Basics of Mechanical Engineering-1

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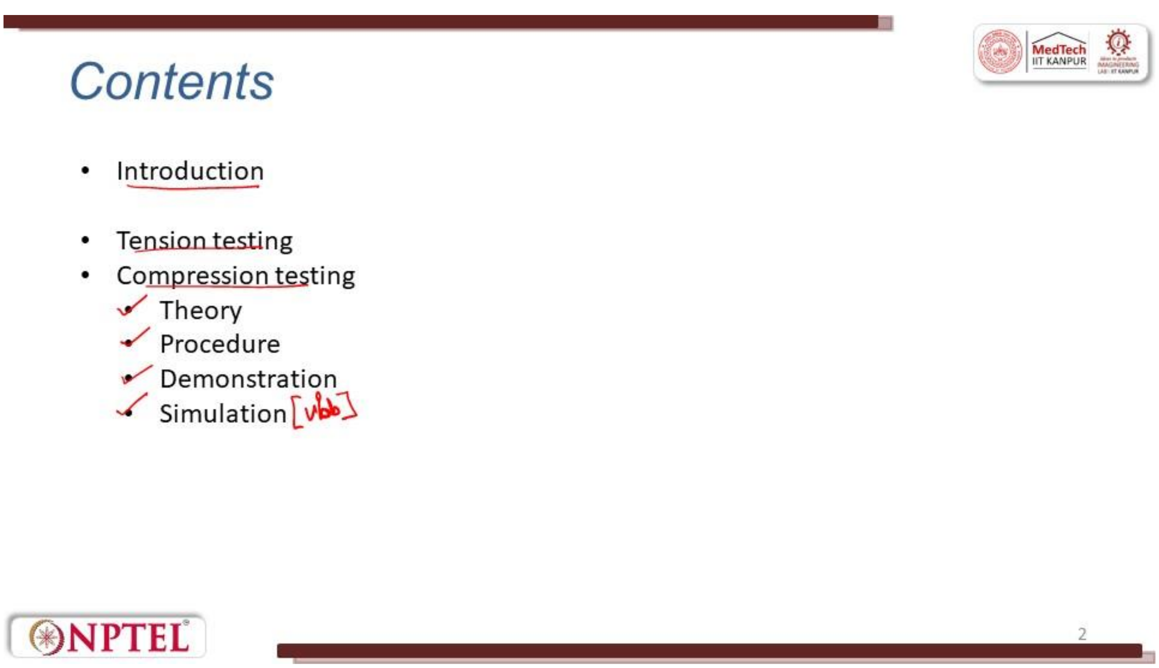
Week 09

Lecture 35

Testing for Tension

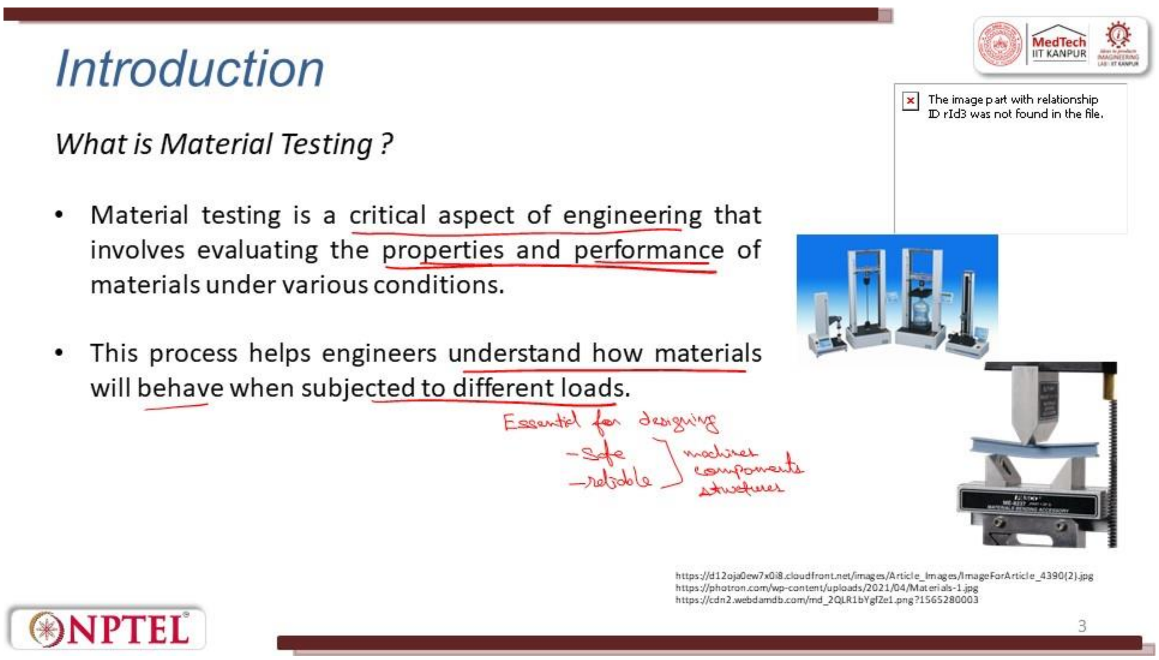
Welcome to the next lecture in the course Basics of Mechanical Engineering-1. We have discussed majorly about the Mechanics, about Units and Dimension in the previous weeks, about the Solid Mechanics. Majorly we have discussed in the past weeks and now we have started introducing the theory of machines.

Regarding the laboratory demonstrations in the Solar Mechanics, we learnt about the Tension, Compression, different properties and how do we test them, a brief introduction was given. This lecture and this week would be covering a detailed laboratory demonstrations on different experiments that we conduct to have the testing of the material at different levels. This lecture basically be covering Testing for Tension and Compression that is we will try to have a Tensile Test and Compression Test in this lecture.



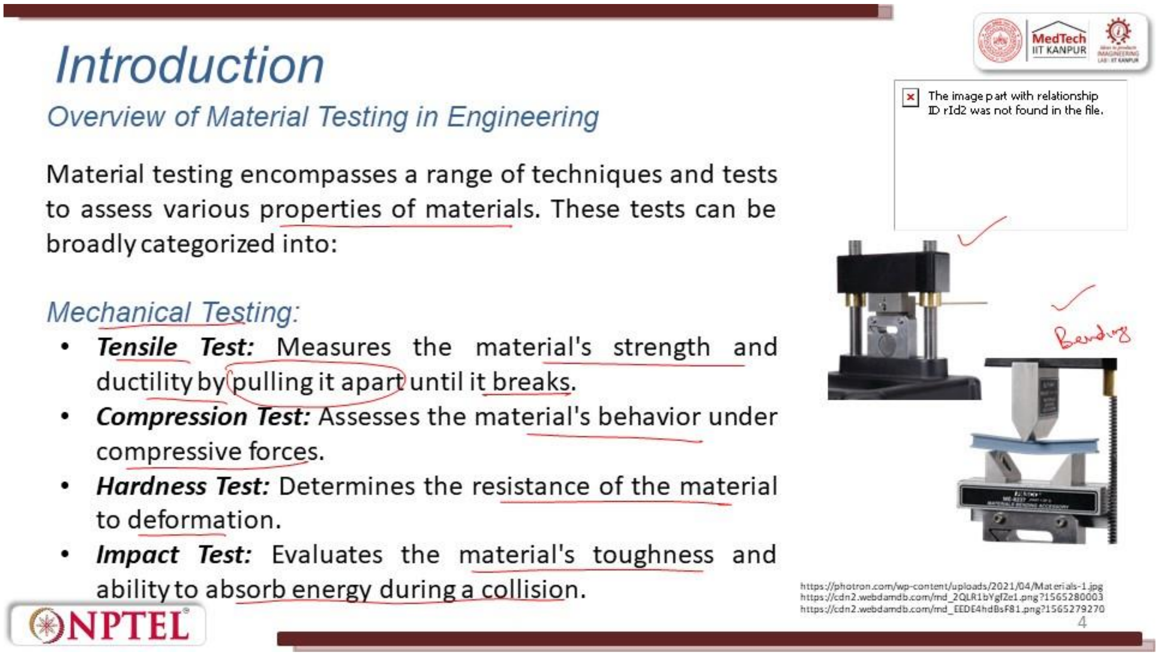
First we will have a quick introduction that what is material testing and why do we really need it. Then we will discuss about the Tension Test and Compression Test. In those, we will try to recall the theory that we have discussed in the previous lectures. We will try to go through the procedure. We will cast a glance over the demonstration that is the video demonstration on YouTube and also simulation that is developed by the VLAB that is Virtual Lab setup.

Initiated or mentored by IIT Madras and this setup for testing is developed by different institutions in India. The demonstrations which I will take for these two test tension and compression are developed by NIT Suratkal.



What is material testing? The question what is material testing could be answered in this way, material testing is a critical aspect of engineering that involves evaluating the properties and performance of materials under various conditions that is properties of the materials and performance of the materials, both the characteristics we try to understand and this helps us or the engineers are helped with understanding how materials will behave when subject to different loads.

So, which is essential? This is an essential requirement for designing safe and reliable structures and components. Safe reliable I would say machines components and we will talk about the compression test that is naturally having application in construction that is I would like to put here is safe structures.

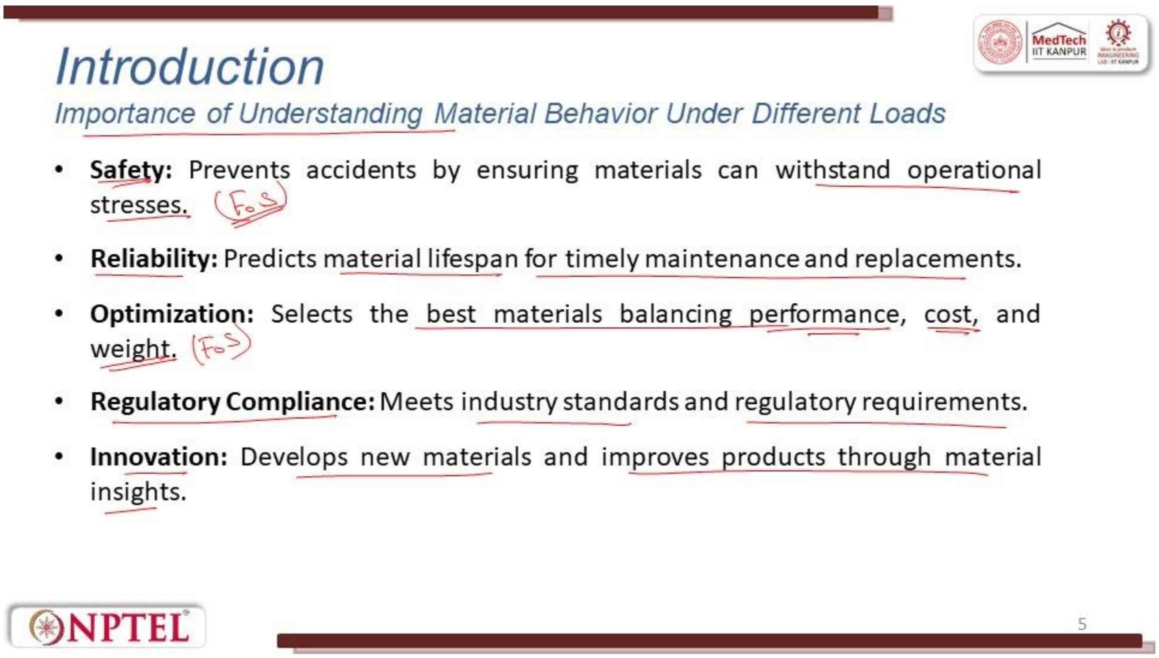


Overview of Material Testing in Engineering. Material testing encompasses a range of techniques and tests to assess the various properties of materials.

These tests can be broadly categorized into these categories. It is mechanical testing in which we have tensile test which measures the material strength and ductility by pulling it apart until it breaks. This is the Tensile test we will go through in this lecture. Also, Compression test is there which assesses the material's behavior under compressive forces. That is, we try to apply the forces in the opposite directions but towards the material.

That is Compression test. Then we have hardness test which determines the resistance of the material to deformation. Impact test evaluates the material's toughness and ability to absorb energy during a collision. So, we have talked about the test, very brief introduction was given. These are the two setups which are given.

This is a bending setup. We will talk about the bending setup also in the coming lectures. So, why testing is important?



The importance of understanding material behavior under different loads. First and the foremost thing is Safety.

Prevents accidents by ensuring materials can withstand operational stresses that is factor of safety that you have learned, we always design based upon the actual application factor of safety is fixed because if factor of safety is always optimized in a way so that material consumption is also not there.

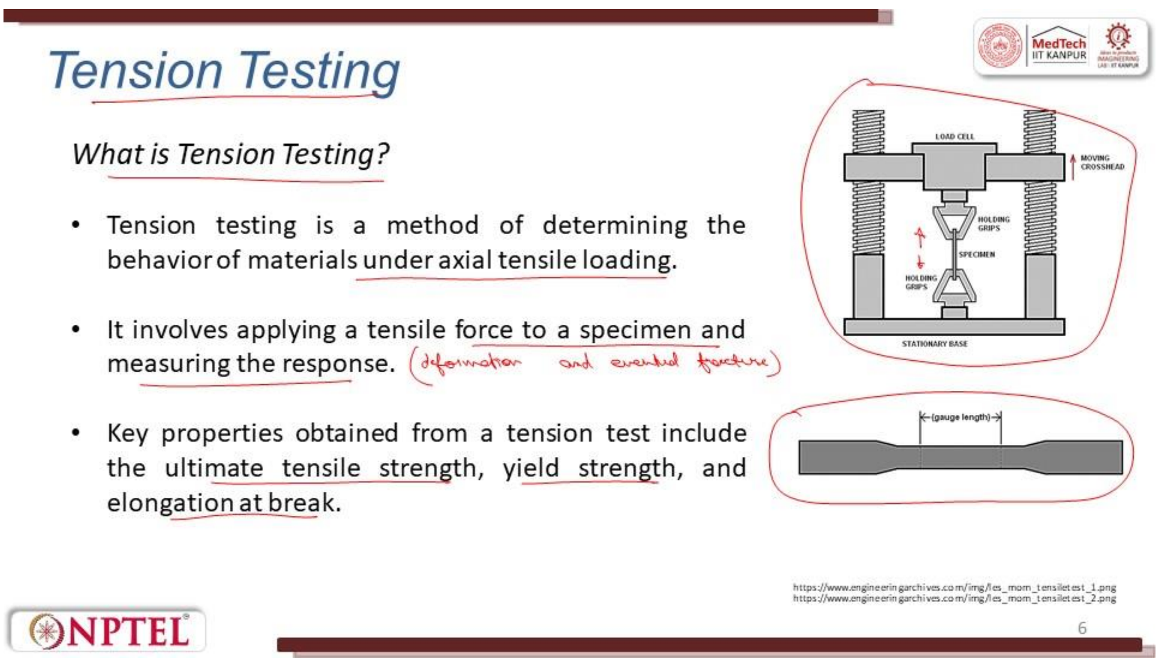
Very heavy and also the strength is also obtained. If factor of safety suppose we just put 10 factor of safety all the time. The material strength or the size of the material that we need to take would be 10 times higher. Weight would be 10 times higher.

So, this is a very critical factor to understand or to put the factor of safety when weight or material usage is also very important factor. Then comes Reliability. Predicts material lifespan for timely maintenance and replacements. Material lifespan we are talking about that is why reliability is major concern here. Optimization selects the best materials balancing performance, cost and weight.

These are the parameters just mentioned. Performance, the cost is the amount of material that we use and the weight of the material. Factor of safety is also factor here. Regulatory Compliance. Meets industry standards and regulatory requirements.

We will see the specimens which are there for different testing are always based upon a standard. The ASTM standard are there, other standards are there. So, we will see the regulatory compliance are always important when we try to develop any product and the test is conducted to understand the material properties. Then Innovation. Develops new materials and improves products through material in size.

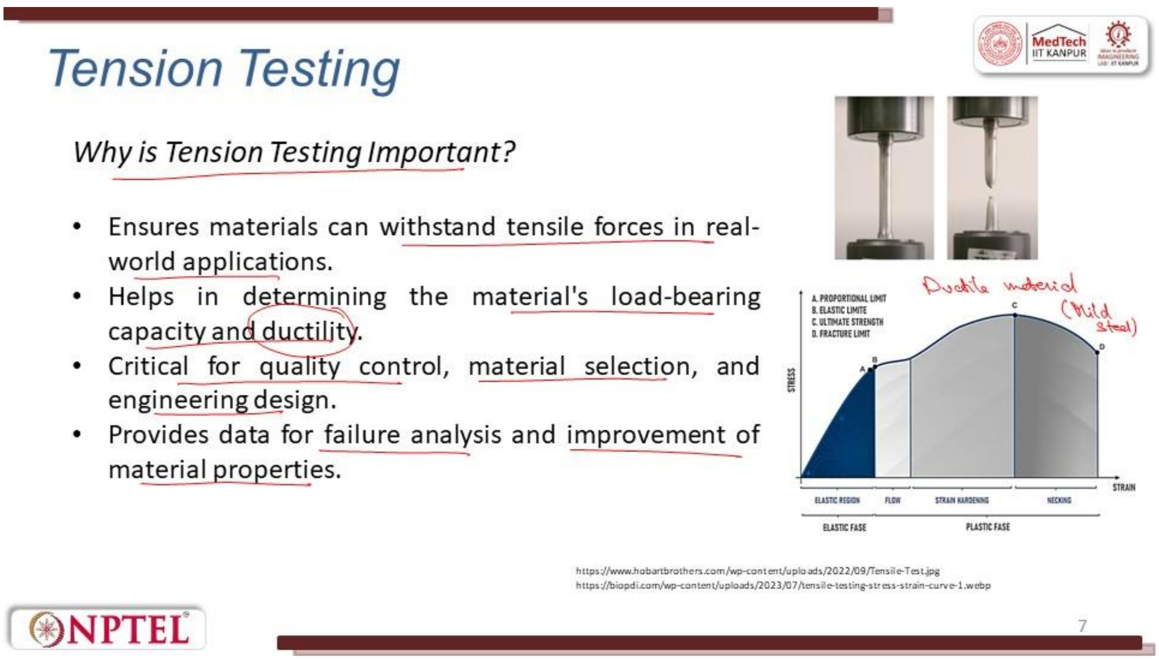
New and modern material are coming up where we are having nowadays for functionally graded materials, we are having composite materials, different tests are conducted over them so that we get the strength as and when required the different materials are developed and tested and those are always the graphs or the test output that we receive or we develop it is equivalent to what is there for the regular test that we do for mild strain, for cast and that is for majorly ductile material for brittle material different tests are conducted and different parameters which are to be calculated may be tensile strength, compressive strength, hardness, impact strength all those are taken based upon the actual application.



So, what is a Tension Testing or Tensile testing? Tension testing is a method of determining the behavior of material under axial tensile loading. So, material is under a load, we are pulling apart the material in two different directions, a specific setup.

We will show you the setup in a demonstration here and this is what is the typical shape of a specimen that is under testing. It involves a tensile force to a specimen and measuring the response. So, this includes material deformation and fracture with that eventual event is fracture. I will put it here. This is for deformation and eventual fracture.

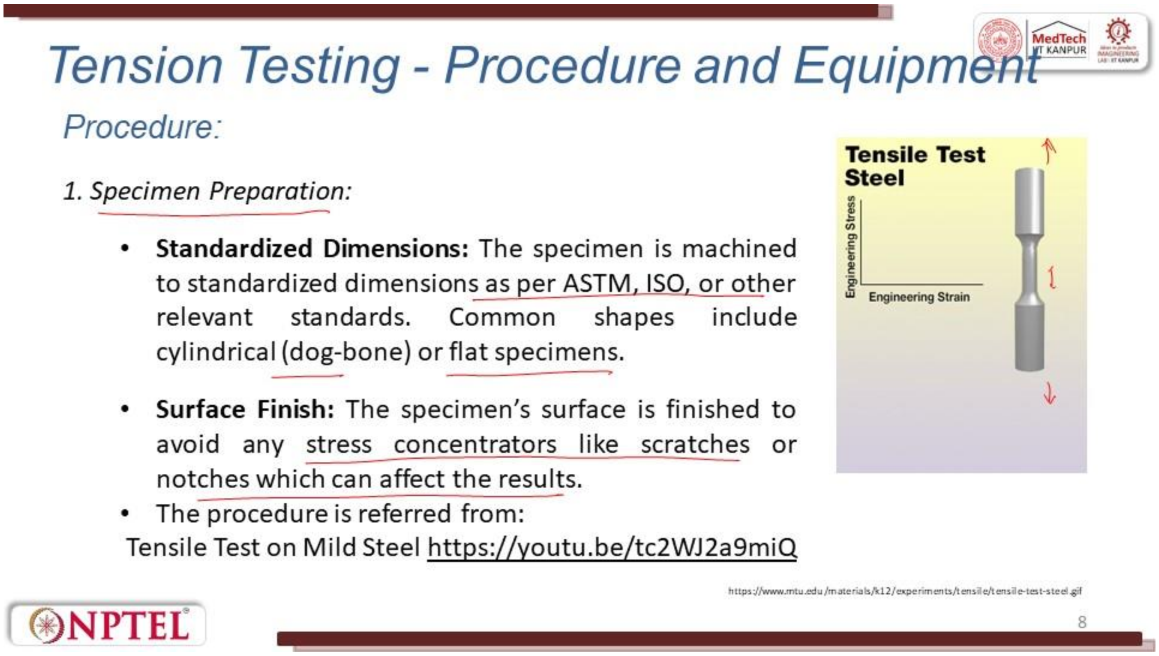
Key properties obtained from a tension test include the ultimate tensile strength, yield strength and elongation at break.



Now, what is the importance of tensile testing? Why is Tension Testing Important? It ensures materials can withstand tensile forces in real-world applications. It helps in determining the material's load-bearing capacity and ductility.

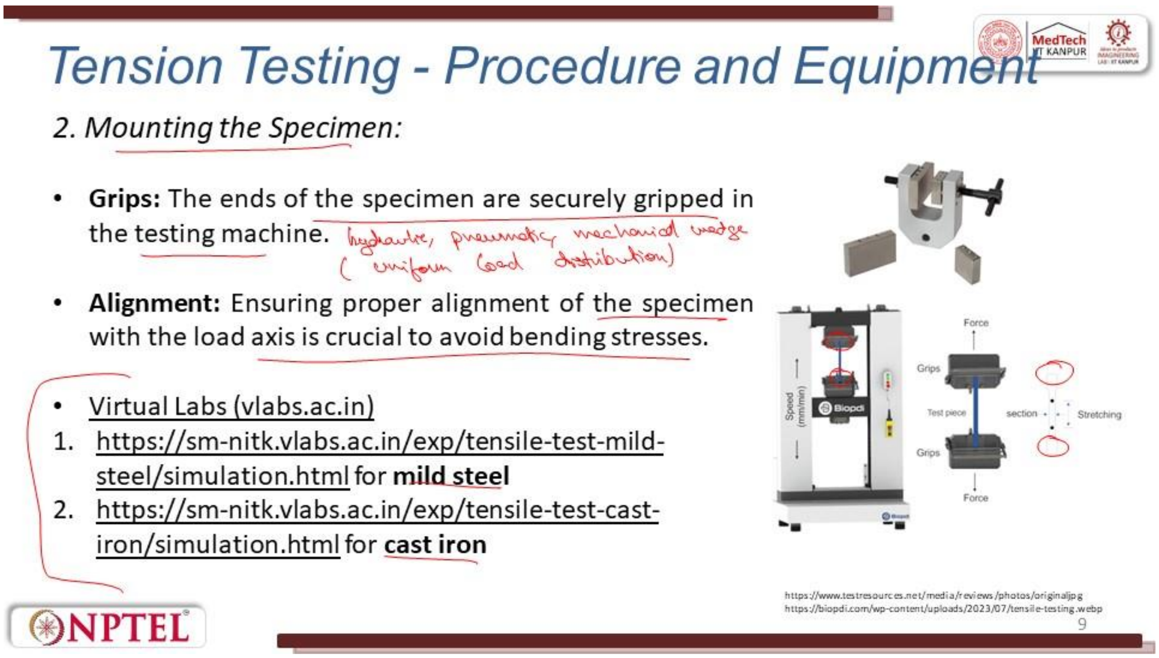
Ductility and Brittleness was discussed in one of the lectures in the last week by Professor Ramkumar. So, those tests we will see how do we conduct in a laboratory environment. Critical for quality control, material selection, engineering design and so on. It provides data for failure analysis and improvement of material properties. So that is stress strain diagram is developed.

This is a stress strain diagram for a ductile material. Typically, if you say this is for mild steel. Next comes the procedure.



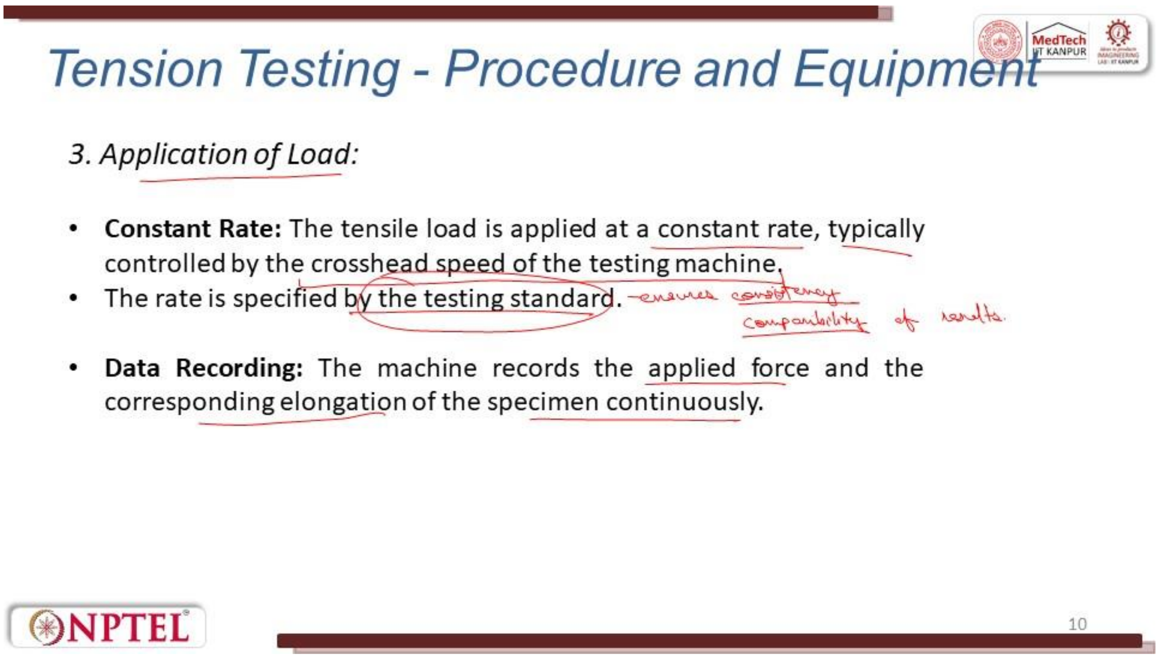
First and the foremost point is the first step here is preparation of the specimen. So this is a typical specimen. The specimen is elongated here. The force is on both the directions here and it is getting elongated. Standardized Dimensions. The specimen is machined to standardize dimensions as per ASTM, ISO or other relevant standards. Common shape include a cylindrical dog bone or flat specimen.

This is your dog bone specimen that you can see in the figure. It is a round specimen. Surface finish, the specimen surface is finished to avoid any stress concentrations like scratches or notches which can affect the result. There is a video here as well that I will show you the laboratory demonstration and I will also walk you through the simulation in the virtual laboratory setup. So, let us first go through the procedure steps.



Second step is mounting the specimen. That is grips, the ends of the specimen are securely gripped in the testing machine that is when the specimen is there, these are the ends of the specimen, these are mounted here in the machine. So, the grips include it could be hydraulic, it could be pneumatic or it could be even mechanical wedges. Purpose is uniform load distribution. So, that is how the grips are designed and different materials are there for which the sizes of specimen could be different.

Next is alignment of the specimen. Ensuring proper alignment of the specimen with the load axis is crucial to avoid bending stresses. I'll show you the virtual laboratory experiment simulation for milestone and cast iron after the procedure.

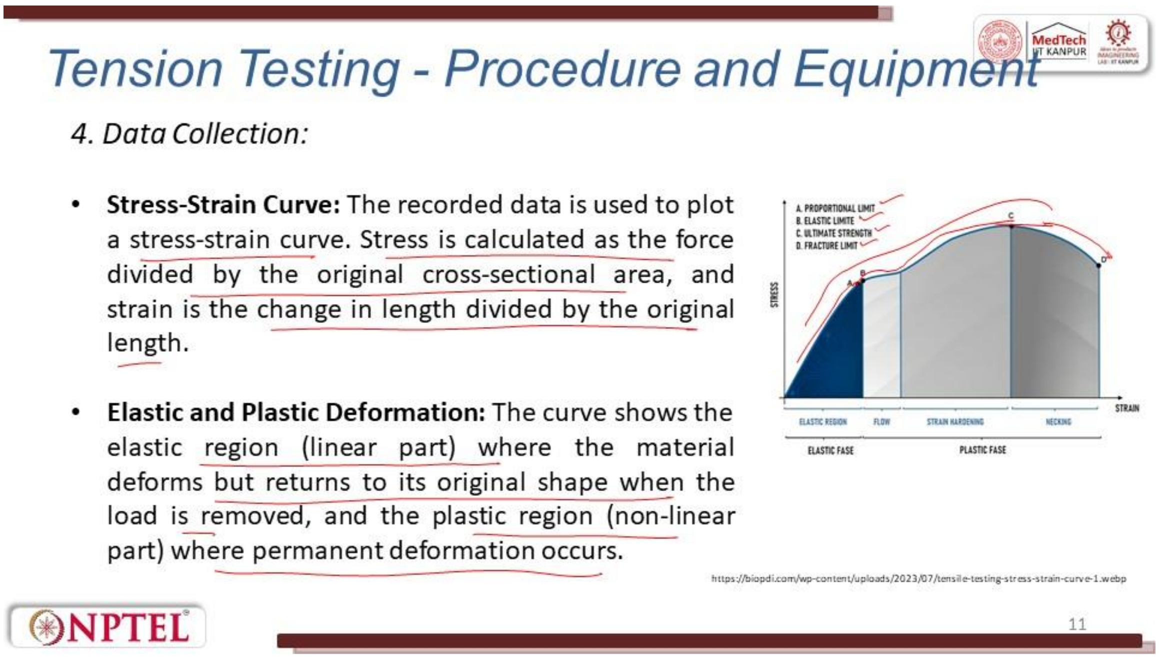


Next step is Application of Load. Constant rate Tensile load is applied at a constant rate typically controlled by the cross head speed of the testing machine.

Slowly there is a nut and bolt mechanism. The machine is applying load slowly to the gradual load application and there is a gradual elongation of the specimen and the graph is also plotted accordingly, we get the data, how do we plot the graph? You will see the rate is specified by the testing standard. Data Recording, the machine records the applied force and corresponding elongation of the specimen continuously. This recording is either downloaded or it is noted using pen and paper. There are modern machines where you just get the complete information using the DRO that is digital display that is there and you can try to get the whole information in the machine itself.

But there are standard machines which do only mechanical testing and other calculations could be done either manually or using your MS Excel or other softwares. So, there is a specified testing standard. Again, I am stressing here, this is a specific standard or testing standard which ensures consistency. So, consistency is one factor, then comparability is also one factor. Comparability of results.

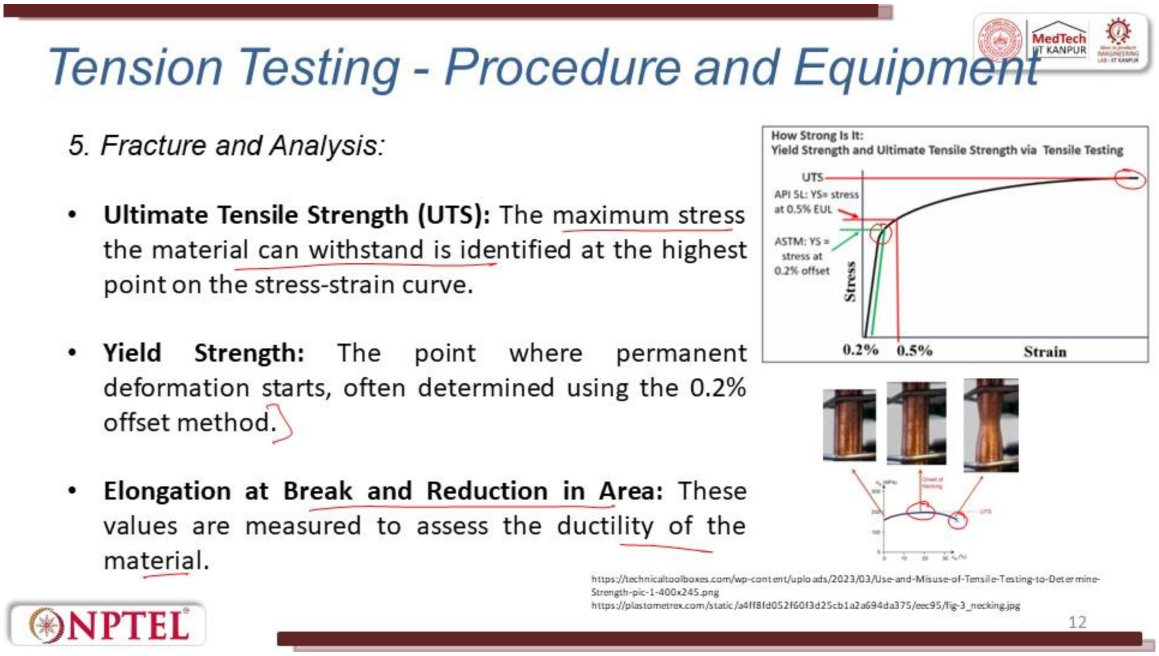
That is one test we conduct at IIT Kanpur. Another test for the same specimen we conduct at MIT US. Then the comparability of the results would be there. The results would be similar provided the material has come with the same specifications.



Then comes the Data Collection. That is we obtain the stress strain curve here. The recorded data is used to plot a stress strain curve. Stress is calculated as force divided by original cross-section area and strain is the change in length divided by the original length.

Elastic and Plastic Deformation, the curve shows the elastic region that is the linear part where the material deforms but returns to original shape when the load is removed and the plastic region non-linear where permanent deformation occurs.

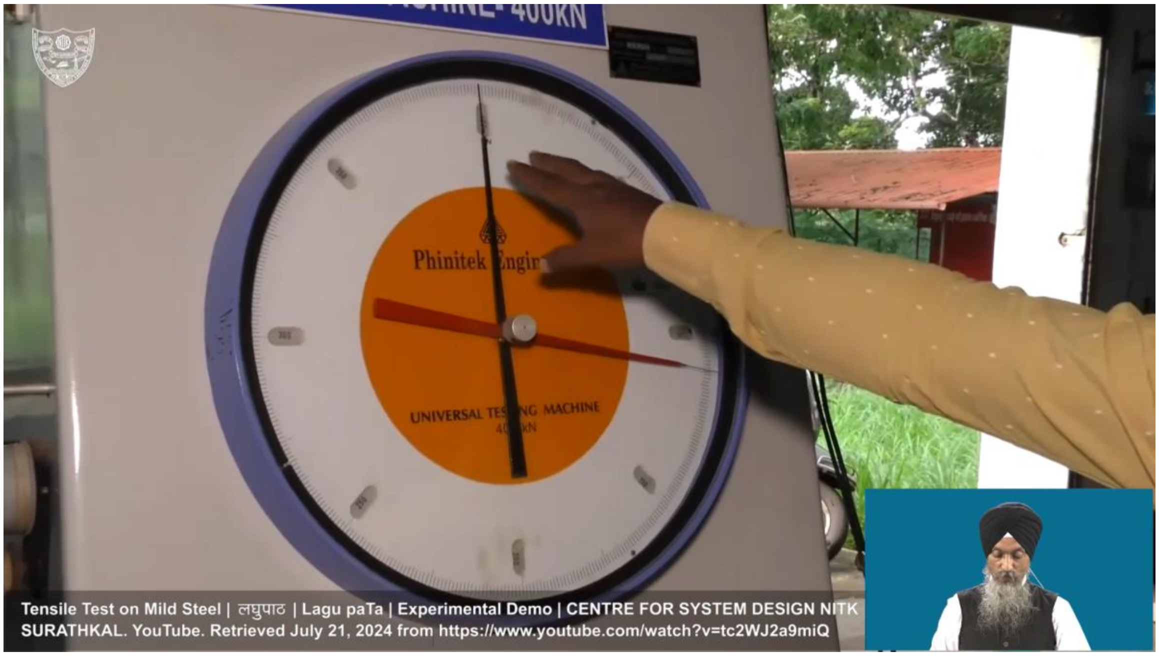
This we have seen multiple times, this is elastic area, then we go to the plastic region and then we reach our ultimate tensile strength and then we go towards the fracture limit, it has been given the points A is Proportional limit B is Elastic limit, C is Ultimate strength and D is Fracture limit.



Then we try to conduct the Fracture and Analysis that is Ultimate Tensile Stress. The maximum stress the material can withstand is defined as the highest point on the stress strain curve. So, this is ultimate tensile strength that is shown here. Yield strength is the point where permanent deformation starts often determined using 0.2 percent offset method. So, here is the yield strength.

You can see here 0.2 percent offset method, the point where the permanent deformation starts, then elongation at break and reduction in area. These values are measured to assess the ductility of the material that is what is the total elongation that is happening for a specific material.

More ductile material would be having higher elongation, less ductile material would be having lower elongation, brittle material would have almost zero elongation at all. So, this is you see this is ultimate tensile strength and this is where the fracture image is there and we try to understand the system.



So, here I have a video that is started by a center for system design at NITK Suratkal and this is a video that I will demonstrate here.

I will come to the full screen mode and try to play the video where the complete demonstration is here. So, this is tensile test for milestone. This is our experimental setup. This is Universal Testing Machine that you could see here. The object is to study the mechanical properties of mild steel under tension load.

So, this is a mild steel specimen. You can see the specimen as per the ASTM standards. First, we measure the initial diameter in two perpendicular directions, we measure it and we get the initial dimensions here like 12.34 millimeter, 12.33 millimeter, then we mark a line straight over it using the chalk and we locate the center point here is using the scale.

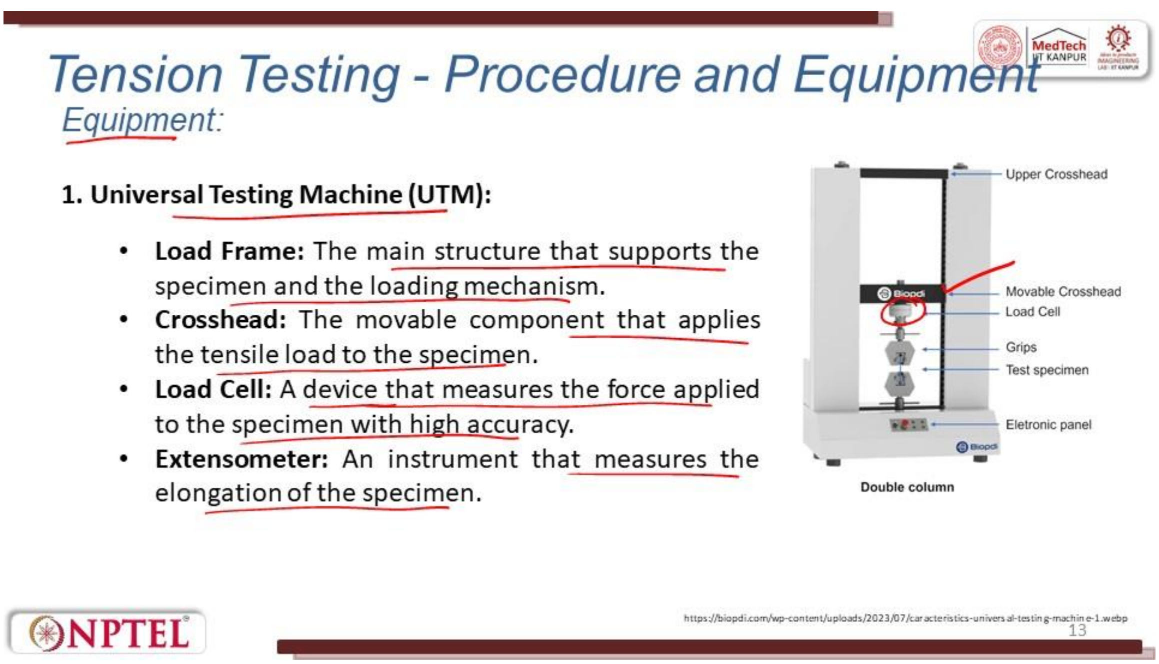
We are marking the center here and either side we are marking the pointers here, punch marks are made at the extreme points. And these punch marks are made at the distance of 2.5 times the diameter of the specimen.

It is 2.5D. I will show you in the simulation as well. You see the punch marks are being made here. And these punch marks are made one by one. And then the test specimen is fixed in the crossheads.

And adjacent crossheads are moved now. Now we are locking the specimen here. The extensometer is then mounted so that we also measure the elongation. And these marks will show you the elongation is there. Now the machine is also set at 0.0.

So now the machine is started for gradual application of load. You see gradually the load will be applied and extensometer is showing that slowly elongation is also happening. So we keep on noting the extensometer readings at regular intervals manual recording is there that is pen and paper recording is there, you can see the elongation is there then we remove the extensometer.

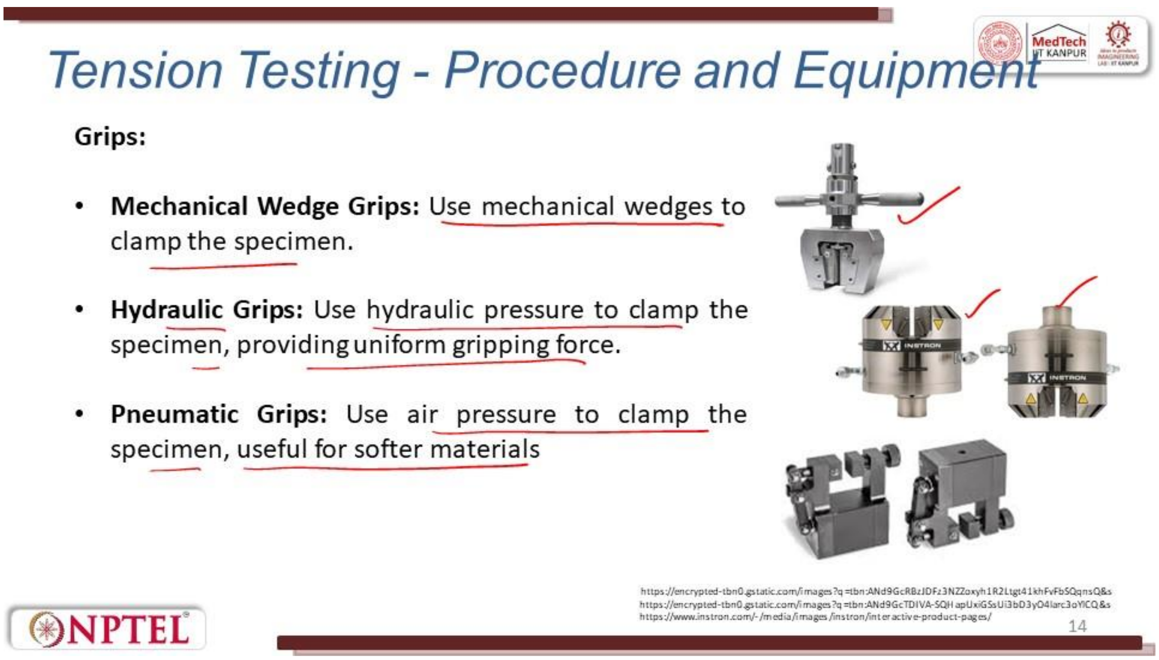
The ivory scale is also showing the reading here you can see the specimen is broken here and this is cup and cone shape breakage. Now we measure the distance here that is the elongation from the points which are marked also the diameters is measured using the vernier caliper and we plot this load versus ivory scale reading graph and also load versus extensometer reading, both the graphs are plotted and then we use calculations or do certain calculations using the observations to measure the Young's modulus over the yield strength and other properties which are there or other measurements which are required. I will take you to the virtual laboratory simulation where you will see how this is all conducted.



So, let me try to first talk about the equipment for tensile testing. So, this is a Universal Testing Machine in which we have load frame that is main structure that supports the specimen and the loading mechanism. So, this is the main structure we have a load frame here and we have cross head that is movable cross head that is here.

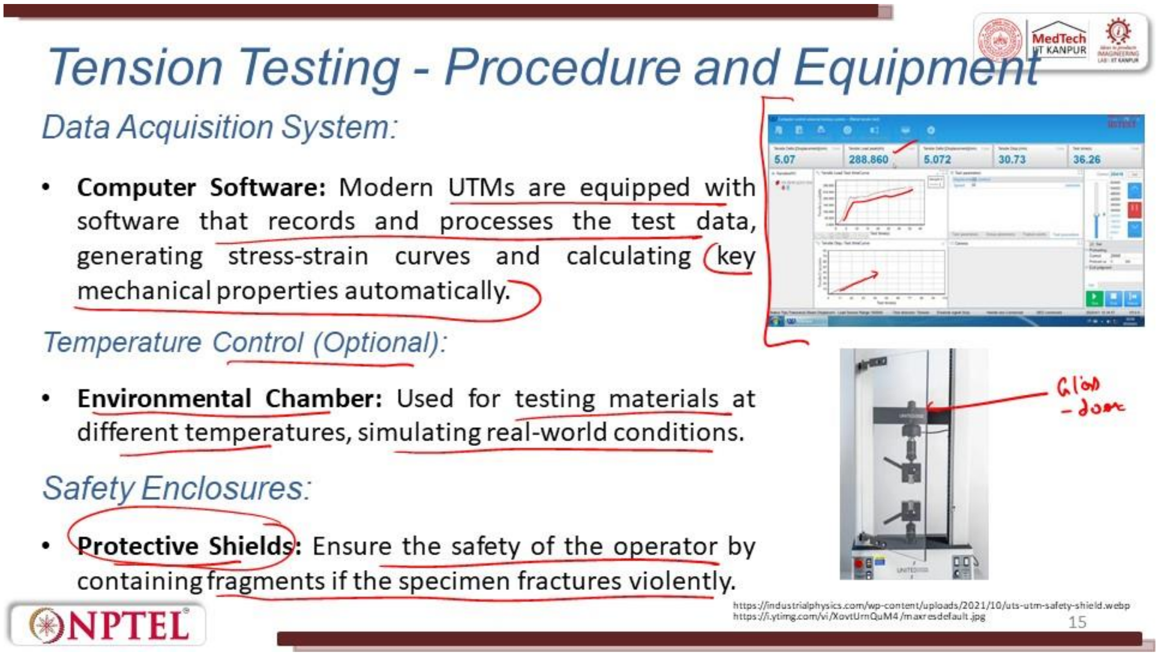
The cross head is a component that applies tensile load to the specimen. Now, Load Cell is here A device that measures the force applied to the specimen with high accuracy. There is a load cell that measures the force that is applied. Then Extensometer is there.

Extensometer is an instrument that measures the elongation of the specimen. Elongation of specimen is measured using extensometer. This is typical Universal Testing Machine.



Let me also show you different grips. These are different grips that I just mentioned in the previous slides. You can see a mechanical wedge grip use mechanical wedges to clamp the specimen, there are mechanical wedge grips using just a mechanical force itself.

We try to grip and then we have hydraulic grips that use a hydraulic pressure to clamp the specimen providing uniform gripping force but these are hydraulic grips which are here pneumatic grips are there that use air pressure to clamp the specimen useful and these are useful for software materials.



And there are computer software available in modern Universal Testing Machines are equipped with the software that records and processes this test data generating stress in curves and calculating key mechanical properties automatically.

So, this is a software interface of a modern machine in which you can see the data is there tensile load what is the load applied to 188 kilo Newton and we have different parameters, we have the stress strain curve already plotted here, we have the tensile display and time curve that is how the time is flowing when we testing is going on. So, temperature control is also optional nowadays because to simulate or to work for the real time situations when the machines or the systems are there under a certain style load at a specific temperature.

For example, in aircraft itself in the components when in the engine those are heated those are also under a certain style load at certain stages. So, that temperature control systems are also there that is environmental chamber is there which is used for testing material at different temperatures simulating the real world conditions.

Then safety enclosures are there that is protective shields ensure the safety of the operator by containing fragments if specimen fractures violently. So, this you can see this is a glass door that becomes our Protective Shield. So there could be certain applications as I mentioned about the aircraft applications.

Tension Testing - Procedure and Equipment

Importance of Equipment Calibration:

- *Accuracy:* Regular calibration of the load cell, extensometer, and other measuring devices is essential for accurate and reliable results.
- *Compliance:* Ensures compliance with industry standards and specifications, maintaining the validity of test results.

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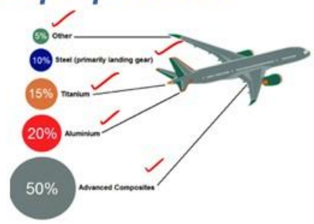
So Equipment Calibration is very important here. First point here is Accuracy, another point is Compliance. Accuracy means regular calibration of the load cell, extensometer and other measuring devices is essential for accurate and reliable results. So this is a regular calibration that is required for having the reliable results. On the other hand, there is also compliance when we are trying to submit our results to the industry or the people who are coming to us for testing, there are industry standards.

So to ensure compliance with industry standards and specifications, maintaining the validity of test results is important. So that is why equipment calibration is also important.

Tension Testing - Procedure and Equipment

Example Application:

- In the aerospace industry, tension testing is critical for assessing the mechanical properties of materials like titanium alloys used in aircraft structures.
- These tests ensure that the materials can withstand the extreme loads and stresses encountered during flight, contributing to the safety and reliability of the aircraft.



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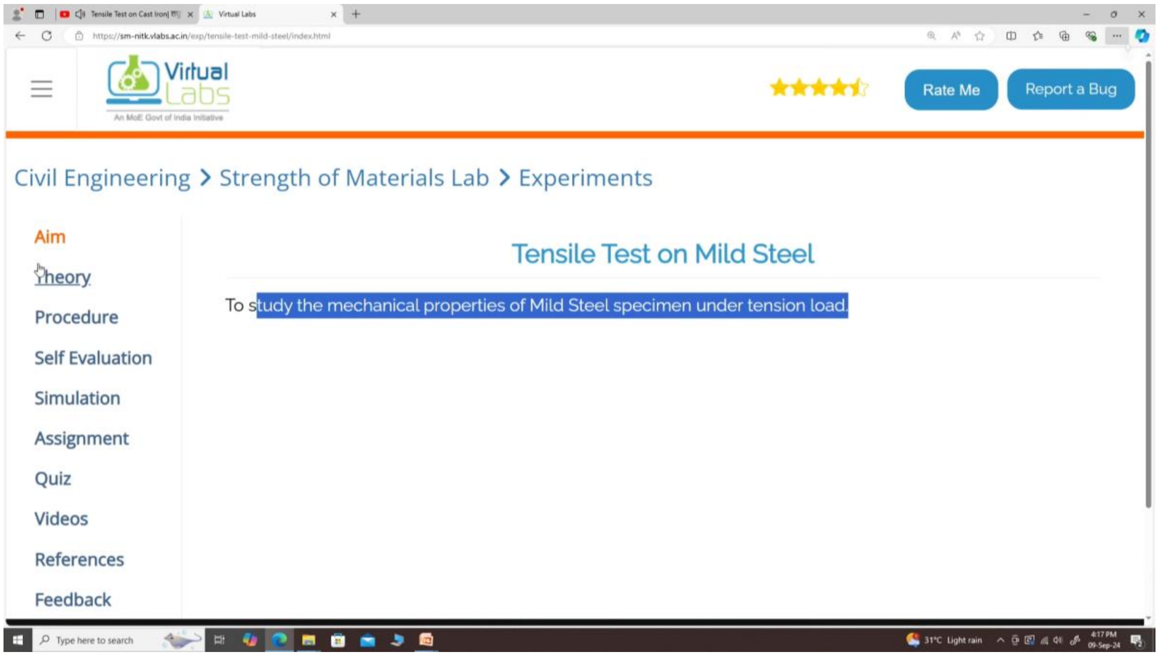
Now comes the Application. You can see in aircraft, different materials are there. 10% of that is steel, 15% is titanium. Titanium you know is having high strength to weight ratio with a very low weight strength is very high because weight is a major consideration when we are trying to design an aircraft. So titanium is there, aluminium is there. And advanced composites are there nowadays, 50 percent of the material is advanced components, 5 percent of the materials are also there.

So, in aerospace industry, tension testing is critical for assessing the mechanical properties of materials like titanium alloys used in aircraft structures. These tests ensure that materials can withstand the extreme loads and stresses which are encountered during flight.

This contribute to the safety and reliability of the aircraft. So, let me now come to the laboratory simulation that is virtual laboratory simulation and I will try to show you the experiments under the virtual laboratory that is developed.



This is mild steel test virtual laboratory. You see in this we have a complete record of the test for example, what is the aim of the test to study the mechanical properties of mild steel. So, it is a mechanical properties of mild steel specimen under tension load.

Then we have a complete theory, the theory that we have discussed through this course as well that what is elastic deformation, what is the flow region, material handling, material hardening, necking and what are the formulas elongation, change in length per unit original length that is there. Then we have reduction in area, change in area per unit original area, tensile strength is ultimate load per unit area. Then yield strength is yield load per unit area, it is we are talking about original area only, then we have modulus of elasticity that is slope into gauge length per unit area. So, all these relationships are given here and how the fracture happens, slowly it is elongation, it is necking is there. Pores are there which are there and the fracture starts, the crack grows at 90 degree to the applied stress.

So, maximum shear stress is here at 45 degrees and then cup and cone shape is formed and fibrous and shear material is obtained here. This is the theory of the test. This is gauge length. Gauge length is the constant length between two ends. So, let me come to the next point, this was theory in virtual laboratory, then procedure that I am mentioning the complete procedure is here, I will walk you through the simulation, then we have some self-evaluation questions here as well; I will come to the questions, these are questions.

So, it is pre-test questions before even conducting the test you should be aware of that which law influence the material up to yield point it is Hooke's law right then while conducting the experiment, the mode of fracture observed in mild steel specimen is, what is the mode? It is cup and cone. Then, what is the distance between punch marks in the experiment? It is 2.5 D. Yield point is the point under stress craft wear. There are four options.

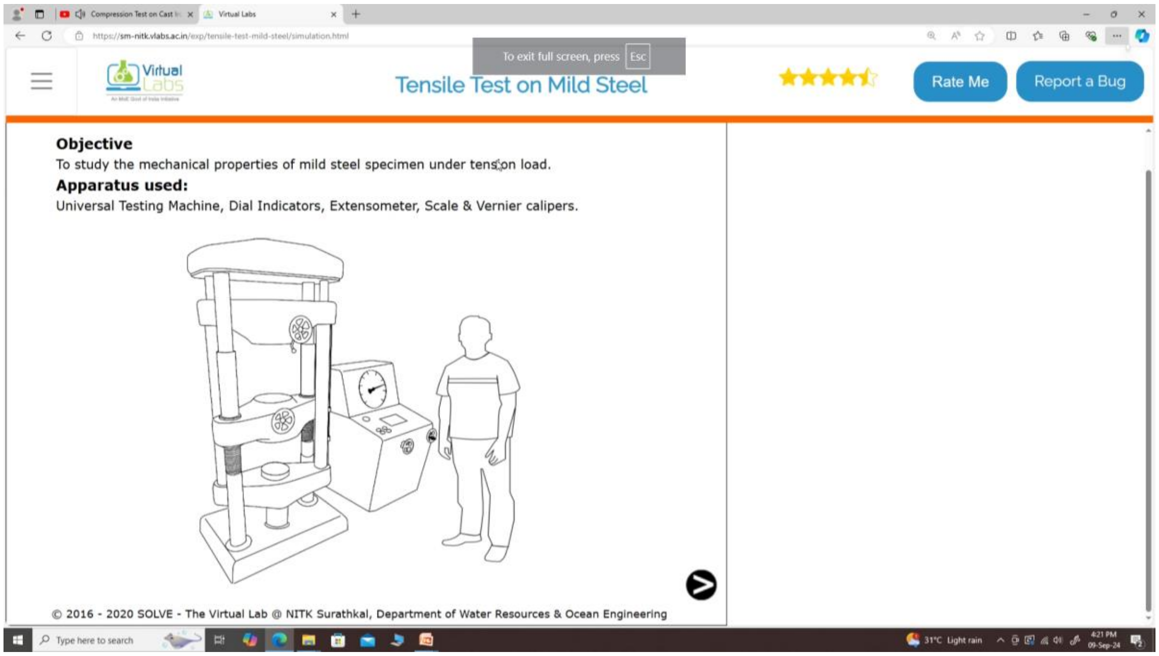
Failure of material occurs, elastic deformation commences, plastic deformation commences. Yes, plastic deformation starts at yield point. So, it is plastic deformation commences at yield point. Elastic deformation of the material associated with toughness, ductility, hardness, permanent deformation. Because we are talking about elastic deformation, it is associated with ductility.

Then we have the arrange in order the sequence of the experiment, when does ultimate load upper yield point elastic region breaking load lower yield when it comes. So, you know in the order of get having different loads or regions here first there is a elastic region that is a constant load and dust deformation only that is not at all permanent.

So, then we get the upper yield point for where it falls to the lower yield point and when we keep applying the load, we reach the ultimate tensile strength, that is the highest point and then only comes the fracture or the breaking strength. So, here which is the option? Upper yield point first, it is first option A could be there, lower yield point, elastic region, no the first is elastic region, C or D could be the points.

Elastic region lower yield point, no. First, it is elastic region upper yield point. Yes, this D is the option. Let me try to submit the quiz. Yes, I have gotten 6 out of 6.

That is all the answers that are correct. So, you should definitely go through these virtual laboratory experiments. And this is a pre-test questions which are there. Now, we come to the simulation.



In the simulation, you see, it has been shown that this is the objective, to study the mechanical properties of mild steel specimen under tension load.

Apparatus uses Universal Testing Machine, dial indicators, accentometer, scale and burring caliper and we go to the next step. Previous was the step 0 when we just showed you the machine. Step 1 is measure the initial diameter of the tension test sample into perpendicular directions using burring caliper. So, it is showing an arrow mark here that is when we click at this point the vernier caliper will start measuring this diameter and this diameter it measure is 12.82 millimeters. Now, it is from one direction, from other direction, from the perpendicular direction.

For instance, if this is my specimen, I will measure the diameter from this side and then I will measure from this side, 90 degree. This is one direction and other direction. From both the directions, diameter is measured. This also ensures that the diameter is constant. It is not elliptical.

So, then I again click here. It is measuring the diameter from the second direction as well. The diameter is 12.82 as well. So the average diameter is 12.82, which is my initial diameter of the specimen. Let me go to the next step.

Step 2. Measure the length of the specimen between the grips using a scale. So I have to now click on the scale. It will measure the length. Yes, this length is known as between grips length or gauge length.

So, this length is 192 millimeters. That is the next step. Now, once you mark the center line using chalk that we showed you in the video demonstration, punch marks are made at 2.5D, 2.5 times of the D. So, here I will click on the hammer, first punch mark. Then, second punch mark, you can see here 2.5 D is 2.5 into 12.82 is equal to 32.05 millimeters. Then, I keep on marking the punch marks here.

Third, fourth, when I click only then it works. Fifth, it is all. So, this specimen is now ready to be mounted over the machine. So, now here there is a V. The crosshead, I will click the wheel and wheel will be rotated to open the distance between the crossheads.

Now, drag the specimen. There was a text popped up here. Drag the specimen to this place. I will drag the specimen here. Now, again I will rotate the wheel to close the distance so that the specimen is held between the lens.

Then extensometer is held here or mounted here. You can see extensometer with two dial gauges which is mounted here. Let us go to the next step. Step 5 is readings on the dials A and B of extensometer are adjusted to 0. So we adjust the reading to 0 here.

And second reading is also adjusting to 0. You can see it is something negative reading here, this pin. This needle in the dial gauge is at some negative value or when I click it comes to 0. So, least count of the sensometer is 0.01 millimeters. Let us go to the next step.

Step 6 is now switching on the machine so that the gradual load is there applied green button is to be post here and the load is being applied here. You can see the extensometer is taking readings and the load is applied very gradually here slowly the reading is being added time and again. So this is now ready, so all the readings that is load in kilonewton from 2.5 to maximum load that you could see here is 60 kilonewtons somewhere here. And ivory scale reading that is in millimeter is 56. It started from 1 millimeter to 56 millimeters.

So, we can download the data as well. If I click the download data, you can see it is downloaded here and this is an actual sheet that is obtained where the data is downloaded. This is just downloaded data and we can use this to calculate our all the readings. Let me go to the next step now. Stop the machine.

Red button is stopping the machine. Six step is over now, the machine is stopped. Let me go to next step, where it has now plotted the data. You can see at any point, I can see the data that is there. Here you can see the data, the load in kilonewton, the extensometer reading for extensometer A and B, both of them record the reading and the average value is taken.

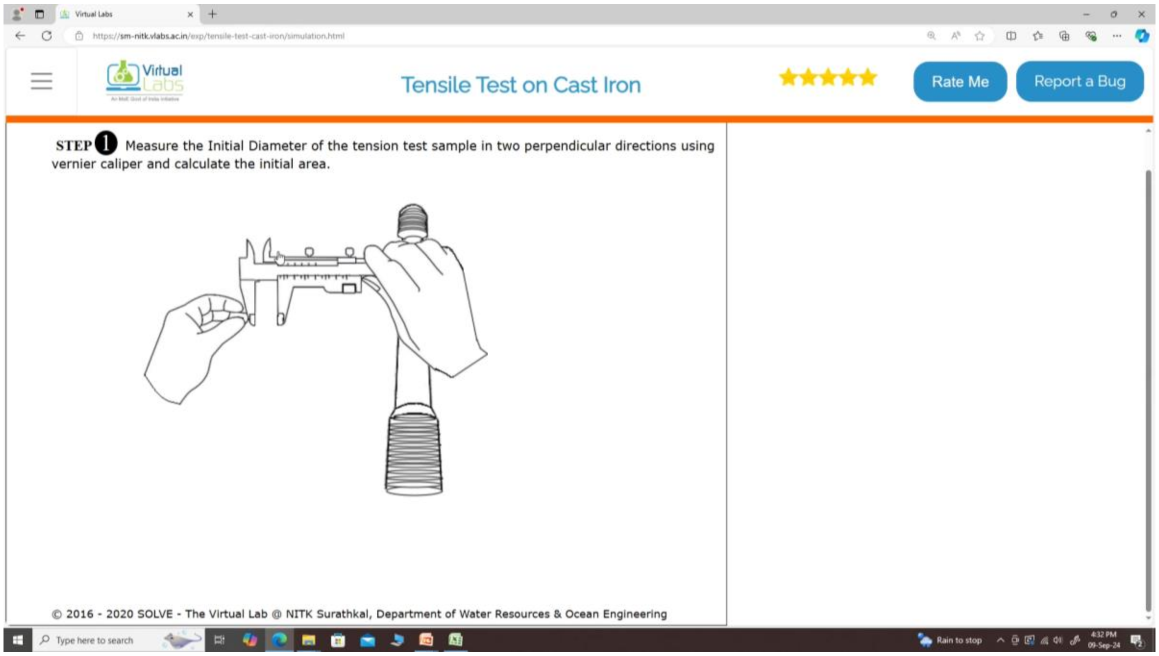
So it is, given here, ivory scale reading is also there. Based upon read reading only, you can see corresponding to value 50 of the load, 14 millimeter is the extension. So, here you can see 14 and 50, the same reading is here. So, this plot is gotten here. Now, let me move to the next step where load versus extensometer reading is there.

Let me see the data again at around extensometer reading of 9.5, the load is 20 kilonewtons here. Let me see that in the graph. So, at around 9.5, it is 20. So, that means this spot is also obtained from the same observation table. So, we can also view the slope.

That is delta x, delta y is cotton, delta x is 4.3, delta y is 9.5, slope is 2.21. So we can keep getting these values and this is how the specimen shape is there. That is cup and cone shape is there. And now we need to measure the diameter that is the final diameter is 8.83 millimeters and we also need to measure the distance between two notch points that is the extension is to be measured. So, we measure this distance.

So, length between the punch mark is 87 millimeters. So, based upon these values and observations that we have gotten initial diameter is this, length of the specimen between grips was this, punch mark at the interval of 2.5 billion millimeter is this. So, this is what we have done in distance. Final length between three punch mark in millimeter is 87, final diameter in millimeter is 8.83, original cross sectional area that is a 0 in millimeter square is 124.68, final cross section area at the neck point is 61.21 millimeter square, least count in millimeter is 0.01, gauge length of the extensometer in millimeter is 120. So, based upon these we can do calculations of the yield strength, tensile strength, modulus of elasticity, percentage elongation, percentage reduction of area, and we can check the observation, we can check the graph, and once we put the values here, we can check the values as well.

So, this was the tensile test. I showed you the video demonstration. I showed you the simulation in the virtual environment using the VLAB that is developed by NLTK Suratkal. I will also like to show you the tensile test for the cast error. The procedure is all same.



The next link is tensile test for the Cast iron. Here only there is a change in material, rest all things are almost same, evaluation questions are almost same. Yeah, some questions could be different, but you can go through them. I will just show you the simulation and show you the final results. In the cast iron, we go through the experiments in the similar fashion.

I click and find the diameter. Then I again click and find the diameter in the perpendicular direction. Then I measure the length and we keep marking the punch marks at a distance of 2.5D. Whenever it shows arrow, I click and then only it works. It is opening.

I will drag the specimen. This is the cast iron specimen. I will then close it. Here dial gauge is used. See this dial gauge is set to 0 value.

Then we switch on the machine. You can see slowly readings are being generated when the gradual load is applied. And here the graph would be different. That only I wish to show you here. So these are the readings which are being obtained here.

It is still going on. So finally, it has broken, yes, it has broken here and we switch off the machine, then we get the curve like this, we do not have any bumps like those were there in the ductile material test. So then I go to try to see the specimen. So this is a straight shape. So then I measure the diameter to understand the changes, to understand that the change is negligible and we try to see the graph and observations and try to check that.

So, here you can see in the theory the specimen breakage is something like this. There is a poor stress, stress versus strain curve, yield point comes here and here it breaks. So, this is how the specimen breaks. So, this is a failure pattern of a cast iron that is a brittle material. So, brittleness and ductility both tests are conducted.

So, next I will take you to the compression test in the next part of this lecture where we will be conducting a test when the forces are applied in the opposite directions, but towards the specimen. And we will also try to see how do we conduct that in a virtual laboratory and we will try to understand the compression test in the next part of the lecture. Thank you.