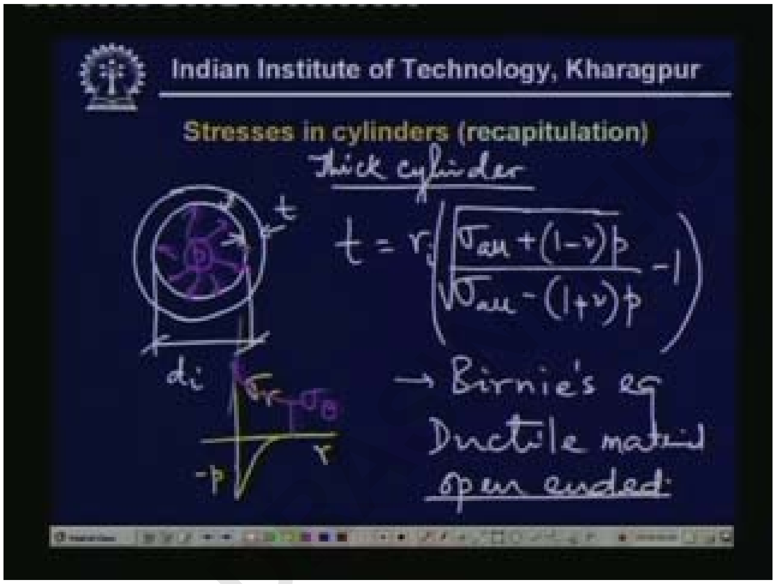
again if p is more than tau allowable that is allowable shear stress then this material will always fail in shear so we'll have to again consider a different technique such that the strength of the cylinder could be enhanced

then ah if the material ductile so this is the case ah um when it fails in shear [Noise]

if the material is ductile then of course this maximum stress criteria can is ah um cannot be used and you'll have to use what is known as Birnie's equations which am going to write down

we have discussed in the last class

(Refer Time Slide: 00:10:33 min)



see here if you want to have for the ductile material then this is ri then under root under root sigma allowable plus one minus nu where nu is the Poisson's ratio times p and sigma allowable minus one minus one plus nu p minus one

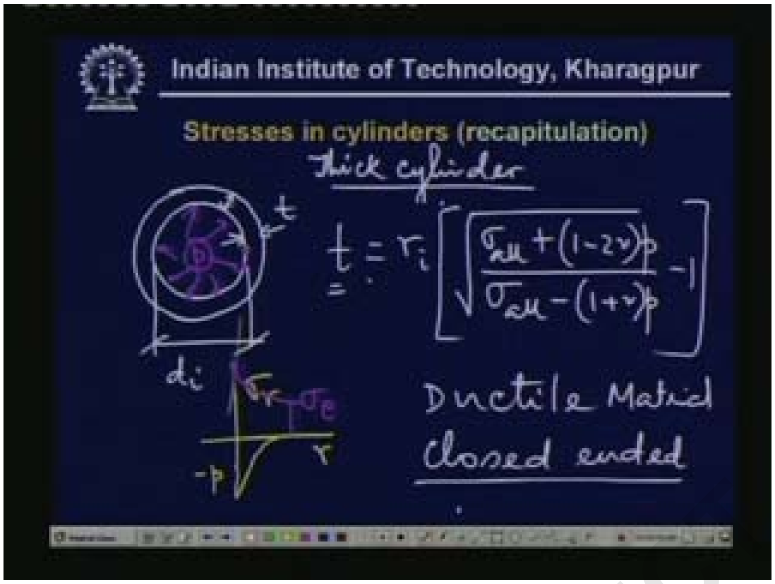
so this is thickness and this comes from the Birnie's equation [Noise] and this is valid for ductile material and open ended cylinder this is very important

if it is close ended then of course in addition to sigma r and sigma theta there'll be another stress that is the sigma z that is longitudinal stress which we have not considered here

but if you consider the longitudinal stress then if you apply the same strain considerations that is ah um the material fails if there {mack}((00:11:41 min)) if a strain

a maximum strain is exceeded then of course we'll have to use another formula (( )) ((00:11:49 min)) formula and that looks like something different

(Refer Slide Time: 0011:59 min)



that is here t is equal to ri times sigma allowable plus one minus two nu times p divided by sigma allowable minus one plus nu times p minus one

so this is for the again for the ductile material [Noise] and this is close ended [Noise] ah this is very important

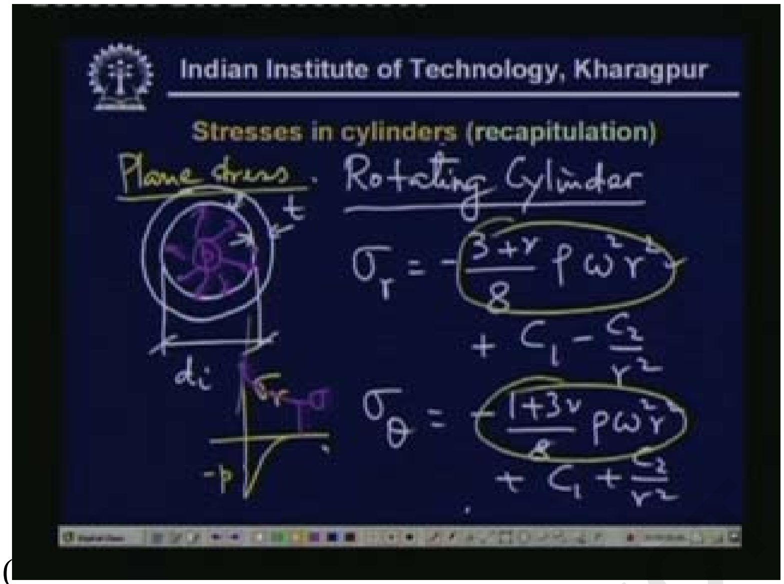
so whenever we have such {con} (00:12:38 min) conditions then we can get this ah proper thickness for which the cylinder is able to sustain ah this particular pressure p

ah again for a high pressure pipe we can use a very similar formula that as the Hooke's stress but now in that case instead of the mean diameter or mean radius we'll have to consider the outer radius

ah this is again for the thick cylinder but very large pressure {ve} (00:13:01 min) ah very {lar} (00:13:03 min) ah high pressure gas or oil pipes we use that kind of formula

so these are for the cylinders which is not rotating neither it is ah subjected to any thermal ((loading))((00:13:17 min)) now if it rotates then of course

(Refer Slide Time: 00:13:29 min)



(

so let us consider the case when its rotating cylinder [Noise] for the rotating cylinder of course sigma r is given by this formula three plus nu divided by eight nu is against the Poisson's ratio

and this is rho omega square r square rho is the density of the material omega is the speed of rotations the angular velocity of the rotations of the disk

again this is based on ah let me write down then this is c one minus c two by r square where c one and c two are constants which are to be obtained from the ah boundary conditions

and ah this is valid and sigma theta will be equal to minus one plus three nu by eight row omega square r square plus c one plus c two by r square

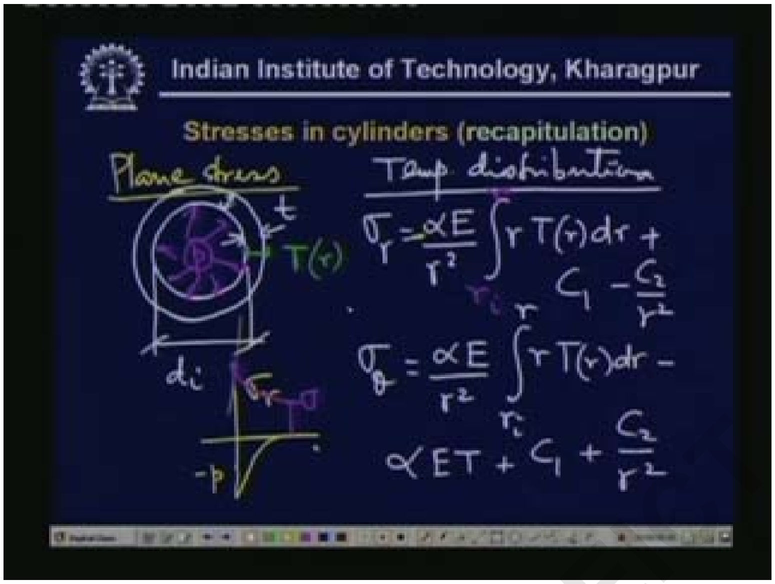
now this is the additional stress which appears only due to so this part appears due to the rotations where as this part appears only due to the rotations but important thing is that this is for ah the plain stress consideration [Noise] plain stress problem

if it is plain strain problem then the ah um then the solution looks the stresses looks different ah we are not going to that

but plain stress problem for that is this may be valid for a thin disk or a very short cylinder if it is very long cylinder then we'll have to consider the plain strain problem which looks a little different now this is for the rotating cylinder

now if it is ah subjected to a thermal load that is now what we have discussed earlier that is if a temperature distribution that if there is a temperature distribution [Noise]

(Refer Slide Time: 00:15:29 min)



that is ah through out this thickness the temperature varies as a function of the r so this is temperature t capital T which is a function of r

now if ah through out the thickness if it varies and then if we use again the plain stress considerations then sigma r is given by alpha

alpha is the uh coefficient of thermal expansion which is known and this is r square then the integral integral is from the lower limit

lower limit is ri and upper limit is r that is the value where we are interested in and this one is r t as a function of r t r and there it is a minus sign

so let us not forget this minus sign over here so this one plus c one minus c two by r square always you see this term remains c one minus c two by r square

this is ah um this is the um basic solutions without any temperature without any rotational effect sigma theta on the other hand looks like [Vocalized-Noise]

alpha E by r square times integral which is ri to r r T r dr again a new term this is minus alpha E times T t is the temperature

you see alpha times t has the dimensional of strain and times Young's modules gives the dimensional of stress

so this is very much clear that is ah consistent in dimensions then c one plus c two r by square

so this is the case for ah temperature distributions and the plain stress again the solution looks little different when you go to the plain strain problem we are not going to do that but this is very very ah um important because normally the pressure vessels are ah um should carry ah some uh liquid or some gas ah that is some material which at at same some very high temperature

for examples the boilers it is expected to carry the the um liquid at high temperature so when the temperature distributions is uneven for the thickness for a large for the thick cylinder temperature distributions is ah um quite uneven and in that case the thermal stress may be developed and that ah has to take into considerations while designing

so these are very important thing

now this is what we have already learnt ah now today we are going to learn how to design a pressure vessel for increased pressure

that is we have seen that there is a limit of pressure which can be withstood by a cylinder a thick cylinder

for example if ((it if the mat))((00:18:47 min)) uh the material fails in tension that is by maximum normal stress then of course if the p is greater than sigma allowable then the material fails

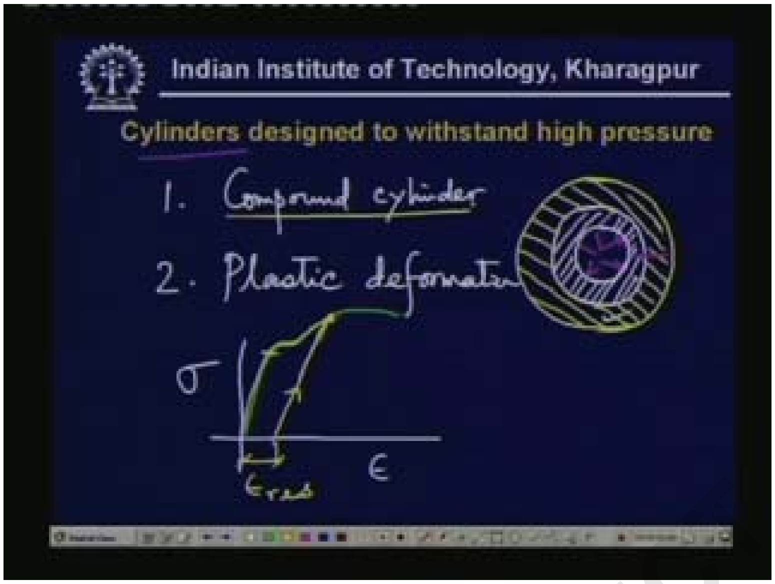
so this is ah not expected we'll have to do some thing where the material can be safe that is the cylinder can be safely designed

if it fails by shear then p if becomes ah greater than tau allowable that is allowable shear stress then it may again fail

so we'll have to design in such a way that the material doesn't fail even if p is increased significantly

so that will be the topic of today's discussions up to this we have only ah recapitulated what we have learnt so far

(Refer Slide Time: 00:19:41 min)



now [Noise] cylinders designed to withstand high pressure {with}((00:19:44 min)) how high that is higher than the limit set by the ((Lames))((00:19:49 min)) equation Lames formula

now there are two techniques that is the first technique is that by compound cylinder [Noise]

compound cylinder

what is that

suppose we have a cylinder and this is a cylinder cross section of it if we take another cylinder of ah of inner diameter which is little bit lower than the outer diameter of this cylinder this particular cylinder

and then hit it and make the diameter little larger than by hitting the diameter changes increases so if by hitting the diameter increases to ah um increases beyond the maximum diameter of this cylinder and then we put it on top of the original cylinder here and then allow it to cool

so after cooling the shrinkage takes place and the other cylinder fits tightly on the top of this particular cylinder

so this is the compound cylinder also there is another way of making this compound that is by press field that we increase we give large mechanical force in order to insert the smaller cylinder with larger outer diameter into the outer cylinder which has a smaller inner diameter

so this is the compound cylinder what happens for this compound cylinder here we are going to see that a compressive stress is developed in the compound cylinder now if the compressive stress is developed then ah um the material is under compressions so when ever we apply uh originally it is under compression

when we apply the external pressure here then of course the tension developed tension [Noise] develops over here because there was initial compressions

now with even with tensions the maximum value of the tension doesn't reach to the allowing level

so this is one way to increase the strength of the cylinder [Vocalized-Noise] sorry

then we have second method which is ((may))((00:22:28 min)) plastic deformation [Noise] [Vocalized-Noise]

a plastic deformation what happens we all know that for a material if we have a stress strain diagram something like this

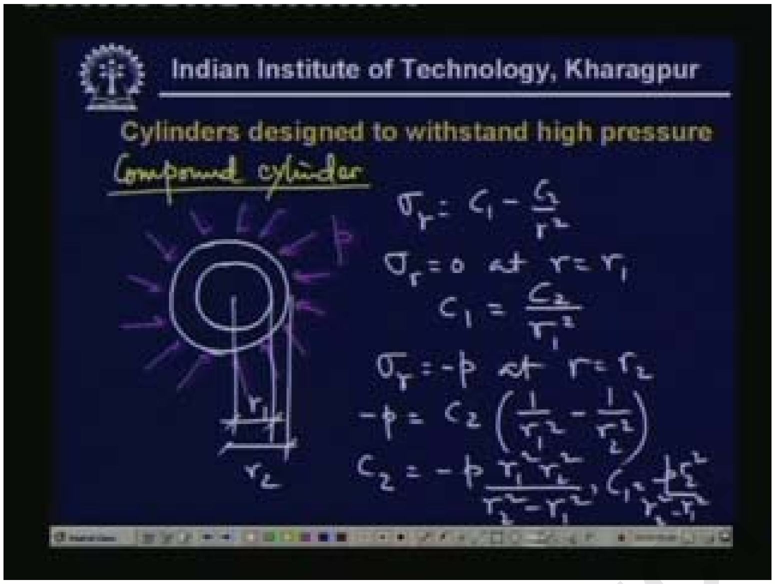
then if we give initial stress to this particular point so it increase the stress and let it go up to this point and then we release the load

then what happens is there'll be some deformation residual and then if we increase this load again then what happens it goes to this ((point)) ((00:23:19 min))

so therefore we see that the the maximum load which could be taken ah um taken by this material has increased therefore it is possible to make the cylinder withstand the high pressure by plastic deformations

but here in this class we are going to study ah the what is mean by compound cylinder and the stress analysis in a compound cylinder

(Refer Slide Time: 00:24:01 min)



so now let us see the compound cylinder [Noise] we know that if a second cylinder is placed or fitted on the top of the first cylinder then the compressive stress develops

so this is this is the inner cylinder and the compressive stress developed over here [Noise] compress compressive {force} (00:24:39 min) stress p is developed

so ah now so this is subjected to ah external external ah pressure you see this distance let us say r one suppose this is r two

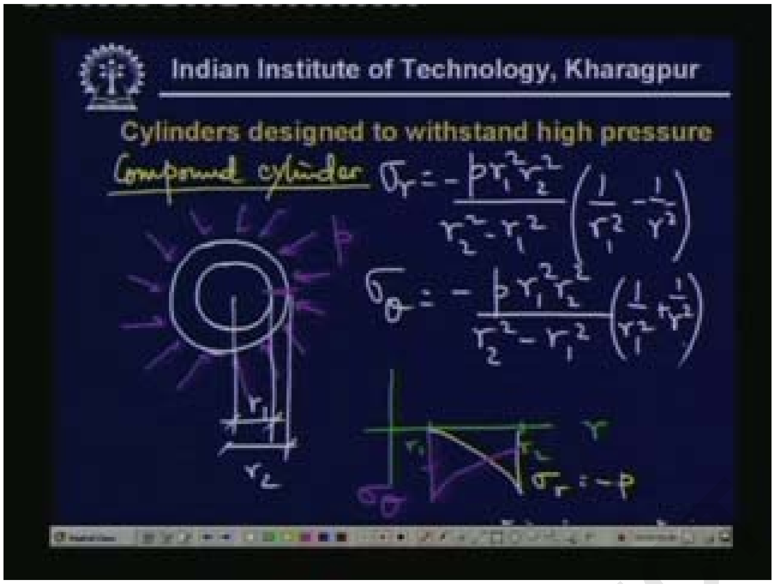
so the Lames equation is equal to sigma r is c one minus c two by r square and the boundary condition is that sigma r is equal to zero at r equal to r one which gives c one equal to c two by r one square

and sigma r equal to minus p at r equal to r two so therefore minus p is equal to sigma one c two one upon r one square minus one upon r two square

so therefore c two is equal to minus p r two square minus i am sorry r one square r two square divided by r two square minus r one square

so if you take this again substitute there c one will be equal to c two divided by r one square that is c one is minus p r two square divided by r two square minus r one square

(Refer Slide Time: 00:26:19 min)



so in that case if you take help of these two equations then what we get sigma r is equal to minus p r one square r two square divided by r two square minus r one square divided by times one by r one square minus one by r two square r square

similarly sigma theta will be equal to c one plus c two by r square and that will be equal to sigma theta will be equal to minus p r one square r two square divided by r two square minus r one square times one upon r one square plus one upon r two square

so what is the nature of the stress distribution across r one to r two it looks something like this this is r from r one to r two r two and we see sigma r is always negative and sigma theta is always negative

sigma r takes a value zero and goes to minus p over here as you can see this is sigma r this is minus p ((up to there))((00:27:44 min)) and sigma theta is quite large over here and goes to this value

so therefore sigma theta sigma theta takes a maximum value at r one and that is equal to ah um sorry this equations will be here

so this is one upon r one square plus one upon r square now the maximum value takes at r one which you can always verify ah because at r one this is twice ah twice p r two square divided by r two square minus r one square one upon r two square

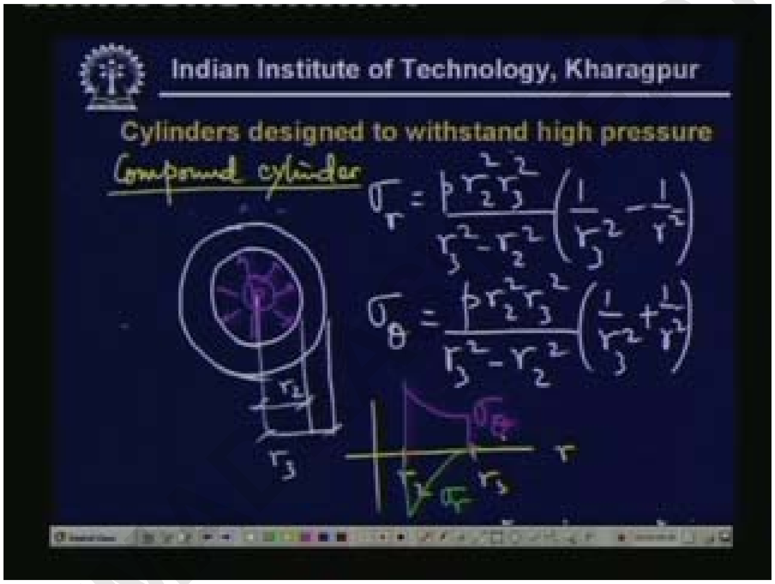
and at r two this is twice p r one square divided by r two square minus r one square which is of course ah lesser than ah lesser than this limit so therefore we say high compressive force is developed across this width now that is very effective because now we have initial stress which is compressive

now we will apply ah apply ah um apply internal force internal pressure then a tensile force will develop tensile stress will develop

and this tensile stress ah if it is ah um even if it is quite high but the resultant the stress will not be that high because of this compressive stress

now let us {lek} (00:29:19 min) look at what happens to the outer cylinder this is so far as the inner cylinder is concerned

(Refer Slide Time: 00:32:16 min)



now for the outer cylinder again what happens is that for the outer cylinder it has radius this is r two which the same as the outer radius of the inner cylinder and this is r three let us see

so now it is subjected to a pressure from inside [Noise] pressure from inside

so now what will be the stress developed

the stress developed is well known and that is from the thick cylinder formulations that is sigma r is equal to p r one square times r two square times divided by r one

sorry r two minus r one square times one by r two square minus one by r square

and sigma theta is equal to p r one square r two square divided by r two square minus r one square one upon r two square ah um i am quite sorry here because we have taken r three and r two not r one and r two so therefore let me write down it again this is equal to sigma r is p r two square r three square divided by r three square minus r two square one upon r three square minus one upon r square

you see this is always compressive and sigma theta is p r two square r three square divided by r three square minus r two square one upon r three square plus one upon r square

so this is always tensile as you can see

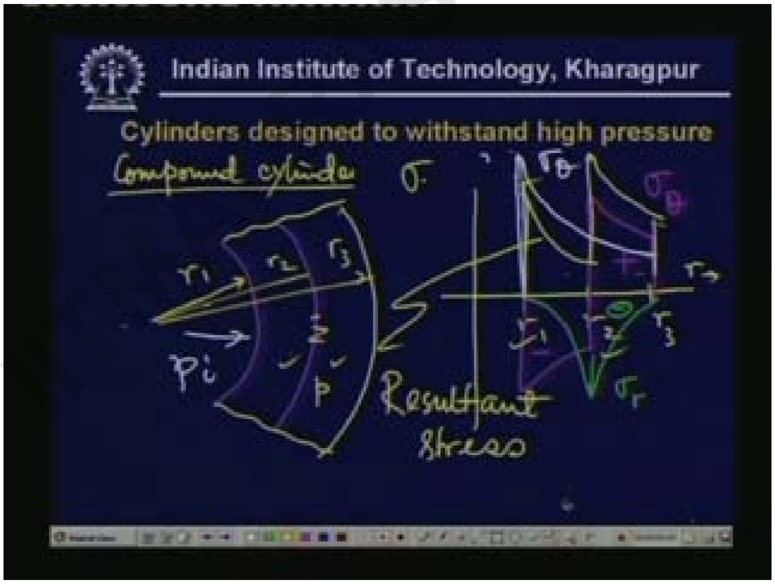
so now the stress distribution is again pretty very well known that is with r if the this is r one this is r two and r three

then this is the sigma r distribution and the other distribution is sigma theta now this is tensile ah so when we see the compress ah the compound cylinder

now look at the cylinder {overhall} (00:32:24 min) over all then what we get the following stress distribution

now this is the stress distribution only for the outer cylinder for the over all cylinder the stress distribution will be [Noise]

(Refer Slide Time: 00:32:48 min)



again if you look at the inner cylinder and this is the outer cylinder i've drawn only the part of it so this has radius r one r two and this is r three

so therefore the stress distribution will be equal to r and this is sigma we have three r one r two and r three

then the ah sigma theta distributions that is sigma theta will be here compressive then tensile so this is the rough distribution of sigma theta of course ah um sigma p uh sigma r that's the radial stress distribution will be something like this here it goes to minus p so r distribution will be something like this

so this is again positive this is negative and this is negative throughout

so this is the overall stress distributions only due to the fitting

now here you see in the inner cylinder of course we have a ah um compressive stress

now if we apply again now we apply here p i that's internal pressure

now we apply some pressure inside so therefore this in that case this could be taken the compound cylinder could be taken as one cylinder and only the the stress due to this p i the distribution of the stress will be equal to

so this is the stress distribution sigma theta only due to p i so now we see that the resultant stress distribution

resultant stress distribution is then very clearly seem to be the following that is here the resultant of this is this one then here now there is a large variations and something like this

so this is the resultant distribution [Noise]

now one thing is clear that here ah we have a large although we have a large ah pressure here but the {com} (00:35:43 min) the ah tensile stress that in the circumferential directions is quite small

and in the outer cylinder of course tensile stress is quite large but if we select the {intern} (00:35:55 min) ah the um that is the pressure that is initial the pressure properly then we can select a such a way that this two ah this two stresses are comparatively same same

that is we have we can design by a proper manner a cylinder which can which is uniform in strength at least roughly uniform because ah um here it cannot be exactly uniform it varies from one cylinder to the other cylinder but it does not vary throughout it varies it goes down again and it goes up and goes down and so on

now again we can extend it to multiple cylinder here we have considered only two cylinders but we can go easily go to the multiple cylinder

and this is very important because we have saved some material with one cylinder we have seen that if we go to the higher radius then effectively all the um the material is not subjected to any stress at all that is a very small stress compared to inner cylinder so if you go increasing r then we are loosing the material in fact because this material it is not been properly used it is not properly stressed

but if we have a compound cylinder then you see all the materials are all stressed to the same extent and they by you have saved some material

so that is very very clear from this diagram that how a material saving can be done as well as a high pressure could be withstood in a cylinder

now this is about the stress distributions i have not written down the exact stress variations which is a complicated

but i have only showed that what is the ah um what kind of stresses will appear and what is the advantage of making a compound cylinder

now remember in the derivations of course we have used this pressure p that is the pressure to ah um pressure between this two cylinders we have designated this to be p

now this was acting externally to the first cylinder and internally to the second cylinder but what is that value of p

that is very important to know because all this distribution that is this distribution and ah um that distribution will depend on on what is the value of p

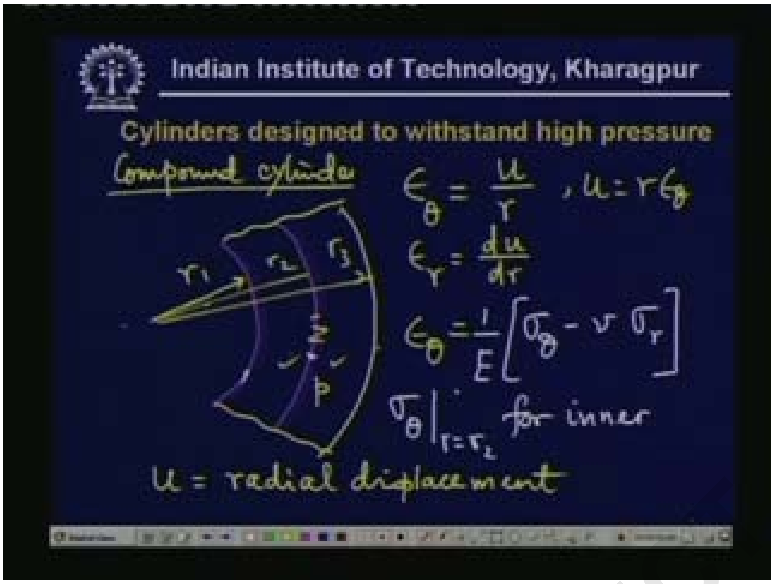
and this value of p exactly depends on the clearance between two ah cylinders

that is i have said already that the outer cylinder has inner diameter which is smaller than the outer diameter of the inner cylinder

and this difference between two cylinders this is the clearance between two cylinders is very important and it is the guiding factor in deciding what is the effect of p but how to get the value of p is statically indeterminate problem and cannot be solved unless you consider the strain into account

if you consider the strain if it((doest bring)) ((00:39:05 min)) strain into the account then what you have is

(Refer Slide Time: 00:39:13 min)



u r that is sigma theta is a strain along the circumferential direction is nothing but u divided by r that is u is the the u is the displacement along the radial direction that is the radial displacement [Noise] and r is the corresponding radius and sigma r is equal to del u or d u d r

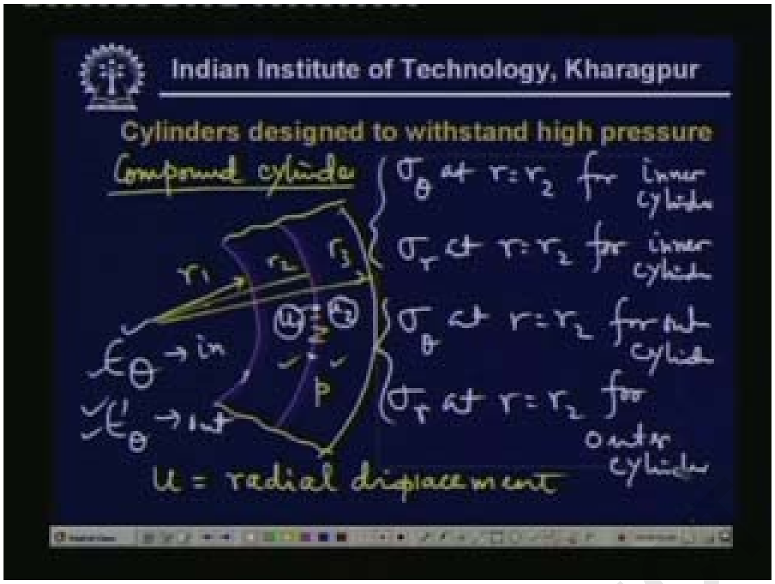
now here we have ah the following fact that u for the first case is u is r epsilon theta and epsilon theta is again if we use the Hooke's law it is one upon E times sigma theta minus nu sigma r

now for a cylinder which is not subjected to p i now of course we have to remember that we are considering only the only the effect of shrinking then sigma theta and sigma r we have to calculate in these two points

now if we calculate sigma r and sigma theta these expressions are known so we know that sigma theta for the outer cylinder that is sigma r theta r is equal to r two for the inner cylinder

inner cylinder and sigma r for r equal to r two for the inner cylinder again and we know we can calculate sigma theta and sigma r for again at r equal to r two for the outer cylinder so we calculate this two things

(Refer Slide Time: 00:41:37 min)



so this two things are to be calculated that is sigma theta at r equal to r two for inner cylinder sigma theta sigma r at r equal to r two for the inner cylinder

sigma r sigma theta at r equal to r two for outer cylinder [Noise] and sigma theta at r equal to r two for ah i am sorry sigma r at r equal to r two for outer cylinder [Noise]

so these are to be calculated and then we'll have to calculate the shear strain shear strain epsilon theta and epsilon theta dash and that is for the inner cylinder and for the outer cylinder

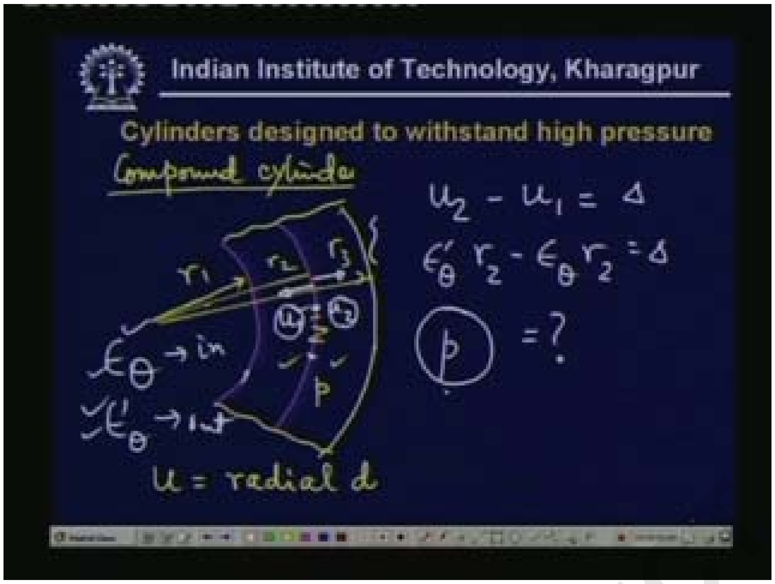
then we can calculate from this two data sigma epsilon theta at the inner cylinder and epsilon theta dash at the outer cylinder all that are equal to r two

then one epsilon theta epsilon theta prime are known then we know the u and u prime that is the displacement

the displacement of this point of any point on it when we consider the point to lie on the first cylinder let us call this to be u one and when it lies on the second cylinder then we call it u two

so it is possible to calculate u one and u two knowing this epsilon theta and epsilon theta prime and once we calculate that then[Noise]

(Refer Slide Time: 00:43:43 min)



then following relation is used that is u two that is the radial displacement

ah of the first of the of the outer cylinder minus u one why minus because there'll be a compressions in the inner cylinder

so inner cylinder this path we'll try to go in where as outer cylinder this point we'll try to go out

so the net displacement will be equal to u two minus u one and that will be equal to the clearance between these two

and once we use this formula again this is nothing but epsilon theta prime times r two minus epsilon theta r two equal to delta

and once we use again the Hooke's law we can get the value of p

so this is ah um quite easy exercise if you follow the this steps

so what we have learnt is that here we can take the pressure we can get large pressures remember because of the ah um the compressive stress developed in the inner cylinder a large pressure could be withstood by the inner cylinder because there are initial compressions

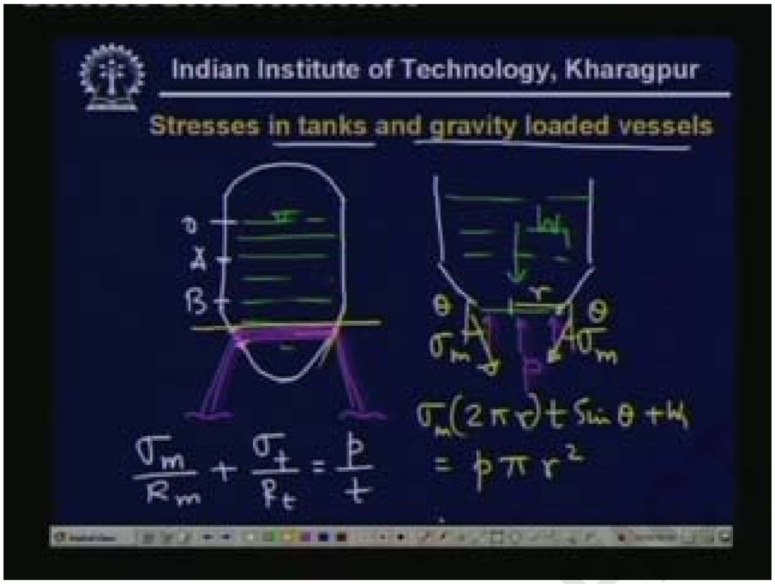
so if we apply external pressure from inside then a tensile stress is developed but that tensile stress ah is to be added to the compressive stress

so therefore the value of the resultant value of the tensile stress is much lower than the single cylinder

so therefore this technique could be used very effectively to enhance the strength of the cylinder

now this ah about the compound cylinder problem

(Refer Slide Time: 00:45:34 min)



now let us look at ah um one or two more things here we have considered only the pressure vessels

and those pressure vessels were of the ah um pressure vessels uniform but in some cases like in tanks or in gravity loaded vessels the pressure may not be uniform

and you'll have to consider the um the weight of the liquid as such

we have not considered the weight of the liquid in the design so far

so suppose this is one such tank and here it contains liquid so this is water level or level and there is a support there is a ring over here and this ring is supported

this kind of tanks we have seen very often now these are the supports now what will be the stress distribution for that

now in order to get the stress distributions we'll have to use again the formula we have derived if it is to be very thin cylinder thin ah pressure vessel

then one can use this famous ah membrane stress formula that is sigma m by Rm plus sigma t by Rt is equal to p divided by t

now p here is variable earlier in membrane stress we in thick in cylinder design we have considered p to be uniform but now p varies you see at this point the pressure is different here at point a the pressure is different and b pressure is some what different here the pressure is zero at point o

so therefore the pressure varies and therefore the stress also varies now what are the stresses

one can expect that there is stress varies but it varies continuously but one expects a sharp change in the ah in the (( )) ((00:47:41 min)) stress near the support

how to how to get that if we cut a section just above the support and draw the free body diagram then the free body diagram is [Noise]

now this is the part this is the water so the entire weight of the water above this above this stiffener or above this ring acts over here

there is a pressure the p over here and there is a stress then what is that stress there are two stresses sigma m and sigma m

now if you write down the [Vocalized-Noise] and suppose this angle is theta and theta that is the tangent makes the angle sigma theta

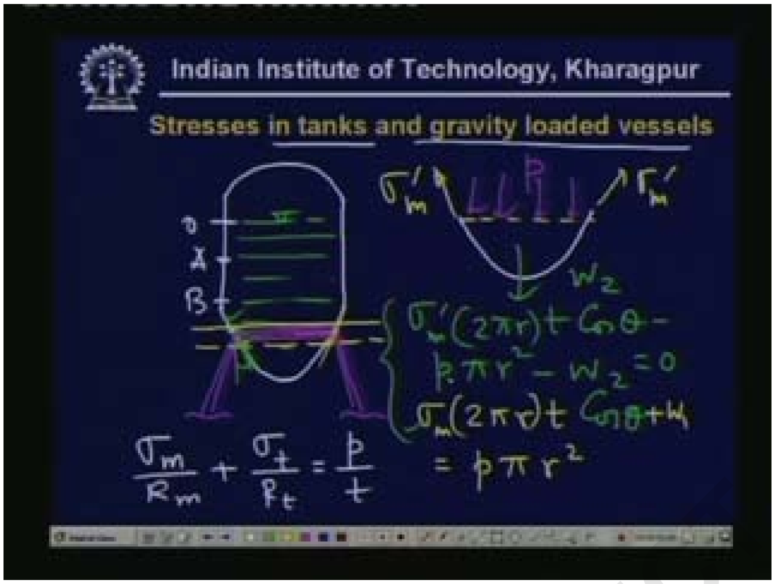
so therefore if you balance the forces then what you get is pr square the total force that is sigma m times the area of cross sections that is two pi r

the radius here is r let us say r so two two pi r times t and psi theta plus w one equal to p times pi r square

now if you take a cut so this is the equation for ah this is the stress sigma m here on top of at least a little ah um at a height little above this ring

now if you take a cut again at a point ah below the string that is the next we are going to consider the cut below it what we get is the following free body diagram

(Refer Slide Time: 00:49:48 min)



that is this is now clear we get the following free body diagram once we take a cut over here then what we get is we consider the lower part

here so we consider the lower part and then uh the stresses developed are again sigma m prime here sigma m prime and the pressure over here is the pressure is same p and the weight the weight is w two

so therefore the ah um total the equation is sigma m prime again two pi r times t and sin ah um yes sin theta ah i want to make corrections here because we have taken this angle to be theta

so this should be cosine theta and not sin theta as we have written so this is cosine theta and so this is sin theta

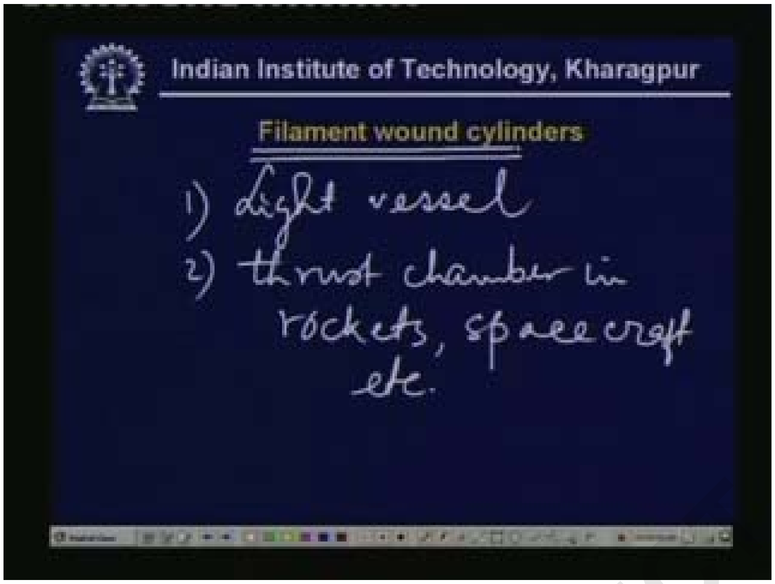
and again this is cosine theta and this minus ah p pi r square and minus w two equal to zero

so once we see once we then take this into account we see that sigma m prime minus sigma m times twice pi r t ah cosine theta will be equal to w one plus w two that is the net weight of this liquid

so that is very expected that if we take here the stress will be more than the stress over here that is sigma m will be more than sigma m prime and this ah um um and this difference will be then due to the weight

and this stress is taken by this foundations of this particular ring so this is stresses in tank and gravity loaded vessels

(Refer Slide Time: 00:52:43 min)

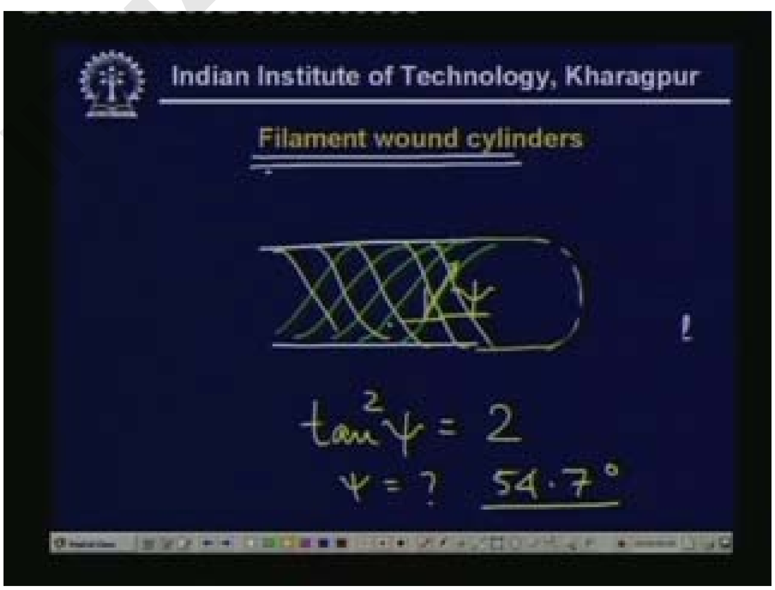


now if if we have a filament wounds cylinder then what happens that sometimes we need to get ah for the light vessels light vessels or may be the thrust chamber in rockets space craft etcetera

in that case we need the vessels to be very very light and that is done by uh making the vessel ah of fiber or composite materials sometimes we make thin a very thin metallic membrane and ah then wrap it with the filaments

so filaments are wire ropes which can take large tensile stress so if you have this if you wrap it up the entire pressure vessel by this filament then a large stress could be could be taken

(Refer Slide Time: 00:53:45 min)



so if you consider the following case then that there is a pressure vessel and there are filaments over here throughout and similarly this is wrapped from the other side [Noise]

so this wrapping depends up on what is the type of this ((head))((00:53:59 min)) so so in one directions it is ((helically))((00:54:03 min)) wrapped then again on the cylinder ((head))((00:54:09 min)) it is wrapped it is taken wound and taken to the other side

so there is {integrated patte }((00:54:09 min)) so there is a integrated pattern of wrapping over here but if we consider this particular angle

let us say psi wrap angle then after we make all the necessary calculations we can take the tan psi if you make out the ah um the free body diagrams which i am not going to do tan square psi is roughly two

so with this we can calculate what is psi and this is about fifty-four point seven degree

so if you make this kind this angle of wrap then it can sustain the pressure the ah um in the same way as a cylinder

so this is very very effective technique

now what we ah have learnt so far first we have learnt how to make a stress calculations for a thin cylinder for a thick cylinder

then for the thick cylinder it is not possible to withstand the pressure very high pressure with the single cylinder alone so therefore we go for compound cylinder

in compound cylinder we ah we ah um wrap the cylinder that is we in we take another cylinder whose inner diameter is little below the outer diameter of the original cylinder

and shrink it that is press it by mechanically or thermal processes

so once this ah pressing is done then it develops internal pressures compressive {pressure}((00:55:31 min)) forces compressive stress

and then it can ((take))((00:55:34 min)) a large tensile stress that is tensile ah that is large ah um internal pressure ah um without failing

so this is very effective technique

there are other cases which we have studied one is tank and gravity loaded vessels and the last we have studied the filament wound cylinder

of course these are very much useful but we didn’t have enough time to discuss of about this so if you are interested you should read from some good books

so this is all from today about the cylinders

so in the next class we begin a new topic

so till then good bye thank you

Preview of next lecture

Transcriber's Name: Gauthami Bhandary

Design of Machine Elements - 1

Prof.G.Chakraborty

Department of Civil Engineering

Indian Institute of Technology, Kharagpur

Machine Design - 1

Lecture No. #39

Design of Breaks-1

dear student let us begin lectures on machine design part one this is lecture number thirty-nine and topic is design of breaks

now there cannot be any doubt that breaks is one of the very important members of the machine the breaks are used normally ah to reduce the speed of some moving components

that is to dissipate the kinetic energy of a moving system to some other form of energy for example heat normally this is heat

now there is a very similar ah component in machine normally ah um this is called clutch but the difference is that in the clutch ah um the two moving parts are {bring in}((00:57:20 min)) are brought ah into um ah ((sincronsity))((00:57:23 min))

that is ah the speed of two parts are brought to the same and in the clutch is the two parts are ah um both of them are moving

where as in breaks one part is normally kept stationery but in both the cases the ah the energy is transferred from one part to the other by means of friction

so here in this members breaks are clutches the friction force plays a dominant role so friction force is a very complicated force and ah normally it is modeled to be ah um a ((Coulomb))((00:58:01 min)) frictions where the friction force is proportional to the friction force applied

so this is very much known to you that ah that how to model a ((Coulomb))((00:58:09 min)) frictions force

but normally ah let me point out that ah in typical situations the friction force the modeling a friction force is a very complicated task because the friction is a microscopic phenomenon

and in order to bring it into the macroscopic scale then many assumptions are to be made so normally we make this assumptions ((named after Coulomb))((00:58:34 min))

so ah the