

Material Science of Steel

3rd April 2014

Name:

Matrikelnummer:

Signature:

Task	maximum available points:	Points:	review: (additional points)
1	3,5		
2	3		
3	3		
4	2		
5	6		
6	3		
7	4,5		
8	4		
9	4		
10	3,5		
11	3		
12	8		
13	2		
14	2		
15	5		
16	4		
17	2,5		
18	5		
19	2		
Sum	70		

You need 44% to pass the exam.

Task 1**heat treatment - 1****3.5 Points**

- a) How do microalloying elements affect the microstructure of steels during hot rolling? (1.5 Points)
- b) TMB-steels have a maximum yield strength after coiling at 600 °C. What is the reason for this maximum? (1.0 Points)
- c) Name the most important microalloying elements (1 Points)

Task 2 **technical heat treatment - 2** **3 Points**

The effectiveness of micro alloying is dependent on the temperature at which the precipitation starts.

- a) Make a qualitative statement about the size of particles that precipitate at 1200 °C, 1000 °C and 800 °C (1,5 Points).
- b) What effects can be attributed to these particles precipitated at 1200°C, 1000°C and 800°C. (1,5 Points)?

Task 3**high temperature properties****3 Points**

The mechanical properties of steels have a high strain rate $\dot{\epsilon}$ dependency at high temperatures. There is a strain rate – stress-curve given in the following diagram.

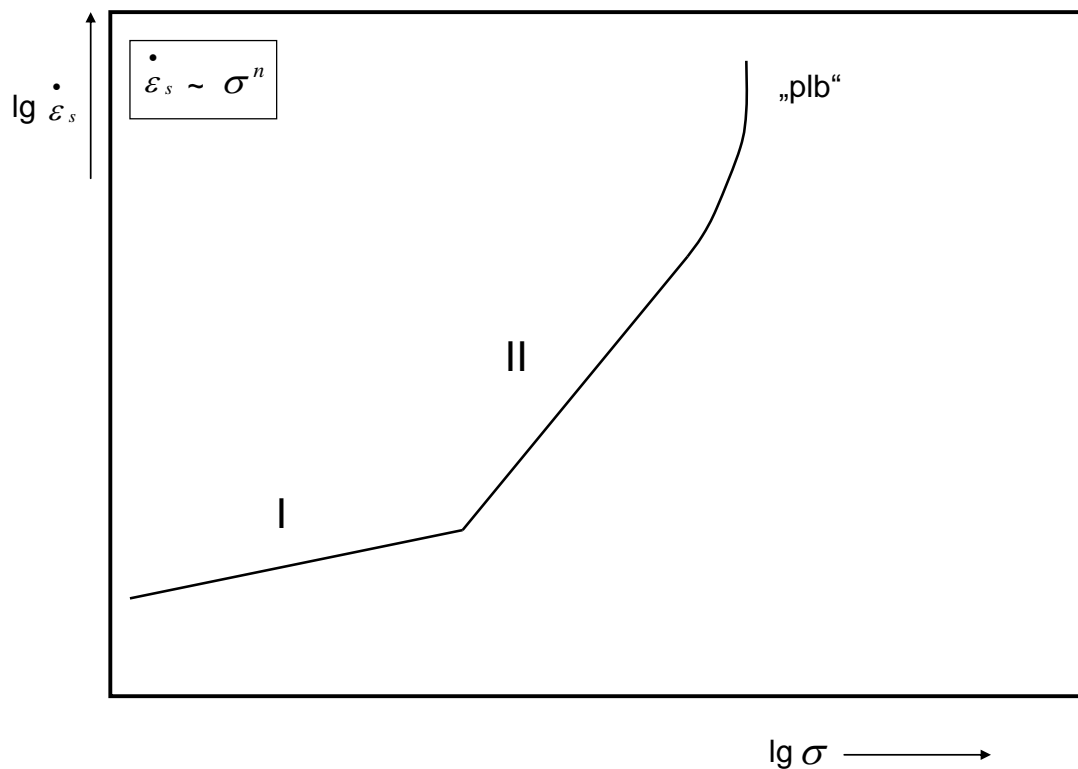
- a) Which creep mechanism is dominant in area I and II in the given chart?
(1.0 Point)

Add the strain rate – stress curve for a material with

- b) a larger grain size (1.0 P) and
c) a lower Young's modulus (1.0 Points)

in the given diagram.

Diagram:



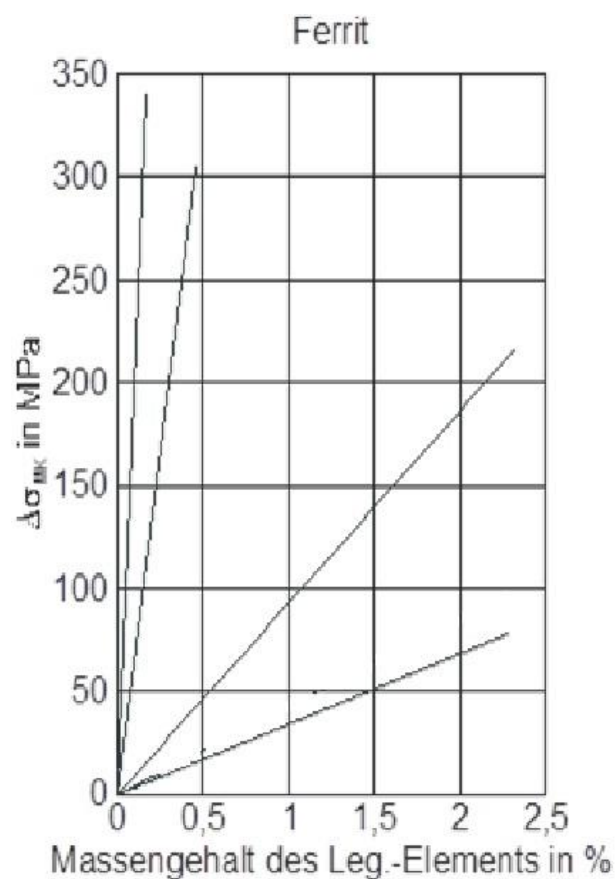
Task 4**microstructure****2 Points**

Improved mechanical properties can be achieved with a reduction of the grain size. Give the equation which is used to calculate the yield strength based on the grain size. Explain the variables used in this equation (2 Points).

Task 5 **microstructure setting** **6.0 Points**

- a) Name four different mechanisms (0-dim, 1-dim, 2-dim, 3-dim) that increase the strength of steels (2 Points)?
- b) Diagram 1 shows the influence of different mass content of different alloying elements on the yield strength of a ferritic steel. Match the alloying elements P, Si, C and Mn with the given lines. (2 Points).
- c) Which alloying element should be used to increase the yield strength? Which should be avoided? Give a rough explanation! (2 Points)

Diagram 1:



Task 6**hot deformation****3.0 Points**

The forging process is very sensitive to the deformation temperature. Forging can be separated between hot forging, warm forging and cold forging.

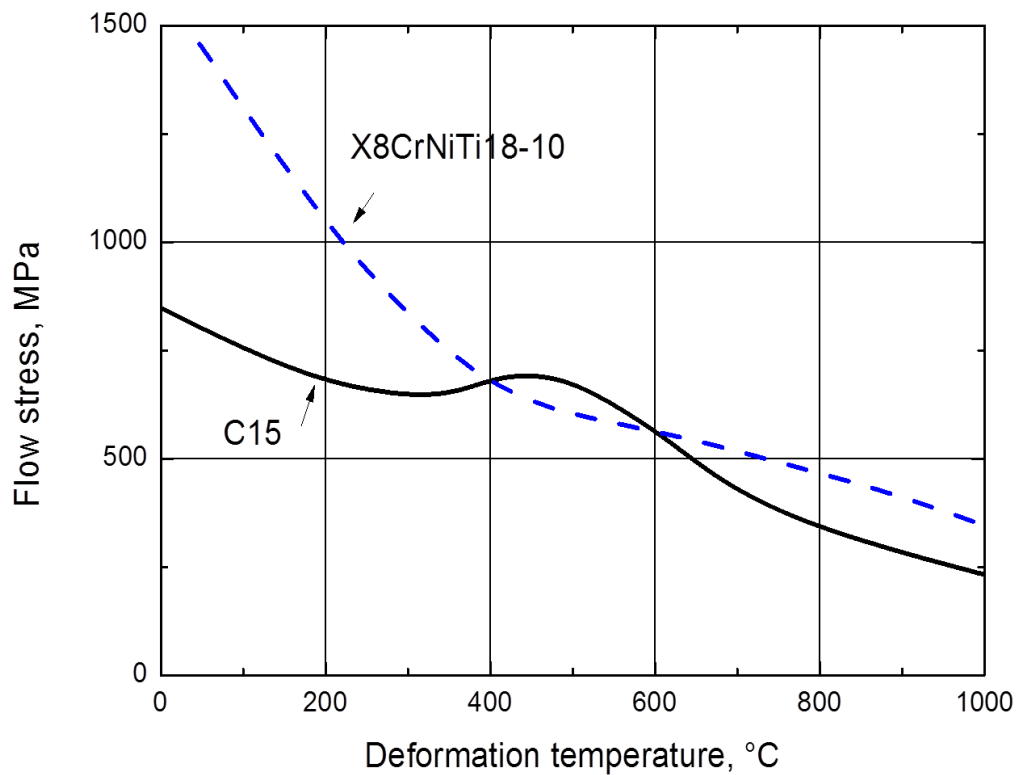
a) Hot forging takes place above a characteristic temperature (material depended). What is the name of this characteristic temperature? (0.5 Points)

b) All forming methods can theoretically be performed at different temperature ranges. Compare 1.) the characteristics of the deformation and 2.) the impact of the deformation on the component in case of hot forging, warm forging and cold forging. Fill out the given table. (1,5 Points)

	1.) characteristic of the deformation (during deformation)	2.) the impact of the deformation on the component
Hot forging		
Warm forging		
Cold forging		

- c) The temperature dependency on the flow stress for a X8CrNiTi18-10 and a C15 steel grade is given in Appendix 1. Explain the behaviour of the C15 (1 Point)

Appendix 1



Task 7**impact testing****4.5 Points**

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

- a) Plot the notched impact energy - temperature curve. Indicate and name important areas and variables. (3,0 points)
- b) Explain the fracture type in the marked areas. (1,5 points)

Task 8**impact testing****4.0 Points**

- a) You are performing a Charpy impact test without additional gauges. How can you determine the impact energy? How can you estimate the impact energy in an "instrumented Charpy impact test"? (2 points)
- b) Discuss assets and drawbacks for both testing methods. (2 points)

Task 9 **fracture mechanic** **4.0 Points**

- a) Explain the differences between linear elastic fracture mechanics (LEFM) and elastic-plastic fracture mechanics (EPFM). Mention the characteristic values for both kinds of fracture mechanics (including units)? (3 Points)
- b) What is the most common method to estimate these values? These values can be used for safety analyses. Write down one basic inequalities used in the safety analysis. (1 Point)

Task 10 **fracture mechanism** **3.5 Points**

- a) Name the different states of slip/ductile fracture (1.5 Points).
- b) Describe briefly the visual appearance of the macroscopic fracture surface in both cases slip/ductile- and cleavage fracture (1 Point).
- c) What is the difference between transcrystalline and intercrystalline crack propagation? (1 Point).

Task 11**fatigue testing****3.0 Points**

Wöhler's method of one-step cyclic testing is the most common way to estimate the fatigue of materials. Please draft a "Wöhler-line". Mark the axes and significant ranges in this diagram (3 Points).

Task 12**tensile test - 1****8.0 Points**

The most common method to estimate mechanical properties of steels is the tensile test.

- a) Stress-strain curves are derived from force-time curves. These force-time curves are measured during tensile tests. Give the information and the equations which are necessary to calculate the lower yield strength (R_{el}), the strain (ϵ), the Young's modulus (E) and the reduction of cross sectional area after cracking (Z) (2.5 Points)
- b) Sketch a stress-strain-curve for an unalloyed structural steel with a yield strength of $R_{el} = 460$ MPa for a
- normalized specimen using a long proportional rod and a
 - normalized specimen using a short proportional rod.

Explain the differences briefly. (2.5 Points)

- c) Sketch a flow curve for a fcc and a flow curve for a bcc material in two separate diagrams. Sketch the temperature dependency of the yield strength and the temperature dependency of the strengthening $d\sigma/d\epsilon$ in both diagrams. (3 Points)

Task 13**tensile test - 2****2.0 Points**

Steel 1 has an ultimate tensile strength of 1000 MPa. The tensile testing machine used to test this steel has a maximum capability of 12 kN. Above this force the machine can be damaged.

The sheet of steel 1 has a thickness of 2 mm. The width b of the tensile specimen should be 10 mm.

- a) What is the maximum force that will be measured for a tensile specimen of steel 1? Should we use the above mentioned tensile testing machine? (1 Point)
- b) What is the maximum width for the tensile specimen that can be used without damaging the machine? (1 Point)

Task 14**tensile test - 3****2 Points**

Give a brief explanation of the following values estimated from a tensile test (2 Points):

- R_{eH} ,
- R_{eL} ,
- R_m and
- $R_{p0.01}$.

Task 15**sheet testing****5.0 Points**

- a) Two materials are compared with regard to their deep drawing properties. Therefore, you carry out flat tensile tests in 0° , 45° and 90° to rolling direction of each material. The results of these experiments are summarised for both materials in the tables below. Your task is to determine the parameters Δr and r_m . (3.5 Points):

Material 1:

	Φ_b	Φ_s
0°	-0,288	-0,177
45°	-0,371	-0,207
90°	-0,205	-0.092

Material 2:

	Φ_b	Φ_s
0°	-0,134	-0,119
45°	-0,198	-0,255
90°	-0.092	-0.065

- b) Which material properties do the parameters Δr and r_m describe. According to the results of a), which material is more suitable for a deep drawing process (1.5 Points)?

Task 16**true stress****4.0 Points**

- a) Explain the difference between a conventional stress strain curve and a true stress - true strain curve (2 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 (2 Points).

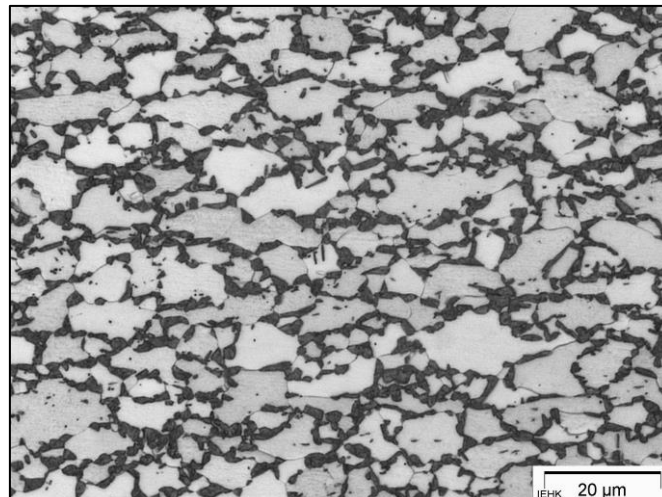
Task 17 **electron microscopy** **2.5 Points**

- a) Explain the differences in SEM- and TEM-investigations. What is the difference in regard to the specimen preparation necessary for each. (1.5 Points)
- b) Which additional method can be applied in combination with electron microscopy? What can be measured using this additional technique? (1 Point)

Task 18**metallography****5 Points**

Metallography can be used to get information about the microstructure of steels.

- a) Appendix 1 shows the microstructure of a dual phase steel (DP-steel) after 5% $\text{Na}_2\text{S}_2\text{O}_5$ etching. Which phases can be seen? Label these phases in Appendix 1 (2 Points).
- b) How is the carbon separated in these two phases (1 Point)?
- c) Draw a sketch showing the difference between a dual phase steel and a duplex steel (2 Points).

Anlage 1:

Task 19**miscellaneous****2 Points**

- a) What is the “Bauschinger-effect” (1 Point)?
- b) What can be done to minimize this effect (1 Point)?