Mechanics Of Solids
Prof. Priyanka Ghosh
Department of Civil Engineering
Indian Institute of Technology, Kanpur

Lecture – 27
Strain Measurement

Welcome back to the course mechanics of solids. So, in the last lecture if you recall we talked about strain and strain in x y plane, and if you know the strain components in x y plane you can find out the strain components in other any arbitrary coordinate system like x prime y prime and so on right. So, and then we were develop and the equations from which we can we could conclude that first strain also you will be getting very similar to your I mean stress concept you will be getting the Mohr circle of strain from where you will be getting the strain components on some arbitrary coordinate system ok.

So, now today what we are going to discuss, we are going to discuss about the measurement of strains because we generally measured the string. So, it is nearly impossible to measure the stress directly. So, any anybody if you if you consider and if you apply some external forces on those on that body basically that body I mean of course, the body is deformable body and the body will show the deformation.

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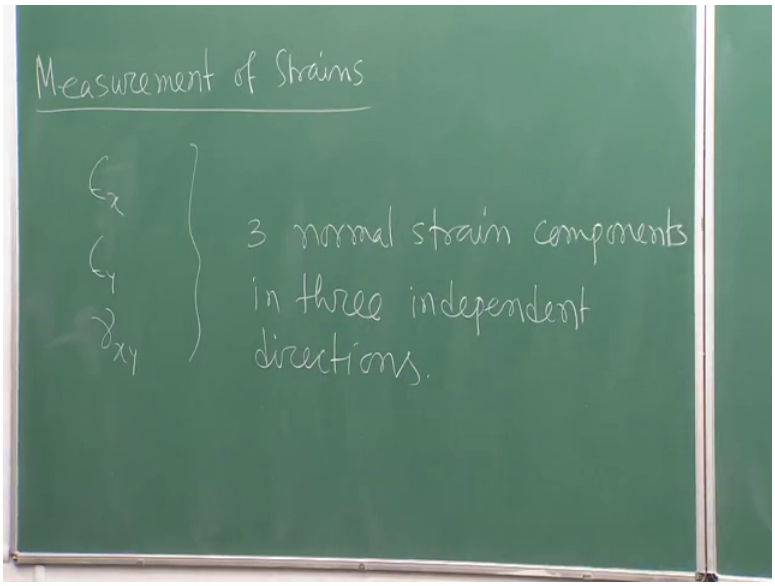

So, we can measure the deformation that is the nothing, but the string, but we cannot specifically measure the stress directly. So, I mean once you measure the strain right. So,

I mean how we can get the info information about the stress that is the question right. So, because stress is also required to be node.

Now, what we do generally in mechanics that we measure the string for any system any deformable body, and then we try to build or try to establish some constitution relation between stress and strain for any particular material. So, for every material you will be getting some constitutive relation that we can we can establish. So, by applying that constitutive relation and from the known magnitude of string we can find out the stress. So, that is kind of back calculation in and then you establish the relation or relation between stress and strain and then you try to quantify the magnitude of stress.

So, in that way we find out the stress. So, the measurement of strain is very very important. Now for that actually you have several say mechanisms or several say tools by which you can measure the strain. So, one of those mechanisms or tools basically we I mean one important say tool is strain gage, you might have hard this words several in your professional carrier right strain gage. So, by using is the strain gage we can measure the strain. Now how the strain gage works generally? The strain gage works I mean with the change in electrical resistance due to the mechanical deformation ok.

So, if you have the mechanical say strain in the in the body because that that is the only thing we are going to find out and that mechanical strain will try to change or alter the electrical resistance of the strain gage and from there we get the signal, and that signal will be studied or analyzed by the by the signal processing unit and then we will get the magnitude of strain. So, in that way strain gage works. So, ultimately what we do we fix the strain gage along the direction of our interest, and then after deformation we get the stain component say measured or of I mean recorded by the strain gage, and from there we can say that along this direction this much of strain has happened ok.

Now, the important thing is that in case of plane strain of course, we are talking about the plane strain condition. So, in case of plane strain you know these are the three. So, if the strains are in x y say plane. So, these are the 3 strain components are required to be obtained right. So, two normal strain components epsilon x and epsilon y and one shear strain components gamma x y, but generally this strain gage measures the normal strain it cannot measure the shear strain. So, what we do generally, we measured the normal

strain and from there in such a way from there we can find out this 3 unknown components epsilon x epsilon y and gamma x y ok.

So, for that we measure 3 normal strain components, in 3 independent directions 3 normal strain components in 3 independent directions. So, 3 aco along 3 independent directions if you considered in the x y plane, and along that we are we can we can fix the strain gage and the strain gage will record the strain along those directions of course, those strains or normal strains. So, from this 3 normal strain components we can the calculate this values of epsilon x epsilon y and gamma x y. So, once you know this values then waste of the things are known to you I mean if you rotate any coordinate system, and by this time you know how to find out the strain components in some arbitrary coordinate system.

So, this kind of arrangement now we will show we will see that how we can arrange this kind of thing.

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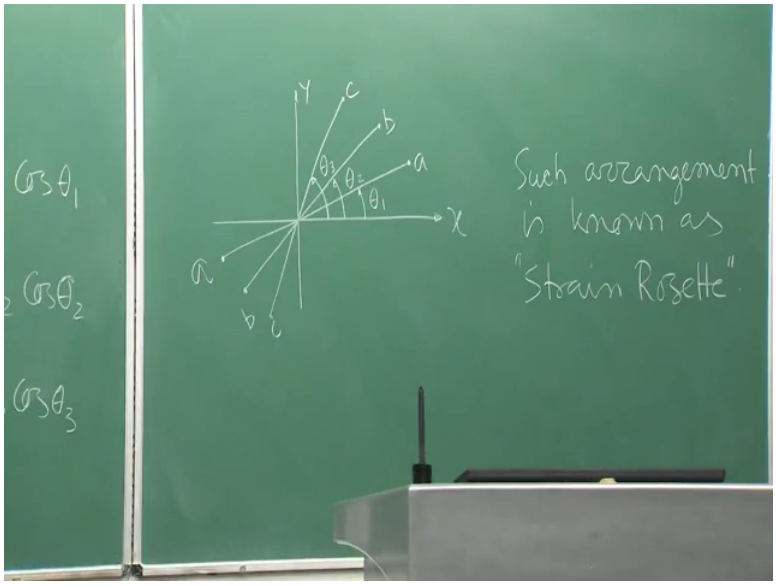

So, the suppose I this is my x y plane, I have any 3 arbitrary directions we are just choosing say this is my direction say a, this is the direction say b b, and this is the direction say c c. Any arbitrary 3 directions we are choosing in x y plane in the in the body we just mark x y plane and then e choose 3 different 3, I mean independent directions and these directions are defined by say theta one; that means, the direction a a plane is making an angle theta 1 with the x axis.

Similarly, b b is making an angle theta 2, and c c is making an angle theta 3 and we are fixing the strain gage along a a direction b b direction and c c direction. So, 3 in strain gages we are putting and we are observing 3 normal strain components. Now if we get 3 normal strain components from the strain gage reading then form there whatever equation we have developed for getting the strain components in some rotating coordinate system say suppose now we are considering a a is one say arbitrary set of axis, b b is another set of arbitrary set of axis, and c c is another set of arbitrary axis.

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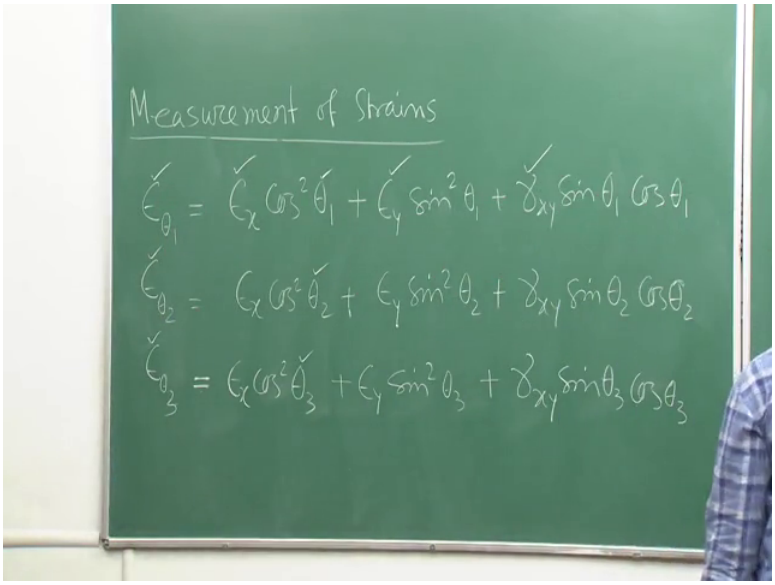

So, if that is their than already we have developed or we have derived this expression epsilon theta 1 can be written as in terms of epsilon x or square theta 1 if you recall the previous lecture discussion you will get it say epsilon y sin square theta 1 plus gamma x y sin theta 1 cause theta 1 right. Similarly I can write epsilon theta 2 is equal to epsilon x cause square theta 2 plus epsilon y sin square theta 2 plus gamma x y sin theta 2 cause theta 2 and further you can write epsilon theta 3 is equal to epsilon x cos square theta 3 plus epsilon y sin square theta 3 and plus gamma x y sin theta 3, cos theta 3 I can write that.

So, in the previous I mean discussion when we talked about this kind of equation the left side was unknown. On the right hand side you were knowing about epsilon x epsilon y and gamma x y and of course, theta 1 was known to you right, but in this case you know the left hand side because you are measuring these are the measure strains from the strain

gauge. So, epsilon theta 1 epsilon theta 2 and epsilon theta 3, so these are the measured strain from different strain gauges strain gauge a strain gauge b and strain gauge c and of course, you know because you are choosing the independent orientation independence say a lines right a b b and c c. So, these arbitrary lines chosen by you only. So, of course, you know theta 1 theta 2 theta 3 and this 3 you are measuring. So, form this 3 simultaneous equations, you can find out this 3 unknowns epsilon x epsilon y and gamma x y. So, this is the idea right and this kind of arrangement is generally known as stain rosette ok.

So, sees this such arrangement is known as strain rosette this is very very important because you I mean whatever theory we are going to develop or we are studying basically you need to get those observations from the experiment right. So, far from a deformable body you just measure the normal strains like this like by putting the strain gauges in this fashion and then from there you will be getting the information about epsilon x epsilon y and gamma x y. So, once you know epsilon x epsilon y gamma x y than rest of the informations like what will be the principal strains, what will be the maximum shear strain, what will be your strain components in some rotate coordinate system. So, all those information you will be getting immediately right and apart from that once you know epsilon x epsilon y and gamma x y you establish some constitutive relation to get the stress components sigma x sigma y and tau x y so, that will be doing later on.

So, I mean we will try to establish a relation between stress and strain. So, that will do later on I hope you have understood that what is the advantage of this strain rosette. Now if you look at this this equations this 3 equations know why it is mentioned that or even not compel to choose the magnitude of theta 1 theta 2 theta 3. So, you can choose as per your own choice. So, there is no compulsion that you have to take theta value like this theta value is like that and theta 3 value like that. So, you are choosing theta 1 theta 2 theta 3 and accordingly you are facing or facing the strain gauge. So, why do not we choose the values of theta 1 theta 2 and theta 3 in such a way that we will be getting or will be minimizing the computational vapoured or computational calculation so, right.

So, you need to minimize the computation calculation by choosing theta 1 theta 2 and theta 3 in such a way that your life will be simple. So, for that what people choose if we

will take generally two different types of strain rosette that mean two different types of arrangement ok.

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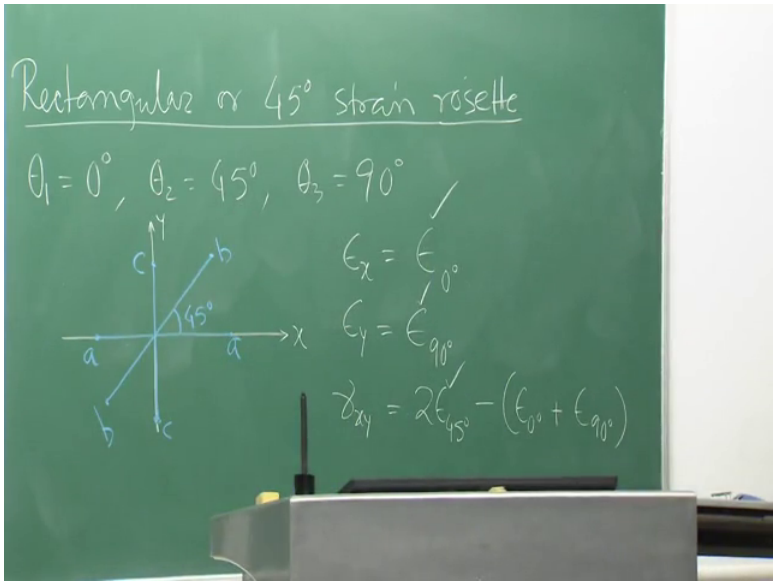

So, let us. So, the first one is rectangular or 45 degree strain rosette. So, we are what you do we choose the value of theta 1 as 0 degree, theta 2 as 45 degree, and theta 3 as 90 degree. So, this values we can choose this is up to us, so how it will look like them. So, this is your x y plane now theta 1 is 0 degree; that means, in the previous figure the line a is coinciding with x axis right fine. So, line a is coinciding with x axis.

Now, theta 2 is 45 degree; that means, the line b b is making an angle 45 degree with x axis. So, that is here this is your b b this angle is 45 degree and theta 3 is 90 degree the line c c is coinciding with y axis then only it will making an angle 90 degree with the x axis. So, this is your line c c. Because this angles or the arrangement of the strain gauges is completely up to you right how you are choosing that. So, then why do not you take the advantage of your less compressional effort?

So, if you choose the axis like then basically you are epsilon x if you put theta 1 equal to 0, theta 2 equal to say 45 degree, and theta 3 is equal to say 90 degree and if you know this strain components from the strain gauge reading they in basically you can write epsilon x equal to epsilon 0 degree epsilon 0 degree means epsilon theta 1, epsilon y is equal to epsilon 90 degree; that means, epsilon theta 3 and epsilon and gamma x y will be 2 epsilon 45 degree minus epsilon 0 degree plus epsilon 90 degree.

So, you just simply measured this strain components from the strain gauge you get the reading, you put in this equation you get epsilon x epsilon y and gamma x y that is to the things you can calculate from by your own like by drawing the Mohr circle or whatever, the understood the concept. So, here now you see that by choosing the arrangement or the strain rosette by choosing the values of theta 1 theta 2 and theta 3 we have minimized our computational effort or computational I mean say calculations right.

Otherwise you can choose any value of theta 1 theta 2 theta 3 there is no compulsion. So, this is known as 45 degree strain rosette or rectangular strain rosette and it is very very popular and most of the experimental strain analysis we will try to follow this strain rosette and there that is rectangular or 45 degree strain rosette now.

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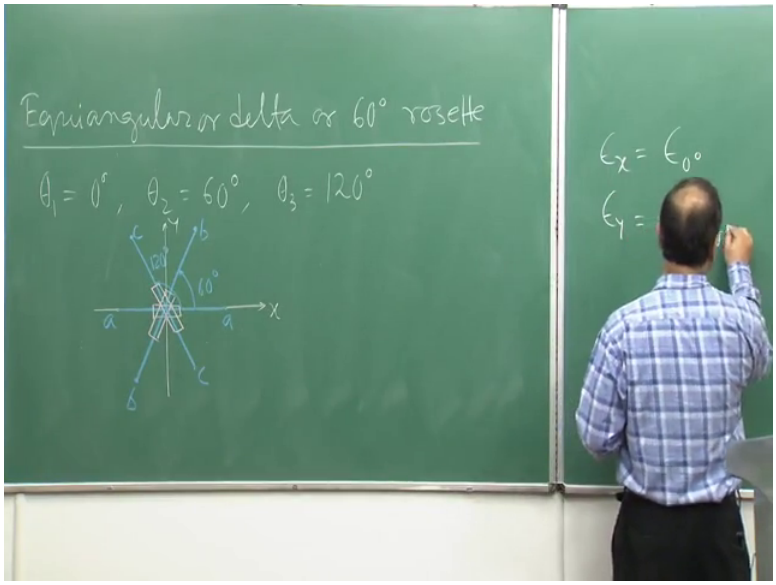

Similarly another strain rosette is there that is 60 degree strain rosette known as equiangular or delta or 60 degree rosette in literature it is mentioned as equiangular or delta or say 60 degree strain rosette. So, here what you do we choose? The value of theta 1 as 0 degree, theta 2 as 60 degree and theta 3 as 120 degree, so what we get this is my x y plane. So, so theta 1 is 0 degree means a a line will be coinciding with x axis. So, that is fine. So, this is like this. So, this you are a a line ok.

Now, b b line will be making an angle 60 degree because theta 2 is 60 degree here. So, b b line will be making an angle 60 degree with x axis this is your b b and c c line will be making an angle 120 degree with x axis because theta 3 is 120. So, this is 60 and this is

another 60. So, this is your c c. So, this is your 60 degree and this is your 120 degree. So, this is the arrangement. So, we will be placing the strain gauge we will be placing the strain gauge like this. So, this is my strain gauge. So, we will be placing the strain gauge like that and then we will measuring the strains. So, from there what will get? So, from there we can simply right epsilon x equal to epsilon 0 degree epsilon y equal to twice of.

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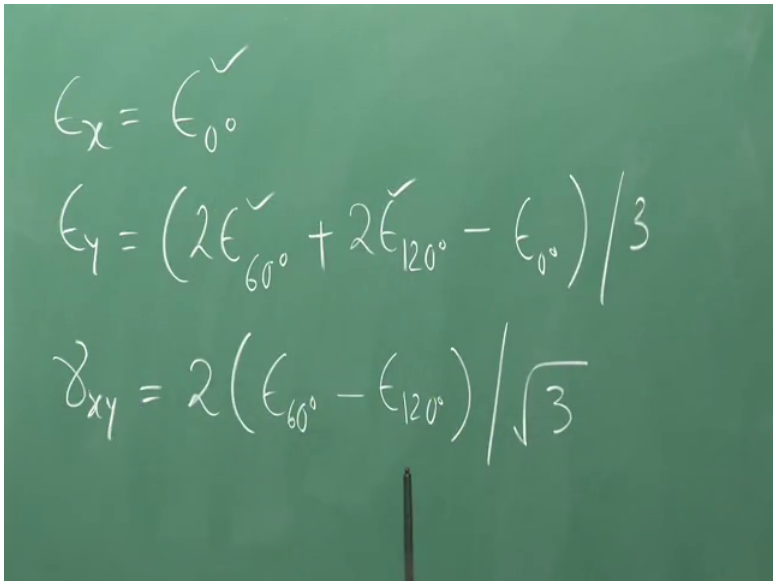

That can be obtained from those 3 equations pretty simply 60 degree plus 120 degree minus epsilon 0 degree by 3 and gamma x y can be obtained as twice of epsilon 60 degree minus epsilon 120 degree by root 3 ok.

So, you measured this things and then you get the strain components in x y coordinate system. So, I mean by from the calculation you can get the strain components like that. Now if you want to find out at least for 45 degrees strain rosette if you want to find out the strain components from the Mohr circle then we can construct the Mohr circle for 45 degree strain rosette. Now let us see how we can construct the Mohr circle for 45 degrees strain rosette at least ok.

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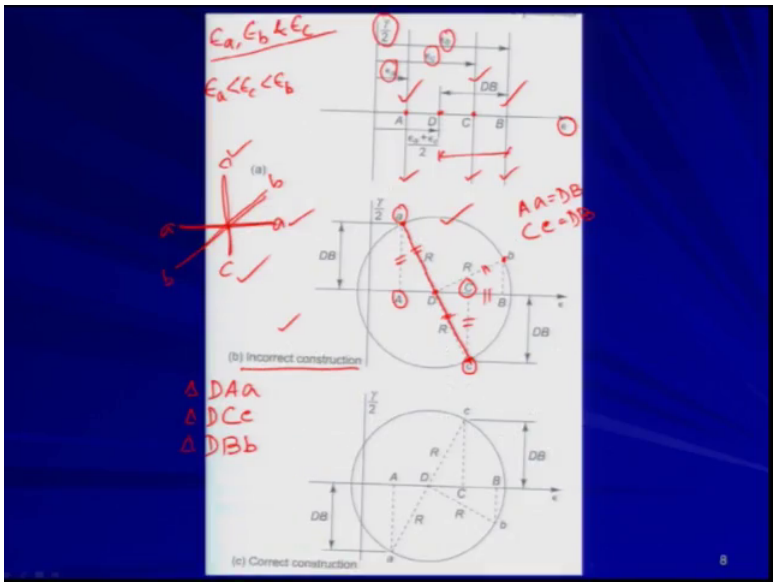

So, now come back to this figure get the process first I mean how we can construct the Mohr circle for 45 degree strain rosette. So, we are first we are choosing epsilon and gamma by two space which is required which is very much required for your I mean Mohr circle for strain.

Now, we know epsilon a epsilon b and from the strain gauge reading that we are measuring now this things we are plotting in this space by drawing one we are drawing 3 vertical lines; that means, parallel to the gamma by two axis we are drawing 3 vertical lines, such that this line the first line is epsilon a distance away from gamma by two axis similarly the second I mean this is the second line and this is the third line and here we are just considering I mean this is I mean just form your reading whatever we are getting as per that we are considering this situation this is the situation we are considering epsilon b is greater than epsilon c is greater than epsilon a. Suppose this kind of arrangement is coming from your strain gauge reading then you are just dropping 3 verticals like this away from gamma by two axis epsilon a distance away epsilon c distance away and epsilon distance away ok.

Now, you look at point d you look at point d in such a way that d is the midpoint between the strains which are making in 90 degree angle like I mean epsilon a and epsilon c right. So, I mean in the 45 degree strain rosette what is there this is a a this is c c and this is b b right is it my 45 degree strain rosette, so this. So, you choose a point you locate the point

d e which is the midway between the two vertical lines representing the strains for the perpendicular axis a and c. So, perpendicular axis a a and c are perpendicular. So, you look at the point d in such a way that that is the mid way between point a and c which are actually perpendicular axis in the in the coordinate system as shown here. So, once you locate .point d.

Now, you measured d b you measured d b now layoff a a come to this figure lay of a a and lay of c c on the vertical lines in such a way that a a is equal to d b, and c c is equal to d b. So, we are just choosing two points point a small a and point small c. So, these two points we have got on this vertical lines. So, these are the vertical lines on this vertical lines we are locating or a we are laying of the distance a a and c c. So, after that what you are doing then considering d as the center, d a or rather a c as the diameter this as the diameter and d as the center you complete the Mohr circle. So, this is your Mohr circle now this Mohr circle is cutting the vertical line drawn at point b at small b point ok.

Now, this point a point b and point c basically are lying on the Mohr circle and they will be defining the a plane b plane and c plane on which we can find out the strain components. Now if you look at this triangles I mean triangle D A a triangle D C c and triangle D B b. So, all these triangles are similar triangle right because two sides of these triangles are similar because a a is equal to say d b is equal to c c similarly this d b is equal to d c equal to d a because they are the radius of the Mohr circle. So, these 3 triangles are similar triangle. Now from this actually if you try to find out now it is not necessary that because you are strain gauge is measuring the strain or normal strain that does not mean that along that axis they will be no shear strain I am on that particular plane there will be no shear strain you cannot say like that ok.

So, that is very true from this figure. So, point a will be denoting plane a right; that means, this is the axis this is the axis here point b we will be denoting this axis and point c we will be denoting this axis. Now if you look at this points point a b and c on the Mohr circle, they are telling about epsilon a, epsilon b and epsilon c along with the shear strain. So, that we are not measuring we are just because you are over strain gauge is capable to measure only the normal strain anyway. So, that is defined to show now whether this Mohr circle construction is right or not because that is written here in correct construction now why it is incorrect you need to find out that.

So, I will stop here today in the next class we will take it again so that we will understand why it is incorrect and what should be the correct construction. So, I will stop here today.

Thank you very much.