# Master Examination „Materials Science of Steel“

## Part 1

### 28th March `13

**Name:**

**Matriculation number:** **Signature:**

| Question | | Max. score: | reached score: | Post exam review: (write down only the points, which have to be added) |
|---|---|---|---|---|
| 1 | | 4.0 | | |
| 2 | | 3.5 | | |
| 3 | | 3.0 | | |
| 4 | | 5.0 | | |
| 5 | | 7.0 | | |
| 6 | | 5.0 | | |
| 7 | | 4.0 | | |
| 8 | | 7.5 | | |
| 9 | | 5.5 | | |
| 10 | | 3.5 | | |
| 11 | | 5.5 | | |
| 12 | | 5.5 | | |
| 13 | | 3.0 | | |
| 14 | | 4.0 | | |
| 15 | | 2.5 | | |
| 16 | | 1.5 | | |
| 17 | PART II | 3.0 | | |
| 18 | | 2.0 | | |
| 19 | | 1.5 | | |
| 20 | | 2.5 | | |
| 21 | | 1.5 | | |
| 22 | | 2.0 | | |
| 23 | | 2.0 | | |
| 24 | | 2.0 | | |
| 25 | | 1.5 | | |
| 26 | | 2.5 | | |
| 27 | | 1.5 | | |
| 28 | | 6.0 | | |
| Summe | | 100 | | |

To pass the exam at least 44% of the point score have to be reached.

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## Question 1 Technical Heat treatment 4.0 Points

a) Name the typical used micro alloying elements (MLE) and the maximum content which is used for thermomechanically rolled structure steels! (1.5 P.)

b) Explain in which process step which alloying element mainly percipitates. (1.5P.)

c) The size of precipitations directly influences the grain refinement and the precipitation hardening. What scale of precipitations are used for both mechanisms. Give the unity and a rough estimation of the diameter. (1.0P.)

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## Question 2 Technical Heat treatment 3.5 Points

Based on compression tests with Rastegaev samples the mechanical properties of steels at high temperatures can be determined.

a) Give two material and test parameters, which have influence on the flow curve at high temperatures. (2P)

b) What kind of test is used to measure the static softening? Give a reason why the holding time within the test has an influence on the static softening. (1.5P.)

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## Question 3 High temperature behaviour 3.0 Points

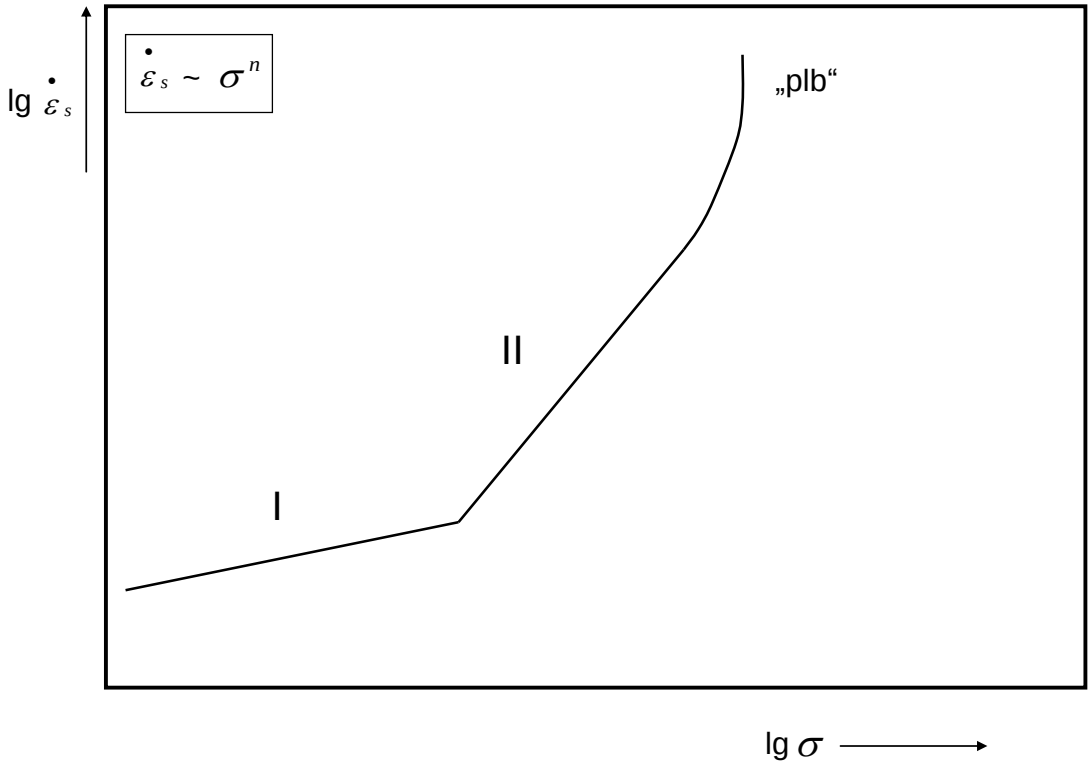
At high temperatures the mechanical properties of steel are highly influenced by the strain rate, ε̇. In the diagram below the strain rate is shown as a function of stress for the area of stationary creep.

a) Which Creep mechanisms are shown at I and II?

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

c) Sketch the shift in the curve for a material with a lower Young's Modulus.

Diagramm:

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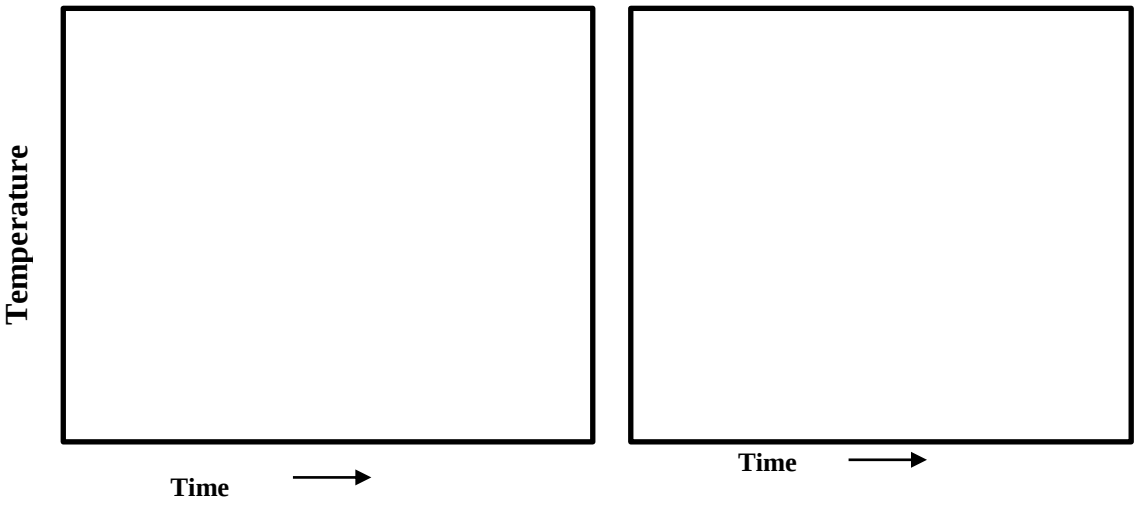
## Question 4 Microstructure design 5.0 Points

Use the given diagrams to sketch the continuous annealing of a cold rolled dual phase and TRIP steel. Add a short description of the phases which can be found during the different process steps of the continuous annealing and draw in the martensite start temperature ($M_S$)!

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## Question 5 Tensile test 7.0 Points

a) Draw within one diagram the stress strain curves of a ferritic steel at room temperature and -120°C. (*2*).

b) In a second diagram please sketch the stress strain curves of an austenitic steel at room temperature and -120°C (2P.).

c) Give a brief metallphysical explanation for the different material behavior of fcc and bcc steels. (*3 P.*).

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**Question 6 True strain, true stress 5.0 Points**

The mechanical properties of steel are usually determined in tensile tests.

a) Sketch a conventional stress-strain-curve with a discontinuous yielding and the according true stress- true strain-curve into one diagram (*2 Points*).

b) Which mechanisms are responsible for the occurrence of a discontinuous yield strength? Explain the Portevin – Le–Chatelier - effect (*2 Points*)?

c) Which disadvantage does a discontinuous yield strength have on the forming of sheet steel for automotive body components (*0.5 Points*)?

d) For which steels is the occurrence of a discontinuous yield strength adjusted by a technical heat treatment (*0.5 Points*)?

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## Question 7 Fracture Mechanics 4.0 Points

a) Explain the difference between the linear elastic and the elastic plastic fracture mechanics. List the proper parameters with units. *(3 Points)*

b) Name the current test methods for the characterisation of the parameters. These parameters are used in a fracture mechanics safety analysis. Write one of the possible equations down. (*1.0 Points*)

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## Question 8 Fatigue 7.5 Points

The fatigue behaviour of metallic materials can be described by a Wöhler-Diagram.

a) Draw schematically a Wöhler-Diagram including the characteristic curves $P_{Ü10\%}$, $P_{Ü50\%}$ and $P_{Ü90\%}$ for a ferritic steel. Inscribe the axis and name the characteristic ranges (*3 Points*).

b) How does a temperature increase influence the $P_{Ü50\%}$-curve (*1 Point*)?

c) Many components are exposed to oscillating charges. Draw the cyclic load-time-curves of a fatigue strength test with sinusoidal load for the states R = 0 and R = -1 (*3.5 Points*).

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## Question 9 Charpy test 5.5 Points

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

a) Plot the notched impact energy-temperature curve. Indicate and name important areas and variables. *(3,0 points)*
b) Give a short explanation for the marked areas. *(1,5 points)*
c) What will be changed within your drawn diagram if a steel with very good toughness behaviour at low temperatures will be compared to your steel. Make a sketch and give a short explanation for the changed curve. (1P.)

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## Question 10 Failure Mechanisms 3.5 Points

a) Name the different states of slip fracture (*1.5 Points*).

b) Describe briefly the macroscopic fracture appearance of slip- and cleavage fracture (*1 Point*).

c) Tell the different possibilities for brittle crack propagation in the microstructure. (*1 Point*).

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## Question 11 Material Characterization – sheet testing 5.5 Points

Deep drawing tests with two sheet steels show the following elongation values ($\varphi_l$ = 0,20):

Material 1

| | ∠ 0° to rolling direction | ∠ 45° to rolling direction | ∠ 90° to rolling direction |
|---|---|---|---|
| $\varphi_w$ | -0,131 | -0,121 | -0,136 |

Material 2

| | ∠ 0° to rolling direction | ∠ 45° to rolling direction | ∠ 90° to rolling direction |
|---|---|---|---|
| $\varphi_w$ | -0,118 | -0,119 | -0,117 |

Describe the

- deep drawing qualities of the two materials and
- the materials' earing tendency.

Give reasons for your answer.

(*5,5 Points*)

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## Question 12 Strengthening mechanisms 5.5 Points

The properties of a component are principally characterized by its mechanical properties.

a) Which possibilities for strengthening a steel exist in general (*2 Points*)?

b) What is the quantitative relationship between yield strength and ferrite grain size. Give a name and an equation for this relation and name the parameters! (*2.5 Point*)

c) Phosphorous is a strong solid solution strengthening element in $\alpha$-iron. Which approximate yield strength increase do you expect due to alloying 0.07 % of this element? What would be the negative effect of a further increase of the phosphorous content (*1 Point*)?

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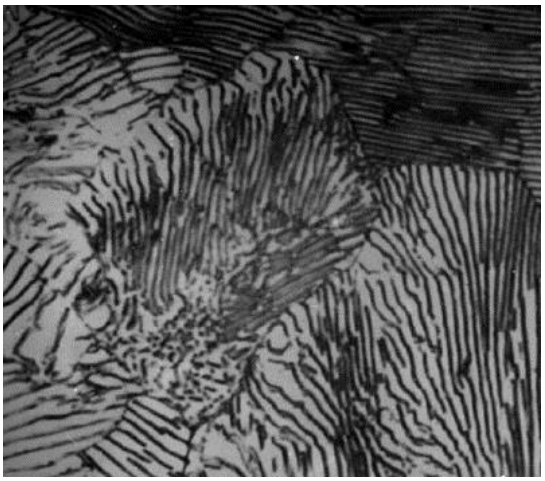
## Question 13 Light optical microscopy 3.0 Points

Metallography allows us to get a better knowledge about the microstructure of materials.
The given picture s is an example for an etched pearlitic steel. Please explain how the etching causes the contrast between the cementite and ferrite phase and leads to the typical lamellar surface visualization. Use a principal sketch for your explanation! (3.P.)



**Picture 1: Etched surface of an pearlitic microstructure**

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## Question 14 Electron Microscopy 4.0 Points

Name a method of electron microscopy appropriate for the following examinations and briefly account for your choice. (4 Points)

a. Determining the fracture mechanism
b. Identifying the chemical composition of an inclusion
c. Proving the twinning in a TWIP-Steel
d. Determining the amount of retained austenite in a TRIP-Steel

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**Question 15 Hardening Mechanisms 2.5 Points**

The influence of the alloying elements C and N on the strengthening differs for fcc and bcc steels. Please explain why the influence on the strengthening behavior of bcc steels is limited by metallurgical constraints and give also the strengthening mechanism for these elements. Compare the effects of N and C on the strain hardening behavior in fcc steels and in bcc steels.

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## Question 16 Testing for hardness 1.5 Points

There are several possibilities to measure the hardness of materials. Give a short description which two are mostly used for determining the hardness of steel. Give a rough explanation about the testing procedure, the used indentors and the analysis of the test. (1.P) Please discuss the connection between ultimate tensile strength and hardness and explain shortly why this cannot be easily used for every material.

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