Strength of Materials

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Lecture - 13

Hi, this is Dr. S. P. Harsha from Mechanical and Industrial Engineering Department IIT Roorkee, I am going to deliver my lecture 13 of the topic of this Strength of Materials, which this course is developed under the national program on technological enhanced learning.

As we discussed in the previous lectures, that you see what the stress and strain components are there and how they are behaving you see, if you know like, if they are combinely applicable or even simply we can say that the non-stress components are there or nor the shear stress components are there. And you see when they are applying combinely, then what exactly the impact is there, how we can locate the maximum, minimum stresses with the analytical method and this graphical solutions altogether.

And what are the components if you apply the load, and you see there are two reasons which we discussed for a perfectly like, if you have you know like the elastic reasons and the plastic reasons, how we can clearly shows the reasons and within this reasons even you see there are some of the limits are there. Like in the previous lecture, we discussed about that, if we have a ductile material; then we can clearly you know like show that what exactly the proportional limit is, what the elastic limit is and what the yield limit is there and how we can correlate those things with within the microstructure part of a material.

And if you go to a beyond some points, then you will find that there is a elastic reasons in which there are certain, you know like the reasons are there within that part like there is ultimate tensile strength is there which we shows that. Actually, this is the maximum strength which with which a material can provide against the load application. And then you see before fracture and then there was a fracture part is there and how we can you know like relate all these points with the property of a material that is E in that is very, very important point.

And that is what you see we say we told that actually whatever the curve which came you see right from point you see you know like point O to A, A to B, B to C, C to D and D to E all those points which we have shown you know like the previous diagram. It was clearly you know like visible visualization is there easy and it is the very much applicable for only ductile material and that material which we have used for that was the mild steel.

So, it can be applicable to those kind of material, which is having less carbon percentage or we can say, which is the pure steel like mild steel or high carbon steel, high stainless steel or we can say you know like the material in which though it has some additives are there, but they are always showing the less carbon. But, if you also in that actually the low carbon steel means you see, if it has a more carbon percentage or if it is you see you know like the cast iron is there or we can say even the concrete is there.

We cannot visualize those points like O to A, A to B, B to C, C to D, because these are not whatever the layers or the microstructures are there in that as I told you, see there were three main categories are there within that; like what is the BCC the body centered or we have SCP or you know like FCC is there, the face centered is there. So, if this kind of microstructures are there within those steel components, then it is not you know like a pretty easy for the other component. If we have a SCP part is there which is has you know like the hexagonal close packing kind of those things are there like we have the diamond and other things.

Though you see they can show some sort of the ductility is there, but we cannot it is not easy to diagnose those things, when it is under the application of load is. So, after applying those things, we found that there ever you see, if you want to you know like visualize those limits, then always there is a ductile material is there and if you want to measure the ductility, then the elongation is there.

So, how much percentage elongation is there, under the application of the tensile loadings, always gives you the ductility, that if and that is what you see we defined the limit for that, that is the 10 percentage to 40 percentages is there. So, we can go you know like up to you know like 25 percent, 30 percent even up to 40 percent, certain material they are exhibiting this kind of thing, we can say that these materials are the perfect ductile material altogether.

And then, you see or you know like we just wanted to categorize, those two you know like different materials in the previous lectures, that if we have a ductile material or if we have a brittle material. Then, how we can characterize those things you see and that is what you see, you know like we have shown that, if this ductile material is there, then how the stress strain curve will come. And if we have a brittle material, then how this stress strain curves will come together.

So, you see in the ductile material we found that all those elastic and plastic reasons, you know like this observed clearly and we can define all those reasons straightway even by in that method or the offsetting method. But, if a brittle material is there, then it was it was not easy to locate those point like the elastic reasons and you see even the yield point or the fracture point and we found that.

Actually that non-linear relationship, that means, the elastic reasons was so small, that once you approach to the yield point and then immediately the fracture is there. So, even usually at it was a very small gap between the ultimate the tensile strength and the rupture point, as far as the cast iron or a brittle material is concerned, under the application of this tensile loading.

So, meaning was pretty simple that whatever the layers are there within those you see you know like the materials, they are not supporting the tensile test. So, you see if you want to apply those materials like, if you want to apply the cast iron for RCC, then it is not a good option. Because, you see even if any you will, let us say the earthquake will come and these, whatever the cast irons are there, under the RCC, they cannot sustain.

They cannot sustain you see, you know like the load and say that is the either up to a certain limit, they can devote that whole building, you see you know like deform that building or else you see the material this building will fill. So, you see always what application is there accordingly, we need to go for the specific kind of material and broadly speaking, you see it is there are two main categories are there.

So, even you see wherever we found that actually the tensile loading can come on the object, always we preferred to go for mild steel either or high speed steel or high carbon steel. And that is what you see you know all our utensils which are which we are using in our home, always because you see when you put on any heater heat application is there and because of the heat application, it is a very good chance of the extension.

So, we cannot say that put the cast iron, put all those things, because there is a good chance of failure. So, that is what you see either we are usually saying that utensils are from the stainless steel, means you see they have you know like the different percentage of the carbon altogether as compared to the brittle material. But, you see if you are talking about any rigid base, about where you see the foundation is there for material, the machine or for you see I need base of the foundation of any this aero plane or the railway bus.

And, whatever like that you see always, we are we cannot put these ductile material, because you see you know like, it is simply extended and if it is extended, then you see you know like all the time, when it is extended under the application of load. Then, it is always tough for us through you know like put all the strengthened part there, so because we are putting the compressive strength towards that.

So, cast iron or any kind of ductile material is always good and that is why you see either for if you go for the rails in the railway or any kind of these things, you found that we have a concrete base kind of that or the wood is there. Because, they are not exhibiting elongation under the application of load, they are always we can absorb the high compressive strength in towards that.

Though you see we are not you know like going in depth of the material science, but this kind of information always is important to analyze the stresses and the strains, if you apply the load. So, in this lecture now you see again we are going to look that actually what exactly the factors which are affecting these properties and then, what the properties are associated with that.

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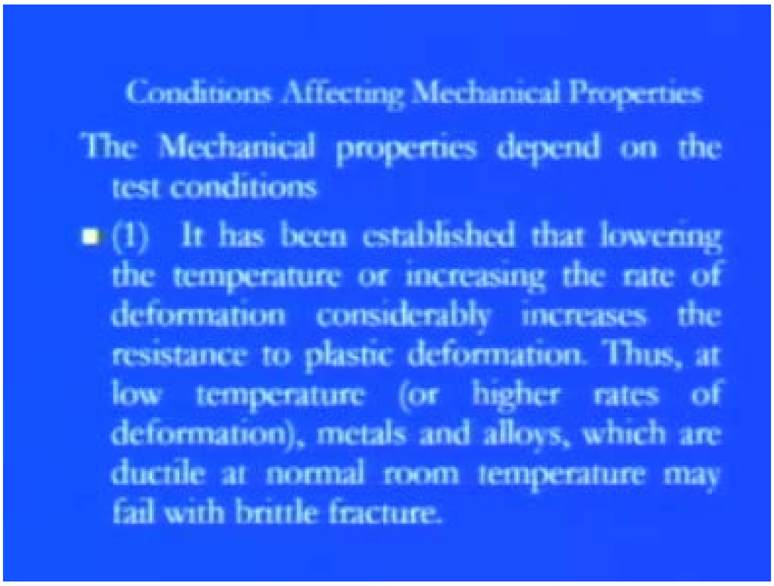

So, now here it is you see first the condition affecting the mechanical property of a material. So, what are those conditions, first the mechanical properties, depend on the test conditions like first is, it has been established, you know like the lowering the temperature or increasing the rate of deformation, considerably increased with the resistance towards the plastic deformation.

Always, you see you see either if you lower the temperature or we even if you apply more and more this rate of deformation. Always, we are going towards the non-linear relationship between the stress and strains and always it gives you a plastic deformation range perfectly.

Thus at low temperature or we can say high rates of deformation the metals and the alloys. Whatever you see, you know like either the ductile or brittle or whatever the alloys, which you are using the composite or the fire woods or the polymers, why I should say which are always ductile at the normal temperature, may fail within the brittle fracture.

Means you see here, first of all, if we are talking about any brittle or ductile material, we have to be very careful that, actually what exactly the melting temperatures are there. Whether you see, you know like, if you are using mild steel and if you are using any you know like some sort of the lower in temperature reasons. Then, you see we cannot exhibit all those ductile properties which we are generally measuring you see here in the previous diagram of a stress-strain curve of mild steel.

So, which is a very essential component here that, whether you see, your rate of deformation is very rapid or your impact loading is there or you see, you know like the kind of deformation is not exactly. Similar, as we have studied you see, because the prime condition which we have applied in the previous figure, that was the static load was there. And under the static load you see by hydraulic or any mechanical part, always we can clearly visualize the point O, A, B, C, D, E all up to the fracture.

So, this was the basic condition, so it is you know like the dominant part is there, that what is the basic condition which can affect the mechanical property of a material and these are the two things, one is the lowering the temperature, that what exactly the temperature reasons are there. Because, once you go below the melting temperature or some less temperature, the low lowering temperatures are there, then the microstructures are not perfectly well stabilized in the material and it cannot exhibit all the property which we are looking for.

And the second was the increasing rate of deformation, because you see it will considerably increase the resistance to the plastic reasons and you see all because the plastic reasons is that permanent set of deformation is there and it is always you see some sort of you know like the distortion. So, permanent distortions are there more and more stress concentrations are there, so you see it is highly you know like we can say that the non-linear part of the analysis is there which is not easily predictable.

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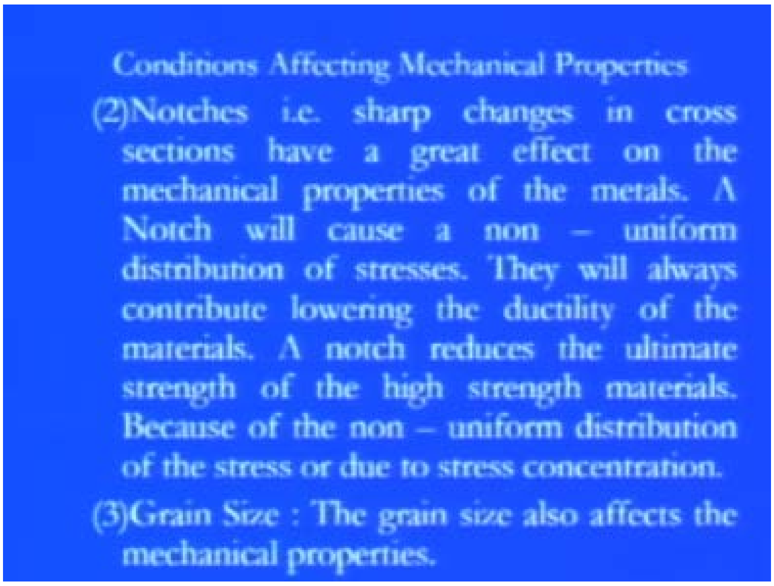

Second, you see notches up to the fracture part, whatever the sharp changes are there in the cross section have a great effect on the mechanical property of a material. Because, you see the notch whatever the notch is there will always cause a non-uniform distribution of the stresses. Because, whenever the notches are there always as I told you that the stress concentrations are there, the stress concentration means the more and more resistive forces are there within an effective area.

So, means you see you know like, when the stress distribution is non-uniform, how we can say that, this is you know like the elastic reasons, this is the plastic reasons. Because, already there is a stress concentration is there within the object that means, there is no you know uniform distribution is there. The stress and they will always contribute the lowering the ductility of a material.

Because, you see if you release the load, you see whatever the percentage elongation is there or if you release the load your body is not coming exactly as it comes in the normal way. Then, we cannot say that this is the perfect ductile material or whatever the percentage elongations are there, they are heavily uniform all across the body. A notch reduces the ultimate tensile strength also you see, because if the notch is there.

Always, if any tearing is there in a material and if you apply the load, we know that the failure will be there right from this notch only. So, always it is lowering the tensile strength also of the material; that means the maximum strength against the load of the high strength material, because of the non-uniform distribution or the stress or due to the stress concentration.

Always, whenever the stress concentrations are there within the material, they will lower the ultimate, you know like the tensile strength of a material or we can say the real strength of material. Then, whatever the load application is there is fairly well chances to fail right from you know like the notch itself. So, this notch is very, very important, so that is what you see, when we are doing you know like the material processing.

Whatever, the heat treatments of the metals are we always see that there should not be any you know like the kind of the crack or the notches should be there within those materials. Because, whenever the load application is there is a good chance and that is what you see all those surface finishing processes are there, the honing, lapping, all those processes are there.

And, just we apply or the micromachining are there, we just apply to remove all those kind of these notches or the cracks from the material to avoid this kind of failure and this is the second condition. The third condition is a internal microstructure part, that is the grain size straightway affect the material property, because if more and more if the if larger grain sizes are there then whatever the cohesions are there in between that they are not perfectly stabilized.

So, that is what you see you know like we are defining, you see either we have a BCC microstructure, SCP microstructure or FCC microstructures are there. Accordingly, if a material having this kind of microstructure, then what exactly kind of applications which we can apply and we can get the kind of deformation or the strain from a material. So, these one you see, you know like some of the three factors which straightway affect the material property irrespective of whether it is a ductile or it is a brittle material. So, if we are talking about the real properties or real characteristic of a material, then we should check all those things prior to apply any load application. Now, come to the real mechanical properties, first of all the hardness.

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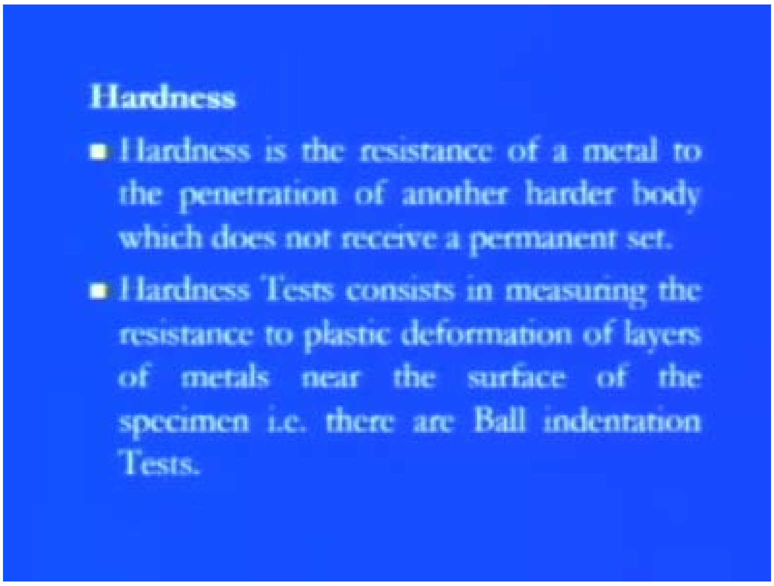

As, I told you see, you know like hardness is nothing but the resistance of a metal to the penetration to the plastic deformation of another harder body. Like you see, you know like we have an object and if you want to check the hardness of a material, what we are doing here we just want to penetrate from harder body of this specimen. So, what we are doing here, you know like, we are simply taking a object, let us say, if we just want to check a mild steel, the specimen and if we have a penetrator, because we need penetrator to penetrate that part.

So, you see we are penetrating the object, until you see, it will not penetrate and whatever you see, once it is penetrating, whatever the reading will come, it will give you the hardness. So, hardness is nothing but the resistance of a material, against the penetration or against the plastic deformation and the penetrator should be harder than this otherwise, you see there should be a penetration, even in the penetrator itself, so we should avoid that situation.

And hardness test, there are you see various hardness tests are there, are various types of the scales are there to measure those things and some of the real scales which we are going to discuss later. So, first of all hardness test consist in measuring the resistance of plastic deformation of the layers of metals, near the surface of a specimen, that is you see there is a Ball indentation test.

Because, you see when you know like, it is always the penetrator is having a circular ball and it is always applying the load compressive load, you see against the permanent set of deformation. So, whatever the resistance will come from the body, it will give you the hardness of a body, so as I told you see in that you always we have a ball penetrator or ball indentation test is there.

This method is consisting you know in a pressing of hardness steel ball, under a constant load P, because again you see in that which is very, very essential condition as we applied in the previous case. Also, that here there should not be you know like the load impact loading is there or jerks are coming, it should be a hydraulic or mechanical, you know like the loading is there and these loading is consistently or continuously increasing. It is not you see you know like immediately, you see apply 10 Newton load and then again the 20 Newton load will come or 30 Newton load will come suddenly like that.

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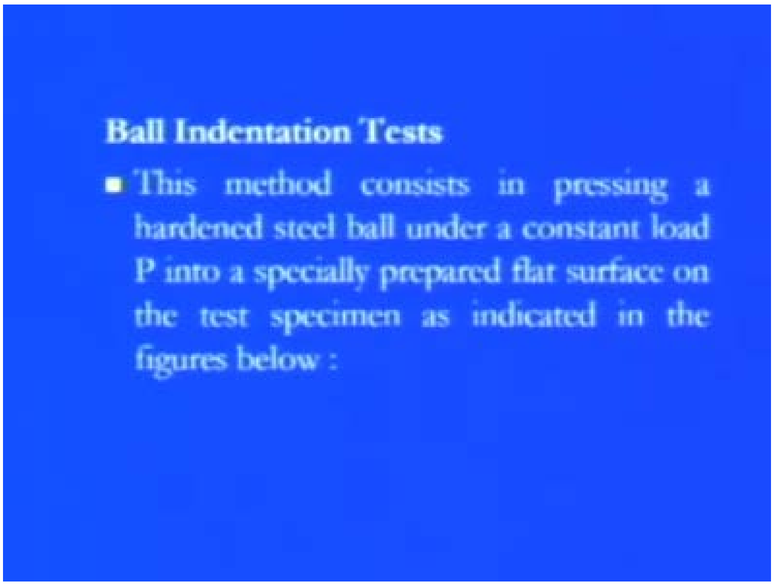

So, here you see one has to be very careful, where the load application is there, the constant load is there and it is just you see you know like more and more and more impressions are there into a specifically you know like, especially prepared flat surfaces on the test specimen.

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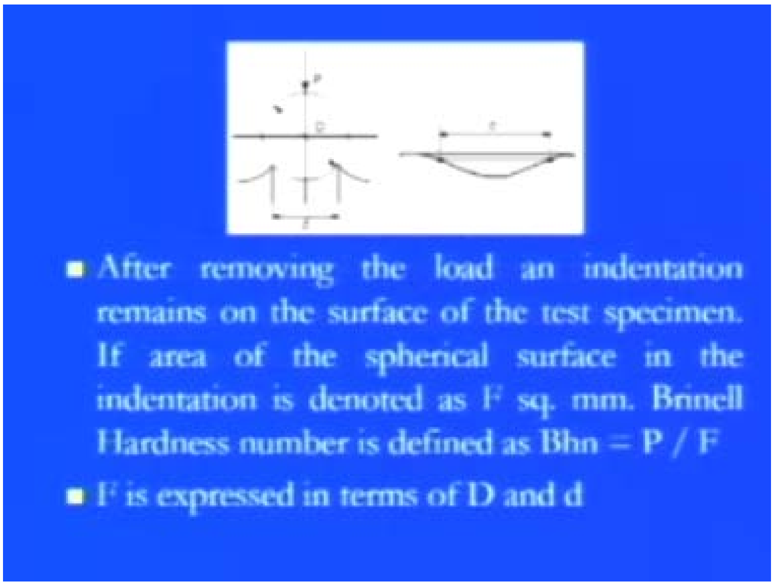

And you know like we can clearly see that, you see here that is the ball indentation is there and we have a material like that. But, after the penetration you see this kind of penetration can come, so whatever the material is coming, which is you see whatever the shape is coming and what are the readings are there, this reading will give you that actually how harder this material is.

So, after removing the load, because you see here, we are applying the load up to the plastic deformation or up to you know like, the indentation, the permanent indentation is there. So, once you remove the load, definitely there is a shape is there of the ball kind, so here after the removing the load and indentation remains on the surface of the test specimen.

And, if the area of the spherical surface, whatever you see this, because now we know the diameter or whatever you see this nature, that actually how much the load application is there and how these shape are taking place like that. And if we know the any of the spherical surface on the indentation, whatever it is, if we can say that is F square millimeter, we can easily calculate the hardness and this method is known as the Brinell hardness method.

So, you see there are Brinell this hardness testing machines are there, which are you know like even available in the many of the labs also. So, pretty easy you see put the indenter ball indenter on you know like this the movable jaw and there is a fixed jaw just keep the specimen then itself a flat surface is there. Put the load, through hydraulic one or the mechanical one, apply the load and go up to the permanent penetration.

Once, you get that now the this scale is just stops there, you would be having a you know like the reading and that reading is coming from the resistance, will give you the hardness of that and that hardness is known as the Brinell hardness. Brinell hardness and it is always showing by number, so you see Brinell hardness number is simply defined, BHN we can say that is P by F P is nothing but the load applied and F is the effective area square millimeter.

So, here you see you know like F can be expressed also, you see because if we have you see the ball diameter D and you see the penetrator area of the whatever the penetration is there D. We can also express these F in terms of that and we can get the BHN accordingly.

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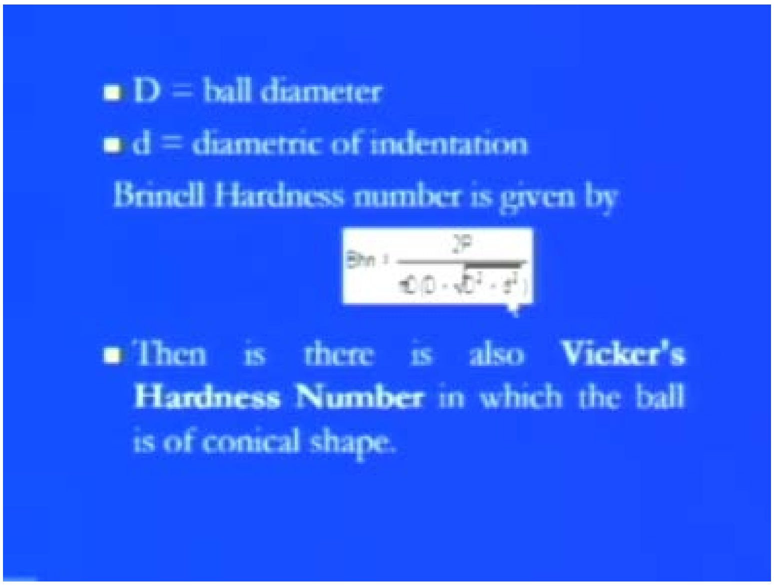

So, if I am saying that the ball diameter was there and the diameter of indentation was there then BHN is nothing but equals to 2 times load application divided by pi D into D minus square root of D square minus d square. That means you see, if you know the ball diameter the penetrator diameter, if you know the what are the impressions are coming you can easily get that what exactly the Brinell Hardness number is. And whatever the number is coming, this will give you a hardness of the material.

So, this is one property hardness is always as I told you hardness is always coming under the plastic reasons. And then, you see there is also the different machine is there that is known as the Vickers's hardness machine in which you see you know like, we have a ball is of a conical shape not of the round shape, we have a conical shape like that and then we can apply accordingly.

So, here you see we can say that there are another variety of the hardness testing machines are, the penetrate shape is different. Because of you see, if let us say, if you want to test a real harder, you know like the material, then the penetrator should be harder. So, generally you see in the in the Vicker's or in other testing machine, you see we are always preferring, you know like we always prefer to use the diamond point in that.

So, that you see whatever the diamond is the hardest material amongst all the material which are available in the on the earth. So, what we are doing here, if you are taking the diamond point, then it can be penetrator of any harder material like you see, if a tool steel is there or if a cutting tool is whatever the cutting tool, that steels are there which they are more harder. Then, always we prefer to use the diamond to get the hardness of this kind of material.

Now, you see we have the different strength, which is known as the impact strength. Because, previously you see prior to that, what we were discussing about the static loading, static load conditions are there, there should not be any impact or the jerk should come. So, that you see the stresses, whatever stress formations are there, they are altogether different from the static one.

So, now you see the static tension test of the notched specimens, do not always reveal the real, you know like this susceptibility of a material to brittle nature. And this important factor is always determine the impact test, because you see we just want to see that actually, when you know like the impact test is there, we use the notched specimen. And this specimen is placed on its supporter, you see the notched specimens are there and we simply put on the supporter to grip like that on the anvil.

So, that whatever you know like the striker is there it can easily strike on that without any abstractions. So, that the blow of the striker is opposite to the notch and you see whatever the impact is coming, it will come exactly and it will simply gives you that actually how much energy or we can say the resistance energies are there for that.

So, for that always you see we need to keep, you know like the specimen in such a way that, there should not be you know like a strike is there and it is generally Izod charpy test is there. Generally, you can find in our laboratory is that actually, you know always we are keeping the striker on the top of that. And in this anvil, you see we are keeping you know like in the two grips of that, whatever the material is there and we are simply releasing that this striker and you see it will go up to a certain height.

So, that whatever the potential end is there, it is converting into the kinetic energy and with full energy, it strikes on that and you see it will go up to a certain height. So, we simply measure the height, that actually after fracture how much height it will go and we will compute the energy accordingly. And this energy will give you the impact energy or we can say it is known as the one of the special property of a material and that this property is known as the toughness of that.

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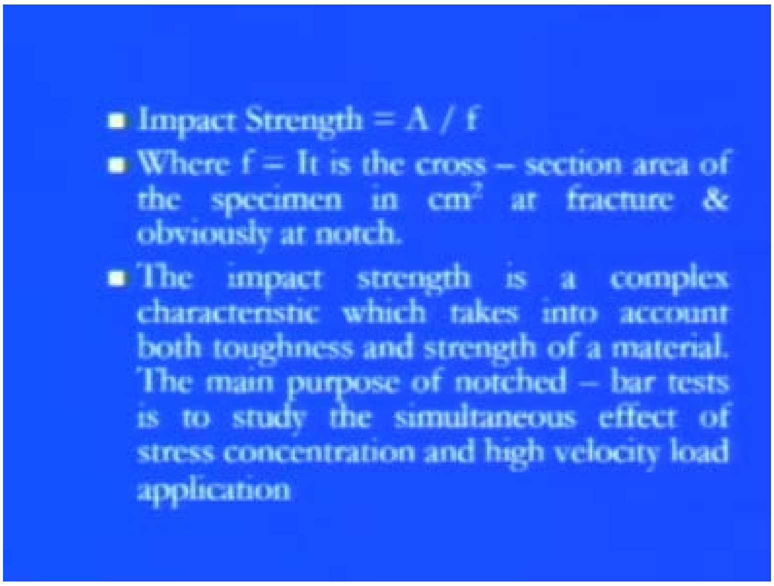

So, impact strength is nothing but equals to A by f, where this f is nothing but the cross sectional area is there of that specimen, which is going up at the fracture level and you see, because it is you know like; obviously, there at the notch only. So, how much you see you know like the fracture this area will come we can simply compute that.

The impact strength is the complex characteristics what are the complex characteristic is there, because if it is not exactly with the layers or the microstructure of those things. It is simple you know like the structure is coming and impacting those things and we are simply measuring the height with the area and we are calculating this A by A, A by f particular. So, it is a complex characteristic which takes into account both toughness as well as the strength of material, but generally it gives you toughness.

So, that is the clear difference, if you want to measure the hardness always we are going for the static loading up to penetration and this is the toughness, you see in which we are simply giving the impacting up to the fracture. So, the main purpose of the notched bar test is to just to study the simultaneous effect of the stress concentration and the high velocity load application.

Because, you see if we have you know like the dynamic characteristic of a load and you see, it is simply the some sort of you know like the fatigue or some sort of the impacting is coming. Then, what will happen up to the fracture, if we have a well this material is there with the stress concentration. So, this study is very, very useful to give this kind of information about the toughness as well as the strength of a material of this kind, impact strength of these things. So, now you see you know like this kind of information which we have discussed about the toughness and the hardness of material then we have the compression test.

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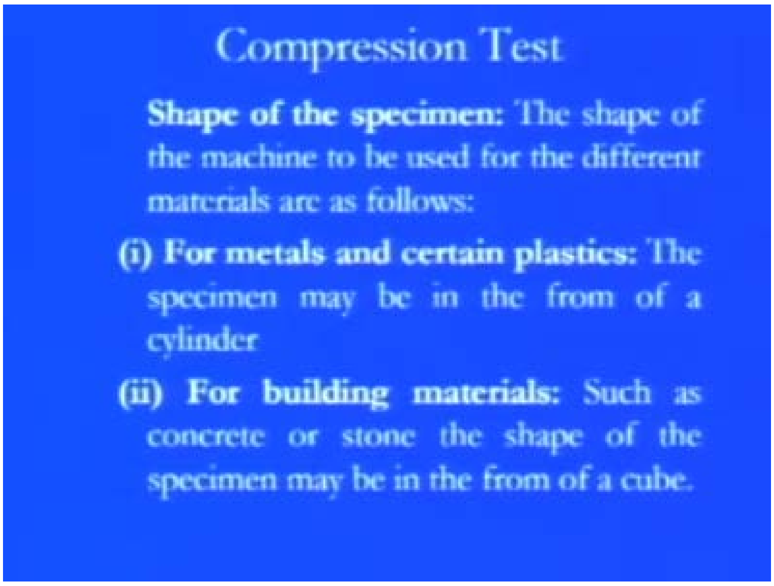

If you see, you know like under this first of all the important thing is the shape of the specimen as we discussed in the previous tensile test. Also here, we would like to go for, what kind of the shape of the machine to be used for the different materials as those things. So, first of all we have for metals and the certain plastics, if you are using a perfect metal or the plastics, then the specimen may be in the form of cylinder.

Because, you see if you are using the cylinder then it is pretty for us to keep those thing in a proper way to apply this compression part. And if you are using a building material like concrete and other parts actually or stones particular, then the shape of specimen may be in form of cube. So, that you see we generally you will find that the concrete materials or the stone materials are always in this cubic shape.

If, you want to keep in a material, so that whatever the load application are there in a realistic way, it is pretty easy for us to apply those compressions on these cube shape of any stone or the concrete. So, you see here, if you are using metal or plastic kind of that then you need to go for you know like the cylindrical part. So, that it can be easily compressed and if we are using you know like the building material and then you need to go for the cube, so that it can be easily compressed accordingly.

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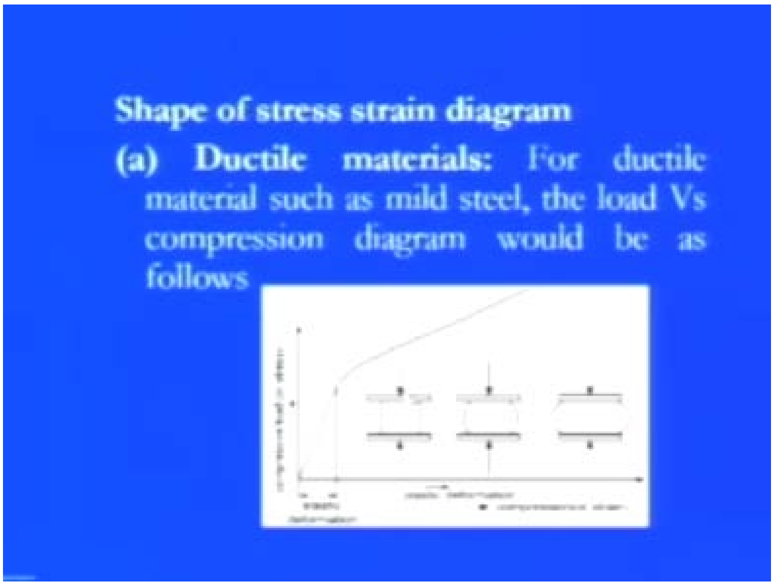

So, now come to the realistic way you see here as we discussed shape of the stress strain diagram, you know like for a ductile material. If you are using such as mild steel, then load versus, you know like this load versus strain or the load versus deformation diagram will give as like you see here. See here like that, one on x axis, we have the plastic deformation, that is the strain part is there on the y axis, we have you know this compressive load or the compressive stresses are there. And if we see the first diagram then we have you know like a uniform structure of any brick or cylindrical part is there.

And on top of that, you see we can simply apply the compressive load, so prior to that you see you know the first thing will come as this linear relationship between the stress strain or the load verses deformation. We can say this is the elastic reasons and can be clearly defined this thing, but once you go in the plastic reasons means there is a non-linear part is there, whatever the slag's are there of these things, the outer surfaces are there. They are simply you know blowing out towards that outer reasons and we can get a deformed shape like that.

So, this deform shape will clearly gives you the plastic reasons, you know like that here we have the elastic reasons is the straight part and the non-linear part is there this one. So, as you move further you will go up to the plastic reasons in that, which is quite different than, you know like the this the tensile test, but since it is a ductile material and the layers are well set up within those things.

So, it is blowing out towards the outward directions, but it clearly gives you that you know like this plastic reasons is there, but it is a kind of a non-linear relationships are there in between that.

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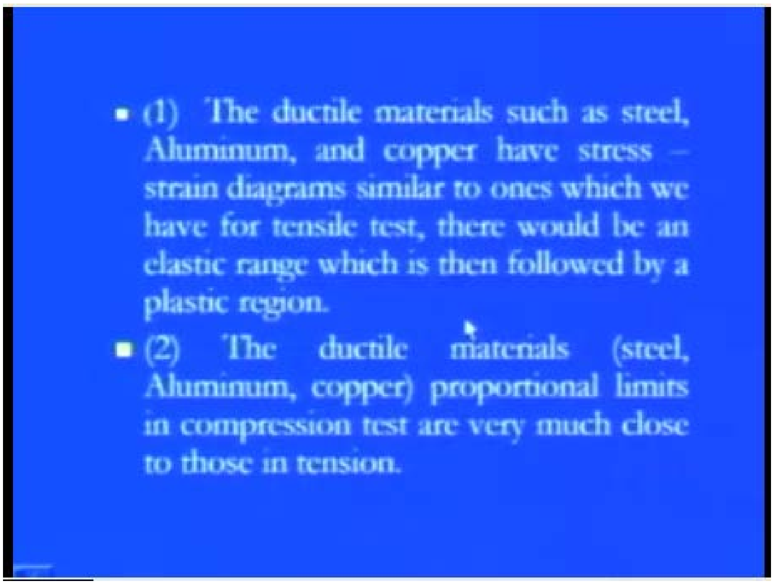

So, the ductile material which you know like these are steel copper aluminum, which has stress strain diagram similar to ones which we have you know like in the tensile test. But, there would be an elastic range, you know like within that, it is simply following by the plastic reasons not by exactly the non-linear as we have seen the ductile one. But, it has you know like the similar kind of trained, the ductile material all those you see they have the proportional limit and compression test. Where, very similar to you know like those in tensile test, because whatever the micro structures and the layers are exactly forming.

So, that the within this elastic reasons, those you know like the stress is exactly proportional two this strains. So, even if we if we solve any kind of engineering problem, always we see that irrespective of it say tensile test or it say compressive test, whatever you see the this modulus are there the young's modulus, the shear modulus or the bulk modulus or this Poisson ratio. They are well applicable to the tensile as well as the compression test within the elastic reasons.

So, there would not be any difference in those things, so while solving any numerical problems we have to be or while doing any engineering designs, there is no difference. If, we are you know like doing for compression as well as the tensile test, when the load application is there within the elastic deformation.

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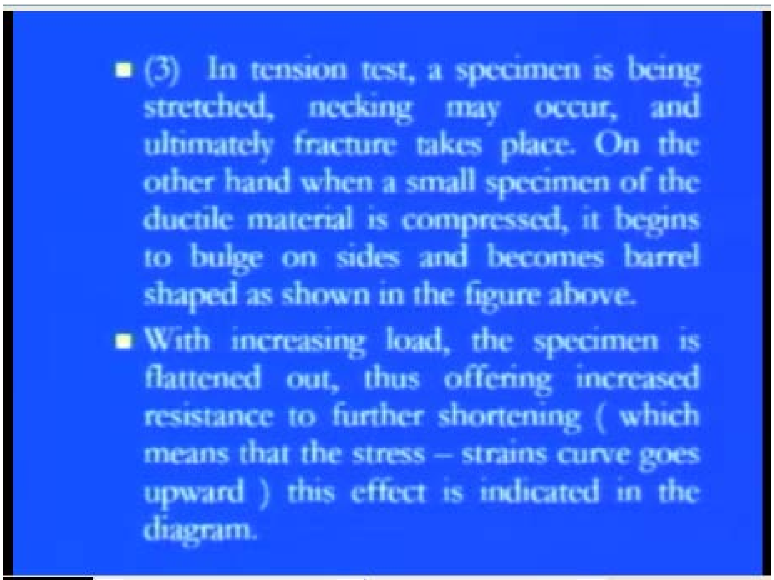

In the tensile test you see a specimen is being stretched and the necking may occur, so whenever you see you know like and a stretched is there and necking occurs, definitely the ultimate fracture will be taking place. Because of the stress concentration on the other hand, when a small specimen of a ductile material like this mild steel or copper or any aluminum is compressed here.

It begins to bulge on sides, you see as I shown in the previous diagram and it becomes a barrel, you know like up to the end part before the failure and with the increasing of this you know like load. Whatever, the specimen which is you see coming as a barrel, you see it is simply flattened down towards the output directions and you see you know like its offering increasing resistance towards the further shortening.

So, as you further shortening towards those things, what a more and more resistances will come out from those things and you see you know like that is why going to this at the loop side as in the ductile this tensile test. It is going towards the sharply increasing part, because of more and more resistances are coming from this, the ductile material against the compression load. So, now if we are talking about the brittle material now, which is you see more of comfortable towards this compression side, they are always you see you know like and the initial linear the linear reasons.

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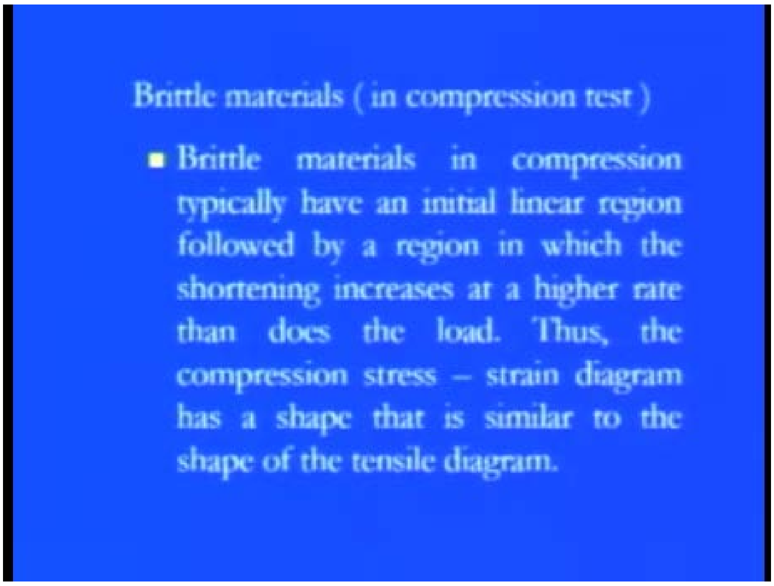

Followed by you know like the non-linear reasons is there, which is you know like having the higher rate of deformation as we have seen in this tensile test of brittle materials. So, if we see the diagram exactly of the same we will find that we have you know like the compression stress strain diagram, the similar kind of shapes as it is there in the tensile test of diagram.

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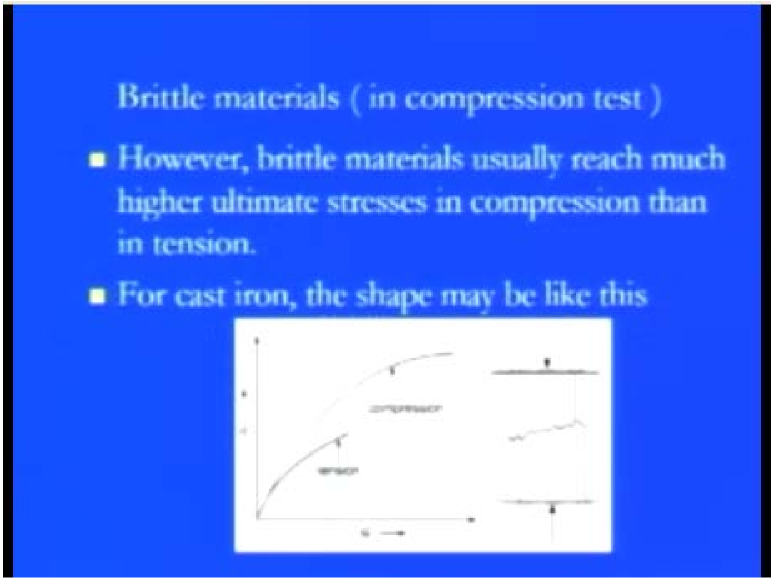

And you can see here the kind of fracture also this irregular shapes are always coming irrespective, whether it is a tensile or the brittle the testing is there at the time of failure. But, if is compare the strength of the you know like this brittle material in a tensile as well as the compression, we would find that there is a kind of three or four times more than you know like the more strength is there in the compression test as compared to the tensile test.

So, always it is preferable to use the brittle material value see the compressive load is there and if it always preferable to use the tensile material, this ductile material when the load application is tensile. So, that is why you see though as I told even in the my previous lectures, also I told you that, actually the foundations and all other you know like this kind of machine foundation or this these or cars or foundations, they usually preferred you know like the cast iron or other.

Or even in the railway tracks, you will find that concrete blocks are there for the compression kind of thing. While you see RCC rods and other kind of you know like the where the tensile loading is there the mild steel is always preferable. So, you know like this kind of diagram will again strengthen this kind of concept, so we have seen in this you know like whenever the ductile material is under tension or compression or brittle material is under tension or compression.

There they are showing you know like the linear ranges for as the ductile, this elastic range is concerned, the linear relationship is there in between the stress and strain. And if we are going for you know like the higher load conditions or we can say the kind of nonlinearity is there in that the relation between the stress strain. Then, we would find that here there are some differences are there as far as the brittle or the ductile material is concerned in tensile as well as the compression test. And, if you go for you know like the brittle material, then again this diagram as we have discussed that, there is a huge difference is there in between the tension and the compression, because they are brittle materials are always good in the compression.

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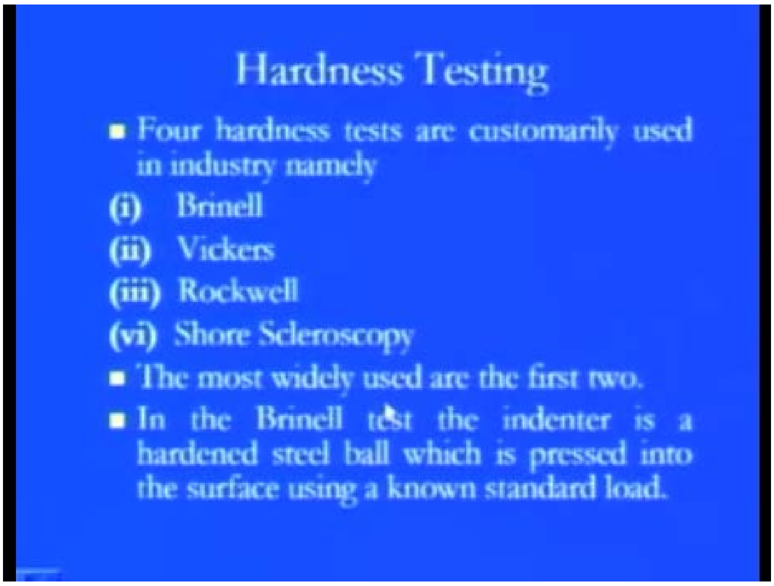

So, now we would come to again back to this hardness testing, where you see there are 4 commonly methods are there, which can be employed in any of the industries like first the Brinell hardness testing machine, Vicker's hardness testing machine, Rockwell hardness testing machine and the Shore Scleroscopy harness testing machine. But, generally we are using as far as the labs are concern or industries concern, the first two, the Brinell as well as the Vicker's hardness testing machine.

In the Brinell, as we have discussed that, indenter is you know like the hardest the steel ball is there and which you know like we just push the impression on the flat surface of the main our specimen. So, you know like there are and we discussed that actually how we can calculate the Brinell hardness test, the number which will give you the hardness of any specific material. It depends on you see you know like the applied load as well as the diameter of the ball indenter as well as this impression. But, there are sudden disadvantage in the Brinell hardness testing machine, hardness testing that one is the main advantage of Brinell hardness test is the Brinell Hardness number is not independent of applied load.

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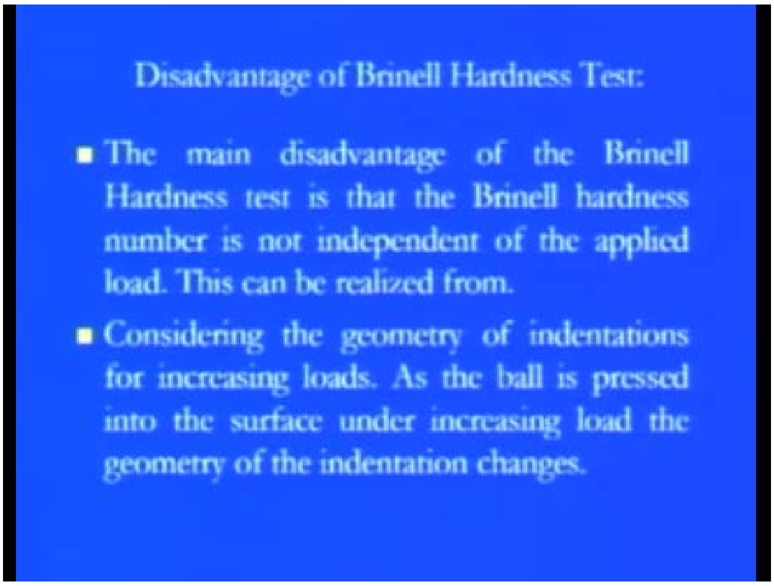

Thus, you see you know like as the load is moving, you know like the hardness is somewhat variation is there, meaning is pretty simple that actually we have to see very careful that actually what exactly the applied load is and what corresponding hardness number is. So, whenever you see there is a slight variation is there, definitely there is a kind of error is there in that kind of hardness number.

Secondly, the considering the geometry of indentation for increasing load, always we found that actually you know like whatever the BHN is coming, it is a somewhere you know like it is depending on the small d. So, again you see you know like, we have to be very careful that actually, whatever the dial gauge is there on the hardness this testing machine, where it goes and stopping those things.

So, always you see actually there are always kinds of some clearance effect is there or somewhat we can say you know like the plus, minus this a flits or whatever you see you know like the scale errors are there, which can be always introduced towards the Brinell hardness testing machine. So, this is a kind of disadvantage we can say, so as a ball is pressed into the surface, under increasing load the geometry of always indentation changes as I told you and kind of always which gives the clearance and always this.

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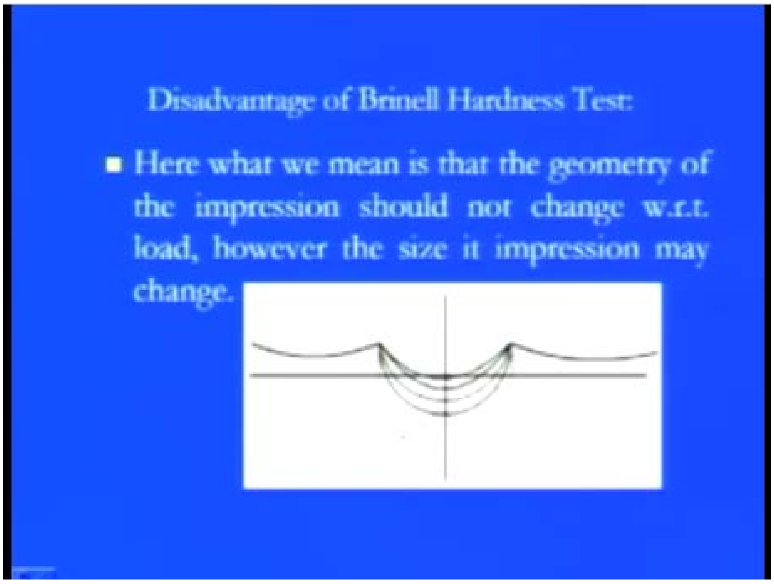

There is a kind of error is there as we have seen you see here in this diagram that, whatever the kind of indentation is there is a different kind of you know like the impression, the circles are coming, so as you see for 1, 2, 3, 4. So, always it gives you a different kind of readings or always you see we have the same material similar kind of loading, but different hardness readings are there, which will give you always different hardness of a specific material.

So, here you see when we mean that the geometry of impression should not change with respect to the load. So, always because it gives you a clear reading about the hardness and if it is changing by any, you know like increasing the load; that means, there is some problem, this is the biggest advantage of the Brinell hardness testing machine. And we should just try to over this kind of situation to get the exact reading or accurate reading of a hardness for any specific material. So, that is what you see sometimes we are going for the next machine that is the Vicker's hardness testing machine. So, Vicker's hardness test follows the procedure, exactly identical with that of the Brinell test.

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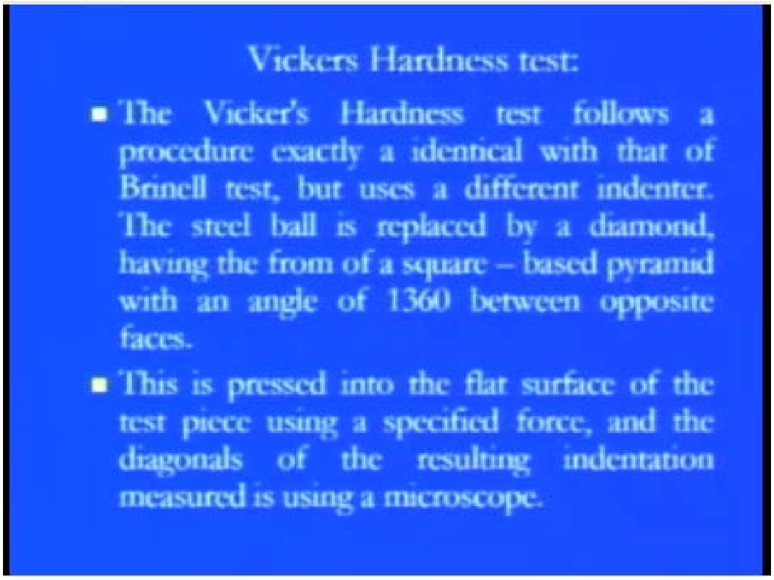

So, means there is no as such the procedure wise all the steps are pretty similar as we have adopted for the Brinell one in which you see first of all we need to see that actually whatever the loads are coming. They are suppose to be static and the flat surface, which is you know like always at the static jaw, it should be in the proper flat. And there should be a proper contact from indenter to this, whatever the specimen is there.

But the you know like, we have a different indenter is there, because you see you know like what kind of material is there according to we have to use the indenter is not does just like you see you know like the spherical ball is there, which we are used in a Brinell testing machine. The steel ball is you know like replaced by a diamond having a form of a square, based you know like just pyramid kind of that, which has you know like always in between there are you know like this kind of angles are there.

And this is you see processed into you know like the flat surface of test piece using a specified force. So, you see always that how what exactly the hardness is there or how harder the material is there. Corresponding, the loads are coming from the indenter and because, it is a diamond point, so even it may if it can you know like rupture the specified material.

So, we have to be very careful that actually, what exactly the material is there and how we can apply the load through the hydraulic this loading conditions. And this diagonals of the resulting always give the indentation of you know like that how much the impressions are. Then using microscope, we can easily find it out that, actually what this diagonals are, there in how much that impression is there and correspondingly you see the Vicker's hardness number is there. So, if we go for the specific geometry, then we would find that actually you know kind of like these, the diagonals are coming on the impressions and we need to measure correspondingly.

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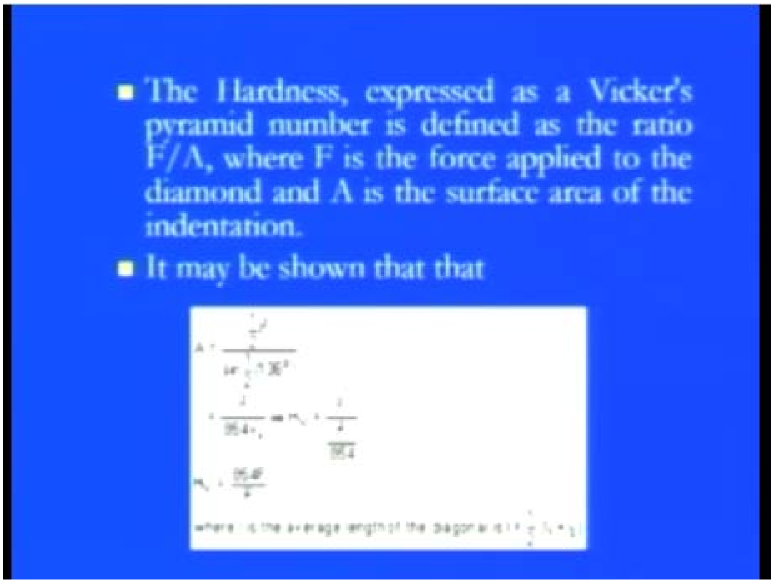

So, hardness expressed as a Vicker's pyramid, because it is a kind of pyramid is there. So, pyramid number is defined by the ratio of F by A where F is nothing but the force applied by the diamond or we can say the indenter and A is the surface area of the indentation. So, you see correspondingly we can easily find it out that, A is nothing but equals to L square by 2 divided by sin of you know like this 136 degree divided by 2.

Because, you see whatever the angle which is coming in between these two lines of a pyramid, it is almost it is nothing but equals to 136 degree. Because, intensely we are keeping this you know like angle in between these two. So, that actually whatever the impressions are coming there should not be any kind of you know like the errors are there in you know like the indentation.

So, if you know like equalize those things and we will find that is nothing but equals to the hardness, you know like of the Vicker's H v, which is equal to F by L square divided by 0.854 or we can say if we are comparing those things, then we would be having 0.854 into F divided by L square. Where, you know like we can find it out, the L which is you see you know like nothing but the average length of diagonal, it is equals to L 1 plus L 2 by 2.

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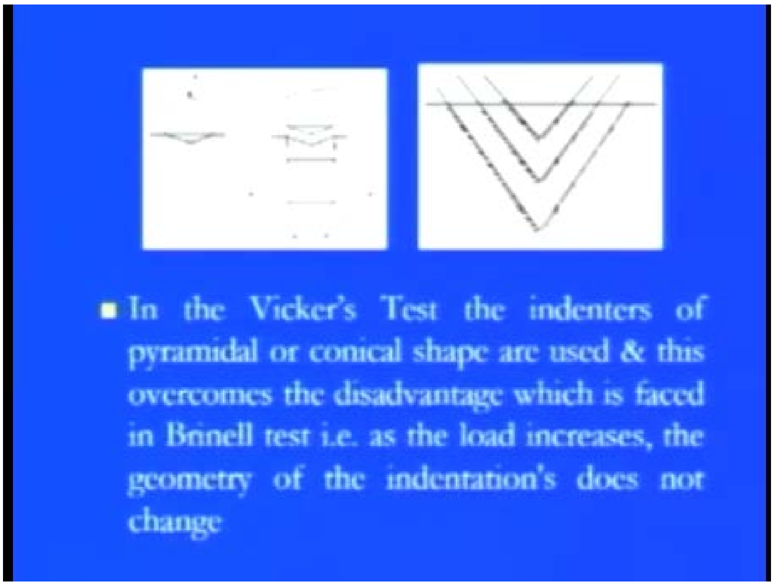

Where, L 1 and L 2 which we can see here you see you know like in the diagram, that we this is the kind of indentation. So, this is L 1 and this is L 2 and you see you know like whatever the average length is coming it is nothing but equals to L 1 plus L 2 by 2. And you see the impressions are coming from these you see you know like the diagonals of a diamond.

So, you these you see here you know like, if we are going to see the surface of this main specimen, then we will find that actually these are the main indenters are coming corresponding to different types of load. So, as you see if you increase, you know like the load condition, and then will find that these kind of indenters, one is this, another one is this, third one is this. So, this kind of shape is coming in between that you see always we just try to maintain the angle of 132 degree.

So, that it will give a perfect reading and whatever the formula in which the previous thing, you see H which is nothing but equals to you know at point eight 5 4 into you know like the force, whatever the applied force is there, divided by the average length. Always, it gives we are clear cut reading about what the Vicker's number is there and once, you have the Vicker number, you can have hardness number of that particular material.

So, in the Vicker's test these you know like the indenters of pyramid, whatever in or we can say the conical shape are used and this overcomes, this advantage which is you know like, which we faced particular in the previous Brinell testing machine. That means, as we will a increase the load the geometry of indenters does not change, that means you see we just tried to maintain, whatever the indentation shapes are coming, just like in this particular figure.

We have seen that actually you know like these the shapes must be in the proper you know like flits are there means, if you increase even the load there should not be any distortion is there, even in the indenter shape, because it is a diamond. So, we can expect this kind of situation here easily, so this is you see the Vicker's test and if we compare with the variation in between the hardness number of you know like as you increase the load.

Away, the Vicker's as well as the Brinell, then we will find that there is a kind of you know like that is the biggest advantage of the Brinell that, as you know like increase the load applied load the kind of hardness is varying.

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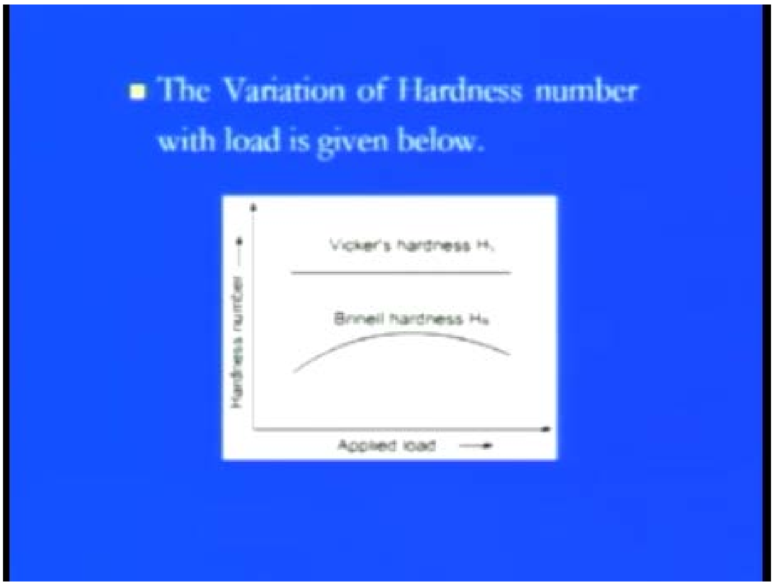

So, if because here we are using you know like the toughest material of we can the hardness material of the material of this the indentation like diamond. So, probably we can expect that actually there should not be any change, so as you increase the load there is no change in the Vicker hardness machine, because of the diamond indenter. But, here since we are using the ball as a indenter part.

So, you see always a kind of non-linear relation is there in between you know like the hardness number and with the increasing of the load. So, that is what you see we can expect this kind of phenomena with the Brinell hardness number.

Now, you see you know like some of the advantage of the Vicker's hardness, though you see, you know like the diamond point is very expensive to use. But, you see as far it applications are concerned, we have to go with the diamond point and we need to use you know like this kind of indenter for any specific purpose.

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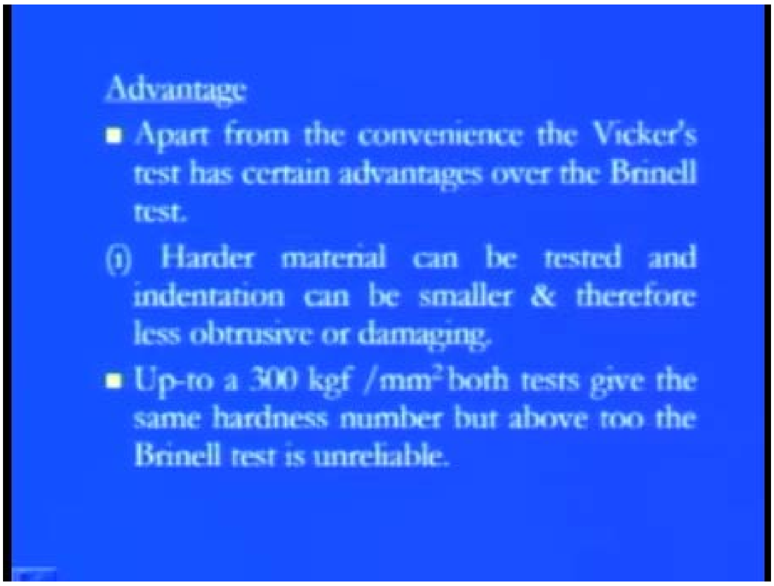

So, certain advantages are there like first of all apart from convenience of the Vicker's test, certain you know like these compressions are there The first is harder material can be tested, because of you see we have the diamond point is there, which is the you know like hardest material amongst all those material are available. So, we since, we are using that one for the indenter.

So, probably we can go for any, you know like harder material to check it out the hardness. So, harder material can be easily tested and indentation can be smaller and therefore, you see the less obtrusiveness or damaging is there. In those material and we can easily, you know like capture, those impressions and we can compute those hardness for a harder material.

And up to you see you know like the 300 kilogram force per mm square, you know like we can easily you know rest, those things on you know like some above the hardness number and some of the loads can be easily apply of this kind of material also. But, you see, you know like about to this one, if we are talking about the Brinell number, then if we are using this kind of material, then it would not be possible for us to go.

Because, whatever the indenter are there, the shape of the indenter is you know like the steel ball. And even if you apply this kind of load then probably, you see the impressions can easily induced in that particular indenter and we would not get a perfect reading of the hardness, so that is why you see this is the biggest advantage in the Vicker's number.

So, you see here you know like for those kind of material in which you know like the the harder materials are there, the Vicker's is the best one. But, the main disadvantage is it, since you see it has a diamond point, so it is bit expensive to use and we have to use very carefully, just to avoid the damage in the diamond point.

The third one is the Rockwell hardness testing machine in the Rockwell hardness test also you see it is a kind of indenters, always because if you want to measure the hardness we always use the indenter. So, indenter we are using the similar kind of thing, when it is pressed into you know like the surface of the test piece. But, it is always differ from the Brinell and harden test in the measurement of hardness is based on the depth of penetration not on the surface area of indent is.

This is actually, how much depth is there, so according to the depth, you see straight way, we can you know like go and measure that with the using of the formula. Now, this is the hardness, this much depth is there, then this is the hardness, if the variation is there in depth, then this much hardness is there.

So, you see here, you know like, we are always trying to put the conical diamond here, as a indenter which is you know like rounded as a apex part is there. And it is bound to be you know like contact with the test piece and you see we are applying the force up.

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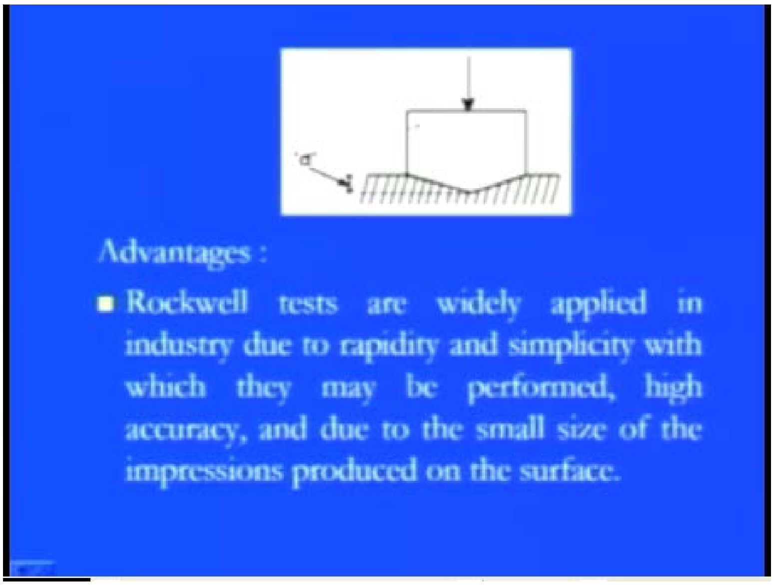

So, that corresponding you know like the impressions are coming in the specimens, so you see here, this is a kind of specimens are there and this is you see, you know like the test part is there. So, as you apply the load since, it is you see you know like the conical shape is there, so we are getting you see here, so you can see this conical shape is there. So, whatever the impressions are coming we can get those diameter and we can you see calculate corresponding hardness is there.

So, some of the advantages are like that Rockwell test are widely applied in the industry due to first of all the rapid and simplicity with the that actually they are simply performing high accuracy is there. Because, you see you know like what we are doing here we are simply going with the depth instead of the surface area. So, once you have the depth you see you can easily go and measure, now this must depth is there, this must depth is there and corresponding hardness is coming.

So, instead of you know like calculating those areas or truncation errors which we have done in previous cases or you see you know like the diamond, which we are using which is expensive part and it is a definitely you see it is pretty risky to keep all this things. So, it is a very simplest thing, that is why you see it is uniformly excepted that part, so and that to simplicity, also there just to measure the depth only. And it has a high accuracy and due to the small size of impressions produced on the surface again it is acceptable inversely, so that is what you see this is the biggest advantage of the Rockwell test. Now, if we are going for you know like, if you leave this hardness, then toughness is coming and toughness, we have discussed that actually if the impact loading is there like that.

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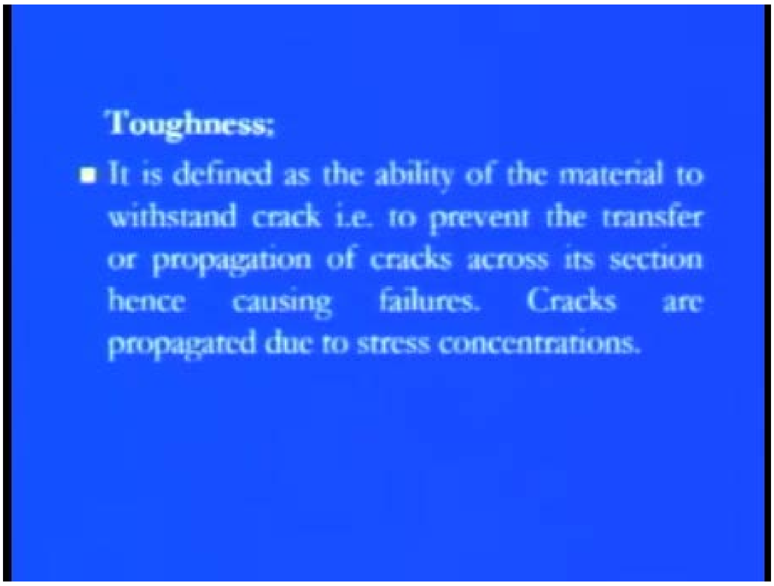

Then, whatever you know like the material is coming from this neck or we can say, whatever the cracks are there, from the stress concentration, the energy is gives you the toughness. So, it is defined as the ability of material to with stand the crack that means, you see to prevent, the transfer or propagation of cracks all across you know like in the this cross section of the bar, hence you see you know like it will cause of failure.

Because, you see it impact is coming and wherever the cracks are there, it is simply because it is a weakest section of the uniform bar. So, you see it will apply the impact and it goes up to a certain height and we can simply measure that, how much energy which it can absorb or we can say that actually, whatever the ability of the material to withstand the crack in the impact loading.

So, sometimes you see cracks are also propagated the due to the stress concentration and that is why we are generally you know like visualizing that, actually wherever the cracks or the spells are there on the surface, always we assume that actually they have the high stress concentration. And this is one more you see you know like the property of the material is there that is a creep.

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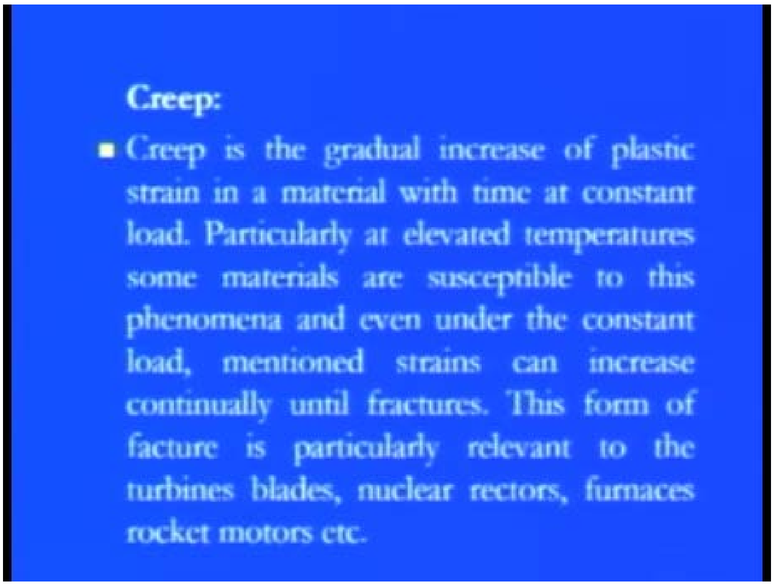

Creep is you know like is gradual increase of plastic strain in a material with the time at a constant loads. So, you see it is gradually increasing, especially in the plastic zone, where the non-linear relations are there in between the stress and strain. So, what we need to do here, whenever, if we are talking about a plastic reasons and you see if you see that actually there is increase in the plastic strain due to the load application. Then, you see we are always going for the creep phenomena particular at an elevated temperature.

Because, the temperature is also plays and key role, when there is a non-linear relationship is there in between the load and deformation. So, if we are talking about an elevated temperature, some materials are susceptible to this phenomenon and even under the constant load, also actually always will find that due to the temperature increase. There is a kind of strain, you know like, I should say the plastic strain is forming and it will go up to the fracture.

So, this form of you know like fracture is particular relevant to the turbine blades, where you see the temperature effect is you know like dominant and there are you see you know like the plastic strains are always coming in the material due to the temperature variations. So, that is what generally you see the nuclear reactors are there where the high temperature reasons are there, even the furnaces are there or the rocket motors are there.

So, meaning is pretty simple that actually, even if the load is constant, but the certain changes are there in this temperature. The thermal stresses are always plays an key role and the creep phenomena is coming within that and it always you see you know like starting from the plastic strain, form of a material. And always approaching towards the fracture of this material and that is what you see we have to be very careful that actually, what exactly you know like these particular material is behaving under the temperature.

And, how the thermal stresses are you know like inducing within that temperature and how they will act when load is increasing or even at the constant load. So, the creep phenomena are always you know like coming with the kind of temperature and you know like with the plastic strain. So, if we are talking about those things, then in the general form the strain verses time graph.

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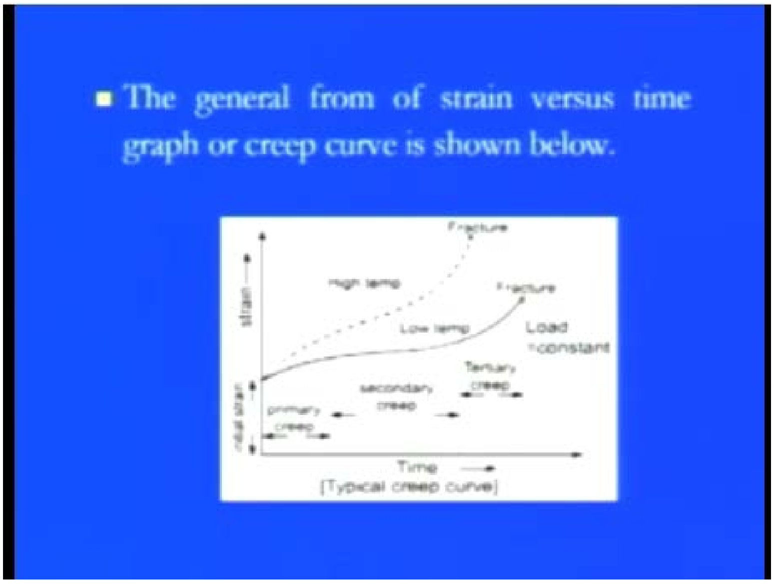

Under, you know like we can say the creep phenomena, it can be you know like shown in this figure, here what we have time, which is you know like time verses the strain. So, as we move further, then we will find that initially, we have you see the non-linear relationship. Because, we are talking about you know like the non-linear relationship between the load verses deformation or we can say it is in the plastic reasons only and when you see we are not applying the loads.

So, that is what you see we are talking about the constant stress only, but as the temperature is increasing you see the low temperature or high temperature. So, you can simply like that, we have the two main reasons, the high temperature as well as the low temperature reasons. And in that you see we have that you know like the different kinds of creeps.

So, if we are talking about you know like the slight variation in that, you know like this strain with the time, we can say this is the primary creep and as we move further. There is slight variations are there, just like there is a smooth variation, I should say of the strain; that means, the deformation with the time as the temperature is keep on increasing.

So, you see here the secondary creep is there and the third creep always lead to the fracture and then you see you know like, if we go for the high temperature, then these you see the clear reasons of primary secondary or this third tertiary creeps, never we find actually. So, all three stresses of the creep, which we cannot even you know like visualize, if we are working on the high temperature and that is why you see you know like either we are talking about a nuclear reactor or the turbine blades or any kind of furnaces.

Due to the creep, the fracture is always there and you know like, it starting from the initial strain, which is always there due to the application of load, but it ends up to the fracture. So, you see here we have all those you know like the kind of the phenomena are there, but the key feature is that, even we are not increasing the load. So, stress formations are pretty similar, but the strains are there due to the temperature, whatever you see the variations are there all round that component.

And, that is why you see, you know like this graph, the strain versus time graph is also known as the creep curve or we can say you know like the standard creep. This figure is there in between the strain and time, so you see, you know like this whatever the deformation is coming and to measure the deformation, the strains are there, versus time or we can say the creep curve.

You see here, there are two main you know like the conditions are there, the one is the initial strain, which as I shown you here a due to the initial application of the load. These initial strains are coming, which is quite constant and we are always taking, you know like this particular condition as the elastic strain. But, the second you know like the stress is coming as a primary creep reasons during, which you see the creep rate or we can say whatever the slope is coming, because of the non-linear curvature.

Always, gives you know like the perfect variation, about the micro structure, that how you know like the micro structures are being setup, due to the temperature variation as you move further from first stage of creep to second stage and second stage to third stage. Even, if the lower temperature is there and even if you are at the high temperature and then you see you know like there are some more things are there.

Like, if the second creep reasons is there, the creep rate is sensibility constant as you actually there is slight variation is there and if we are going for the tertiary reasons. Then you see during, which the creep rate is isolated and it will always tends towards the fracture of the material that means you know like, if even if the load conditions are constant. We are not applying any load, you see here and the surrounding, you know like the situation is pretty comfortable for an element. But, temperature plays a key role, thermal stresses are being developed and due to that actually always there is a fracture is there.

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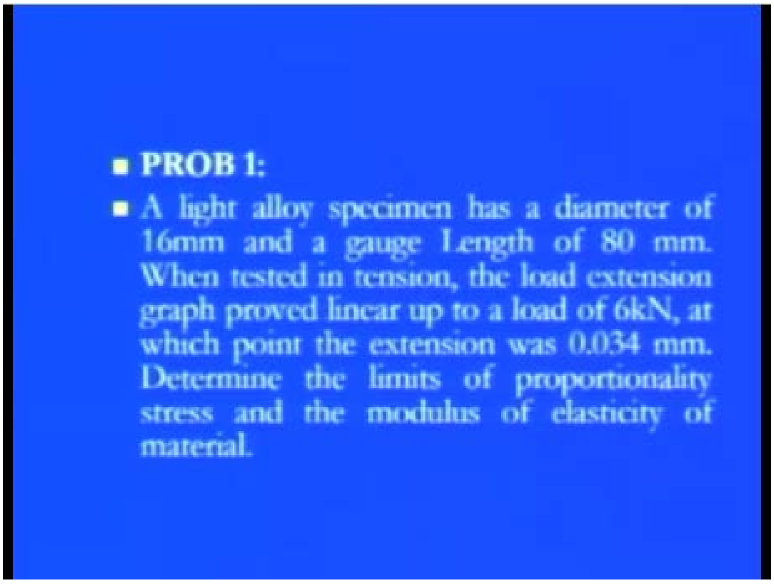

Now, we are talking about particular numerical problem, you see here, that if lighter alloy specimen has a diameter of 16 mm, a gauge length is of 80 mm, when it is tested in a tension. Now, if we apply the tensile load and due to this particular, if we have you know like the load extension curve is there as we have see you know like the strain versus. Like that actually and the similar kind of all five reasons are coming you see the plastic and the elastic.

This you know like the stages and in that you see all those five points are there in that, if we are going up to a linear, you know like reasons and the load application is 6 kilo Newton; that means, you see if you want to go for the elastic reasons. We have the load of 6 kilo Newton at which the point extension is 0.034, that means you see, when you apply the load, it was the extension was 0.03 4 mm.

Now, we need to find it out the limit of proportionality, that because we are going up to elastic limit only and the modulus of elasticity. Because, these two constants are simply defined for this reasons only and you know like for that what we need to do, what we need particular, we have you know like the diameter.

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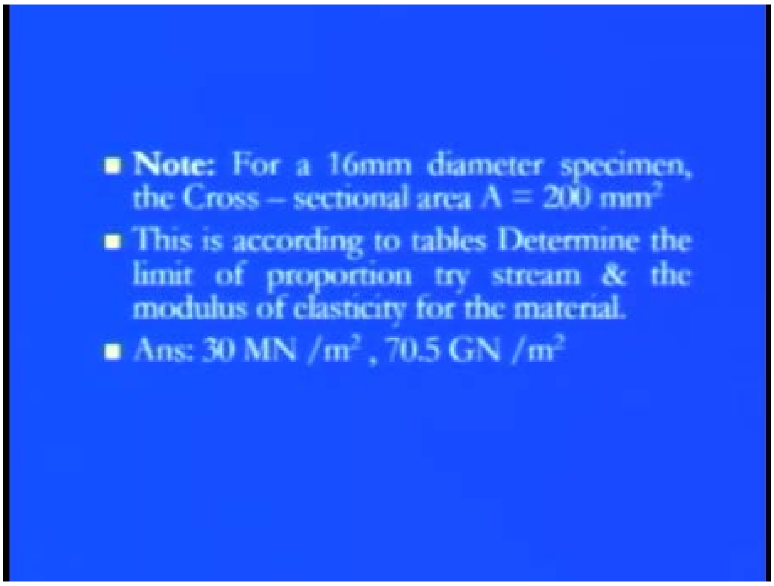

So, once you have the diameter once you have the cross sectional, you know like the vision, so you can find it out the once you have the area, you have the load. So, we need to go up to the limit of proportionality and you know like we need to find it out the modulus of elasticity.

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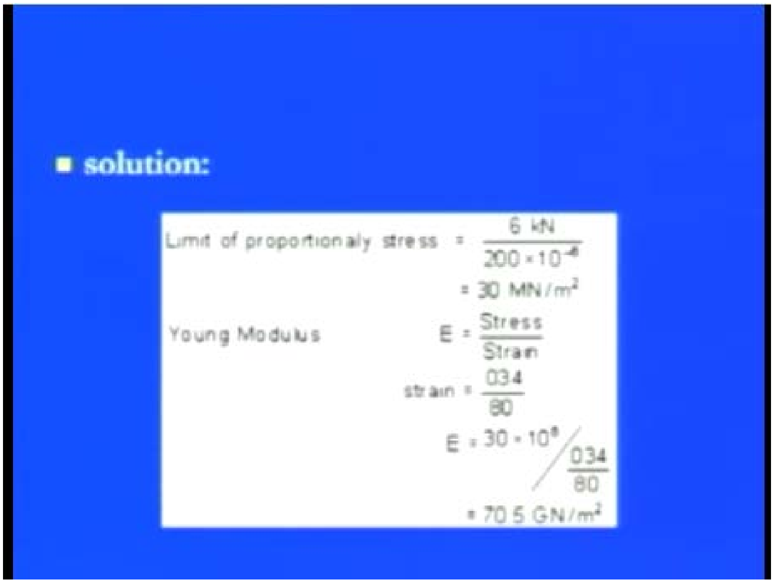

So, you see you have this answers you can verify or you can solve this thing that, this is the area you know like and the load is there. So, load divided by area will give you the stress, you have, you know like the strain, because the deformation is given to us, so it is pretty you know like easily measurable. So, once you have the stress, once you have the strain, you can find it out the modulus of elasticity.

So, E is nothing but equals to stress by strain, put those value get the value of E, which is nothing but equals to 70.5 Giga Newton per meter square. So, you see here in this lecture, what we discussed, we discussed about, you see that, how these you know like the stress formations are there in those materials, why these materials are responsible and what are the other properties, which are associated with the material.

Other than the stress and strain, that we have seen that you know like the hardness is there and even to measure the hardness there are Brinell hardness test machine. This Rockwell hardness is there, Vicker's hardness is there and then if you want to measure the toughness, then you see, you know like the Izod chapry impact testing machine is there.

So, through which we can easily get, those you know like the toughness of material, then another phenomena which we discussed about the creep, that how creep is playing an important role. You know like, where for calculating the stress, you know which are developing during the operation of either the turbine blade or the furnaces or any kind of you see the nuclear reactor, where high temperature reasons are there and how these you see three parts of the creeps are coming in the phenomena.

When, we are drawing the standard creep curve in between the strain and time, so this kind of you know like the relations, which we can easily set up in those limits. So, now you see as we move further, now we will we are going to discuss about that, actually if we have a tensile bar. Still, now you see we discussed that, actually if the load is coming, you know like on the tensile bar, then how they are reacting how we can calculate the stresses.

But, if you see the bar is subjected by two or one or you know like one, two or three load, means more than one load is there, then how we can you know like calculate means in the same bar means. Earlier, we have discussed about the three mutually perpendicular loads, but here we are saying that actually, the two different magnitudes of loads are acting on a bar in the same tensile part. Then, how the stresses are you know like, where the stresses are maximum where the minimum and how these are you know like formations of strains. The stresses and strains are there, within the object that, we are going to discuss in the next lecture.

Thank you.