Design of Machine Elements – I

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Lecture No - 22

Rivet Joints

dear student welcome to the video lectures on machine design part one

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this is lecture number twenty-two and the topic is design of riveted joints

now in the last few lectures you were taught how to design one non-permanent joint non-permanent in the sense that [Vocalized-Noise] the joints are such that any time they could be dismantled or {desas} (00:01:13) de assembled disassembled if the requirement arises

so this are the non-permanent type joints there is another kind of joint which is known as the permanent fasteners or permanent joints

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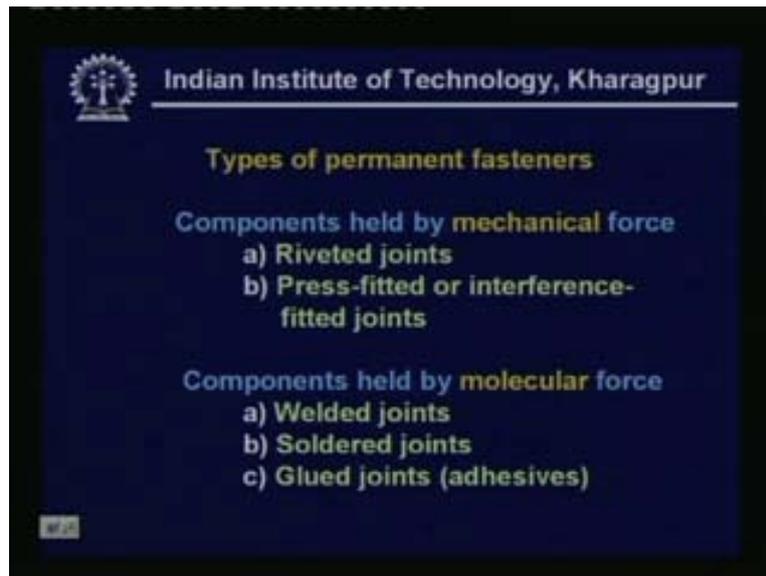
so let us come to the types of permanent fasteners again the permanent fasteners are those fasteners where the components can be disassembled only by ah damaging those components

so here the these are permanent joints now again the components are held by two methods they may be held by mechanical force that is we give a large mechanical force such that they are held together there are two {examp} (00:02:00) two cases two examples one is the riveted joints which will be the subject matter of today's lecture the second is press-fitted or interference-fitted joint this is again will be taught in somewhat in details ah later afterwards um but here the purpose of the joint is that we press the press one part into the other and make a joint a permanent joint

the components could be held together by molecular force there may be few situations that is we talk of welded joints we may talk of the soldered joints and we talk of glued joints or using the adhesives

so these are very important joints and will be discussed later on

so now we start discussing on the riveted joints

now let us come to the basic geometry and the types of rivets we must know what is a riveted joint how does a rivet look like and so on so let us see

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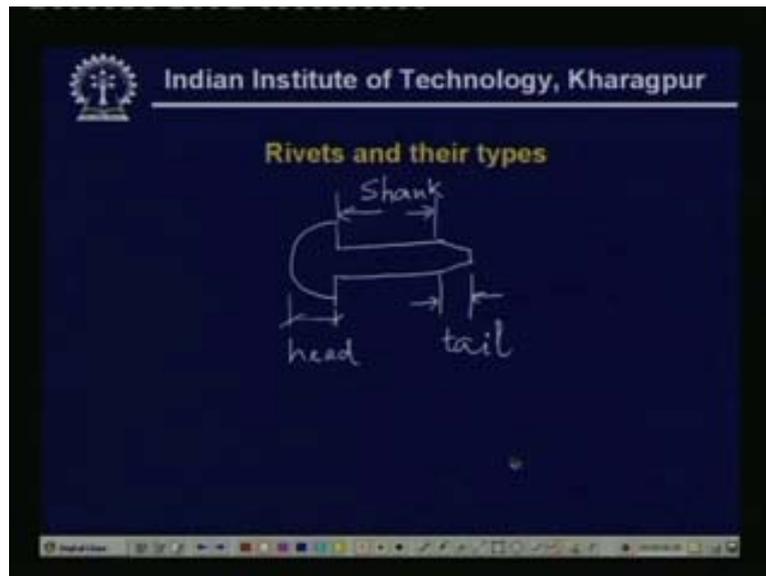
a rivet it {consis} (00:03:11) it looks like the following

so this is the rivet now this part which is which looks rounded is known as the head and this part which is roughly cylindrical in shape this is known as this is known as the shank and this one which is tapered its known as tail

now this kind of [Vocalized-Noise] rivet is made by forging there may be hot forging or cold forging which you know already

now how a joint is made with the help of this rivet let us look at the joint

what we have here

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let us say we want to join two pieces together so this is part of this is a part and this is another plate

now we want to join them together what do you do first drill a hole or sometimes punch a hole if the plate is very thin then we should drill a hole and uh {als} (00:04:53) of course ah if the plate is too ah thick then we cannot punch because it causes lot of stress so we drill a hole now the what will be the diameter of the hole that is again specified by the standard depending on ah the size of the the diameter of the rivet at the shank that is a shank diameter of the rivet ah the hole size is selected this is selected according to the standard

what we do then we drill a hole so this is a hole and then again we insert the rivet this is the head part and this is the tail part we hold this by a fixture or a ah die together that is this is a die or this is the fixture and then [Vocalized-Noise] we bring another die which has the similar shape this die is brought in and then we apply pressure

now that could be done by hand or by some machine some power driven system and then it gets deformed this tail part gets deformed and when the complete deformation has taken place we get ah the following shape

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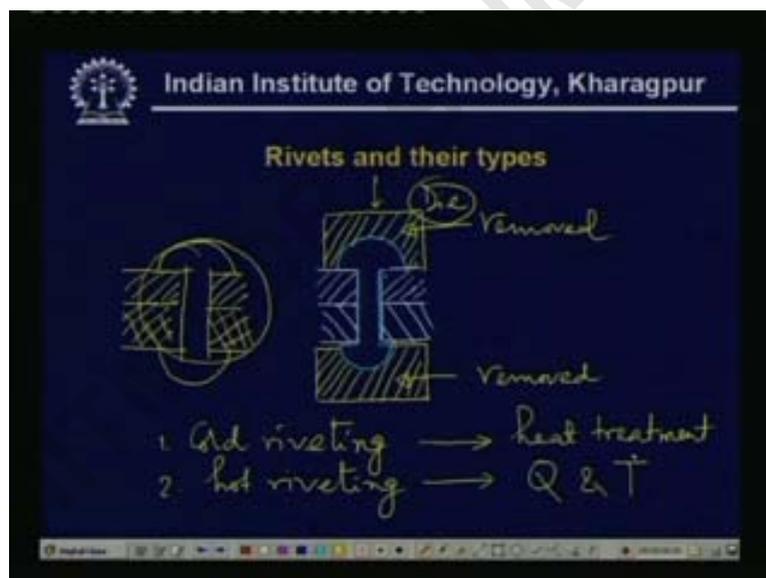
so this is the permanent [Vocalized-Noise] {fih} (00:07:26) permanent joint made then we remove these two dies that is this are now removed this is known as die and this is to be removed

then what we get a joint which looks so this is the riveted joint now you see that it cannot be taken out without damaging this entire members so this part of the member ah part of the plate has to be damaged and then it could be dissembled ah so this is about the rivets ah now you see that in order to make the rivets we have to give a large force

so therefore a compression will take place and with compressions there will be the stress developed so we have to relief this stress now there are two kinds of riveting one is known as the cold riveting where the mechanical force is given to the cold rivet then a large residual stress develop and we will have to relief this residual stress by heat treatment

so cold riveting followed by heat treatment there may be another process which is the hot riveting that is first this tail part is brought to a temperature where is a large temperature of let us say thousand degree {centi} (00:09:20) Celsius and then uh it is forged now once the deformation takes place then we have to cool it so there will be a tempering or quenching and tempering then it has to be made with a ah specific standard because otherwise we may get ah the {compre} (00:09:39) uh different kinds of stress developed into the member

so these are the different types of ah the riveting process

now [Vocalized-Noise] the rivets could be used mainly for structural joints that is the ah it it is it's purpose is to take up some load right

so it is also used to make a joint fluid ah leak proof that is the joint has to be fluid tight and then we have to do certain extra ah process extra care so there is those are um named as Fullering or Caul king

so we have what is known as Caul king or Fullering to make the joint leak proof now this we have to read from the book there are ah various methods of Caul king or Fullering so you have to ah look at some reference book

what we can study now is what are the different types of rivets used now for that we look up to some figure

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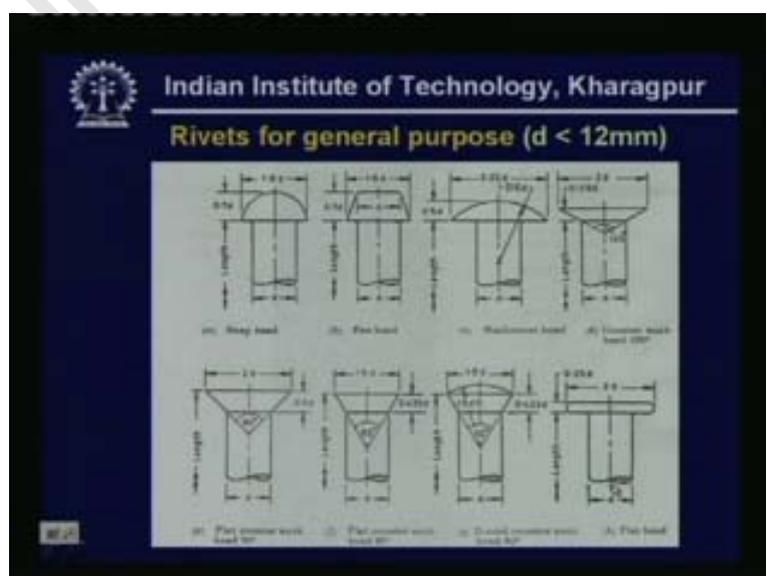
now here these are the rivets for general purpose now there are rivets for general purpose that is to ah to be used in the structural member there are rivets for boilers that is whenever we have a pressure vessels we need the pressure vessels to be leak proof and therefore extra care has to be taken to make this joint a ah fluid tight

so there are different ah altogether different kinds of rivets available for the boilers now let us look at rivets for general purpose now if the diameter of the hole is less than twelve millimetre then we use the following types of rivets

again this are made to some IS standard there are standard available you open up any book and machine design hand book you will see those standards

here you see here the head is little bit hemispherical so this is known as the snap head

we have this span headed which looks somewhat like a trapezium here because this is in nothing but a conical ah uh (( )) (00:12:21) shaped here the diameter is d and this diameter that is diameter of the held uh of the head is minimum one point six times d normally ah the diameter is taken to be one point five two two times of d also there will be cases where we get more than two times that is here you see in the mushroom head ah rivets we have two point two five times d now it looks relatively flat this face we have counter shank head one twenty degree angle

so this is again another type of rivet where the diameter is two d again this is flat counter shank head which is which has including angle ninety degree

we have another type which has including angle sixty degree then this is round counter shank instead of here a flat surface we have a rounded surface as you see here then we have a flat head that is here the head is really a flat and there is no counter shank

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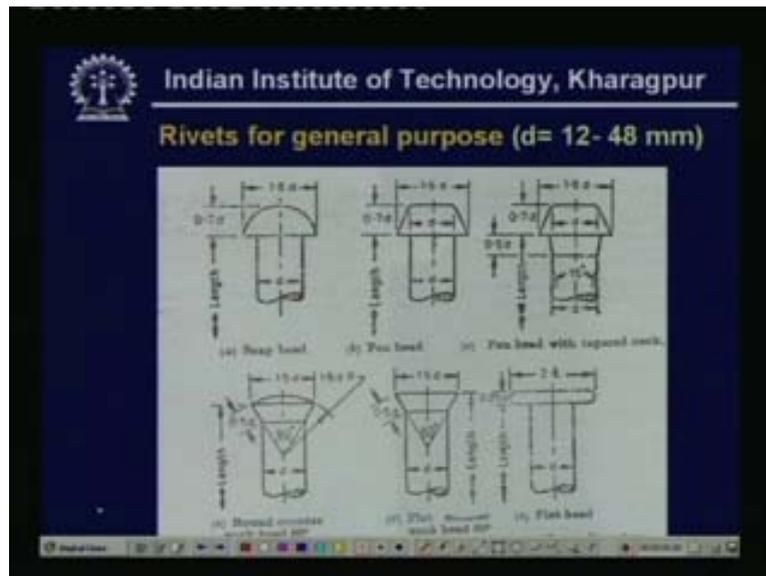
then if the diameter is more than twelve millimetre {bush} (00:13:44) but less than forty-eight millimetre then we have this kinds of rivets

one is snap head here again it looks very much similar {wa} (00:13:53) the distance here is one point sixty we have pan head now this is the length we measure the length from this part here the height is point seven again the height here is point seven so this is pan head

now here the pan head with taper neck here the neck is little taper because it has a large ah large diameter so there is a chance that there may be stress concentration here so we make the neck little tapered

we have a round counter shank head sixty degree this you are acquainted with now because in last slide i showed this kind then flat counter shank head with sixty degree angle and then flat head this looks almost the same as that which were shown earlier now this are the rivets for general purpose

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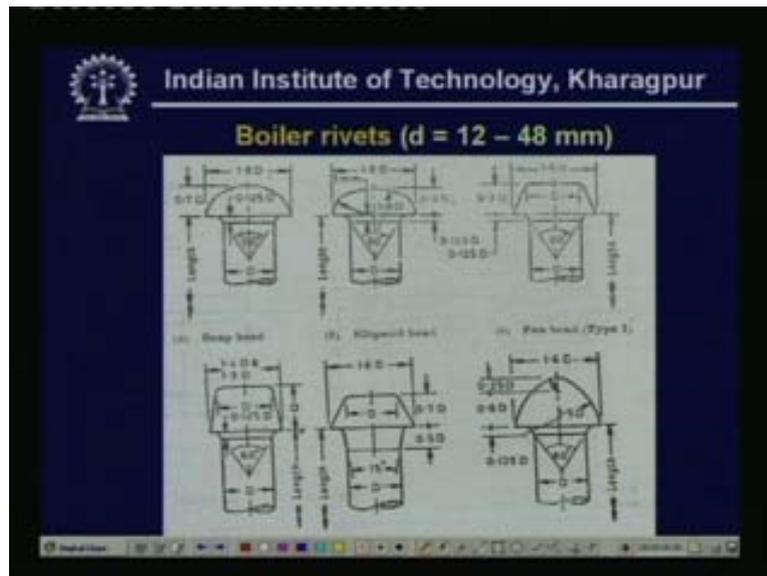
now when we go for rivets for the boilers then we come across the following types

here this is again snap head but now it has a shoulder okay here you see the neck then we have ellipsoid head here the shape is ellipsoid now these are made again by dies so by forging

then we have a pan head it looks very similar but now here we have this kind of neck okay now here invariable you will see that in boiler boiler rivets you will have always this necks now these are used for ah fullering or Caul king that is to make the joint ah fluid tight

then we have again the pan head but here the ah this a angle is sixty degree so we have kind of pan head then again this kind and we have this {typ} (00:15:51) this shape here here this very curious looking shape but this is manufactured okay so these are the rivets ah used mainly in boiler

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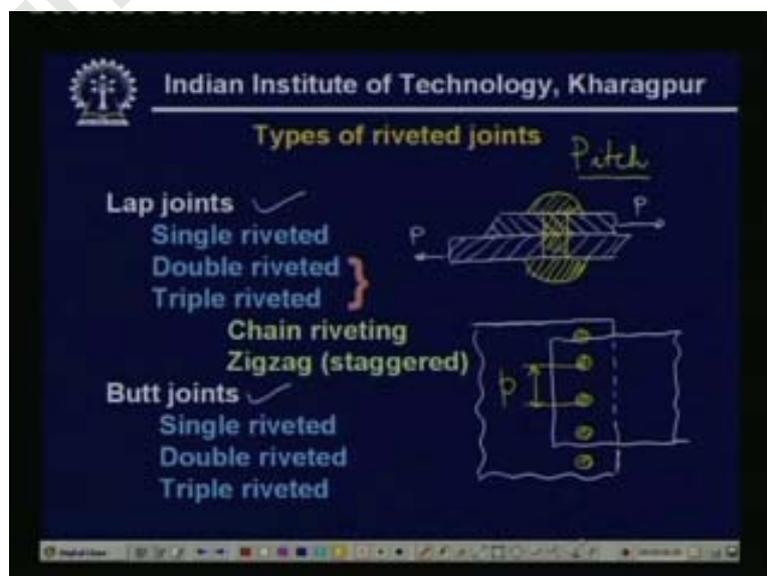
now we come to the point so [Vocalized-Noise] we we should know how many types of riveted joints are available

now the riveted joints are mainly of two types one is lap joint and one is butt joint now let us discuss one by one

lap joints suppose uh i want to join two plates then one way of joining will be to ah bring two surfaces one above the other and then make a rivet

so here is a rivet so this is the rivet now this kind of joint is known as lap joint

if you look from the top then we have rivets here number of rivets this two are the parts of the two plates now here these are the uh this row is the row of rivets now here this is single riveted now important thing is this distance between two consecutive rivets in a column that is or in a row you can say so this distance is called the pitch of the rivet pitch

we can have also double rivet now there are few possibilities you see

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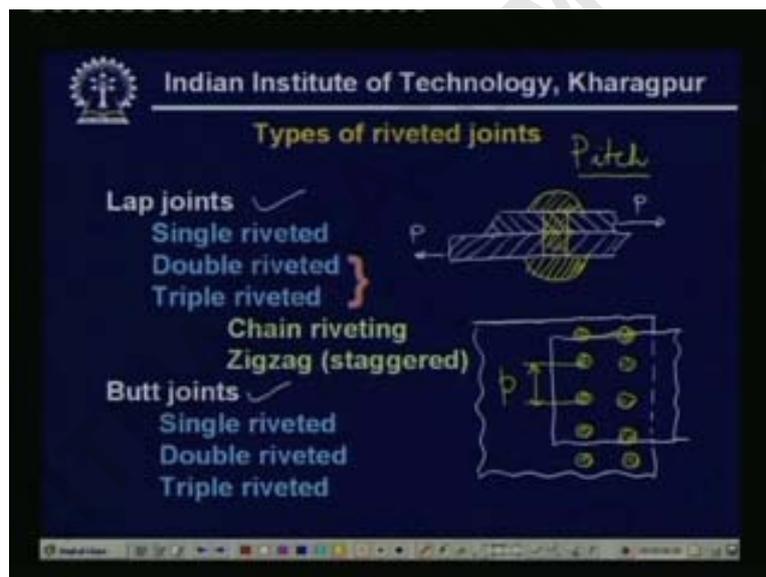
there may be a rivet which is in that fashion that is there are two rows double rivet and then this double rivets will be in chain riveting that is these everywhere there will be in a single row or in a {si} (00:19:27) single line there will be two rivets okay

if it is triple riveted then there may be case where in a single line there are three rivets so this is the chain riveting

there may be a situation where instead of chain riveting we have a zigzag or staggered riveting how does it look like it looks like

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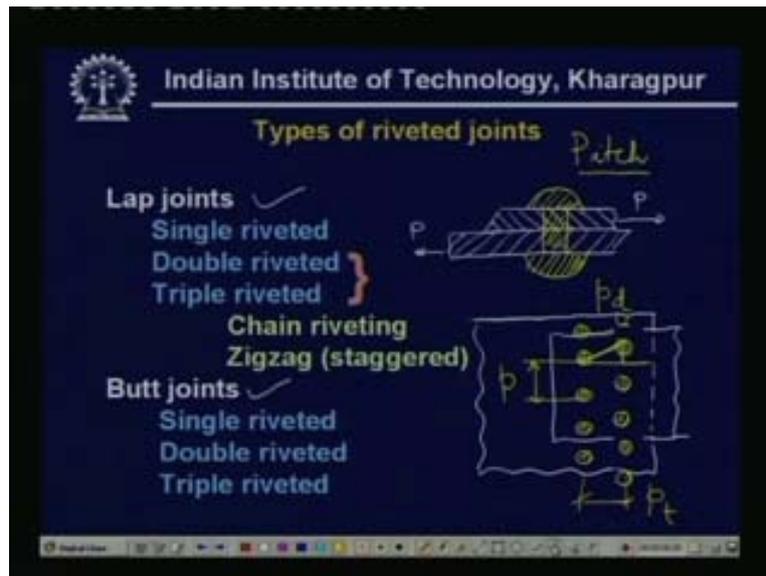
the following here we have a rivet here we have a rivet and so on so now there is a distance now this is not on the same line but it is little distance away

now this length is known as pt that is the transverse pitch now it earlier it was pitch now it is transverse pitch and this length that is p this length diagonal length this pd called the diametrical pitch

now you see the see that there is a relation existing between p pd and pt that is very easy to derive

now this are all about the lap joints there may be a triple riveted just like double riveted there may be triple riveted quad triple riveted etcetera etcetera

butt joints how does the butt joint look like now butt joints will be

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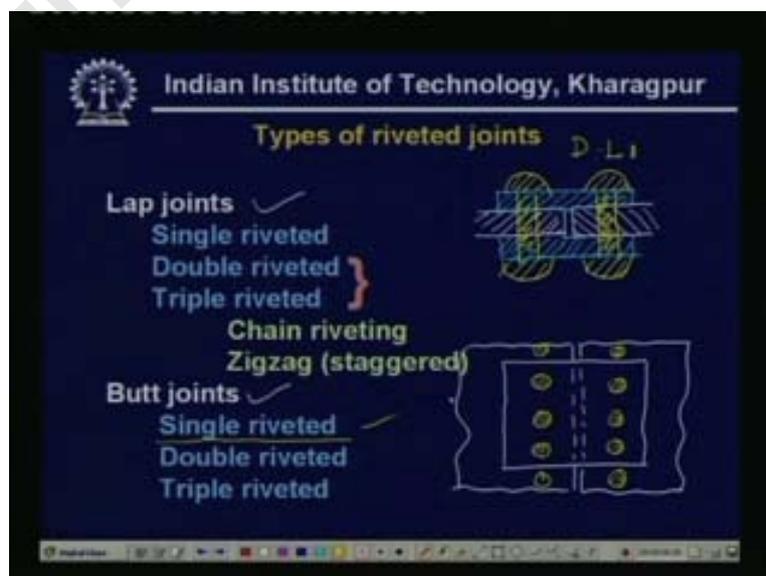
here we have two plates which are kept face to face that is no overlap between so these are two faces of the plates to be joined we bring one cover there so there should be one cover so this is a single cover butt joint there may be double cover also

so there are two covers and through this cover and the plate we insert the rivet that is there is a rivet through through okay this is the rivet

now this is known as the butt joint

now if you look from top there there is the cover plate and there are two plates which are to be joined together and there are rivets throughout

so this is again a single riveted butt joint

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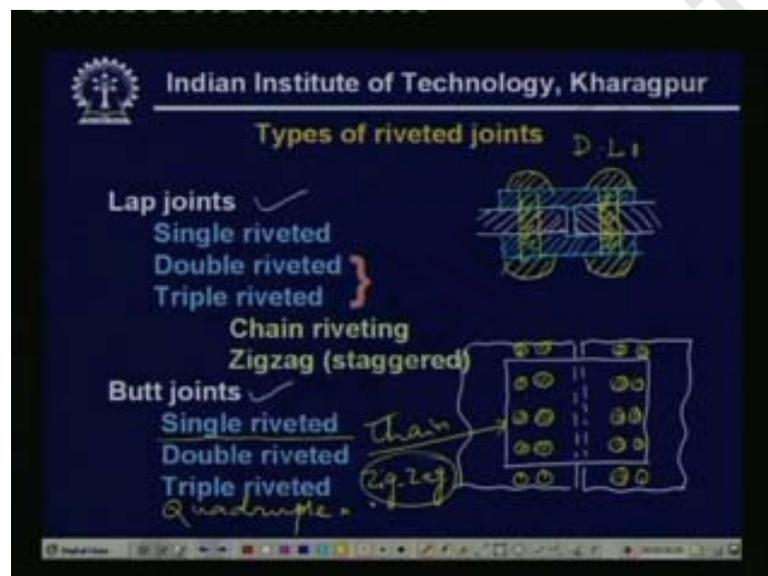
there may be two rivets that is a double riveted butt joints is possible

so there are two rivets and this is again a double riveted chain type so this is chain riveting

we can also have ah double riveted joint which is in zigzag pattern {ith} (00:23:45) it is just like the lap joint which i had drawn earlier

we can have triple riveted again chain riveting or zigzag riveting we can have quadruple quadruple riveted which can may be zigzag or chain riveting configurations

now this are the different types of riveted joints

what we now consider is the design of a riveted joint

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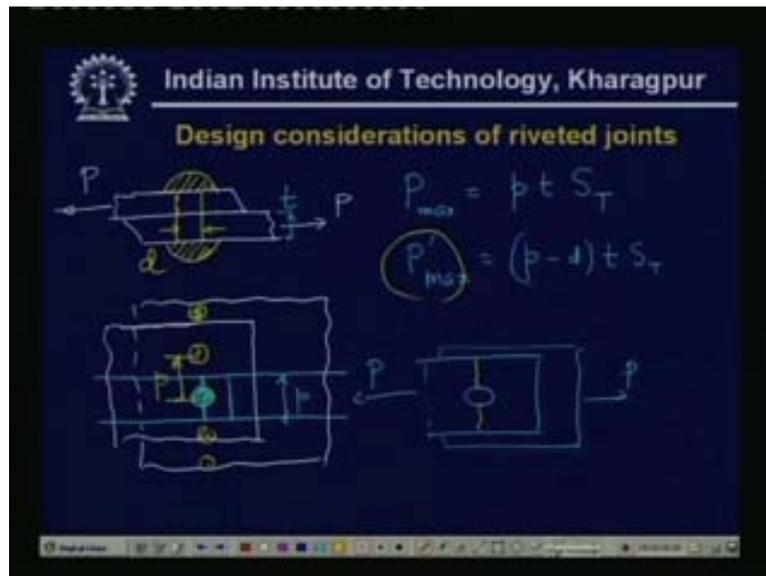
now what you see is that [Vocalized-Noise] suppose we consider uh a lap joint

let us consider a lap joint with only one single riveted now if you look at the plate now it will be subjected to pressure this two plates are subjected to pressure because it has to take some load now we have this rivet over here so on

the distance between two rivets is the pitch and the diameter of the rivet let us say d

now you see without the rivet the suppose instead of making it a joint we had one single piece single piece of the plate then it's how much strength it could have taken

suppose we have a plate of of width let us say p we take this much plate distance p which this lies half between the {boh} (00:26:21) ah the rivet lies half way between these two lines

so therefore if you take a plate of width p then how much load can it withstand the maximum load which could be withstood is P max is equal to the area suppose we take the {tot} (00:26:41) the cross section that is the width t so p times t times the allowable or that is the ah strength in tension so this is the maximum load which could be taken by this plate

we may have now with the with the rivet it's area of cross section is reduced now here you see the entire area now gets reduced by this amount there is a hole so therefore with rivet suppose now with rivet the maximum load which could be taken is now p minus d because this is the effective area available the length is p minus d something has been eaten away by this rivet p minus d times t times ST

if you take more load then what will happen it will tear so this is the plate here if you pull it then it may tear somewhere here

so it will tear so in order to prevent this tearing we will have to restrict our maximum force to this limit

now sometimes we talk of the efficiency of the plate now here what is the efficiency of the plate the efficiency of the plate is the the load maximum load carried by the plate with rivet divided by the maximum load carried by the plate without rivet

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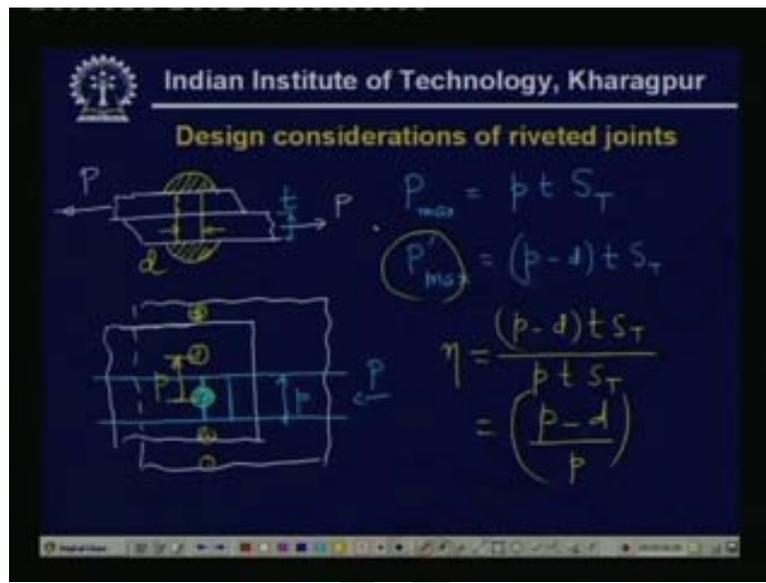
maximum load carried by the plate with rivet is p minus d times t ST and without rivet it is p t ST so therefore the efficiency is p minus d by p

now so you see the efficiency is very important because the maximum load capacity has gone down by some amount

so while designing a joint we will have to uh we will have to design such a way that ah the entire load that is the the thickness or some other parameters has to be chosen taking care of this efficiency or the fact that the joint has been weakened by introducing some foreign elements like rivets

we can have also other types of failure what you see here is the failure of the plate now the joint may also fail by shearing that's what we see next

now here this is the the configurations without any ah well breaking now it can fail suppose there is a movement

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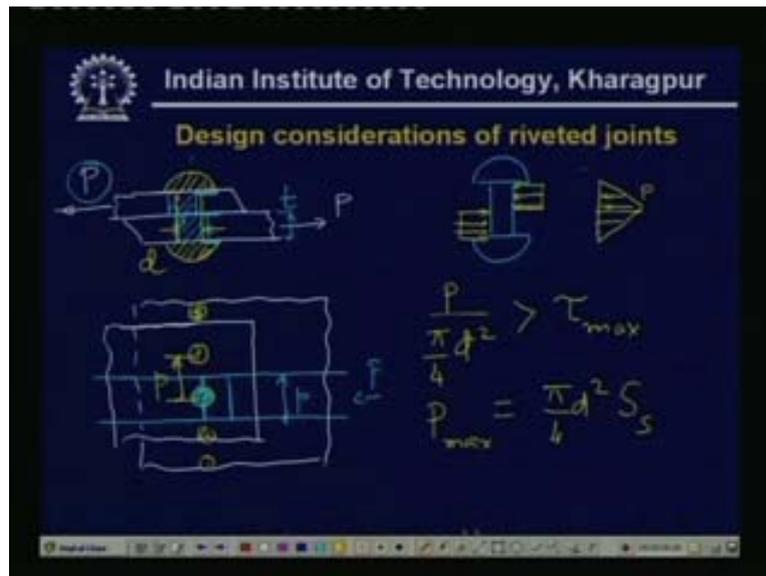
so suppose the p is such that it moves this way so this part has moved

so instead we have a rivet now it was subjected to force now when we make rivets it is subjected to the normal force right so there is a compressive force between the rivet head as well as the plate between two plates and as well as here between the two between the rivet plates and the head

so therefore a lot of friction force will be developed and when we apply small p so this p could be taken by this friction force itself but if we increase the p then the friction force gives away and then because there is always some ah clearance between the rivet diameter and the hole diameter so therefore one part of the plate will be in contact with the rivet and the other part of the plate ah will be will be ah will be loose

similarly for the lower plate the opposite part will be in contact and the other part will be again loose so therefore when we have this kind of situation if p is large enough then we have the force distribution something like this force distribution on the therefore we see what will happen

now this this part of this rivet is subjected to shear force the shear force distribution looks somewhat like this maximum shear force is P so therefore if P is such that P by the area of this rivet that is pie by four d square if this exceeds tow max then the failure will take place okay again with the shear force there may be bending but if the if the length is too small then the bending could be neglected but the bending may really occur

so now ah we we come to the case so this is the shear force distribution the maximum shear stress is given here so therefore the maximum P max due to shear must be equal to pie by four d square times S in shear that is the ah strength in shear [Vocalized-Noise]

now this is for the lap joint suppose we consider a butt joint instead of a lap joint then what will happen then you see for a butt joint

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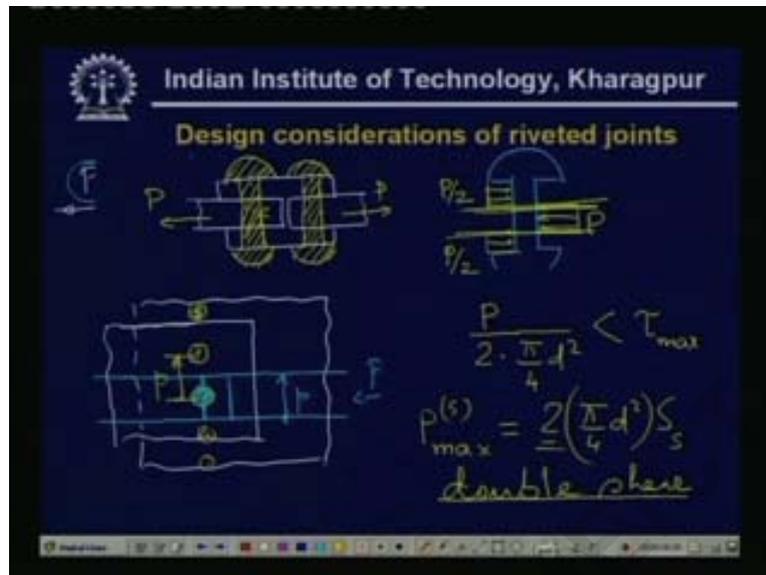
we have cover plates and there are rivets okay there are again a single butt joints

now if you pull it by a force P and P then if the P is large enough then what happens then the bolt will be {subje} (00:34:09) ah the rivet will be subjected to different kind of pressure distribution here this is the rivet and this part this part is subjected to a large pressure P and half will be taken by this cover plate and the half will be taken by this one so therefore now we have the maximum that is shear the shear will take place and we have the maximum shear stress to be now

now maximum shear stress is P by two here because you you you can verify from ah this distribution that here if if this is the total is P then it will be taken P by two P by two therefore in this section the shear force will be P by two and this will be taken by the area and that must be less than T max

so therefore the maximum load that can be taken without shearing the rivet is now so P max in shear will be equal to twice pie by four d square Ss

so now this is in double shear because you see from the last expressions we have multiply a by a factor two that is that comes because of the two cover plates so it has taken half the load ah with the cover plates

now this is how we can carry more load with the help of a butt joint double cover plated butt join

now with a single cover plated {blut} (00:36:34) joint butt joint of course again the P max will be same as a lap joint that is pie by four d square Ss

now this is another type of failure of the rivet joint now we come to other type of failure that is

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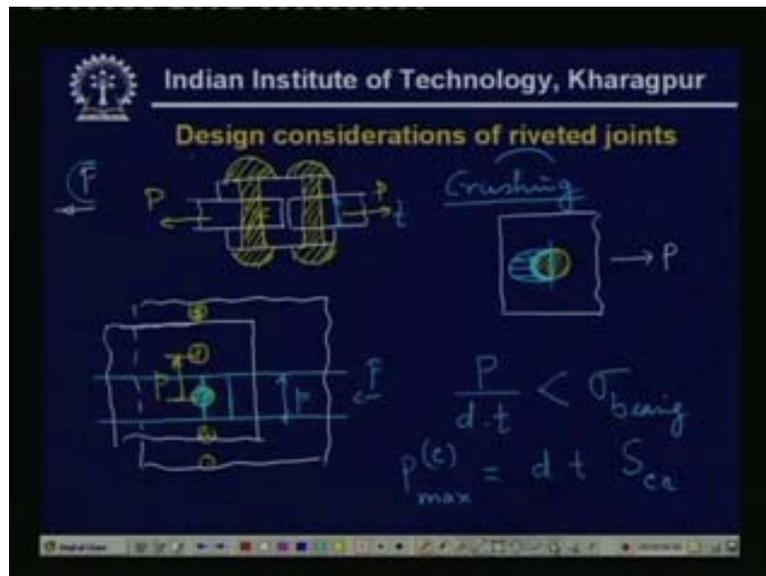
when we look from the top on one joint then what we see is that and here is a rivet

now what we see is that this rivet is subjected to other kinds of pressure also so here we have a distributed force etcetera now if this contact force is too high then this part may be damaged so this is a crushing right so we have the crushing failure and [Vocalized-Noise] although this is distributed but ah the stress the average stress developed will be equal to P divided by the the area or the bearing area which is equal to the projected area which is d times times the thickness that is if the {who} (00:38:12) thickness is t this will be the bearing stress and that must be less than equal to sigma bearing

so now we can take a maximum load to be P max in crushing will be equal to d t d times t times S crushing which is the crushing strength

now this again the value of S crushing or the shear strength etcetera those are available from ah from the table on the literature they are available in the machine design hand book you can have a look at them if you wish

now this are the different types of failure another interesting kind of failure may occur at the margin how does it look like suppose

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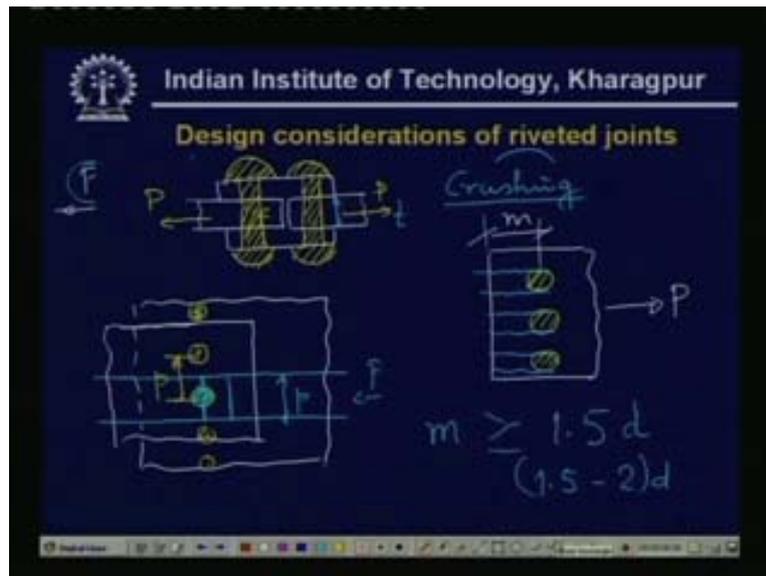
we have a plate and the rivets are placed here it is subjected to a force P now if this length is known as the margin m

now it may happen that if the if this length is too low that is m is too small then the failure may take place here so entire thing may shear off okay

so therefore this kind of failure again can be prevented if we take m sufficiently large and normal practice is that m is to be taken more than one point five times the d normally it is taken to be one point five to two times d so if this safe distance is kept then this failure could be avoided

now this are ah the types of failure for the single riveted joint

there is one thing called the joint efficiency and this is defined that way that is we now define the joint efficiency

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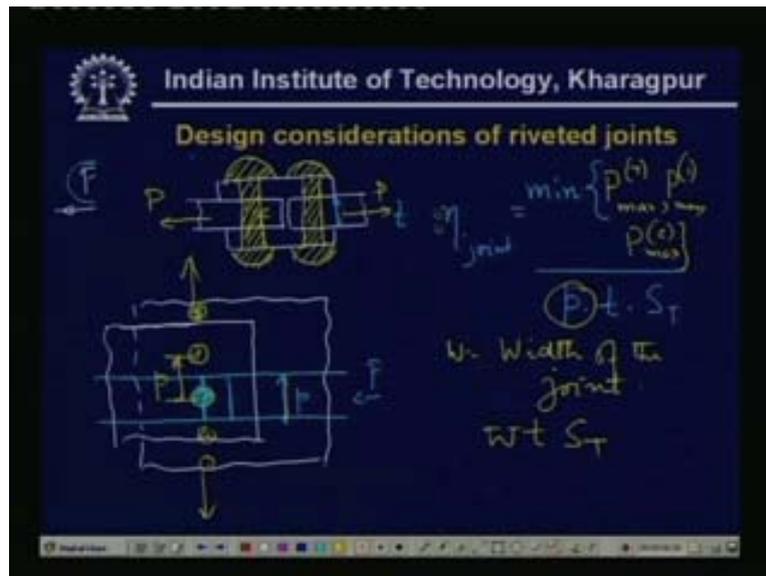
joint efficiency is the maximum load that could be carried and this this is definitely the minimum of those loads minimum of P in tension P max in tension that is the tearing P max in shear and P max in compression

we will have to take the minimum of that divided by P max without any ah without any rivet and that was p minus d times t times ah i am sorry this is p times t p times t times ST

so this is how joint efficiency is defined now here you might have noted that we have defined the joint efficiency for one pitch length only

now when there is a running ah pattern that is a row is formed for a large distance then we can define the joint efficiency for a single pitch

if we consider the structural joints which has finite width then we consider the joint efficiency for the entire joint and in that case this P has to be replaced by w that is the width of the of the joint

definitely this is the total load taken by this joint uh had it been a one single join uh single uh plate and not uh the jointed plates okay

so [Vocalized-Noise] this is how efficiency of the joint is defined but we have defined the failure patterns we have ah discussed the failure patterns for a single change but chain but if ah there are more number of chains then various interesting and many other complicated things may happen

take for example

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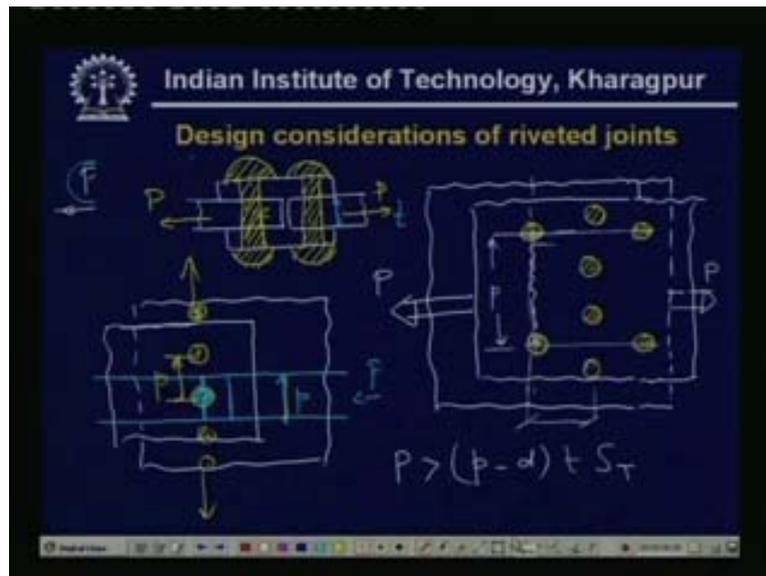
a case where there are more number of so it may so happen that let me and so on

let us say this kind of case okay then this is the pitch this is the pitch and there are more number of (( )) (00:45:12) more number of rivets in the second row than the first row

so therefore how many types of failure could occur suppose the P is large enough um suppose the force is applied here there is a large pres force applied and similarly force is applied there

so [Vocalized-Noise] a force is applied there so therefore here it may tear from this point this row okay so if the pressure of the or the force is such that if p is for example greater than p minus d now again we consider the part of the joint which has width p so therefore if you consider this part then here the cross section area will be equal to p minus twice the radius of this bolts because there ah or the rivets because there are two rivets which participate half of which participate every time so this is p minus d this distance and this times t the thickness of the plate times ST

if P is greater than that then what happens then this part will be torned but there are other possibilities also now it may so happen that this part doesn't get torned but something else that is

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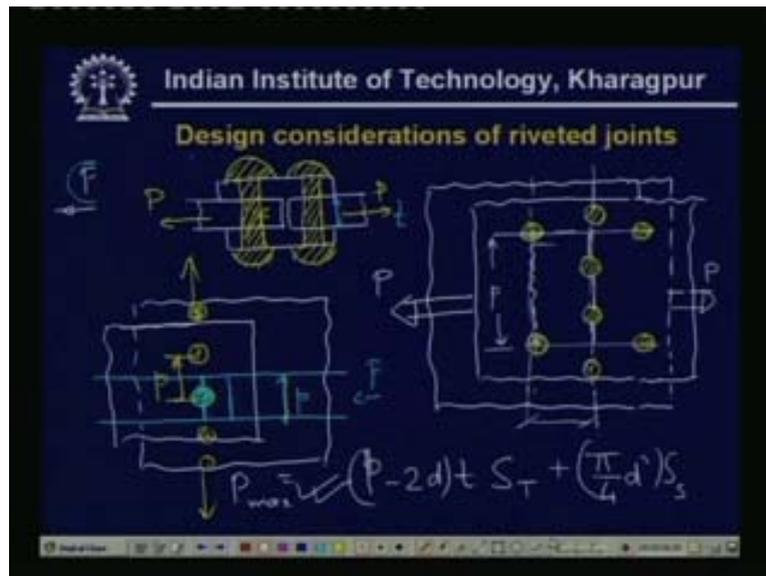
here suppose it t this this row tears this row tears then what will what will happen then the tearing force necessary will be equal to the tearing force necessary will be p minus two d times {sie} (00:47:28) sigma ah times t times ST and then once it gets torned but it can be torned only by crushing or ah shearing of this

so once this happens then it is to be sheared so the shearing takes place and ah therefore the net force taken for shearing will be equal to equal to ah pie by four d square times Ss

so this is the net force required to tear this part okay and so we can define the efficiency that is the force required to t to ah for the joint to be broken divided by the force it can withstand so we will have to define the efficiency by a using this formula that is this is the P maximum which could be taken [Vocalized-Noise]

in a multiple that is single or double or triple {rive} (00:48:41) triple rivet ah then there uh there arise many such kinds of possibilities

again we have when we have different uh rows then the the joints may fail by complete shear or complete crushing how does it happen let us see

so if the plate is quite ah tough but the joint is not that hard that is the weak joint

then what happens all the rows or the all the ah rivets could be could be sheared and what will be the net force that is the maximum force which could be withstood that is P max

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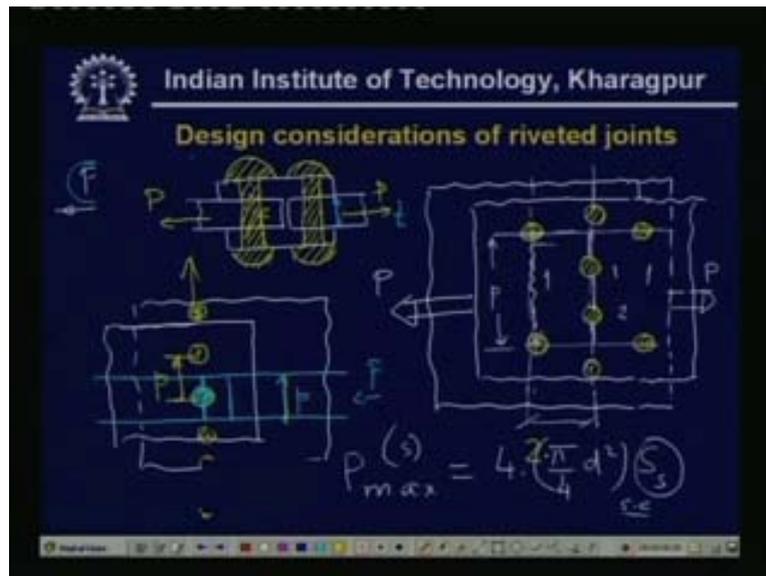
when everyone gets sheared will be equal to the total number of rivets participating in a single pitch that is one two half from this that is see one and one

so there are four rivets complete rivets therefore four times pie by four d square and Ss or if the crushing strength is low then instead of Ss we will have to write Sc that is the crushing strength ah i am sorry then of course this will be different let us not then hardly make this statement

it is if it is now covered by ah it's a butt joint now it is a double covered if this is a double covered now this is for the single covered or may be the or for the lap joint for a double covered so this is for the single cover now if for the double cover we will have to multiply by two here because every bolt will be uh will be ah the shearing of every bolt will be resisted by two cover plates so this factor has to be taken into account

thus given a joint you have to know how to calculate the maximum force ah which could be withstand withstood by this joint this is how we can go for designing
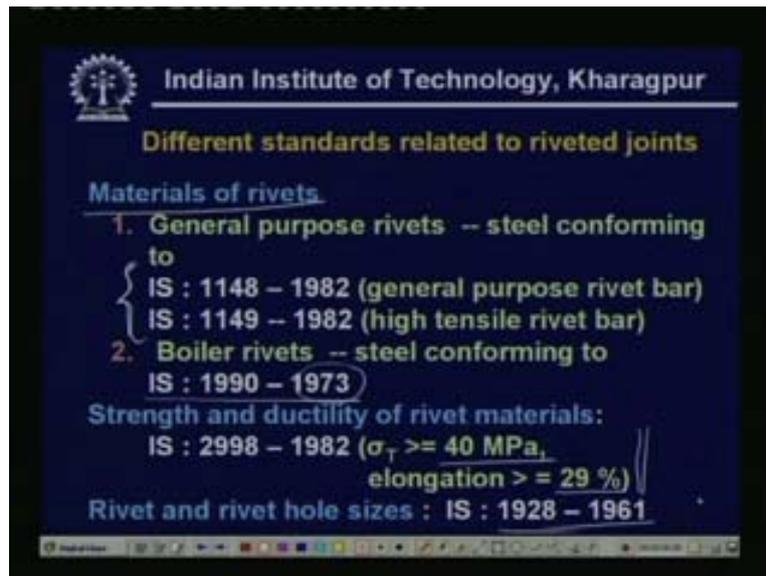
now we come to the efficiency of riveted joints normally the

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the types of joints now there may be lap joint single rivet double riveted triple riveted normal efficiency the range may go from fifty percent to sixty percent

for double riveted it may go from sixty percent to seventy percent the maximum which could be taken is seventy-seven here in the last case the maximum is sixty-three

again for the triple riveted we can have the maximum to be eighty-six point six so you see if we increase the number of rows that is if we go from double to triple the maximum efficiency or the overall the normal efficiency goes on increasing that is very natural because if we make the joint more and more hard then it's load carrying capacity goes high

similarly we have when we have butt joint then for a corresponding lap joint and butt joint you see the butt joint has a larger capacity that is the efficiency is large it for the single riveted double cover it may go from fifty-five to sixty percent

for double riveted seventy-six to eighty four for triple riveted eighty to eighty-eight and the maximum of ninety-five percent efficiency could be reached

for a quadruple the maximum could be reached almost ninety-nine percent okay so this are all about the efficiency of the riveted joint

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Indian Institute of Technology, Kharagpur

Different standards related to riveted joints

Materials of rivets

1. General purpose rivets -- steel conforming to
   IS : 1148 – 1982 (general purpose rivet bar)
   IS : 1149 -- 1982 (high tensile rivet bar)
2. Boiler rivets -- steel conforming to
   IS : 1990 – 1973

Strength and ductility of rivet materials:
   IS : 2998 – 1982 ($\sigma_T \geq 40$ MPa, elongation ≥ 29 %)

Rivet and rivet hole sizes : IS : 1928 – 1961

now we come to the different standards related to riveted joint

so we have the materials of rivets now we know the general purpose rivets they are made of steel or aluminium

now we have seen from the uh manufacture the how the rivet is formed that the material has to be hard otherwise it will break but at the same time material has to be ah somewhat ductile so the ductility is quite important for the general purpose is {riv} (00:53:35) riveted rivets are made ah from the steel which has to come from this to this specification given in this two codes so we must always refer to different codes otherwise no ah design could be accepted in a in this national standard

the boiler rivets which has to be enough strong that is the ah fluid tightness has to be uh considered

then we have to consider a different riveted different standard then ah this is given IS nineteen hundred ninety nineteen seventy-thee it was formulated in nineteen seventy-three

the strength and ductility of the rivet materials as i said it must be strong so the minimum of forty mega Pascal is required as well as the elongation has to be at least twenty-nine percent

again ah this specifications tells that it has to be heated to let us say six fifty degree centigrade and again cooled and it must retain this kind of property is that is the elongation is twenty-nine percent and ah sigma t that is the strength is tensile strength is forty mega Pascal

the rivets and holes rivet hole sizes wiz i which i talked off a has standard nineteen twenty-eight nineteen sixty-one

so this are the standards which are to be used

now we have known the various ah various aspects of riveted joints now you know how to calculate the strength of a riveted joint how to calculate the efficiency of a joint what kind of rivets are have to used now here is a homework problem for you

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which of course you have to ah the answer will be provided next class but what it says that a double riveted lap joint with zigzag riveting that is important we need to have zigzag riveting designed for a thirteen millimetre thick plate assuming the safe working stress in tension shear and compression are eighty mega Pascal sixty mega Pascal and one twenty mega Pascal respectively find the efficiency of the joint

so here we need to joint thirty millimetre thick now here i tell that the diameter of the rivet will be more or less this t in millimetre when t is greater than t is the thickness of the uh plate now if it is greater than eigh eight then we can use this formula which is called the {unu} (00:56:11) Unwin's formula

now once we know this d then we can refer to some hand book and get the ah efficiency of the joint so this ah will be provided the solution will be provided the next class so till then ah i take leave thank you

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dear student let us begin the lecture on machine design part one
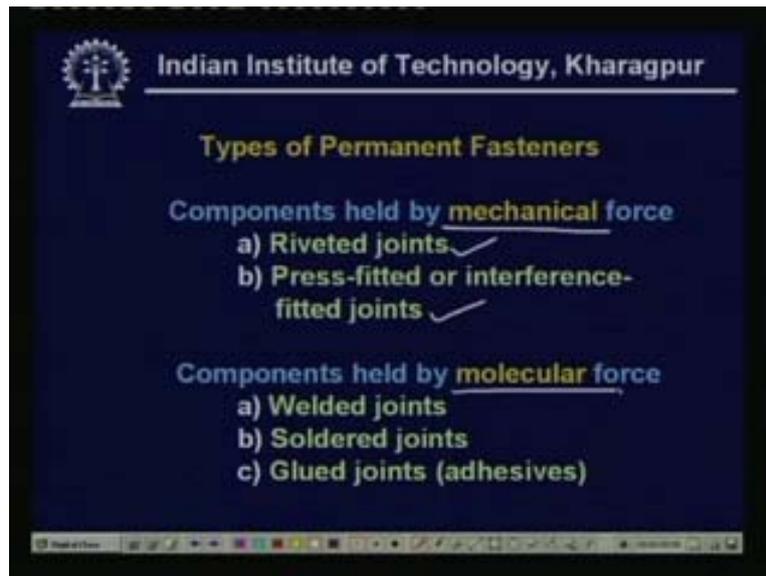
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this is lecture number twenty-three and the topic is design of welded joints this will be the first part of the topic

now if you remember welded joint is a part of the joints which is normally known as permanent fasteners

let us look at the different other type of permanent fasteners [Vocalized-Noise]

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so this is the slide which was shown previously in the last lecture now i want to repeat that again

the permanent fasteners have two types they are of two types one is ah the components which are held by mechanical force [Vocalized-Noise] and there are two kinds one is the riveted joints which we had discussed earlier and the second one is the pres-fitted or interference fitted joints

the other type is that where the components are held by the molecular force now this are the ah by