Mechanics of Material
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Introduction and Mathematical Preliminaries

Lecture – 01
Part 2
Introduction to the course
Concepts and equations in this course

Let us understand what are the basic concepts in mechanics that we will be looking at in this course and what are the equation that connects them.

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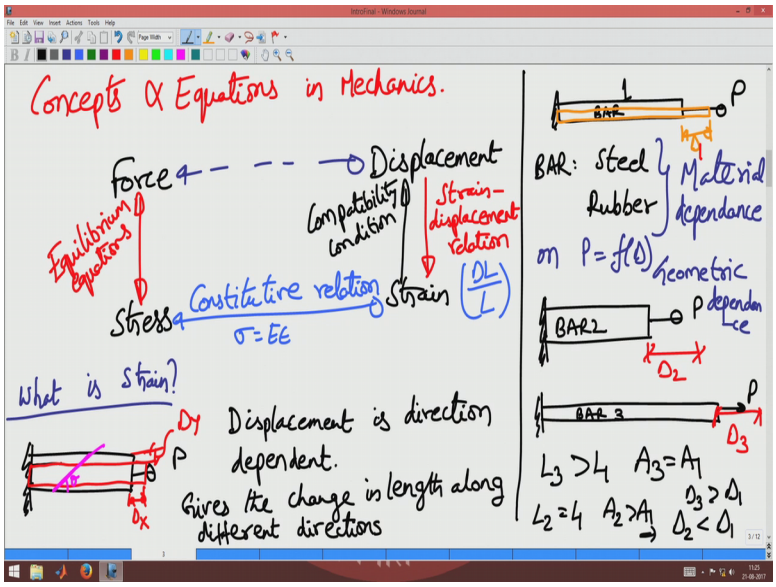

So, now I am interested in, I am going to concentrate on concepts and equations in mechanics. So, there are 4 concepts in mechanics, essentially what we are trying to do is relate force to the displacement. Now we are not going to relate them directly, but we are going to relate them through two other quantities called as stress and strain. Let us first understand why do you need these two concepts and why cannot relate force and displacement directly.

The reason is the following. Say I have a bar to which I am apply a load P, let us assume this bar is, this is the bar let us assume the bar is made of steel and or rubber. For the same force P that let us assume that this bar deforms into another bar of this shape. So, it has elongated by a amount delta. Now is a relationship between the force and the

displacement delta they are same for steel and rubber, no right, steel will deform a much less compared to rubber bar. So, we find that there is dependence on the material. So, this shows as a material dependence on the relationship between force and the displacement. So, there is a material dependence on the relationship between force and the displacement.

Next let us say I have two bars, one bar is thicker than the other one and I have another bar which is longer than this bar 1, let us say this is BAR 1, this is BAR 2 and this is bar 3. Now which one will show a longer elongation or which of these let us say this is delta 1 I apply of force and this expanse by delta 2 and this expanse by delta 3. I have applied a force P on each of these bars and the corresponding elongation under gone is delta 1, delta 2 and delta 3. And I am assuming the length of BAR 3 is greater than length of BAR 1 area of BAR 3 is equal to area of BAR 1 then I know that delta 3 will be greater than delta 1. Longer BAR will elongate more in case of BAR 2, let us assume length of BAR 2 is same as length of BAR 1, but area of BAR 2 is greater than area of BAR 1 this would imply delta 2 would be less than delta 1.

In other words the geometry of the body has a role to play in determining what this function is. So, there is material dependence and then there is a geometric dependence. If you want to relate the force and displacement directly such a relationship will have will depend upon both the material and the geometry of the body. So, you will not have any predictive capability of such a relationship.

In other words I have to find this function this function will have some constants. So, I have to do some experiments to find the constant, once I find the constants and relate the force and displacement I cannot use that relationship to understand what will happened for a different geometry of the body or on the body is made of a different material. So, you want to work on the geometric and material dependence of the body and hence you define two countries call stress and strain.

Now what is strain? Now let us consider this BAR 2 just because it has a start a geometry this easy format to explain some things here, now what happens when I apply a force P this BAR is going to shorten a bit and it is going to elongate by amount delta X and let us say this shortening is delta Y this is going to shorten a bit and elongate a bit.

In other words the displacement is not same in all three directions, displacement is direction dependent its shortest in the Y direction elongation is the X. So, at some inclination point some inclination like this at theta what happens to this length it will elongate or shorten depending upon what its orientation is. What strain does is it gives you the displacement or the change in length strain gives, the change in length along different directions. Essentially what it tells you is, you give me a displacement field it will tell you how the length changes in different directions. So, this equation that connects the displacement and the strain is called as the strain displacement relation. This ensures that the geometric dependent that the longer BAR will elongate more is loss because it gives you a measure of how the length changes from different directions normalize with respect to its length.

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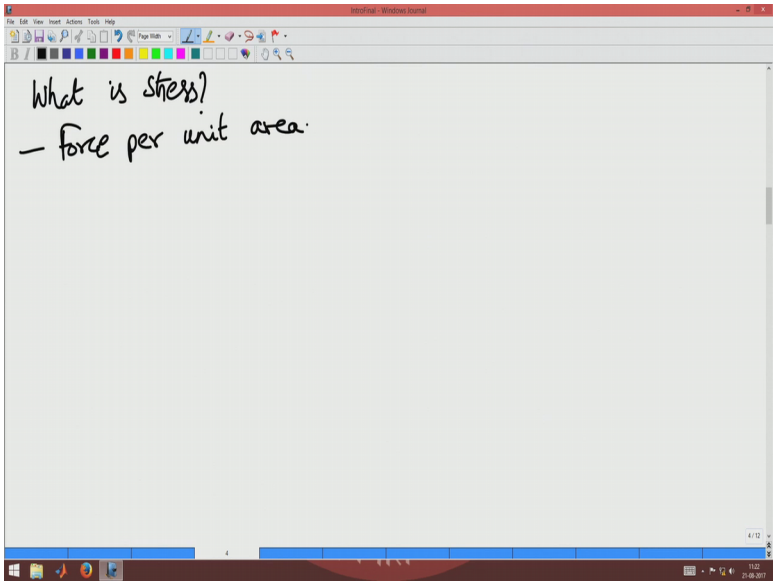

Now, let us understand what stress is. Typically stress in a previous courses or in your high school you would have understood it has force per unit area, stress would have been defined as force per unit area. While this is a good now definition for starting purposes you will find in this course that this is not adequate definition just like stay in different change length per unit, length is not an adequate definition or incomes to studying mechanics of deformable bodies.

So, now in this course we will see what stress is, in fact stress and strains are what are called a second order tenses and we will see what a second order tenser is, how do you

find its components and so on in the course. So, stress is force unit area. In other words what happens is you are essentially relating the force and the stress to lose the geometric dependence on the body. The relationship that relates the force to the stress is called as the equilibrium equations, equations and just like stay and displacement relationship lost the geometric depends on length per say the equilibrium equations will lose the geometry dependence on the area of the body.

In addition to these two equation there is a third equation which connects the stress and the strain and this relationship is called as constitutive relation. What this relationship does is it relates this stress and the strain you would have seen and equation of the form E epsilon or E is the Young's modulus, this is an example of a constitutive relation. The force equilibrium and moment equilibrium equations are examples of equilibrium equations, are in fact the equilibrium equations. So, similarly strain displacement relationship could be change in length delta L by L is a potential strain displacement relationship which we will generalize later.

Now, there is a reason for me having this arrow there a reason for me in having this arrow point like this alone instead of pointing in both ways are like I did here. In case of these two relationships you can relate the stress and the strain stress in either way. And on other hand if I what to go from strain to displacement, if I what to go from strain to displacement there is what is called as the compatibility condition that I have to use.

The point here is in mechanics in continuum mechanics in the way we are going to deal with we are not going to allow for suppression of two surfaces that is if the surface are joint like this I am not going to allow suppression of two surfaces to form a void in between nor I am a going to allow interpenetration of these surfaces that is this surface cannot move in penetrate and come on this side. So, you are not going to allow these two to happen in any of the scenario that you are going to consider. The mathematical condition that enforces this is the continuity of the displacement feel or the compatibility condition that you are going to use.

So, basically there are 4 concepts in mechanics what is called as force, displacement, stress, and strain. And there are 4 equations that connect these concepts the equation that connect these concepts are the equilibrium equations, the constitutive relation, the strain displacement relationship and the compatibility condition.

In this first lecture I am just introducing these things in this course will spend about a month understanding each of these concepts and each of these 4 equations in more detail. So, essentially you have to understand that mechanics means is not much complicated there is only 4 concepts, 4 equation which we have to use judiciously to solve boundary problems.