Master examination

„Part I: Materials Science“

20.02.2018

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	7		
2	4		
3	9		
4	3,5		
5	6		
6	6,5		
7	8		
8	6		
9	10		
10	10		
11	4		
12	11		
13	4		
14	4		
15	4		
16	3		
Sum	100		

You need 44% to pass the examination.

Task 1 tensile testing (Kripak) 7 Point(s)

a) Sketch the stress-strain-curve for an IF-steel (Steel without solute interstitial atoms) and label the characteristic values. Furthermore, indicate 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)

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 (Kripak) 4 Point(s)

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

b) Which region of the technical stress – strain curve can be used to calculate a true strain – true stress curve? Explain your choice briefly! (2 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

Task 3 strain rate dependency (Kripak) 6 Point(s)

The deformation behavior of steels is significant dependent on the strain rate and the temperature.

a) Sketch a stress-strain curve for a ferritic-pearlitic steel in the three given diagrams in Figure 1. Consider the temperature related effects during the plastic deformation! (3 Points)

b) Add a stress-strain curve for a specimen tested with a higher strain rate in each diagram and indicate the difference of the accelerated strain rate! (3 Points)

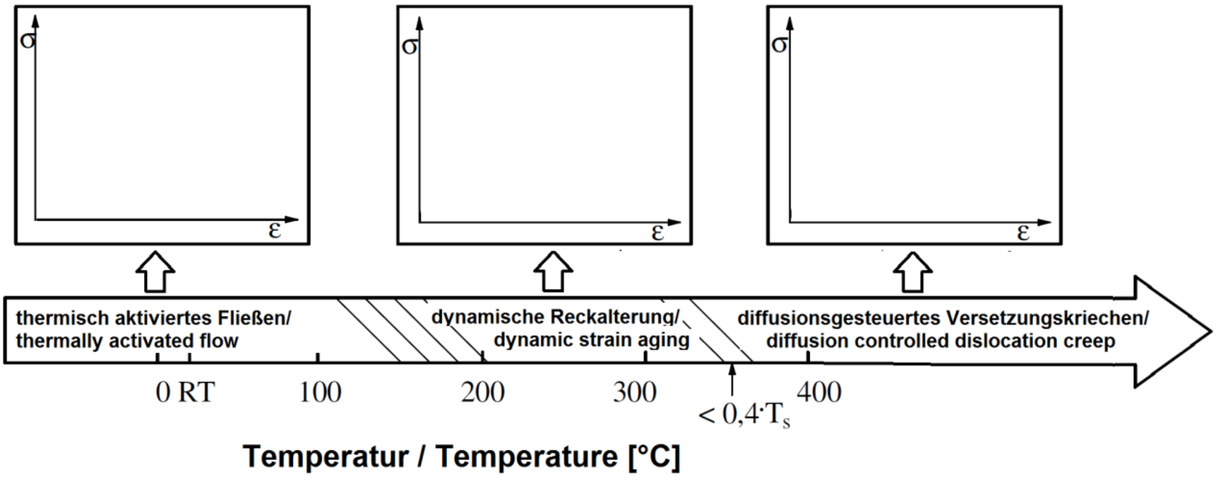


Figure 1

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 4 strengthening mechanisms I (Sharma) 5,5 Point(s)

The performance characteristics of a component are determined by its mechanical properties.

a) Which strengthening mechanisms do you know? (2 Points)

b) What is the relationship between the yield strength of unalloyed steel and the ferrite grain size (name and formula)? Name the parameters! (2.5 Points)

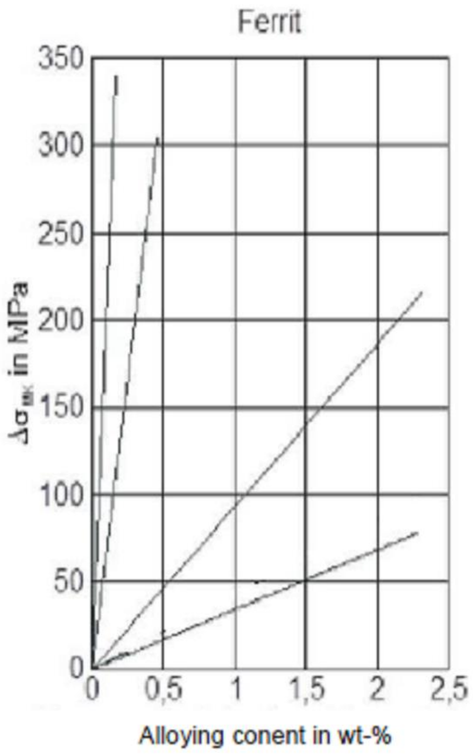
c) Name at least two strengthening mechanisms active in martensite? (1 Point)

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 5 Strengthening mechanisms II (Sharma) 4 Point(s)

a) The yield strength of steels can be increased by solid solution strengthening. **Appendix 1** shows the effect of content of different alloying elements on the yield strength of ferritic steels. Indicate which line corresponds to the following alloying elements: i) P, ii) Si, iii) C, iv) Mn (2 Points).

Appendix 1:



b) Which alloying element is the most favorable for solid solution strengthening? Which alloying elements should not be used to strengthen steel? Give a short explanation for each alloying element mentioned in task a)! (2 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

Task 6 Thermomechanical treatment (Sharma) 5 Point(s)

The temperature at which the precipitation starts influences the impact of the micro alloying elements on the steel.

a) Make a qualitative statement about the size of particles that precipitate at 1000 °C and 600 °C! (1 Point)

b) What effects can be attributed to these particles precipitated at 1000°C and 600°C? (1 Point)

c) Specify the approximate range in percent by weight for micro-alloying elements! (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

d) The micro-alloying elements V and Nb can form carbonitrides of the type Me (C, N). Are they dissolved or precipitated when heated prior to hot forming to approx. 1250 °C? (1 Point)

e) Draw (qualitative) the grainsize evolution as a function of the temperature for a (i) micro alloyed und (ii) non-micro alloyed steel in figure 1! (1 Point)

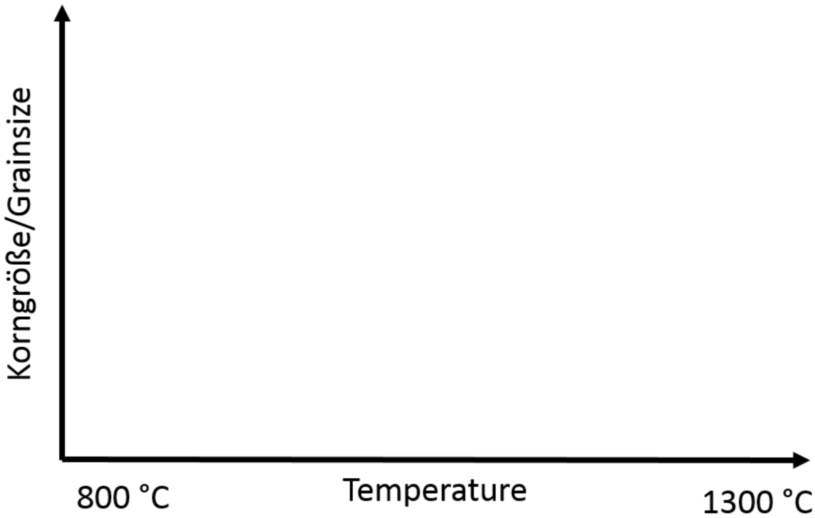


Figure1:

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 7 Fracture mechanisms (Novokshanov) 5 Point(s)

The fracture mechanisms of bcc steels are temperature dependent.

a) Sketch a stress-temperature-diagram, which can be used to show the switch from ductile to brittle fracture behaviour of bcc-steels! (3 Points)

b) Describe the microscopic appearance of the fracture surface at high and low temperatures, respectively! (2 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

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

Cracks were discovered in the casted structural elements of a bridge that was built in 1779 („Ironbridge"). The size and arrangement of the cracks need to be inspected to assess the component safety. Because of the age of the bridge, no material certificates are available.

a) Which fracture mechanics criteria give a sufficient toughness proof? Name at least two! (2 Points)

b) Which samples are in this case more suitable for the fracture mechanics analysis, SENB or CT, and why? Keep in mind that the sustainability of the bridge should be minimally affected! (2 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

c) Which kind of deformation and fracture behavior would you expect from the material of the bridge? Sketch schematically the force-crack opening displacement diagram! (2 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

Task 9 Charpy impact testing (Novokshanov) 8 Point(s)

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

a) Figure 1 shows the impact energy as a function of the testing temperature for two different steels. Sketch the force-deflection curve according to an “instrumented Charpy impact test” for point 1 and point 2 in one diagram and explain both lines! (4 Points)

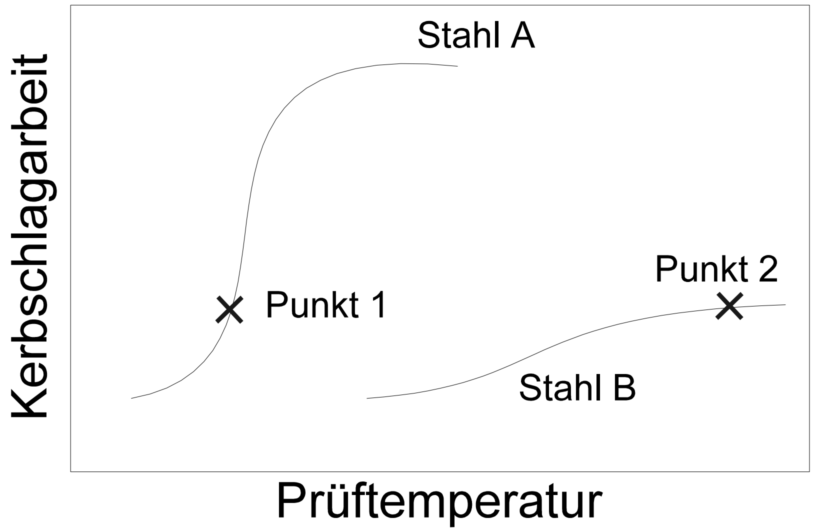


Figure 1:

b) Explain the difference between the standard Charpy impact test (without additional instrumentation) and the “instrumented Charpy impact test”, briefly. (2 Points)

c) Discuss advantages and disadvantages of both kinds of Charpy impact testing. (2 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

Task 10 Fatigue testing (Pöperlova) 10 Point(s)

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

a) Sketch a sinusoidal stress-time-curve with exactly two cycles. Mark the following characteristic values (σ_m, σ_a, σ_U and σ_L). (3,5 Points)

b) Sketch the sinusoidal stress-time-curve like in a) for the stress ratios R=0 and R=-1. Furthermore, state the equation to calculate the stress ratio R. (2 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

c) The fatigue loading of a material constitutes the plastic deformation in so-called persistent slip bands (Figure 1). Sketch the (i) extrusions and (ii) intrusions in figure 1. (2 Points)

d) Sketch the crack propagation stage I (macro crack formation) and stage II (macro crack growth) in Figure 1. Consider the principal stress. Explain the crack configuration in stage I. (3 Points)

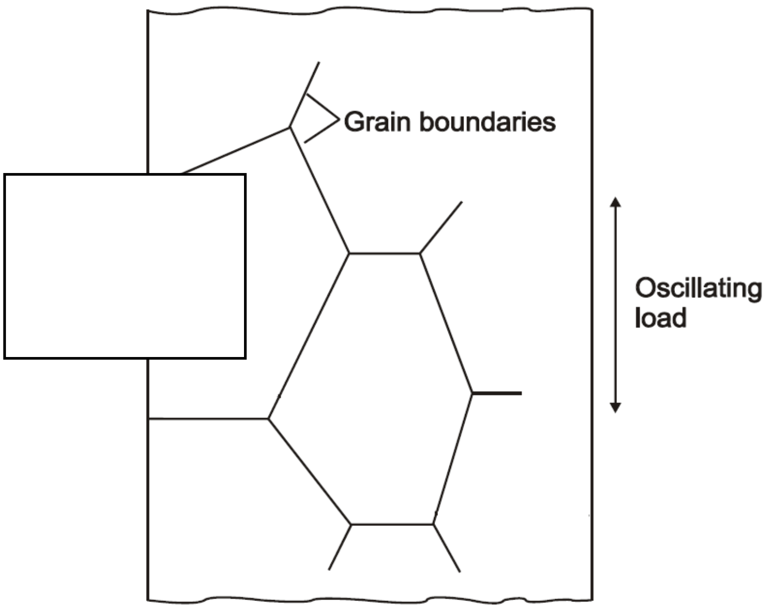


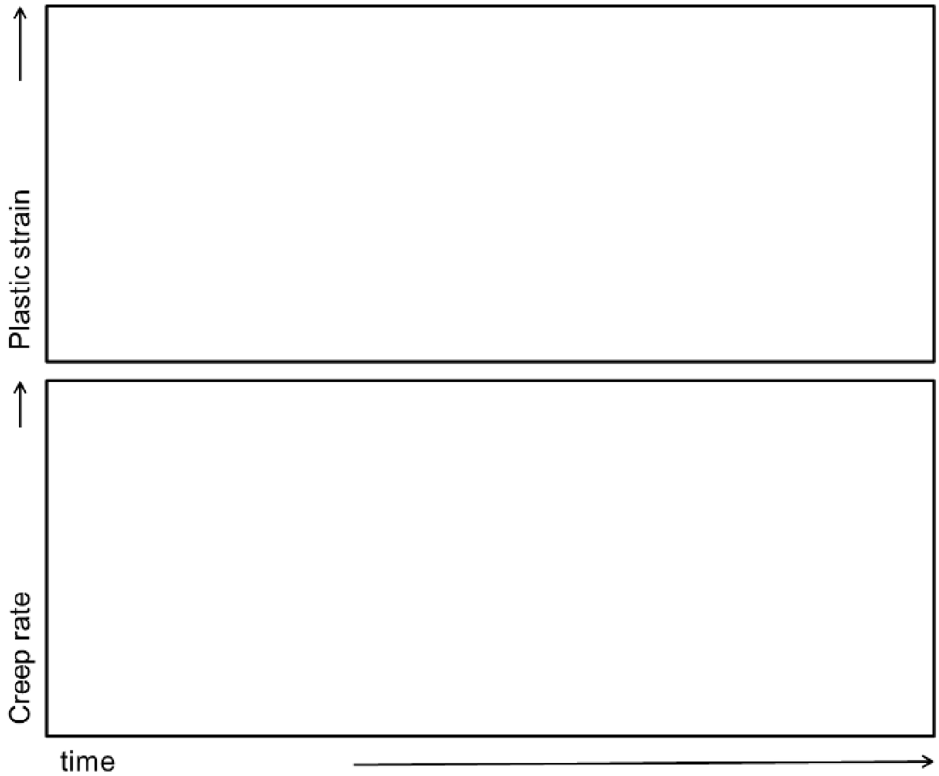
Figure 1:

Task 11 High temperature properties I (Sharma) 6 Point(s)

a) The high temperature behavior of materials is strongly controlled by diffusion controlled processes. Sketch the plastic strain- time diagram which can be determined from creep tests in the upper diagram of Appendix 1. Furthermore add the areas of i) stationary creep, ii) accelerated creep and iii) transient creep. (2.5 Points)

b) Sketch the corresponding creep rate in the lower diagram of Appendix 1. (1.5 Points)

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

c) Name 4 metallurgical phenomena which occur during creeping (2 Points)

Task 12 Sheet testing I (Wesselmecking) 11 Point(s)

a) Assign the given materials i)–iii) to the given car body parts A (roof), B (front body structure) and C (B-pillar) (**Appendix I**). Explain your choice briefly. (3 Points)

i) Mild Steel, UTS ˜ 300 MPa
ii) UHSS, UTS > 1000 MPa
iii) HSS, UTS > 500 MPa

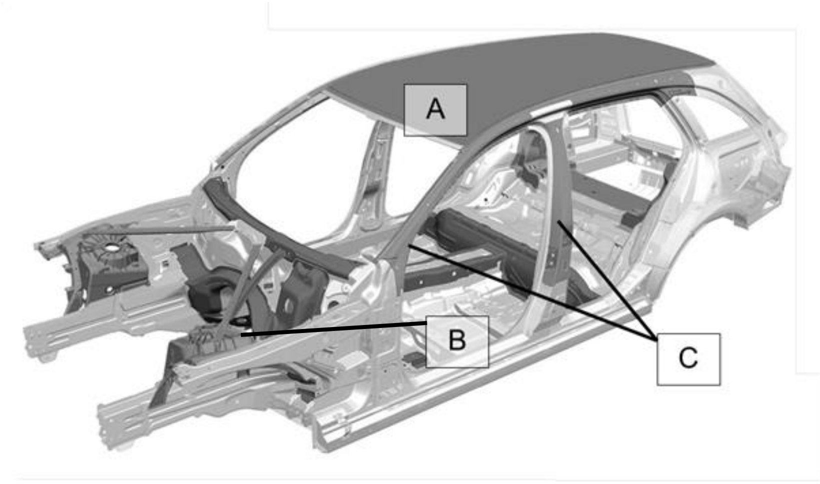


Figure 1

b) Sketch a schematic forming limit diagram for the steel i and ii (3 Points)

c) Dynamic tensile tests at high strain rates $\dot{\varepsilon}$ > 1/s are used to characterize materials used for crash relevant automotive parts. Sketch the strain rate dependency of the i) yield strength and ii) ultimate tensile strength of an automotive body steel grade (ZStE180BH) in **Figure 2.** (3 Points)

Figure 2

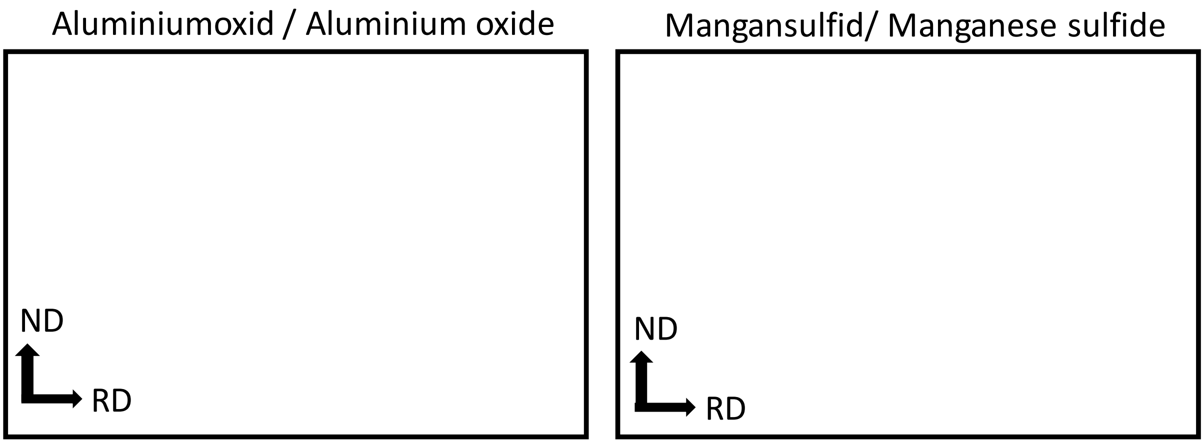
d) Almost 90% of the deformation energy is converted into heat during the deformation of metals. During testing this heat is released to the surrounding. (i) What is the influence of this so-called dissipation energy during dynamic tensile tests using high strain rates? (ii) How do you call this effect? (2 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

Task 13 Metallography I (Pöperlova) 3 Point(s)

Metallography is used to get important knowledge about non-metallic inclusions in steels.

Explain the characteristics of Manganese sulfide and Aluminium oxide after cold rolling steels. Therefore, sketch the above-mentioned inclusions after cold rolling in the figures in figure 1 and explain the shape of the inclusions. (3 Points)



ND: normal direction / Blech Normalenrichtung
RD: rolling direction / Walzrichtung

Figure1:

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 14 Metallography II (Pöperlova) 5 Point(s)

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

(a) The given picture is an example of 5% $Na_2S_2O_5$-etched dual-phase steel. Which phases are detectable? Mark the corresponding phases in figure 1. (2 Points)

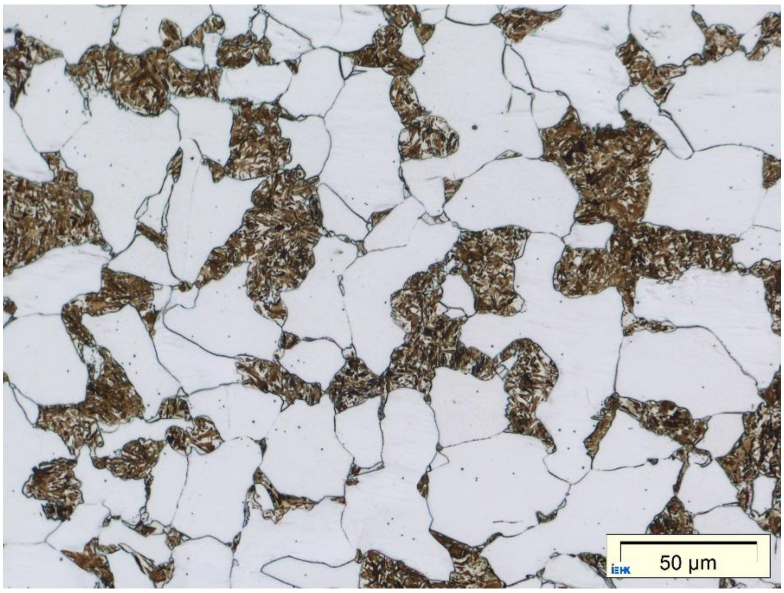


Figure1: Micrograph DP-Steel

(b) Which of both phases is enriched in carbon? (1 Point)

(c) What is the different between the microstructure of a dual-phase steel and a duplex steel? (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 15 Electron microscopy (Pöperlova) 6 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? (2 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 (2 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 16 Bauschinger effect (Pöperlova) 3 Point(s)

a) What is the “Bauschinger-effect”? (2 Point)

b) By which heat treatment can you overcome the “Bauschinger-effect”? (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 17 High temperature tensile test (Kripak) 5,5 Point(s)

The high temperature behavior during continuous casting of steel can be described by high temperature tensile tests.

a) Name two types of hot cracking during continuous casting of steel and give the reasons for these types! (2 Points)

b) Define the zero ductility temperature (TZD), the zero strength temperature (TZS) and the hot crack tendency in the temperature interval (?To). (1,5 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

c) Sketch the correlation between the reduction of area and the force during solidification of steels in the continuous casting process in figure 1 with the help of the diagrams reduction of area=f(T) and maximum force=f(T) in the temperature region from T_{liq} to 800°C. (2 Points)

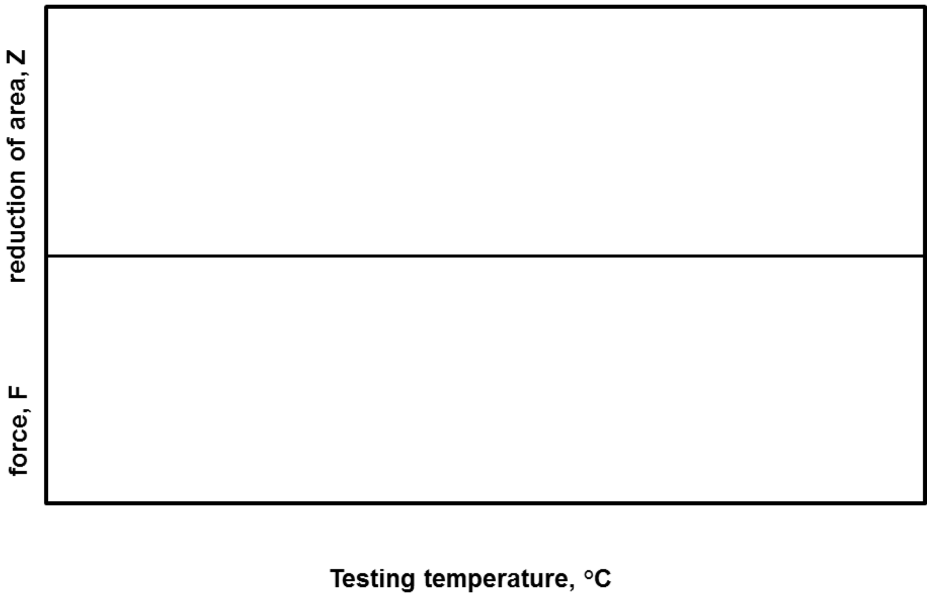


Figure 1

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