Master examination

„Materials Science of Steel“

28.02.2017

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 (additional points)
1	6		
2	4		
3	7		
4	4		
5	5.5		
6	10		
7	5		
8	6		
9	7		
10	5		
11	6		
12	9.5		
13	10		
14	4		
15	3		
16	8		
Sum	100		

You need 44% to pass the examination.

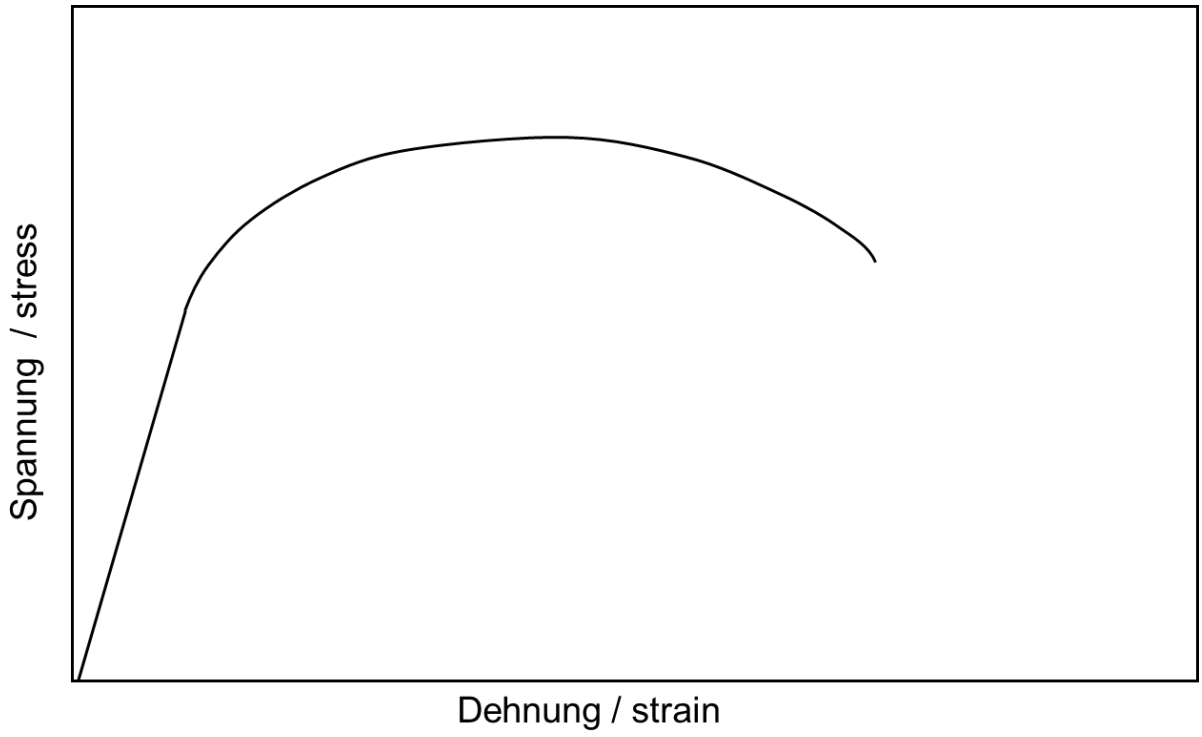
Task 1 Tensile test 6 Point(s)

Appendix 1 shows a continuous engineering stress-strain-curve.

a) Which two characteristic stress values and two strain values can be directly determined out of this diagram? Indicate how these values can be determined on the axes. (4 Points)

b) Sketch a material with a higher strain hardening value n (e.g. a dual phase steel) in the same diagram. Consider the same young's modulus and the same yield strength for both materials. (2 Points)

Anlage 1/ Appendix 1



Head of Department: Univ. Prof. Dr.-Ing. W. Bleck Fon: +49 241 8095782
E-Mail: bleck@iehk.rwth-aachen.de Fax: +49 241 8092224

Task 2 true stress – true strain 4 Point(s)

a) Explain the difference between a technical stress–strain and a “true stress”–“true strain”-curve. (2 Points)

b) Sketch a technical stress – strain curve and highlight the region, which can be used to calculate a a “true stress”–“true strain”-curve. Explain your choice briefly. (2 Points)

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Task 3 true stress – true strain 7 Point(s)

a) Sketch a “true stress”–“true strain”-curve for a ferritic steel at room temperature and at -120°C in one diagram. (2 Points)

b) Sketch a second diagram containing the “true stress”–“true strain”-curve for an austenitic steel at room temperature and at -120°C. (2 Points)

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c) Explain the metal physical background for the different material behavior of these steels, briefly. (3 Points)

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Task 4 Portevin-Le-Chatelier 4 Point(s)

a) Sketch a technical stress-strain-curve determined under quasi-static testing conditions for a bcc steel with 0.1 wt.% Carbon at i) room temperature, ii) 120 °C and 500 °c in one diagram (3 Points).

b) Explain the "Portevin-Le-Chatelier"-effect which occurs at 120 °C briefly (1 Point).

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Task 5 Hot tensile test 5.5 Point(s)

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 Point)

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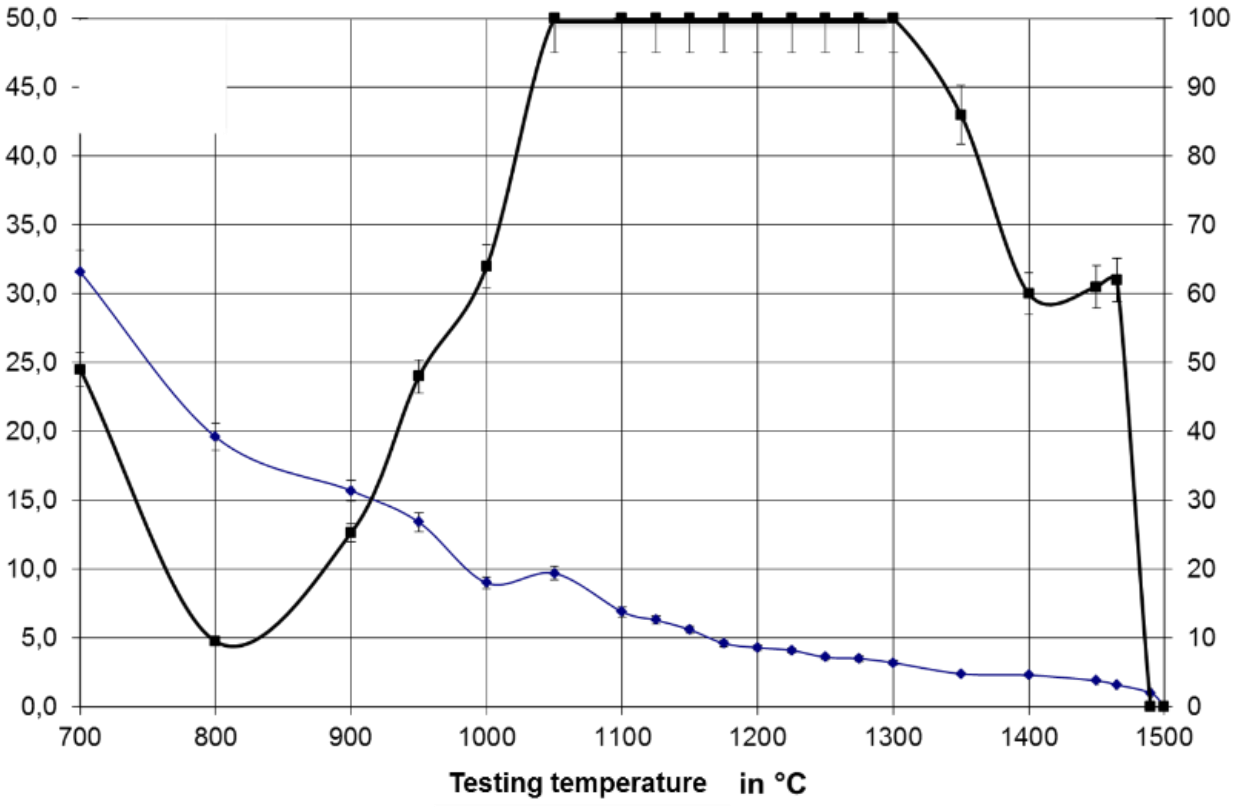

Figure 1: Werkstoff A / Material A

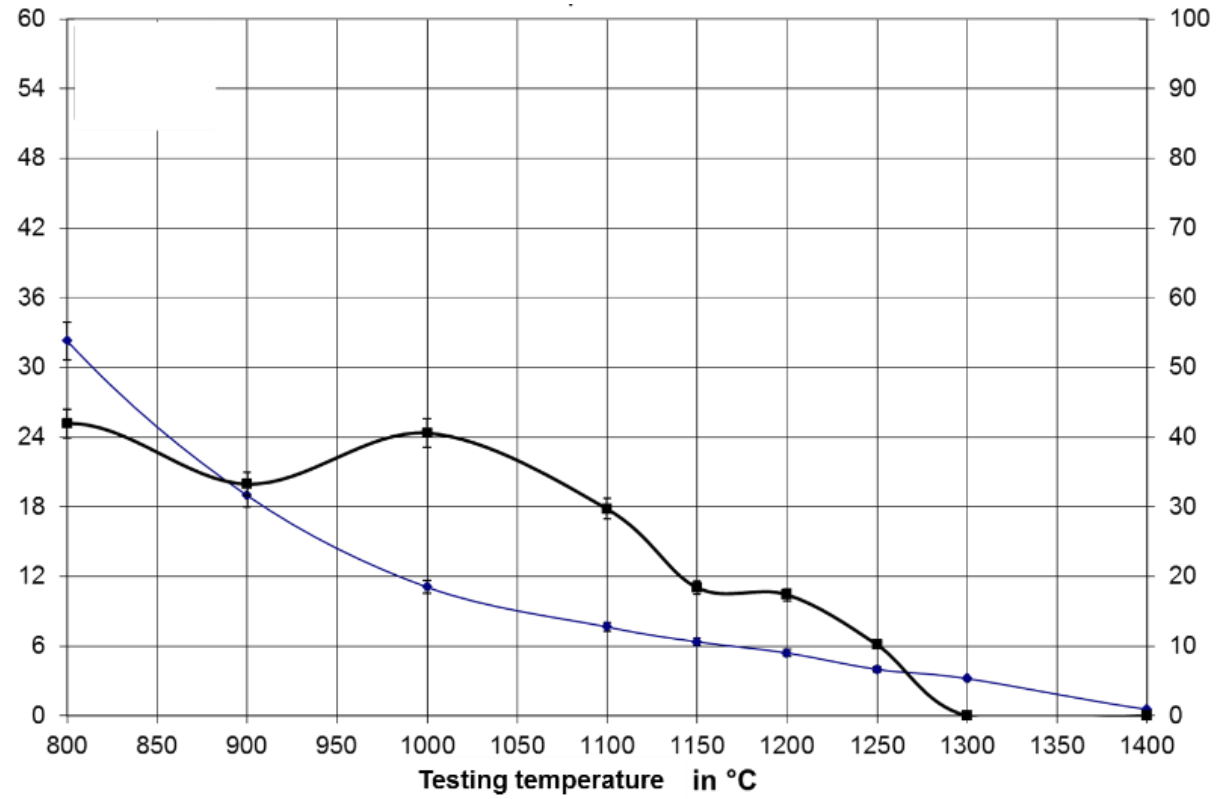

Figure 2 Werkstoff B / Material B

Head of Department: Univ. Prof. Dr.-Ing. W. Bleck
E-Mail: bleck@iehk.rwth-aachen.de
Fon: +49 241 8095782
Fax: +49 241 8092224

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: Hot tensile test specimens for different testing temperatures

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

Head of Department: Univ. Prof. Dr.-Ing. W. Bleck Fon: +49 241 8095782
E-Mail: bleck@iehk.rwth-aachen.de Fax: +49 241 8092224

Task 6 Considère-Criterion 10 Point(s)

"True stress"-"true strain"-curves do not have a maximum force which can be correlated with the beginning of necking. The uniform strain can be calculated using the Considère-criterion.

a) Derive the equation for the Considère-criterion to calculate the uniform strain. (6 Points)

Head of Department: Univ. Prof. Dr.-Ing. W. Bleck Fon: +49 241 8095782
E-Mail: bleck@iehk.rwth-aachen.de Fax: +49 241 8092224

b) Sketch the Considère-criterion. (4 Points)

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E-Mail: bleck@iehk.rwth-aachen.de Fax: +49 241 8092224

Task 7 Strengthening mechanisms 5 Point(s)

a) Name four different strengthening mechanisms for steels (2 Points).

b) State the empirical equation used to calculate the yield strength of steels based on the grain size? Explain all parameters which are necessary for this equation. (3 Points)

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E-Mail: bleck@iehk.rwth-aachen.de Fax: +49 241 8092224

Task 8 TMT 6 Point(s)

a) What are the three common microalloying elements used in thermomechanical treated construction steels. How much mass-% of these alloying elements are added to the steel? (2 Points)

b) In which processing steps does each of these elements precipitate? (3 Points)

c) The size of the precipitations influences grain refinement and precipitation strengthening. What is the approximate size of these precipitations to influence each of these mechanisms? (1 Point)

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Task 9 Fracture mechanisms 7 Point(s)

a) Name the different steps of slip fracture. (3 Points)

b) Explain the difference between transcrystalline and intercrystalline crack configuration. (2 Point)

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

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Task 10 Fracture mechanics 5 Point(s)

a) Explain the difference between the linear elastic and the elastic plastic fracture mechanics. Specify the respective characteristic values with their units. (3,0 Points)

b) Name the current testing method to determine these parameters. These parameters are used for fracture mechanics safety analysis. Specify one of the possible basic equations for a safety analysis. (2,0 Points)

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Task 11 Impact testing 6 Point(s)

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

a) Sketch an 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)

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Task 12 Cyclic testing 9.5 Point(s)

a) The fatigue behavior of metallic materials is commonly described using S-N curves, also known as Wöhler curves. Sketch a Wöhler curve for i) pure cupper and ii) a S355 construction steel for a testing condition with a medium stress $\sigma_M = 0$ MPa. Label the axes and indicate the following characteristic: R_m, low cycle fatigue strength, finite life fatigue strength and fatigue strength as long as they can be defined. (5,5 Points)

b) Describe the damage mechanism owing to cyclic loads, briefly. (4 Points)

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Task 13 sheet forming 10 Point(s)

Tensile tests with two sheet steels in different directions show the following elongation values (φelongation = 0,20):

Material 1

	∠ 0° to rolling direction	∠ 45° to rolling direction	∠ 90° to rolling direction
φ_W	-0,131	-0,121	-0,136

Material 2

	∠ 0° to rolling direction	∠ 45° to rolling direction	∠ 90° to rolling direction
φ_W	-0,118	-0,119	-0,117

Calculate the perpendicular (r), the average (r_m) and the planar anisotropy (Δr) for both materials and describe the

i) deep drawability of the two materials and

ii) the materials' earing tendency.

Explain your answer and state all necessary equations. (10 Points)

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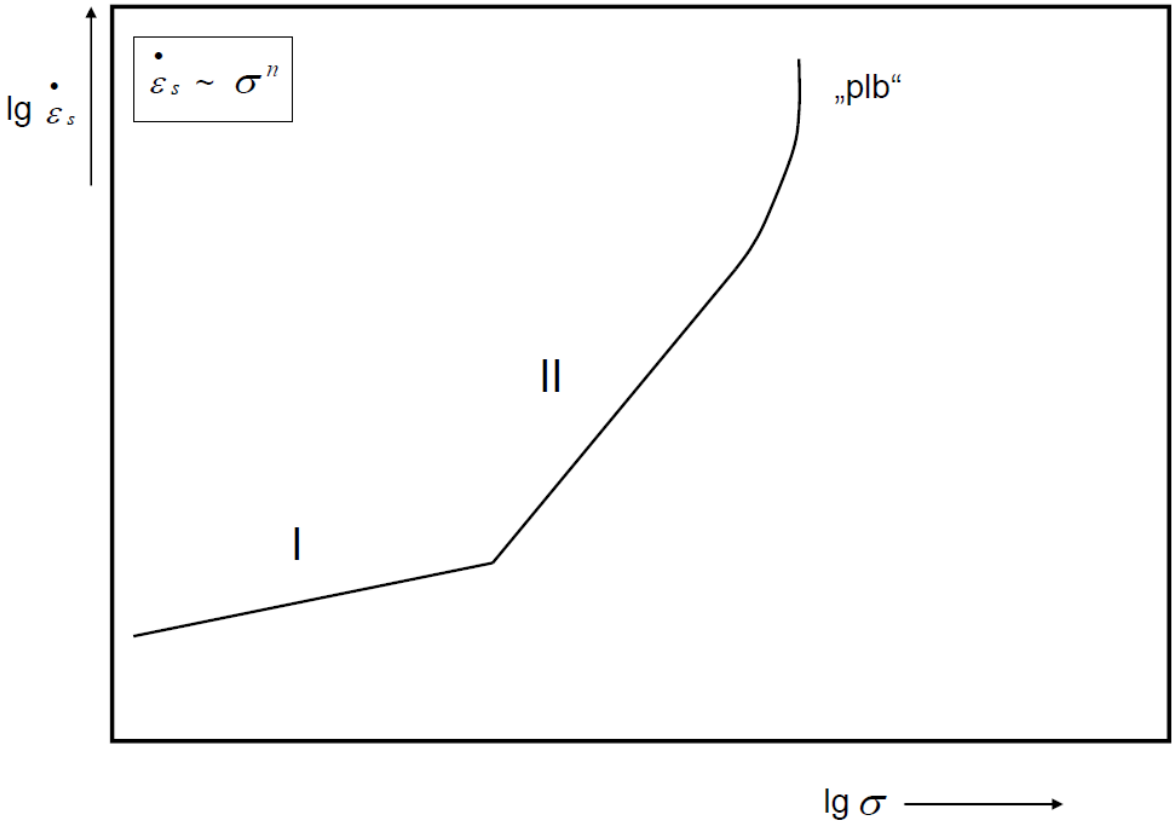
Task 14 High temperature properties 4 Point(s)

At high temperatures the mechanical properties of steel are highly influenced by the strain rate, ε̇. In the diagram below the strain rate is shown as a function of stress for the area of stationary creep.

a) Which creep mechanisms are shown in regions I and II? (2 Points)

Diagram:



b) Sketch the shift in curve if a coarse grained material is used. (1 Point)

c) Sketch the shift in the curve for a material with a lower Young's modulus. (1 Point)

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Task 15 Metallography 3 Point(s)

Metallography allows us to get a better knowledge about the microstructure of materials. Figure 1 shows a sketch of a pearlitic microstructure after deep etching. Explain the principle of this etching treatment. What is the reason for the relief and therefore the high contrast of the surface? (3 Points)

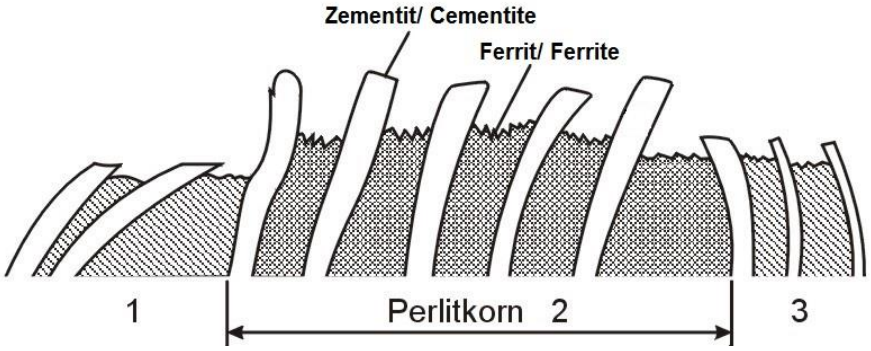

Figure 1: Deep etching of a pearlitic steel.

Head of Department: Univ. Prof. Dr.-Ing. W. Bleck Fon: +49 241 8095782
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Task 16 Electron microscopy 8 Point(s)

a) What is the microscopic resolution limit of light optical microscopes and Transmission electron microscopy? (2 Points)

b) What is the complete name of the following abbreviations for electron microscopic analytic methods? (4 Points)

SEM:

TEM:

EMPA:

EBSD:

c) Which of these analytic methods can be used to measure the chemical composition? Describe the principle of this/these analytic method(s). (2 Point)

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