Introduction to Materials Science and Engineering
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Lecture -131
Creep

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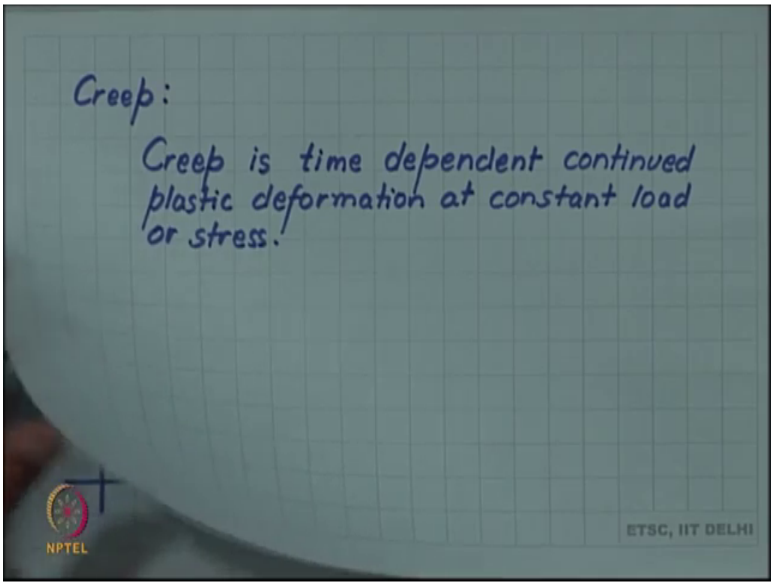

Creep:

Creep is time dependent continued plastic deformation at constant load or stress.

Today, we are going to discuss a phenomenon called Creep. It is a kind of a special kind of plastic deformation, but before we get into the detail discussion of this phenomenon, let us look at a demonstration by Shrikanth.

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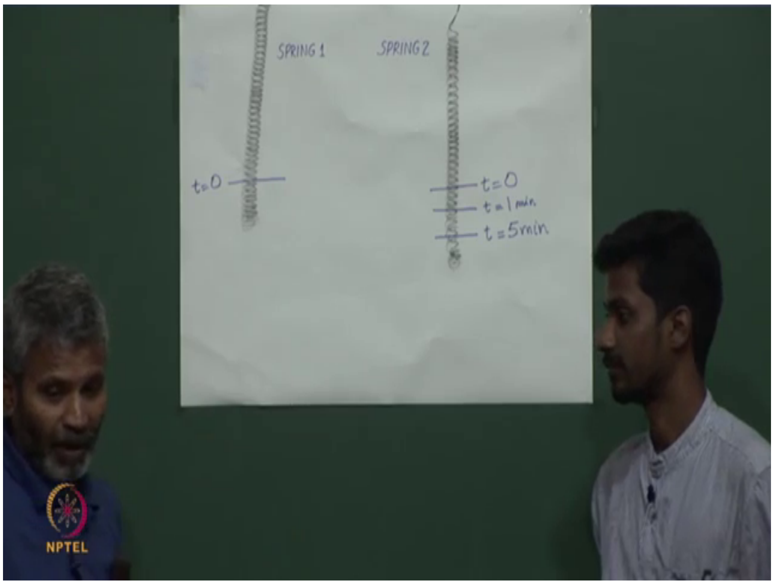

Here is Shrikanth ready with his demo. What do you have Shrikanth?

Student: I have two springs; one is already up there, the second one is with me, I will be putting it up and I will be marking the end points of both the springs.

And I think you are going to put some weights on them.

Student: No sir, I will not be putting any weights on them, we will just wait and see; what happens.

If you were not going to put any weight on them, what will happen? Nothing will happen.

Student: Let us see sir what happens.

While Shrikanth's demo is a going on, let us discuss some other interesting questions related to this phenomenon.

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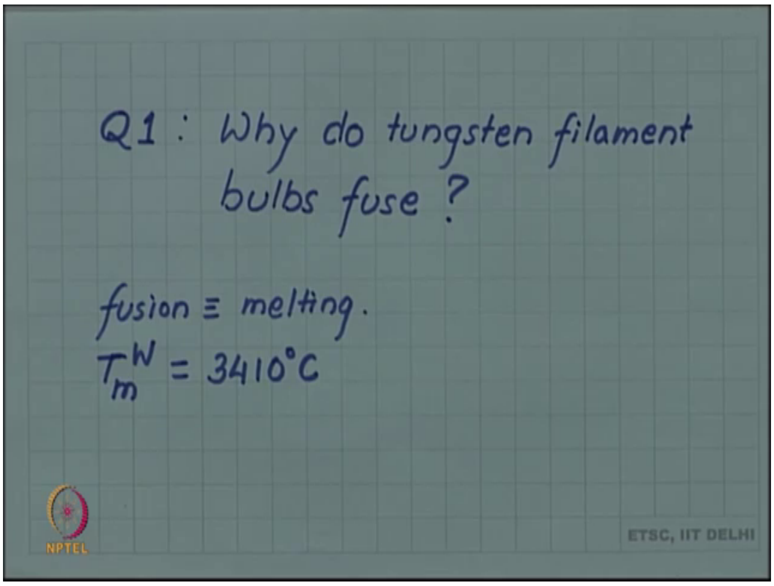

Q1 : Why do tungsten filament bulbs fuse ?

fusion ≡ melting.

$T_m^W = 3410^\circ C$

The first question is why do tungsten filament bulbs fuse? These are the old fashioned bulbs. Now going rapidly in obsolescence, you can see that there is a tungsten filament and that filament finally, comes to an end of its life and that is called that the bulb has fused. So, why do bulb fuse? Now fusion has such the meaning of fusion is melting. But does the bulb filament really melt? Filaments are made of these filaments are made of tungsten and the melting point for the tungsten is about 3410 degree Celsius that is a very high temperature and if that sort of temperature can reach in the filament that did not only filament, but many other components can also melt.

But that does not happen. So, maybe the what we call bulb fusing or filament fusing is not really melting, but simply breaking.

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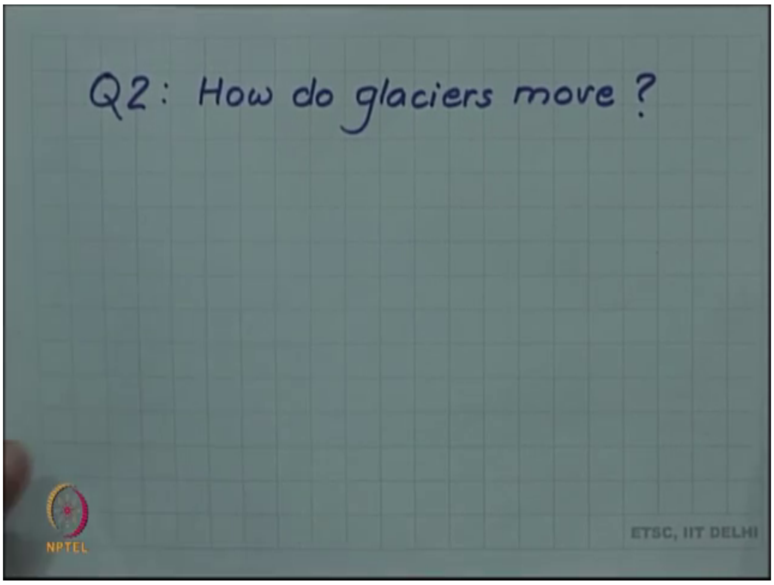

Q2: How do glaciers move?

Another question; now, we are taking this question from geology that how do glaciers move? Glaciers are huge mass of eyes which are slowly moving but is the movement just normal sliding or it is a deformation; we will look at that.

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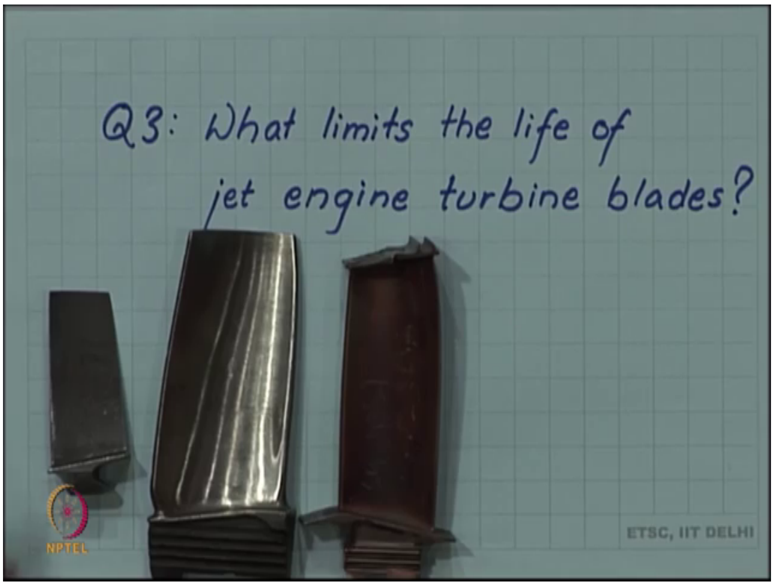

Q3: What limits the life of jet engine turbine blades?

And our final question is what limits the life of jet engine turbine blades? I have some example of turbine blades from aircrafts of Indian Air Force. You can see here, these are 3 turbine blades from different turbine of aircraft; we will look at them in detail.

But all of them have already failed and the failure involves certain deformation or certain deformation mechanism; what is that deformation? What causes the end of a blades life? So, these three questions are apparently related apparently unrelated, but they are actually related because the answer to all these questions is the phenomenon which we are going to study that is creep.

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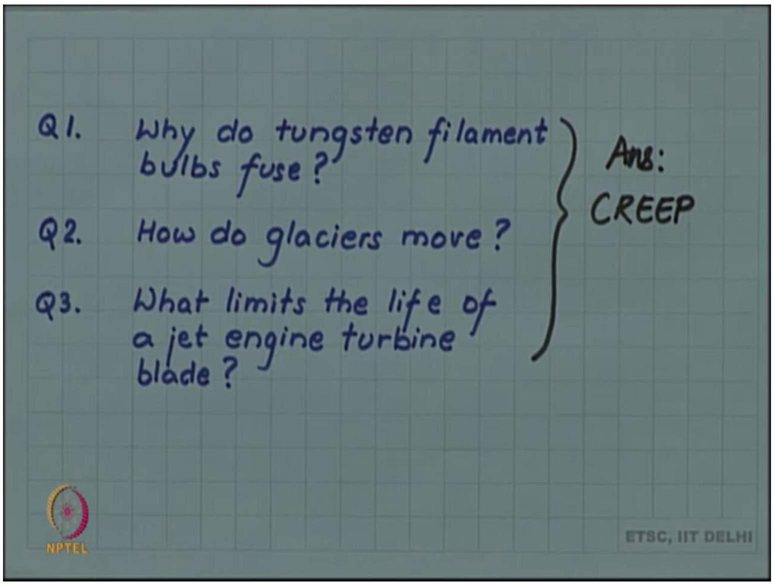

Q1. Why do tungsten filament bulbs fuse?

Q2. How do glaciers move?

Q3. What limits the life of a jet engine turbine blade?

Ans: CREEP

So, the tungsten filament bulbs fuse because the tungsten filament actually fails or breaks by creep glaciers move because it is not simple sliding of ice mass, but actually this ice or snow deforms as the glaciers move and the deformation mechanism is that of creep and the limit of the life of jet engine is also decided by the creeping of the blades. So, then what is this phenomenon of creep? So, before we answer this question, let us see how far our friend Shrikanth has progressed, yes Shrikanth, what do you have now?

Student: As you can see, spring 1 has stayed there just like you said, but spring 2 has elongated and I have been noting down its end points after certain time intervals so.

I can see it is drawing as a function of time without you increasing the load on it.

Student: Yes sir.

There is some load on it its own self weight, but beyond that; you are not putting any load and that self weight is on this spring also it is not elongating; of course, if I increase the force on it, I can elongate it also and this is elastic deformation, I think if I pull it hard enough, it may undergoes some plastic deformation also. So, I have plastically deformed it, but for deformation, I had to put an increasing load on it, but here under constant load the spring is deforming.

Student: Yes sir.

So, this is a different kind of plastic deformation than the normal plastic deformation which is spring 1 underwent when I put an extra load on it. So, as you saw in the case of that demo that one of the springs was continually deforming as a function of time although we had put no load on it. Although we had not put any external load on it, its own self weight was a still acting on it, but that self weight was constant. So, under constant load a spring 2 was continuously deforming; this kind of phenomenon is called creep. So, creep is time dependent continued plastic deformation at constant load or constant stress.

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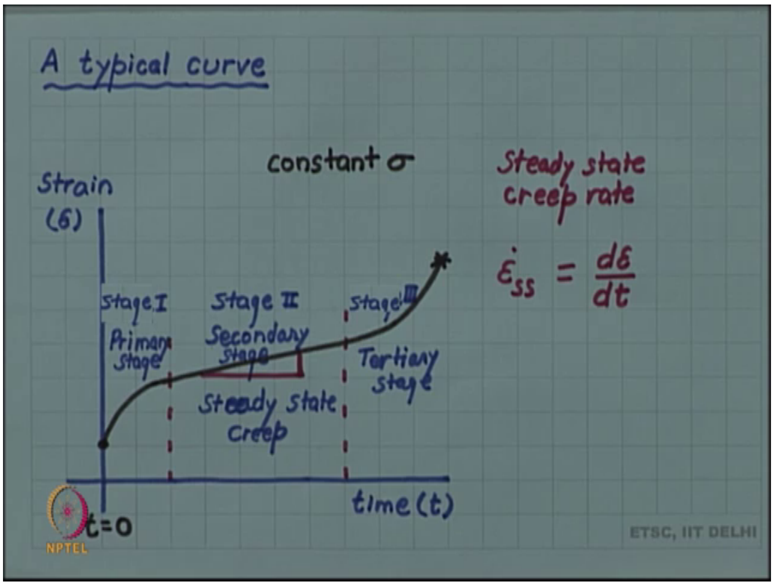

The results of creep test is usually plotted as a creep curve where we plot a strain as a function of time because we are keeping the stress constant. So, unlike the stress strain diagram which we had before constant stress we have a strain time diagram because it is a continued plastic deformation as a function of time. So, a strain is plotted as a function of time. So, if you plot a strain as a function of time, you get what is called a creep curve at time t is equal to 0, there will be some initial deformation as soon as the load, the load is put on the material after that even though load is not being increased as a function of time material starts to deform and so, the strain builds up and finally, at large enough a strain the material will break.

So, you can see here that this is the typical creep curve of a strain as a function of time with constant stress; three stages are seen here is common to divide it in three stages; stage 1, stage 2 and stage 3 let me write this. So, the first stage is stage 1. It is also called primary stage, here you can see that the creep rate was initially the strain rate of the creep curve is called the creep rate or the strain rate.

So, the strain rate is initially quite high and is gradually becoming less. So, that is stage 1, then we have a stage 2 is also called secondary creep or secondary stage and this has one because the creep rate is constant. This is also called a steady state steady state creep and finally, at the end of the steady state creep the creep rate again begins to rise and finally, leads to fracture this is called stage three or tertiary stage.

So, we have a stage 1, stage 2 and stage 3; primary, secondary or tertiary and the secondary stage also known as a steady state creep because the strain rate is constant, this constant strain rate is important in the design of creep design or creep life of material and this is called the steady state strain rate which is the slope of the curve in the steady state regime. So, this is a typical creep curve.

Now, the question is why in this case, we had a strain as a function of time whereas, in the previous plastic deformation studies which we had the stress strain curve we associated a given strain for each stress. So, their time was not one of the parameters. So, for every stress, there was a strain, but now even at a constant stress as a function of time a strain is increasing. So, what is the difference between these two kinds of behavior of material? So, one important parameter which causes this difference is the temperature.

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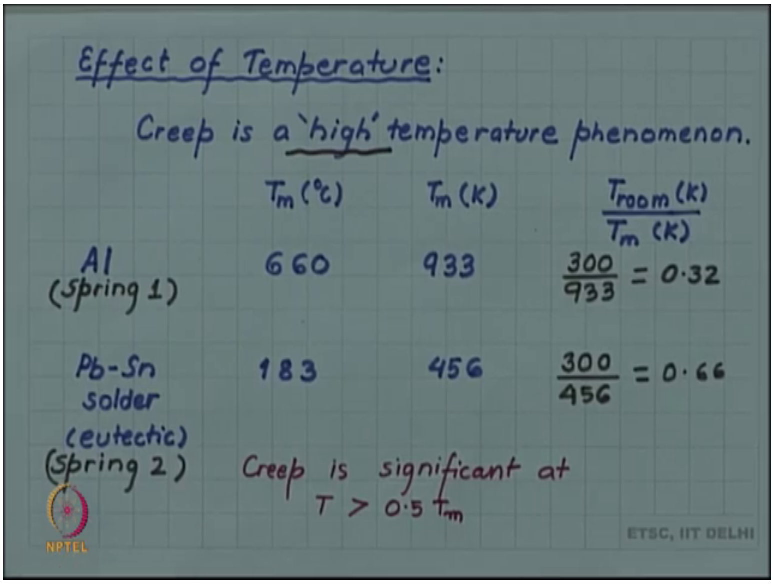

Effect of Temperature:

Creep is a 'high' temperature phenomenon.

	T_m (°C)	T_m (K)	$\frac{T_{room}(K)}{T_m(K)}$
Al (Spring 1)	660	933	$\frac{300}{933} = 0.32$
Pb-Sn solder (eutectic) (Spring 2)	183	456	$\frac{300}{456} = 0.66$

Creep is significant at $T > 0.5\ T_m$

To creep is considered to be a high temperature phenomenon and by high we mean with respect to the melting point. So, the same room temperature can be high for one material and a can be not so high for the other material. You have already seen this in the demo which you saw just now. So, one of the springs was made of aluminium. So, the spring which did not deform the spring 1 are non deforming, the spring was made of aluminium and its melting point is 660 degrees Celsius which converts to 933 Kelvin and if we take the ratio of room temperature which let us take as 300 Kelvin.

So, you get a ratio of about 0.32 whereas, for the Lectin solder wire, your spring 2 in the demo was Lectin solder wire and as you remember from your phase diagram studies that a eutectic solder has a melting point of 183 degrees Celsius. So, if you take that as the melting point and convert it into Kelvin which is 456, then the same room temperature for 300 Kelvin will now be about 0.66 for the Lectin solder wire. So, the room temperature is 66 percent of the melting point for the solder wire, whereas, it is only 32 percent of its melting point for aluminum. So, the room temperature test is a high temperature test for Lectin solder, but not so high temperature test for aluminum.

So, it is usefully seen that creep is significant creep is significant at temperature greater than about 0.5 t m.