**Principles of Metal Forming Technology**
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**Lecture – 05**
**Concept of Stress and Strain**

Welcome, to the lecture on Concept of Stress and Strain. So, we will be discussing about the concept about the stress and strain. So, in the metal forming aspect as we know that here we deal with the forces which act on the body, resulting into the generation of stresses and strains and so, we must to know that how these stresses are basically represented how this is stress is are generated, how you know you nominate them or how you name them like that or even the different types of strains or so.

So, when we talk about the forces which are acting on the body they are normally the external forces which are acting and there are two types of external forces surface force and body force.

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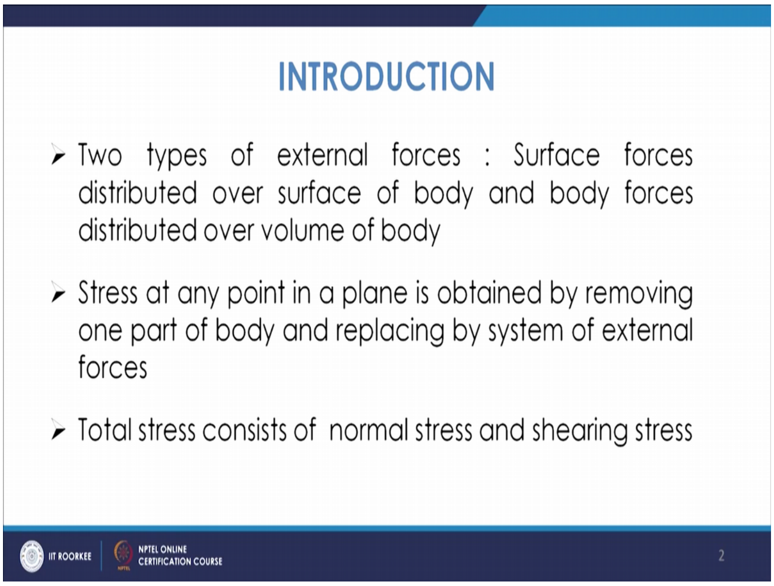


So, when the forces are distributed over the surface of the body, then they are known as surface forces and then when they are distributed over the volume of the body, then it is known as the body forces like gravitational pull or so, they are the example of body forces. Now, the static forces which are occurring they are known as the surface forces.

Now, when these forces are implied on the body and then as we know that for representing the stress what we do is that, we cut certain portion of the body and then we find the free body diagram and from there you find the force, which is you know resultant force which is acting at certain point and in that we try to find the or define the stress in that case.

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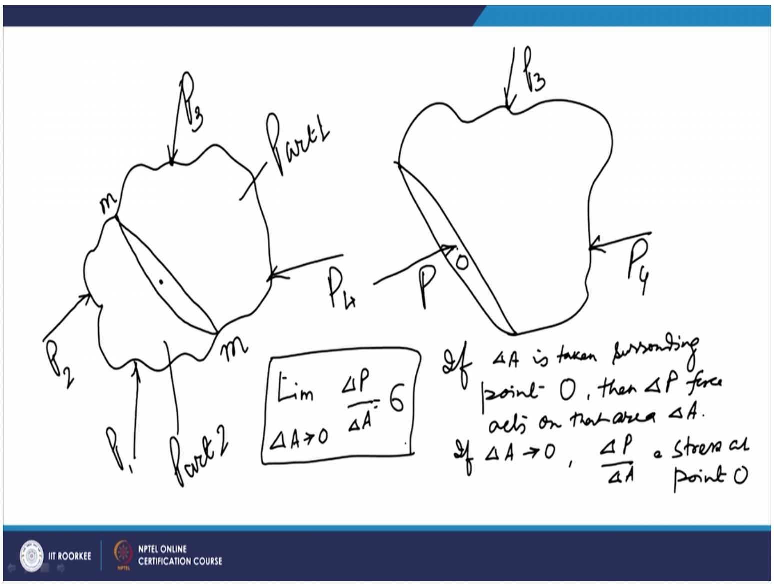


So, what we do is that, if suppose you assume that you have a body on which you have different type of forces acting. So, suppose you have a body like this. So, suppose this is a body and you have different types of forces which are acting on the body suppose this is P 1, then there may be force like P 2, then you have force like P 3, then you have force like P 4.

So, suppose the body on the body you have on the surface of the body you have different forces, which are acting and the body is in the condition of static equilibrium, so, in that case you know you have to find that, what is the stress value at any point on any plane. So, suppose you are defining a plane like this; suppose you define a plane which is suppose m, m and on this plane you want to measure the stress at suppose any point. So, there is a point on any plane inside the body and on that you have to find the stress in that case.

Now, you know that this body which is subjected to different types of forces in the equilibrium so, what you do is, you basically take this part out and try to find the stress at that particular point now if you look at. So, if you take this portion out. So, it will be looking like this and here you have this plane. So, that is what I mean normally it will be like this. So, this is this part which you we have taken so, you have this as P 3 and then you have this as P 4. So, now, this is your, this is the part 1 of the body and this is your part 2 of the body this is part 1 and this is part 2.

Now, what we do is so, you remove this part 1 of the body. So, you are taking this part to this portion. So, this is your part 1 and if you see that this P 3 and this is P 4 which is acting like this and then you are replacing all that force with the system of forces. So, you have you have to find the stress at this point. So, you will have resultant force here and then this is your P which is acting and basically you are representing this p. So, that you know the body is still in equilibrium.

So, it means that whichever point was at whichever location there is no at all any change. So, that way you have taken the free body diagram of this part 1 and you are basically representing by this set of forces so that it will retain all the you know each point in part 2 of the body in the same positions. So, that is how you are trying to have an isolation of this part 1 and in that.

Now, the thing is that if you take this point around this point if you take the very small area delta A. So, in that case and if they are you this delta P force is working on it is. So, suppose if actually delta A is taken surrounding point O. So, we are taking this. So, this is your point O at which you want to find the stress. So, and you know that so, so delta P force acts on that area that area delta A.

Now, when we try to define the stress basically stress is defined at a point. So, when this delta A will be limiting towards 0 in that case the limiting value of the load when the delta A is turning into 0, that is known as the stress value at that particular point. So, what we do is if delta A is limiting towards 0 in that case the delta P upon delta A that will be that will be known as a stress at point O. So, that is how you define the stress at a particular point. So, in an nutshell what we see is that you get limited limit of delta A turns towards 0, delta P upon delta A and that will be the value of the stress. So, that is how you calculate the stress at a particular point.

Now, the thing is that when we are in this case we are assuming this plane to be m; m now if the same point is there, but if the plane orientation is changing in that case the stress will change.

If you have any other plane from here passing in a different orientation in that case the stress you know will be different at that particular point. So, what we do is normally we it is convenient to use that stress which is inclined to area over which it is acting. So, that way you can present in a better way you can have the explanation of the stress. Now, that can be further understood by looking at this particular figure. So, what happens that what we see that when you have a force component working now in that case you will have a two types of forces.

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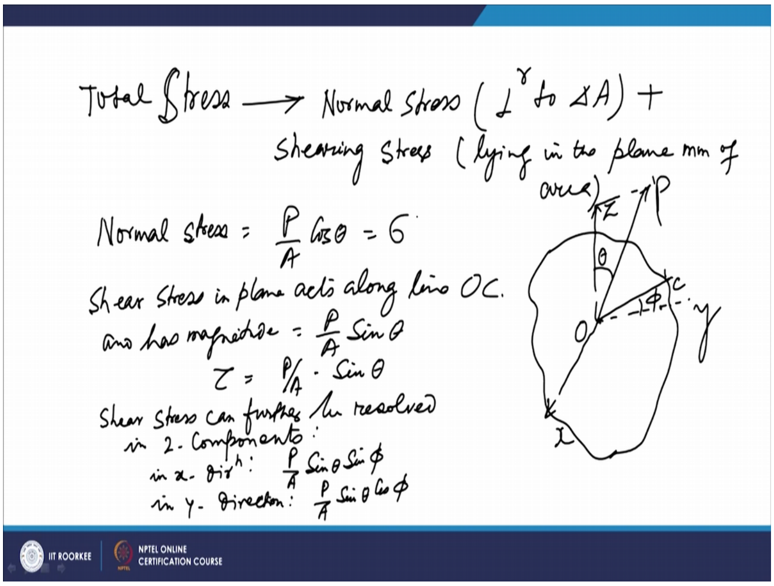


So, if you have total force. So, total force or you can say total stress, now this total stress which is acting you have a two components. Now, one is the normal stress so, that will be working perpendicular to this area. If you look at that you know stress which is generated at that point so, one will be acting perpendicular to that area and another will be acting you know in lying in that same plane. So, so what will happens. So, that will be known as the shearing stress.

Now, shearing stress it is lying in that plane. So, now the thing is that when there is a force which is acting. Now, it will have two components if it has inclination then it will have two components as we know one will be perpendicular to the plane another will be in the plane. Now, again that can be understood by referring to the figures. So, suppose you have such kind of you know body now in that suppose, this is your P which is acting now in that case what happens that, this P if suppose it makes angle theta with the z axis. So, what will happen now in that case P cos theta will be the component along the z direction. So, P by A cos theta that will be basically the stress in the vertical direction or or in the direction perpendicular to the plane and that is known as the normal stress.

So, normal stress so, this is the normal component P cos theta and then the area is A so, P by A cos theta. So, this is your normal stress. Now, again we the one is the normal component another component will be in the plane basically. So, it will have two components one is here and another will be like this now the thing is that so, so, it will be it is resultant, right. So, now, the thing is that if this. So, basically you will have this how this is how you will have it is resultant. So, this will be the resultant of so, you will have now the thing is this is your this is your in the plane it is working and here you have other you know directions. So, suppose this is your x axis, this is your y axis and this is the component of this P in the plane.

Now, if. So, suppose this is C, now if this direction this component is making angle phi with the y axis in that case now you will have no. So, it is a basically xy plane is a vertical plane is. So, the horizontal plug is vertical plane is the z plane and then you have horizontal plane is the xy plane. So, suppose this components is making angle phi with the y axis. Now, the thing is that this component will be if it is P cos theta this will be P sine theta. Now, it has two components it is making phi with the y axis. So, P into sine theta into cos phi will be the stress in the y direction and that will be a type of shear stress.

So, if you look at shear stress so, shear stress in plane acts along line OC. So, that is your shear stress so, this is a shear stress this is your normal stress and it is resultant is your total stress. Now, this shear stress has again two components and it has magnitude and has magnitude. So, if the normal stress have magnitude of P by A cos theta it has a magnitude of P by A sine theta.

So, we write shear stress we define as tau and tau will be P by A into sine theta. So, this is your shear stress. Now, this shear stress again has two components; one will be in the x direction, another will be in the y direction. So, so again for that we have to find those components. So, shear stress can further be resolved into two components. So, it will have two components; one is along the y direction, another is along the x direction. So, along the y direction since this P sine theta is making angle phi with that so, in the y direction you will have P sine theta cos phi and in the x direction you will have P sine theta sine phi; in x direction P by A sine theta sine phi and in y direction P by A sine theta cos phi.

So, what we see in general that we see that when we talk about the stresses when we try to define the stress is what we see that you know on any given plane you have one normal stress that you see that this is your normal stress and then you will have two set of you know shear stresses along the x and the y axis. So, this is how you represent the stresses at any point. So, normally what when we talk about normal stresses they are normally denoted by this sine and when we talk about the shear stresses this is so, that is tau and as we know that it is working in the along the plane.

So, in that you have two directions attached normally it is two dimensional plane and then in that case it will be represented by tau and both this directions like x, y or so, it will be coming like since it has it is working you know in a particular direction and you know, it is perpendicular to some plane so, that way you give one you know terminology to it and in that case tau will be have the two you know directions attached.

So, you have sigma xx or sigma yy or sigma zz and tau will have two components with two different directions tau xy or tau yz or tau xz. So, basically there are two subscripts which are required for these shear stresses and for the normal stress you can come with only one subscript like sigma x or sigma y or sigma z. Again, this there is nature also defined to it and it may be positive or negative. So, normally when we talk about the normal stresses they are either you know tension or compression. So, when we talk about the tension force they are positive and when we talk about compression forces they are negative.

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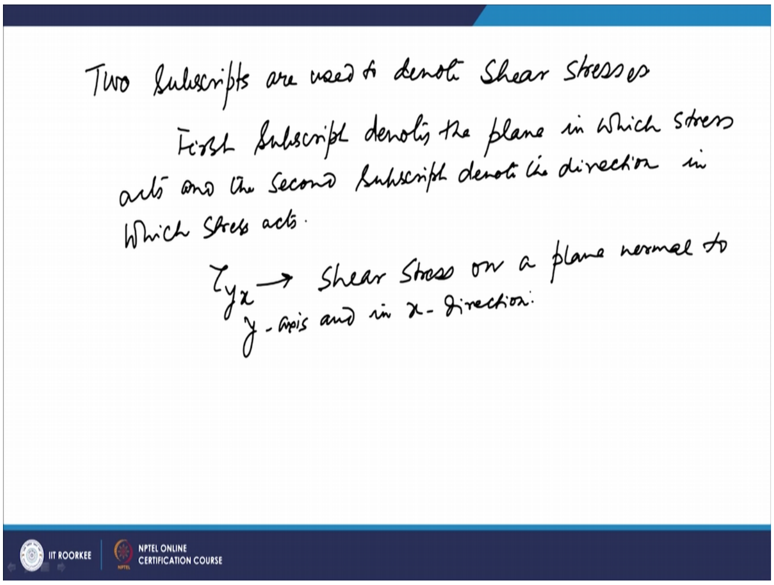


Similarly, when we talk about the you know this shear forces here you use two subscripts. So, two subscripts are used to denote shear stresses. So, what we do is the first subscript now, in this case what happens that first subscript the first subscript basically, it will be required for you know the plane it is going to discuss about the plane in which the stress act. So, first subscript denotes the plane in which stress acts and the second subscript will denote the direction, in which this stress acts and the second subscript denote the direction in which stress acts so, this is how.

So, if suppose you have tau yz so, basically stress is working on a y plane normal and I mean this is working in a plane, which is normal to the y axis and then it is working in the z axis. So, tau y axis tau yx if you look at so, it will be shear stress on a plane normal to y axis and in the direction of x direction so, in and in x direction, ok. So, this is how you try to denote the stresses.

Now, coming to the so, in the case of shear stress also you have some denotations that whether it will be positive or negative. So, if they denote basically if the points in the are basically in the positive direction on positive phase then they are the positive and if in a negative direction then on the positive face then it is told as negative. So, in that way we denote the we give the value or the sine to this shear stresses.

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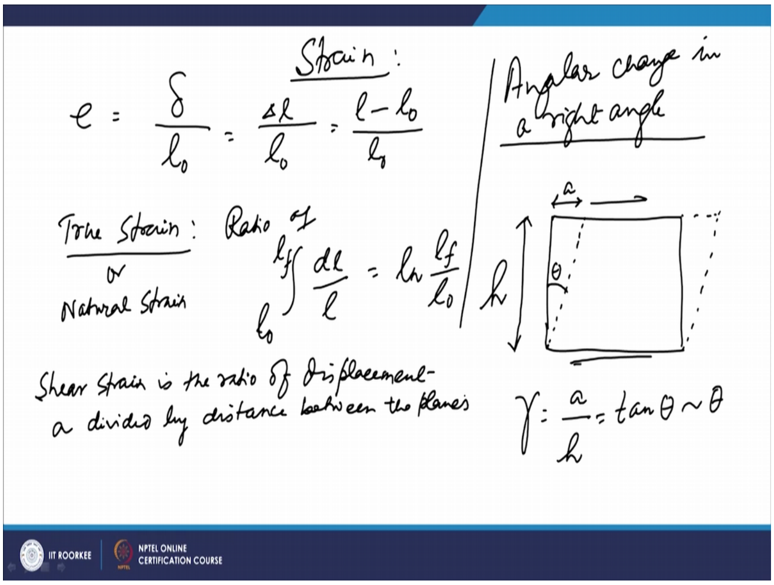


Now, coming to the concept of a strain and type of strain, when we talk about the strain now, we define the strain by the change in length to the original length of the body. So, what we define e? E is defined as the strain and this is defined as delta that is your change in the length and divided by the original length. So, basically it will be change in length we call it as delta l and then it will be like l naught. So, if the final length is l and initial length is l naught in that case it comes like this. So, it will be basically l naught and so, that is how the strain is computed because this is change in length to the original length.

So, now strain at a point is the ratio of the formation to gaze length as the gaze length is approximating towards the towards 0. So, that is how the strain at a point is defined. Now, this is known as normally in terms of metal forming we call it as engineering strain when we are basically finding the change in length of the material and then we are dividing with the original lengths. So, that will be find in engineering strain. Now, in the case of metal forming there is another type of strain which is more realistic which is defined is the true strain. So, true strain basically it is defined as the change in the linear deformation divided by instantaneous value of the dimensions.

So, this is ratio of so, it will be you know it will be divided as dl by l and then it will be l naught to l f. So, it will be you know change in the length divided by instantaneous length. So, that way we calculate the this true strain and then in that case if you look at if you take this integration that will be l n of l f by l naught. So, this is how you compute the true strain. So, basically what happens true strain has more realistic meaning in case of metal forming and that is also known as natural strain or true strain or you can also call it as natural strain we will more discuss more about it when we start discussing about the plasticity theory.

Now, there is another type of strain that because in the case of elastic deformation it may result also in the change in the initial angle between any two lines. So, in that case a different type of strain is also defined and so, the angular change so, angular change in a right angle now, what happens that you know you have suppose one such type of element and then if you apply the stress in this case and because of this stress if suppose this the member takes this sip.

If you apply the stresses on this you know surface now in that case, in that case what happens, that this element which is there it has a height suppose of h in that case what happens that there will be you know change in the angle between the two lines. So, this line which is vertical it has inclined to certain angle theta.

Now, in this cases what we define the strain as the you know shear strain and what you see is that if suppose this is the change now in this case what we define the shear strain as a upon h, now this is the h that is height of this plane now this dimension of the plane. Now, this a by h as you see it will be nothing, but equal to tan theta. Now, what we see is that normally this theta value is very very small and in those cases you can approximately take it as theta if theta is taken in terms of radian.

So, , what happens that in this case you get the different type of strain and that is known as you know the shear strain and this shear strain is equal to that displacement a so, what we see is that the shear strain you define as the displacement that is a and divided by the distance of the plane h. So, shear strain is the ratio of displacement a and that is divided by the distance between the planes divided by distance between the planes.

So, this is how you get this shear strain values and so, basically you get this shear stress normal stress and then you have shear stress. In the case of shear stress you have the engineering strain and then you have the shear strain you and also you have alongside the engineering strain and you have the true strain. We will discuss more about this in the coming lectures.

Thank you very much.