Basics of Mechanical Engineering-1

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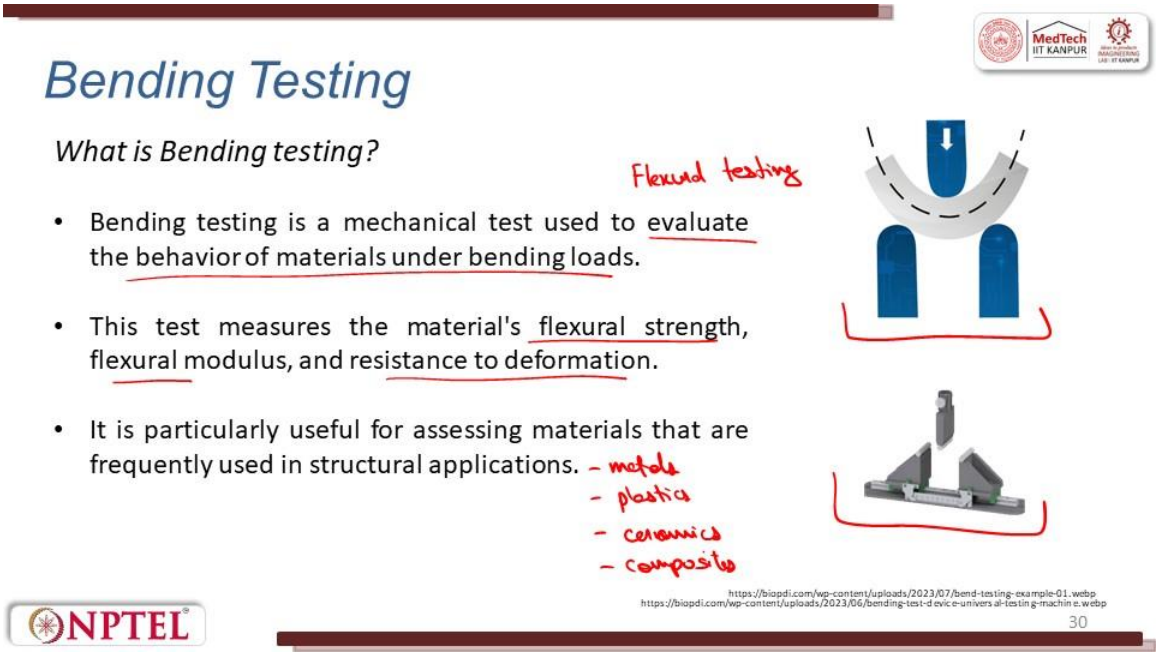
Lecture 38

Testing for impact loads

Welcome to the lecture series on the material testing in the course Basics of Mechanical Engineering-1. We have discussed about various testings in the previous lectures. We have talked about the Tensile Test, Compression Test and Bending Test. This was discussed, this lecture will focus on the Impact Loads, that is the Charpy and Izod test would be discussed. The two impact load testing setups are there which are prevalent for testing the specimen for impact loading.



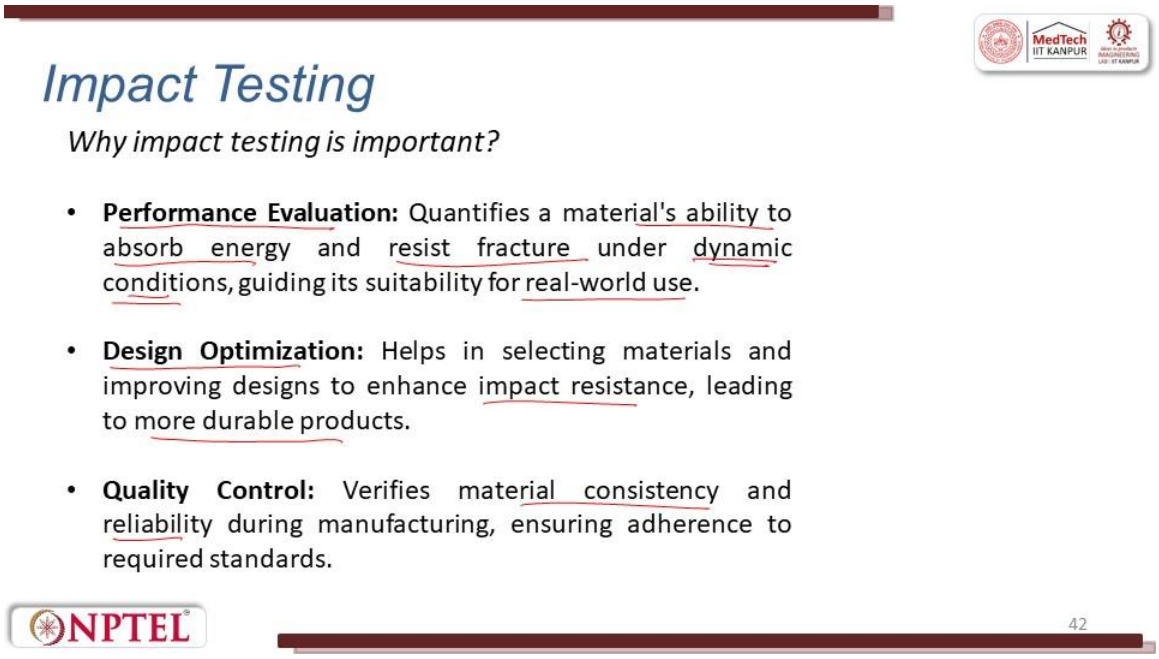
Impact Testing. What is Impact Testing? Impact testing is a method used to assess the behavior of materials when subject to a sudden loading condition such as impact or

shock. This test measures the ability of a material to absorb energy under dynamic loading providing insights into its toughness and resistance to fracture. Impact testing is crucial for evaluating the performance and reliability of materials in applications where sudden impacts or dynamic loads are common.

So this is a specific impact testing machine we have a striking edge so here energy is stored in the form of potential energy this potential energy is converted into the kinetic energy here

We will watch that in the video. There is a scale that shows loss of energy. This loss of energy is then put proportional to the strength this specimen had. So, this is a test piece that is held here because this test speed is hit at the end. So, it is our ISER test.

So there are differences between Izod and Charpy, I will give you the differences. So this is axis of rotation, this is friction pointer, the supports are there so that the specimen doesn't slip. There are test pieces here, main machine framework is here. So this is a setup that is there for the Charpy test. Where the notch to get the specimen broken or to get the specimen bent is at the center.



Why impact testing is important? First is performance evaluation. This quantifies a material's ability to absorb energy and resist fracture under dynamic conditions, guiding its suitability for real-world use. Wherever or whenever impact is there or dynamic

loading is there, impact could come. So this is designed for the real-world use for its performance in these conditions.

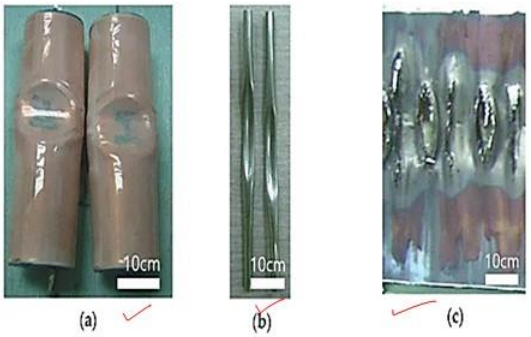
Then is Design Optimization. It helps in selecting materials and improving designs to enhance impact resistance leading to more durable products. Quality Control. It helps in verifying the material consistency and reliability during manufacturing, ensuring enhance to the required standards.

Impact Testing – Procedure and Equipment

Procedure:

1. Specimen Preparation:

- **Standardized Specimens:** Prepare specimens according to standardized dimensions (ASTM, ISO, etc.), typically as rectangular or cylindrical shapes.
- **Surface Preparation:** Ensure the specimen surfaces are smooth and free from defects to minimize variability in test results.



(a) (b) (c)

https://pub.mdpi-res.com/energies/energies-15-02509/article_deploy/html/images/energies-15-02509-g001.png?1648553146

Let us go through the procedure. First is Specimen Preparation again based upon the ASTM or ISO standards the specimen are prepared here.

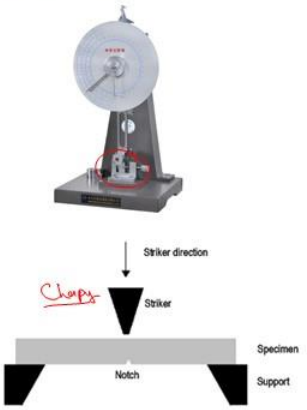
Surface Preparation, specimen surface roughness has to be smooth and free from defect so that there is no variability.

There are some specimen which are shown here which have gone through the impact testing.

Impact Testing – Procedure and Equipment

2. Testing Apparatus Setup:

- **Impact Tester:** Use a dedicated impact testing machine designed to deliver controlled impact forces to the specimen.
- **Specimen Mounting:** Securely mount the specimen in the testing apparatus to ensure it remains stable during impact.
- The test procedure refer as https://www.youtube.com/watch?v=tpGhqQvftAo



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Testing Apparatus, we have Impact Tester, use a dedicated impact testing machine designed to deliver control impact forces to the specimen. Specimen mounting, securely mount the specimen in the testing apparatus to ensure it remains stable during the impact.

So that is why we put it on a holding device here. So this is a striker, it comes in this direction, when it is a center always remember again, it is Charpy test and there is a notch, there could be kinds of notches I will show you the kinds of notches could be V notch, it could be U notch, it could be socket notch and there are supports so that the specimen is bearing the force completely and it is not transferred to any other part of the machine.

Impact Testing – Procedure and Equipment

3. Measurement and Calibration:

- **Calibration:** Calibrate the impact tester according to the manufacturer's guidelines to ensure accurate and consistent results.
- **Measurement Instruments:** Use sensors or transducers to measure impact force and deformation of the specimen during testing.

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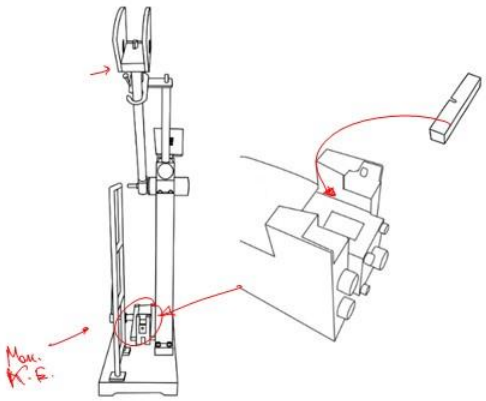
Impact Testing – Procedure and Equipment

4. Conducting the Test:

- **Apply Impact Load:** Release a pendulum or striker from a specified height or velocity to strike the specimen.
- **Record Data:** Capture the impact force and deformation parameters (such as energy absorbed, displacement, and fracture type) during the test.



https://sm-nitk.vlabs.ac.in/exp/charpy-impact-test/simulation.html

Then we conduct a test. Apply impact load that is when the load is held here, it is carrying a potential energy, it is released pendulum or striker from the specified height or velocity to strike the specimen. Here kinetic energy is maximum. Maximum kinetic energy. So, when we record the data capture the impact force and deformation parameters such as energy absorbed, displacement and fracture type during the test.

The specimen is held in the specimen holder vice here and this vice is here, this vice is here and then we conduct the test.

Impact Testing – Procedure and Equipment

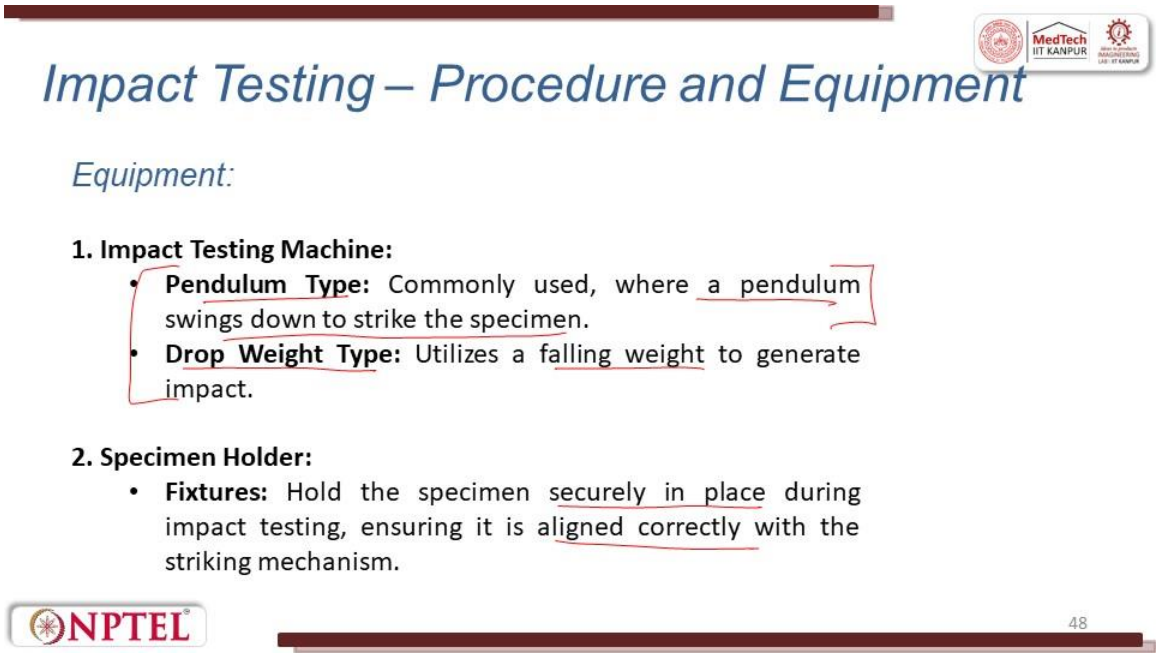
5. Data Analysis:

- **Evaluate Results:** Analyze the recorded data to determine the material's behavior under impact, including its toughness, energy absorption capacity, and resistance to fracture.
- **Compare Standards:** Compare the test results with established standards to assess compliance and suitability for intended applications.
- Virtual Labs (vlabs.ac.in)

1. https://sm-nitk.vlabs.ac.in/exp/charpy-impact-test/ for **Charpy impact test**
2. https://sm-nitk.vlabs.ac.in/exp/izod-impact-test/ for **Izod impact test**

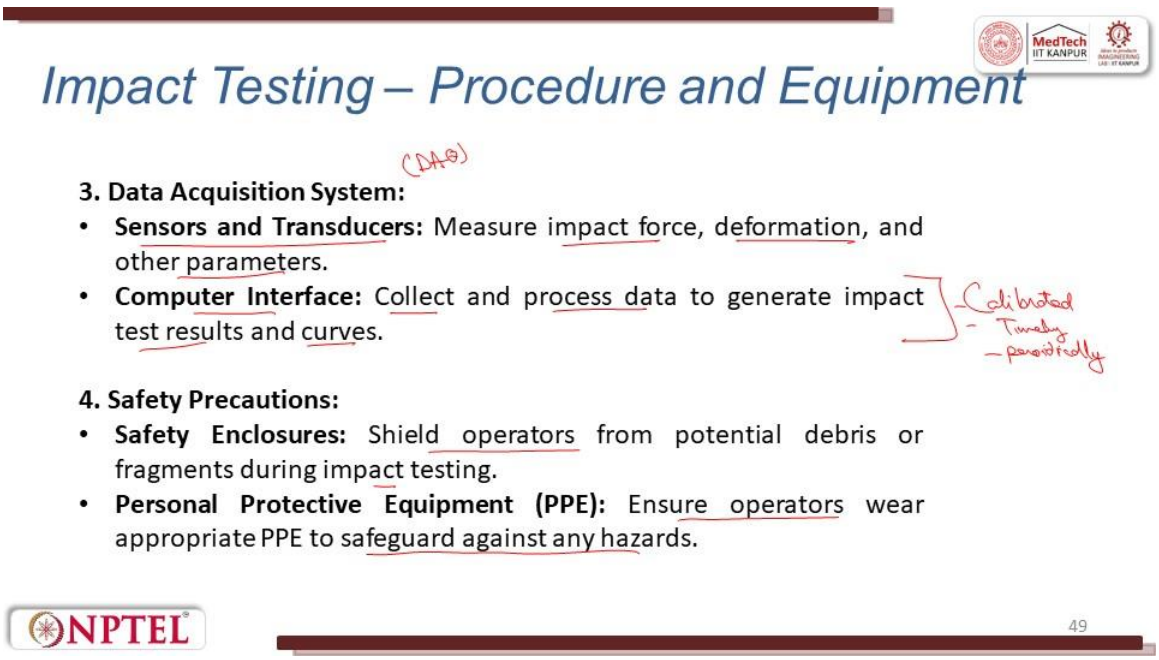
Then we go for the Data Analysis that is we Evaluate the Results, analyze the recorded data to determine the materials behavior under impact including its toughness, energy absorption capacity and resistance to fracture.

Then we Compare the Standards that is we compare the test results with established standards to assess compliance and suitability for intended applications.



To talk about the equipment, it could be pendulum type or drop weight type that is impact testing machine. Pendulum type equipment is very commonly used where a pendulum swings down to strike the specimen or a falling weight could also be used to generate the impact.

So, there are two kinds of equipment but pendulum type equipment is smaller in size and is generally used for the impact testing. Specimen holder fixtures hold the specimen securely in place during the impact testing. This ensures it is aligned correctly with the striking mechanism.



Then comes the DAQ (Data Acquisition System) or we call it as DAQ (Data Acquisition Sensors) and transducers. The setup that I will show you would be having a manual dial indicator, but there are nowadays sensors and transducers that measure the force and just display it on a digital display board. It measures the impact force, deformation and other parameters. Computer Interface helps to collect and process the data to generate impact test and curves.

Only the point is it has to be calibrated and calibration has to be timely and periodically. It is maybe each three years it has to be pre-calibrated, each year it has to be calibrated or after a number of tests, maybe after 100 tests, 1000 tests, there are specifications with the machines which are given, it has to be calibrated accordingly.

Then comes Safety Precautions, Safety Enclosures, shield operators from potential debris or fragments during impact testing, the PPE that is 'Personal Protective Equipment', ensures that operators are safeguarded against any hazards.

Now, I will show you a video where the impact test that is a Charpy impact test is conducted on two test specimens. First test specimen is strain aged plain carbon steel S235 and second specimen is the normalized steel.

You will see the strength that is for the normalized steel is very high that is the energy that will be absorbed for the normalized steel would be heavy because normalized steel is

heat treated and it has gained strength accordingly. So, let us go through this video and I will come to the simulation part of the impact test. The standardised Charpy impact test has been designed to measure the toughness of materials under impact loading and multi-axial stress state. A pendulum impact testing machine is used to do so. The pendulum on the machine has a heavy weight at the end.

This is lifted into the starting position in step 1. Then the tester checks whether the testing machine has been adjusted accurately. In order to do this, he turns the drag indicator downwards and releases the pendulum without a test specimen. The drag indicator stops at position zero. This proves that the pendulum has the correct starting position and that the friction is correctly compensated.

The machine is ready for the tests. First test, strain aged plain carbon steel S235. This is our test specimen. It has been machined to standardise size and shape with the characteristic V-shaped notch. The tester places the specimen on a support in the lower part of the machine and adjusts its position with a centring device.

Next, he turns the drag indicator downwards again and checks that everything is prepared correctly. Perfect, the test can begin. The pendulum is released, it swings downwards and hits the specimen with its rounded hammer pin. The specimen absorbs part of the pendulum's energy so the pendulum doesn't reach the full height on the other side. The amount of energy that has been absorbed by the specimen can now be read off at the position of the drag indicator.

It only amounts to 13 joules in this test. Here is the main principle of the measurement. In its starting position, the pendulum only has potential energy. It is given by mass of the hammer m times gravitational acceleration G times starting height H. After the pendulum has been released, the hammer moves downwards, hits the specimen and then only swings to height small h.

Exactly at the first reversal point, the pendulum again only has potential energy, which is m times g times small h. The energy that has been absorbed by the specimen is called notch impact energy, kv. It corresponds to the difference between the two potential energies. The first specimen only shows very little plastic deformation. A mostly flat, slightly glittering fracture surface has been formed. This is another important indication that this kind of steel is only able to absorb small amounts of notch impact energy.

It shows mainly brittle behavior due to the strain ageing effect. Second test. The second specimen has been made from Normalized Steel S235. It is also placed on the support and centered. The tester turns the drag indicator to its starting position, rechecks all safety measures and releases the pendulum.

This time the impact sounds much deeper and richer. An impressive energy of 182 joules has been absorbed by the specimen. Here the specimen did not break into two pieces. Instead it was pushed through the counter bearings under heavy plastic deformation. In comparison with the strain aged steel, the normalised steel absorbs much more notch impact energy and behaves in a very tough manner.

The Charpy impact test is not only carried out at room temperature. Materials with body-centred cubic crystal structure, such as plain carbon steels, show a characteristic S-shaped curve of the impact energy versus temperature. In the so-called upper shelf region, the material absorbs a lot of energy and behaves in a tough manner. At low temperatures in the lower shelf region, only a small amount of impact energy is absorbed and brittle fractures occur. Metallic materials with a face-centred cubic crystal structure, on the other hand, do not experience a ductile to brittle transition.

These materials retain their ductile behaviour towards low temperatures and are therefore well suited for low temperature applications. I think this video made it very clear that there was a potential energy that converted into kinetic energy and how the specimen is broken or the specimen is bent depending upon the energy that is absorbed here. Each time the specimen behaves little different. That is why we go through three trials at least when we try to conduct a test. This was the Charpy impact test.

Izod impact test is also there when the specimen is broken at the end. So, let us go through the simulation part of it.

So, this is the virtual laboratory experimental setup for the Charpy impact test. The aim is to find the impact resistance of mild steel. I have picked mild steel specimen here.

The 3D part is given here where the machine setup is given. A fracture energy is given. So this is the setup of the specimen. There are anvil here on which the specimen is mounted. We need to make sure that the notch is facing in the opposite direction to the striker.

If striker is coming from this direction, notch is in the opposite direction. Notch should be in this direction. So, here the specimen will strike at the plane end or plane surface of the specimen. So, now test supports are there width of the specimens are all given here the diagram is mentioning it very clearly. When I will show you the specimen getting broken or you when you watched in the video specimen was broken, you saw there was brittle setup here or brittle fracture area was there that is shown white here and there was ductile fracture area that is shown grey here.

Also, you can see the A and B are width of the specimen when we try to look at the cross-section of the breakage. So, this is brittle fracture and ductile fracture that transition between them, the impact energy this is the plot that we have gotten and the notch is in a way that it is 10 mm and later contraction is just like this. So, we can calculate the shear area and this is the notch section these are the nominal dimensions of the notch length is

55 mm, width is 10 mm thickness is 10 mm and we have also been given the machining tolerances here. It is this earth material. Then we have kind of the notch shapes.

That is V-shaped notch is there. Then we have U-shaped notch. We have socket notch in which there is a circle of 2 millimeter. That is a hole of 2 millimeter. Then it is socket.

The different notch types are there to conduct a test. These all are the standards developed by different manufacturers. Standard organizations such as ASTM or certain ISO standards are there. So let us go through the evaluation questions first. In Charpy impact test, the specimen is kept as, so it is simply kept there, so that is why we can select here it is simply kept as a supported beam.

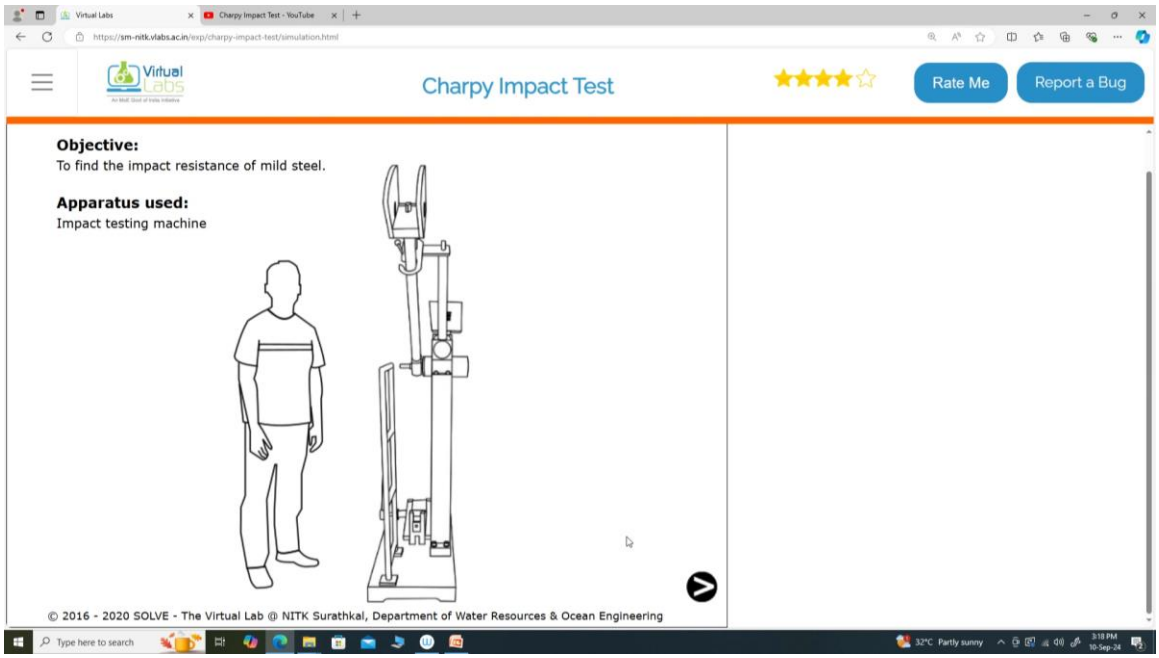
It is not overhung, it is not cabling cantilever, it is not fixed at any end, it is just kept there. Then tensile and bending stress also gives impact resisting qualities of material. No, then silent bending stress does not give the impact resistant properties. Match the following in the chalky test angle at the tip of the hammer. It is one angle at the tip of the hammer is 30 degrees.

The angle has to be matched. One is D. So, there are two options A and D which are showing one is D. Then radius of curvature at the supports is 10 millimeters. So, that means 1-D, 2-E, again A and B could be the answer. Third is length of the specimen. Length of the specimen that is for the sharp impact test is 55 millimeters.

So, that is 3 is matched with B. So, answer should be A in which angle of the tip of the hammer is 30 degrees. The radius of the curvature at the support is 10 mm, the length of the specimen is 55 mm, the width and thickness of specimen are 10 mm each, that is scale core section and distance of the center of notch from end of test piece is 27.5 mm, which is half of the length of the specimen. This is 55 by 2. This one is marked. Next question, stress induced in a body due to suddenly applied load compared to when it is applied gradually is 2 times.

When suddenly applied load is there, stress that is induced is double. So, that we have also discussed in one of the numerical questions in the previous lectures. Then next question and the last one is, quantitative result of the impact test, the energy needed to fracture a material can be used to measure the toughness of the material and when we are measuring toughness, we are also measuring the yield strength. Let us submit it 5 out of 5. Please get 5 out of 5, keep resubmitting, understand it completely.

This is what is the purpose of having a self-evaluation or pre-test evaluation before conducting a simulation.



Let us go through the simulation and we will have three trials. This is the Charpy impact test setup and this is using sensors and transducers where the reading would be displayed here. I have to just release the load here, I will just rotate this lever and the load is released here in the pendulum and there is a loss of energy due to friction that is 1 joule that is this is the calibration of the machine before testing 1 joule of energy is lost when no specimen is there at all.

Try to get our specimen, these are damages of specimen that we have discussed, length is 55 millimeter, width and thickness is 10 millimeter; each the depth below the notch is 8 millimeters and distance that is the center of the specimen, width point is 25.5 millimeter that is the sense of center of notch from ends of the test piece.

This is a specimen that is with us and we can select either cast iron or mild steel and try to test it, let me select mild steel only. This is mild steel, length is given here, breadth is given here, depth is given here, depth of notch is also given here and this is V type notch.

So, this is my specimen holding vice here and on this vice, I will drag the specimen and just put it here just as a simply supported beam. Let us go for the trial one. Now, I have to release the load.

The test piece is not broken here, that is test piece is not broken by the striking energy of the machining machine. So, the impact value obtained is indefinite. We have obtained any value whatever it could be because specimen is not broken. The test is invalid here. That is loss of energy is 1 joule.

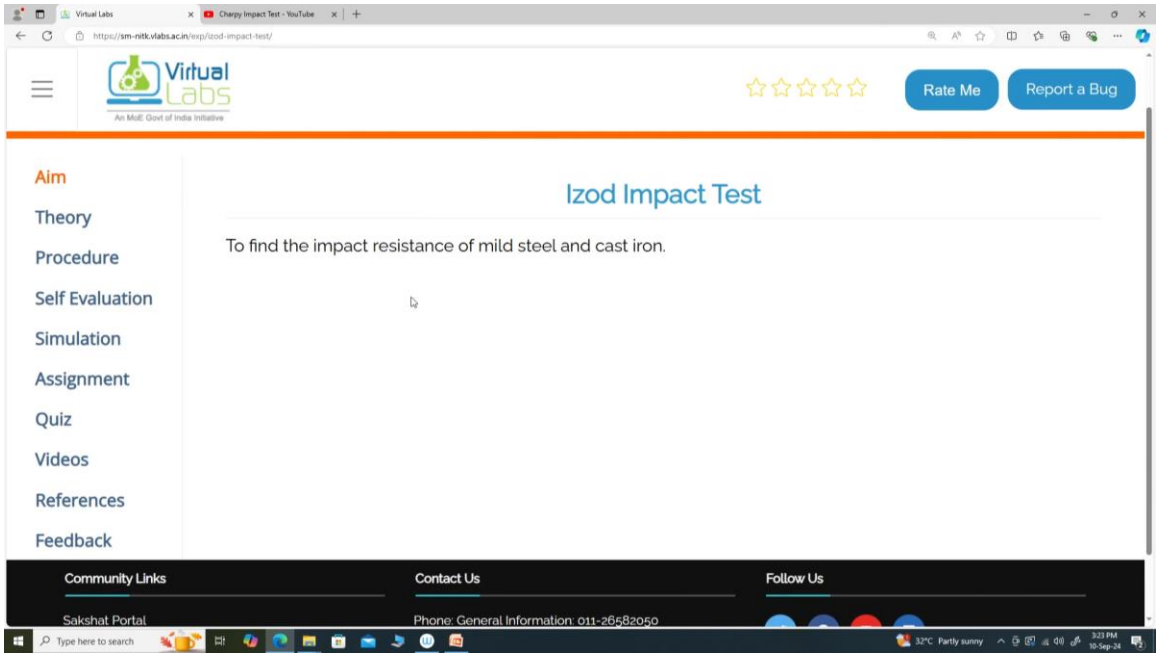
The total loss of energy during transit of hammer is indefinite. The energy for the failure specimen is Et - Ef. That is total energy minus the loss of energy. That is indefinite. Let us go through a second trial mild steel specimen again.

The second trial again, I will put the specimen here and conduct my test. I have to release the lever. Yes, now the specimen is broken. Specimen is broken and it is showing that the energy that is loss is 43 joules that is total loss of energy during transit of hammer Et is equal to 43 joules. The energy of failure of specimen that is Et - Ef, Ef was 1 joule that is 43 - 1 is 42 joules.

Let us conduct the third trial or in the second trial let us try to first see the calculations how do we get 42 joules. This is the second trial result, third trial again I will mount, the specimen mounting is just keeping the specimen so that it is exactly at the center, then we conduct a test in the similar fashion, again the specimen is broken and energy that is lost here is 43 joules, again the same energy has come it could be different.

It could be maybe if it is 43, it could be 44, it could be 42 but again we have gotten the same values and we will find the final values that is for the first trial there was indefinite because the specimen did not break. In the second and the third trial both of them have gotten the loss of energy during transit of hammer as 43 joules.

This energy minus the energy loss due to friction. That is 1 joule is 42 joules each. So average energy of failure of specimen is 42 joules. This is the result of the Charpy impact test.



Let me also go through the Izod test here. This is the Izod impact test. Where the aim is to find the impact resistance of mild steel and cast iron. Theory, only the difference between the Izod and the Charpy test is in Izod test, we break the specimen at the end. So high stress concentration factor at the tip of the notch area of local yielding of material reducing the stress concentration effect.

So, there are certain interfaces of the notch given here to show the weak interface and these all could be studied. So, this is our experimental setup which is very similar to what we had in the Charpy impact only we see the scale is here and lever arm is there and hammer is here and the specimen is held in this way here the striking height is here with a striker would hit or strike the workpiece.

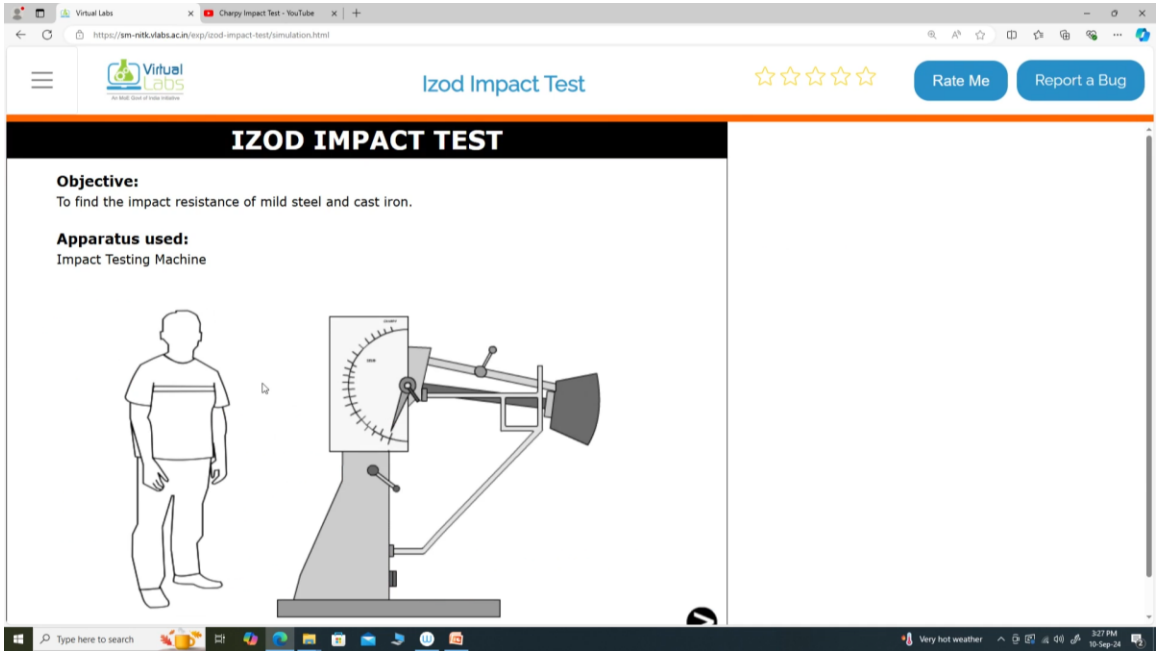
The radius of curvature of the striking edge is there and direction of impact is here and notch direction is towards the striker. This is also one of the differences. The notch direction in the Charpy test was opposite to the striker. Here the notch is towards the striker. So, test specimen dimensions are here 75 millimetres and we have at 22 millimetres from the hammer striking point the notch centre point.

So, this is 45 degrees V notch. Let us try to go through the self-evaluation questions. IZOD impact test angle at which pendulum is placed from the ground is 90 degrees. How the test piece is supported here? Here we have a vertical cantilever and it is supported accordingly.

Which property of metal is used to check in this test? Tactility, toughness, bitterness, malleability. Definitely we are checking the toughness here. The initial energy of hammer is 164 joules. This was written in the theory.

I am just marking the answer. According to the IS course dimensions, the length of the test piece is 75 mm. What is the depth of the notch of IS test specimen? The depth of the notch was 2 mm only. The toughness value of material A and material B are 60 joules and 5 joules respectively.

Which of the following statement is most suitable? The toughness value of material A is quite higher than material B. Let us see the statements. Material A is harder than material B. Material B is more brittle than material A. Material A is more tougher than material B. The material B is more ductile than material A. Here because we have gotten toughness value, we can talk about the brittleness here. So, here I will put it as material B is more brittle than material A. Let me submit. I got 7 out of 7.



Let us go to the simulation part here. This is our apparatus and different components of operators were shown in the theory. Let me go to the test step 1. Select the ISO test specimen.

I will select mild steel once again and length of the specimen is 75, breadth is 9.3, depth is 9.4, depth of the notch that is D is 3.34 millimeters. The loss of energy, we will first

review just for the friction loss is conducted by adjusting the pointer to 164 joules. This pointer is set at 164 joules. Then the pendulum is released by operating the lever without keeping the specimen. So, without the specimen let us see what is the loss of energy.

2 joules of energy is lost just due to friction. Now let us try to start conducting the experiment, we have again the specimen held here in the vertical form that is 90 degree to the ground and radius of curvature of striking edge test piece, everything is given here as we saw in the theory. Let us now conduct the experiment. It will release the pendulum and it is broken. Total loss of energy due to transit of hammer is 44 joules.

So energy for failure of specimen is total loss of energy minus loss of energy due to friction. That is Et minus Ef. It is 44 minus 2. That is 42 joules. And initial energy of hammer was 164 joules.

So here energy of failure is given. Second trial. Second trial again for the same specimen size. I will release the hammer, specimen is held here. Test piece was not broken by the stacking energy of the testing machine.

So impact value obtained is indefinite. So this test is a fail. Let us go to the third trial now. Here length of specimen is given, breadth is given, depth is given, depth of the notch is also given. Let us try to test this.

Specimen is held. The notch is in the direction of the striker. It strikes. It is broken now. And the energy that is obtained here is 56 joules.

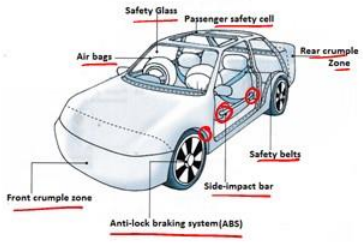
56 joules implies the energy for failure of specimen would be 56 minus 2 would be 54 joules. So that energy we have obtained. For the first trial, the total energy lost was 44 joules. And for the second it was indefinite, for the third it was 56 joules. Accordingly we have gotten the energy for the failure of the specimen as 42 indefinite and 54 for the trials 1, 2 and 3 respectively.

So average energy of failure is average of these two values that is $\frac{42 + 54}{2}$ that is 48 joules. This is how we conduct the impact test.

Impact Testing

Example Application of Impact Testing in Automobile Industries

- Ensures Safety: Evaluates how vehicle components withstand crash scenarios.
- Guides Material Selection: Determines optimal materials for crashworthiness.
- Drives Design Innovation: Improves vehicle safety standards and regulatory compliance.



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Impact test also has multiple applications to showcase a few of those, I have just picked applications in automobile industry. So, it ensures safety, it evaluates how vehicle component would start crash scenarios. When the crash is there, there are certain points when the locking is there, these points are there.

In the scenario of the crash, what impact energy is required at safety belt points, at side impact. These are the points or the areas in a vehicle, in a car where impact could be bound. That is front crumble zone, the ABS system, the side impact bar, the safety belts, rear crumble zone, passenger safety cell, safety glass, airbags, all of them bear impact in the case of accidents, in the case of sudden breakings or so.

So, guides material selection determines optimal materials for crash-worthiness, drives design innovation that it helps to improve the vehicle safety and standards and regulatory compliances. So, this was impact testing.

I will also discuss hardness test and some other test in the coming lectures. We will continue the material testing series.

Thank you.