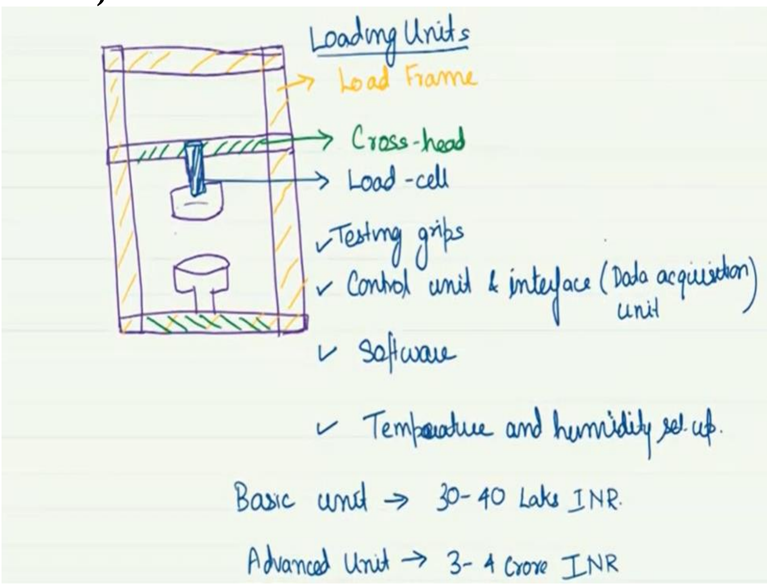
Mechanical Behaviour of Material - I
Prof. Shashank Shekhar
Department of Materials science and Engineering
Indian Institute of Technology, Kanpur

Module No # 02
Lecture No # 09
Universal Testing Machine

Welcome back students so as we mentioned in the previous video, that video lecture that in this particular lecture, we will be looking at the equipment itself the equipment that is used for tensile testing, which is UTM Uniaxial Tensile Testing Machine. So let us start with what are the important components of a testing machine.

(Refer Slide Time: 00:48)



So let me draw simple schematic of how a UTM looks like. So, there is a frame now it is supposed to be vertical although my drawing may not show it exactly like that. So, this is a frame and this is called a double vertical frame. There can also be a single vertical rod for supporting it and it all basically determines what will be the total cost of the equipment and in here you would have a testing job somewhere over here.

This is the bottom jaw the top jaw and this top jaw would be connected to a moving part which will be called cross head. So this part that we are looking at this is the frame there is one important component actually it should be called load frame. And you would see that the quality of data depends a lot on the quality of the frame that you are using. Then the other important component is the crosshead.

So, you see this is the moving part. This one usually happens to be in stationary but this is also acts like a cross head and this is also a cross head. So cross side is the one that moves up and down to pull the sample and in which you would place your load cell. So before I come to load cell let me write down cross head so this is another important component. Now, you are pulling the sample, but you need some device which would actually measure what is the total load acting on it.

And that device is nothing but a load cell. So usually you would have load cell attached to this which would measure how much load is acting? And as a preliminary data, the amounts of movement across head makes from are you estimate the elongation of the sample so these are the 3 most important part or the units of the loading structure. So these are the 3 loading units apart from that you will also have testing grips.

So depending on whether you have a flat sample around, sample of threaded sample, you will have different types of testing grips over here. You will also have this load cell and or change in the elongation connected to a electronics which will make the measurement and then give the data output to the computer. So you need a control unit and interface. So this interface would also be basically your data acquisition unit.

Again, a good system would mean that it will acquire data at a much faster rate and also transmit the data out of it very high rate. Now once the data goes into the computer there you need an interface software interface, which will read the data and analyse the data. So you need a software these are the most basic components of a UTM Apart from that now a days you can also have UTM, which do measurements at high temperature or under some humidity conditional.

So you will also have temperature and humidity set up and usually the set up would encompass, or will contain the whole thing inside it so that your sample is properly inside the at particular temperature or particular humidity condition. And in that set up for in that atmosphere you will be able to do the measurements. So the overall system looks very simple but you would be surprised at what is the cost of such units?

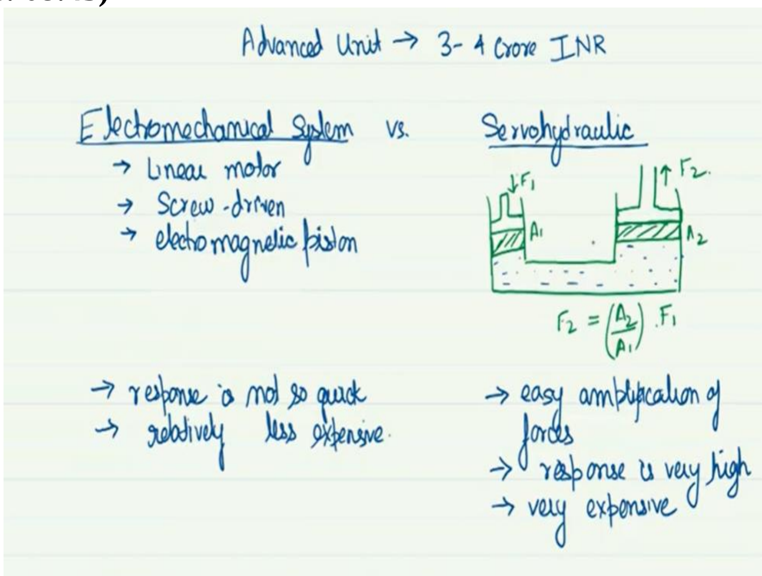
Like I said a lot of it depends that a good quality data depends on a good quality load frame a good quality load cell then your grip should also be good quality so that they there is no micro slip. So you are holding the sample like this and it is holding. The grip is holding like this. But if there is a clip is not holding properly then maybe micro slip and because of that the strain that you get would be erroneous.

And no matter how good quality it is. There will always be some amount of micro slip, but then a good quality machine will have will try to minimize this so basic unit of such equipments would cost anywhere between 30 to 40 lakhs, a very basic unit Indian rupees. And if you want some atmosphere or even a very high strain rate, then the overall mechanics of the system the load fame they need to be much better quality.

And in that case, you will have to advanced units can cost easily as much as three to four crore Indian rupees. So you can see that this simple looking device or equipment is not so simple. It has a lot of cost involved with it and therefore a lot of opportunity for Innovation. So that one can make these systems at a much lower cost in fact, there is an Indian company which has now already been brought up by US conglomerate so there is still a lot of opportunity of innovation in making a, lower-cost equipment like this.

So now we have seen the overall setup. But one thing that is missing here is, what is actuating or causing the movement of this crosshead. Now overall there are 2 different types of setups which can cause 2 different you can say origin of energy which causes the actuation or activation of actuation of the process and these 2 can, this can be classified into 2 categories.

(Refer Slide Time: 08:43)



One is the electro mechanical system versus servo hydraulic. So in this one you have basically a motor so something it may be a linear motor which causes. The movement up and down movement of the sample of the cross head, or it can be a screw driven system. So it is a motor, which rotates the screw and because of which the cross head moves up and down. Or it can be electromechanical system, which pushes the Piston up and down electromagnetic system.

On the other hand in servo hydraulic you have a hydraulic system which is which looks something like this. The shape the overall functioning of this is what allows a very large amplification of forces here. So there is fluid in here and there is a piston on one side which applies a force in the other direction. So you apply the force in this direction F_1 area cross sectional energy as A_1 here the cross-sectional area is A_2 and this will cause the force F_2.

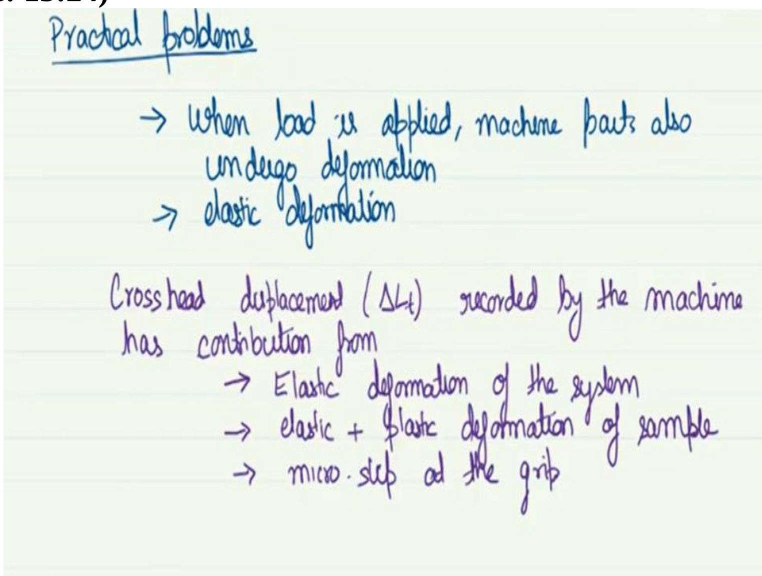
So you can clearly see $F_2 = A_2 / A_1$ time's F_1. So this kind of system allows easy amplification of the forces and that is one thing and here you have the liquid easy amplification of forces. So you can apply very large loads in this kind of system. Second is that since it is liquid the movement is very easily or in quickly, transferred so movement is very quickly transferred or I would rather directly write the response is very high.

But then this kind of system is also very expensive. On the other hand electromechanical systems are much cheaper, but then their drawbacks are that response is not so high not so quick. But the good thing is that it is relatively cheaper or less expensive. So these are the 2 different types of system which actuate the cross head and cause the displacement of the, or elongation of the samples.

And which are then measured by the electronics that displacement as well as the loads. And these are captured or recorded by the computer system and then you can transfer. Once you have the load versus displacement data then from where you can obtain engineering stress versus engineering strain or true stress true strain up to the UTS point. And beyond the UTS point if you want the data, then like we said earlier, you will need to get the actual diameter of the neck region, and then, you can also translate that data into true stress true strain.

So, that is the one aspect of the machine. Another aspect that we need to understand about the machine is that what are the practical problems that may arise?

(Refer Slide Time: 13:24)



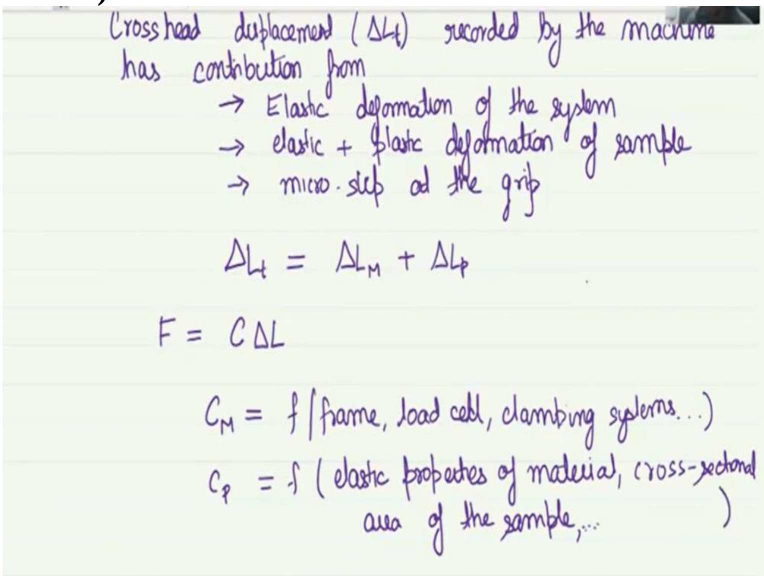
The Practical problems that can arise in a machine and because of which so much science and engineering goes into making this machine is that. When you are applying the load, you should also realize that it is load is also being applied back onto the equipment and therefore the equipment will also deformed. So first let me write when load is applied machine parts also undergo deformation. So what type of deformation would it be?

Would it be elastic deformation or plastic, deformation? If it were plastic deformation there after every tensile test the machine would have permanently changed a little bit and then it would not be usable. So clearly it is not plastic deformation it is only elastic deformation and the next question that may arise. Is that if it is elastic deformation, why are we concerned? We are concerned because the data that you are getting also involves or includes the elastic deformation of the system. So we will see what we mean?

So for example, let us say the cross head is moving so crosshead a displacement will call, which is being recorded by the system, let us call it ΔL_t. Now, this ΔL_t recorded by the machine as contribution from various sources. One, it has the contribution from the elastic deformation of the System. It has the elastic plus plastic deformation of the sample, which is what you want to actually measure.

This is the only part that you want to measure and then apart from these we also get what is called as micro slip. Like we said earlier that you are holding the sample, but they will because of the region where the grip is holding the sample. There will be some amount of slight amount of slipping, and that will also add to the total crossing displacement data. So micro slip at the grip not this micro slip at the grip is something that we can minimize but we cannot eliminate for the time being, we will ignore that part.

(Refer Slide Time: 17:01)

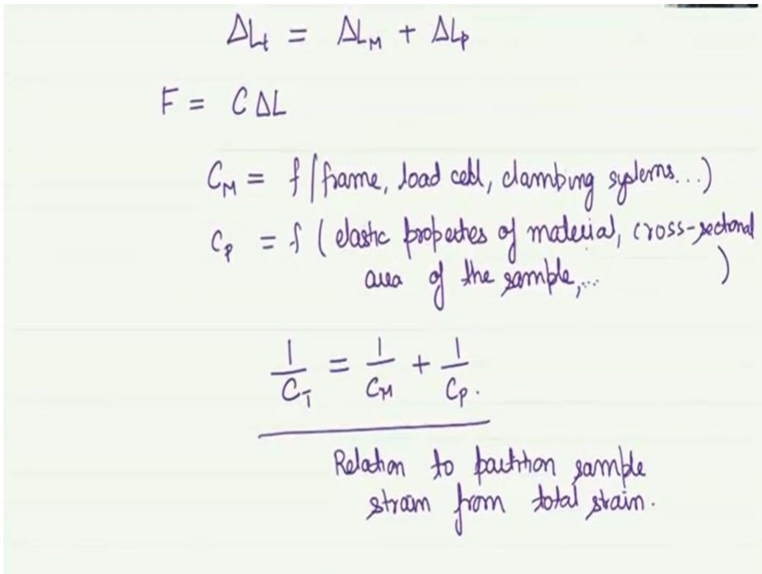


Let us look at what is the relation between ΔL_t and the ΔL_M, which is the displacement of the machine plus ΔL_p , which is the displacement of the system. Now we know that force is equal to. What is? Where, is the stiffness so if stiffness is the C times, ΔL . Now, stiffness for the, what is the stiffness of the machine, and its stiffness of the Machine, this is related to the frame.

It will be a function of the frame. How good is the fame? How stiff is the frame load cell? Because load cell is also part of this frame load, then the clamping system, wherever you have your joining 2 parts, their stiffness will also come into picture. So the overall machine, stiffness is actually function of several components, and these are just important ones. On the other hand, the stiffness of the sample is a function of the elastic properties.

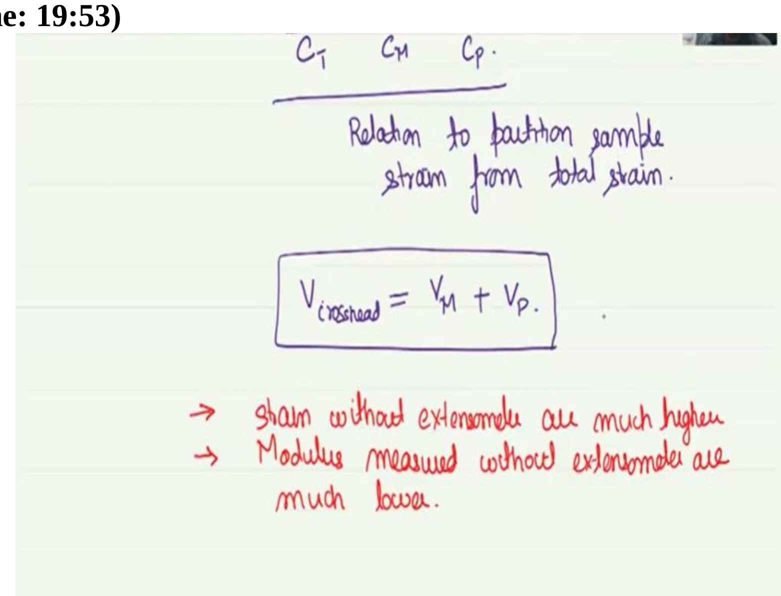
So basically the slope of the stress strain curve plus it is also a function of the cross-sectional area of the sample. And apart from this whether how good sample how the sample is made the quality of the sample, for example, it may be flat or not flat so all those good go into determining the stiffness of the sample.

(Refer Slide Time: 19:00)



Now, if we use this relation and put it over there, then we know that the overall stiffness of the system total is equal to the stiffness of the machine plus the stiffness of the sample. And this is a relation which is used to partition sample strain from total stranger. And based on this relation we also know that cross said velocity that means applying on during the elongation is not the same as the sample deformation rate.

(Refer Slide Time: 19:53)



So the V deformation or the V cross head = V_M. So, the rate at which the machine is deforming plus the rate at which the sample is defined. So these 2 things together, clearly tell us that the data that we obtained from the equipment has to be looked at carefully understood properly. And if you do not carefully, partition the data you may get very erroneous data. For example what you would observe is that?

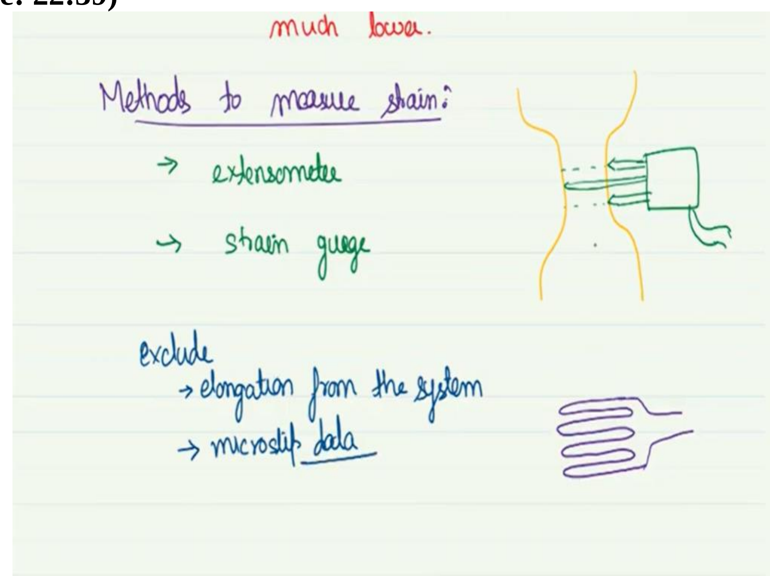
Strain without any external method of measurement. So if you are using, only the cross head for measuring the strain so let us be usually the system is called extensometer. So strain without extensometer or much higher. So that we can obtain from our relation over here $\Delta L_t = \Delta L_M + \Delta L_P$

so this is the ΔL_t that you are calculating, but this is what you wanted. So this is, this one is much higher than what you wanted.

And if the strain is much higher, it means the stress versus strain slope in the elastic region would be much lower. And therefore modulus measured without extensometer is much lower. In fact, in one of the recent labs is that we are doing in our campus in the mechanical Behaviour lab. We measured the elastic modulus for aluminium samples and it came out too close to 12 to 13 GigaPascal. When the modulus of elasticity for the aluminium is close to 60 GigaPascal its somewhere between 60 to 65.

So you can see that elastic modulus because so much lower, of course, this is important quality data. If we refine it, we can get much higher modulus, but still it will be lower than the actual value that you expect, which is close to 60, to 65 MegaPascal. So, next, is that now that you understand the strains calculated using directly from the cross head is not accurate. So what is the better way? What are better ways to calculate stream.

(Refer Slide Time: 22:39)



Whenever you are trying to get good quality data used for which you can use the publication then you have to measure strain using one of these techniques. In fact, some of the papers and reviewers will not accept the data if it has been, if where the Strain has been calculated directly from extensometer. So, one of the methods is extensometer. So extensometer is basically showing device which sticks onto the surface of the sample.

So let me draw roughly our sample now what the purpose of extensometer is that it will attach will have a knife type 2 edges. And then it ties up in one way or other to the sample so that it remains stuck over here. And then this data will go into the electronics. Now, when the sample is elongated and this will become the gauge length for this. So now when the elongation takes place it will measure only the elongation between the changing the distance between these 2 blades.

And therefore, this will give you a much more accurate because it is not anyways, being affected by the stiffness of the system all the micro slip so everything gets excluded. So this system is able to exclude all that additional elongation data. Other method is what is called as strain gauge. So this is actually resistance strip a very small resistance strip. So you apply it over here, onto the surface so it has like this.

And again these are the 2 ends of the resistance wire and what it is measuring is that when the length elongates the resistance changes. So this system is actually measuring the change in the resistance and therefore, it needs to be calibrated a little bit. But once you have calibrated this gives again gives very accurate data and both of these systems are able to exclude stream, from the system I will say elongation from the system and micro slip inform data.

And therefore, this, method is very helpful in giving us very accurate data and to be able to, then measure even sensitive data like elastic modulus. So this lecture would have given you idea about the equipment, UTM Universal testing machine or the tensile testing machine and we have seen what; are the important components? And we have seen what; are the limitations and how to overcome some of those limitations? So with that, we will come to an end of this lecture thank you.