**I. Question 1**

**I.1. Creep deformation**

Creep deformation is very particular behaviour of a material. This term is used to describe the permanent deformation of a material at high temperature over time, at a level of stress that would not cause any permanent deformation at room temperature. As a consequence if the strain of a material depends only on the stress at low temperature, as the temperature is raised, strain also depends on time and temperature.

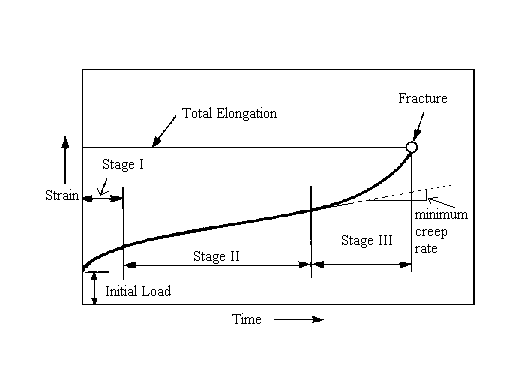
This behaviour can be summed up in a single equation:[[1]](#footnote-2)  
 (equation 1.1)

The temperature at which creep deformation can be observed also varies a lot depending on which material is considered. Indeed, temperature is considered high for a material if it is close enough to its melting point. As a general rule, creep starts when:

T>0.3 or 0.4TM for metals  
T>0.4 to 0.5TM for ceramics [[2]](#footnote-3)

For example, aluminium which has a melting point around 900°C starts to creep a 300°C but diamond which as a melting point around 3500°C will not creep before approximately 1500°C.

Furthermore, creep tests can be run on specimens in order to precisely understand their creep behaviour. A typical creep curve can be seen on figure 1.1 below.

  
Figure 1.1: A typical creep curve for metals ceramics and polymers

As it is shown on that figure, strain time-dependence is obvious. The material goes through different stages and the second one (also called the steady state) is the most important to understand the creep behaviour of a material.

Also, it is established that calculating the strain rate of a material during this regime is possible using the following equation:[[3]](#footnote-4)

(equation 1.2)

Where A, n and Q have to be found experimentally because they vary from a material to another.

**I.2. Why may a creep fracture occur at a low macroscopic failure strain compared to the tensile ductility?**

Sometimes creep fractures can happen at unexpected and low values of strain.

Indeed, if for instance a certain stress is applied on a specimen, creation of voids can occur on boundaries which lie normal to the tensile stress. Obviously, theses voids are microscopic sources of higher values of stress within the bulk of the material. As a consequence they grow quickly by diffusion processes[[4]](#footnote-5) until they link, which lead to failure quicker than predicted regarding the tensile ductility.

Ductility

Units: Dimensionless (strain)

The tensile ductility is the permanent increase in length of a tensile specimen before fracture, expressed as a fraction of the original gauge length.

**I.3. Creep experiments**

As it has been said before, the three constants A, n and Q of equation 1.2, have to be found experimentally. This is what is going to be done in this section.

Creep experiments carried out on metals samples at a constant temperature (527°C) but different applied stresses gave the following data for the steady state creep rate,:

Table 1.1: Results under constant temperature

|  |  |
| --- | --- |
| Stress, (MPa) | (s-1) |
| 100 | 4 x 10-11 |
| 200 | 1,3 x 10-9 |
| 300 | 9,7 x 10-9 |

Experiments on similar samples at constant stress (150Mpa) but at different temperatures gave the following results for the steady state creep rate,:

Table 1.2: Results under constant stress

|  |  |
| --- | --- |
| Temperature, (°C) | (s-1) |
| 527 | 3 x 10-10 |
| 652 | 1.2 x 10-8 |
| 727 | 7.9 x 10-8 |

As a reminder, the general equation established to calculate the strain rate is equation 1.2

* The constant Q is going to be calculated first:

If the data of table 1.2 is considered:

A, and n are constant. As a consequence, =

Therefore,

Numerical calculation gives three possible values (depending on which T1 or T2 are chosen) but the mean value for Q is:

Q ≈ 185 kJ mol-1

* Calculation of the constant n:

If the data of table 1.1 is considered,

A, and T are constant. As a consequence,

Therefore calculation gives a mean value for n:

n ≈ 5

* Calculation of the constant A:

Q and n have already been calculated and are now going to be used to find the numerical value or A.

So far, ≈

As a consequence, A ≈

Using the steady state creep rates values of table 1.1 and 1.2,

Table 1.3: Results of the A constant calculation

|  |  |  |  |
| --- | --- | --- | --- |
| Temperature, T (K) | Stress (MPA) | (s-1) | A |
| 800,15 | 100 | 4 x 10-11 | 4,85 x 10-39 |
| 800,15 | 200 | 1,3 x 10-9 | 4,92 x 10-39 |
| 800,15 | 300 | 9,7 x 10-9 | 4,84 x 10-39 |
| 800,15 | 150 | 3 x 10-10 | 4,78 x 10-39 |
| 925,15 | 150 | 1.2 x 10-8 | 4,46 x 10-39 |
| 1000,15 | 150 | 7.9 x 10-8 | 4,83 x 10-39 |

Which lead to a mean value for A of:

A ≈ 4.78 x 10-39

As a consequence the general expression for the dependence of the steady state creep rate on stress and temperature is:

≈ (equation 1.3)

**I.4. Estimate the time to failure of a sample**

The sample considered here is subjected to a stress of 250MPa and at a temperature of 627°C (900.15 K). Equation 1.3 is going to be used to estimate the time of failure:

Calculation gives:

≈ ≈ 8.5 x 10-8 s-1

Therefore, ≈ 8.5 x 10-8 s-1

Finally, ≈ 8.5 x 10-8 t

All the samples failed at a creep strain of 0.12. As a consequence:

t ≈ ≈ 1.4 x 106 s ≈ 16.2 days

Approximated value.

1. Engineering Materials 1, Ashby and Jones, Chapter 20 page 274 [↑](#footnote-ref-2)
2. Engineering Materials 1, Ashby and Jones, Chapter 20 page 274 [↑](#footnote-ref-3)
3. Engineering Materials 1, Ashby and Jones, Chapter 20 page 279 [↑](#footnote-ref-4)
4. The science and Engineering of Materials, D.R. Askeland, Chapter 23 page 790 [↑](#footnote-ref-5)