Creep Deformation of Materials
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Part 6
Creep and different Factors That Influence Creep Deformation-Part 6.

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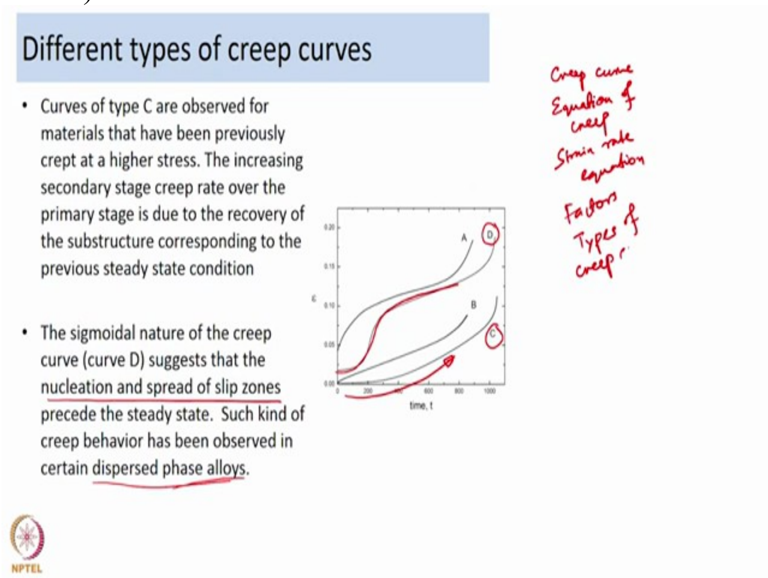

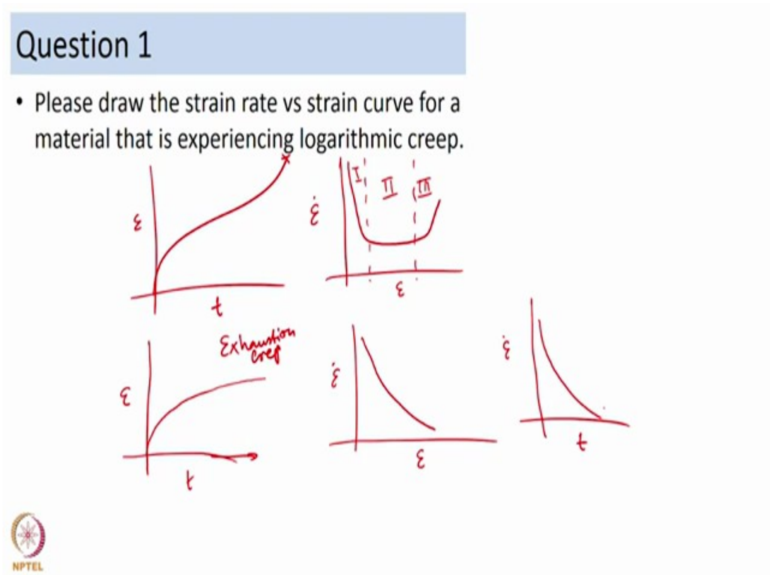

So just to summarise the portion covered in this set of lectures. So we talked about creep curve, we talked about the equation of creep, the strain rate equation, we talked about factors and also we talked about types of creep curves. So now a small tutorial on the portion that has been covered so far. So the 1st question relates to logarithmic creep. So the question is please draw the strain rate versus strain curve for a material that is experiencing logarithmic creep.

So a general creep curve, you have primary, secondary and tertiary. And if you plot the strain rate versus strain for a regular creep curve, this is how it will look like, this is the primary creep stage, secondary creep stage and tertiary creep stage. Now, in this question I am asking you to plot the strain rate versus the strain curve for a material that is experiencing logarithmic creep. So if you remember we said logarithmic creep is also known as exhaustion creep. So, in exhaustion creep, the creep strain rate of deformation continues to reduce, so it does not achieve a steady-state heat of creep in.

So the strain rate of deformation continues to decrease, it is also known as exhaustion creep. So the strain versus time will look like that, so for logarithmic creep, the strain rate versus strain curve would look something like that. So it will continue to go down in strain that as plastic deformation happens. So that is how a material that is experiencing logarithmic creep or exhaustion creep, the strain rate versus strain would look like. Alternatively, if you plot strain rate versus time, even in that case you will see something like that.

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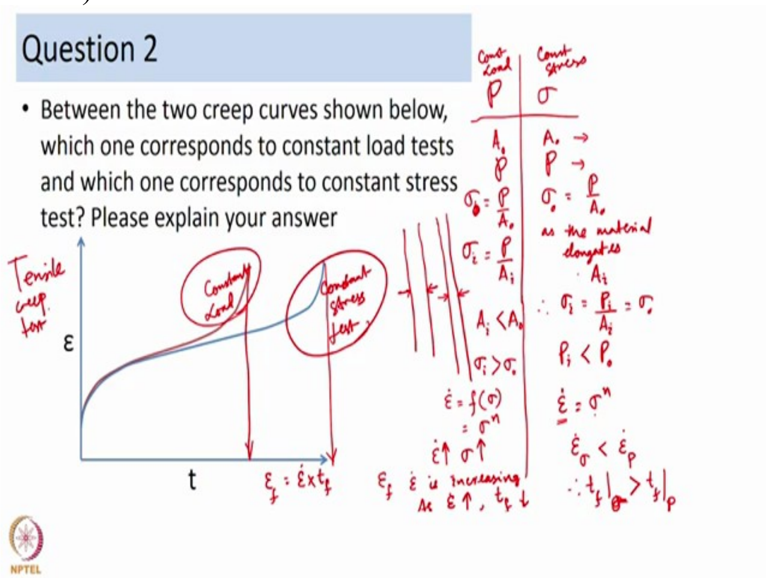

that was question 1. So now let us move to question 2. So, the question 2 is about, between the 2 curves shown below, so in this case I am showing you 2 curves, one in red and one blue. So the question is which one response to constant load tests and which one corresponds to a constant stress tests and also please explain your answer. Now what is the main difference between a constant load and constant stress test? Obviously in a constant load test, the load that you apply at the beginning of the test say P is going to stay constant till the end of the test, creep best.

Whereas in a constant stress test, the stress that you apply, Sigma is going to stay constant which means as the material starts deforming and as the cross-section down, you will also have to change the applied load accordingly, so that the stress remains constant throughout the test. So the answer to the question is, this is a constant load test and this is a constant stress test. the creep curve here corresponds to constant load, the creep curves here corresponds to a constant stress.

So the time to failure in a constant load test will be lower compared to the time to failure in a constant stress test and also the material reaches the tertiary creep region faster in a constant load as compared to a constant stress tests. So the explanation is as follows. So, you have, say the initial cross-section area was A0 in both the cases. So constant load, the applied load was P in both case and since P is going to stay constant, A0 as the material starts extending, the cross-sectional area is going to come down.

So initial stress Sigma i for a constant close low test is P over A0. And, let us call it Sigma 0, so initial stress is Sigma 0 and instantaneous stress, so stress at any point Sigma i is P over Ai. And since A i is going to be lower than A0 on account of the fact that material is extending, so Sigma i is going to be greater than Sigma 0. So what this also means is, since the stress is constantly increasing in a constant load test, the strain rate of deformation, since strain rate of deformation is a function of Sigma and say it relates to stress, so by that relation So Epsilon 0 is going to be some form of dependence on stress is Sigma to the power n.

So as Sigma increases, strain rate of deformation also increases. So as the strain rate of deformation increases, the material is going to go towards failure faster. So, for the same strain, so, if the failure strain is Epsilon and if the strain rate of deformation is increasing, so Epsilonf is equal to some strain rate into time to failure tf. As Epsilonf, Epsilon dot increases, the time to failure is going to come down. So that is what is happening in a constant load test.

Now let us look at the constant stress state condition so, tell condition, so you have A0 and the applied load is P, the initial stress acting on the, applied stress is P over A0. As the material elongates, so the cross-sectional area is going to become Ai, instantaneous stress Sigma i is equal to, so the cross-sectional area is Ai. So the instantaneous stress should have been P over Ai but because you are trying to keep it constant equal to Sigma 0, so you have to reduce the applied load. So Pi is going to be lower than the applied load P0.

So you constantly, regularly reduce the applied load so that you can keep the stress constant. And because you are reducing the applied load and keeping the stress constant, so again Epsilon dot is equal to some function of stress. So it is say Sigma to the power n. Since Sigma is constant, so Epsilon dot is going to stay constant till a point and so what happens is the time to failure rate, since Epsilon dot here in a constant stress test is going to be lower than the constant load test.

So the time to failure in a constant stress test is growing to be greater than the time to failure in a constant load test. So, this is the difference between the 2 types of creep comes, constant load as well as constant stress type of creep curve. So you are basically entering into tertiary creep lot faster in constant load test. And of course this description we are talking about tensile creep test.

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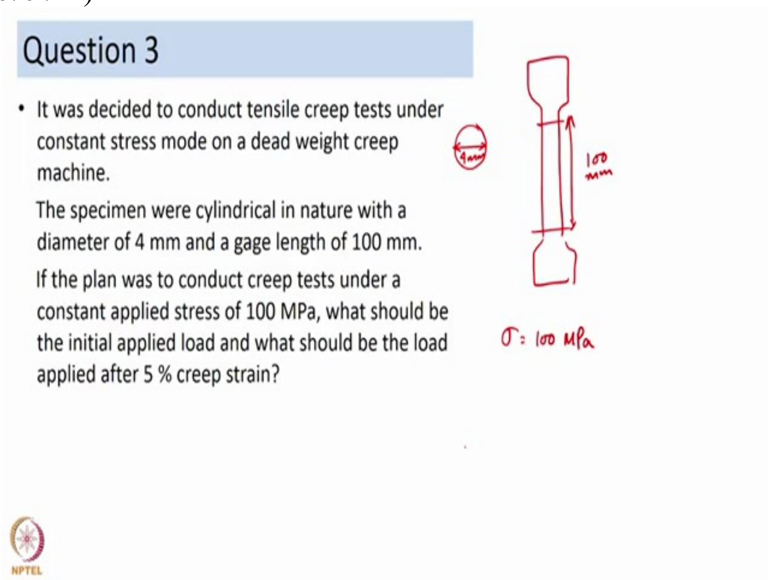

Now, let us look at question 3, now this also and so this also relates to the constant stress and constant load kind of testing. So the question is as follows. So it was decided to conduct tensile creep tests under a constant stress mode monitored bit creep machine. So the specimen were cylindrical in nature, so the cross-section is that, cylindrically nature with a diameter of 4 mm and the gauge length of, so say the gauge length was 100 mm. So if the plan was to conduct creep tests under a constant applied stress of 100 MPa, what would be the initial applied load and what should be the load applied after the material as experienced 5 percent creep strain.

The question is, initially for that cross-section of material, what should be the load applied so that your stress Sigma is equal to 100 MPa and how much would the load be after the material has experienced 5% creep strain so that the material continues to experience a constant stress of 100 MPa. So let us look at the solution.

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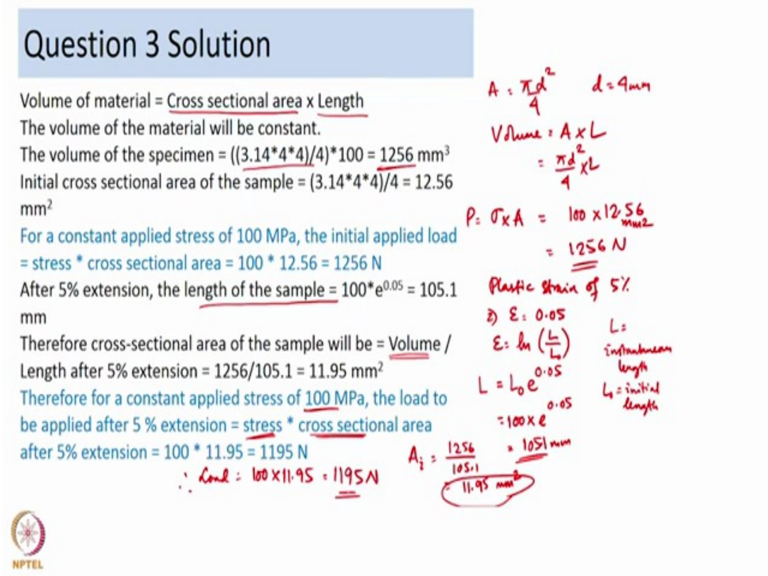

So the important thing here is to remember the volume of the material is constant and the volume of the material is basically, a product of the cross-sectional area and the length that is under our testing. So here, the cross-sectional area A is equal to pie d square by 4, so that gives you d is equal to 4 mm, so that gives you 3.14 into 4 into 4, so volume will be A into L, so that will be pie d square by 4 into length L. So essentially you get 1256 mm cube.

Now for a constant applied stress of 100 MPa, the initial applied load, so the initial applied load for the 1st bit, so the applied load should be P is equal to Sigma times, so that is 100 MPa into 12.56 millimetres square. So that makes it 1256 newtons. So with a constant applied stress of 100 MPa, the initial applied load should be 1256 newtons. Now 2nd bit, after 5 percent extension, what should be the applied load? So we are talking about a strain of 5 percent, so plastic strain, so this implies Epsilon is equal to 0.05 and plastic strain is defined as lon of L over L0.

So L is the instantaneous length of, L0 is equal to initial length. So therefore L is going to be L0 into E to the power 0.05. So the instantaneous length of the sample is going to be 100 into E to the power 0.05, that makes it 105.1 millimetres. So the instantaneous length or the length of the sample after 5 percent extension is going to be 105.1 mm. So when the material has extended in length, at that point what will be the cross-sectional area of the sample.

So by considering constant volume conditions, so the length of the cross-sectional area will be the volume divided by the length after 5 percent extension. So that is going to be 1256 divided by 105.1. So the cross-sectional area A corresponding to instantaneous length of 105.1, the cross-sectional area will be 11.95 millimetres square. Now the, since it is a constant stress test, so we are good to keep the stress constant at 100 MPa. So to keep the stress constant at 100 MPa, the load that needs to be applied after 5 percent extension is the stress into the cross-sectional area corresponding to 5 percent extension.

the cross-sectional area corresponding to 5 percent extension is given here, 11.95, so the load will be, the applied load should be 100 into 11.95. So that makes it makes it 1195 Newton. So the applied load at 5 percent extension should be 1195 Newton so that the materials continues to be in a constant stress condition. So that is the solution to this problem. Okay, now let us look at question 4 or problem 4.

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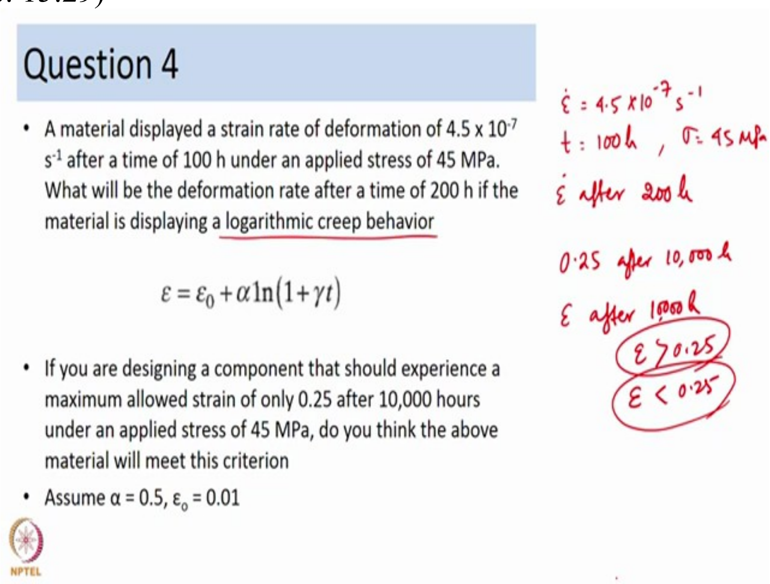

So this corresponds to, this question relates to logarithmically behaviour. So here we are talking about a material that is displaying a standard of deformation of 4.5 into 10 to the power -7 seconds after a time of 100 hours. And then applied stress of 45 MPa and the question is what will be the strain rate of deformation after 200 hours, that is part one of the question. And part 2 of the question is if you are designing a component that would experience the maximum allowed strain of only 0.25 after 10,000 hours, do you think the above material will meet this criterion or not?

So essentially the question is how much will be the strain, how much will be the creep strain after 10,000 hours. Is it going to be greater than 0.25 or is it going to be less than 0.25. If it is greater than 0.25, then obviously your product is not going to survive 10,000 hours of operation. If it is less than 0.25, then your product or your company is going to survive 10,000 hours of operation.

So basically these are the 2 parts, 1st part is find out the strain rate of deformation after 200 hours, the 2nd part is find out the plastic strain after 10,000 hours of operation and check whether it is meeting the required performance of only 0.25 plastic strain. So, we are going to solve this in the next page.

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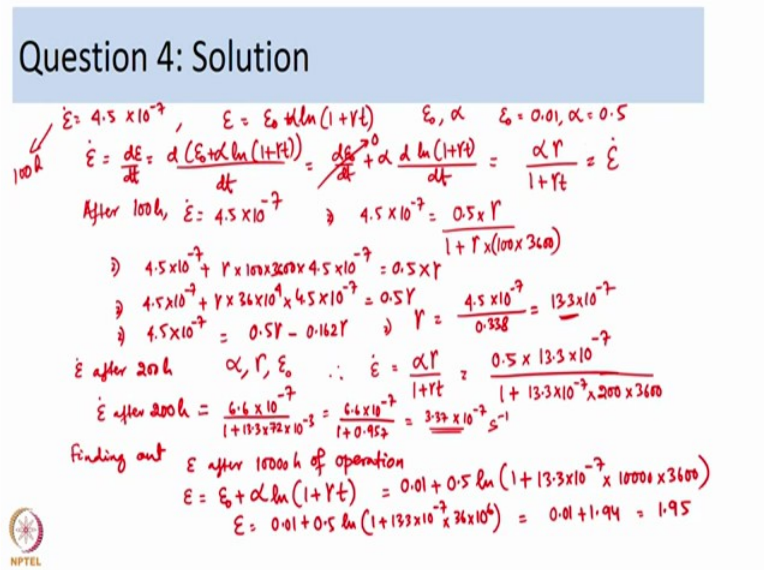

So and logarithmic creep curve is defined by Epsilon is equal to Epsilon 0+ lon Alpha lon 1+ gamma t. We have already Epsilon 0 value and alpha value, Epsilon 0 is equal to 0.01 and Alpha is equal to 0.5. So, Epsilon is equal to Epsilon 0+ Alpha lon 1+ gamma t. So the strain rate of deformation Epsilon dot is going to be d Epsilon over dt, that is equal to d of Epsilon 0+ Alpha lon 1+ gamma t over dt, that is equal to d Epsilon 0 over dt + Alpha d of lon of 1+ gamma t over dt.

This is a constant equal to 0, so that it basically comes out as alpha into gamma over 1 over 1+ gamma t. So the strain rate of deformation is given by that equation. Now, the strain rate of deformation after 100 hours is Epsilon dot is equal to 4.5 into 10 to the power -7. So this implies 4.5 into 10 to the power -7 is equal to 0.5, that is the value of Alpha into gamma, so we do not know gamma. So 0.5 into gamma divided by 1+ gamma into 100 hours, so 100 is, 100 into 3600 seconds.

So one hour is 3600 seconds, so 100 hours is 100 into 3600 seconds. So, this will give us gamma, so 4.5 into 10 to the power -7+ gamma into 100 into 3600 into 4.5 into 10 to the power -7 is equal to 0.5 into gamma. this implies 4.5 into 10 to the power -7+ gamma into 36 into 10 to the power 4 into 4.5 into 10 to the power -7 is equal to 0.5 gamma. this implies 4.5 into 10 to the power -7 is equal to 0.5 gamma -0.16 to gamma. So this implies gamma is equal to 4.5 into 10 to the power -7 divided by 0.338.

So that gives gamma as 13.3 into 10 to the power -7. So that is the value of gamma. So now, so the 1st part is find out the strain rate of deformation after 200 hours. So look at the question. So it said what will the deformation rate after a time of 200 hours, the material is displaying a logarithmic creep behaviour. So now what we have with us is, we know the value of Alpha, we know the value of gamma, we know the value of Epsilon 0.

So therefore strain rate which is equal to Alpha Gamma by 1+ gamma t, so Alpha, by 1+ gamma t is Epsilon dot. So Epsilon dot is equal to, so we know the value of Alpha, which is 0.5, we now know the value of gamma which is 13.3 into 10 to the power -7, so divided by 1+13.3 into 10 to the power -7 and time is 200 hours, so 200 into 3600. So therefore the strain rate of deformation after 200 hours is equal to 0.6 into 10 to the power - 7 divided by 1 +13.3 into 72 into 10 to the power -3.

13.3 into 72, so that is equal to 6.6 into 10 to the power -7 by 1+0.957, this is 0.6 divided by 0.957. So that is equal to 3.37 into 10 to the power -7. So the strain rate of deformation after 200 hours is 3.37 into 10 to the power -7. So if you observe the strain rate of deformation after 100 hours was 4.5 into 10 to the power -7. And the strain rate of deformation after 200 hours is 3.37 into 10 to the power -7 seconds. So the strain rate is decreasing and that is what you expect in a material that is exhibiting logarithmic creep or experiencing exhaustion creep.

So the strain rate of deformation is 3.37 into 10 to the power -7. Now let us look at the 2nd bit of the question, which was about finding out if the material is going to experience a maximum strain of only 0.25 or is it going to experience higher after 10,000 hours of operation. So basically the question is finding out Epsilon after 10,000 hours of operation. So, all that we have to do is we have to input Epsilon 0 value, Alpha value and then find out lon of 1+ gamma t.

So Epsilon, Epsilon 0 is 0.01 and alpha we know is 0.5 and lon of a 1+, we already know gamma is 13.3 into 10 to the power -7 and time is 10,000 hours, so it is 10,000 into 3600.

Therefore, Epsilon is going to be 0.01+0.5 times lon of 1+13.3 into 10 to the power -7 into 36 into 10 to the power 6. So that makes it 0.01 +1.94. So the overall it becomes 0.01+1.94, that is equal to 1.95. So that is a lot of plastic strain that the material is going to experience.

And it is clear that this value 1.94 is going to be greater than the 0.25 value that the engineer was planning on designing the component for. So the maximum strain that you wanted or streaks engineer wanted was only 0.25 but what you have found out is after 10,000 hours of operation the murderer is going to experience 1.95 plastic strain. So, clearly the above material will not meet this criterion. So the material is creeping a lot higher than what you wanted it to, so you have to discard that material.

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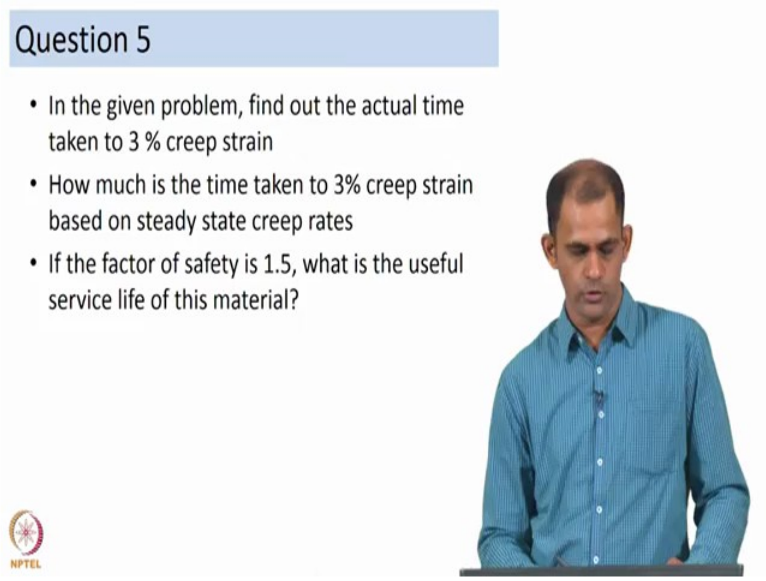

So this was about question 4 and how to use equation such as this to determine the creep behaviour of a creep state of a material. So now let us look at another question which is also similar in the sense we are going to talk about, you are trying to find out the amount of plastic deformation the material is going to experience. And here you are going to use it creep curve. So here is how the creep curve looks like. And I have given you some numbers, so it is experiencing a plastic state, so this is going to be percentage.

So it is experiencing a plastic strain of 2 percent after 20 hours and it is experiencing a plastic strain of 2.5 percent after 60 hours of operation. And it experiences around 85, 3 percent plastic strain after 85 hours of operation. So the 1st 2 if you see, this is in the steady-state creep range and 3 percent, the material is already in the tertiary creep range. And the question is, in the given problem find out the actual time taken to 3 percent creep strain. So the actual time taken to 3 percent creep strain is come, you can directly find it out from the figure.

So it is around 85 hours approximately. Now how much is the time taken to 3 percent creep strain based on steady-state creep rates. Now a lot of times, engineers tend to design their components based on the steady-state creep rates. The reason is it is, you can achieve your steady-state creep rates, typically creep experiments can last very long and by the time you go to a tertiary creep regimen failure, it may take you at least a few hundreds of hours.

And when you are trying to, if program is accelerated in recess you are trying to develop a product quickly and you want to know the behaviour of the material in quick time. You cannot wait or you cannot afford for the material to go till failure because in that process you are going to spend months of time just to get an understanding, basic understanding of the creep behaviour of the material. So typically what engineers tend to do is, they allow the material to enter into the steady-state creep range.

So once the material goes into steady-state, and you know that in the steady-state reach and the strain rate of deformation is going to stay constant for a fairly long time. So then you can use the steady-state creep rate and get an approximate idea of how much time it will take for the material to reach a certain level of plastic deformation. So that is what we are going to do in this question. So it is talking about the time taken to 3 percent creep strain based on steady-state creep rates.

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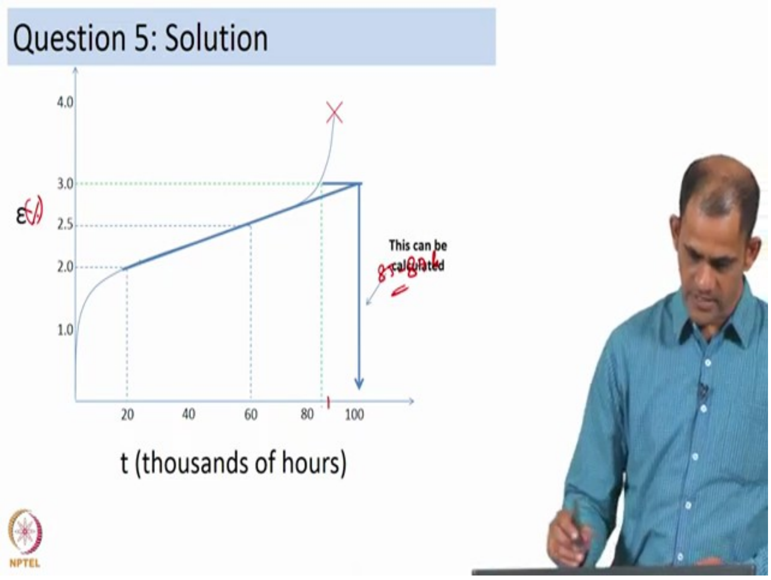

And finally if the factor of safety that the engineer has with him is 1.5, what will be the useful service life of this material? So these are the 3 bits to this question, now 1st bit is already answered. So the 1st bit is 3 percent strain, so 3 percent strain, it takes you around 85 hours, it is 85 to 87 hours. So the material reaches a plastic strain level of 3 percent in around 85 to 87 hours. On the 2nd bit is how much is the time taken to 3 percent creep strain based on steady-state creep rates.

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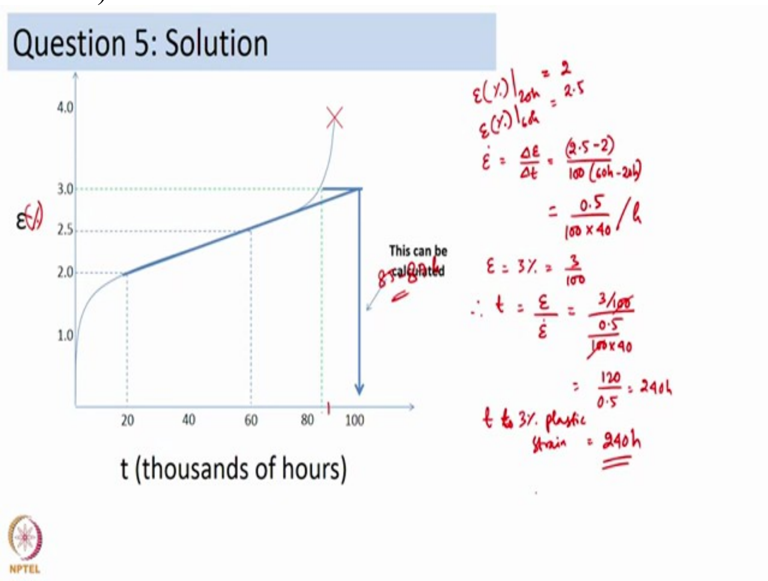

So let us now try to find out the steady-state creep rates. So, at 20 hours the plastic strain, 20 hours is 2, at 60 hours, 60 hours the plastic strain is 2.5. So the strain rate of deformation on steady-state is equal to delta Epsilon by delta t. So that becomes 2.5-2 divided by 100 and delta t is 60 hours - 20 hours. So that is equal to 0.5 divided by 100 into 40. And this is per hour basis. Now your goal is to find out how long will it take to reach 3 percent creep strain.

So your strain is 3 percent, so that is 3 by 100 and you want to know how long will it take to reach 3 percent. So the time taken to reach the person based on steady-state creep rates will be equal to the strain divided by the strain rate. So the strain is 3 over 100 and then you divide it by 0.5 by 100 into 40. So you get 240 hours. So the time taken to reach 3 percent plastic strain is equal to 240 hours. So that was part 2 of the question.

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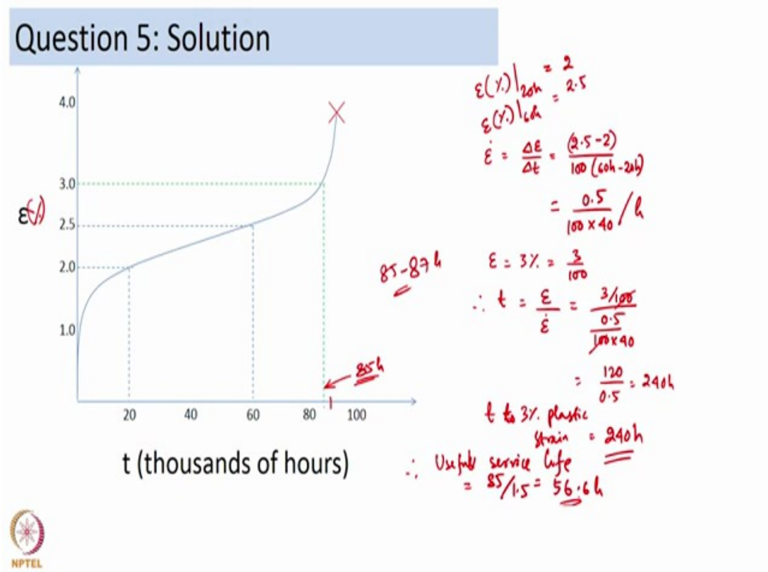

And then let us look at part 3 which is a factor of safety. So the factor of safety is 1.5, what is the useful service life of this material. So, we are talking about 3 percent creep strain, so the factor of safety we are going to use with respect to 3 percent creep strain. So if you are allowed maximum plastic deformation of 3 percent and what we see is the actual time taken is only 85 hours and says the engineer has to use a factor of safety of 1.5. So therefore the useful service life of the material is going to be 85 over 1.5.

So that will turn out to be 56.6 hours. So it is 56.6 hours assuming that the maximum allowed strain is only 3 percent. So the maximum allowed strain. (Video ends here abruptly).