Master examination

„Materials Science of Steel“

01.03.2016

Name:

Matriculation number: **Signature:**

Task	Points:	Points achieved:	Points after review (additional Points)
1	11.5		
2	4		
3	4		
4	8		
5	3		
6	4.5		
7	7		
8	6		
9	10		
10	6		
11	3		
12	7		
13	8		
14	7		
15	4		
16	7		
Sum	100		

You need 44% to pass the examination. The examination is divided into three parts which have to be passed separately. The final result is calculated as follows:

37.5 % Written examination (“Materials Science of Steel”)

37.5 % Oral Examination (separate date)

25 % Written examination (“Materials Science of Steel –Steel Design”)

Task 1 Tensile test 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: *(4.5 Points)*

Lower yield strength (R_{eL})

Strain

Young's modulus

Reduction of cross sectional area after cracking

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. (3 Points)

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c) Explain the temperature dependency of the yield strength and the strengthening ($d\sigma/d\varepsilon$). 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 true stress – true strain 4 Point(s)

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

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

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Task 3 Portevin-Le Chatelier 4 Point(s)

a) Sketch a technical stress-strain-curve for a bcc steel 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 100 °C, briefly (1 Point).

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Task 4 TMT 8 Point(s)

A thermomechanical treatment can improve the mechanical properties of steels.

a) Which strengthening mechanisms can be observed in thermomechanical treated steels. How is toughness influenced by these mechanisms (5 Points)?

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b) Draw schematically the development of static recrystallization as a function of temperature and time a) for an unalloyed and b) for a Ti-microalloyed steel in the thermomechanical treatment in the temperature range >A_3 in figure 1. (2 Points)

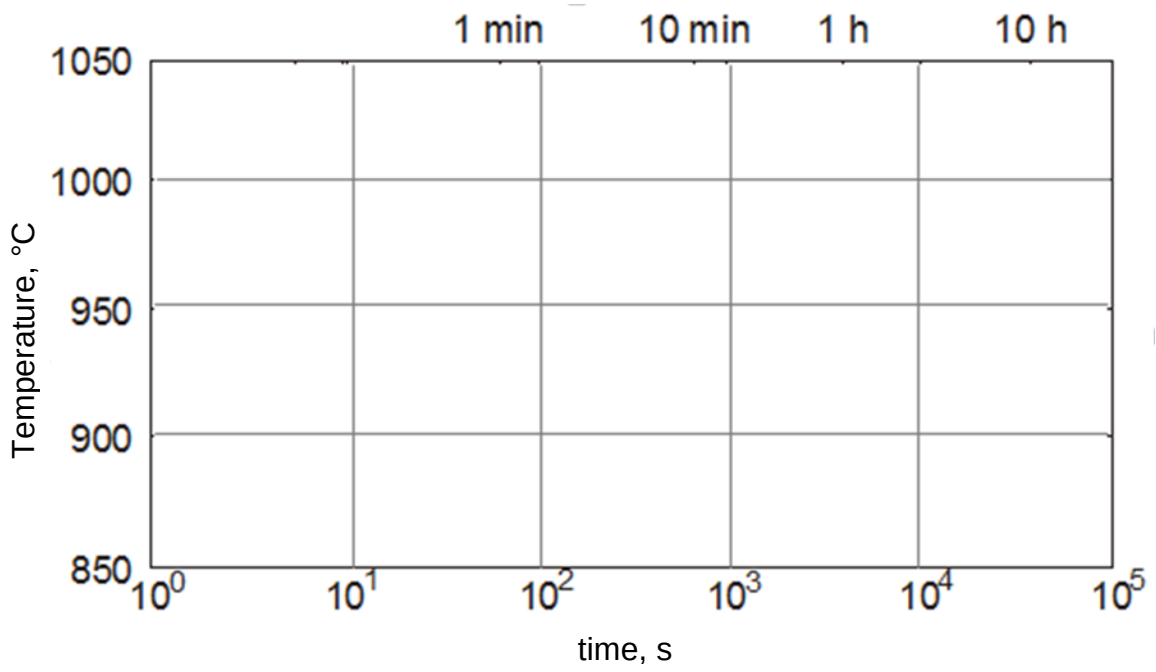

Figure 1

c) Name two additional micro alloying elements, beside Ti, which are used for thermo-mechanical treated steels. (1 Point)

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Task 5 Strengthening of steel 3 Point(s)

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. (3 Points)

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Task 6 Strengthening mechanisms 4.5 Point(s)

Patenting is a process of producing ultra-high strength steel wires for application in tyre cords. The wires are passed through a furnace at 950-970 °C to produce a uniform austenite grain size, followed by rapid cooling in a molten lead bath at 570°C. Afterwards the material is cold drawn. A typical steel used for this purpose contains, in weight percent, 0.8 C, 0.2 Si, 0.5 Mn, 0.01 P and 0.01 S.

a) Which kind of microstructure is produced? (1 Point)

b) In the following table, list the strengthening mechanisms attributable to different factors like the chemical composition, processing and microstructure: (3 Points)

Table 1

Factor	**Corresponding strengthening mechanism**
a. Composition (0.8 C, 0.2 Si, 0.5 Mn, 0.01 P and 0.01 S)	
b. Wire drawing process	
c. Microstructure	

d) How much GPa in strength can be achieved in these patented steels? (0.5 Points)

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Task 7 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 8 Fracture mechanics 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)

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)

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Task 9 Charpy impact testing 10 Point(s)

a) Charpy impact tests can be used to characterize the toughness of steels. 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 10 Cyclic load 6 Point(s)

a) 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).

Figure 1

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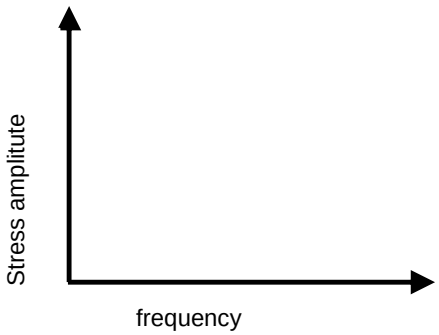
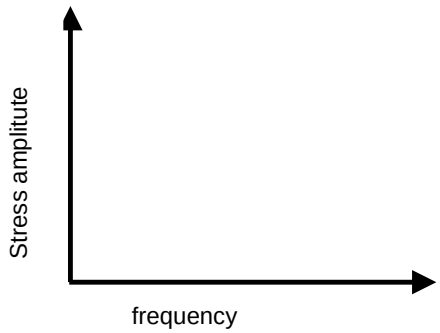
b) Beside the approach from “Wöhler” the service fatigue life of a component can be determined using step series of “Gassner” block program tests. For these tests the forces for the different cycles are not constant. This is closer to the loads of the component in its life time. Sketch an amplitude collective for a “Gassner” and a “Wöhler” experiment. (An amplitude collective shows the frequency of each stress amplitude during the experiment). (2 Points)

Wöhler



Gassner



c) Sketch a “Gassner“-curve for the same material in the diagram you sketched for task a). (1 Point)

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Task 11 cyclic load 3 Point(s)

a) What is the “Bauschinger-effect” and what is the reason for this effect? (2 Point)

b) What can be done to minimize this effect (1 Point)?

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Task 12 High temperature properties 7 Point(s)

While designing creep-resistant steels, it is important to consider some basic material factors.

a) Discuss the role of the crystal structure on the creep resistance of high temperature steels. Which crystal structure has the highest creep resistance? Give a short explanation (2 Points).

b) Explain why martensitic or bainitic steels have a higher creep resistance compared to ferritic steels (1 Point)?

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c) Why are single crystals used for high temperature applications instead of polycrystalline metals? (1 Point)

d) How is solid the solution strengthening different at high temperatures compared to room temperature? (1 Point)

e) Which kind of particles, i) carbonitrides or ii) intermetallic phases should be used for particle strengthening at high temperatures? Give a short explanation. (2 Points)

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Task 13 Sheet testing 8 Point(s)

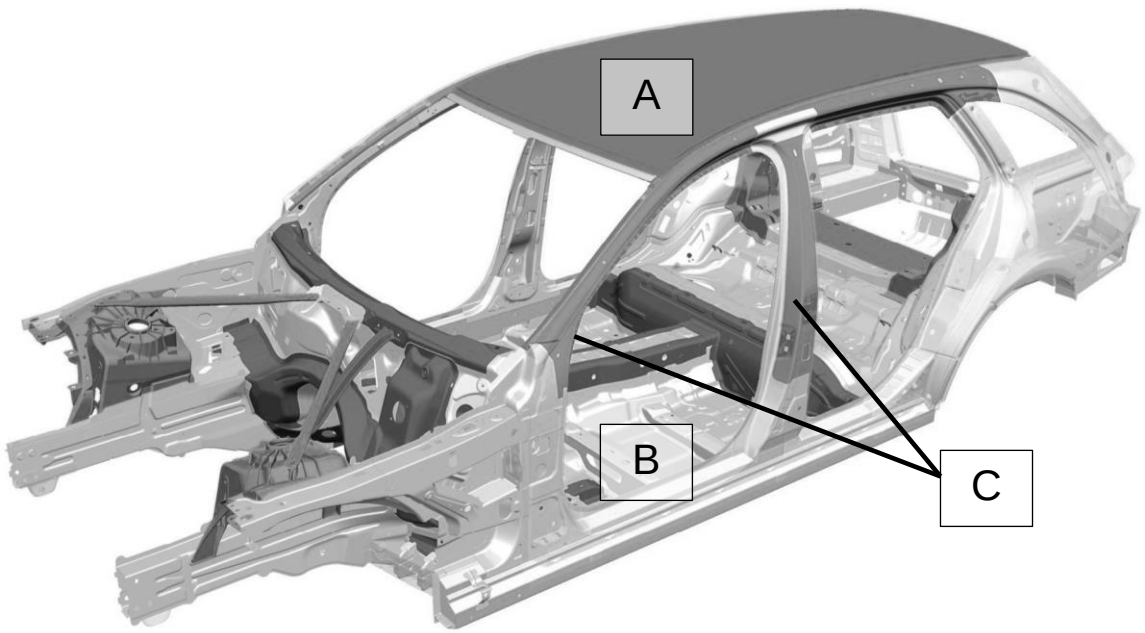
a) Assign the given materials i)–iv) to the shown car body parts A (roof), B (front body structure) and C (B-pillar) (Appendix I). Give a short explanation for your choice! (for each part there can be several kinds of material) (3 Points).

i) Mild Steel, UTS ≈ 200 MPa

ii) UHSS, UTS > 800 MPa

iii) Aluminium

Appendix



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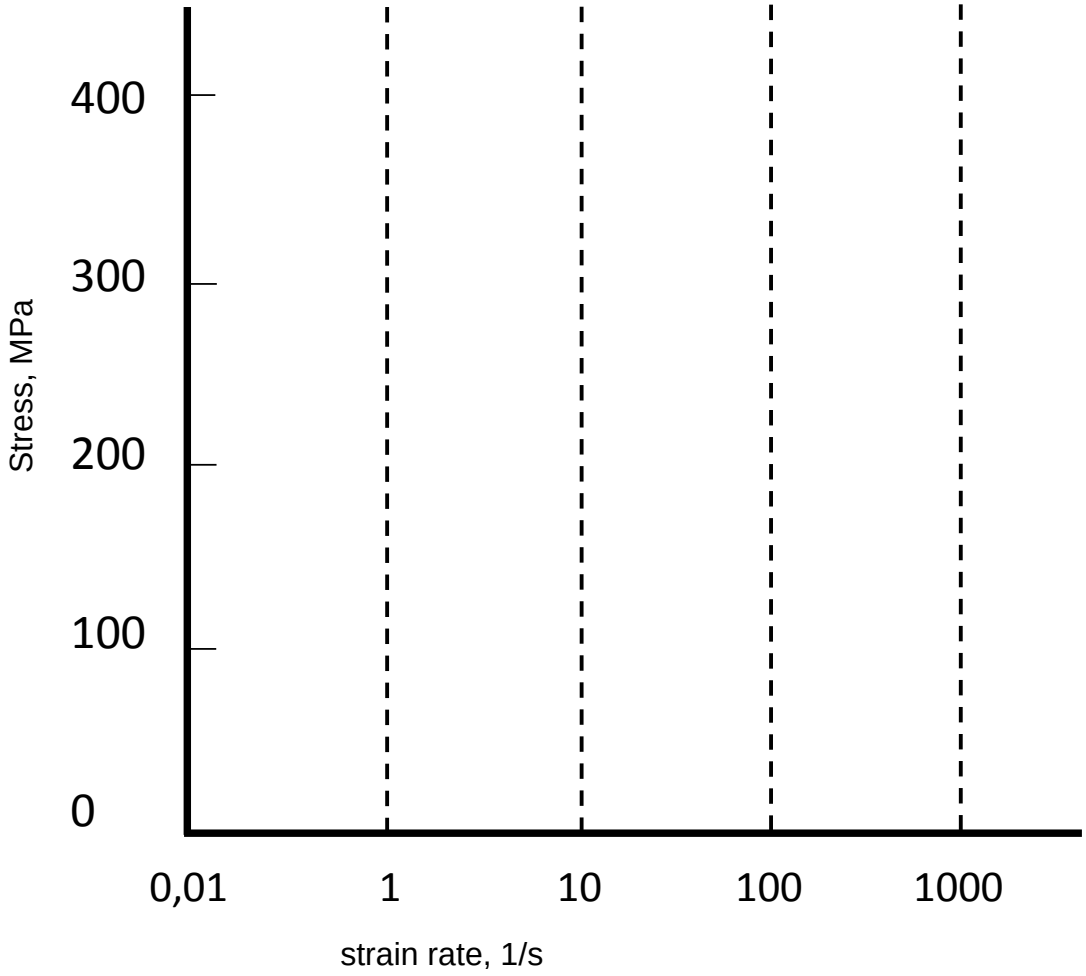
b) Dynamic tensile tests at high strain rates $\dot{\varepsilon} > 1$ 1/s are used to characterize materials used for crash relevant automotive parts.

Sketch the strain rate dependency of the i) yield strength and ii) ultimate tensile strength of an automotive body steel grade (ZStE180BH) in Appendix 2 (2.5 Points).

Appendix



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c) Almost 90% of the deformation energy is converted into heat during the deformation of metals. During testing this heat is released to the surrounding. What is the influence of this so-called dissipation energy during dynamic tensile tests using high strain rates? How do you call this effect? (1.5 Points)

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d) What describes the strain rate sensitivity? What is the result of a i) positive or ii) negative strain rate sensitivity (1 Point)?

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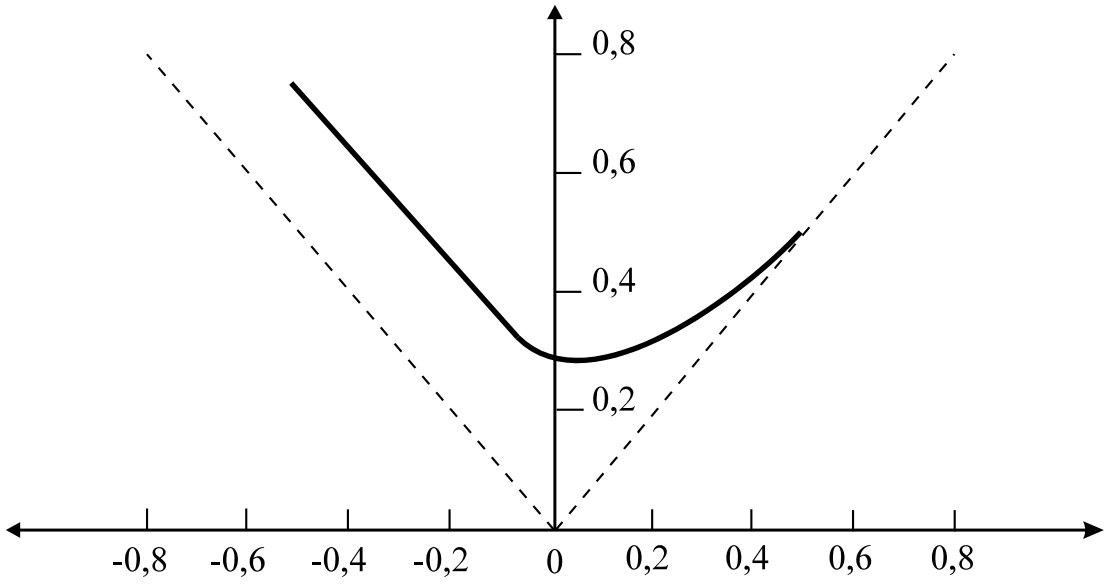
Task 14 Sheet testing 7 Points

The cold formability of sheet metal can be described with forming limit diagrams.

a) Label the axes of the diagram in Figure 1 and mark the characteristic strain states. (5 Points)

Figure 1:



b) How does an i) increased sheet thickness or a ii) better lubrication change the position of the curve (2 Points)?

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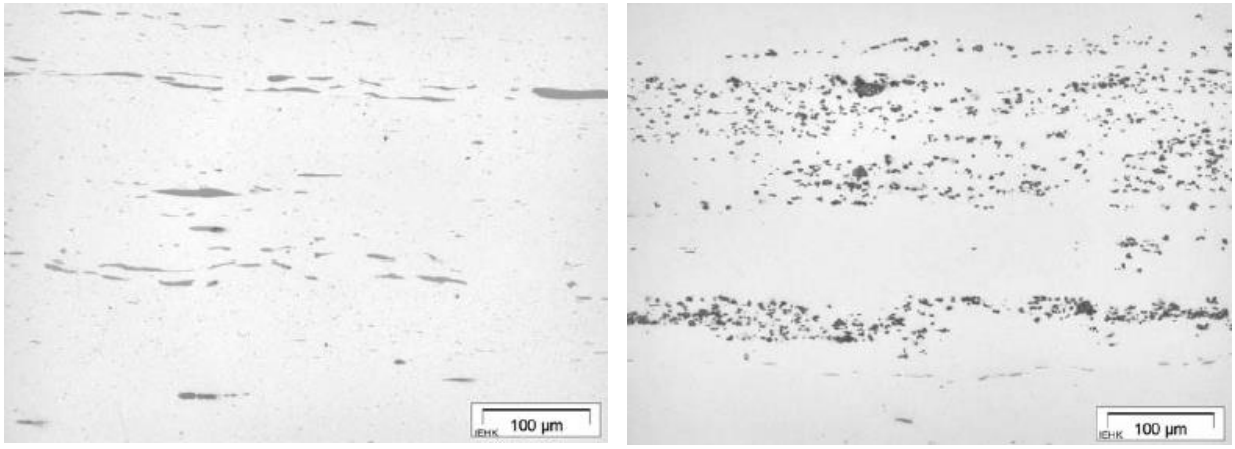
Task 15 Metallography 4 Point(s)

Metallography can be used to analyze non-metallic inclusions. The pictures in figure 1 show different kinds of non-metallic inclusions in steel after cold rolling. One picture is showing manganese sulfides and the other aluminum oxides. Assign the given pictures and explain your choice briefly! (4 Points)

Figure 1:



a b

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Task 16 electron microscopy 7 Point(s)

a) What is the microscopic resolution limit of light optical microscopes and Transmission electron microscopy? (1 Point)

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? (1 Point)

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