Engineering Fracture Mechanics
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Module No. # 06
Plane Strain Fracture Toughness Testing

We were looking at various specimens that are used for plane strain fracture toughness. We saw the compact tension specimen. Then, we moved on to three point bend specimen.

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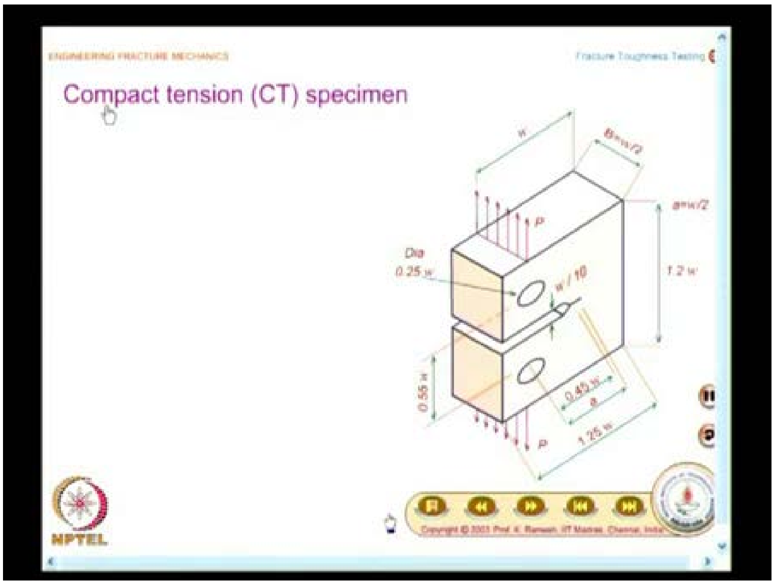

I said, this is the very popular specimen, mainly because, it is simple to fabricate and even the loading fixtures, to load it in the machine are easier to make.

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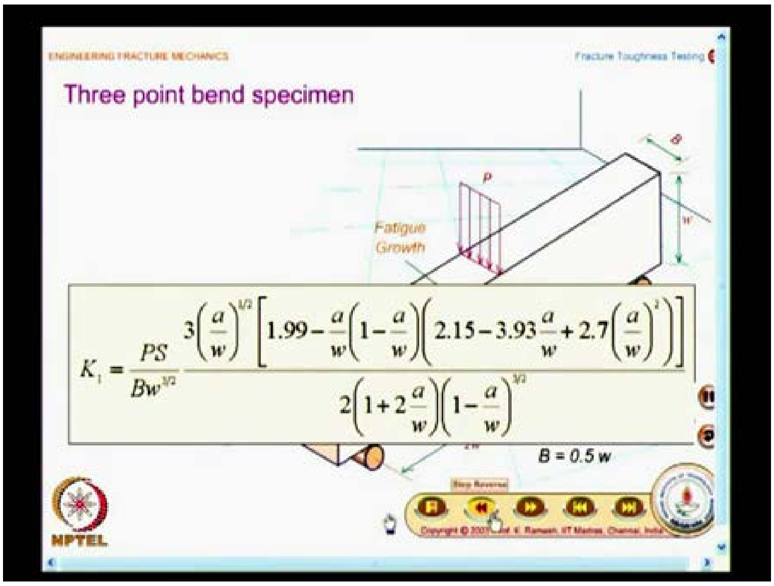

We have also looked at the value for stress intensity factor.

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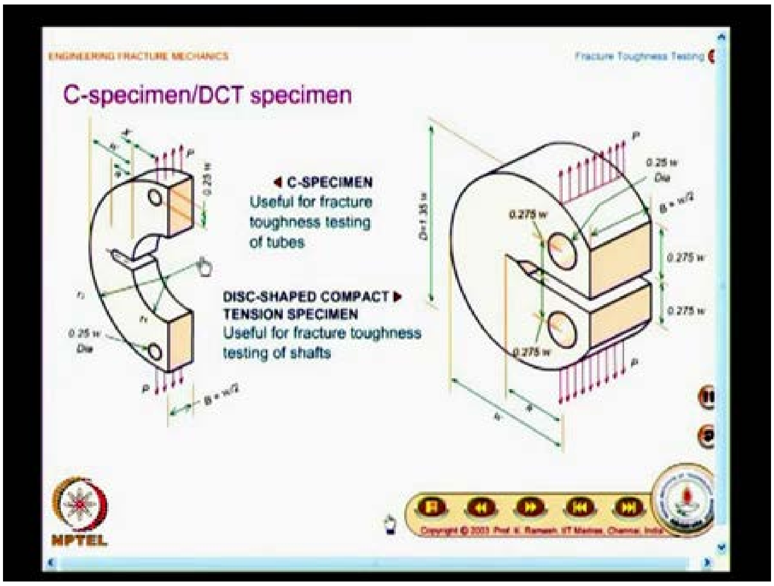

Then, we moved on to other forms of specimens that are used and I would like you to make a two dimensional sketch of this. This is a C-specimen.

This is useful for fracture toughness testing of tubes. It is convenient for you to take a specimen from the tube. And you have the crack length measured from this edge, that is what is given as crack length. And for this also, you have the boundary collocation solution for S I F available. You also have another set of specimen, which is known as disc-shaped compact tension specimen. Here the crack length is measured from the load application point. This is the value of a. Make a two dimensional sketch. And this specimen is useful for fracture toughness testing of shafts. And for all these cases, you have expressions for evaluating stress intensity factor. So, from the experiment, you will measure the critical load P and the critical crack length. So, with that, you would be in a position to estimate the stress intensity factor and the expression is given as follows.

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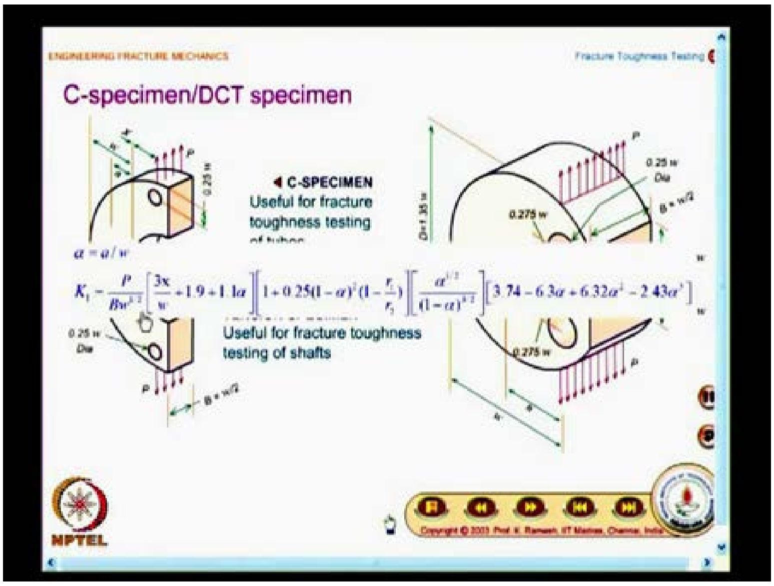

This is for the C-specimen. It reads like this: K 1 equal to P by B w power half multiplied by 3 x divided by w and you have the distance x marked here; that is the distance of the crack beginning from the load application point, plus 1 .9 plus 1.1 alpha, where alpha is the a by w ratio, the whole multiplied by 1 plus 0.25 multiplied by 1 minus alpha whole squared multiplied by 1 minus r 1 by r 2; and you have a factor alpha power half divided by 1 minus alpha power 3 by 2 multiplied by 3.74 minus 6.3 alpha plus 6.32 alpha squared minus 2.43 alpha cubed. This is for the C-specimen.

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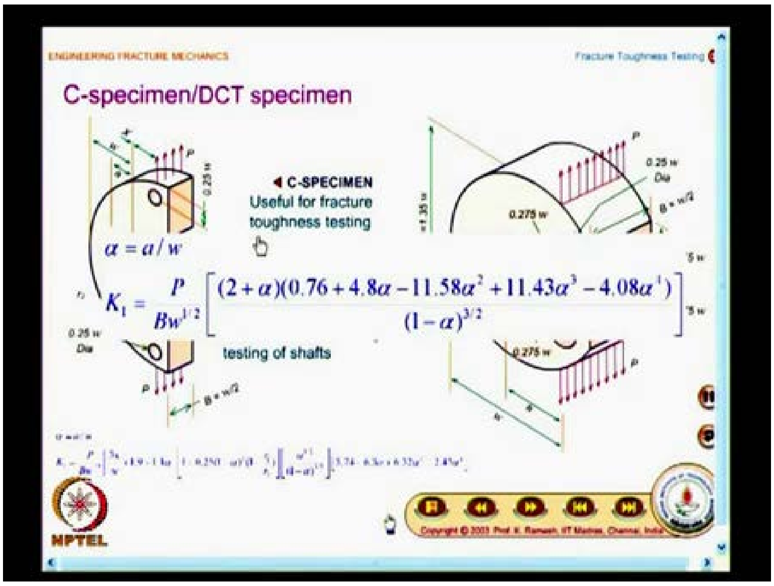

And you have for the disc-shaped specimen K 1 equal to P by B w power half multiplied by 2 plus alpha into 0.76 plus 4.8 alpha minus 11.58 alpha squared plus 11.43 alpha cubed minus 4.08 alpha power 4 divided by 1 minus alpha whole power 3 by 2. So, you have the expressions for C-specimen as well as the D C T specimen.

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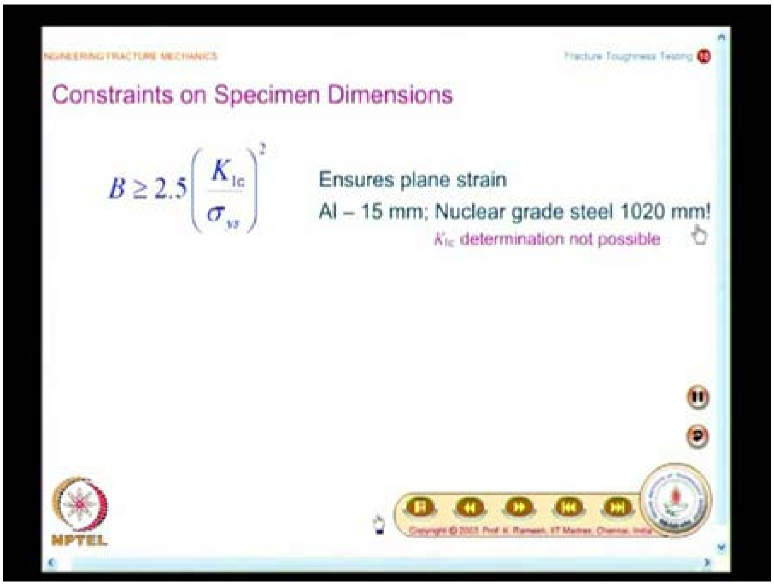

And, we now move on to look at, what are the constraints on specimen dimensions. When we discussed modeling of plastic zone, we looked at from the plastic zone size consideration. The thickness B is given as greater than equal to 2.5 times K 1 C divided by sigma y s whole squared. This condition is necessary to maintain plane strain situation in the testing. And it is interesting to note, what is the thickness of the specimen when the material changes? Suppose, I have an aluminium high strength alloy, it would be around 15 millimeter, where LEFM is applicable. On the other hand, if you go for a nuclear grade steel, if you substitute the values of K 1 C and sigma y s in that, the specimen size, that is the thickness, is 1020 millimeters..

In fact, a person can sit on the specimen. Such pictures have also have been shown in some of the literature; and you will not have a machine to break the specimen; because it is so thick and heavy, it is just not possible, and in such situations, LEFM is not really applicable. So, that is the reason why people went for EPFM for nuclear grade steel. You have plastic zone developed, and you cannot have 1020 millimeter specimen to be breaking; and K 1 C determination is not possible.

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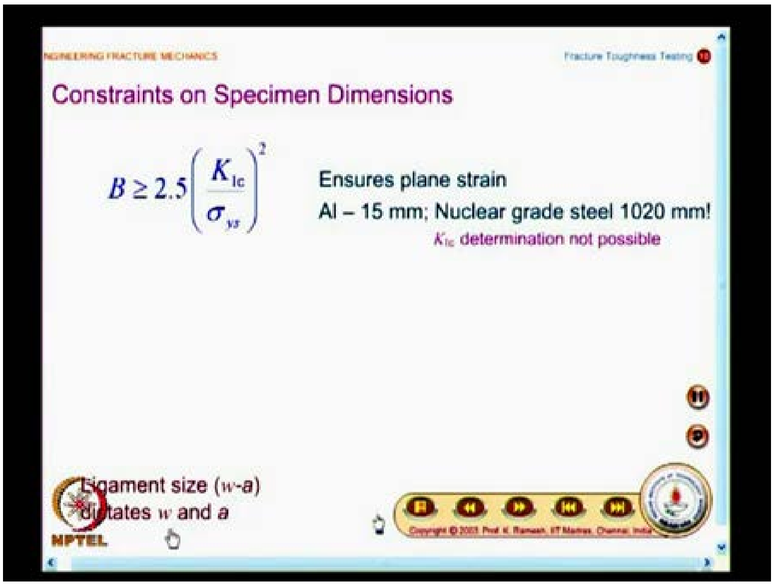

Then, you also need to have considerations on what should be the size of the ligament, that is, what is the length w minus a, which in turn dictates, what should be w and what should be a.

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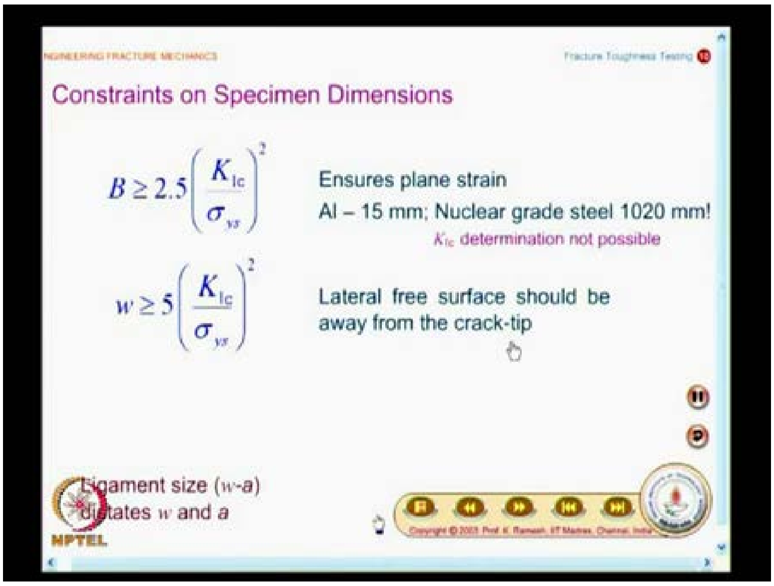

So, you have recommendations for that. The recommendation for the width is, it should be greater than or equal to 5 times K 1 C divided by sigma y s whole squared. And the reason, for w to be of this value, is to keep the lateral free surface away from the crack-tip. You know, we have already seen, in the case of SIF evaluation, back free surface correction factor, front free surface correction factor. So, when you are going in for fracture toughness testing, you would like to have the lateral free surface far away.

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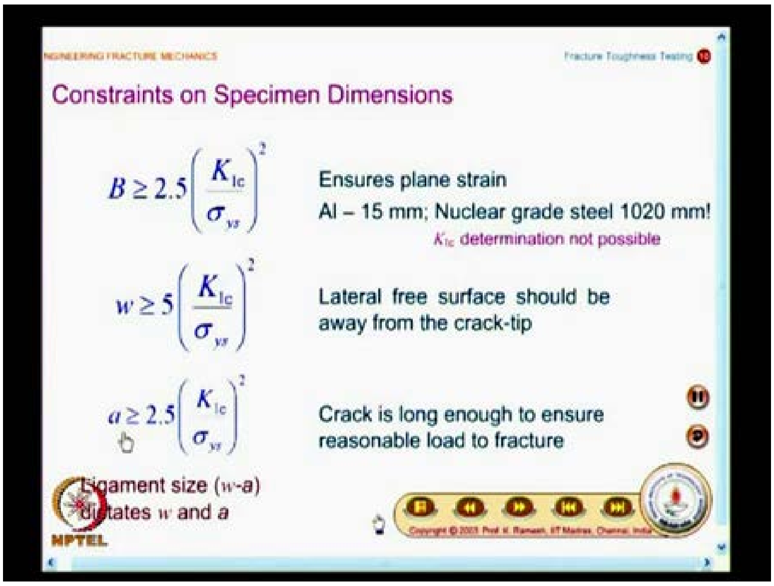

So, you have a recommendation for what should be the value of w, and you also have a recommendation for what is the length of the crack a. It should be greater than 2.5 point times K 1 C divided by sigma y s whole squared. And if you have really noted, in all the standard specimens for fracture toughness testing, the value of a by w is around 0.45 to 0.55; you maintain it like that. So, if you go for non-standard specimens, then, you will have to individually worry for how B should be selected and how a should be selected. In the case of standard specimens, the specimen dimension takes care of it. And, why do you want to have a very long crack? If I have a long enough crack, you need to have only a reasonable load to fracture. So, that simplifies your testing methodology also.

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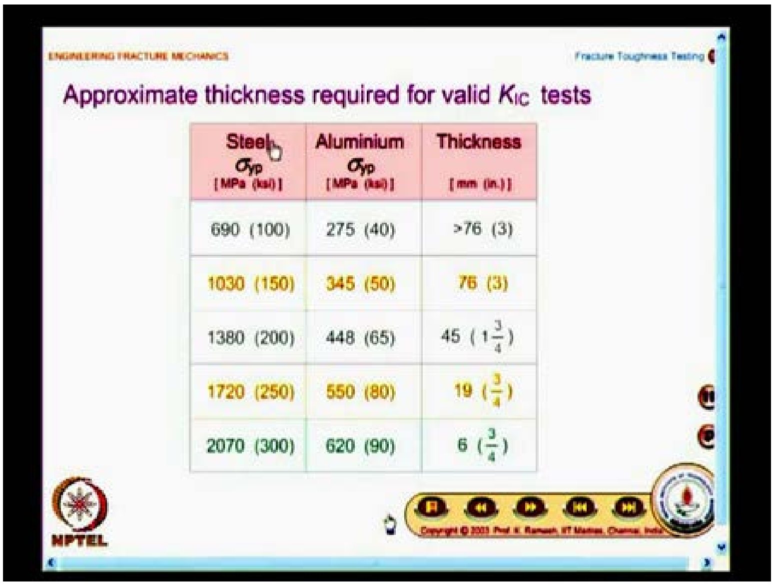

So, that is the way you have to look at it. And you also have a very interesting table, which gives an idea about the thicknesses required for valid K 1 C tests for steel and aluminum. I would like you to write for 3 different values; what you have in the first column is the yield strength of steel; second column, aluminum material is shown; the yield strength is shown; the third column gives the thickness necessary for K 1 C tests. So, what you find is, when I have steel of yield strength of 690 MPa or aluminum of 275 MPa, you need a specimen, thickness should be greater than 76 millimeter.

On the other hand, if I go for high strength alloys, in the case of steel, if it is 1380 MPa, 448 MPa for aluminum, the thickness is like 45 millimeter. So, almost two thirds of it. On the other hand, if you go for a very high strength alloy, yield strength is 2070 for steel and aluminum 620 MPa; you need a specimen of a just 6 millimeter thickness. It is enough if you write for 3 different values. This gives you an idea, how the thickness is very important. As the strength increases, thickness also decreases. LEFM is ideally applicable for high strength alloys.

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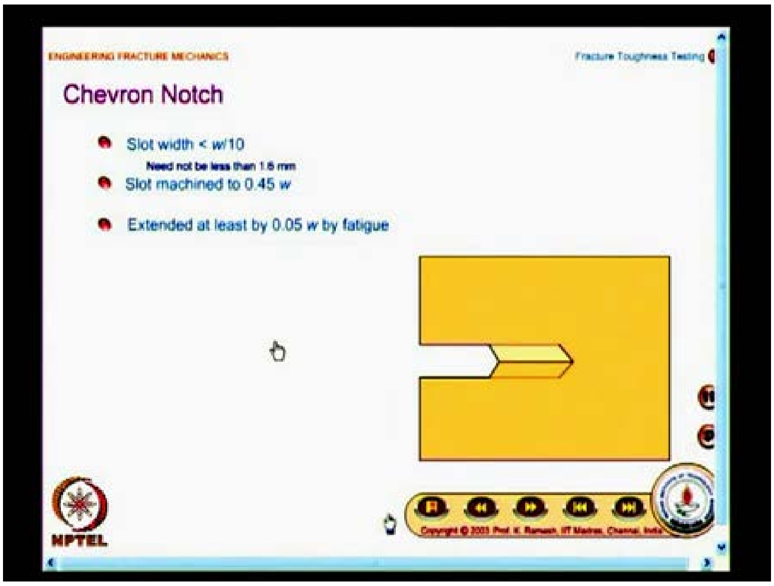

You know, in the last class what I had told you was, we have a diagram of chevron notch. There are certain restrictions the code gives; what should be the slot width, what should be the length of the slot and what should be the extension of fatigue crack. For all these, you have recommendations given. And usually, chevron notch specimen is shown like this. You have a line here; you have a line here; you have a line here and also 2 lines here.

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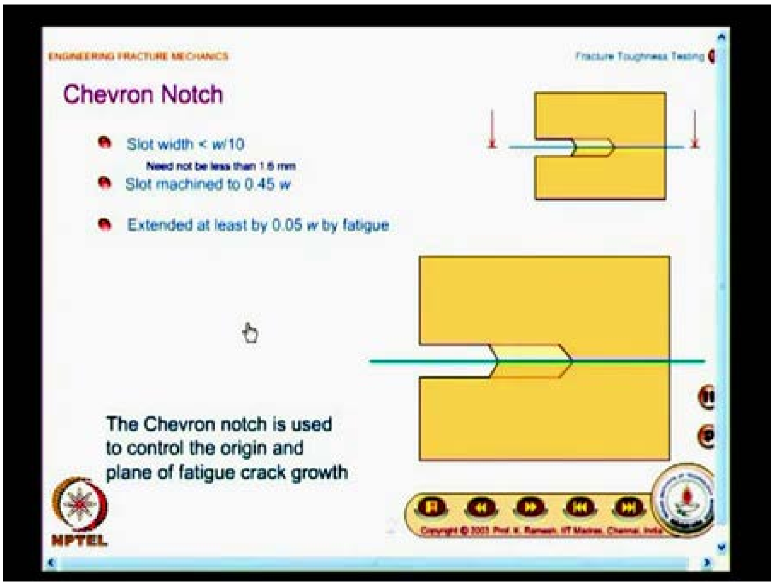

In the last class, I had asked you to go to your understanding of engineering drawing, and try to give, a three dimensional picture of how these lines can be interpreted.

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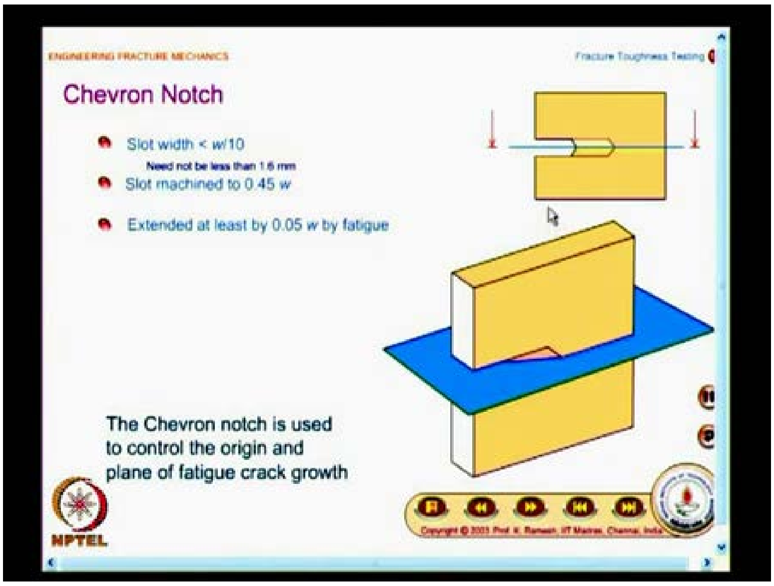

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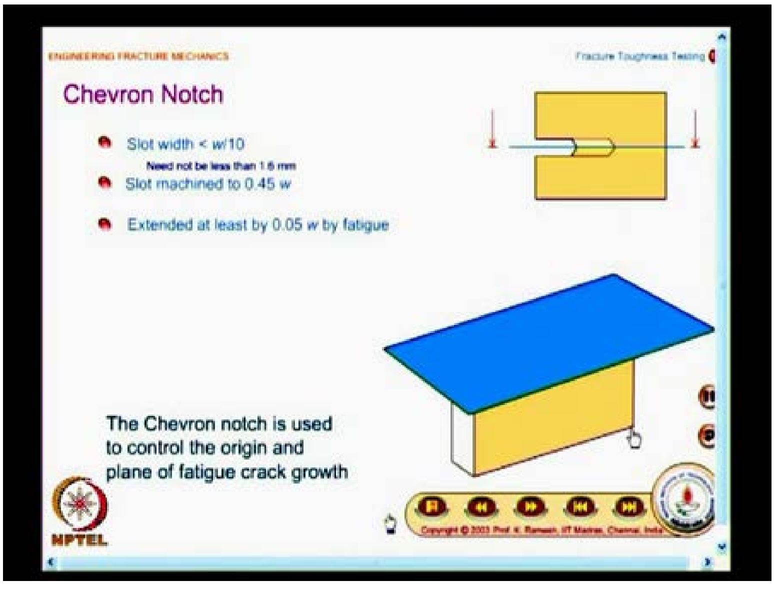

You have a clue in that whole figure, and this where we stopped. Have any one of you come with those results? I think quite a few, you, you have come with your result? You can raise your hand. And, anyone else? Yes, that is good. If you make an attempt, it is very nice. You know, you have to make an attempt. And let us see, how the specimen looks like. The chevron notch is used to control the origin and plane of fatigue crack growth. Here it is.

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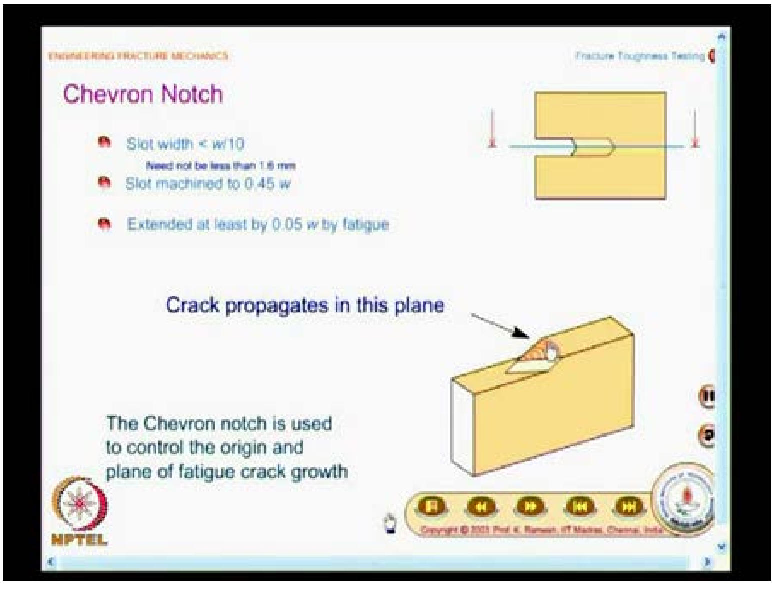

So, this explains for all the lines; you have this inclined line, that explains this inclined line. And this inclined line explains this line, and whatever the horizontal line you have, is the one which you have as the inclination. And what is the advantage here? When I apply the load, this corner is the weakest point. So, crack will originate from here. And you make this particular plane weak, the crack will follow that plane. So, you are able to control the origin of crack, as well as the plane in which the crack will advance. Because, for fracture toughness testing, we need a natural crack. You have seen the pictorial representation of the chevron notch.

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I have brought 2 specimens, one is a blown up model which is made on a Perspex thick sheet. You have the chevron notch here and you also have the cut top surface. And you have a miniature sized, compact entrance specimen, which I want to give it to the class, so that, you have a firsthand understanding of how the chevron notch is made and how does it look like.

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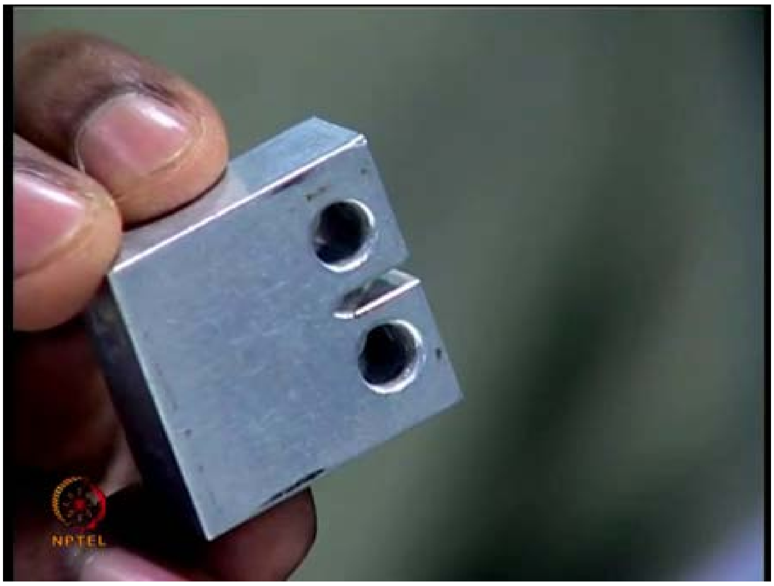

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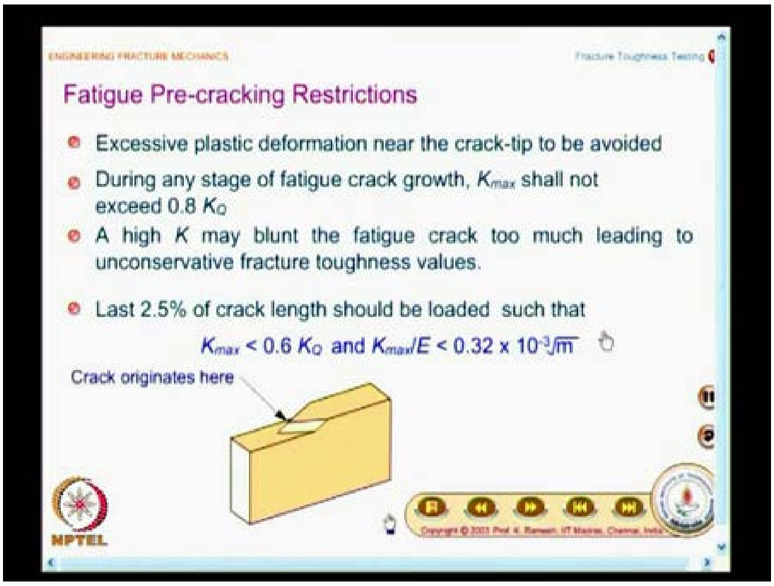

And in order to get the fatigue pre-crack, there are restrictions, how the loading should be applied. The focus is excessive plastic deformation near the crack-tip is to be avoided. Because, you are wanting to do plane strain fracture toughness, where the plastic zone is very very small. So, inadvertently, you should not introduce plastic zone by wrongly performing the pre-cracking procedure. During any stage of fatigue crack growth, K max shall not exceed 0.8 times K Q. You have already seen, K Q is the candidate fracture toughness. The reason is, a high value of K may blunt the fatigue crack too much, leading to un-conservative fracture toughness values. Not only this, during the last 2.5 percent of crack length should be loaded such that, K max is less than 0.6 K Q and K max divided by Young's modulus is less than 0.32 into 10 power minus 3 root of meters.

You know, these are all very stringent restrictions. And, in fact, a person performing the fracture toughness testing has to adhere to that. One of the assignment problems gives you this experience, and if you do that, you will be in a position to understand how these conditions could be imposed, at least in your calculations. So, you have set of recommendations for fatigue pre-cracking and it is linked to what is the value that we are going to evaluate finally. So, (( )) you do not know what is K Q; this is where the challenge lies. You have to have a reasonable guess work, when a new material is given to you.

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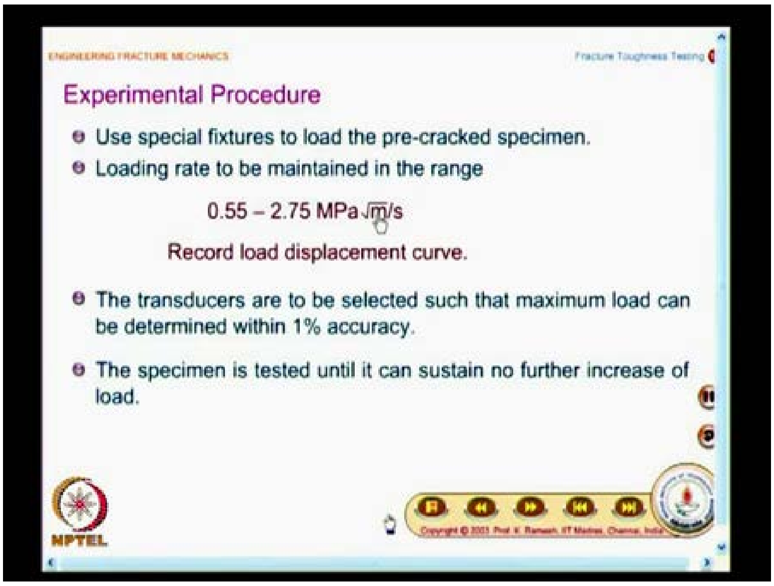

And what is the experimental procedure? You have to use special fixtures to load the pre-cracked specimen; loading weight should be maintained in the range 0.55 to 2.75 MPa root meter per second. You know, this is very important. In all our discussions, we have said, we have to load it gradually. How gradual it is? A code gives you the recommendation. We have this as 0.55 to 2.75 MPa root meter per second and you have to record the load displacement curve; this is very important. Only from that, you would be in a position to evaluate the parameters needed for fracture toughness determination.

And, whatever the transducers that you use for measurement of load, as well as the displacement, they are to be selected such that, maximum load can be determined within 1 percent accuracy. You do not want to make a calculation error on the maximum load. The specimen is tested until it can sustain no further increase of load; that means, at the end of the test, specimen breaks. This is what you are really looking at.

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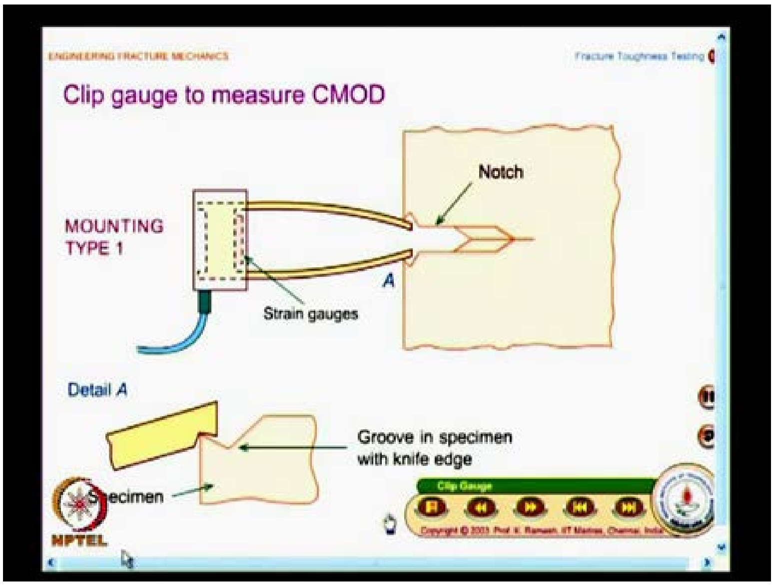

When you say you have to measure the load displacement, it is done by a clip gauge. People measure the crack mouth opening displacement. From your other transducer you get the load; from another clip gauge you get the crack mouth opening displacement. You know, this is where it is mounted to the specimen. Some detail is given; it could be mounted like this or it could have a sharp (( )) swivel type of edge and then you can have a detail like this.

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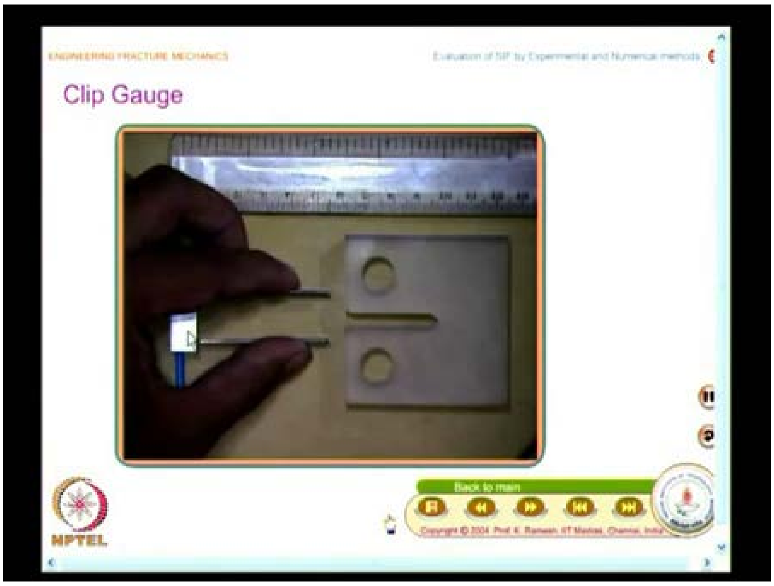

And in reality, what you do is, a clip gauge is taken and inserted into this; and this would measure the crack mouth opening displacement.

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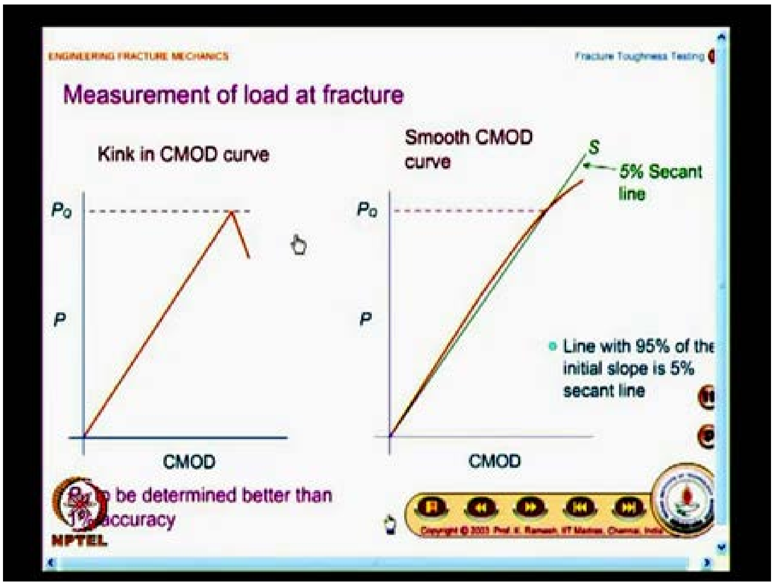

And, how do you measure the load at fracture? We have a nice curve here; it simplifies your evaluation of the load. Make a neat sketch of this. People classify 3 different varieties; they also classify it as type 1, type 2, type 3. This is type 1; this is type 3; you would also see type 2. So, I have on the x axis crack mouth opening displacement; on the y axis, I have the load. And in this case, what happens is, the load increases and you have a nice kink on the curve. And the load is referred as P Q. This also happens to be the maximum load in this type of specimen behavior. We could also have the P versus C M O D curve, being a curve like this, there is no apparent way, that you can locate the value of P Q.

In fact, it I will go rise and then you will have somewhere P max and then, the specimen will fail. That portion of the graph is not shown. What is then here is, when you have a non-linear type of response, you draw a 5 percent secant line. And what is the 5 percent secant line? A line with 95 percent of the initial slope is 5 percent secant line. In fact, I could redo the animation and you could see how the graph is drawn. This is for the case, when there is clear kink and identification; when the variation is non-linear it is like this and you draw this line; and hit it. It hits this and you get the value of P Q. So, any value which is with a subscript Q , you use it for finding out the candidate fracture toughness.

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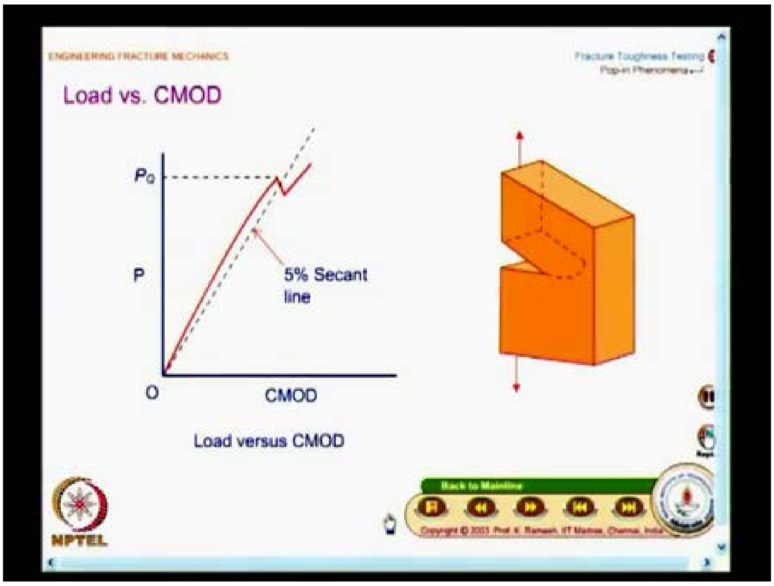

Now, what we are going to look at, is what happens, when I have pop-in. You have already heard the sound. In certain specimens, you will also have a pop-in phenomenon. So, if there is a pop-in phenomena, the shape of the graph will be like this; then it will rise up and you will have a P max. Because, in the case of pop-in phenomena, we said, there would be a sudden jump in a thumb nail fashion. Only after some other increase in load, the specimen will completely break. I would repeat the animation here also. You can hear the pop-in sound. I think you can hear it now. And you again draw a 5 percent secant line, but what you take as P Q as, this sharp height is what is taken as a P Q. So, the idea of getting the load versus C M O D graph is to find out, what is the value of P that you should substitute, for finding out fracture toughness.

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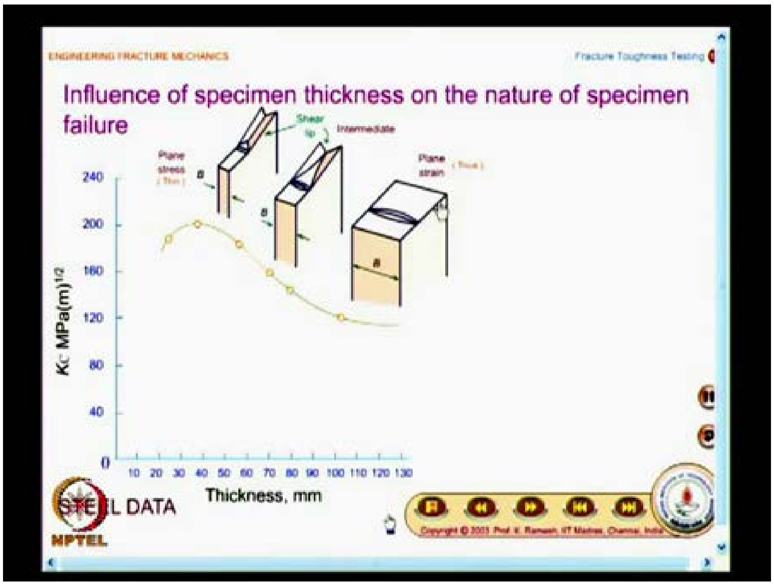

And you know, we have seen different types of material behavior. And you also find, as a function of specimen thickness, the way the fractured surface will appear is also different. When I have a complete plane strain situation, you will have a fracture like this. I think I can magnify it for you.

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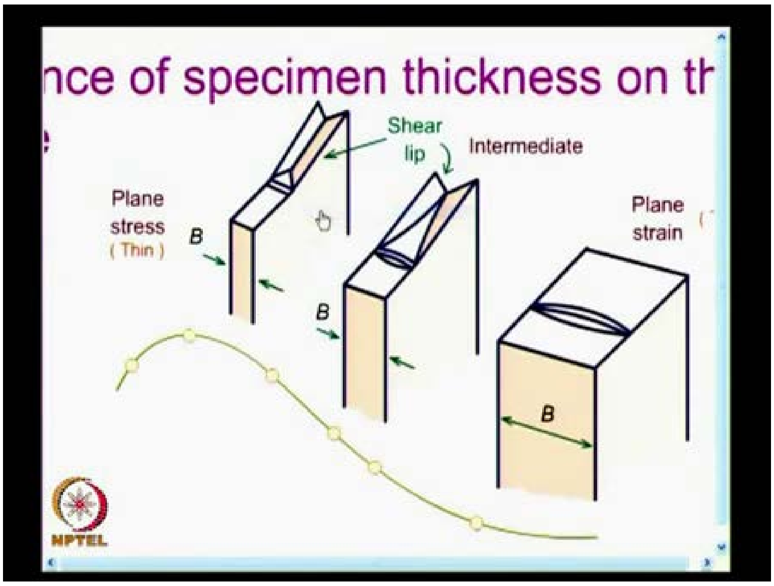

So, what you have here is, the fracture toughness varies like this. For plane stress specimens, what you have here is, prominent shear lips. You see, for an intermediate thickness specimen, you would also have seen it in the last class, when we discussed plastic zone, initially it is like a plane strain, and towards the end, you have a shear lip. Make a neat sketch of it, as much as possible. The moment you come to a thick specimen, where you could ensure plane strain situation, you will have a flat surface. And this is taken as a material property. The value of fracture toughness under plane strain condition is taken as the material property. For thin panels, you need to find out. You will see how to do plane stress fracture toughness testing.

So, essentially, when you do not know what should be the thickness, you will be hovering in this zone; if the thickness is not sufficiently large to have a plane strain situation, it may be having intermediate value.

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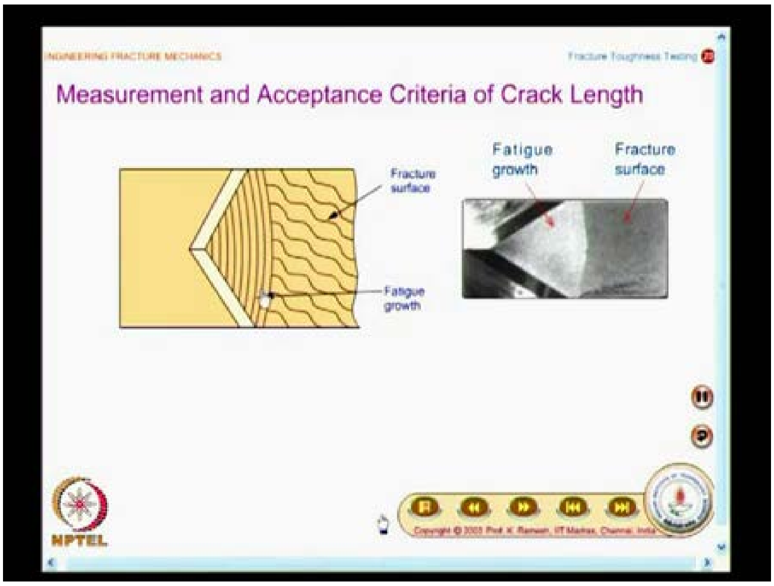

And finally, once the specimen is broken, you have a set of requirements on how to measure the length of the crack and what is the acceptance criteria. Here, you have 2 pictures; one is a sketch. The sketch shows, this is the specimen and this is the chevron notch and you have the crack front. And how do you see the crack front? The crack front is not straight. In the case of through the thickness specimens, which we had looked at earlier, we simply put that as a straight line, because it is only a model. When you physically produce a natural crack, the crack would propagate only in this fashion. So, one of the restrictions is, what amount of curvature can you tolerate? So, you have a growth phase of the crack and there is a fracture surface. And I think I can enlarge this picture. This is a broken specimen.

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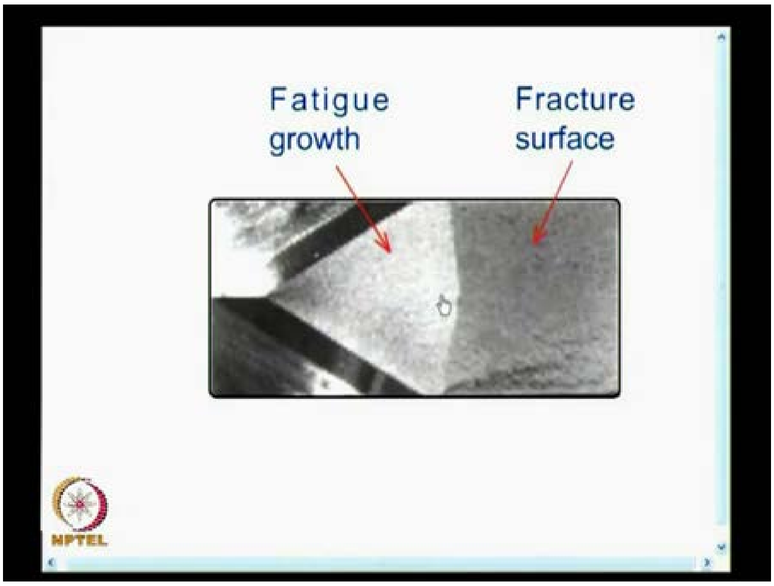

So, you could see the chevron notch here, and this is the region, where you have the fatigue crack growth. Definitely, this is not straight. It is having a curvature. And you should also note that, there is a portion which comes out of the chevron notch. The chevron notch ends here and you have a small distance. You will be surprised; even these distances are noted in the code. You cannot have anything other than that. We will have all this. What is the value it is coming out on this side of the specimen? What is the way it is coming out in this side of the specimen? What is the way the curvature is there? All this measurements are essential for you to accept the test.

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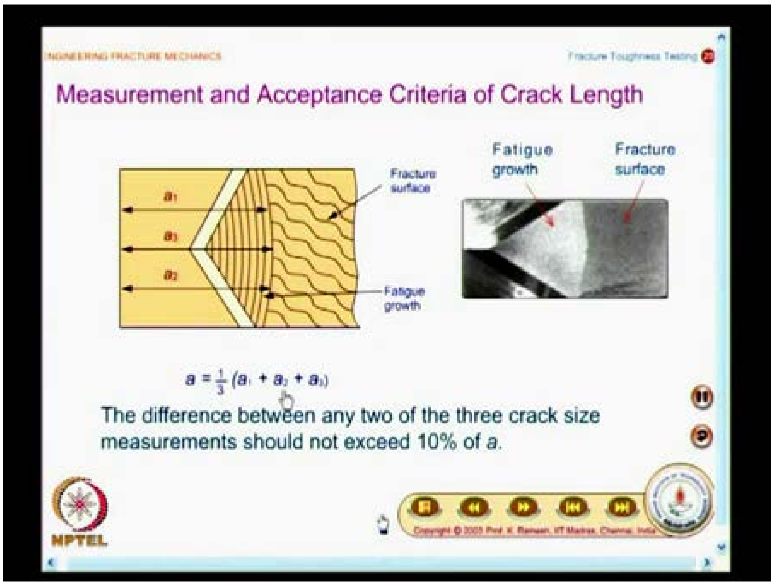

So, we will see one by one. For measuring the length of the crack,you make 3 measurements; one along the center of the specimen and one measurement, half way up, another measurement half way down. So, you have this as a 1, a 2 and a 3. So, from these 3 measurements, you get the crack length as a equal to 1 by 3 a 1 plus a 2 plus a 3. The code says, how you should measure and qualify whether you can accept or not. I measure a 1, a 2, a 3, and what is the acceptance criteria is, the difference between any 2 of the 3 crack size measurements should not exceed 10 percent of a.

See, in the case of load measurement, we had seen P Q and there is also a P max; only when you have a case where there is a kink, this P Q and P max merge. In the other two cases, P max is slightly higher than P Q. There again, the recommendation is P Q and P max difference should not exceed 10 percent. And here, you find, in general, you will have a varying crack front. In the drawing it is shown as simple r; here it is different. So, when you make the measurements a 1, a 2, a 3, you have to ensure, finally, whether these measurements exceed 10 percent of a. If that is so, then you may have to discard the test. You have to go and do the pre-cracking very carefully.

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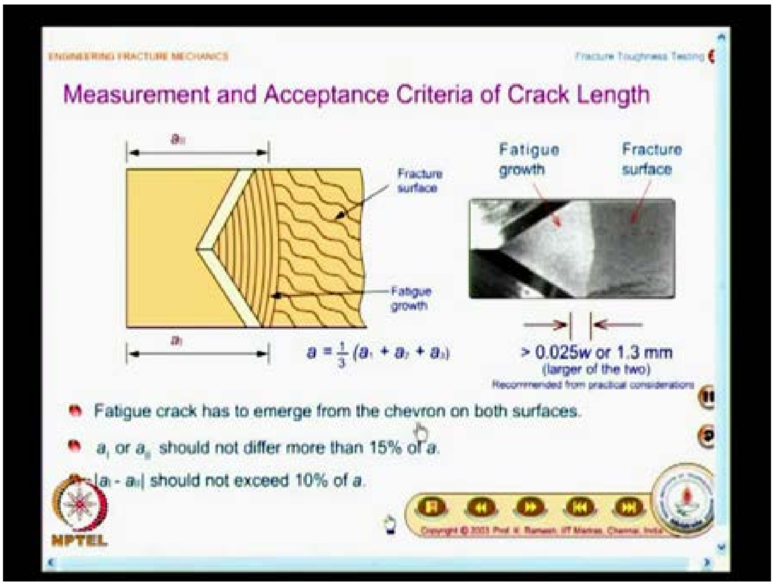

Then, as I mentioned, you also need to have, what should be the length that it comes out. The code says the fatigue crack has to emerge from the chevron on both surfaces. See, you see the crack length, only after the specimen is broken. You know, it is very difficult to measure the length of the crack as you do the loading; you have to have certain non-destructive type of measurement to see the crack has advanced beyond the chevron notch.

So, the code says, it should be 0.025 w or 1.3 millimeter; you have to see larger of the two. This is recommended from practical considerations. See, I am sure in a class like this, why I get into such minute details. In fact, I am not giving you very many minute details; I am only giving you certain salient, important features of the code. That itself is very alarming; there are too many details. But if you really look at the code, for everything the code specifies. You have to first digest what the codes say, then, you will have to get it implemented. It is a challenging task. So, the first requirement is, you cannot have a crack stop before the end of the chevron notch; it should come out. How much it should come out, is shown here.

And there is also another restriction; it should not come out too much. It says, if you measure a 1 on this surface and a 2 on the other surface, they should not differ more than 15 percent of a; and a 1 minus a 2 should not exceed 10 percent of a. So, measurement of crack length is not a simple task; it is an involved task. So, that means, the operator who is involved in fracture toughness testing, should have developed some skills; otherwise, it is just not possible; because, the materials are too expensive.

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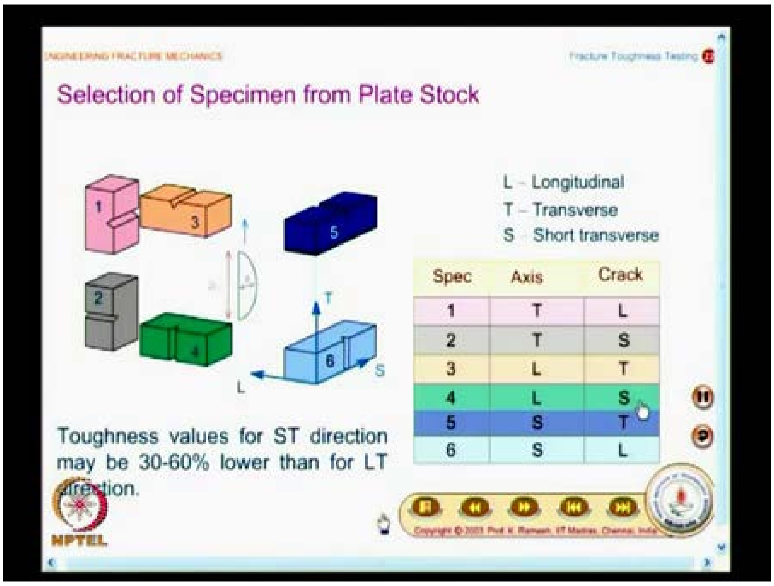

So, we have seen, what way we will have to measure the thickness, measure the length of the crack. Another aspect, I have also been mentioning in the case of fracture mechanics, we bring in the material anisotropy in the testing in a very systematic fashion. So, you have a plate stock, where you have the axis marked as L, T as well as S. Make a sketch of it. Depending on the manufacturing process, its strength will vary on different directions. If it is extruded along the length direction, you will find it will have more strength. And what the codes say is, you have to select the specimen, appropriately from the plate stock. You should know which way the specimen is aligned. You write the specimen 1 and 2. You make a sketch of it.

So, in the case of specimen 1, the axis is given as T and the crack will advance in the direction L. That you can see. I have the crack here; as I apply the load, the crack is expected to advance in the L direction. So, it would be dictated by fracture toughness in the L direction. And you have the specimen 2, where still the axis is same, it is in the T direction, like the specimen 1, but the crack is expected to advance in the S direction. So, what you should do is, you should go back to your rooms, fill in the pictures for the other cases 3, 4, 5, 6. So, you could have a combination of L T, L S, S T, S L and so on.

And in this plate stock, you also have a surface crack shown. See, because the way the specimen is prepared from the plate stock, its fracture toughness may vary. Suppose, I have a surface crack in an actual specimen, whose properties vary from direction to direction, you would not be in a position to assess how the surface crack will grow, unless you know the fracture toughness along various directions. That is what is summarized here. The toughness values for S T direction may be 30 to 60 percent lower than for L T direction.

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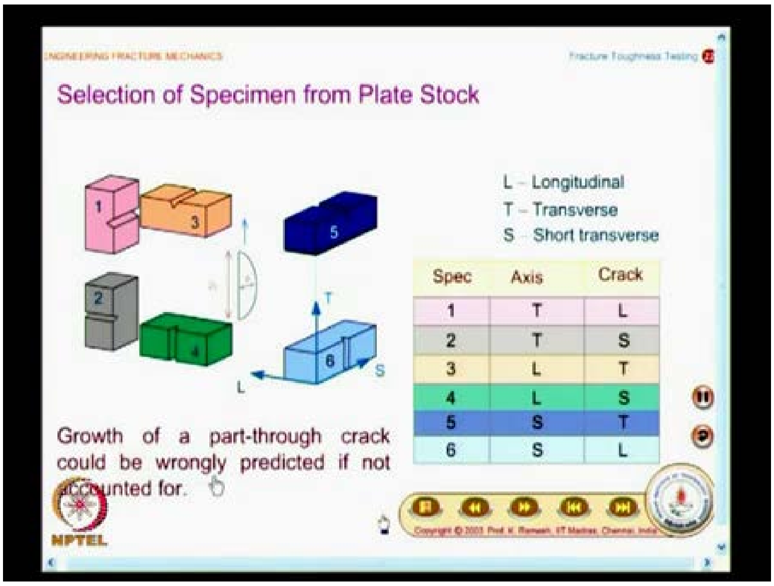

What is the consequence? The consequence is, growth of a part-through crack could be wrongly predicted, if not accounted for. This we had seen, even in leak before break criterion. I said a semi elliptical flaw would try to become an… from a, a semi elliptical flaw would try to become a circle, because K is very high and you want that crack to move further and create a leak in the pressure vessel; then, it should take some sufficient time for it to move sideways.

So, this is dictated by stress intensity factor as well as the fracture toughness. So, in fracture toughness testing, you also take special care to bring in the material anisotropy and find out the appropriate properties. This is very systematically done.

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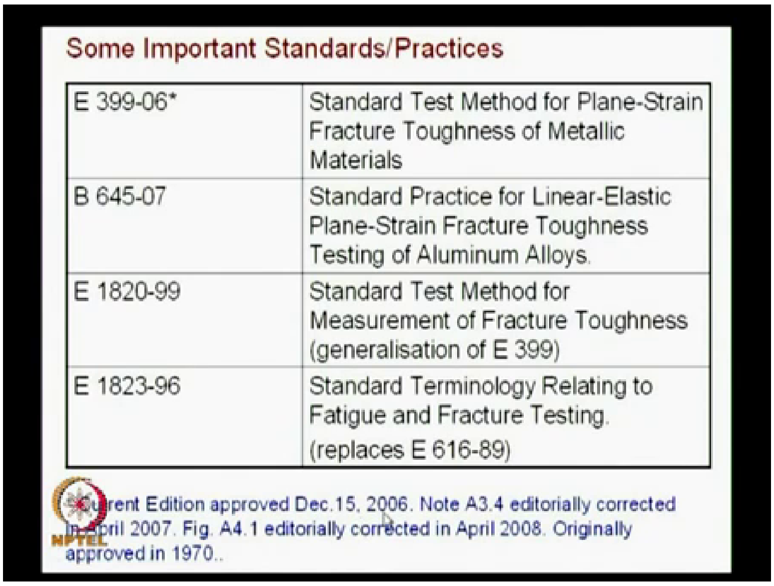

Now, let us back to some of the standards. You have important standards and practices in fracture mechanics. And we had actually looked at certain features of E 399-06 and this 06 implies the year in which, finally the standard is released. And you have a history for this. The current edition is approved on December 15 2006 and you also have this summary, in this. A particular section, that is note A 3.4 is editorially corrected in April 2007 and a figure A 4.1 editorially corrected in April 2008. Originally the code was approved in 1970. Why I brought this to your attention is, codes keep changing. People bring in more and more experience and slightly modify it, to suit current understanding. It is not that, once a code is developed, people follow it blindly; it is not so.

If some researchers find, there is an anomaly, people do make a modification, after due consideration. And your code E 399-06 is the standard test method for plane-strain fracture toughness of metallic materials. And in that, you have a reference to B 645-07, 07 is the year in which it is approved. This is a standard practice for linear elastic plane-strain fracture toughness testing of aluminum alloys. This is for a metallic materials and this is, certain recommendations for aluminum alloys.

Then you have another standard E 1820-99. It is a standard test method for measurement of fracture toughness. It is a generalization of E 399. Then you have another standard E 1823-96, Standard terminology relating to fatigue and fracture testing. This replaces E 616-89. You know I had already mentioned, there is overlap of symbols between fatigue and fracture. So, people also looked at this issue and standardized which way those quantities have to be referred. You know, whenever a standard is developed, for it to percolate down to people, it takes some time. It does not happen immediately. And, we look at features of some of these standards.

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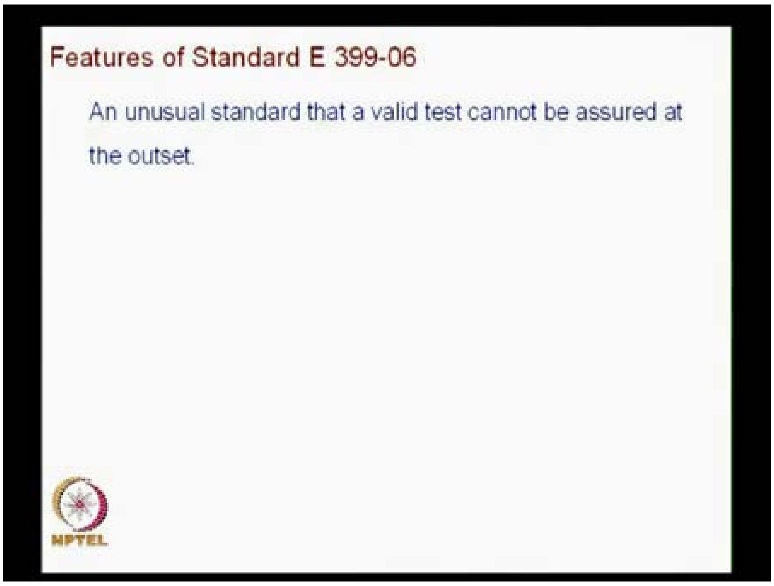

I have not given all the standards; only a selected few I have taken. And if you look at features of standard E 399-06, it is an unusual standard that a valid test cannot be assured at the outset. That we have seen. You have to find out K Q and if K Q satisfies all your restrictions, in terms of specimen dimension, crack length, pre fatigue cracking restriction, so on and so forth, then you call it as fracture toughness.

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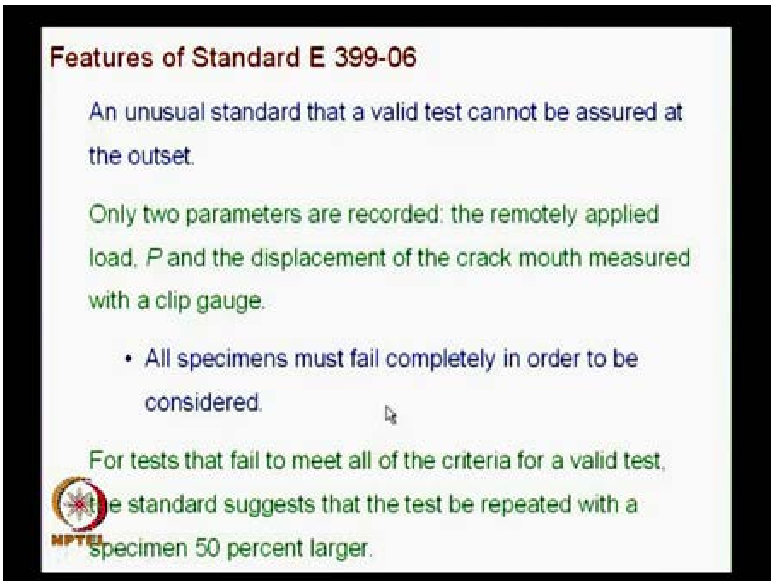

So, it is a very unusual standard, from that point of view. And what is that we have recorded? We have recorded only two parameters; one is the remotely applied load P and the displacement of the crack mouth, measured with a clip gauge. So, these are the two measurements we ultimately make, but initially you do a fatigue loading to generate a natural crack. The actual test is done by monotolic loading. You do not vary the force there cyclically; you monotonically, gradually apply. How gradual, that is also dictated by the code. And we have also noted that, all specimens must fail completely in order to be considered.

Suppose the test becomes invalid; that is a possibility. Because, it does not guarantee that the test would be final. For tests that fail to meet all of the criteria for a valid test, the standard suggests that, the test be repeated with a specimen 50 percent larger in thickness. Based on the thickness, all other dimensions are fixed. So, you will have to go for this kind of change in thickness and redo the test.

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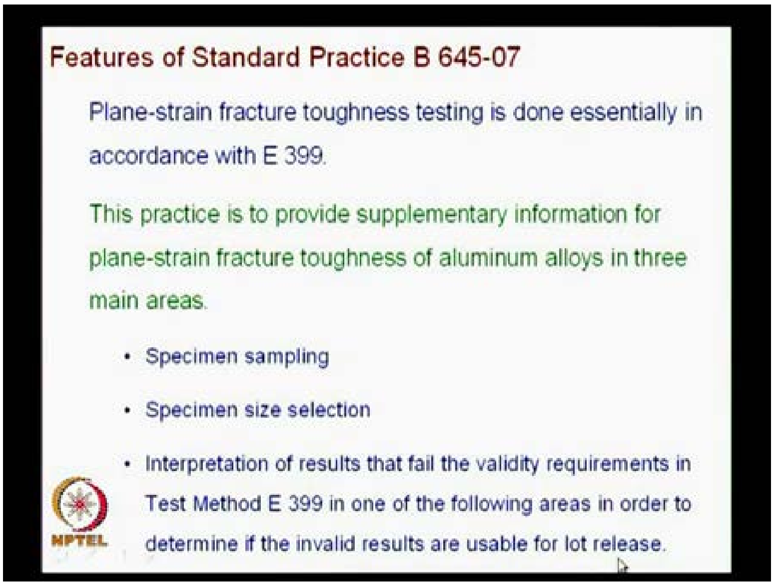

So, you have certain difficulties in E 399. Let us see, what are the features of standard practice B645-07? Plane-strain fracture toughness testing is done essentially in accordance with E 399; however, it provides supplementary information for plane-strain fracture toughness of aluminum alloys in three main areas. Some sort of a relaxation. That is, you perform a test, you do not throw all your results out; if some results can be salvaged, that is what this practice has looked at. The three main areas are specimen sampling, specimen size selection and interpretation of results that fail the validity requirements in test method E 399 in one of the following areas, in order to determine if the valid results are usable for lot release.

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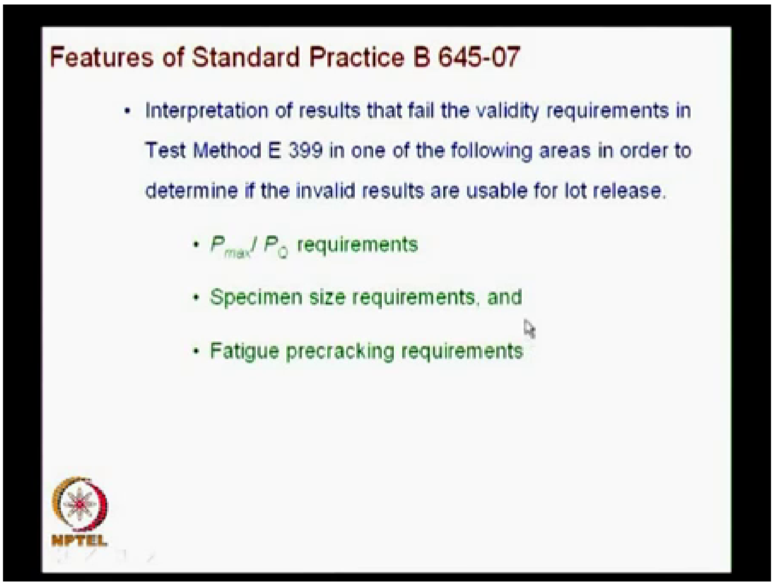

So, it is essentially like, how well a test can be salvaged? We will also see, what are the areas, if there is a fault in satisfying this P max divided by P Q requirements, what could be done? What is the specimen size requirements and fatigue pre-cracking requirements? So, if the conditions are not completely met, this provides a via media to accept some of them. It is not that, you summarily reject; is there any way you could salvage the test data?

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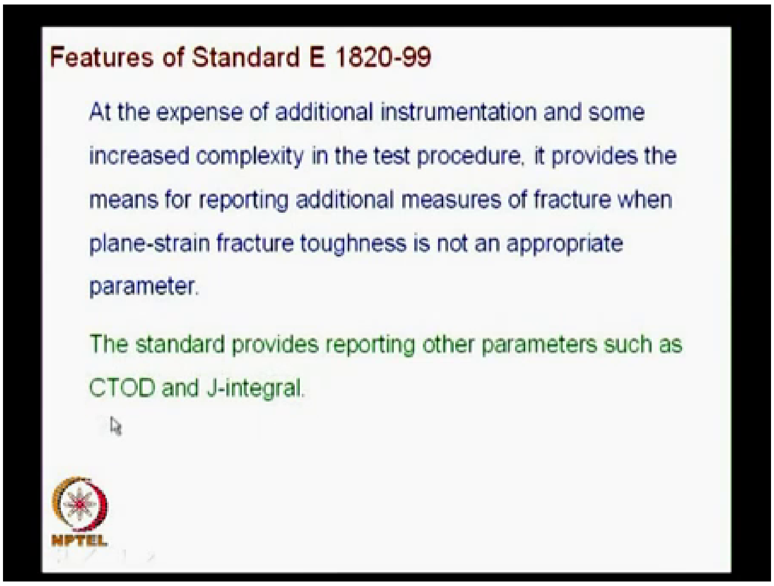

Now, we move on to features of standard E 1820-99. And what it does is, at the expense of additional instrumentation and some increased complexity in the test procedure, it provides the means for reporting additional measures of fracture, when plane-strain fracture toughness is not an appropriate parameter. See, this is mainly because, the test is expensive. If you look at, plane-strain fracture toughness tests, even by E 399, lot of procedures in comparison to a tension test. It is expensive, no doubt. But at the end of the test, if you find that your geometric parameters were not alright, you simply discard. In order to avoid that, you have to pay a price; the price you pay here is, additional instrumentation and some increased complexity in the test procedure.

We are not getting into the test procedure, but we at least know, if you want to do that, go to code E 1820. And what it does is, the standard provides reporting other parameters such as C T O D and J-integral. So, these are meant for essentially, elastoplastic fracture mechanics.

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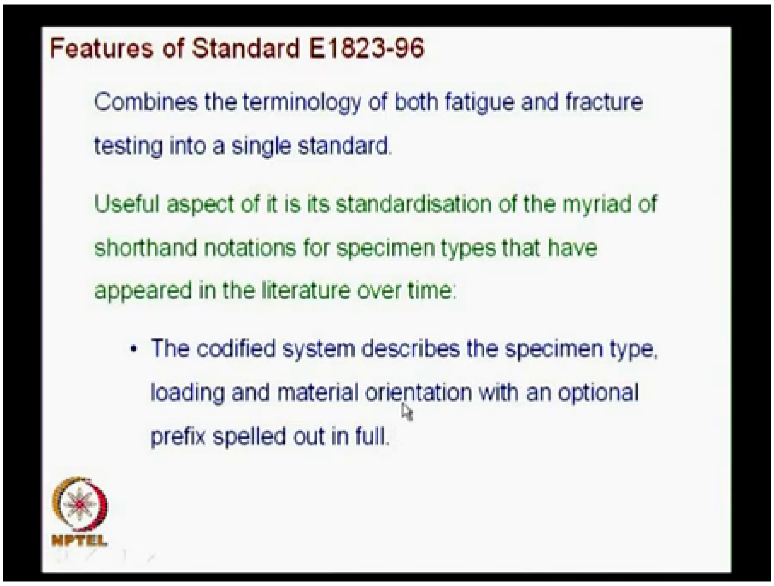

So, you do not give up; you try to get other fracture parameters from the test. And we will also see features of standard E 1823-96. This combines the terminology of both fatigue and fracture testing, into a single standard. Useful aspect of it is, its standardization of the myriad of shorthand notations for specimen types that have appeared in the literature over time. We have seen C C T, we have seen S E N, but they give a different recommendation on how to label the specimens. The codified system describes the specimen type, loading and material orientation with an optional prefix spelled out in full. You would see some examples. You see the examples, then, you will know what is the essence of this code.

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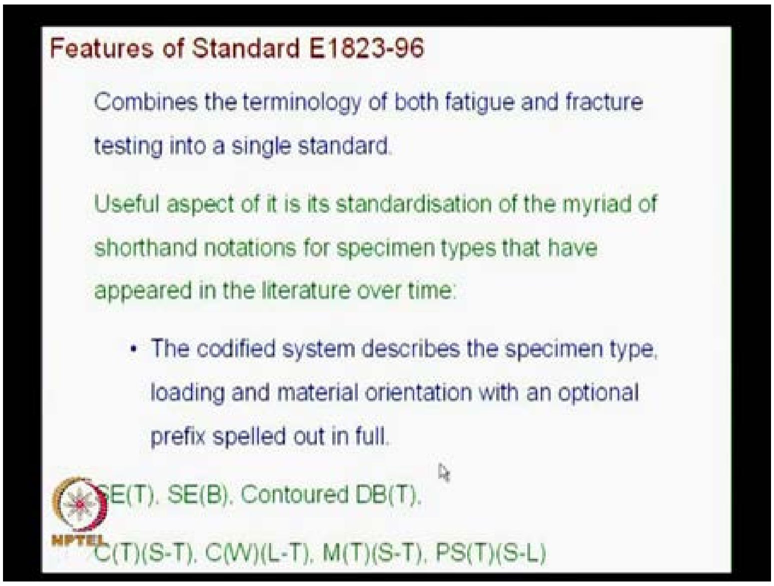

So, you will have something like S E within bracket T. So, this is nothing, but single edged specimen, with a tensile loading. When I have S E B, it is the single edged specimen with a bending loading. And you have a prefix, it is a contoured DB specimen. We have this double cantilever beam specimen; it is subjected to tension. Why it is contour? We have seen, if you want to have a constant K, you could design a specimen where the height of the specimen varies.

So, in order to denote, that you have this as contoured D B T. Not only this, they also bring in the direction of the specimen that is taken up. I have the C T specimen; you do not put it as C T; C bracket T, you put. And you also have within brackets, S hyphen T. So, this is the S T type of specimen taken out from the plate stock. And you have this C W, which is the surface crack; that is what this denotes. And you have this for L T direction. Some sample; this is a middle crack; that means, C C T specimen what you have said, said this as a middle specimen, middle crack specimen, subjected to tension. And this is part-through surface crack P S T S hyphen L. I am sorry, here it is C W is compact tension specimen, subjected to wedge loading. T denotes tensile loading; B denotes bending load; W denotes wedge loading and M denotes the middle crack; that is the center crack specimen; P S denotes the part-through surface crack.

So, this is like a sample. You know, you will have to know. Suppose, you take a paper which follows this course and then abbreviates the specimen, you should know that, you have already heard this in this course on fracture mechanics.

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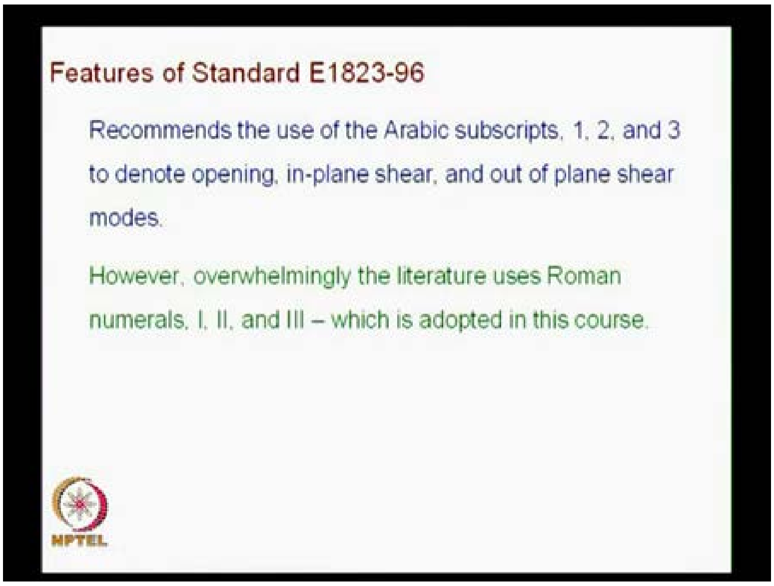

And there is also another, very interesting recommendation this code gives; no one seems to have followed it. It recommends the use of Arabic subscripts, 1, 2 and 3 to denote opening, in-plane shear and out of plane shear modes. But most books follow, Roman numerals I, II and III and which is what is adopted in this course as well.

So, in this class, what we have looked at is, we have looked at features of fracture toughness testing; essentially looked at the plane-strain fracture toughness. We have looked at the chevron notch and we have also looked at the specimen, that I had given you an idea, how an actual specimen looks like. Then, we moved on to how to measure the crack, what are the recommendations attached to it, how to measure the load and how do you report those values. Then finally, we have also looked at, from a plate stock, which way you take out the specimens. And then, we saw selected few standards that are of importance in fracture testing. There are many standards available; we have just looked at a few selected standards and also their features. Thank you.