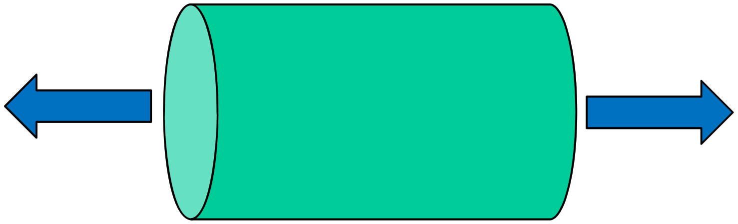
Engineering Materials MECH 390

Tutorial 2

Chapter 6
Mechanical Properties

6.4:A cylindrical specimen of a nickel alloy having an elastic modulus of 207 GPa and an original diameter of 10.2 mm will experience only elastic deformation when a tensile load of 8900 N is applied. Compute the **maximum length** of the specimen **before deformation** if the maximum allowable elongation is 0.25 mm ?



$E=207$ GPa
$D_o=10.2$ mm
$F=8900$ N with elastic zone
Compute $L_o=?$ at elongation(Δ)=0.25 mm

Ans.=475 mm

6.7:For a brass alloy, the stress at which plastic deformation begins is 345 MPa, and the modulus of elasticity is 103 GPa.

a) What is the maximum load that may be applied to a specimen with cross-sectional area of 130 mm^2 without Plastic deformation?
b) If the original specimen length is 76 mm, what is the maximum length to which it may be stretched without causing plastic deformation?

σ_y=345 MPa

E=103 GPa

A_o=130 mm^2

L_o=76 mm

Compute F_{max} and L_F without plastic deformation?

a)

$$\sigma = \frac{F}{A} \Rightarrow$$

$$\therefore F = \sigma . A$$

$$= (345 \text{ x } 10^6 \text{ N/m}^2)(130 \text{ x } 10^{-6} \text{ m}^2)$$

$$= 44{,}850 \text{ N}$$

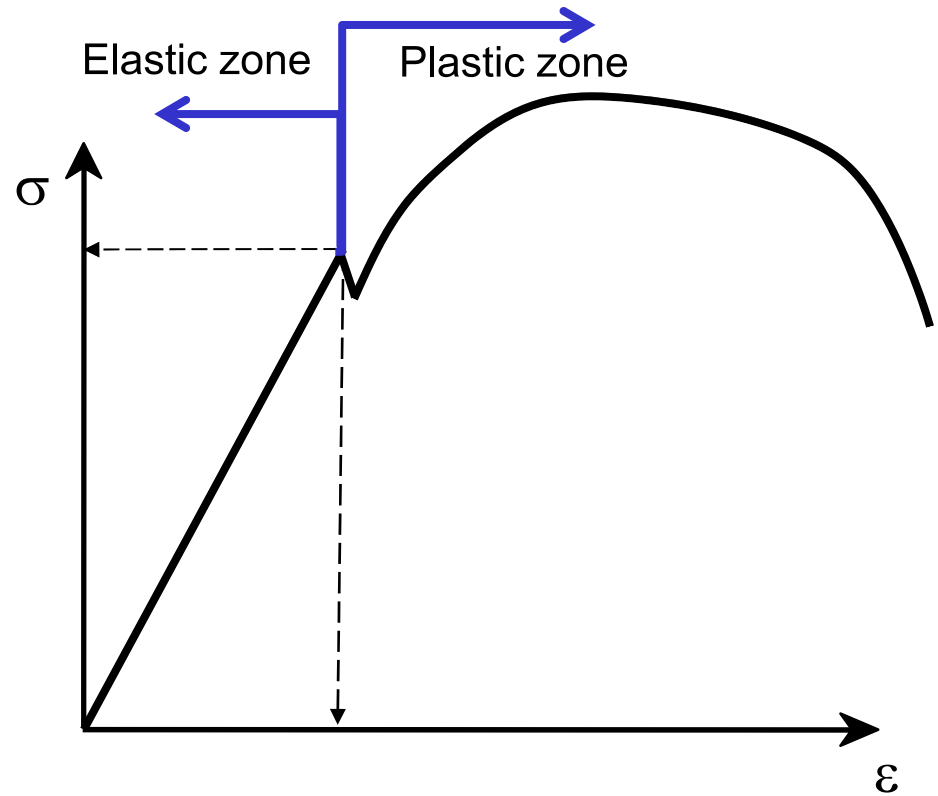
b)

$$E = \frac{\sigma}{\varepsilon} = \frac{\sigma}{\Delta L / L_o} = \frac{\sigma}{(L - L_o)/L_o} \Rightarrow$$

$$\therefore L = L_o\left(1 + \frac{\sigma}{E}\right)$$

$$= (76 \text{ mm})\left[1 + \frac{345 \text{ MPa}}{103 \text{ x } 10^3 \text{ MPa}}\right]$$

$$= 76.25 \text{ mm}$$



6.14:A cylindrical specimen of steel having a diameter of 15.2 mm and length of 250 mm is deformed elastically in tension with force of 48,900 N. Using the data contained in Table 6.1, determine the following:

a) The amount by which this specimen will elongate in the direction of the applied stress?
b) The change in diameter of the specimen.Will the diameter increase or decrease?
c) What would be the shear modulus (G)?

D_o=15.2 mm
L_o=250 mm
F=48,900 N deformed elastically
Table 6.1:E=207 GPa, ν=0.3

Compute elongation(ΔL), diameter change (Δd), shear modulus (G)?

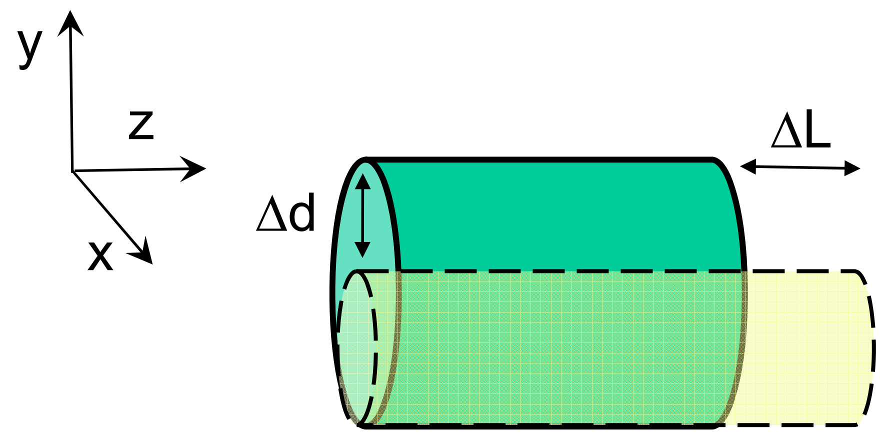
a)

$$E = \frac{\sigma}{\varepsilon} = \frac{F/A_o}{\Delta L/L_o} \Rightarrow \text{knowing that } A_o = \frac{\pi}{4}\text{d}^2$$

$$\therefore \Delta L = \frac{4F.L_o}{\pi.d^2.E} = \frac{(4)(48{,}900\ \text{N})(250 \text{ x } 10^{-3}\,\text{m})}{(\pi)(15.2 \text{ x } 10^{-3}\,\text{m})^2(207 \text{ x } 10^9\,\text{N/m}^2)}$$

$$= 3.25 \text{ x } 10^{-4} \text{ m} = 0.325 \text{ mm}$$

b)



$$\nu = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\Delta d/d_0}{\Delta l/l_0}$$

$$\Delta d = -\frac{\nu\,\Delta l\,d_0}{l_0} = -\frac{(0.30)(0.325\ \text{mm})(15.2\ \text{mm})}{250\ \text{mm}}$$

$$= -5.9 \text{ x } 10^{-3} \text{ mm}$$

The diameter will……?

c) Relation between Elastic constants is:

$E=2G(1+\nu)$

$$\therefore G = \frac{E}{2(1+\nu)} = ...?$$

Note: Poisson’s ration is always positive and less than 0.5

6.19:A brass alloy is known to have a yield strength 0f 249MPa, a tensile strength of 310 MPa, and an elastic modulus of 110 GPa. A cylindrical specimen of this alloy 15.2mm in diameter and 380mm long is stressed in tension and found to elongate 1.9mm.

•On the basis of the information given, is it possible to compute the magnitude of the load that is necessary to produce this change in length? If so, calculate the load. If not, explain why?

σ_y=249 Mpa

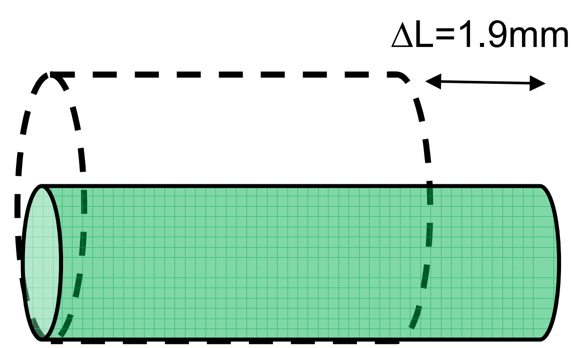
σ_{ult}=310 Mpa

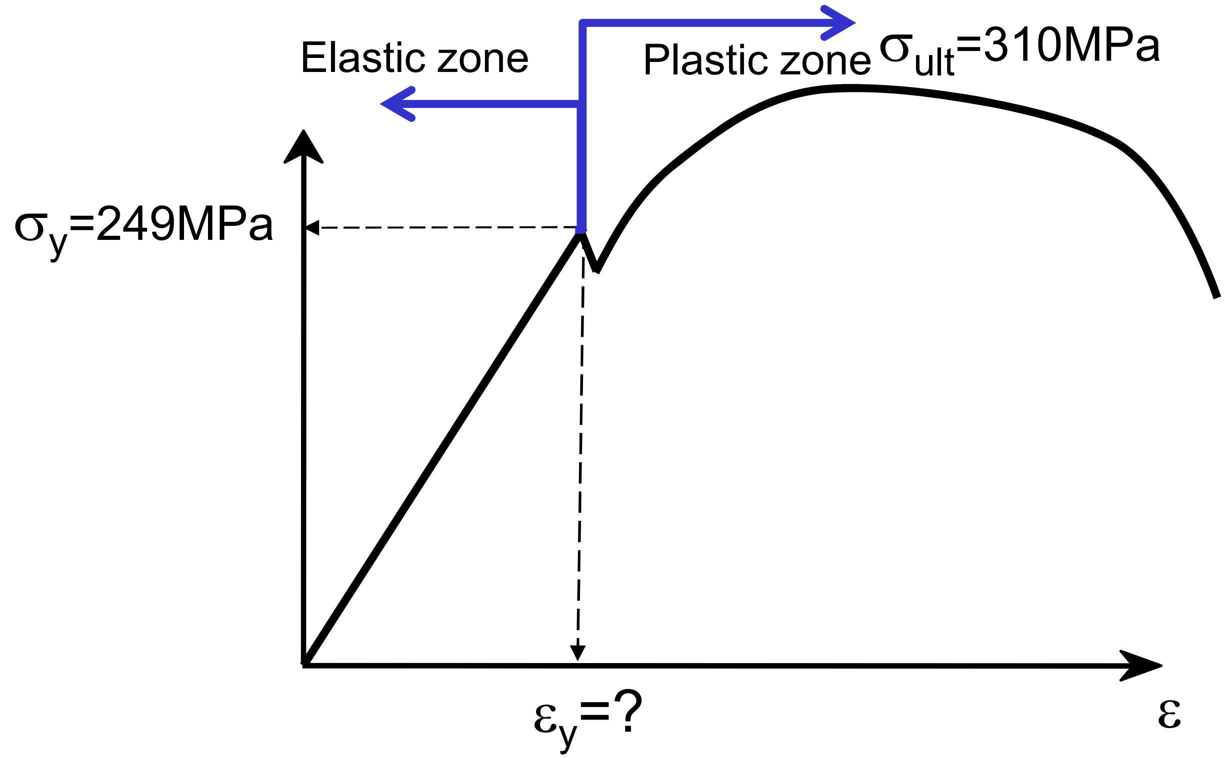
E=110 GPa

D_o=15.2 mm

L_o=380 mm

ΔL=1.9 mm





$$\varepsilon < \varepsilon_y \Rightarrow Elastic$$

$$\varepsilon > \varepsilon_y \Rightarrow Plastic$$

$$\varepsilon = \frac{\Delta l}{l_0} = \frac{1.9 \ \text{mm}}{380 \ \text{mm}} = 0.005$$

$$\varepsilon_y = \frac{\sigma_y}{E} = \frac{240 \ \text{MPa}}{110 \text{ x } 10^3 \ \text{MPa}} = 0.0022$$

Therefore, computation of the load is not possible since $\varepsilon > \varepsilon_y$

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Chapter 8
Failure of Metals

8.16:A 6.4 mm diameter cylindrical rod fabricated from a 2014-T6 aluminum alloy is subjected to reversed tension-compression load cycling along its axis. If the maximum tensile and compressive loads are +5340 N and -5340 N respectively,

- determine its fatigue life. Assume that the stress plotted in Figure 8.34 is stress amplitude ?
- If the safety factor is 1.5, what would be the fatigue life ?

D=6.4 mm

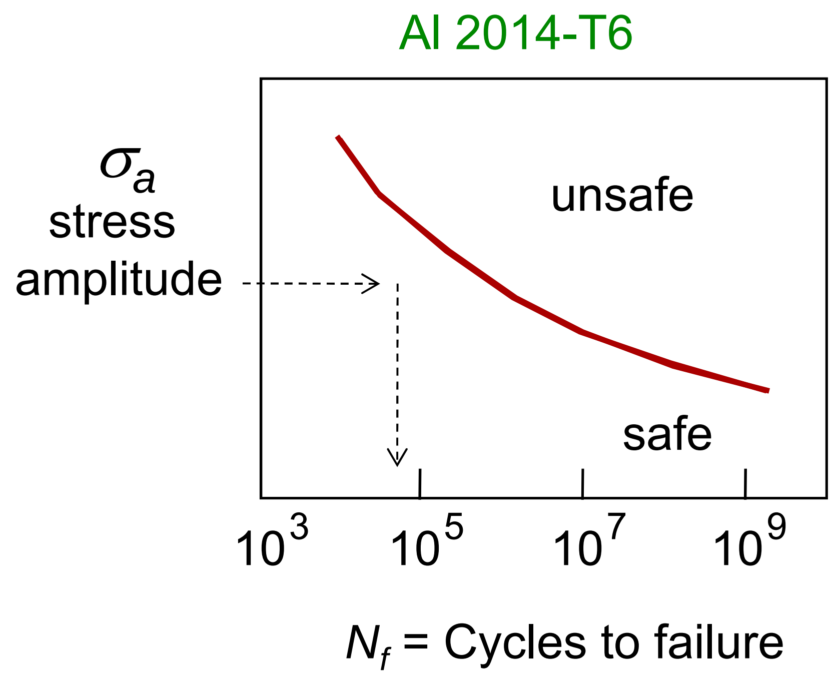
F_{max}=+5340 N

F_{min}=-5340 N

Find N_f=?

If safety factor is 1.5, Find N_f=?

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$



$$\sigma_{max} = \frac{F_{max}}{A} = \frac{F_{max}}{\pi\left(\frac{d}{2}\right)^2}$$

$$= \frac{5340 \text{ N}}{(\pi)\left(\frac{6.4 \text{ x } 10^{-3} \text{ m}}{2}\right)^2}$$

$$= 166 \text{ x } 10^6 \text{ N/m}^2 = 166 \text{ MPa}$$

$$\sigma_{min} = \frac{F_{min}}{A} = \frac{F_{min}}{\pi\left(\frac{d}{2}\right)^2} = \frac{-5340 \text{ N}}{(\pi)\left(\frac{6.4 \text{ x } 10^{-3} \text{ m}}{2}\right)^2} = -166 \text{ x } 10^6 \text{ N/m}^2 = -166 \text{ MPa}$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$

$$= \frac{166\ \text{MPa} - (-166\ \text{MPa})}{2}$$

$$= 166\ \text{MPa}$$

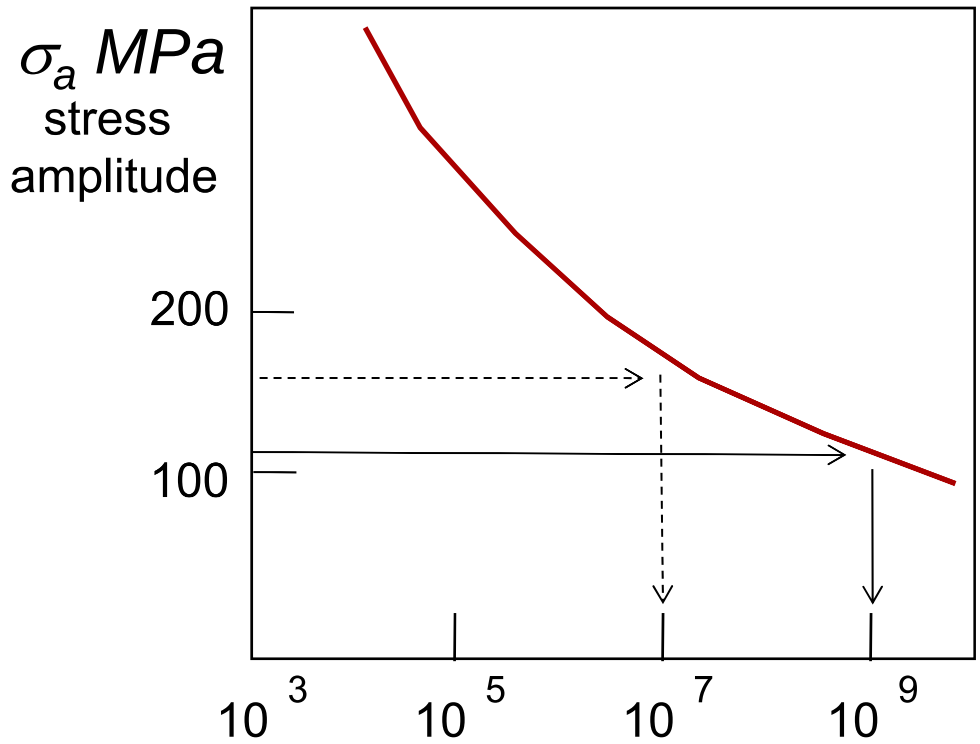
$N_f=10^7$

If safety factor is used:

$$\sigma_w = \frac{\sigma_a}{N} = \frac{166MPa}{1.5} \approx 111MPa$$

$N_f=10^9$

Al 2014-T6



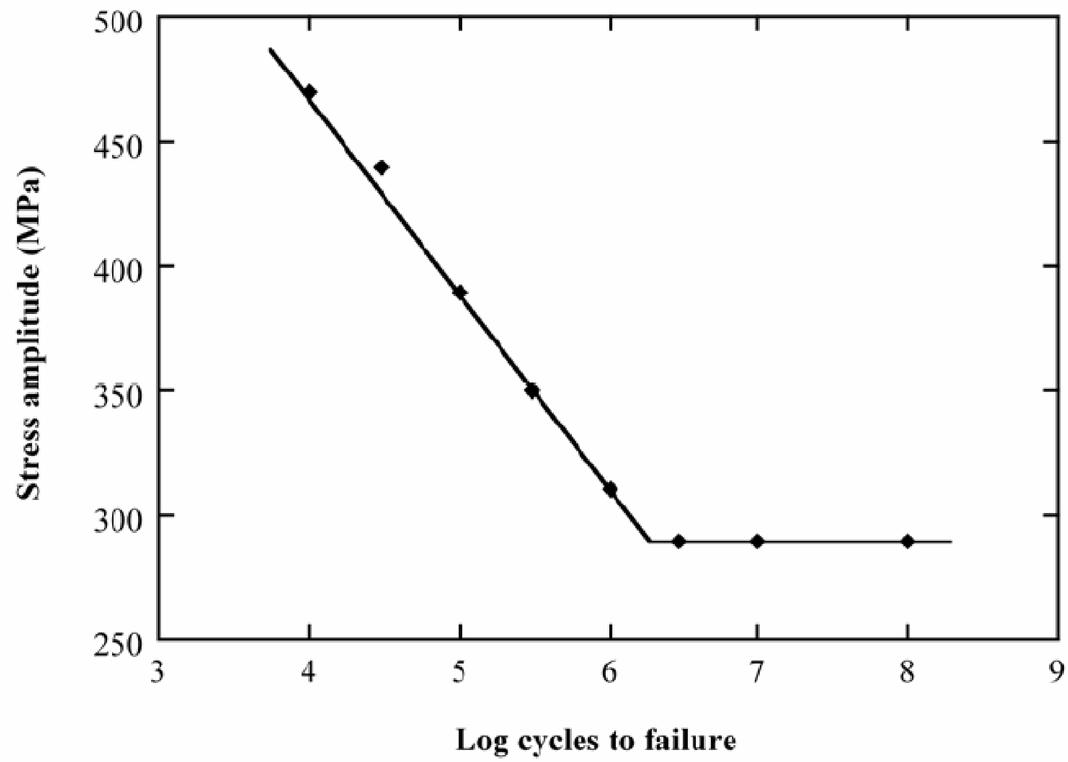
N_f = Cycles to failure

8.20:The fatigue data for a steel alloy are given as follows:

a) Make an S-N plot(stress amplitude versus logarithm cycles to failure) sing these data.
b) What is the fatigue limit for this alloy?
c) Determine fatigue life time at stress amplitude of 415 MPa and 275 MPa.
d) Estimate fatigue strength at $2*10^4$ and $6*10^5$ cycles.

Stress Amplitude MPa	Cycles to Failure
470	10^4
440	$3*10^4$
390	10^5
350	$3*10^5$
310	10^6
290	$3*10^6$
290	10^7
290	10^8

a) S-N Curve



b) Fatigue limit =290MPa

c) Fatigue lifetimes at 415 MPa is about 50,000 cycles (log *N = 4.7)*

Fatigue lifetimes at 275 MPa is ***<u>infinite</u>***

d) Fatigue strengths at 2 x 10^4 cycles (log *N = 4.30)* = *<u>440 MPa</u>*

Fatigue strengths at *6 x 10^5 cycles (log N = 5.78)* = *<u>325 MPa</u>*

8.28: A specimen 1015mm long of a low carbon-nickel alloy is to be exposed to a tensile stress of 70MPa at 427°C.

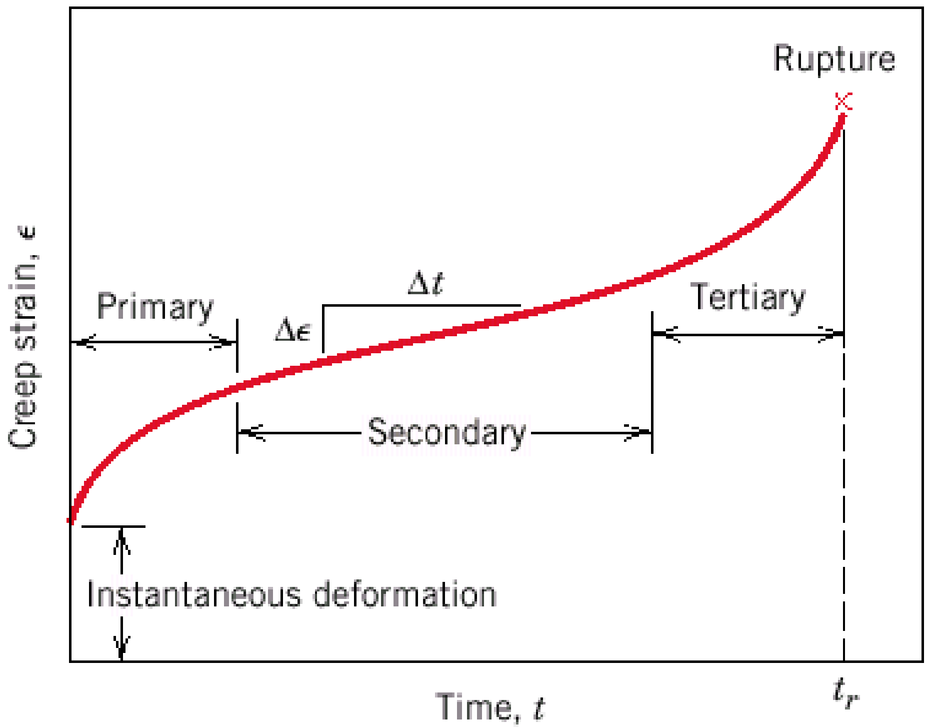
- Determine its elongation after 10,000h. Assume that the total of both instantaneous and primary creep elongation is 1.3mm.

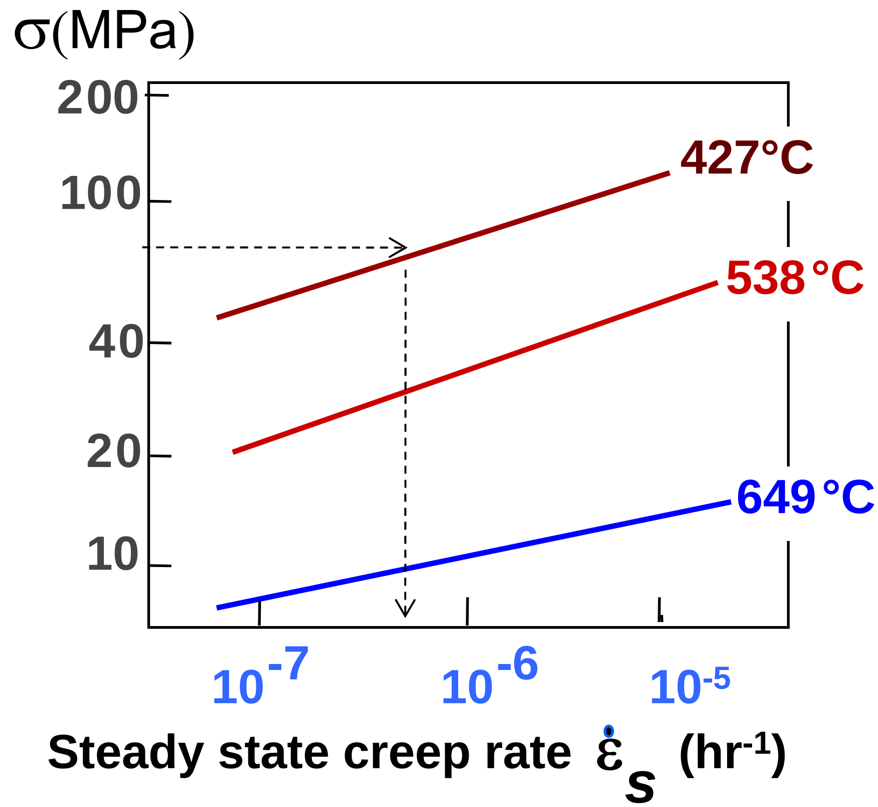
$L=1015mm$

$\sigma=70$ MPa

$T=427^oC$

Find ΔL after 10,000h?





ΔL=(Instaneneous+Primary)+Steady State (secondary)

$Steady$ state strain rate $\dot{\varepsilon}_s =$ **4.7 x 10^{-7} /h at 70MPa and 427°C**

$$\varepsilon_s^{\bullet} = \frac{\varepsilon_s}{time} \Rightarrow$$

$$\varepsilon_s = \varepsilon_s^{\bullet}.time$$

$$= 4.7 \text{ x } 10^{-7} \text{ /h} * 10{,}000\text{h}$$

$$\therefore \varepsilon_s = 4.7 \text{ x } 10^{-3}$$

$$\Delta l_s = l_0\, \varepsilon_s = (1015 \text{ mm})\left(4.7 \text{ x } 10^{-3}\right) = 4.8 \text{ mm}$$

ΔL=(Instaneneous+Primary)+Steady State (secondary)

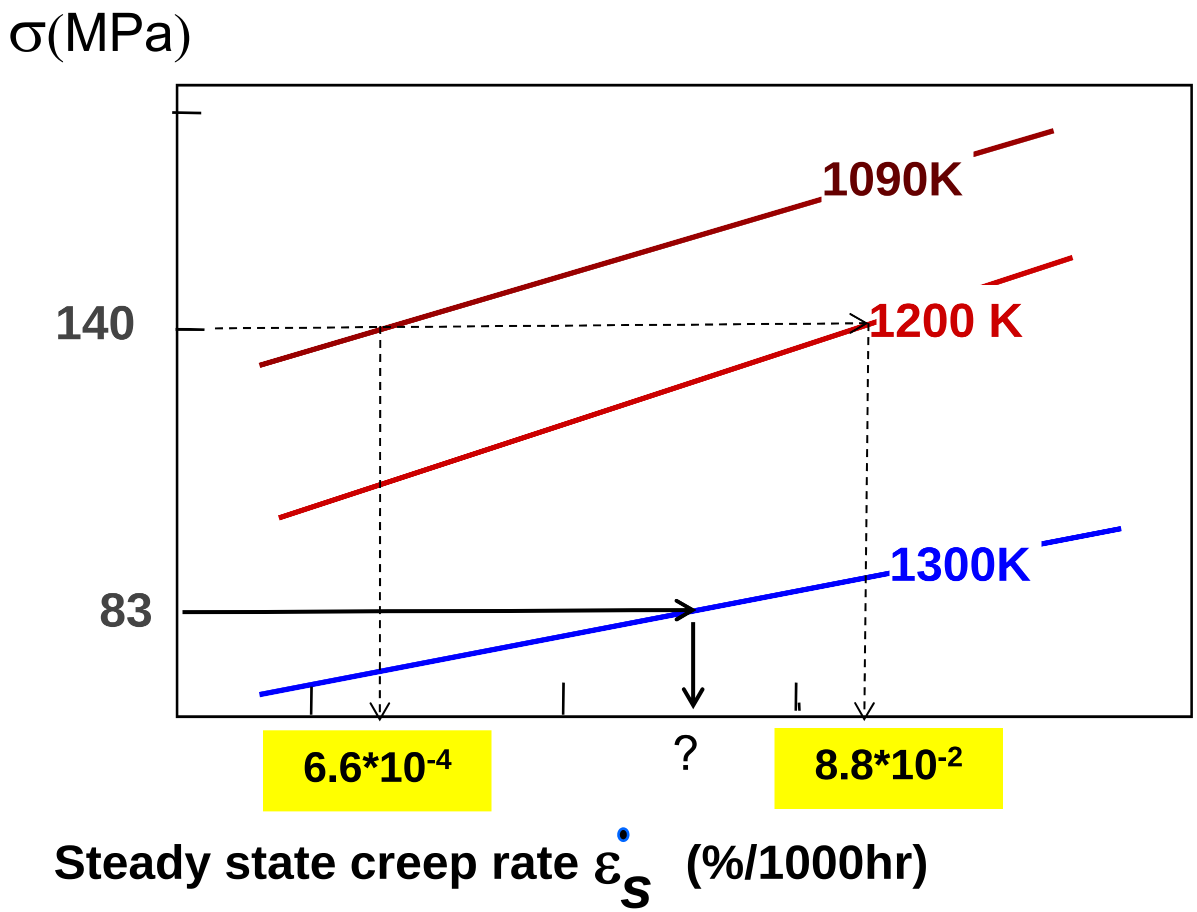
=1.3mm+4.8mm
=6.1mm

8.35: Steady-State creep data taken for an iron at a stress level of 140MPa are given below:

$\dot{\varepsilon}_s$ (h^{-1})	T(K)
$6.6*10^{-4}$	1090
$8.8*10^{-2}$	1200

- If it is known that the value of the stress component ***n*** for this alloy is 8.5, compute the Steady-State creep rate at 1300K and a stress level of 83MPa.

Find $\dot{\varepsilon}_s$ at 1300K and 83MPa


σ(MPa)
140
83
1090K
1200 K
1300K
6.6*10-4
?
8.8*10-2
Steady state creep rate ε̇s (%/1000hr)

$$\dot{\varepsilon}_s = K_2 \sigma^n \exp\left(-\frac{Q_c}{RT}\right)$$

- strain rate: $\dot{\varepsilon}_s$
- material const.: K_2
- applied stress: σ
- stress exponent (material parameter): n
- activation energy for creep (material parameter): Q_c
- Gas constant 8.31J/mol-K: R
- Temp.(K): T

K_2, Q_c, n are constant for the same material

$$\left.\begin{aligned} \ln\left(6.6 \text{ x } 10^{-4}\ \text{h}^{-1}\right) &= \ln K_2 + (8.5)\ln(140\ \text{MPa}) - \frac{Q_c}{(8.31\ \text{J/mol-K})(1090\ \text{K})} \\ \ln\left(8.8 \text{ x } 10^{-2}\ \text{h}^{-1}\right) &= \ln K_2 + (8.5)\ln(140\ \text{MPa}) - \frac{Q_c}{(8.31\ \text{J/mol-K})(1200\ \text{K})} \end{aligned}\right\} \quad \begin{aligned} K_2 &= 57.5\ \text{h}^{-1} \\ Q_c &= 483{,}500\ \text{J/mol.} \end{aligned}$$

$$\therefore \varepsilon_s^{\bullet} = \left(57.5\ \text{h}^{-1}\right)(83\ \text{MPa})^{8.5}\exp\left[-\frac{483{,}500\ \text{J/mol}}{(8.31\ \text{J/mol-K})(1300\ \text{K})}\right]$$

$$\varepsilon_s^{\bullet} = 4.31 \text{ x } 10^{-2}\ \text{h}^{-1}$$