Mechanical Behavior of Materials -I
Prof. Sudhanshu Shekhar Singh
Department of Materials Science and Engineering
Indian Institute of Technology, Kanpur

Lecture - 44
Impact Testing

(Refer Slide Time: 00:13)

Welcome back class to our course mechanical behaviour of materials. So, today we are going to talk about impact testing. So, the first question which comes to mind is you know why we are studying impact testing. So, if you remember when professor Sudhanshu Shekhar was discussing about tensile testing he must have mentioned to you that the strain rate what we use during tensile test is around say in the range of 10 to power -2 to 10 to the power -4 per second.

But there will be many applications where the strain rate will be much higher than what we use in tensile test. And if that happens the behaviour of the materials is also going to significantly change especially say impact testing so impact testing also has a very high strain rate. So, in that scenario the materials behaviour is going to change and that is one of the reasons why we should we need to study impact testing.

So, materials behaviour change during very highest rate and in impact testing we have a very high strain rate you so this is same impact testing one of the examples impact loading. You must have heard the name impact so when you when something is being impacted the strain rate at that time is very high. So, this is the reason we need to study impact testing how material is going to behave during impact testing impact loading as well as what are the different tests which one can perform to measure the materials behaviour.

So, in fact you know when your strain rate is very, very high a material tends to behave a brittle tends to show brittle type of behaviour especially if the temperature is low. So, we are going to also study about DBTT which is ductile to brittle transition temperature. So, during impact loading or when you have high strain rate a material can behave can show the properties like orbital material is going to show. So, a ductile metal tend to show brittle behaviour.

(Refer Slide Time: 04:10)

So, overall if you see when I say that you know a ductile material can tend to become brittle there are three ways but the tile material can become brittle one is highest strain rate, second is low temperature third is triaxial stress so you have presence of notch etcetera. So, this will increase brittleness. So, if you have a high strain rate if you are testing at higher strain rate and the test is being conducted at say low temperature.

And the material the sample specimen contains some notch etcetera which can generate triaxiality. So, if these three combinations are there material tends towards brittleness and you will see eventually that when you do the impact testing you are going to have all these three criteria in the impact testing itself. So, for now remember that when we do impact testing, we are going to measure something called notch toughness or impact toughness.

You already know about the toughness. So, the energy what we measure in the impact testing we call it as notch toughness or impact toughness. So, one more thing you have to note that impact testing is more of a qualitative nature means you know it can be used as a comparison method it is not an absolute value it is not a material property. It can be used for as a comparative study or a comparison between different materials.

(Refer Slide Time: 06:45)

So, now let us understand how do you do impact testing so what equipment you use. So, here I am showing you the equipment what we have in our lab. So, you have scale here you can see this is your pendulum or hammer you can see somewhere here which you cannot see you have an anvil where you are going to place the sample. And I am going to show you how you place the sample. I am also going to show you the sample dimension which is standard.

And there are two different types of metrics we use in impact testing those will be discussed today. So, your hammer will be placed here on the top and then it will be released. It will come down and in the anvil on the envelope the sample your pendulum is going to hit the sample it is going to break it. And then you are going to see some value in the field and that value you have to know that will be called as impact energy or impact toughness or notch toughness.

So, this is very simple equipment which we use for impact testing. So, basically remember you are going to have a pendulum then scale then anvil where you are going to place the sample. So, you can do at room temperature or high temperature or low temperature because we are going to talk about DBTT so low temperature.

(Refer Slide Time: 08:20)

So, here I have shown another schematic. So, you have a pendulum here hammer and you have a sample just for your understanding which is placed on the anvil you are releasing the hammer it scratches the sample and then you are going to achieve a different height of h dash. So, initially the sample or hammer height was, h after it has fetched the sample the height is h dash. You can note that h dash is less than h that means some of the energy has been lost.

One of the ways to lose the energy is your friction air friction. But some of them will be also lost by imparting energy to the sample which will lead to the fracture is not it and that is what we measure. So, we can write the energy conjunction absorption computed from the difference between h and h dash. So, that will be impact toughness. It will be given as mg h - h dash and typically unit is in joule.

So, the initial energy is mgh final energy is mgh dash you have to take the difference between the two and that will be given as impact toughness. So, some of the; energy has been given to the sample for deformation and if it is completely brittle for fracture. So, this is how we perform the impact testing.

(Refer Slide Time: 10:39)

Now what are the different is so this is the general concept of performing in impact test. So, we have two different methods, one is Charpy and another one is Izod. So, the basic difference between Charpy and Izod will be the placement of the sample on the envelope and you will see that. So, before that both are standard test so you are going to have standard sample dimension then in the sample you are going to have notch and this is the reason I mentioned.

When you do impact testing, I eventually are going to observe the three criteria I mentioned notch low temperature and highest strenuous highest strain rate is inbuilt. It is inherent to the impact testing that is always there. Notch is inbuilt in the sample as part of standard and you will see in some time from now that we are going to do test at different temperatures so at some point of time, we will be testing the sample at low temperature also.

So, all the three criteria are going to met during impact testing. So, this notch is actually going to provide you stress concentration. And in general, in India, we prefer Charpy test. So, that is the mostly widely used impact testing out of these two in India. So, in India Charpy test is widely used. So, let us see the sample dimension now.

(Refer Slide Time: 13:08)

So, this is the sample how it is it looks like. So, it is a square shape sample. You can see the procession is square shaped and this dimension is 10 millimetre. This dimension is also 10 millimetre and distance from the notch is 8 millimetre and this is the notch here. So, in this region in front of the notch you are going to have stress concentration and this is the standard sample and standard dimension for the notch we have 45 degree V notch.

So, it is a V shape and the angle is 45 degree and since this is 8 millimetre and the overall dimension is 10. So, the notch length is 2 millimetre.

(Refer Slide Time: 14:36)

Now Izod and Charpy I just mentioned that depending upon the placement of the sample on the anvil we will name them either Charpy or Izod. So, this is how we place the sample in Charpy test. So, you have anvils here so, this is your anvil, this is your sample and your hammer it is going to turn from this side so this is your hammer. So, you are going to release the pendulum from this side and it is going to hit the surface which is opposite to the notch.

And your notch will be placed like this on the side of the anvil. So, you are going to see fracture occurring in this particular region here, so, this is how sample is placed on in the Charpy test.

(Refer Slide Time: 15:57)

Now this is the placement for Izod test. So, you have anvil here as usual. This is your sample notch you can also see now your hammer you are going to hit the sample at this particular point like this so this is your hammer. So, if your sample is like this you are going to hit on the top here hammer will go like this. So, now hammer is going to hit on the same side as of the notch and if you compare with the charge test here hammer is going to hit on the opposite side of the notch.

So, this is the placement of the sample on the anvil. Both are different in the different test Izod and Charpy test.

(Refer Slide Time: 17:08)

So, now when we do this test, we can do a different temperature, is not it? So, room temperature we can always do so whatever I just showed you till now we are assuming that we are doing at room temperature. So, you can do the test at different temperature and then you can measure the corresponding energy in the scale in the equipment. So, with respect to temperature you are going to obtain different notch toughness or say impact energy or impact toughness.

So, what you can do you can plot impact energy on the y-axis and temperature on the x-axis. And with different temperature you are going to obtain different impact energy. So, you are going to get a curve which will look something like this. So, as you decrease the temperature your impact energy will be decreasing that means it is going towards more brittleness, is not it? So, first thing what you observe here is decreasing the temperature.

So, decrease the temperature it is going to decrease impact energy. So, lower the temperature your impact energy is going to be low that means it is going towards more brittleness. So, here at very high temperature you are going to have the tile behaviour somewhere here you are going to have misbehaviour and at a particular temperature you are going to see a transition from ductile behaviour to brittle behaviour and that particular temperature is called DBTT.

So, below certain T, the mode of failure or fracture is brittle. Some temperature here where the mode of fracture is going to be brittle and we are going to call as DBTT one of the criteria you are going to see that DBTT definition is going to have different criteria will be used to define DBTT. So, one of the criteria is this and so what we do we can see now the fracture surface so you have fractured the surface.

Now look at both the fracture surfaces. We have two surfaces two parts of your samples. So, you look at the fracture surface and by looking at the fracture surface also one can determine whether it has a brittle behaviour, a brittle fracture or ductile fracture or combination of brittle and ductile fracture.

(Refer Slide Time: 20:59)

So, if your fracture surface is granular, it shows shiny texture and cleavage these characteristics are for brittle behaviour. And if it is of say shear character fibrous and the texture is dull then this will be your characteristics for the ductile behaviour. So, by looking at the fracture surface if it is very shiny one can say that oh it is brittle. And if it is dull then it is ductile and if it is a combination of both then yes, it is having both mixed type of failure.

It has some amount of brittle failure some amount of ductile failure. So, this is how we classify by looking at the fracture surface.

(Refer Slide Time: 22:22)

And I have here one example this was done in our lab and here your temperature is increasing or say decreasing in this direction. So, this is at low T so if I marks it T 1 T 2 and T 3 so we have samples and then what we did we did impact testing at three different temperatures. So, we did a T 1 and T 2 and T 3 and then at these three different temperatures we took the photographs using mobile and now we are looking at the surface so here your T 1 is less than T 2 and T 3.

Now if you look here very closely you can say that you know T 3 is looking dull and T 1 is looking shiny. Similarly, T 1 has a cleavage type. The sample is very flat has compared to T 3 so we can say that this type of behaviour is your ductile type and this one is more towards brittleness and in between two you will see that you are going to have combination of both. But even in T 2 you will see that you know it is more towards brittleness compared to ductile behaviour because more shiny surface.

So, the fractions of you know shiny surface and the dull surface will change depending upon the temperature. It is not like 50, 50 might be 90 10 or 10 90 depending upon the temperature. So, you have two criteria to 25 or say measure DBTT one is based on the impact energy and second is based on the fracture surface observation and we will use these two to define what we call as DBTT.

(Refer Slide Time: 24:37)

So, there are different criteria to define DBTT and both are based on either energy versus temperature curve or fracture appearance versus temperature curve. So, now we will learn about criteria for transition temperature. So, here we have two terms which you see here so one is your impact energy versus temperature and another is your appearance fracture surface appearance pressure appearance versus temperature. So, we will use both of them.

So, the red one we have seen before it is fracture toughness impact energy versus temperature. So, x axis is always temperature here so here we have say impact and let me change the colour so that so red one is your impact energy and the black one here is your fracture surface appearance that means in this case percentage cleavage fracture. So, if you look at the fracture surface you should be able to calculate how much percentage of the fracture surface area is of cleavage type that means brittle behaviour sort of.

So, that percentage you have to calculate and plot with respect to temperature and if you do that you are going to get black term and red one is the impact energy we are measuring from the equipment. So, there are two ways to define it, one is based on the impact energy which comes from the equipment and second one is the fracture surface percentage cleavage fracture calculation which you will be doing by looking at the surface or say in low mag low mag microscope.

Now let us define some temperatures here so we have let me use blue colour. I do not see blue here. So, one is your T 1 which will be this particular point. This point here is called T 1 which is a fracture transition plastic or the probability of brittle failure is negligible. So, this is T 1 then we have T 2 which will correspond to a point here I will discuss all these one-by-one T 2 but T 2 corresponds to a temperature where you are going to observe 50% cleavage fraction.

And that corresponds to this particular point here in the x axis. Now we have T 3 which is the temperature average of upper cells and lower cells. So, if you see this is your upper cells and this one is your lower cell. Somewhere here you are going to have average of upper cell and lower cell region so this temperature will be called as T 3. Now there is one more two more one is corresponding to 20 joule impact energy.

This will be called as temperature T 4 which is defined as the ductile transition temperature and the last one is T 5 which is called as nail ductility temperature where the fracture will be predominantly or same 100 cleavage which will correspond to this particular point T 5. So, you see T 1, T 5 and T 2 will be calculated from the black curve so, T 1 corresponds to a point where you are not going to observe brittle failure. Our cleavage percentage is almost 0.

T5 is a temperature where cleavage percentage is almost 100% and T 2 is a temperature where you are going to observe 50% cleavage and 50% ductile behaviour. Now T 3 and T 4 will be based on the rate impact energy versus temperature term where T 3 is the average of the upper cell temperature and the lower cell temperature and T 4 is called the ductility transition temperature which is defined as a temperature where energy impact energy is 20 joule a specific value.

So, this is how we define the transition temperature they are different criteria and one of the most famous out of these are is ductile transition temperature DTT and the reason is because it is very simple you have to just plot impact energy versus temperature and wherever you are going to get

20 joule as impact energy that temperature will be called as DBTT or in this case ductile transition temperature. So, let me write down one by one.

So, first one is T 1 which is called FTP or fracture transition plastic and it says that the probability of brittle fracture is negligible and this is your T 1 and you can see it, in this plot here so, we are using black plot and you can see that the percentage leverage fracture is almost 0 and that is what it says the probability of brittle fracture is negligible so that is T 1. Next is T 2 it is the temperature at which you are going to observe 50% cleavage and 50% share.

For the ductile and brittle type behaviour and this temperature is called as FATT which is fracture appearance transition temperature. So, this is your T 2 which corresponds to this particular point where you are going to observe 50% cleavage and 50% share. Now T 3 so T 3 is a temperature which is the average of upper and lower half cell. So, this is your T 3 and, in the plot, this corresponds to this and I mentioned this is your lower half cell and this is your upper half cell here.

(Refer Slide Time: 34:24)

Now next is T 4 and this is the most famous among all these it is called ductile transition temperature. And why it is most famous? Because it is the most simple one temperature DTT so it is most accepted and the value will correspond to 20 joule. So, you have to get the temperature at which your impact energy is 20 and that will be defined as T 4. Now last is T 5 which is this point here and it is called nil ductility temperature.

So, here you are going to observe most no prior plaster deformation. So, fracture with almost no plastic deformation that means it is 100 cleavage that is what we discussed and you can also write probability of the tile fracture is negligible below this. So, we have five different criteria to measure transition temperature and the most famous or most accepted is DTT which corresponds to a temperature at which your energy impact energy is 20 joule.

(Refer Slide Time: 37:13)

Now the last topic in this impact testing is the effect of crystal structure on DBT. So, you know you have say FCC crystal structure or BCC or FCC so how your curve is going to change so that is what we are going to talk about. Now so you have FCC, BCC, HCP so what is going to happen? So, let me first plot it so you can have a situation like this or say this one another one and the one which we have learned something like this.

So, the red one here will correspond to lower strength FCC, HCP metals, green one will correspond to high strength materials. And the blue one which we have studied till now in this particular topic is for low strength steels so BCC and SS is impact energy and here you have temperature so you are going to observe you can observe either of these three plots. So, the red one corresponds to FCC and HCP low strength material.

So, there you are going to see that there is no as such no transition temperature and the decrease in impact energy is not very significant. High strength materials by nature is brittle mostly brittle. You are anyway going to observe low impact energy. You can see the impact energy value is small in this region compared to the FCC material impact energy is going to be high. And here also you are not going to observe the tile transition temperature typically.

But if you have steels type of materials you are going to observe a transition temperature, we have which we have discussed so that is the blue curve here. So, let me write very quickly so lowest strength FCC metals such as aluminium, copper and most HCP metals they are not going to experience. So, do not experience transition temperature so they do not experience transition the ductile to better transition.

Similarly, you know if you talk about high strength materials same thing. So, they will not experience so let me write here itself do not experience transition but their impact energy is an even low. So, this ductile to brittle transition you know this will be typically you are going to observe low strength steels where you are going to have BCC crystal structure. So, this is what I wanted to discuss about impact testing.

And remember that impact testing we are going to observe very high strain rate as compared to what we see in tensile testing. Thank you.