Design of Machine Elements – I

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Lecture No - 21

Shaft Couplings – II

dear student let us begin the lectures on machine design part one

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this is lecture number twenty-one and the topic is shaft coupling this is the concluding lecture on the same topic

so before going to the subject proper today let us recapitulate little bit what we have learnt in last lecture

we talked about the couplings now couplings are used to connect two shafts for relatively long time and there are primarily two {cutt} (00:01:21) types of couplings {onh} (00:01:23) one is rigid coupling as the name suggests the coupling is made of a rigid material

there are few kinds of rigid couplings which we discussed namely French coupling which is the common type of coupling then sleeve or Muff coupling then we discussed clamp coupling and

then compression couplings but it was end of the lecture we mentioned that there are few disadvantages of the rigid coupling so we are going to start from that point today [Noise]

let us look at some of the disadvantages of rigid coupling now

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first no provision for shaft misalignment

now i want to emphasize here that shaft misalign there may be few kinds of shaft misalignment one may be here one shaft another shaft here so this is a parallel offset

may be shaft one here another there so this is angular offset or angular misalignment and there may be a combination of both that is there may be a an offset and angular mismatch

so these are the three basic types of misalignments and the rigid couplings are incapable of providing for {th} (00:02:45) this misalignments

then large bending stress develops whenever there is a misalignment if you want to bring the shafts together then ah a large bending stress is developed and that is detrimental because when the shaft runs then it leads to {fah} (00:03:00) fatigue loading large fatigue loading also

again ah if we attach the rigid coupling where there is a large bending moment due to various other reasons then also the bending moment is quite detrimental

the last point and which is very important that is shock and impact loads get transmitted so the rigid couplings are not capable of ah providing any cushion to the shock or impact loads

now the main point of departure today will be the flexible couplings now these above advantages can be reduced to some extent you will see uh after today's lecture that what are the extents ah by flexible couplings

so let us now come to the flexible coupling

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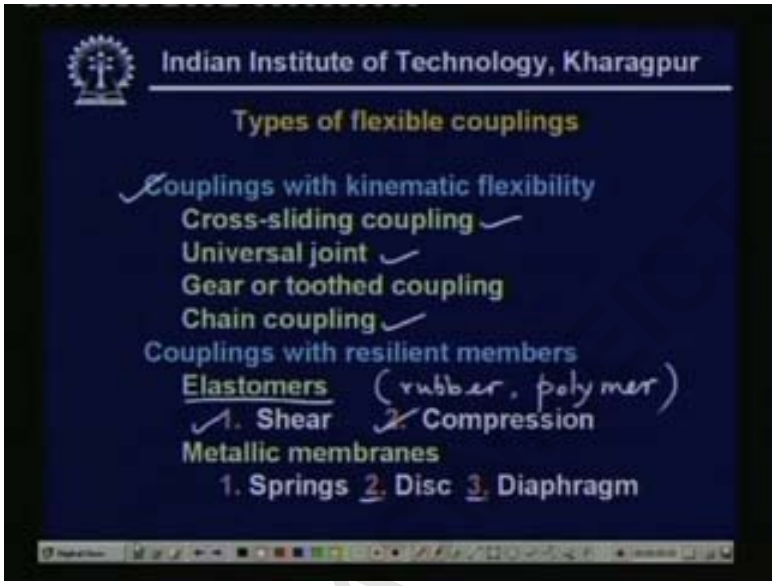

now there are few types of flexible couplings one is the couplings with kinematic flexibility {tha} (00:04:08) that is the flexible members or the flexibility of the coupling is ah is made by having some kinematic player inserted between

so depending upon the kinematic pairs the {flexe} (00:04:23) the couplings may have ah different kinds of flexibility one type is cross-sliding coupling here we use two prismatic pairs universal joint which uses spherical or ah umm special mechanism gear or toothed coupling this is again ah higher pair mechanism and chain coupling which consist of large number of revolute pairs so it leads to a large flexibility of the coupling

then couplings may be of resilient members now here the flexibility is brought in by the {hel} (00:04:56) with the help of the members which have there in ah in flexibility

now the most often used flexible members are elastomers that is they may be rubber or some polymer or some synthetics

now the again uh work in basically two or three ways one is shear and another is compression

again sometimes we use metallic members now metal as such is very rigid but whenever we {mateh} (00:05:30) make a thin plate of metal that is metallic membrane then we can get a large amount of flexibility so that all of you must know

then flexible metallic members could be used in various ways it may be used as a spring then disc and diaphragm

so these are the basic types of ah flexible couplings which we are going to discuss now

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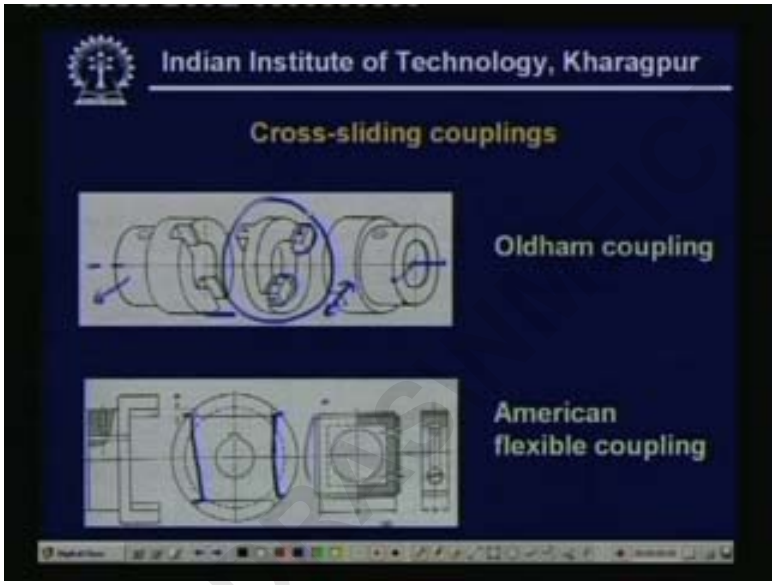

the first comes the Oldham coupling here see this is again this name is non not {nuu} (00:06:11) new to you because while ah learning kinematics you must have come across this name this is a mechanism which has three pair ah um the four joints which is one is revolute pair and two prismatic pairs and one revolute pair let us see how they are attached

so this is one part of the shaft this part is connected to one shaft this part is connected to other shaft and here there is an one floating member and on this floating member we have two tongues which are ah umm which have made ninety degree effort

similarly here we have two slots which meet or mate the ah these two tongues

now you see here we have revolute pair there in this locations we have prismatic pair and there we have another prismatic pair and again this is revolute pair and so um you might of ah learnt that the inversion kinematic inversions of these mechanisms may be elliptical trammel or uh hand operated pump etcetera

now Oldham coupling how does it operate how does it act to flexibility you see whenever there is a little offset from this distance now here one uh um point is that Oldham couplings work when there is parallel offset it doesn't take much care of the angular misalignment

but whenever a parallel offset is there so this coupling that is this part gets engaged but it can slide over over this slot so therefore the slot the the um the length of engagement gets changed but it transfers torque from one shaft to the other shaft

then [Noise] a variant of Oldham {coup} (00:08:03) ah uh cross-sliding coupling is known as American flexible coupling which again works on the similar principle here one ah shaft one part is shown here it is there is one ah ((recess)) (00:08:20) here which the cross section or from this side it looks like that similarly there will be one another coupling another half which will have recess here

so inside there is a square hallow and this is filled by this kind of slider so this is again and you can this is again flexible coupling may stung the cross sliding movement

this ah a hollow is made here to reduce the weight and ah the this part is made by elastomers or some kind of uh um ah synthetics which reduces the weight

now these are about the Oldham coupling now let us look at the design principles of Oldham coupling

you see the the torque gets transmitted by means of these tongues so it is very important to design these tongues so the this strength will be taken by these tongues itself

now we are going to see ah how um uh how ah a designer can approach this problem

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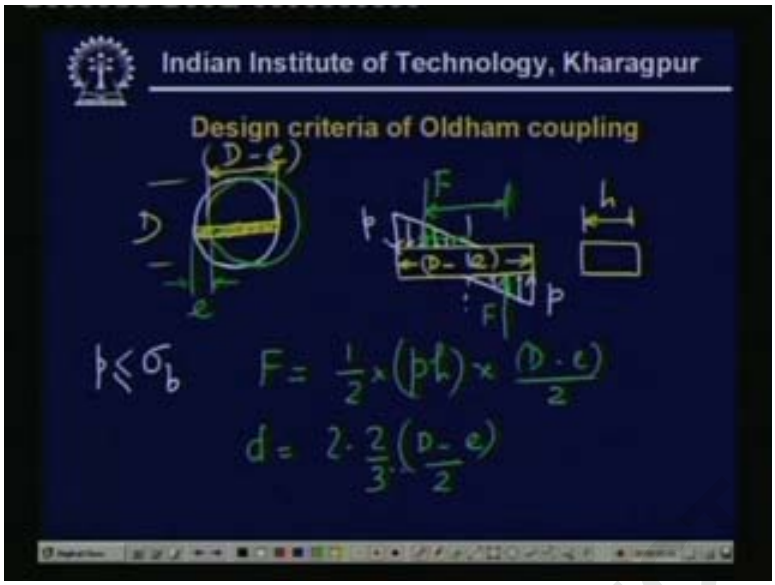

now coming to the design criteria of Oldham coupling let me draw the side view of a shaft so this is the coupling and the other part of the coupling or other part of the coupling gets shifted by some amount let us say e this distance is e

then the slider h is there this is the slider that is that floating member now this portion is only subjected to pressure

if the diameter original diameter is D then this is D minus e what you can verify very easily

then ah see we i draw the this is again the slider and this length is D minus e this is the end view of which so which has width h say and this length is D minus e therefore the force will act on it

now it is difficult to find out the exact distribution of the force but what we can assume that the force is now triangularly distributed that is the distribution is somewhat like this

so it goes from zero to a maximum p now again what will be the p this p again depends on the material so it depends exactly p must be less than equal to sigma bearing that is the bearing stress must be ah p must be lesser than this bearing stress

so once this is done then you can find out we can replace this entire loading by a ah by a torque and what will be this torque this torque is now you see here the equivalent load is F and there F F is equal to half times p the area of this triangle ph is the force per unit length times D minus e by two and then we have the distance this distance is two of this distance which is equal to so d will be equal to two of this is two third of D minus e by two

therefore the torque will be now if you do these calculations then the torque becomes

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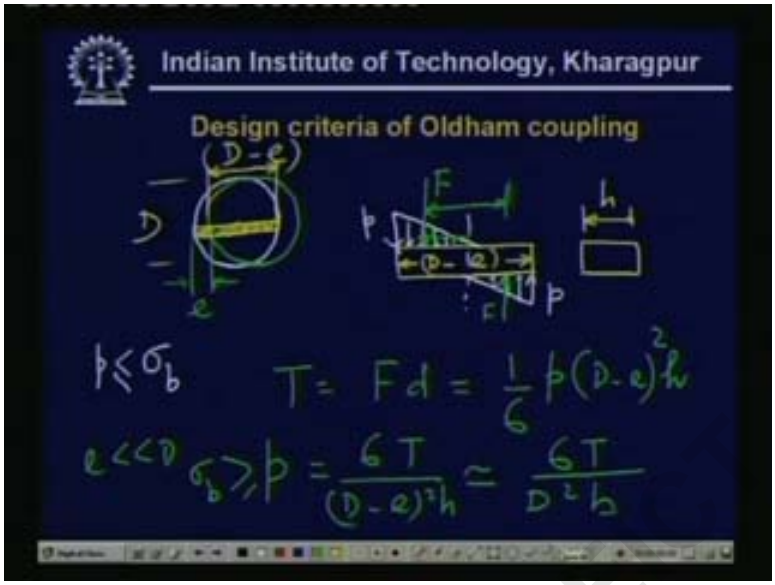

then the torque becomes equal to F times d which is equal to one sixth you see p D minus e whole square times h

so from which we can find out that the maximum pressure p will be equal to six T by D minus e square times h if d if e is much much smaller than d then this is {approximally} (00:13:45) approximately equal to this D square h

now you know this torque the capacity of the of the coupling and so you can find out this p

now p must be lesser than sigma b therefore you can design uh what will be this h so this thickness could be designed that way

well now this is for the case when there is no clearance but {suppo} (00:14:15) but invariably there will be some manufacturing tolerance etcetera so there will be some clearance let us see what happens for the clearance case

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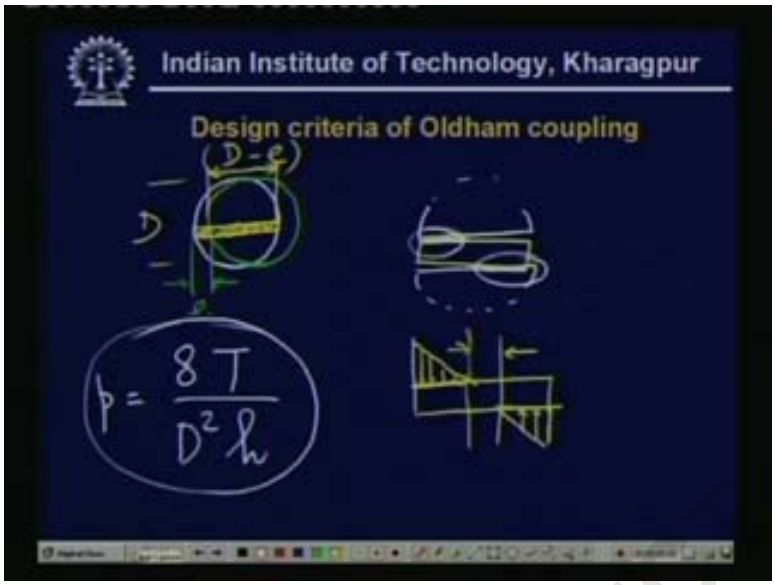

so whenever we have some clearance the you see that if this is the part of the this one is the part and here suppose there is a clearance the slot

so now the effective length will be much reduced so if the pressure acts not over the entire surface but over a small surface so if i write elaborately or much longer then it becomes something like this

so this length there will be a gap between the pressure length and this again this length is of course different

so therefore we have to uh we have to get some corrections and usually normal procedure is to take the p to be eight times T divided by this capital D square so this is from this we can get the dimensions or get check for the stresses

now this is about the old design of Oldham coupling now let us see what are the problems with the Oldham coupling

you see whenever there is an offset of p then this floating member it makes a revolution of ah again it the floating member the center of the floating member makes a circle with ah radius e and because it rotates with radius e and it has some mass so therefore some uh centrifugal force is developed and when a centrifugal force is developed in one member then it leads to bending stress in the shaft that you must or verify that you draw a diagram and it will be immediately clear but this bending stress is again fluctuating so again it leads to fatigue stress that is a variable loading and the shaft may be subjected to the high uh fluctuating stress which may lead to failure

so it it's always advisable to reduce the weight of this floating member because then the bending stress will be will be then small

another defect is that there is always a rubbing taking place here okay this this rubbing again causes wear and tear

so a high wear and tear takes place and {wis} (00:17:14) with wear wear and tear of course comes the frictional laws therefore the efficiency goes down

so there are few advantages that is bending stress may be developed then the ah wear and tear may take place or the efficiency may go down because of the high frictional torque the frictional resistance

now this is about the Oldham coupling now let us come to another kind of coupling

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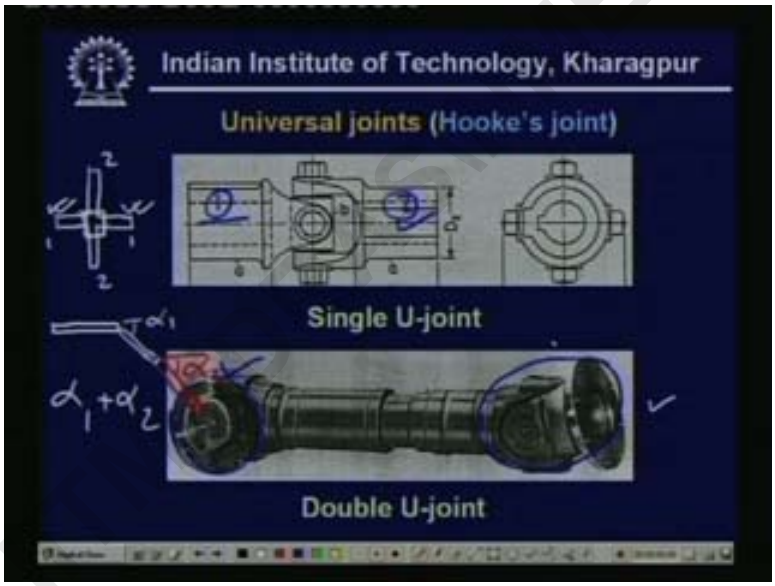

which is known as universal joint let me describe what is known as universal joint

here you see universal joint was ah okay this is also sometimes called Hooke's joint it was for ah i mean this was proposed by Hooke's but the entire analysis was done by Cardan much later so sometimes you can hear the name Cardan joint also so the basic analysis was done by Cardan also although it was uh made uh for the first time by Robert Hooke

now uh what are the basic principles here now this is the part of the shaft this is a part of the shaft and here you have ah well this is connected to another shaft this is shaft one this is shaft two okay now this is connected by means of what is uh known as the Cardan pear or some kind

of pin now that pin looks little odd so this is this is not a single pin so pin sometimes some likes looks like this

now this part this shaft is connected to this pin so the shaft one is connected to this pin and shaft two is connected to that pin that part of this pin

so therefore when the shaft one rotates then you see the shaft two will be rotated

now it can take care of some angular misalignment so [Noise] we will see in the uh in few minutes that how does it take care of this angular misalignment but it can take care angular misalignment

then this ah the amount of angular misalignment which can be taken care may be increased if you joint two two such ah {uni} (00:19:59) universal joints together so we make double joint

so how say this is the first shaft let us say now the second shaft is somewhere here so this is alpha one which the maximum angle can take {pla} (00:20:18) uh can be taken care and usually {theh} (00:20:21) by one Hooke's joint you can take care of upto forty- five degree angles but then if we can add one third member into that then we can take care of alpha two so the total may be alpha one plus alpha two which is the total angular misalignment which can be taken care of

what you see here is nothing but two sub joints okay here one joint you see one joint here another joint is there so therefore two joints are used and this main {luhh} (00:21:03) ah act to the flexibility of the whole system

now where ah are these {hoo} (00:21:09) Hooke's joints used or universal joints used they are used mainly when we whenever we want some correction because of uh some in an inevitable manufacturing defects or may be because of vibrations for example in automobiles when we want to transfer the power from gearbox to the back axle it may be used ah when we give motion to adjustable shafts for example multiple spindle drilling machine it may be used even when we want to give power to a movable part that is that could be used for example in the knee of the milling machine so there are few ah uh various uses of the universal joints

now we are going to look at some of the problems or the [Noise]

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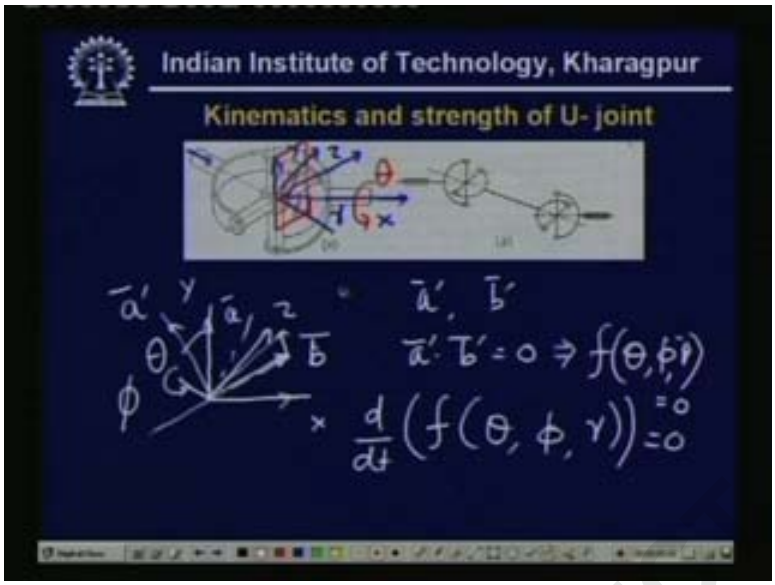

may be the kinematics and strength of U joint now let me explain this with the help of this diagram

what you see here is ah the the joint and this is the very {simpli} (00:22:15) simplified view of this joint this is the one shaft which is let us say driving shaft and this is the driven shaft

now here this shat suppose with design the denote this name x this is x axis this is y axis and this one is the z axis

now the another shaft now here this pin makes an angle gamma with the x axis now this shaft is or the this line is on the xy plane so therefore this angle is gamma and definitely this also makes ninety degree with the uh or ah yes this this always makes ninety degree with the with this thing

so therefore if you analyze it a little bit carefully then what you see is that this one that is whenever you gave a rotation here so if it rotates by angle theta let us say then this vector if i write down this is x y and z so this vector it rotates by when it rotates then this vector and both this one z so this rotates by so this pin this particular pin rotates by angle theta

and now look at the other shaft that shaft this pin makes an angle here so now you can find out this vector which is a bar prime now originally the other vector was here b now after rotations that is rotate by angle if the driving shaft is rotated by angle phi then this rotates this goes to a new position b prime

now you can find out a prime and b prime and now that must be in terms of those angles phi and uh theta and gamma

now you know that a prime this of vector quantities so a prime dot b prime is zero that is the pins are at ninety degree apart

now if you use these conditions you get one relationship between theta phi and gamma now where gamma is the angle made by the two axis the two shafts ah the acute angle made between the two shafts okay now you have this relationship ah i am not going to derive this but i ask all of you to have a look into this {goh} (00:25:25) whenever you have some time just try to derive this this is not that difficult

now when you differentiate it once so if you make d dt differentiate of these entire expressions f theta phi gamma equal to zero you get this following relationship

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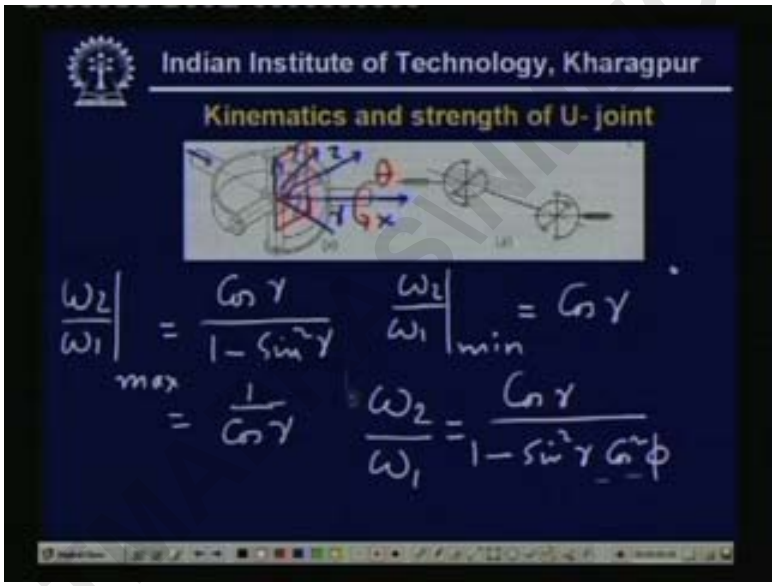

you get this relationship that is theta dot is equal to cosine gamma divided by one minus sin square gamma cosine square phi and phi dot

so this is the relationship between theta dot which is the angular velocity of the driven shaft and so let me write down this is omega two and divided by omega one will be equal to cosine gamma and one minus sin square gamma cosine square phi

and again if omega one that is the angular velocity of the driving shaft is constant then phi is nothing but omega one t

so now you see this the angular velocity of the driven shaft is now time varying so here we have this difficulty that although the [Noise] although the uh the angular velocity of the driving shaft is constant the angular velocity of driven shaft is now changing with time

now let us look at the maximum and minimum values of that now omega two maximum by that is this will have maximum value when maximum occurs when this denominator is minimum that is this part is maximum and that can occur when phi cosine phi is ah so the the maximum value of it will be sin square phi right

so therefore we have cosine phi a cosine gamma divided by one minus sin square gamma again if you write one minus sin square gamma to be cosine gamma so this is nothing but one {mina} (00:02:59) one by cosine gamma and then so this is the maximum value what about the minimum value

the minimum value will be when ah this one is maximum and that may that can be only one so this is cosine gamma so therefore it varies from one by cosine gamma to cosine gamma right

so if gamma is ah say uh for the maximum limit forty-five degree then this varies from route two to one by route two so this is the there is a high fluctuations between the angular velocity

the relative change in the angular velocity can be written this way

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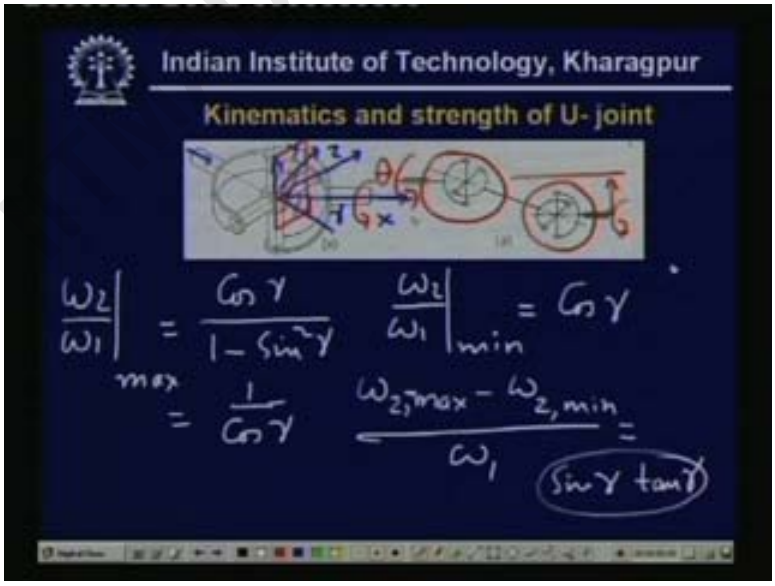

so relative change that is omega two minus omega two max minus omega two min divided by omega one is the maximum change and that you can prove to be cosine one by cosine gamma

minus cosine gamma which you can ah um do a little trigonometric manipulations and you get this is sin gamma times tangent gamma

so one thing is clear that if gamma is uh zero then this becomes zero so uh um for a perfectly aligned shaft you get the same ah uh speed as that of the um whatever uh you get the same speed that of the ah driving shaft

but if gamma is variable then uh non zero then you get some value of this so this is quite important because we get a {boah} (00:29:57) what is known as the {vah} (00:29:59) of variable velocity variable speed and with variable speed comes the variable bending moment and that is also very much detrimental

so now we see that [Noise] one problem with the universal joint is that it leads to non uniform angular velocity of the driving shaft now how to take care of that

if you can use two such two such spheres see here and there so there are two ah universal joints now here the thing is that [Noise] they must be parallel these two are parallel shafts and these two are in the same plane let us whenever that happens then we can say we can see that this the angular velocity of the driving shaft will be equal to angular velocity of the driven shaft so by combining two universal joints we can get uniform velocity

there are other mechanisms also or other kinds of universal joints also which use a single ah um single ah universal joint but it can have uniform velocity so those are called synchronous universal joint

so there are few kinds you can ah have a look at them ah in some good reference books but ah those are used in automobiles mainly in Soviet Russia

now there is another problem which i am going to talk write now

here that is that is you see that

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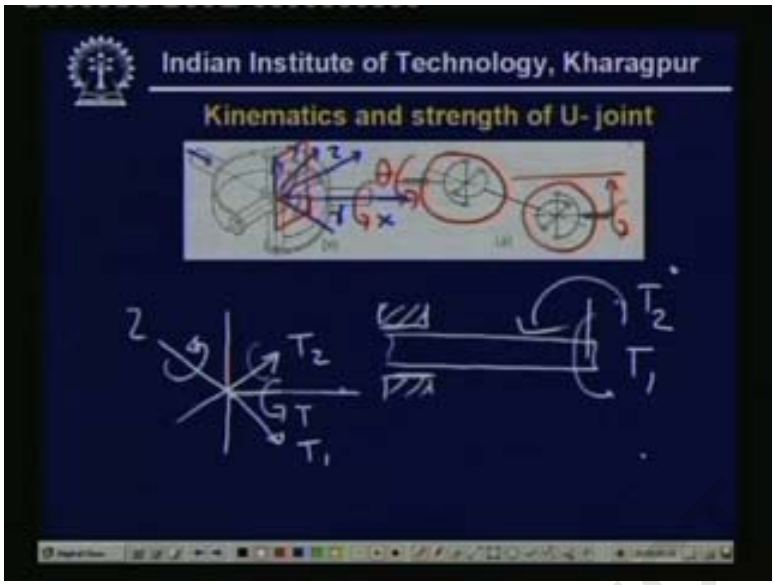

now if this is the pin now here one shaft is aligned that way another shaft is aligned a little (( )) (00:31:50) then if you give a constant torque here T then this part one part can get okay if you can divide that is you can have some component T one and some component T two

so what happens then this T one is responsible for turning of the shaft whereas what happens for this T two so this T two induces some bending moment see if you look at the shaft this shaft shaft two then what you see that there is one T one and there is another T two and this T two is nothing but the bending moment

so you will have to have some bearing here and this bearing gets stressed and it leads to again ah um fluctuating stress and that may lead to failure so these are the problems with the universal joint

ah well nevertheless these are very popular joints popular types of couplings in order to couple to very heavy heavy equipments and these are in use

so these are all about the universal joint

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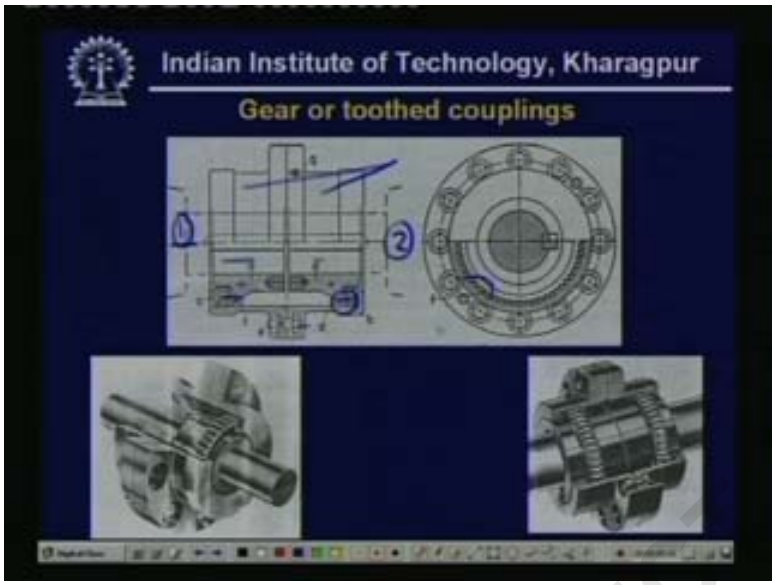

now we look at another kind of joint another kind of coupling which is known as gear or toothed coupling

here [Noise] you see this part so again the flexible member is ah the gear i shall explain how but this part let us see the diagram this is the shaft one and this is another shaft two and this is connected by means of this sleeve okay there are two sleeves here there say see these are the parts of the sleeves and sleeves have teeth that is gear teeth on the external surface

again there is another shield which which ah there are couple of shields which are flanged together as you see here and this shields has umm internal gear teeth

so therefore the gear teeth match as you can see here so now this gear teeth can lead to some amount of flexibility how you know that there there exists some backlash in the gear teeth so because of uh the kinematic or manufacturing defects there may be some backlash and purposefully here some backlash is kept so whenever there is some angular {manufac} (00:34:32) angular misalignment then that backlash can take care of that misalignment

so this one way it can take care angular misalignment or ah maybe sometimes also the parallel offset misalignment

when there is there is axial movement then of course it is very {eas} (00:34:52) easy to see that one gear teeth tooth can slide above the other tooth very easily because there is lubrications there so therefore it can take some amount of axial movement

so therefore this is very much useful and what are the advantages of this kind of gear or toothed coupling

one is that it can have a very large capacity right the torque capacity is very large secondly the [Noise] speed may be very high the gear may rotate at a large speed and third and which is very very important that is it is very easy to manufacture a gear so the productabilility is productivity is very very large for the gear coupling therefore it has got white acceptance amongst the industrial in uh uh industrial applicances

but ah few things which we want to say here

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for example what you see here is a what you see here is again the gear coupling but here the gear is is sparred gear that is straight tooth gear whereas here in this gear now you see this gear is ah has some other kind of teeth

so in one case we have this kind of sparred gear so this is the one tooth of the gear so this is here what you see in the left figure in the right figure you see there is relatively pin to a spherical surface and you see this is somewhat bent and this is known as crowned gear this is crowned gear

so it again gives a little bit of flexibility to the overall system now this is something about the gear or tooth coupling

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now let us come to another coupling which is known as chain coupling here you see chains are used so there are two shafts shaft one and shaft two and again it is connected by to ah flanges

but there are sprockets there what you see this is the these are the sprockets and on sprockets we have these chains now chains are very flexible as all of you know as you know therefore it leads to some {flexh} (00:37:48) gives some flexibility to the coupling arrangement so this is very very ah accepted kind of accepted couplings and there are large number of manufacturers for this change chain coupling

here what you see is again the photograph of a chain coupling here the usual chains are used and but there are double ah there are double rows of chains

what you see here in this diagram again the similar kind of chain but now it is made of nylon so this is nylon type chain coupling

why it is used it definitely as you uh have might have guessed by now that it leads to some damping of the ah um of the coupling so it provides some damping arrangements as well

so these are uh some kind of chain coupling

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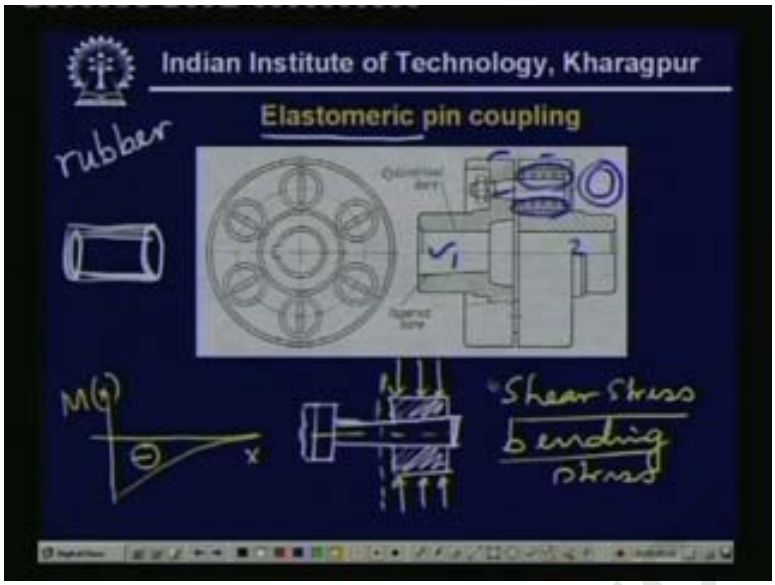

now again the next thing is the elastomeric pin coupling

now here we first ah come across this term elastomeric coupling here what we do we use elastomers that is mainly the rubber material we use elastomers the most useful is a rubber because it has a large ah storage capacity of um {loa} (00:39:21) load that is it can take a large stress and of course it's now a days it is easy to manufacture and prepare

now let us look at the salient features what you see here is this is again one shaft this is the shaft two this is shaft one and again there are two flange coupling now this is very much similar to flange coupling but unlike the other flange coupling which we have studied earlier this has ah inherent asymmetric so this part is not symmetric so this is not symmetric as that now this is connected by bolts now here we have this elastomers

now the elastomers may be a ring type there is there a small ring or that may be a bush type or sometimes we have this kind of elastomer this is a bush which is bound around this part of this bolt bolt here and then it provides some flexibility now when you want to design that then definitely what is most important part is that bolt

now this bolt design for the flange coupling we have seen already but here the difference is that here for example i draw the part of this bolt on top of it this elastomer and again the load comes on this elastomer here comes the load right and that comes from ah that comes from the bearing pressure on the elastomer

now you see the this is part that is which is subjected to both bending and the sheer force now you see that [Noise] there will be shear stress there will be shear stress in the bolt as well as there will be bending stress

you see if you can draw the bending moment diagram you can have some kind of bending moment diagram which is something like this

so it is it has ah some bending stress here and there will be the shear stress so you have to calculate both the bending stress and the shear stress and there from you calculate

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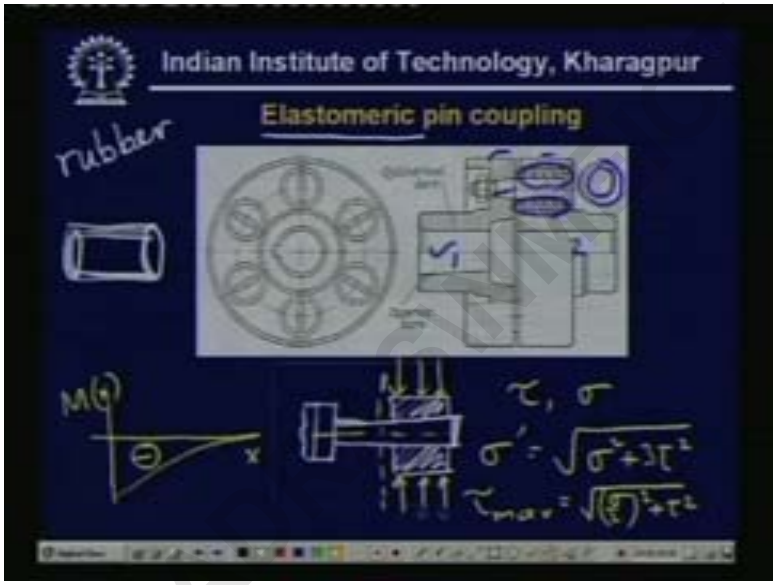

tau sigma and then you calculate either sigma prime is sigma square plus three tau square if you use the Von Mises theory of failure or if you want to use the maximum shear stress then maximum shear stress will be tau max will be equal to sigma by two square plus tau square and either way you can check for the uh safety or the strength of the bolt or you can design the bolt if you want

now another uh uh another way of looking at the stress is that of the

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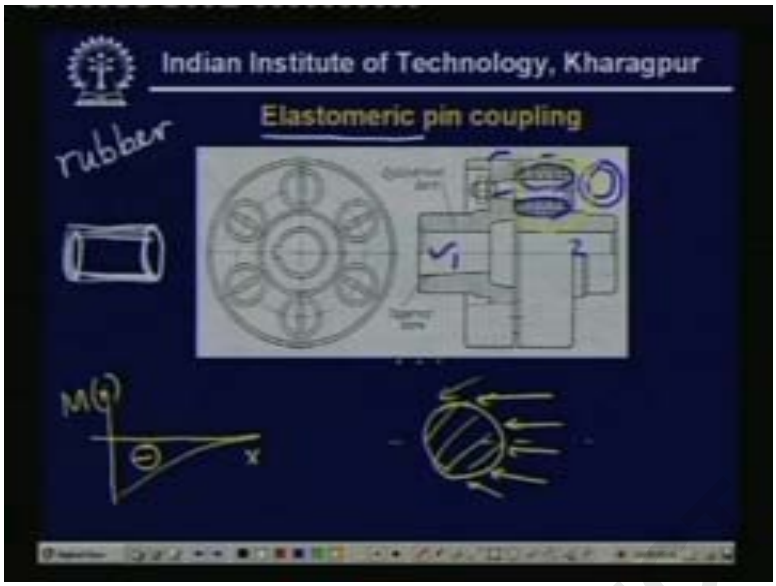

the bush here the bush as you see is subjected to or the elastomer is subjected to bearing pressure right and this bearing pressure you can calculate and the procedure is very similar to calculating the bearing pressure is the bolt in the flange coupling so we are not going to discuss this

so these are this is {ari} (00:43:52) again a modification of the flange coupling where we have used some kind of flexibility into it now this is about the elastomeric pin coupling

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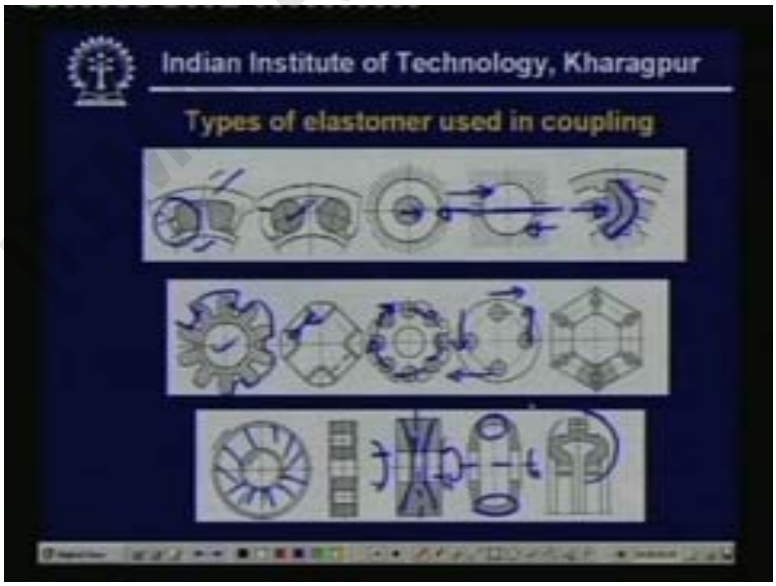

now let us see the types of elastomers used in coupling

so there are various kinds of elastomers which are used as a member of coupling and these elastomers they are used either in shear or in compressions but compression is the most favored only because that there is no need of bonding

you can imagine if you want to ah shear it shear a rubber then you will have to bond between two surfaces whereas this bond in bonding is unnecessary if you want if you use the compressive stress

now here what you see here there are again ah there are two cases where a number of elastomers are used as you see in the first row and there may be a case where a single elastomer is used which you see in the in the other rows

so this is the case where number of elastomers are used and this is again working principle is compressions

so this is the part of shaft one shaft and this is the part of the other shaft and they are connected by means of those compressive elastomers

again this is the case this looks like a trapezoid where here it looks very much like a circle so ah now again this is compressions what you see here is again compression you get compression {forhm} (00:45:50) from here compression from there but here you get both shear and compressions it is subjected here {jected} (00:46:01) here so you see that you can get compressive stress as well as the shear may occur along this plane

here you get in this figure you get compression as well as bending now because the force is acted here force is applied there so this bending might take place that is it may deflect this way and that leads to bending

if this case this is a single member now this is subjected to compressions in the two in two shafts each of the shafts you will get this kind of kind of sprockets okay which when work they lead to compressive stress inside this member so this is ah very much useful and this is used as rubber sprocket member

this again has a complicated motions here this part this is compressed and this is compressed similarly here the entire is this way along the clockwise direction

here one part is in clockwise direction and another the anticlockwise here of course there is a torsion what you see here there is a torsion so this is the elastomer then it is subjected to torsion

similarly here similarly here this is subjected to torsion if this is connected to one shaft and this is connected to other shaft when it rotates then you see a large torsional stress or torsional is developed so {sheh} (00:47:51) shear stress develop uh as well as in addition to pure torsion it {alwa} (00:47:57) it also withstands some of shear

here you see both the effect of torsion as well as shear so when this is one shaft this is other shaft so whenever this way it occur ah it uh um moves in this way then of course you get a large shear stress in this region

similarly here so these are the few cases were um of these are the few type of elastomers which are used in coupling

now if you want to know more about the elastomeric couplings then you should read some book we are not going to start now uh um speak on the elastomer any more

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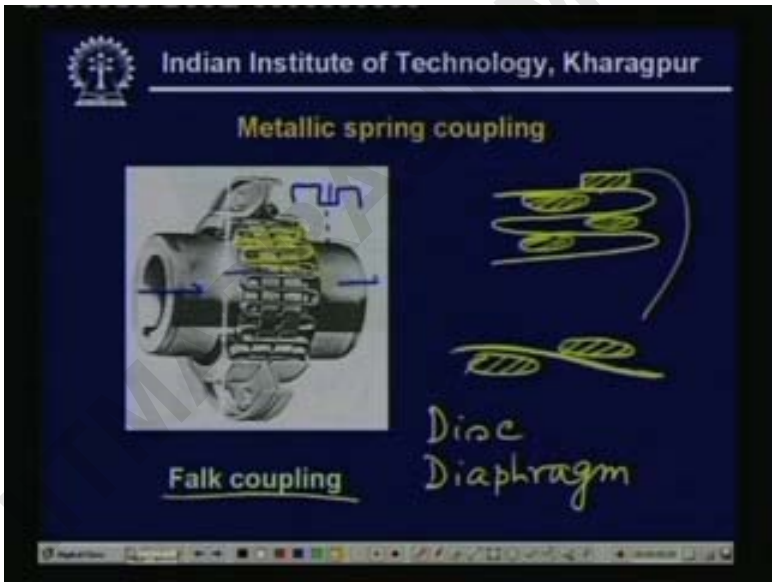

now let us come to another kind of coupling which is known as metallic spring coupling [Noise] here what you see is a two shafts two shafts and this is connected by coupling here there are two flanges and and this flanges there are two halves here what you see two protrusions something like this and there are slots cut over here on the top of the slots we use these springs as you see here

so there are springs and these springs they look like so this is one part this is another part similary here there is one part there is another part

so now if you look at the spring then this is one side of the spring these are the two parts as i see here this way

now whenever there is a shock then it can take care of the shock this gives sufficient flexibility and this is very much used this is sometimes called the Falk coupling but this is metallic spring couplings there are other kind of coupling metallic couplings we {ush} (00:50:33) which use the disc or diaphragm

now again if you ah want to know more about this disc diaphragm {coup} (00:50:50) coupling please look at some reference book

now what we have known we have known few types of flexible coupling uh the first kind is the kinematic flexibility that is flexibility with the kinematic members and we used Oldham coupling we used ah we {vee} (00:51:11) studied uh universal joint again we studied what is known as the gear or teeth coupling and also chain drives and in the flexible members we have used the elastomeric coupling elastomeric coupling we used we have only studied the pin type elastomeric coupling or sometimes pin bush coupling and ah then i have shown you some types of elastomers which are used then lastly we have studied something about the metallic spring coupling

now these are uh uh the broad overview of different kinds of flexible coupling

let us look now at

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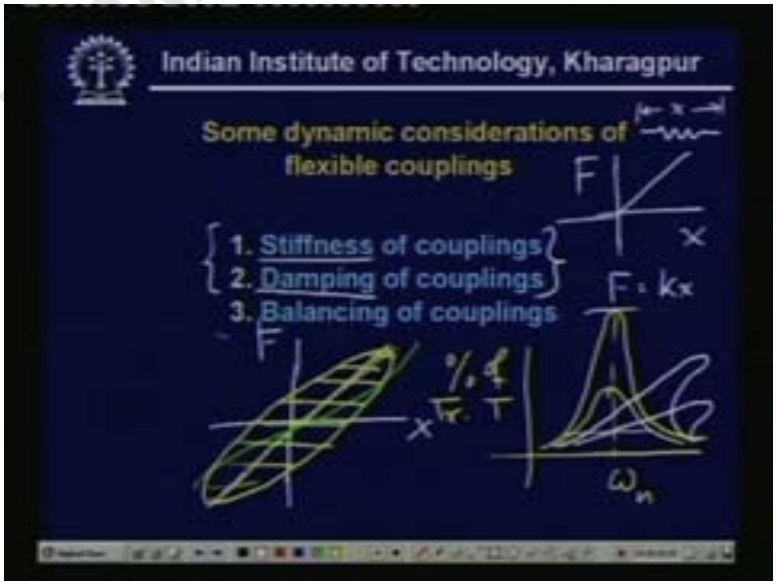

some dynamic considerations of the flexible coupling here when we design some flexible coupling we will have to look we have to take care of few things one is the stiffness of the coupling and stiffness is just like when you talk of stiffness of a spring it is that if you have the spring then if you elongate and elongate by a distance x if you elongate by a distance x then you measure the force then you get this kind of curve and the slope is known as the stiffness so the stiffness is given FKx

now [Noise] then the second point is the damping of coupling now whenever there is ah motion is involved then it must damp out and those two are very much essential because because the flexible couplings should also ah absorb some of the shock load for {examp} (00:53:08) take for example the case when we have reversal of drive okay in uh two way drive the there may be backlash because of backlash there may be sudden shock on the drive system and we have to take these shock of the absorb the {shoh} (00:53:24) shock ah in the coupling itself and we should not allow it to be transmitted because if it is allowed to be transmitted then the torsional vibration may takes place and that may lead to large fatigue stress and which may lead to the ultimately lead to the failure of the member so the stiffness and damping are very very important thing

you see sometimes when you have this kind of this diagram then the stiffness if it is linear stiffness this diagram looks like this so if you elongates then it falls on this line but if it is non linear that may sometimes happen that if it is nonlinear then it may be something like this then when there is a damping present then whenever you you ah give excitations to it then it traverse one loop per cycle which is known as the hysteresis loop okay this area of the hysteresis loop will be governing what is the damping inside it

now if the linear spring is used linear damping is used then what you get that if you find out the percentage of the load transmitted so this is the percentage of transmitted load transmitted torque or so then with damping you get this kind of distributions that is if the natural frequency frequency of excitations that is excited force is almost equal to the natural frequency we get a large transfer

but if we {deh} (00:55:05) use the damping high then of course this peak gets down if we use the nonlinearity then you get this kind of relationship

so you see use using the nonlinear we can reduce this maximum limit with large distance and the last point what we must know is the balancing of coupling that is very important and you must know that in a dynamic rotating system we always have to balance the machines

so these are the various points of the flexible coupling which you must consider so that is all from today and thank you very much

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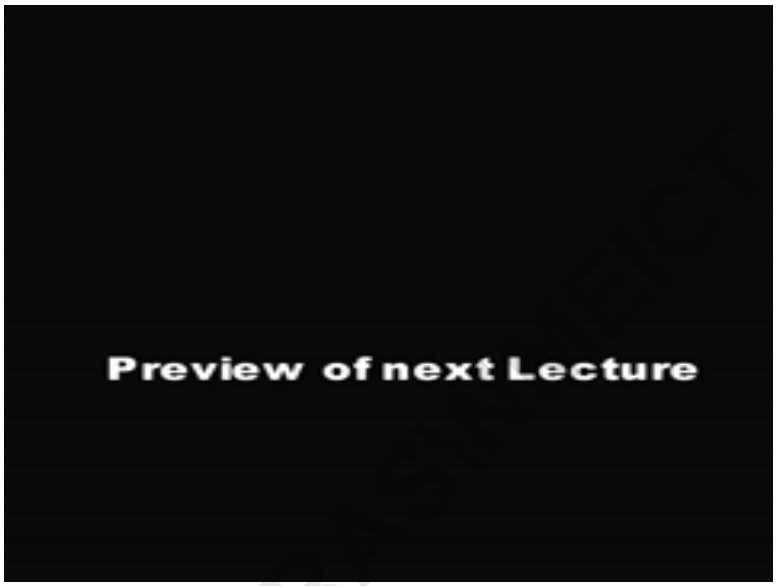

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lecture number twenty-two and the topic is design of the riveted joints

now in the last few lectures you were taught how to design one non permanent joint

non permanent in the sense that [Noise] the joints are such that anytime they could be dismantled or {disas} (00:56:11) de assemble disassembled if the requirement arises so these are 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 uh 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} (00:56:58) two cases two examples one is the riveted joints which will be the subject matter of today's lecture the second is the press-fitted or interference-fitted joints

this again will be taught in somewhat details ah later afterwards um but here the purpose of the joint is that we uh press the press one part into the other and make the 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 type of rivets we must know what is the riveted joints how does a rivet look like and so on so let us see

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rivets it {conese} (00:58:08) it looks like the following so this is the