Basics of Mechanical Engineering-1

Prof. J. Ramkumar

Dr. Amandeep Singh

Department of Mechanical Engineering

Indian Institute of Technology, Kanpur

Week 03

Lecture11

Hardness, Toughness, Impact and Creep

Welcome to the next lecture. Here we will try to cover Hardness, Toughness, Impact and Creep. All these four are mechanical property related to material. In the last couple of lectures, we have been time and again talking about Stress-Strain graph, Uniaxial Tensile testing, Compressive Load, Tensile Load and Shear Load.

On top of this, Hardness, Toughness, Impact and Creep plays a very important role. These four properties can be derived after doing a Stress-Strain Curve test. But independently, there are instruments to measure these properties. Hardness is a very fundamental property. As a common man, we always try to scratch and see some material.

We scratch it using a nail or we scratch it using a very hard point. A broken glass. Or through your nail in the finger we scratch it. And then we say, oh, the material is very hard. The hardest material known to us is diamond. Or what happens many a times, when you see in the basketball court, around the post they would have put a toughened material, because the players come with so much of speed, they might try to bang against the surface.

So when they bang it should not be a damage for them, so they always have covered with a rubber material. So rubber material, there is a tough material, wherein which the energy is absorbed without deformation, toughness. Impact is when I drop the water bottle, when I drop this water bottle down, will it deform? When I drop this pen down, will it deform? So, that is Impact.

A glass tumbler, when it falls down, it shatters. A stainless steel tumbler, when it falls down, does not shatter. So, that is nothing but Impact. Then comes the Creep.

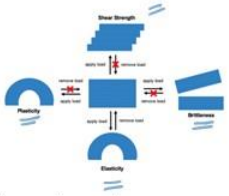
Contents

- Introduction to Mechanical Properties
- Hardness
- Toughness
- Impact
- Creep
- To Recapitulate

Let us see the content of today's lecture. I will little bit introduce mechanical properties. Then I will try to move into hardness, Toughness, Impact and Creep.

Introduction to Mechanical Properties

- **Mechanical properties** are the fundamental characteristics that describe a material's behavior and performance under applied forces.
- Imagine you're building a bridge. You wouldn't use the same material for the delicate suspension cables as you would for the sturdy support beams, right? That's where mechanical properties come in they are the fundamental characteristics that describe how a material reacts to external forces, like pulling, pushing, twisting, or bending.



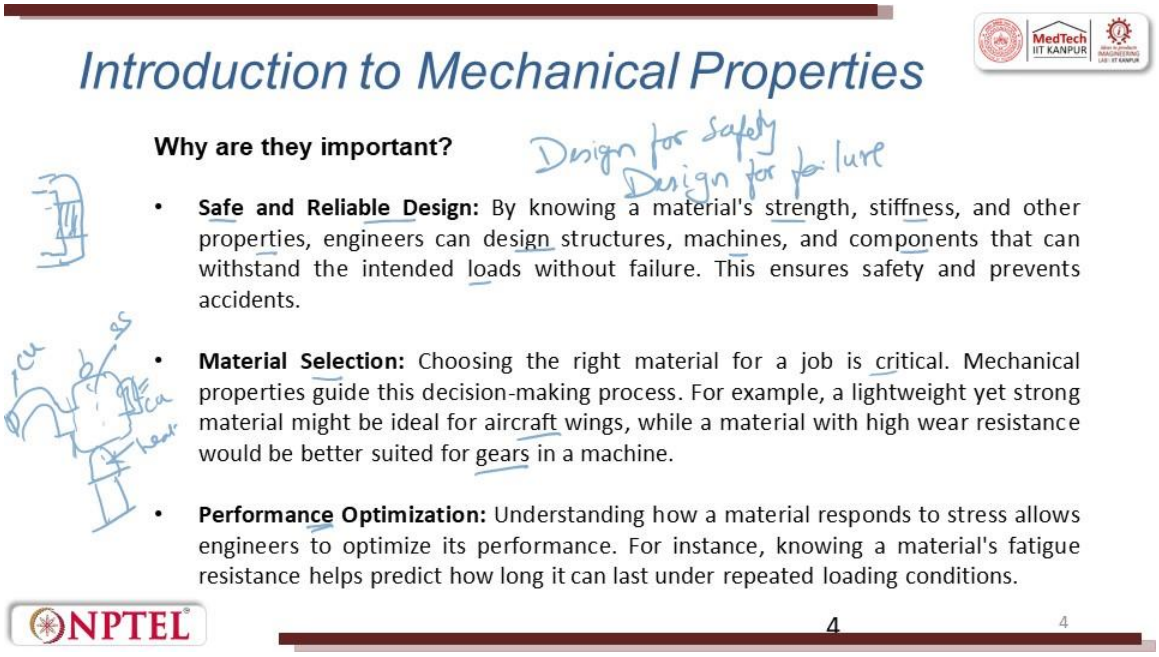
Source: https://upload.wikimedia.org/wikipedia/commons/1/13/Mechanical_Properties_of_Crystalline_Materials.png?20210223160337
https://mechtics.com/manufacture/definition-of-mechanical-properties-of-materials

Mechanical properties are the fundamental characteristics that describes a material's behavior and performance under applied force or load. So you see here, a mechanical property when it is done, what are all the characteristics you can talk about? One is stiffness.

You can talk about strength, ultimate tensile strength, elasticity, plasticity, ductility, malleability, hardness, brittleness, creep, formability, castability and weldability. All these properties can be found out by doing a mechanical testing. Imagine you are building a bridge. You would not use the same material for the delicate suspension cable as you would for the sturdy support beam. That's where mechanical properties come into existence.

They are the fundamental characteristics that describe how a material reacts to the external force like pulling, pushing, twisting or bending. So you can see here, this is plasticity, this is brittleness, this is elasticity and this is shear strength. A same material is expected to do all these functions. For example, when you sit in a plastic chair, the plastic chair has to have resistance to shear because you sit and glide in the chair. Second thing is the chair should have compressive strength.

The chair should have little bit of flexibility to accommodate a heavy person and a light person. The load has to be taken by the chair's leg. The chair's leg will be stiffened. Sometimes they give a metal strip inside or sometimes they add material in the leg. So they do all these things to manage the load. So for doing so, you need to understand the mechanical property.



As I told you, why is it important? It will help in bringing out Safe and Reliable Design. By knowing the material strength, stiffness and other properties, an engineer can design structure, machines and components that can withstand, intended load without failure. So, design for safety, design for failure are something which are very important.

When I take this water bottle, the lid is designed for failure. When you apply a torque, it has to fail so that it gets opened. Design for safety is when I construct a chair or when I construct a building, it should withstand heavy breeze and seismic waves. So, all these things are very important to understand mechanical properties. Material selection is very important.

Recently, I was travelling at a tea shop. They gave us a tea kettle. The tea kettle was made out of stainless steel here. It had a beautiful neck and here it was made out of copper. In order to have symmetry in the object, they have used also copper here.

Now think of it, when you heat the kettle, the heat of stainless steel thermal conductivity and copper conductivity is completely different. So when I wanted to hold the kettle by hand, I cannot do it. So what are the possibilities? I will have a handle and on top of the handle, I will try to put some material which is insulating.

And now the other big challenge was, how do I weld copper to stainless steel? Because they have varying thermal conductivity properties. That's a big challenge. And the neck,

whatever it is, when I am trying to pour, by chance, if it tries to touch with your hand or finger, it burns. You look at it, the improper selection of material has made the application very difficult.

Finally, the tea kettle had to be changed by the tea shop vendor. So, material selection is very important. When you are trying to choose material, you have to choose material such that it can absorb energy or it does not absorb energy. For example, the wind shield, what is placed in the car, bus, they are all using toughened glass material. There are two glass layers and in between they will also have an adhesive layer.

When a stone hits from a preceding vehicle at a very high speed, from the tyre it comes and hits your windshield, the windshield should not shatter. So here what we do is, we try to choose a right material. If you try to choose a very hard material, what will happen is, it will be hard material, many a times is brittle, so it will shatter. So you have to choose a right material for a right job. Mechanical properties guide this decision making process.

For example, a lightweight yet strong material might be ideal for aircraft wings. It has to be as lightweight as possible. It has to be as ductile as possible, as malleable as possible because you are going to make a complex profile. It has to be as light as possible because any small weight you take and then fly, it is all going to be on your myelids. So it has so light weight yet strong and then strong here room temperature or at the airport the temperature can vary in Indian conditions.

It can vary from 12 degrees or 6 degrees Celsius. It can go up to 48 degrees Celsius at the land condition. And once it starts flying it can move from 48 degrees Celsius to minus 20 or 30 degrees Celsius. Huge temperature difference. Right. So look at it.

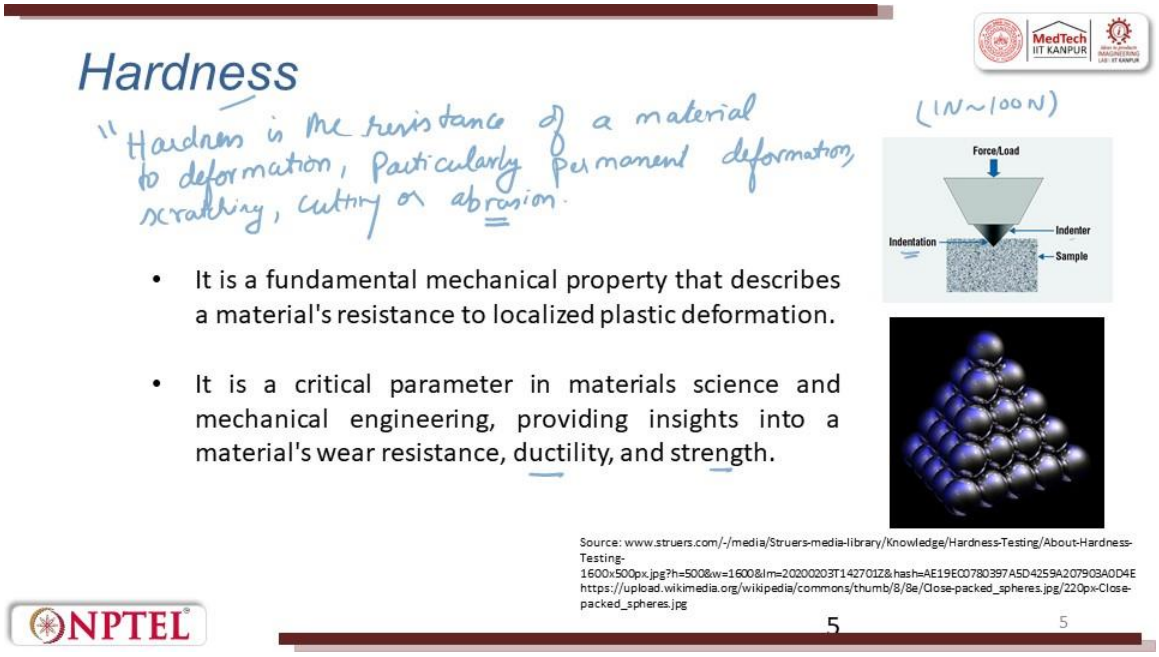
So you have to make a right choice. And then when you are trying to make a material for gear, gears are very important because they are going to transmit energy from one point to the another. So when we use gears, we always try to use a huge load to rotate. Just a simple example, you can take sugarcane juice making machine. So you can see here people will be applying so much of torque to rotate.

It's a heavy gear where there has to be lot of crushing which has to happen. The juice has to be extracted. The gear has to be as strong as possible. Here we don't choose a light weight. We choose a heavy material or a denser material.

Here we always choose mild steel or stainless steel gears. Let's move from this profile to a lower profile. We want toys. The toys also has gear. These gears have to be smooth and has to have very low friction.

The toy has to be also very light. The toy has to be used for a longer time because the kid would love to use the toy. So here the gear will be lightweight and it will be with lower friction. So aluminium cannot be thought of but polymer will be. The proper selection is very important.

When we want to do performance optimization, we always try to take the material property and see how the material responds to the stress allows engineer to optimize the performance for instance, knowing materials, fatigue resistance helps to predict how long it can last under repetitive loading conditions. So optimization is very important, we can reduce the material or try to improve the process parameter.

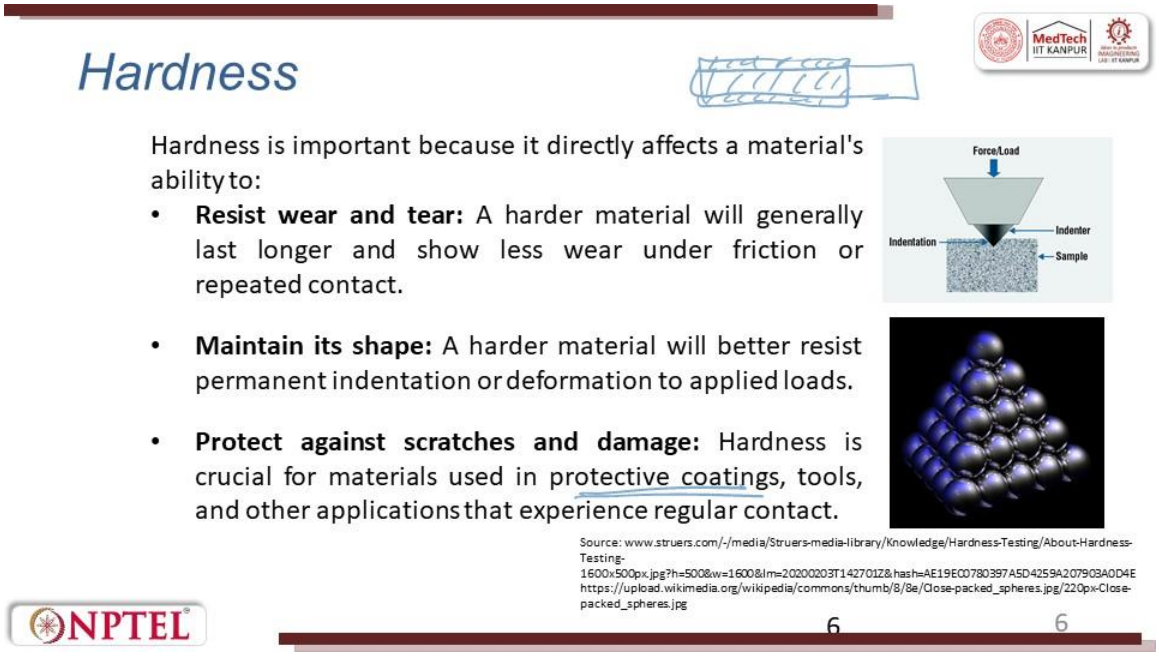


Now let us look into the another mechanical property which is Hardness. It is the fundamental mechanical property that describes a materials resistance to localized plastic deformation. So, if I wanted to define hardness I can write it like this hardness is the resistance of a material to deformation, particularly permanent deformation, scratching, cutting or abrasion.

The difference between cutting and abrasion is cutting, the cutting tool is a solid big material. Abrasion means the size of the tool. Tool is basically the counter which is there. So, it is Abrasion. Amount of material removal is small, amount of material removal is big.

So, hardness is the resistance of a material to deformation, particularly permanent deformation like scratching, cutting or abrasion. It is a critical parameter in materials science and mechanical engineering providing insight into the materials wear resistance, ductility and strength. Generally, what we do is in order to find out the hardness of a given material, we try to take the material and indent the material with a hard substance applying load. If you do not apply load, you can just do scratching. If you apply load and do not move, that is called as Hardness Testing.

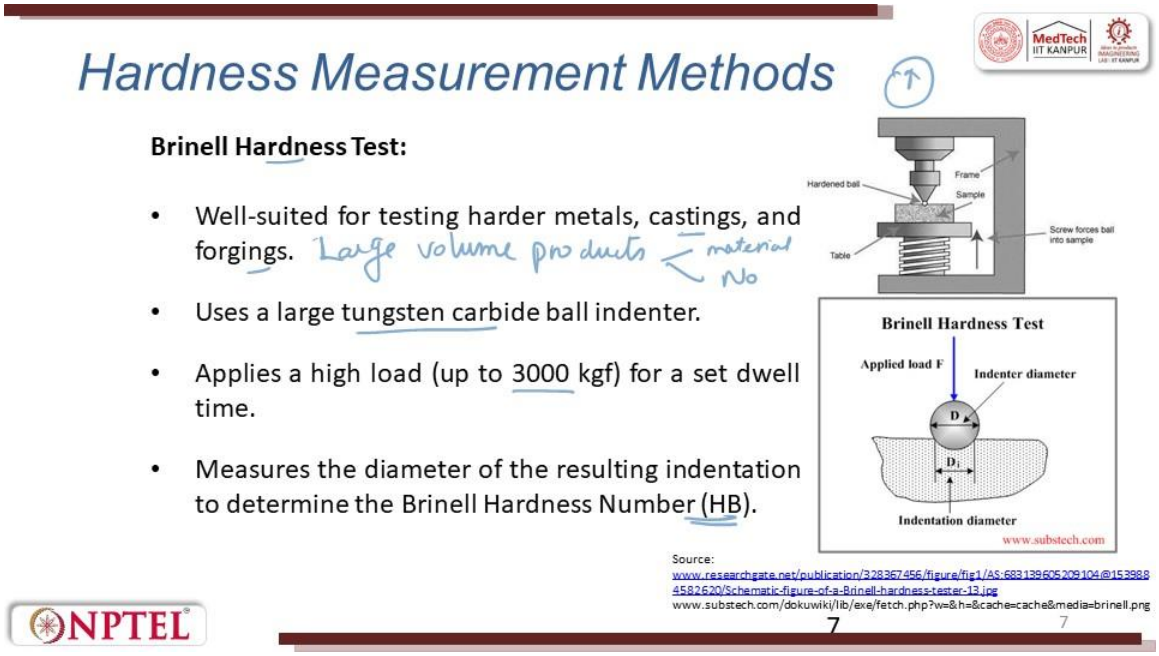
So, you can try to use an intender. Intender is a hard material. The process of intender striking against the material will be called as Indentation and you apply load. So, here we try to apply load. Maybe from 1 Newton to 100 Newtons depending upon your requirement and see what is the material response. By looking at the indentation, you can also try to talk about the elastic and plastic deformation.



Hardness is important because it directly affects a material's ability to resist wear and tear. A harder material will generally last longer and show less wear under friction or repetitive

contact. It also helps us in maintaining its shape. A hard material will better resist permanent indentation or deformation to the applied load.

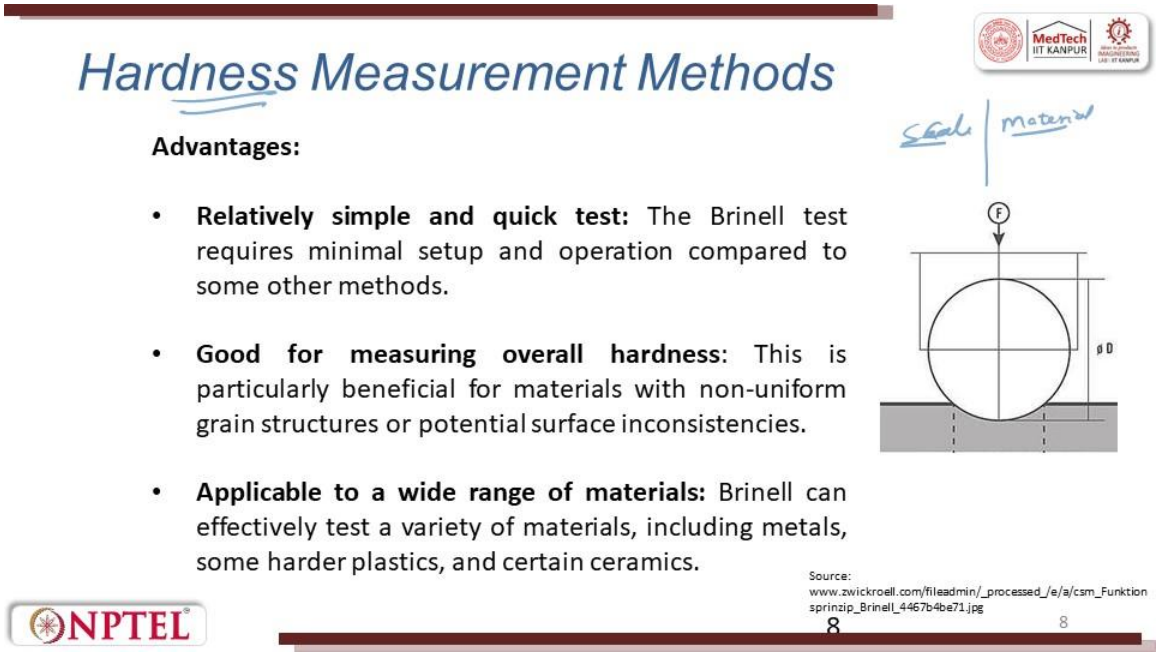
Protect against scratches and damage. Hardness is crucial for materials used in protective coating, tools and other applications that experience regular contact. So, if you wanted to make a scratch proof material, we will always go for coating. Paint is a coating. So, like that you can also try to coat with material. For example, you can have a solid rod and then coat it with another material wherein which the friction can be reduced to a large extent. So, Hardness, right.



So, in hardness, there are several methods. One is called as Brinell Hardness Testing. Brinell Hardness Testing is again a hardness testing machine here in which we use a ball to indent. It is well suited for testing harder materials which is made out of the process of casting and forging.

So, casting and forging in the olden days they always used to make a large volume products. Ok. Large volume products both in terms of material volume and I am also talking about numbers. So, here it is very difficult for you to go and do mechanical testing. So, what we do is we always go and do a hardness testing. So, in the olden days they had ball.

So, the ball has a diameter 'd' and then when you apply force, it tries to make an indentation. The indentation diameter is 'di', then there is a formula through which you try to find out what is the Brinell Hardness. Generally, the ball which is used is tungsten carbide and the load which is applied is up to 3000 kgf measures the diameter of the resulting indentation to determine the Brinell hardness number HB. Finally, there is a dial here. This dial tells what is the number and based upon the number, you can try to find out what is the hardness.



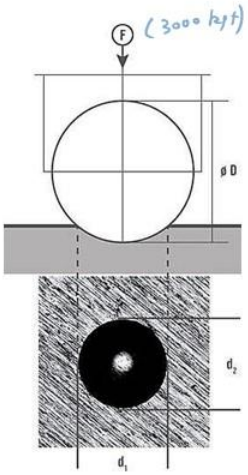
So, it is relatively simple and a quick test. Is this hardness testing good for measuring overall hardness? It is particularly beneficial for materials with non uniform grain structure or potential surface inconsistency. We always go for this hardness testing.

And the next one is, it is applicable to a wide range of material. In this Brinell Hardness, we have a scale and then in this scale we also have material. So, moment we do the scale number, we can try to find out what is the material and to some extent you can also try to find out what is the materials composition. So, all could be done by a simple test of hardness testing.

Hardness Measurement Methods

Disadvantages:

- **Large indentation may damage the workpiece:** The significant indentation size created by the Brinell test can leave a permanent mark on the material.
- **Not ideal for thin materials:** Due to the depth of the indentation, the Brinell test might not be suitable for very thin materials.
- **Force selection can be crucial**: Choosing the appropriate test force is critical in Brinell testing.

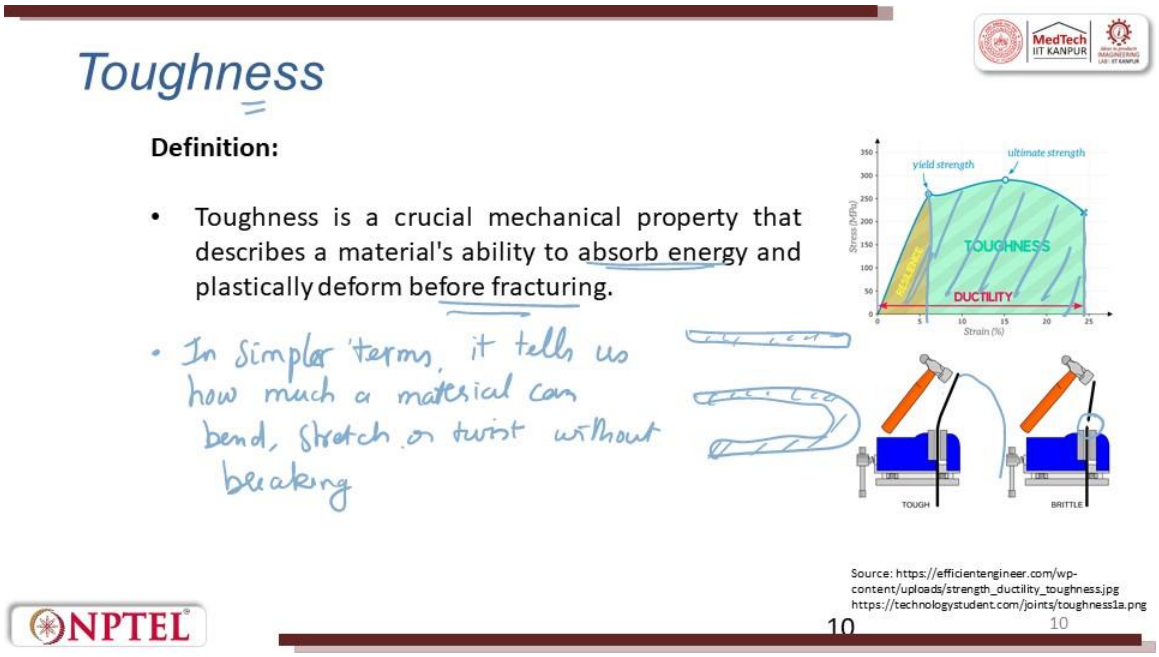


Source: www.zwickroell.com/fileadmin/_processed_/e/a/csm_Funktionsprinzip_Brinell_4467b4be71.jpg

9

The disadvantage is large indentation may damage the workpiece. So, after you do an indentation predominantly, there is a plastic deformation. So, you will have to scrap that part and in today's scenario scrapping a part is costly. So, we would try to see how do we make sure without doing a large indentation but still to get the hardness value. And the second thing not ideal for thin materials, it is always used for thick materials because the force you will use up to 300 kgf, right. So, it glass and all cannot be thought of using it.

So, non-ideal for thin materials and brittle materials force selection is very crucial. Suppose you choose a wrong force, the load is very minimum, you will not see any indentation. So, you cannot have an interpretation saying that the material is hard. So, a proper load application or the force selection is very important.



The next important property is Toughness. The Toughness property can be found out from the stress strain graph. From the start of yield to the fracture point, the area under the curve is called as toughness. Here, the material deforms, but it does not break. The energy within that is called as Toughness. Toughness is a crucial mechanical property that describes a material's ability to absorb energy and plastically deform before fracture.

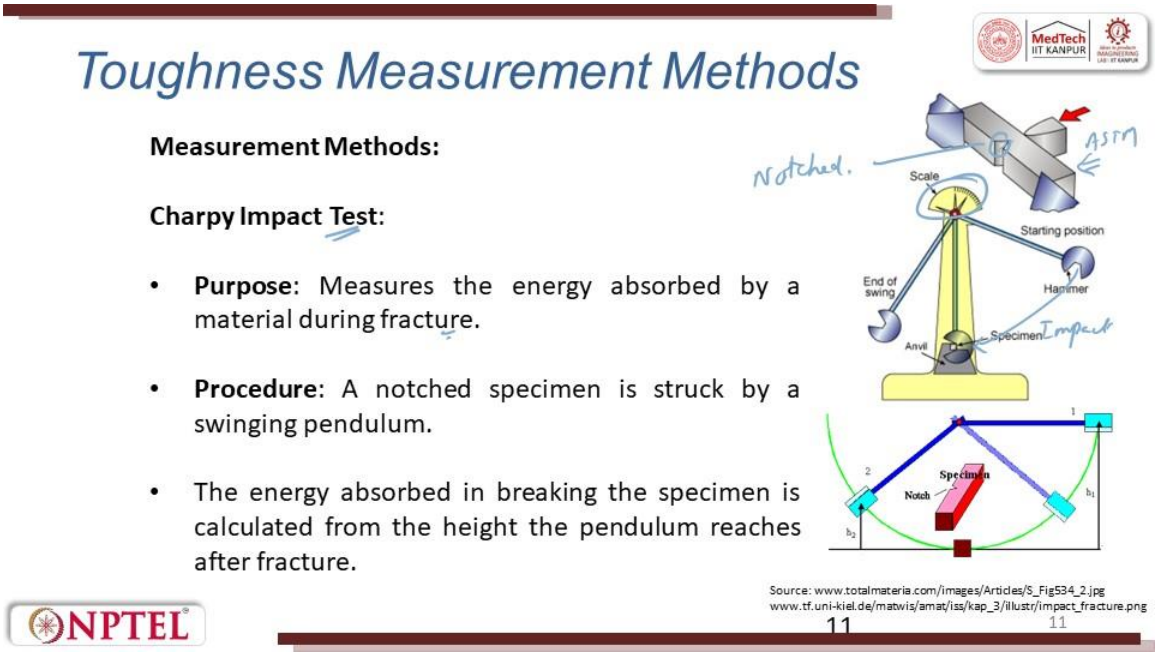
For example, let us take two simple examples. Suppose you have a rod. You wanted to bend the rod and make something like you. Or you want to make a hairpin which women use. So you want to bend it and then make. So what you do is, you hold it in a vice and then try to keep the rod.

You hammer it and then you bend it. You bend it a straight line into a U. So, now when you try to hammer it, it absorbs energy. When it absorbs energy, it easily helps you in bending. Otherwise, if the toughness is poor, it does not absorb energy, it fails. So, that is why you see many of the holding like gem clip.

And the paper clips all are made out of rods or wire where in which the toughness is very high. When you go into polymers, it is much higher. There is a terminology which is used during the resistance. During the area under the curve, only under the elastic limits is called as Resilience Term. Sometimes in the examination they can ask, define Resilience.

Here you will try to say the area under the curve within the elastic limits is called as Resilience. Within the plastic region it is called as Toughness. So, this in simpler terms or simple terms, It tells us how much a material can bend, stretch is also part of it, stretch or twist without breaking a stiffness. For example, on top of a compound wall, you will see twisted rods.

It gives you a very good aesthetic appearance. So, twisted rods, that is all basically toughness. And if you cannot do it in the cold state, room temperature state, what we do is we slightly heat it and then we twist it. So, in simpler terms, it tells you how much a material can bend, stretch or twist.



This is found out by a Charpy test. Charpy test, the purpose is to measure the energy absorbed by a material during fracture. So, here there is a ASTM standard. According to the ASTM standard, we prepare the sample. When we prepare the sample, we initiate a crack. In order to find out exactly what is the toughness of the material, energy it can store, we initiate a crack or a notch and then in the opposite side we try to hit.

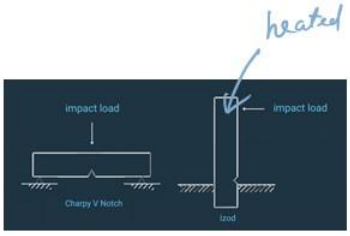
So here what we do is, we try to have a load and that load is moved to a distance. From there it is allowed to hit. It is impact. So it swings and hits and then the energy is absorbed here and the rest of the energy allows, after breaking it allows the end of the twist. Based

upon the swing, the values here, we try to find out what is the toughness. The procedure is a notched specimen.

A notch, this is called as a Notch. A notched specimen is struck by a swinging pendulum. The energy absorbed in breaking the specimen is calculated from the height of the pendulum reached after the fracture. So here is the height. So from here it swings, it hits the material and it goes here. So this is H1, this is H2. From this they do a calculation and try to say what is the energy absorption.

Toughness Measurement Methods

- **Orientation**: The specimen is supported horizontally, and the notch faces away from the pendulum.
- **Significance**: Provides insights into the material's ability to withstand sudden impacts, **particularly useful for evaluating the brittleness or ductility at different temperatures.**



Source: www.impact-solutions.co.uk/wp-content/uploads/2018/04/Blog-Image-Template-title-font-28-70.png

12

So the orientation, you can keep the sample like this or you can keep the sample like this. Orientation of sample is also important. The specimen is supported horizontally and the notch faces away from the pendulum or it can be on the other way around.

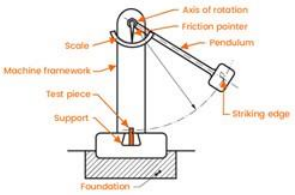
Significance provides insight into the material's ability to withstand sudden impact, particularly used for evaluating the Brittleness or ductility at different temperatures. You can also use it for varying temperatures. That means to say the sample will be heated and then you can try to do the test. So, this particularly tries to tell you what is the ductility, malleability things possible in the process. For example, in forging, you wanted to deform material to a large extent.

So, how much energy you should apply or is the material able to withstand the force what you apply at room temperature and at higher temperatures?

Toughness Measurement Methods

Izod Impact Test:

- **Purpose**: Also measures the energy absorbed during fracture, similar to the Charpy test.
- **Procedure**: The specimen is clamped vertically with the notch facing the pendulum.
- The pendulum strikes the specimen at the notch, and the energy absorbed in breaking the specimen is measured.



Source: www.impact-solutions.co.uk/wp-content/uploads/2018/04/Blog-Image-Template-title-font-28-70.png
www.nextgentest.com/wp-content/uploads/2021/02/small-animation-compressed.gif

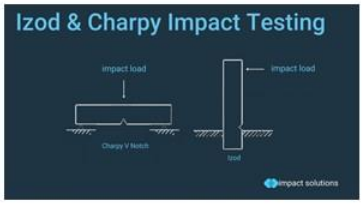
13

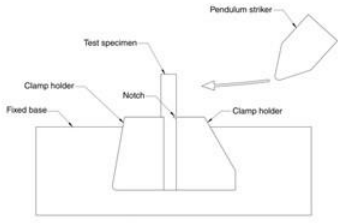
Charpy was one test. We also have Izod. So, Izod impact test. The purpose is also measure the energy absorbed during fracture similar to Charpy. This is the other thing. So, here we hit the material and then we record the reading.

Hit and then we record the reading. Procedure is the specimen is clamped vertically with the notch facing the pendulum. Earlier it was against, now it is towards the pendulum. Here the pendulum strikes the specimen at the notch. And the energy absorbed in breaking the specimen is measured. Okay. So, this is a difference between Izod and Charpy.

Toughness Measurement Methods

- **Orientation and Notch Position:** The vertical clamping and notch orientation differentiate it from the Charpy test.
- **Significance:** Commonly used to assess the toughness of polymers and plastics, as well as metals.





Notched izod impact test

Source: www.impact-solutions.co.uk/wp-content/uploads/2018/04/Blog-Image-Template-title-font-28-70.png
ars.els-cdn.com/content/image/3-s2.0-B9780323310161000015-f01-27-9780323310161.jpg

The orientation and the notch position, the vertical clamping and the notch orientation differentiates it from the Charpy test. Significance, commonly used assess the toughness of polymer and plastic as well as metal. So that is done by Charpy test.

Toughness

Example:

Steel in Construction:

- **Purpose**: Structural steel must be tough to endure impacts and dynamic loads.
- Example: steel beams & columns need to absorb energy from impact & cyclic load.

So examples, Steel in Construction industry. Suppose or the purpose is structural steel must be tough to endure impact and dynamic loading. So the real world example is going to be the steel beam, the steel beams and columns need to absorb energy from impact and cyclic load. So, suppose if there is a machine inside or if there are lot of people walking, if there are lot of people jumping, so it is impact.

So, the advantage of toughness is it improves safety, it improves ductility, versatile in application, enhance energy absorption. What are the disadvantages? Higher materials cost, increased weight, manufacturing challenges and brittle behavior at low temperature. So, these are the things which help us by doing the toughness. Suppose toughness means you want to absorb lot of energy, you increase the weight if you want to have higher toughness. So that is the thing which is laid down here, Impact.

Impact

- Impact strength, also known as **impact toughness**, is a crucial mechanical property that describes a material's ability to resist fracture under sudden, high-velocity loading.
- It essentially tell us how well a material can be handled a sharp blow or impact without breaking.
- It is a measure of the material's toughness under sudden loading conditions, reflecting how much energy it can absorb during a high-speed impact.

Impact strength also known as Impact Toughness is a crucial mechanical property that describes a material's ability to resist fracture under sudden and high velocity load.

Impact is when you are trying to keep a tank on top of your roof. And then you open water, right and the water falls from a certain head so that is also an impact load a student jumping impact load, right. So impact toughness is very important, it essentially tells us how well a material can be handled a sharp blow or impact without breaking. We do a crash test in the car. As soon as the car is developed, we do a crash test and see what is the impact when we travel at 60 kilometers, 100 kilometers per hour.

What is the impact to the human? When will the airbags open? So all these things are Impact Test. It is a measure of the material's toughness under sudden loading condition reflecting how much energy it can absorb during a high speed impact test.

Impact

Significance of Impact Strength:

- **Impact forces:** This could be anything from a hammer blow to a car collision or a dropped object.
- **Shock loading:** This refers to a sudden application of a large force, such as an explosion or a rapid change in pressure.
- **Dynamic loads:** These are loads that change rapidly with time, putting additional stress on the material compared to static loads.

The significance of impact test, impact force. It could be anything from a hammer blow to a car collusion or a dropped object. See, impact force is very important. We are trying to work on a project wherein which an old man or a lady weighing 80 kgs slipped down. How do we protect them? So, that is impact. So, impact force is very important. Shock loading.

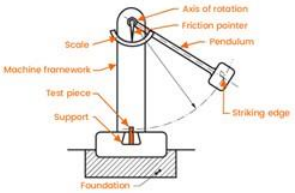
This refers to a sudden application of large force such as an explosion or a rapid change in pressure. For example, a blast of a pressure vessel, a blast of a cracker. It is an explosion wherein which light is there, huge pressures are there, energy is dissipated. And suppose you put a cracker inside a bottle and then blast, it just shatters the bottle, right. So, that is explosion.

We use this when we want to do clad two materials, we keep the two sheet of materials and then keep a dynamite at the bottom. We explode and they take the shape. So, dissimilar material joining is also used by explosion. Dynamic loads, these are loads that changes rapidly with respect to time, putting additional stress on the material compared to a static load. Shock load and Dynamic load. Dynamic load means changing with respect to time.

Impact-Measurement Methods

Charpy Impact Test:

- **Procedure**: A notched specimen is struck by a pendulum hammer, and the energy absorbed during fracture is measured.
- **Outcome**: The energy absorbed indicates the material's toughness and resistance to impact.
- **Use Case**: Commonly used for metals and polymers to determine their behavior under sudden loading conditions.



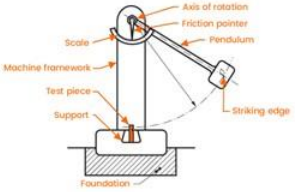
Source: www.impact-solutions.co.uk/wp-content/uploads/2018/04/Blog-Image-Template-title-font-28-70.png
www.nextgentest.com/wp-content/uploads/2021/02/small-animation-compressed.gif

So, Charpy Impact Test is done for it and notched specimen is struck by a pendulum hammer and the energy absorbed during fracture is measured. In outcome, the energy absorbed indicates the material's toughness and resistance to impact. Use case commonly used for materials and polymers to determine the behavior under a sudden loading condition.

Impact-Measurement Methods

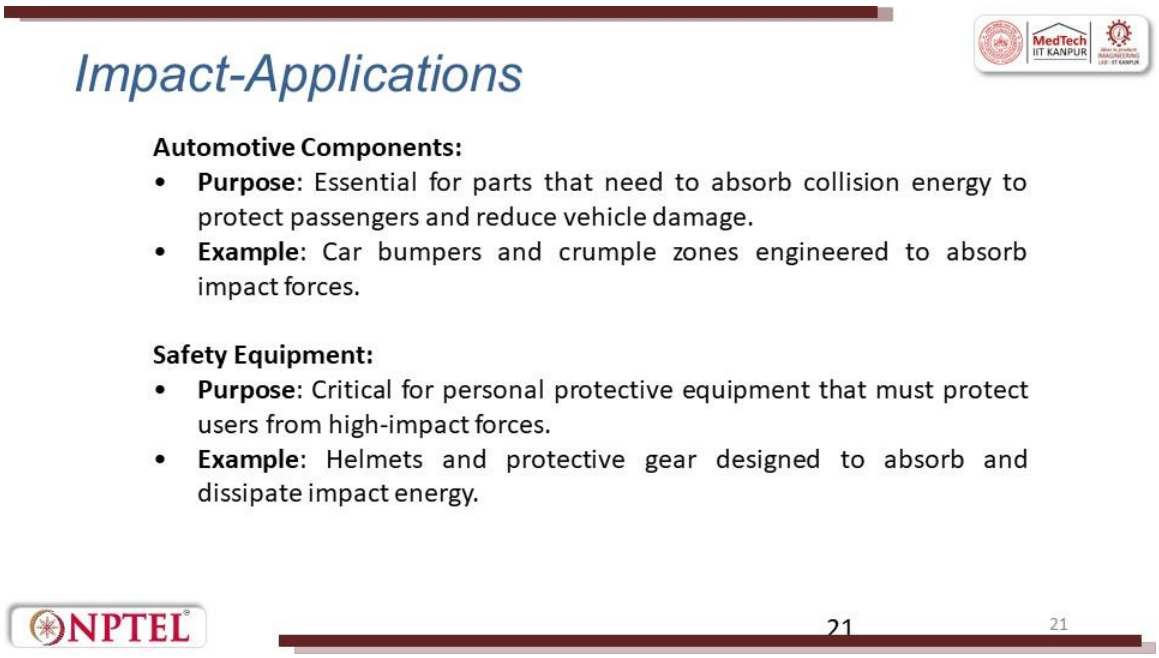
Izod Impact Test:

- **Procedure**: Similar to the Charpy test but with the specimen clamped vertically and struck at the notch.
- **Outcome**: Measures the material's resistance to impact with different notch orientations.
- **Use Case**: Frequently used for plastics and metals to compare impact resistance.



Source: www.impact-solutions.co.uk/wp-content/uploads/2018/04/Blog-Image-Template-title-font-28-70.png
www.nextgentest.com/wp-content/uploads/2021/02/small-animation-compressed.gif

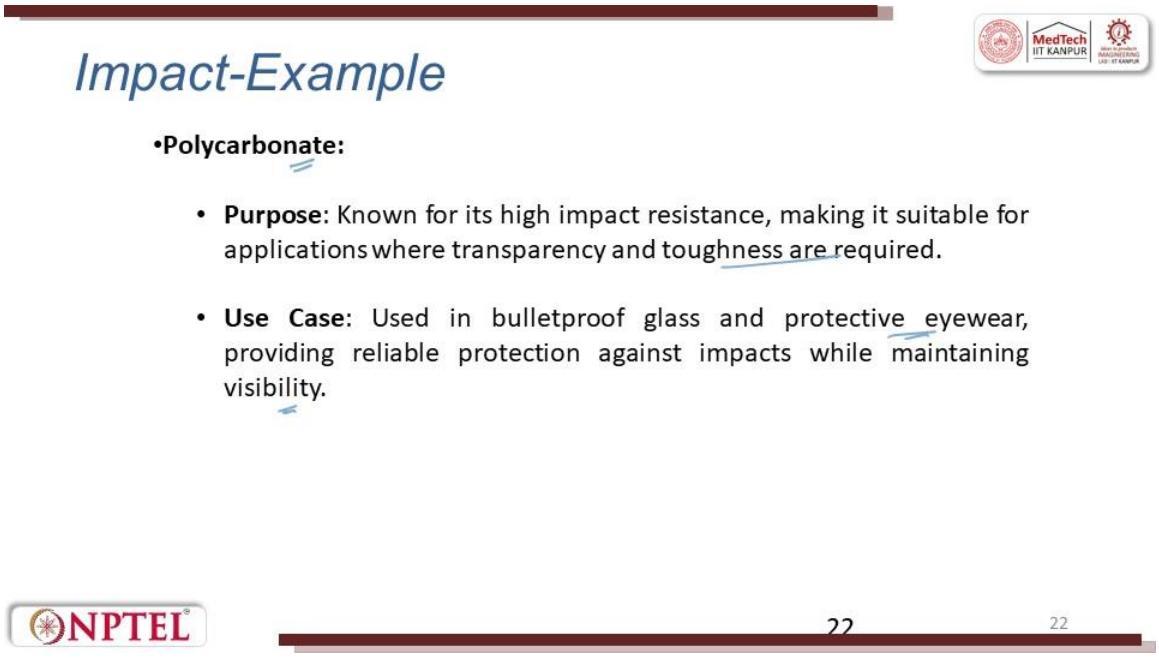
So the procedure is similar to Charpy test but with the specimen clamped vertical and struck at a notch. The outcome is measure, the material resistance to impact with different notch orientation. A use case is frequently used for plastic and materials to compare the impact resistance.



So impact finds lot of application in automobile engineering and also in safety equipment. A person trying to climb a wall and all of a sudden he slips. So there is a impact load.

The cable whatever he has tied around him should protect him from falling. Same way with respect to lift. When the lift is going up, elevator is going up, all of a sudden, if there is a power cut, there will be an immediate arrest of the cable moving up or down. So, at that instant there is a huge impact load which comes to the cable. So, automobile components, essential for parts that need to absorb collusion energy to protect passengers and reduce vehicle damage.

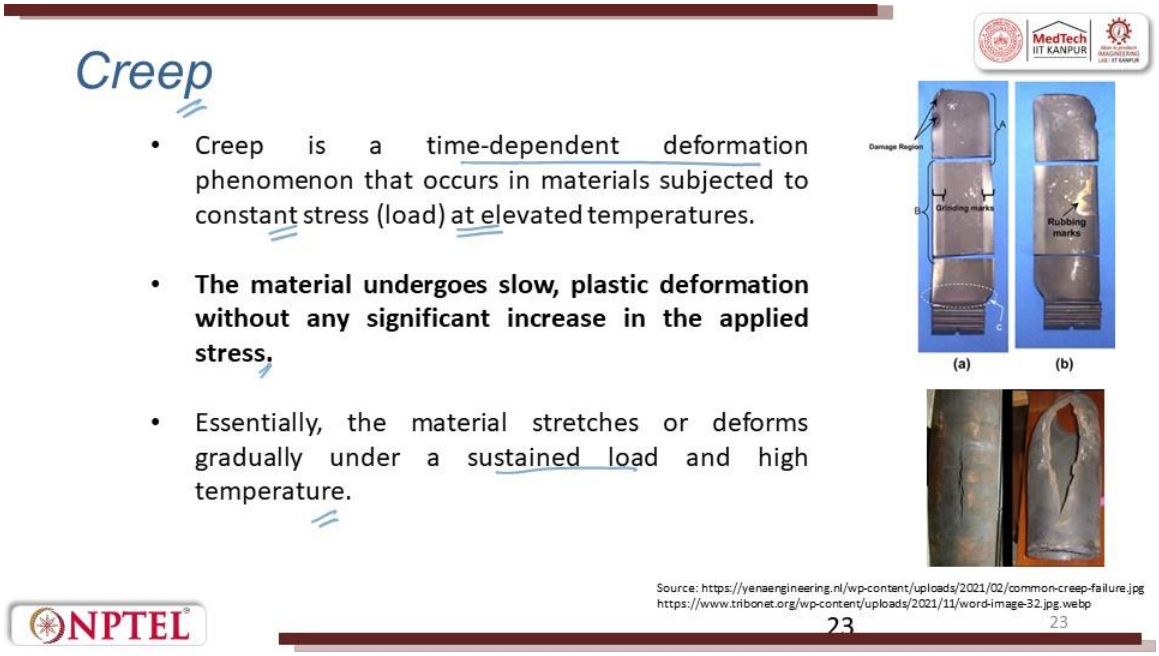
The car bumpers and the crumble zones engineered to absorb impact force. The safety equipments as I told you critical for personal protection equipments that must protect from huge or very high impact force. Helmets and protective gears designed to absorb and dissipate impact energy.



When we use polycarbonates today, we are using polycarbonate, polymers are getting replaced or metals are getting replaced by polymers. Polycarbonate is finding out lot of application today, known for its high impact resistance.

It is suitable for applications where transparency and toughness are required. For example, glass or polycarbonate. When you go to museums, when you walk through the museums, there are transparent partitions, which partitions between you and the fish tank or something like that. So there, there is lot of impact load. Use cases used in bulletproof glass and protective eyewears.

Providing reliable protection against impact while maintaining visibility. So protective eye wears when there is a impact it has to when there is a stone hitting it should not shatter.



The next property for discussion is going to be Creep. Creep is a time dependent phenomena. You try to take a polymer.

An example is many a times we try to hang flower pots in our house tied to a polymer to a hook. At some point of time, the polymer gives off and then the flower pot falls down and crashes. What is the phenomena? The phenomena is nothing but the creep behavior. Creep behavior, creep is a time dependent deformation.

Because of the weight, the polymer slowly deforms. It is with respect to time, it gives away. That occurs in the material subjected to a constant stress load at elevated temperature. As far as polymer is concerned, we are talking about room temperature. When you talk about metals, it is at elevated temperature.

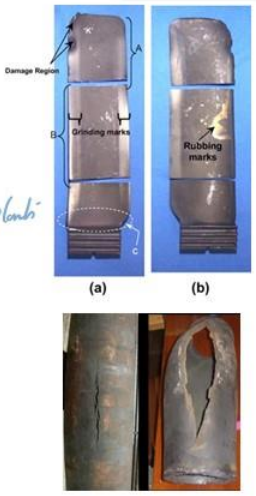
A time dependent deformation, constant stress at elevated temperature is creeped. The material undergoes slow plastic deformation without any significant increase in the applied stress. So, you can see here turbine blades, it undergoes a creep phenomena with respect to temperature or with respect to pressure or with respect to fluid flow. Essentially, the material's stretches or deforms gradually under a sustained load and high temperature. Whenever a flight lands, immediately the airline's engineer, he just goes towards the fan of the aeroplane and then he checks all the blades, whether there is any visible crack or damage which is seen because of creep behavior.

Creep

Importance of Understanding Creep:

Creep is a crucial consideration for engineers working with materials in high-temperature applications, such as:

- Turbine blades in jet engines & power plants
- Pressure vessels in chemical processing
- Nuclear reactor components
- High-temperature pipelines



Source: https://yenaengineering.nl/wp-content/uploads/2021/02/common-creep-failure.jpg
https://www.tribonet.org/wp-content/uploads/2021/11/word-image-32.jpg.webp

24

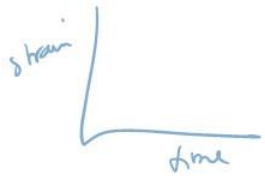
The Importance of Understanding Creep. Creep is a crucial consideration for engineers working with materials in high temperature applications such as turbine blades in jet engines and power plant. Next pressure vessel in chemical processing. Then nuclear reactor components.

Then you have high temperature. Pipelines, petroleum pipelines, gasoline pipelines sometimes they use it. So, all these places the creep is a very very important property to be measured. How does it been measured?

Creep- Measurement Methods

Creep Test:

- **Procedure:** A sample is subjected to a constant load at a specific temperature, and the deformation is measured over time.
- **Data Analysis:** The test results are used to plot a creep curve, showing strain vs. time, and to identify the material's creep rate and stages.



The Creep is always done by a Creep test. The procedure is the sample is subjected to a constant load at a specific temperature and the deformation is measured over time. Creep tests are long duration tests. Today we have accelerated creep test rigs also. Data analysis, the test result are used to plot a creep curve showing strain versus time and to identify the materials creep rate and stages. So, here showing strains versus time strain versus time you see the property.

Creep-Application

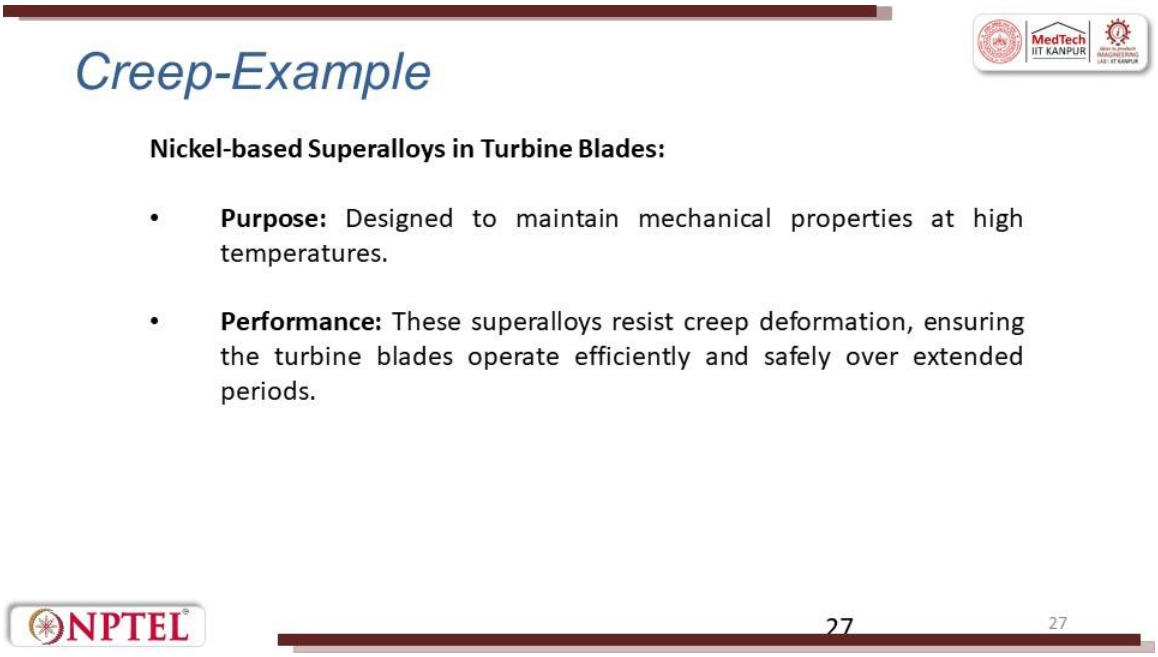
Turbine Blades:

- **Purpose**: Used in jet engines and power generation turbines, operating at high temperatures and stresses.
- **Material**: Nickel-based superalloys, which resist creep deformation.

Nuclear Reactors:

- **Purpose**: Structural components exposed to high temperatures and radiation.
- **Material**: Stainless steels and other alloys designed to withstand long-term creep.

So creep applications turbine blades, nuclear reactors in turbine blades. It is the purpose is used in jet engines and power generation turbines operating at a high temperature and stress material which are used are nickel based alloys which resist creep deformation.



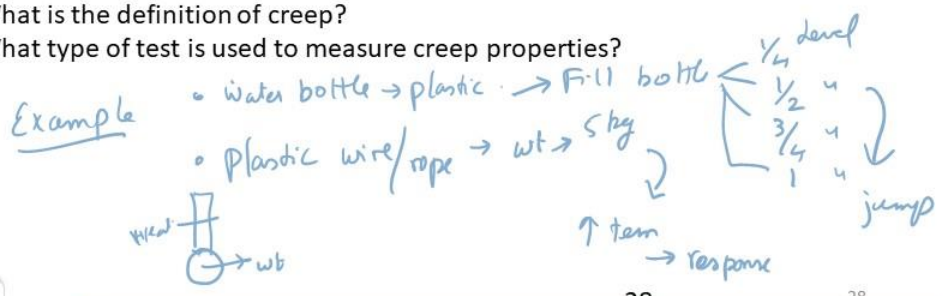
These are all nickel based alloys are all new latest exotic materials. They develop these materials to meet out to the requirement. Nuclear reactors, structural component exposed to high temperature and radiation, stainless steel and other elements.

Again this is a material which gets evolved. So here it is like a cycle manufacturing and application. It is a process which goes like this. You try to manufacture a material to meet the application. Whatever you do application, then if it is not good, you go for this.

And in between step comes the property evaluation. Right. Manufacture before it is found to application, you do property check creep application. After the application is done again on the service condition here it is a specimen, here it is a service condition material. So then you try to improve the manufacturing. So it is a cycle which goes. Nickel based Superalloys in Turbine Blades designed to maintain mechanical properties at very high temperatures. The performance is these super alloys resist creep deformation ensures the turbine blade efficiently and safely over extended period.

To Recapitulate

- What is hardness and how is it typically measured?
- Describe the difference between the Brinell and Rockwell hardness tests.
- Define toughness and explain how it is different from hardness.
- How does the Charpy impact test measure the toughness of a material?
- What is the definition of creep?
- What type of test is used to measure creep properties?



28

To recap in this lecture we saw, what is hardness? How is it typically measured? What are the different types of hardness? Brinell hardness which is ball in under, Rockwell which is diamond in under or a tip in under.

Define toughness, explain how it is different from hardness, how does sharpie test work in impact, what is the definition for creep and what type of test is used to measure creep properties. Today, you will try to see two examples which is do it by yourself. First example is or a do it by yourself problem. First one is you will try to take a water bottle of half a liter water bottle, half a liter which is predominantly plastic which is sold in the shops, right. So plastic bottles and then you will try to fill the bottle with one-fourth, half, three-fourth and one.

For example, one-fourth level, one-half level, three-fourth level and one full level. You will fill it up with water and close the lid and then jump on it. See the response of the material in terms of impact and in terms of energy absorption. Next, you will try to take a plastic wire, plastic wire or rope, tie it up with a weight of maybe 5 kgs. You have to choose a rope which can withstand 5 kgs and then you will tie it up.

Then you try to increase the temperature at the mid level. So, you are trying to take a wire. You have a weight which is attached to it and here what you do is you try to heat it. Load is there and try to heat with increasing temperature.

See what happens to the entire response. So this will try to give you a feel for creep. So these two examples I want you to try so that you can understand and appreciate the lecture whatever we have gone through.

References

- D Halliday & R Resnick, Physics Vol-II, Wiley Eastern, 1993
- Hibbeler, R.C., Engineering Mechanics: Statics, Pearson, 2016.
- Khurmi, R.S., & Gupta, J.K. (2005). A Textbook of Machine Design. EURASIA PUBLISHING HOUSE (PVT.) LTD.
- H.K. Malik & A.K.Singh, Engineering Physics, Tata McGraw Hill, 2011

These are the references which we have used in this lecture.