Introduction to Materials Science and Engineering
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Lecture – 146
Fatigue

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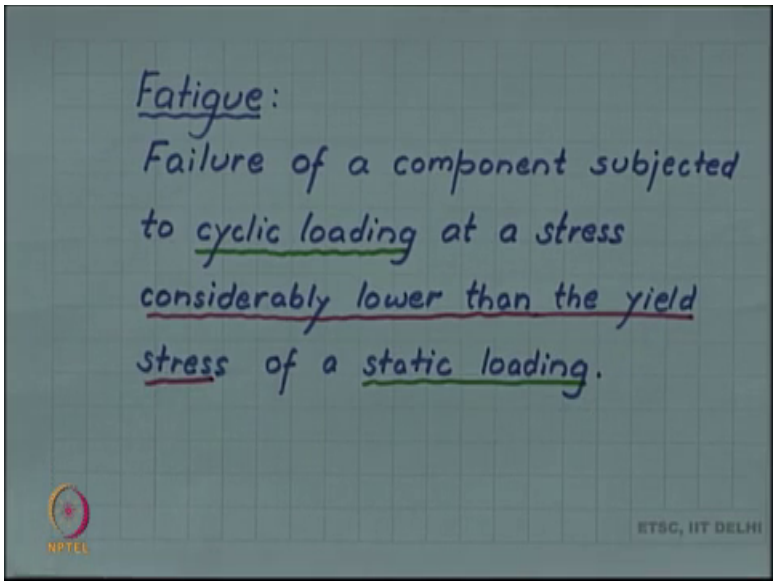

Let us discuss, a very interesting failure mechanism known as Fatigue. Fatigue is failure of a component, subjected to cyclic loading. This is important it is not a static loading, but cyclic loading in which the stress is continuously changing and it is changing in an oscillating fashion. It is going up and down. So, failure of a component subjected to cyclic loading at a stress considerably lower than the yield stress of a static loading. So, in a static loading failure happens at a yield stress, but in dynamic loading, we have failure at a stress considerably lower than the yield stress.

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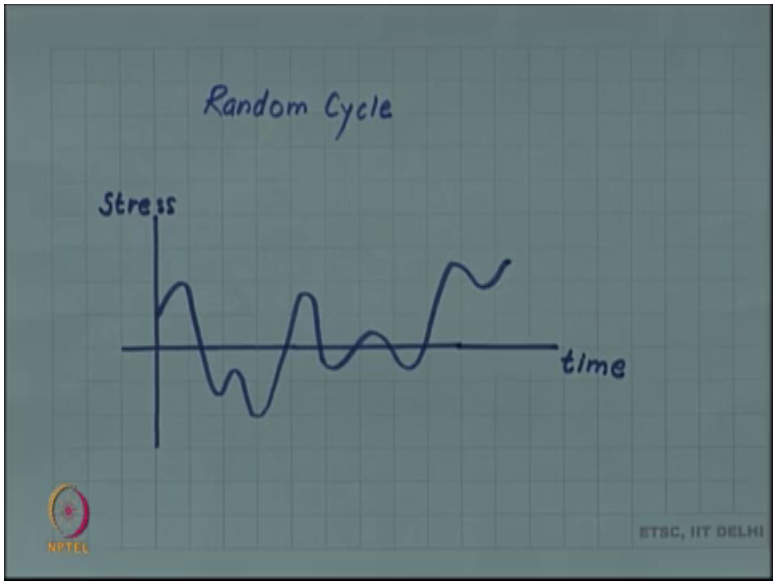

This is also important, this is the failure in cyclic loading is at a stress considerably lower than yield stress.

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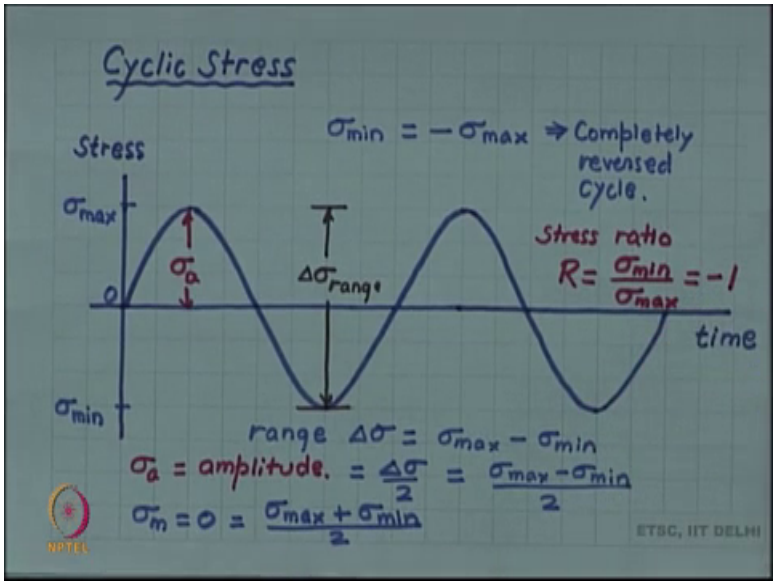

Let us look at what a cyclic stress means. Here we have a nice symmetric completely reversed cyclic loading. In which the stress varies from 0 to a maximum tensile stress sigma max and then comes down, to a minimum stress which is a compressive stress and has the same value in magnitude as sigma max.

So, if this kind of loading continues and is a sinusoidal kind of loading, then we can define several parameters like the maximum and minimum stress we have already

defined. Then, the difference between the maximum and minimum stress this total stress value, this is called the range. This is range; then the value from the mid of the range to the maximum value that is called the amplitude.

This is the amplitude and the mean value which in this case is 0, sigma mean is the mid value here. So, the amplitude we can define sigma range delta sigma, sigma max minus sigma min and amplitude will be half of the range and the min value which is 0 in this case is actually defined as the mid value of sigma max and sigma min which is sigma max plus sigma min by 2.

So, this kind of cycle where sigma min is equal in magnitude, but opposite in sign sigma max is tensile, but sigma min is compressive. So, this kind of cycle is called completely reversed cycle. One more parameter we define called the ratio R; the stress ratio which is defined as sigma min by sigma max.

So, in this case for a completely reversed cycle this will be minus 1; because sigma min being compressive is negative, but is equal in magnitude to sigma max which is tensile and so it is positive. So, the ratio becomes minus 1.

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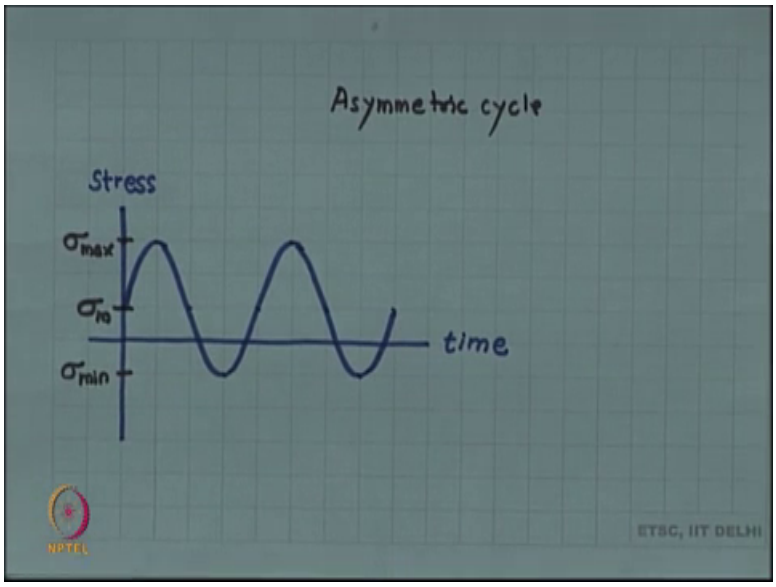

That was a completely reversed cycle. This one shows an asymmetric cycle. Asymmetric cycle where the sigma max and sigma min are not equal in magnitude and thus the mean sigma, sigma mean is also not 0, but in this case has some value.

We can also have Random Cycle shown here; which is not defined as a single sinusoidal, but has several maxima and minima varying over time.

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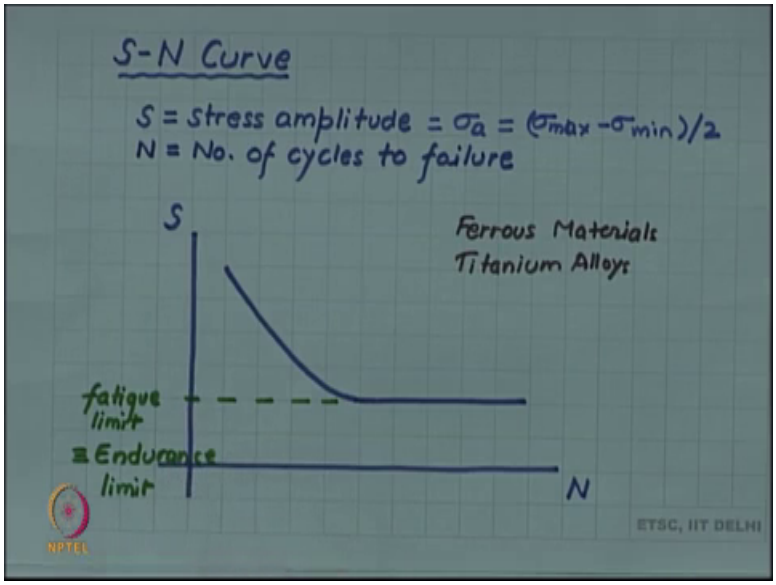

The result of fatigue test; a fatigue test is done by alternating the stress amplitude up to the failure of the component. So, S gives the stress amplitude which we had denoted by sigma a. Amplitude which is sigma max minus sigma min by 2. The result is shown as an S N curve shown here. So, S is the stress amplitude, N is the number of cycles to failure and for some kind of material, but some ferrous material, also some titanium alloys show a decreasing number of cycles decreasing life. So, the number of cycles to failure can also be called a fatigue life for that particular a stress value.

So, the life of the component keeps decreasing or rather increasing as you decrease the stress amplitude, but beyond a certain point which we are calling a fatigue limit or also known as Endurance limit. There is no further decrease; there is no failure of the component with any further decrease in the stress amplitude. So, there is no fatigue failure below the stress amplitude equal to fatigue limit.

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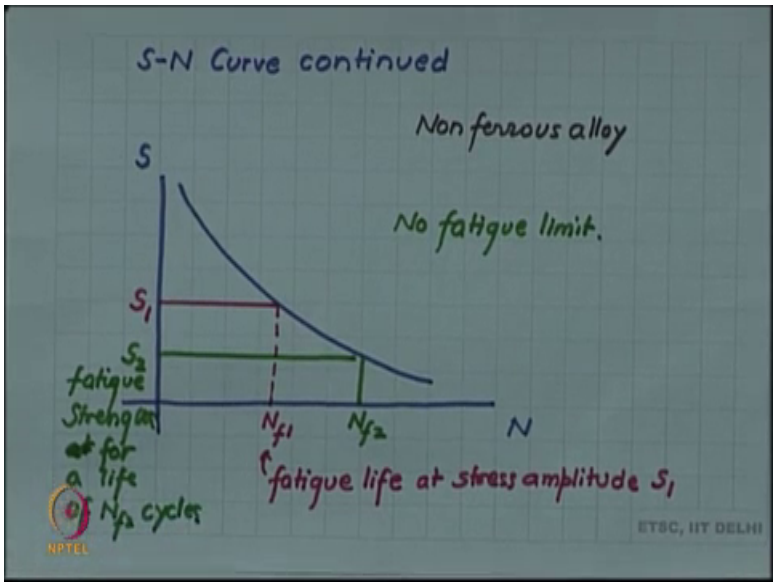

But a different kind of behavior is seen in some non ferrous material. Non ferrous alloys where there is no fatigue limit in this case.

The curve does not become horizontal there is no fatigue limit. So, no fatigue limit can be specified. So, this kind of curve is described by either you can have a specified value of stress amplitude. So, let us say that the stress amplitude S is specified to some value. Let us say S 1, then N f1 is called the fatigue life at stress amplitude S 1 or you can define a life.

Let us say N f2 and find the stress amplitude corresponding to that. In this case, this stress amplitude will be called the fatigue strength for a life of N f2 cycles.