Master examination

„Part I: Materials Science“

23.03.2018

Name, first name:

Matriculation number:

Declaration: I am healthy and able to take part in the examination.

Signature:

Task	Points:	Achieved Points:	Points after review (only additional points)
1	11,5		
2	7,5		
3	9		
4	8		
5	6		
6	8		
7	10		
8	10		
9	7		
10	12		
11	5		
12	6		
Sum	100		

You need 44% to pass the examination.

Task 1 tensile testing (Kripak) 11,5 Point(s)

The tensile test is a standardised method for the characterisation of mechanical properties of metals.

a) Stress-strain curves are experimentally derived using force-time curves. Give the equations and the corresponding information of the experiment which are necessary to calculate (i) Lower yield strength (R_{eL}), (ii) Strain, (iii) Young's modulus (E), (iv) Reduction of cross sectional area after cracking. (4,5 Points)

b) Sketch a stress-strain-curve for an unalloyed structural steel with a yield strength of R_{eL} = 460 MPa for a

(i) normalized specimen using a long proportional rod and a

(ii) normalized specimen using a short proportional rod.

Explain the differences briefly. (3 Points)

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c) Explain the temperature dependency of the yield strength and the strengthening (ds/de). Sketch flow curves for different testing temperatures for i) a fcc and ii) a bcc microstructure to explain your answer. (4 Points)

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Task 2 high temperature tensile test (Kripak) 7,5 Points

a) Figure 1 and Figure 2 show the mechanical properties as a function of the testing temperature determined from several hot tensile tests for two different steels. Label both Y-Axes for both figures. Which material is more suitable for strip casting? Explain your choice briefly. (3 Points)

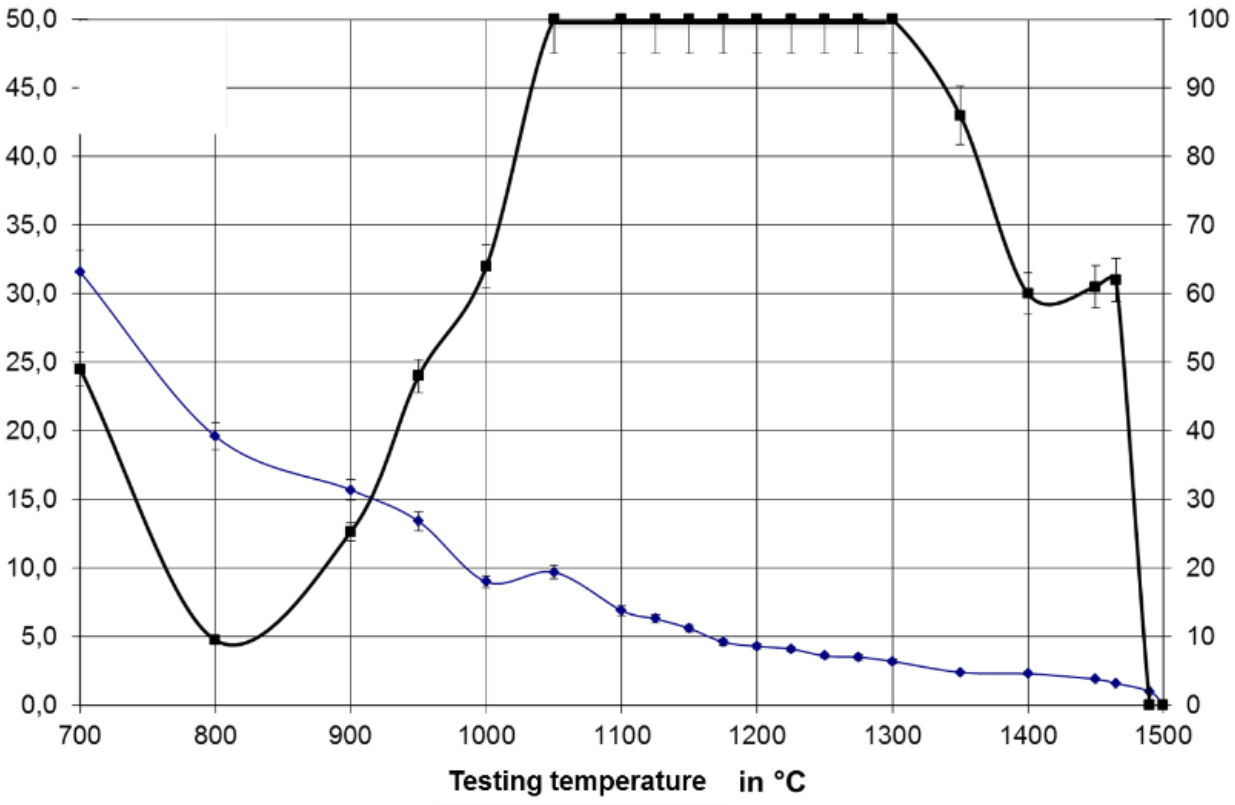

Figure 1: Material A

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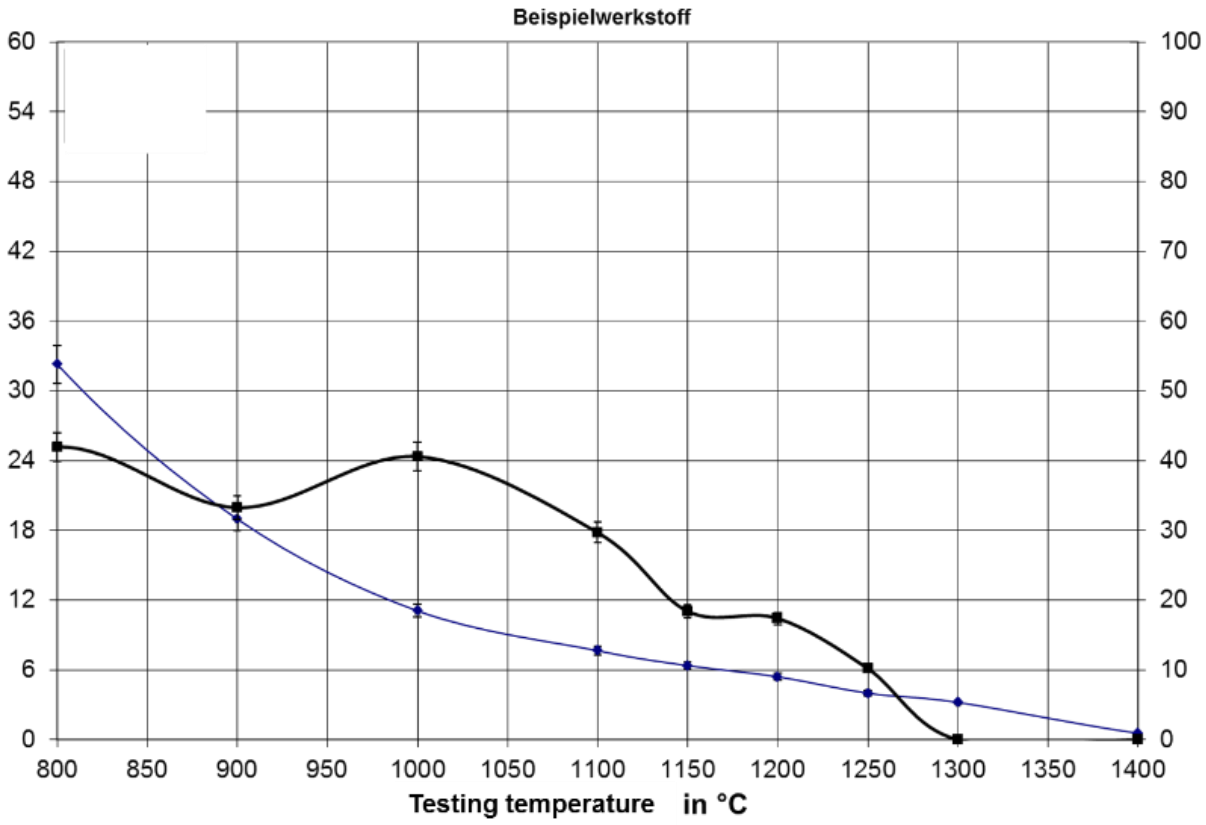

Figure 2: Material B

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b) Figure 3 shows three specimen after testing at 950°C, 1200°C and 1500°C of material A. Which specimen belongs to the previous mentioned testing temperatures? (1,5 Points)

a)  b)  c) 

Figure 3:

c) Explain the minimum of the curves at temperatures between 800 and 900°C? (1 Point)

d) What is the name of the characteristic temperatures which are at 1300°C and 1400°C for Material B? What is the consequence if the temperature difference ?T between this temperatures is too big? (2 Points)

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Task 3 strain rate dependency (Kripak) 9 Point(s)

The flow characteristics strongly depend on temperature and strain rate. **Figure 1** shows stress-strain curves for three characteristic temperature ranges.

a) For every temperature range in **figure 1** there are three stress-strain curves given. Assign the strain rates ($\dot{\varepsilon}_1 > \dot{\varepsilon}_2 > \dot{\varepsilon}_3$) to the responding stress-strain curves. (3 Points)

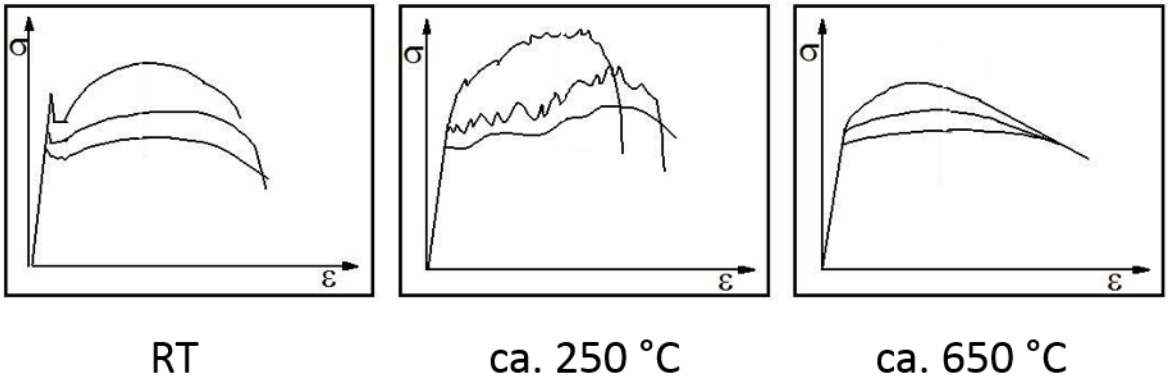

Abbildung 1/Figure1

b) What is responsible for the volatile curve progression at 250 °C? (2 Points)

c) Describe the characteristic metal physical mechanisms and phenomena during deformation at RT and ca. 650 °C. (4 Points)

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Task 4 thermomechanical treatment (Sharma) 8 Point(s)

The thermo-mechanical-treatment can be used to control the mechanical properties of hot rolled material directly during hot forming.

a) Which 4 strengthening mechanisms can be controlled due to TMT-processing? How do these affect the toughness of the steel? (5 Points)

b) Which alloying elements are used to control the processing area “no recrystallization of austenite”? What are the effects of these alloying elements? (3 Points)

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Task 5 Fracture mechanic (Novokshanov) 6 Point(s)

For the fracture mechanics safety analysis the K-Concept is established.

a) Describe the difference between the stress intensity factor K_I and the fracture toughness K_{IC}! (2 Points)

b) Explain the K-Concept with the correct formulas! (2 Points)

c) Name the established tests for characterization the toughness! (2 Points)

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Task 6 Fracture mechanisms (Novokshanov) 8 Point(s)

a) Name the material mechanical criterion for slip fracture and name the different steps of slip fracture. (4 Points)

b) Describe the macroscopic fracture appearance of slip- and cleavage fracture (2 Points)

c) Explain the difference between transcrystalline and intercrystalline crack configuration (2 Points)

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Task 7 charpy impact testing (Novokshanov) 10 Points

Charpy impact tests can be used to characterize the toughness of steels.

a) Explain the standard charpy impact test (without additional instrumentation). Consider the specimen geometry, measuring technique and further boundary conditions. (2 Points)

b) How can you measure the impact energy for a standard charpy impact test? How can you evaluate the impact energy for an “instrumented charpy impact test”? (4 Points)

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c) Sketch the measured curves from an “instrumented charpy impact test” for a very brittle and a very ductile steel in one diagram. Label the axes. (4 Points)

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Task 8 fatigue testing (Pöpperlova) 10 Point(s)

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

a) Sketch an S-N curve (Wöhler diagram) and name axes. Subsequently, plot the influence of the mean stress ($\sigma_m<0$, $\sigma_m=0$, $\sigma_m>0$) and indicate the alternate fatigue strength σ_W in the same diagram. (5 Points)

b) For fatigue testing in the elastic-plastic region, a nonlinear correlation between stress and strain occurs for non-notched specimens. Sketch a (i) stabilized hysteresis loop and a (ii) corresponding cyclic stress-strain curve. How can the cyclic stress-strain curve be determined? (5 Points)

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Task 9 high temperature properties (Sharma) 7 Point(s)

a) What is the difference between solid solution strengthening at room temperature and that at elevated temperatures (~600 °C) in terms of the characteristics of alloying elements (size)? (1 Point)

b) Which elements are preferred for solid solution strengthening of steel at room temperature? Name at least two! (1 Point)

c) Which elements are preferred for solid solution strengthening of steel at elevated temperatures (~ 600 °C) Name at least two! (1 Point)

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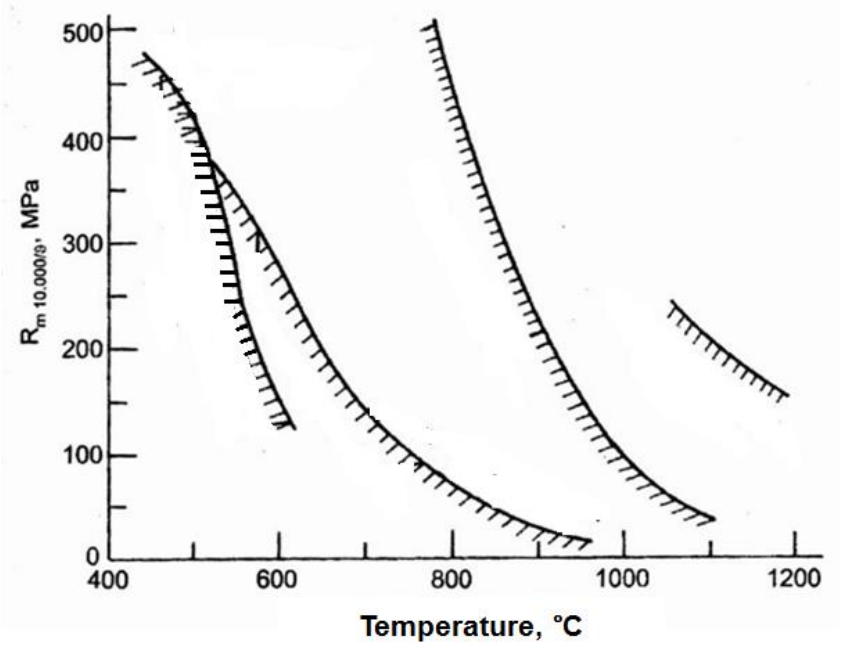
d) Place the four alloys (i-iv) to the corresponding creep strength curves in figure 1! (2 Points)

i. Ni-base alloys

ii. Bainitic /martensitic steels

iii. High-melting alloys

iv. Austenitic steels (2 Points).



Abbildung/Figure 1

e) In modern boiler tubes, 9 wt.% Cr is used to adjust a martensitic microstructure. Name two possibilities to stabilize the microstructure against creep! (2 Points)

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Task 10 sheet testing (Wesselmecking) 12 Point(s)

For sheet materials, different test methods are used to examine materials under different stress and strain conditions.

a) Please sketch the sample geometry of a Nakajima sample and describe how you would adjust the sample geometry to study different minor deformations degrees. How does the minor deformation degree change as a result of the adjustments you have made in the sample geometry? (3 Points)

b) Draw an exemplary forming limit diagram. Show the area of minor deformation degrees in which the Nakajima attempt is valid. (2 Points)

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c) What is the ratio of major to minor deformation degree during the Bulge Test? (1 Point)

d) How is the draw ratio defined for the cupping test? (1 Point)

e) Draw a typical result diagram of the cupping test! Which two parameters are varied? In which three areas can the test results be classified? (5 Points)

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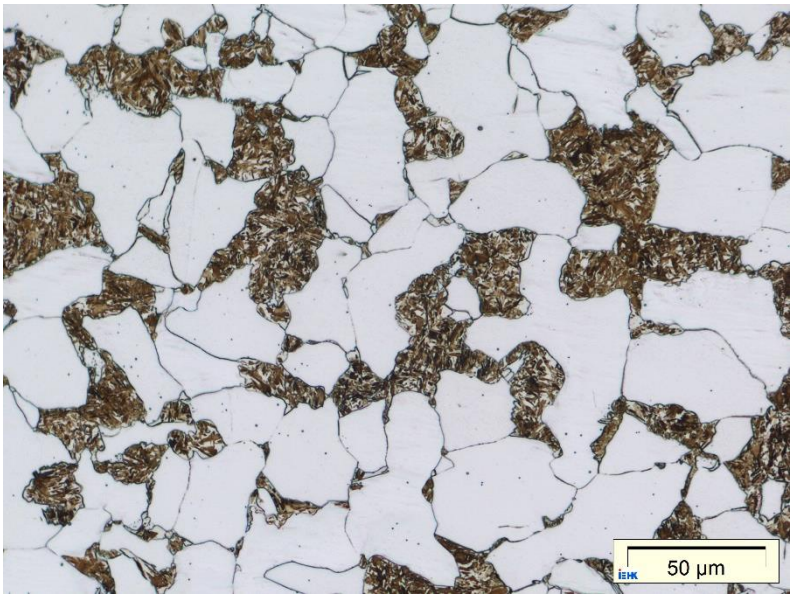
Task 11 Metallography (Pöpperlova) 5 Point(s)/Punkte

Metallography allows us to get a better knowledge about the microstructure of materials.

a) The given figure 1 shows a 5% $Na_2S_2O_5$ - etched Dual-phase steel. Which phases are visible? Mark the corresponding ones in figure 1. (2 Points)



Abbildung/Figure 1

b) How is Carbon distributed in these two phases? (1 Point)

c) What is the different between a Dual-phase steel and a Duplex steel? (2 Points)

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Task 12 Electronmicroscopy (Pöperlova) 6 Point(s)

a) What is the resolution limit of Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM)? (2 Points)

b) Explain the differences of the specimen preparation for SEM and TEM investigations resulting from the measuring principle of each electron microscope. (2 Points)

c) You want to proof Niobium carbonitrides (diameter ca. 4 nm) in your material. Which microscope do you choose? Which method (bright field or dark field) must be used? (2 Points)

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