

Master examination

„Material Science of Steel“ – Pt. I

24.02.2015

Name:

Matrikelnummer:

Signature:

Task	Maximum Points:	Points achieved:	Review: (only additional points)
1	7		
2	6		
3	6		
4	6,5		
5	5,5		
6	5		
7	6		
8	6		
9	6		
10	8		
11	3		
12	4		
13	4		
14	8		
15	6		
16	7		
17	6		
Sum	100		

75% of the final mark will be calculated from the written examination “Material Science of Steel – Pt. I” and the result of the oral examination.

The remaining 25% of the final mark can be achieved in the written examination “Steel Design”.

Task 1**tensile test****7 Points**

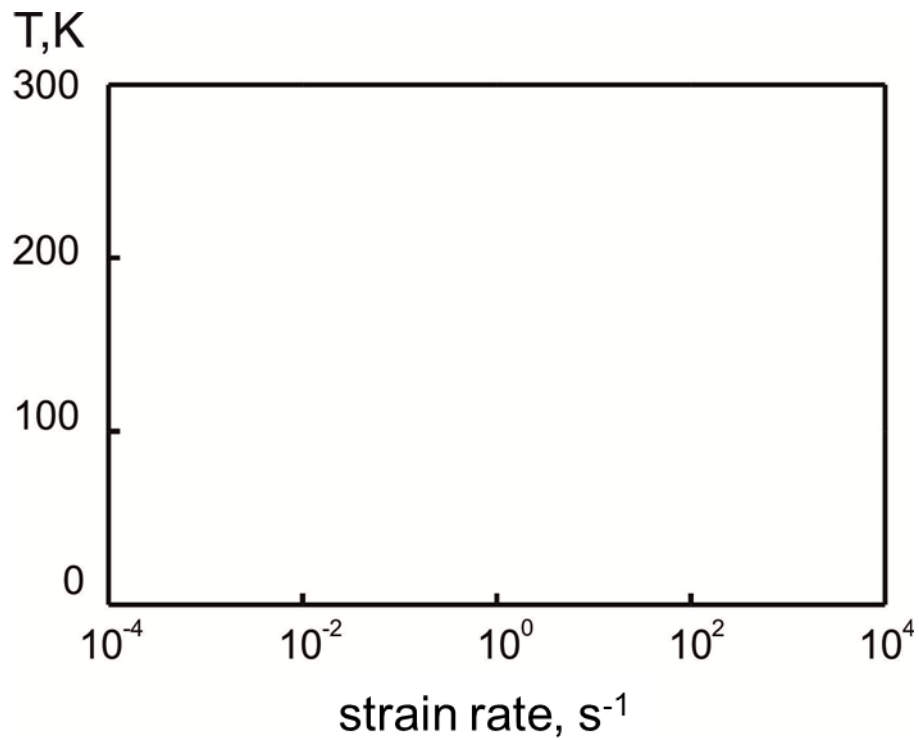
- a) Sketch the stress-strain-curve for an IF-steel and label the characteristic values. Furthermore, mark the regions of homogenous and inhomogenous deformation (*4,5 Points*).
- b) What is the maximum load that can be applied on a specimen before permanent deformation occurs? What is characteristic for this load (*2,5 Points*)?

Task 2**true stress****6 Points**

- a) Explain the qualitative difference between a conventional stress strain curve and a true stress - true strain curve (3 *Points*).
- b) Sketch a conventional stress strain curve and mark the range where the true stress and the true strain can be derived from by means of calculation. Give a reason for the range you choose (3 *Points*).

Task 3**strain rate dependency****6 Points**

The flow characteristics strongly depend on temperature and strain rate. Please fill in the characteristic areas in the prepared figure. Please also describe the characteristic phenomena of each area (6 Points).



Task 4**Bake Hardening****6,5 Points**

Bake hardening is an advanced processing technique to produce low carbon steels, used for car bodies, with high strength.

- a) Please explain bake hardening effect. Sketch the influence of BH-annealing treatment on a stress-strain-curve (*4,5 Points*).
- b) What are the advantages of this process for automotive sheet? (*2 Points*)?

Task 5**TMB****5,5 Points**

Microalloying elements influence several metallurgical phenomena during thermomechanical rolling.

- a) Which phenomena are influenced and in which way? (2 Points)

- b) Explain in keywords the mechanisms responsible for the increase of strength in a steel which is microalloyed with (1,5 Points):
 - niobium
 - vanadium!

- c) In which process steps do these alloying elements precipitate (1 Point)?

- d) Furthermore, explain how the toughness is influenced by these elements. (1 Points)

Task 6 **microstructure adjustment** **5 Points**

- a) Which methods do you know to increase the strength of metals? (2 Points)
- b) Give the equation which is used to calculate the relationship between the ferrite grain size and the yield strength? What is the name of this equation? Name all parameters in this equation. (3 Points)

Task 7 **fracture mechanisms** **6 Points**

- a) Define the terms brittle fracture, cleavage fracture, ductile fracture and slip fracture. (*4 Points*)
- b) Explain the appearance of the surface of a cleavage fracture and a slip fracture. (*2 Points*)

Task 8**Charpy impact test****6 Points**

An easy test for determination of the toughness of a component is the Charpy impact test.

- a) Plot the impact energy-temperature-curve. Indicate and name the important regions and characteristic values. *(3,0 points)*
- b) Explain the marked regions briefly. *(3,0 points)*

Task 9**fracture mechanics****6 Points**

- a) Sketch two specimens which can be used for fracture mechanics. Indicate the forces which are applied on the specimen. (3 Points)
- b) Explain one experiment from task a) in detail. (2 Points)
- c) What is the characteristic K_{IC} -value? Which unit is used for this K_{IC} -value? (1 Point)

Task 10**fatigue testing****8 Points**

The fatigue behaviour of metallic materials is commonly described using S-N curves, also known as Wöhler curves.

- a) Sketch a Wöhler curve. Label the axes and name the characteristic ranges (4,0 Points).
- b) Sketch a sinusoidal stress-time-curve with exactly two cycles. Mark the following characteristic values (σ_m , σ_a , σ_u and σ_o). Furthermore, give the equation to calculate the so-called R-Value (4,0 Points).

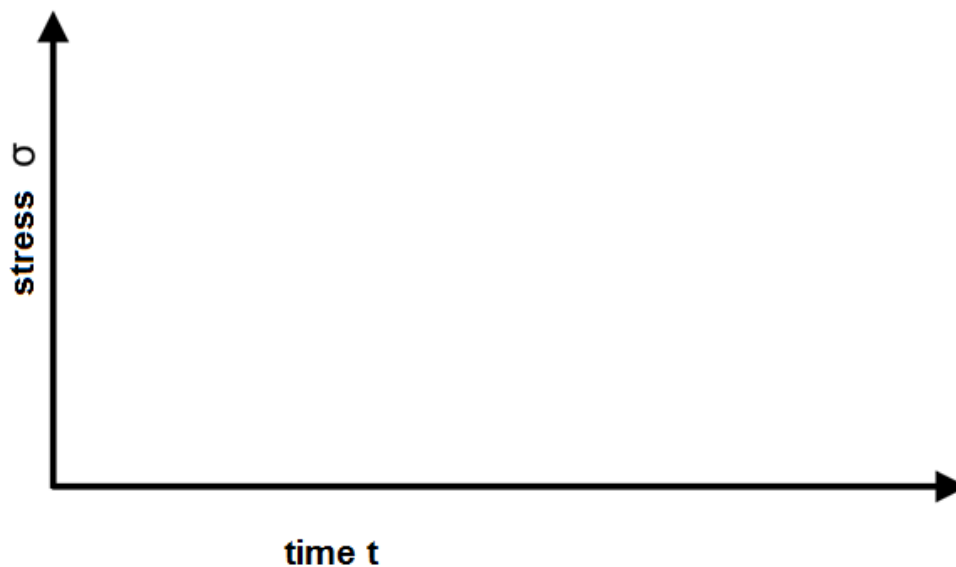


Figure 1: cyclic-loading experiment

Task 11**Bauschinger-effect****3 Points**

- a) What is the “Bauschinger-effect”? (1 Point)
- b) What is the reason for this effect? (0,5 Points)
- c) What can be done to minimize this effect (1,5 Points)?

Task 12 material behavior at high temperatures **4 Points**

The mechanical properties of steels have a high strain rate dependence at high temperatures. There is a strain rate – stress-curve given in the following diagram.

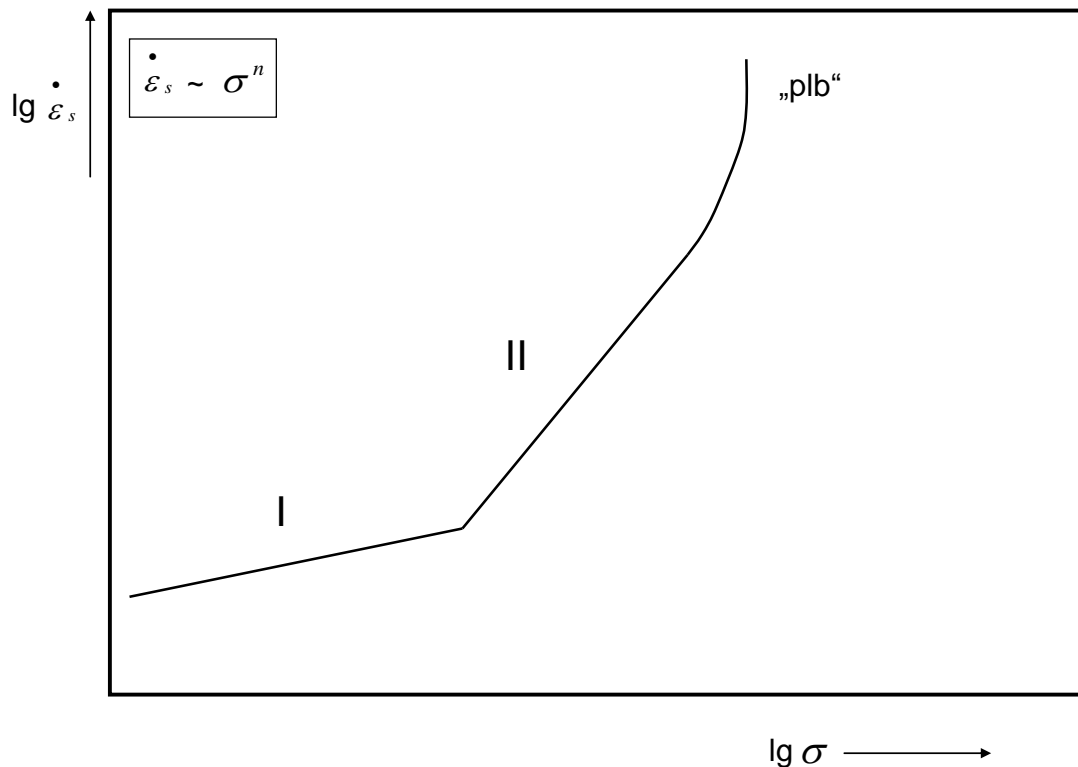
- a) Which creep mechanism is dominant in region I and II in the given figure?
(2.0 Point)

Indicate the strain rate – stress curve for a material with

- b) a larger grain size (1 Point) and
c) a lower Young's modulus (1 Point)

in the given diagram.

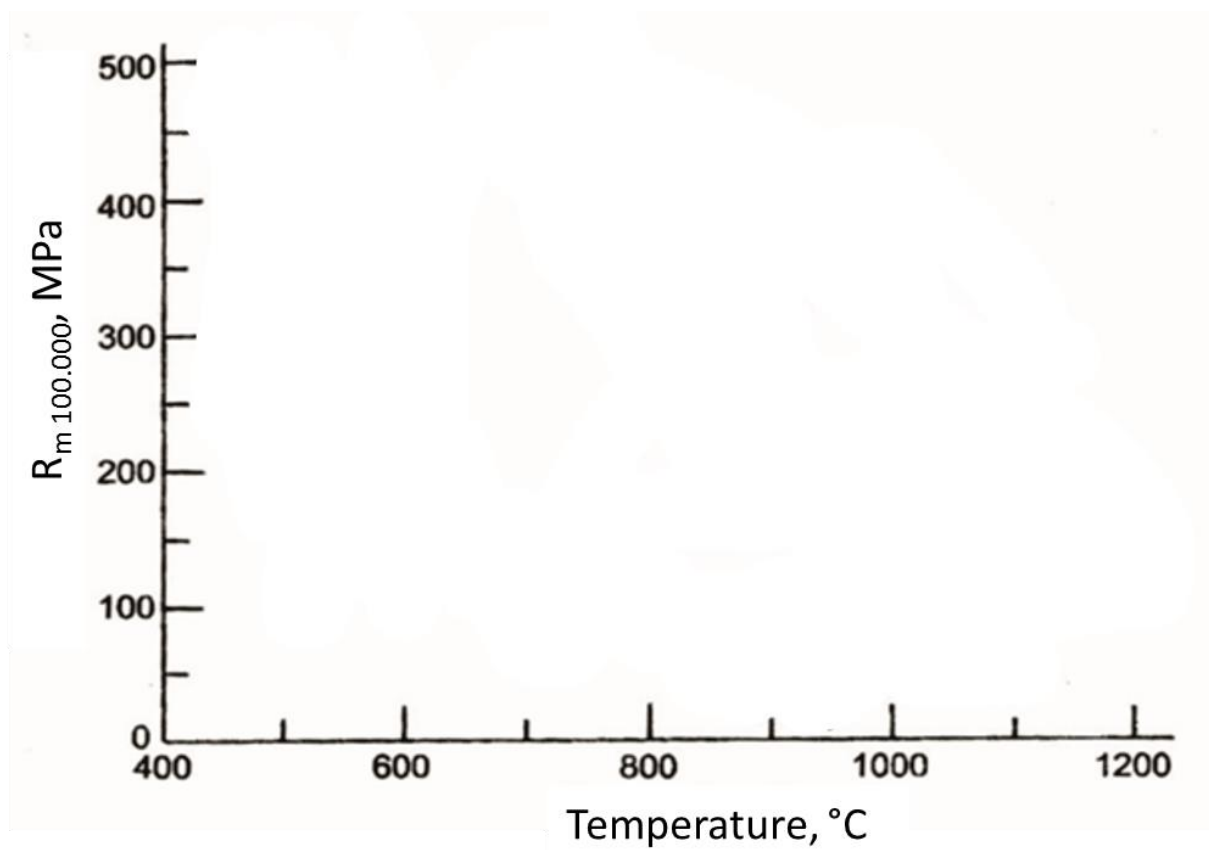
Figure 1:



Task 13 **Material behavior at high temperatures** **4 Points**

a) In the Figure given below, draw schematically the 100,000 h rupture strength for different material groups such as (3 Points):

- i. Austenitic steels
- ii. Bainitic / martensitic steels
- iii. Ni-based alloys



b) What is the maximum working temperature for bcc-steels? (1 Point)

Task 14**sheet testing I****8 Points**

- a) Name four common sheet testing methods. (2 Points)
- b) Correlate the sheet testing methods of task a) with the strain states:

$$\varepsilon_1 = -\varepsilon_2$$

$$\varepsilon_1 = -2\varepsilon_2$$

$$\varepsilon_1 = -\varepsilon_3,$$

$$\varepsilon_1 = \varepsilon_2$$

of a Forming Limit Diagram (FLD) and name the characteristic regions. (4 Points)

- c) How can the hole expansion ratio λ be determined? Please name the used variables. (2 Points)

Task 15**sheet testing II****6 Points**

The r-value represents a characteristic value for the anisotropy of a material. This value can be determined from tensile tests, using flat samples. Calculate the mean r-value for a steel which has been tested under the following conditions (6 Points):

Initial thickness $b_0 = 20$ mm

Initial length $l_0 = 100$ mm.

The following values have been measured after a homogenous deformation:

specimen orientation in relation to the rolling direction	b_1 mm	l_1 mm
0°	19,1	107,4
45°	16,6	134,8
90°	17,2	125,6

Task 16**Metallography****7 Points**

- a) In figure 1 there is a sketch (side-view) showing two ferrite grains which have been etched using nitric acid (HNO_3 – deep etching). Make such a sketch for a nitric acid etched pearlitic steel having two different orientated pearlite colonies. Label each constituent of pearlite. (4 Points)
- b) Explain how this etching leads to a contrast on the surface of the specimen. (1 Point)
- c) What is the color of each constituent of pearlite (mentioned in task b) if you were to observe them separately? (2 Points)

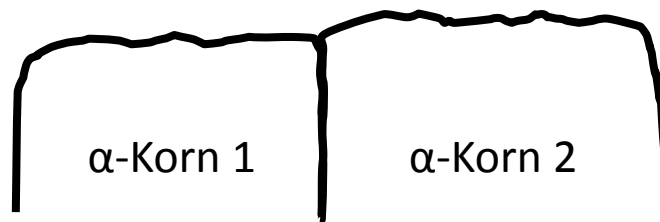


Figure 1

Task 17**electron microscopy****6 Points**

a) Which microscope should be used to perform the following tasks: (3 Points)

- Determination of the perlite fraction of an hypoeutectoid steel
- Determination of the size of NbC in a thermomechanical treated steel
- Quantification of the voids on a fracture surface

b) Which analyzing method should be used to solve the following tasks: (3 Points)

- Determination of the retained austenite fraction of a TRIP-steel
- Determination of the chemical composition for a phase of a duplex-steel