Master examination

„Metallic Materials“

01.03.2016

Name:

Matriculation number: **Signature:**

Task	Points:	Points achieved:	Points after review (additional Points)
1	13		
2	4		
3	3		
4	6		
5	6		
6	3		
7	4		
8	9		
9	6		
10	9.5		
11	8		
12	8		
13	10.5		
14	4		
15	6		
Sum	100		

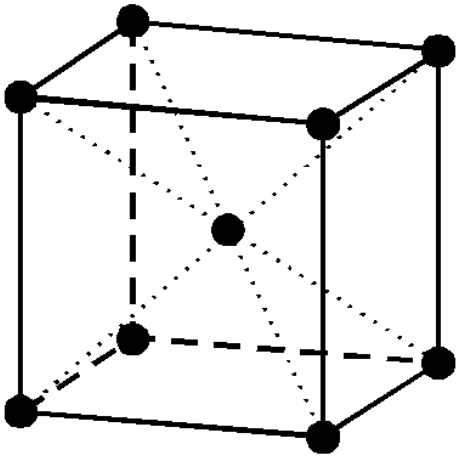
You need 44% to pass the examination. The examination is divided into two parts. The final result is calculated as follows:

50 % Written examination (“Metallic Materials”)

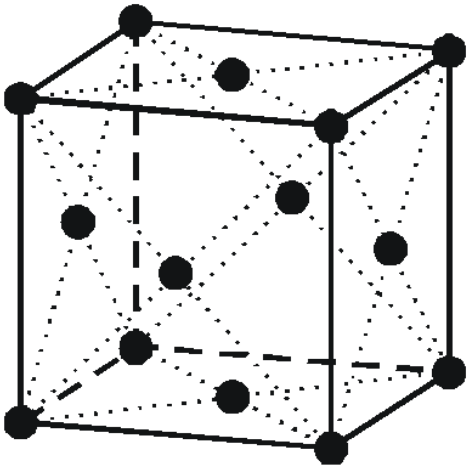
50 % Written examination (“Microstructures, Microscopy & Modelling)

Task 1 Crystal structure 13 Point(s)

Two crystal structures available for **pure Fe** are body centred cubic (bcc) and face centred cubic (fcc) under 1 atm. The lattice points in the structures are shown below.



bcc



fcc

a) What are the **temperature ranges** at which the respective crystal structures (bcc, fcc) are stable under 1 atm? (2 points)

b) What are the **closest-packed plane** and **closest-packed direction** in each structure? Use Miller indices. (2 points)

	closest-packed plane	***closest-packed direction***
bcc		
fcc		

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c) Calculate the **atomic packing density** in each structure assuming atoms as hard spheres. Show the details of your calculation. (4 points)

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d) Two kinds of interstitial sites exist in both bcc and fcc structures as octahedral and tetrahedral interstices. Figure out **the number of each interstitial site per unit cell** in both crystal structures. (2 points)

e) Imagine that carbon exists in fcc and bcc structured Fe as an interstitial solute. Which kind of interstitial sites does carbon occupy in each structure? It is known that the **solubility and diffusivity of carbon** varies depending on the crystal structure. Explain **the reason** for the differences based on your answers to (c) and (d). (3 point)

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Task 2 alloying elements I 4 Points

Most steels have a face-centred-cubic lattice at higher temperatures. Alloying elements affect the region of this phase.

Name at least four alloying elements, which narrow the γ-region, as well as four alloying elements, which expand the γ-region. (4 points)

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Task 3 alloying elements II 3 Points

The solubility of alloying elements in steel has a great temperature dependency. Sketch the solubility of carbon in BCC-Iron from room temperature till 723°C. How much carbon is in solution at this temperature? (3 Points)

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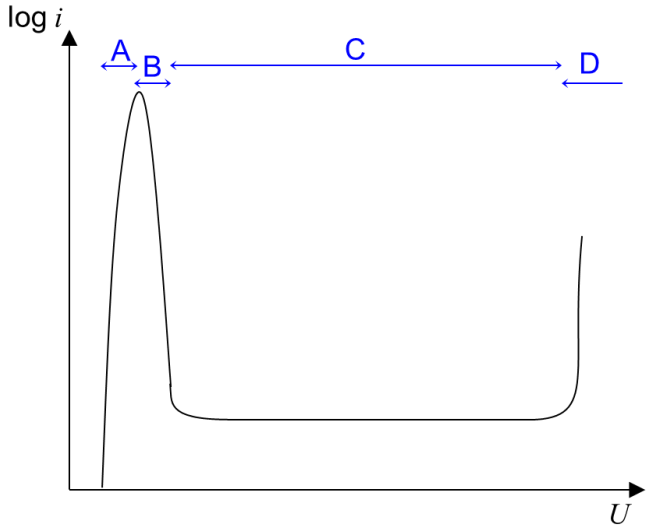
Task 4 alloying elements III 4.5 Points

When a metal is immersed in solution, either oxidation or reduction takes place. The processes may generate or absorb electrons, which affects the potential or current in the system. A schematic of potentiodynamic curve (*i*: current density, *U*: potential) of a metal is shown below. According the morphology of the curve, regimes are classified into active, transition, passive, and transpassive regimes as shown.



A :Active regime
B :Transition regime
C :Passive regime
D :Transpassive regime

U_R :Equilibrium rest potential
U_{act} :Activating potential
U_{pass} :Passivation potential
U_b :Breakdown potential
i_{pass} :Passivation current density
i_p :Passive current density

a) Mark important potentials and densities (U_R, U_{act}, U_{pass}, U_b, i_{pass}, i_p) in the diagram. (3 points)

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b) Explain the phenomena occurring in each regime. (2 points)

c) How are the potentiodynamic curves of stainless steels affected by the concentration of Cr? (1 point)

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Task 5 phase transformations 6 Point(s)

An unalloyed carbon steel with 1,2 % C is heated up homogenously to temperatures

- 50 °C above A_{ccm}
- between A_{ccm} and A_1
- slightly under A_1

a) Which microstructure do you expect at these three temperatures? (3 points)

b) Which microstructure do you expect if the specimens after heating are quenched in brine water? (3 points)

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Task 6 ferrite-pearlite phase transformation 3 Point(s)

a) A defined interlamellar spacing appears in pearlitic microstructures during cooling. How is the interlamellar spacing influenced by supercooling? Give an equation that describes the relation between supercooling and the interlamellar spacing. (2 point)

b) During pearlite formation recalescence occurs. What does recalescence mean? (1 point)

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Task 7 ferrite-pearlite phase transformation 4 Point(s)

Match the following steels (i)-(iv) with the corresponding microstructures given in Appendix 1 and name all microstructural constituents of these micrographs (4 Points)

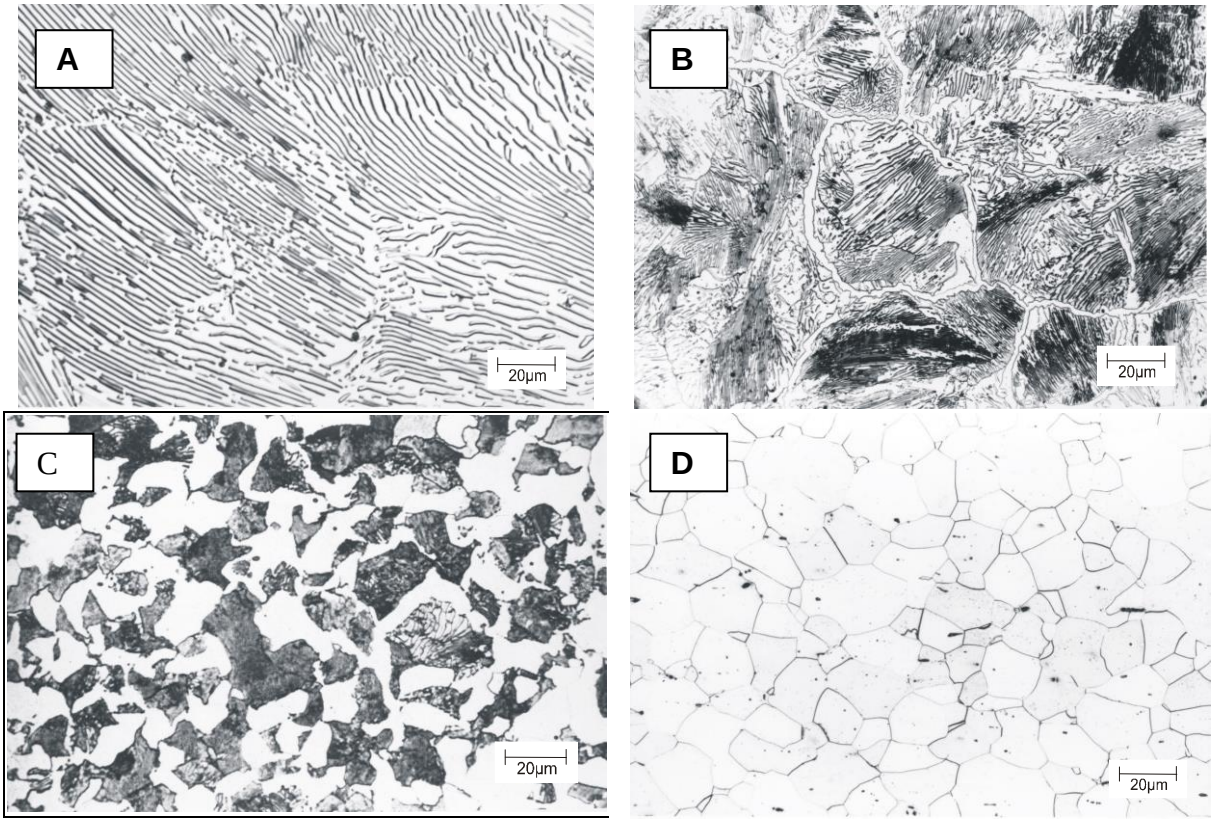
(i) low carbon steel

(ii) eutectoid steel

(iii) hypereutectoid steel

(iv) hypoeutectoid steel

Anlage1:



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Task 8 Martensitic phase transformation 9 Point(s)

The martenistic transformation consists of two deformation steps: in the first step, the crystal lattice changes – in the second step leaves the lattice invariant changes.

a) Explain the lattice changing deformation according to Bain, briefly. Illustrate your explanation using three labelled sketches. Name the axes and indicate the direction of the Bain-deformation. (5.0 Points)

b) Martensite has a higher strength compared to austenite. Name the four effects which contribute to the high strength of martensite. (4 Points)

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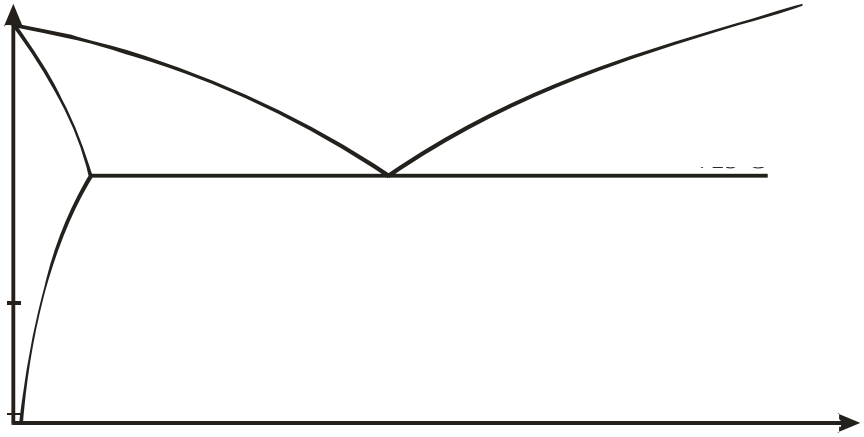
Task 9 bainitic phase transformation 6 Point(s)

a) Depending on the phase transformation temperature and/or the carbon content different kind of bainitic steels can be observed. One possible separation between different bainitic steels is to separate between “upper” and “lower” bainite. Sketch the stability bound between “upper” and “lower” bainite in the given Fe-Fe_3C-diagram in appendix 2. Add necessary construction lines and necessary temperatures (4 Points).

Appendix 2:



b) Besides the bainitic ferrite, secondary phases might be present in bainite. Name at least two of them! (2 Points)

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Task 10 aging 8 Points

a) Define the term “aging” from a material science point of view. What are the two main important factors which influence aging (1 Points)?

b) What are the three preconditions that the aging of steels can occur (1.5 Points)

c) What is the influence of aging on the stress-strain-curves of deep-drawing-steels? Name two reasons why this phenomenon is undesirable? (3 Points)

d) “Temper rolling” (skin pass rolling) can be used to avoid aging in deep drawing steel grades which are very sensitive to aging. Explain the process step “temper rolling” and the effect of this treatment on the aging behaviour of steels. *(2 Points)*

e) Point out two additional methods to avoid the aging in steels. (1 Point)

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g) An artificial aging effect during the production of sheet material is used to improve the mechanical properties of sheet material for cars. This aging is caused during the painting process at ~ 200°C after deep drawing. What is the name of this effect that takes place during painting? Which mechanical property is improved due to this treatment? (1 Points)

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Task 11 CCT- and TTT-diagrams 8 Points

a) What kind of diagram can be observed in Appendix 3 (1 Point)?

b) Which three experiments do you need to perform to create such a diagram mentioned in task a) (3 Points)?

c) What is the shortest annealing time and corresponding annealing temperature that are necessary to achieve:

- a pure bainitic
- a pure pearlitic

steel (2 Points)?

d) What microstructure does the steel show after water quenching to room temperature according to the CCT-Diagram from task a)? (2 points)

Appendix 3

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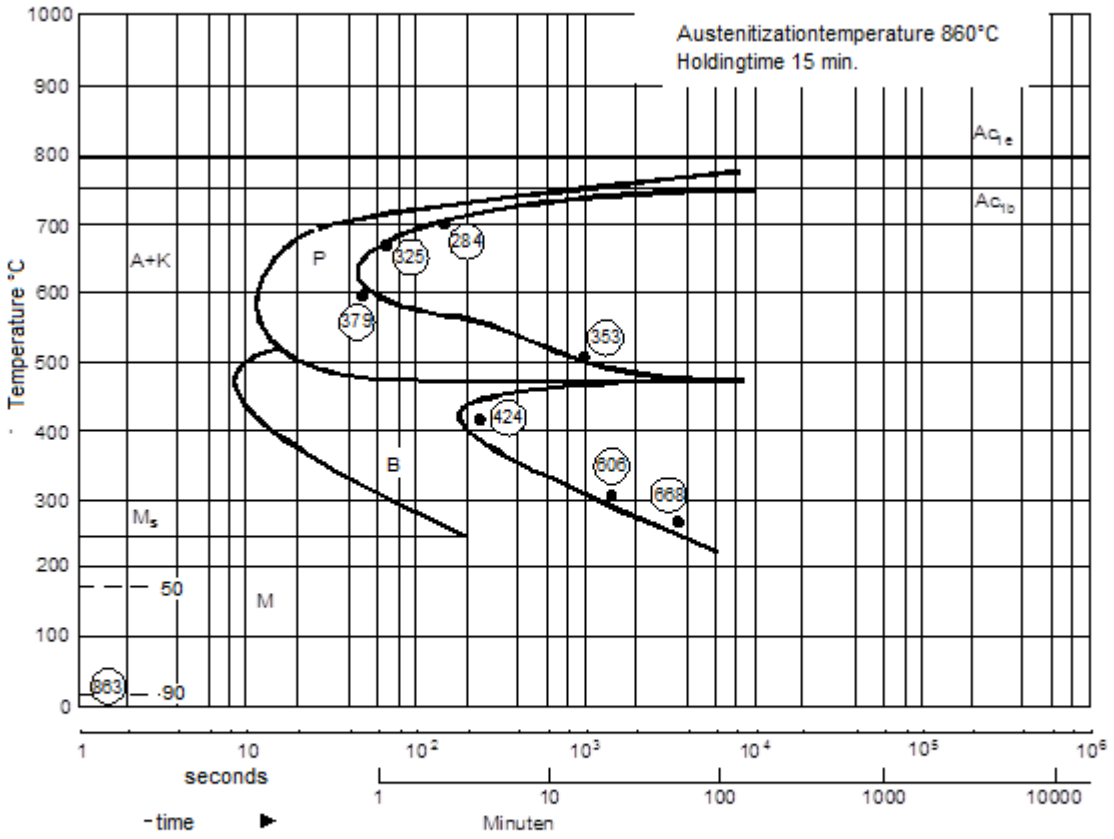
chemical compositior.	C	Si	Mn	P	S	Cr	Cu	Mo	Ni	V
in %	1,04	0,26	0,33	0,023	0,006	1,53	0,20	<0,01	0,31	<0,01



A Austenite
A+K Austenite + Carbides
K carbide formation
◯ hardness in HV

P Area of pearlite formation
B Area of bainite formation
50,90.. volume fractions in %

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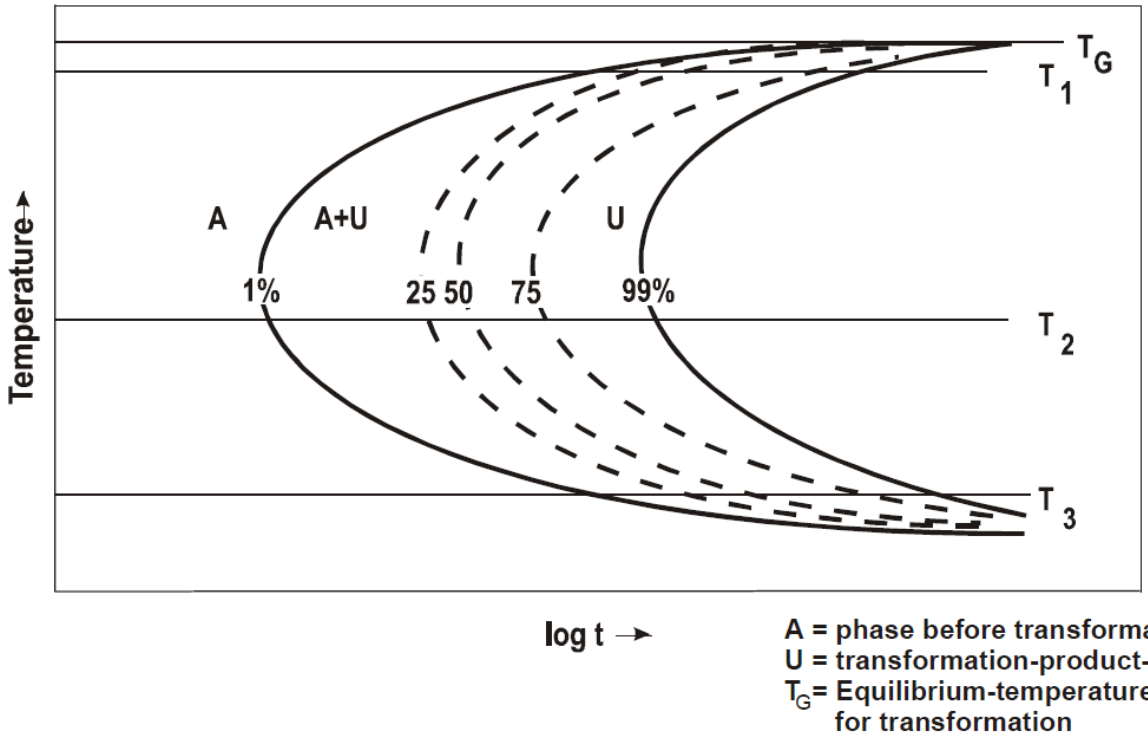
Task 12 CCT- and TTT-diagrams 8,5 Points

In Appendix 4 you can find a C-shaped curve for an isothermal diffusion controlled phase transformation.

Appendix 4



a) Explain the different starting times for the phase transformations for the isothermal temperatures T_1, T_2 and T_3. (6 Points)

b) Which isothermal treatment, T1 or T3, will result in a larger grain size? Explain your answer briefly. (2 Points)

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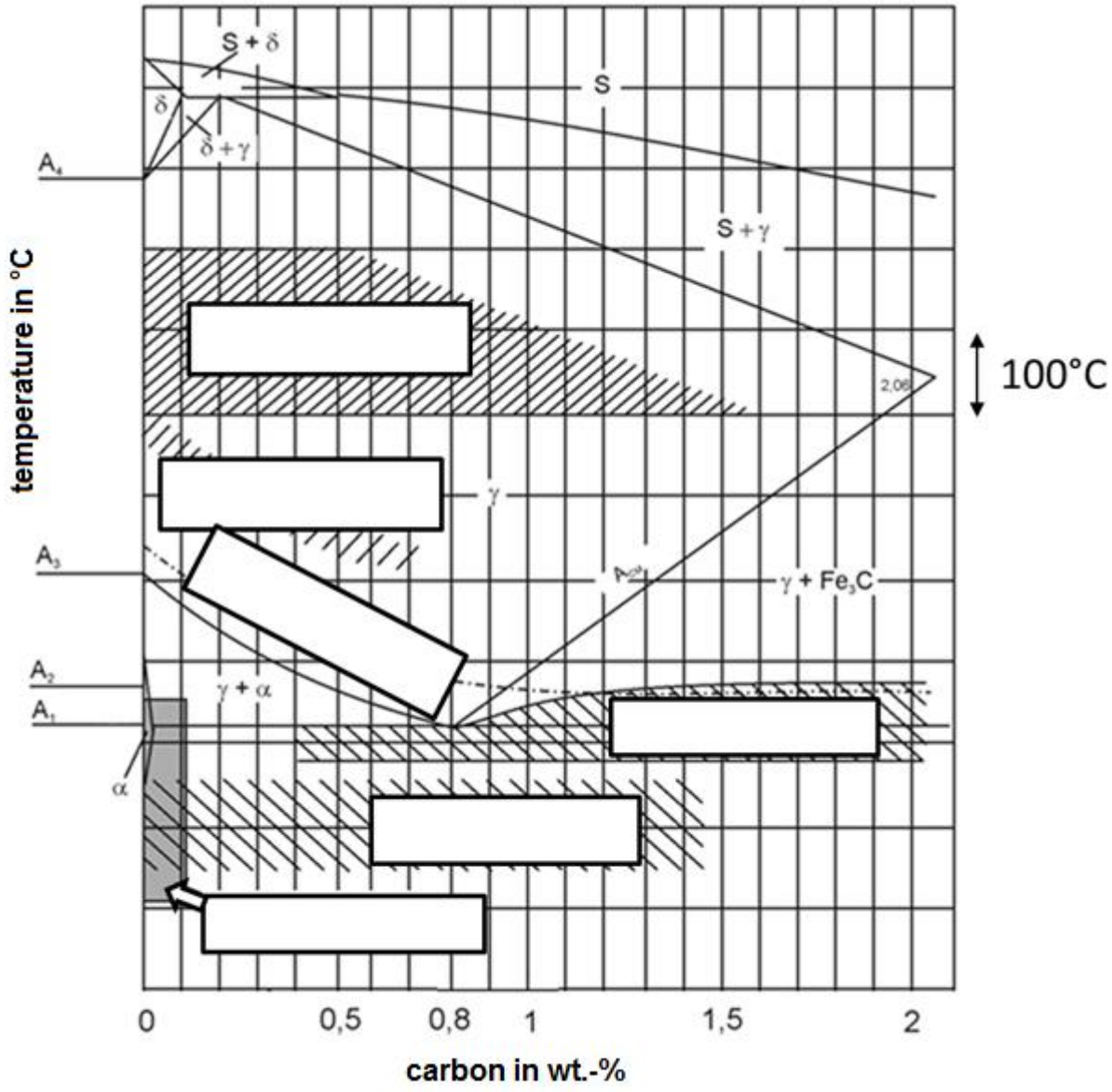
Task 13 technical heat treatments 11 Points

Appendix 5 shows a section of the Fe-C diagram, where different regions for heat treatments are marked.

a) Add the following temperatures on the y-axis in the Appendix 5: 500 °C, 1000°C, and 1500°C. (1.5 Points)

Appendix 5



b) Add the name of the different heat treatments in the empty boxes in Appendix 5. (6 Points)

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c) After casting of steels segregations can be observed which come from the solidification. Explain the term “segregation”, briefly. (1 Point)

d) Which heat treatment from task b) can be used to remove these segregations? (1 Point)

e) Why is this treatment only carried out for high-quality steel grades? (1 Point)

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Task 14 technical heat treatments II 4 Points

Deep drawing is a common forming process for sheet steels for automotive applications. To ensure a good deep-drawabilty of cold rolled steels a special heat treatment is carried out.

a) Which technical heat treatment is carried out after cold rolling and what is the purpose of this action? (2 Points)

b) Name two different industrial processing routes for this heat treatment. (2 Points)

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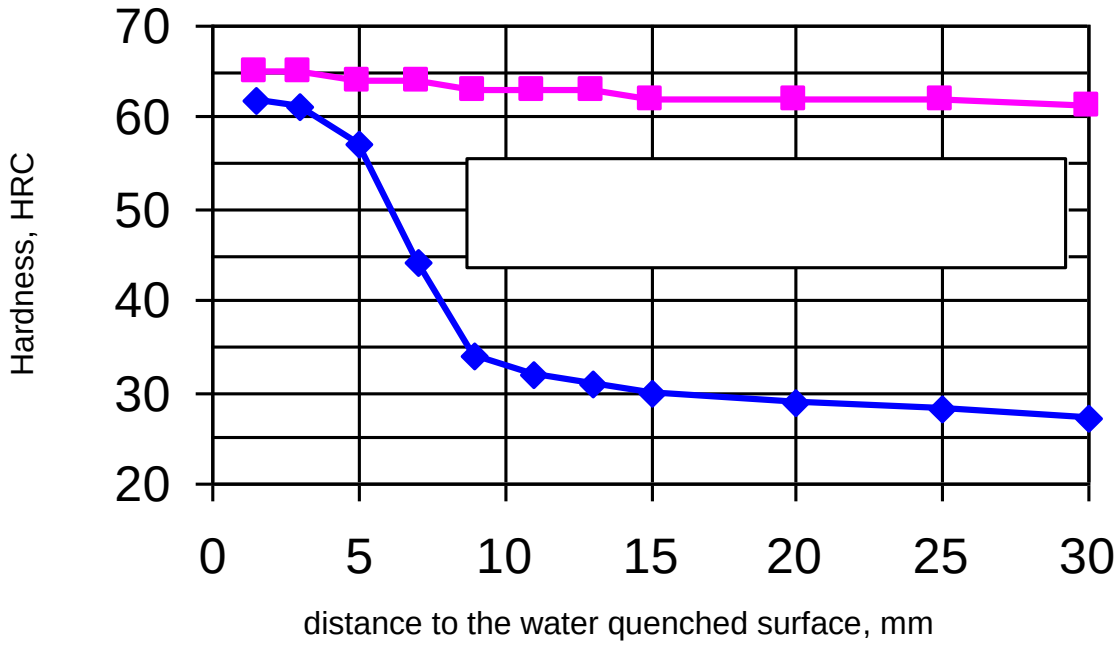
Task 15 Quenching and tempering 11 Points

Hardenability describes the ability of a steel to transform after austenitizing into martensite and/or bainite by quenching. It is characterized by the variation in hardness as a function of the distance to the water quenched surface of a workpiece (Jominy end quench test).

a) Name two substitutional elements which increase the hardenability. (2 Points)

b) There are two Jominy-curves for a C45 and a 51CrV4 given in Appendix 6. Which steel grade belongs to which line and which steel would you recommend if you need a steel which has a hardness of 60 HRC in the core of a rod with a 10 mm diameter after quenching? (2 Points)

Appendix 6



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c) What is the influence of this quenching on the ductility of the material? How can you achieve an optimum combination of strength and ductility? (2 Points)

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