Master examination

„Metallic Materials“

27.07.2016

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 (additional Points)
1	10		
2	6		
3	5		
4	6		
5	4		
6	2		
7	6		
8	3		
9	6		
10	9		
11	6		
12	6		
13	8		
14	6		
15	8		
16	9		
Sum	100		

The overall grade for the examination of „Metallic Materials“ will be weighted from the results of the respective parts "Microstructure, Microscopy and Modelling" and "Metallic Materials” for a duration of 90 minutes each.

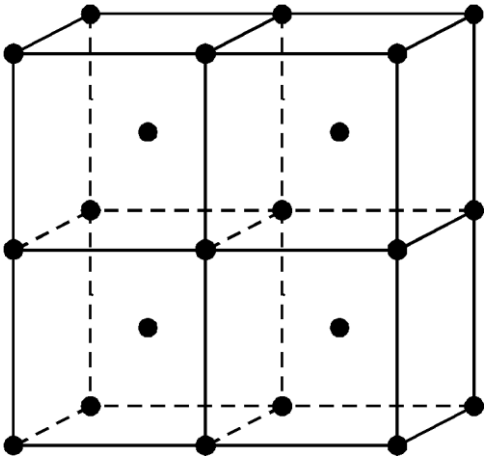
Task 1 Crystal structure 10 Point(s)

A feature of iron is that different crystal modifications can occur in its solid condition: the body centered cubic (bcc) and the face-centered cubic (fcc) lattice.

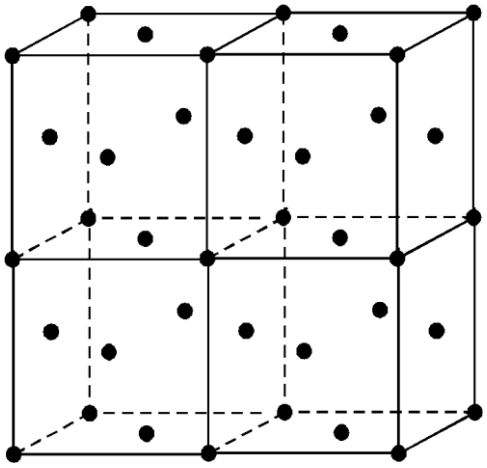
a) In **annex 1** both a bcc-lattice (grid) and a fcc- lattice (grid) are given. Highlight in both lattices an example for an octahedron gap and a tetrahedron gap and draw the corresponding octahedron and tetrahedron in the respective lattice (*4 Points*)

b) Which differences exist between the two lattice types concerning the number and size of the gaps? Which consequences result from this for the diffusion characteristics and the solubility of C in Fe (*6 Points*)?

Annex 1:



bcc-lattice



fcc-lattice

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Task 2 Magnetic properties 6 Point(s)

Basically, an external magnetic field induces an electrical current within the materials electron shell, which results in an internal magnetic field.

a) Describe the types of magnetism occurring in metals. Sketch the magnetic moments for these types of magnetism in the Figure 1. (4 Points)

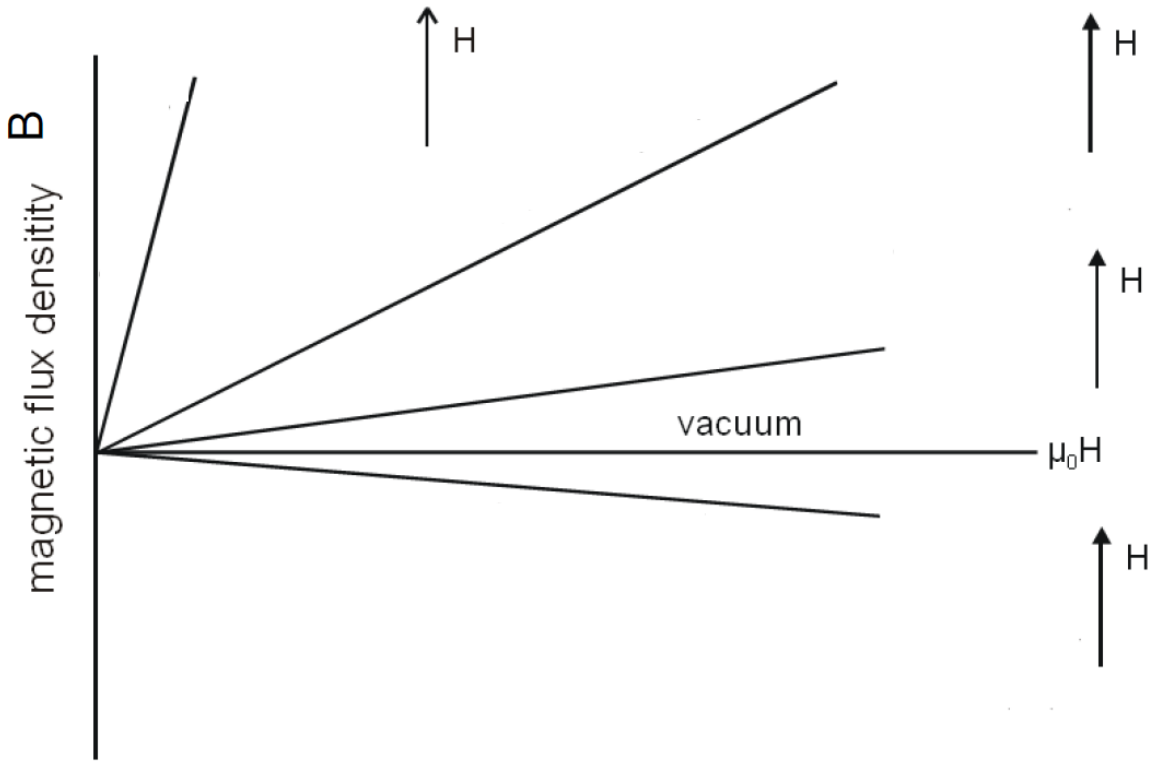

Figure 1

b) Explain the Curie temperature T_c briefly. (1 Point)

c) Why is Si the most favorable alloying element for electrical steels? (1 Point)

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Task 3 Alloying elements 5 Point(s)

In the metastable Fe-Fe_3C phase diagram several phase transformation reactions can be found.

a) Write down the respective transformation reactions (reacting phase(s) → produced phase(s)) and the carbon contents of all participating phases. (4 *Points*)

1: eutectic reaction:

Equation (phases): _____ → _____

C contents: _____ → _____

2: eutectoid reaction:

Equation (phases): _____ → _____

C-contents: _____ → _____

b) Indicate the equilibrium temperature for the eutectoid and the eutectic reaction. (1 Point)

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Task 4 Stainless steels 6 Point(s)

Chromium is an important alloying element for the design of corrosion resistant steels. Sketch a current-density potential-curve of a stainless steel in Figure 1. Indicate all characteristic current density and potential Points from the legend in the sketched diagram. (6 Points)

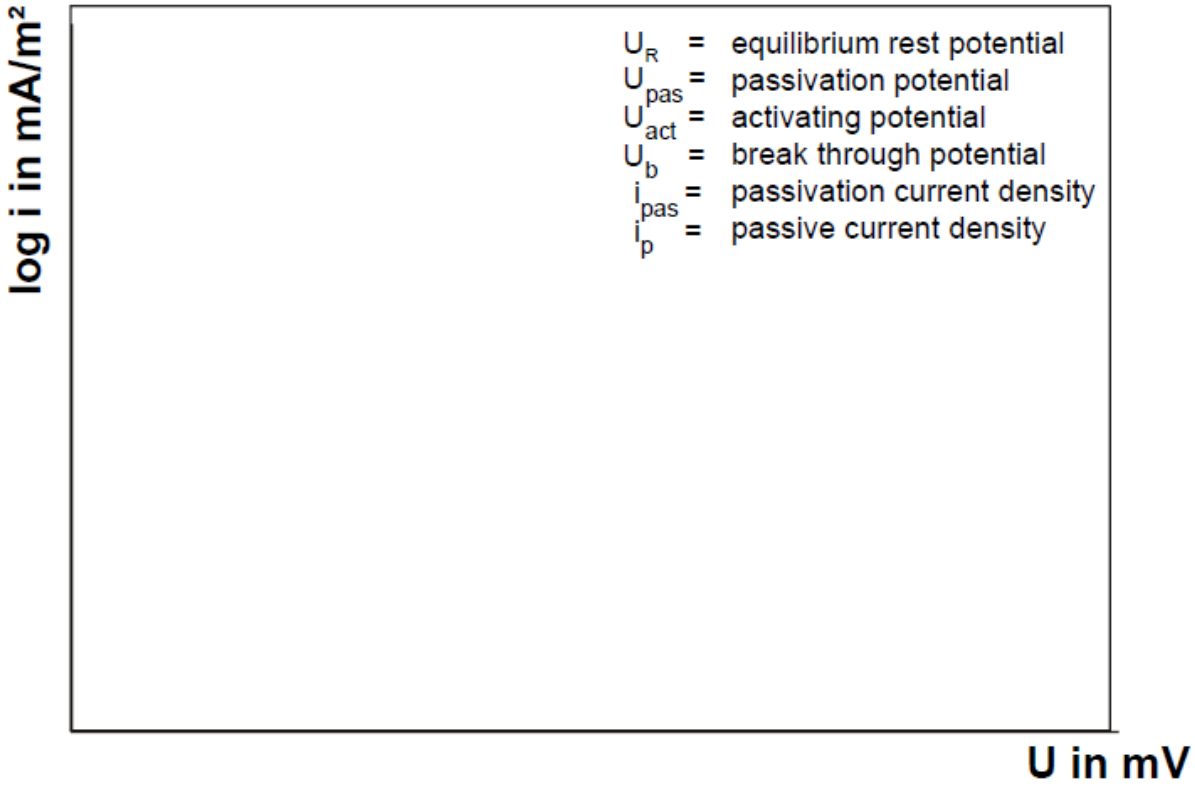

Figure 1 current density potential-curve of a stainless steel

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Task 5 Stainless steels II 4 Point(s)

Stainless steels can have fcc or bcc lattice structure depending on their chemical compositions.

a) What is the lattice structure of the following steels: (1 Point)

- X6Cr17
- X5CrNi18-10

b) Sketch a stress-strain diagram for steel X6Cr17 and X5CrNi18-10. Consider yield strength, strain hardening and total elongation. (2 Points)

c) Is the corrosion layer of Cr-alloyed steels affected due to welding? Explain your answer briefly. (1 Point)

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Task 6 Phase transformations 2 Point(s)

The austenite decomposition into its different microstructure constituents plays a major role for the processing of steels.

Which two basic types of phase transformations can occur during austenite decomposition (2 Points)?

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Task 7 Phase transformation II 6 Point(s)

A non-alloyed steel with a carbon-content of 1.2 % C is heated to the following temperatures:

- above A_{ccm},
- between A_{c1} and A_{ccm} and
- just below A_{c1}

In all cases the steel is held just as long as full soaking of the material is guaranteed.

a) Which microstructures occur at each of the 3 given temperatures (3 Points)?

b) How are the microstructures from a) affected when quenching in salt brine (3 Points)?

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Task 8 Ferritic-Pearlitic Phase transformation 3 Point(s)

After metallographic analysis of an 0.5 mass-% C containing steel the microstructure consists of 80% pearlite and 20% ferrite.

a) What should be the equilibrium fractions of ferrite and pearlite for this steel (*2 Points*)?

Note: use the lever-rule!

b) How can the observed microstructure be realized in the selected steel (*1 Point*)?

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Task 9 Bainitic phase transformation 6 Point(s)

a) What is the approximate temperature range for the bainitic phase transformation (2 Points)

b) What are the two steps for a bainitic phase transformation (2 Points)

c) Name at least 2 phases which can exist in the bainitic ferrite matrix in bainite structure (2 Points).

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Task 10 Martensitic phase transformation 9 Point(s)

Heavy undercooling of austenitic microstructures changes the conditions for diffusion dramatically. Thus the diffusion controlled $\gamma-\alpha-$transformation may be suppressed in favour of the martensitic transformation.

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

a) Explain the model for the lattice changing deformation according to Bain briefly. Illustrate your explanation by three labelled sketches! Name the axis and give the direction of the Bain-deformation. *(4 Points)*

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b) Which 2 lattice invariant deformations occur in Fe-C-Martensite? *(1.0 Points)*

c) Carbon atoms are primary located in the octahedron gap of the austenite lattice. Explain the effect of increasing carbon content on the tetragonality of martensite! (1.0 Points)

d) Draw a sketch of the martensite start temperature M_s and the martensite finish temperature M_f in diagram 1 for increasing carbon content! Explain the curve briefly! *(2 Points)*

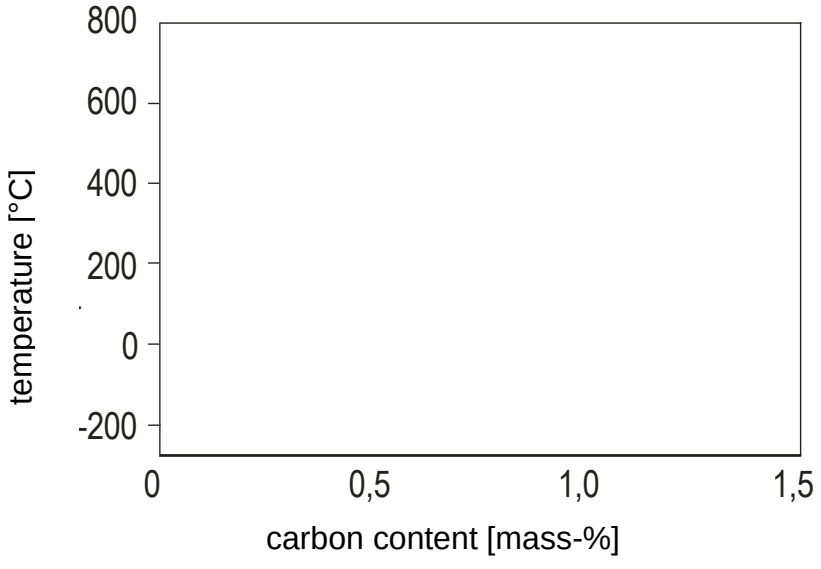

Diagram 1

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e) Which microstructure has a steel (carbon content 1 %) after water quenching from the austenite region ($T_{austenitisation}$>T_{Accm})? *(1.0 Points)*

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Task 11 Aging of steels 6 Point(s)

Bake-Hardening steels are used in the automotive industry as high-strength steels.

a) Describe the different steps taking place during the Bake-Hardening treatment. Explain the role of C and dislocation density (*2 Points*).

b) Sketch qualitatively in a diagram the stress-strain curve of a Bake-Hardening steel before and after the Bake-Hardening treatment. (*2 Points*)

c) Is it possible to use the Bake-Hardening effect, if the 20-minute heat treatment is carried out at 80°C or at 400°C? Discuss your answer by explaining the processes occurring in the material at these temperatures. (*2 Points*)

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Task 12 CCT-Diagrams 6 Point(s)

Figure 1 shows the standardized transformed amount in dependence of logarithm of time for a diffusion controlled transformation process (e.g. ferrite formation). The results show a sigmoidal curve.

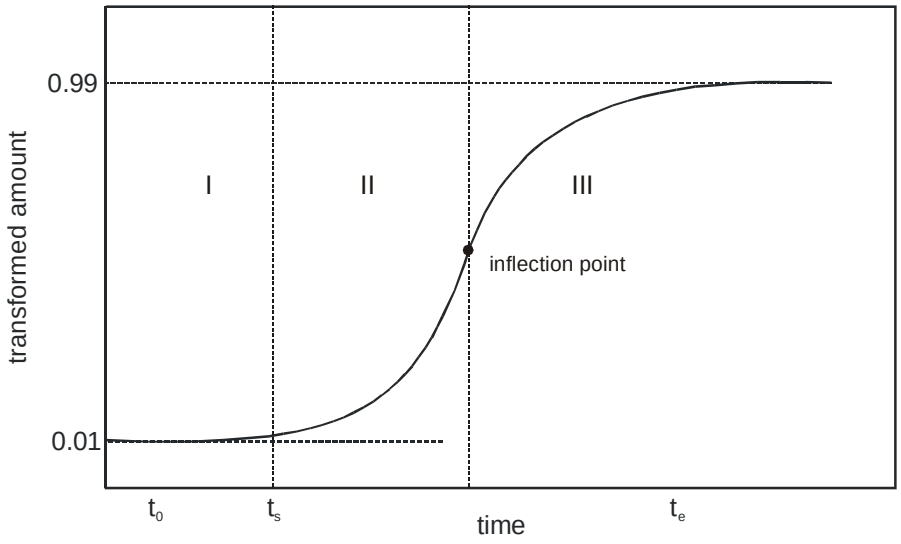

Figure 1:

a) Explain the processes in the three given ranges briefly (*3 Points*).

b) Give the equation describing the ferrite formation and name required constants and variables (*3 Point*).

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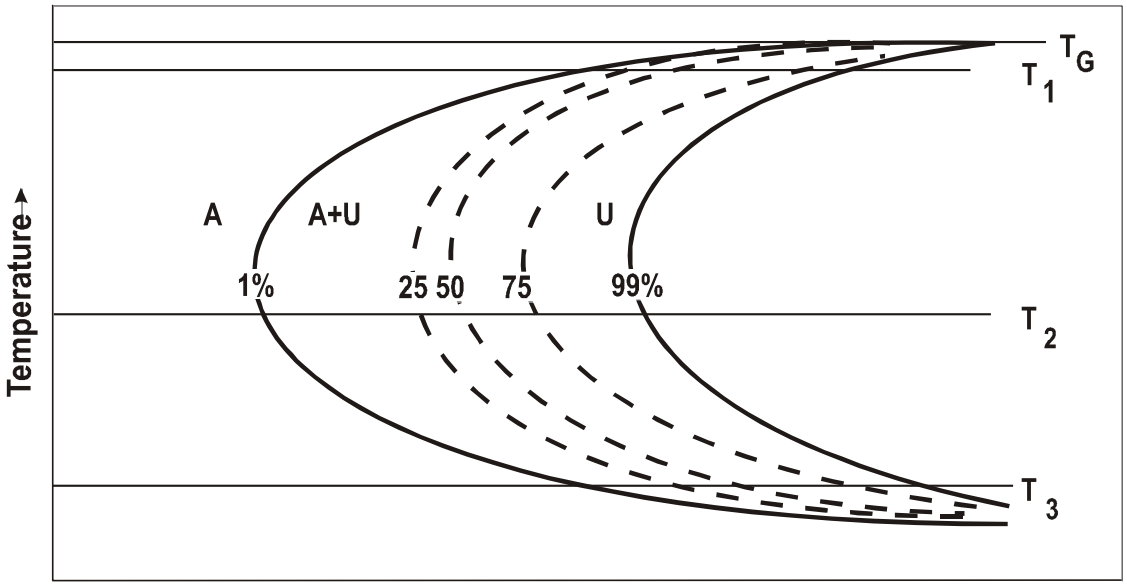
Task 13 CCT-Diagrams II 8 Point(s)

In **Figure 1** you find a schematic drawing of the typical C-shaped run of a diffusion controlled transformation in a TTT diagram.

Figure 1:



A = phase before transformation
U = transformation-product-phase
T_G = Equilibrium-temperature for transformation

a) Give an explanation for the time-shift in start and finish of transformation at the marked temperatures T_1, T_2 and T_3 (*6 Points*).

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b) Do you expect a larger grain size after the transformation at T_1 or at T_2? Explain your answer (*2.0 Points*)!

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Task 14 technical heat treatment I 6 Point(s)

An annealing treatment is performed on industrial processed cold rolled steel before further processing, e.g. deep drawing.

a) What is the purpose of this annealing treatment? (1 Point)

b) What is the influence of this annealing treatment on the mechanical properties compared to the properties before cold rolling? (1 Point)

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c) What is the difference between this annealing and normalizing? (1 Point)

d) There are two different processing approaches for this annealing treatment. Name both and explain what is the economic for each procedure. (3 Points)

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Task 15 technical heat treatment II 8 Point(s)

Figure 1 shows a section of the Fe-C diagram, where different regions for heat treatments are marked.

a) Please add in the diagram shown below the values for the important temperatures A_1, A_2, A_3 and A_4 ! (2 Points)

b) Add die names of the different heat treatment in the corresponding boxes in the diagram! (6 Points)

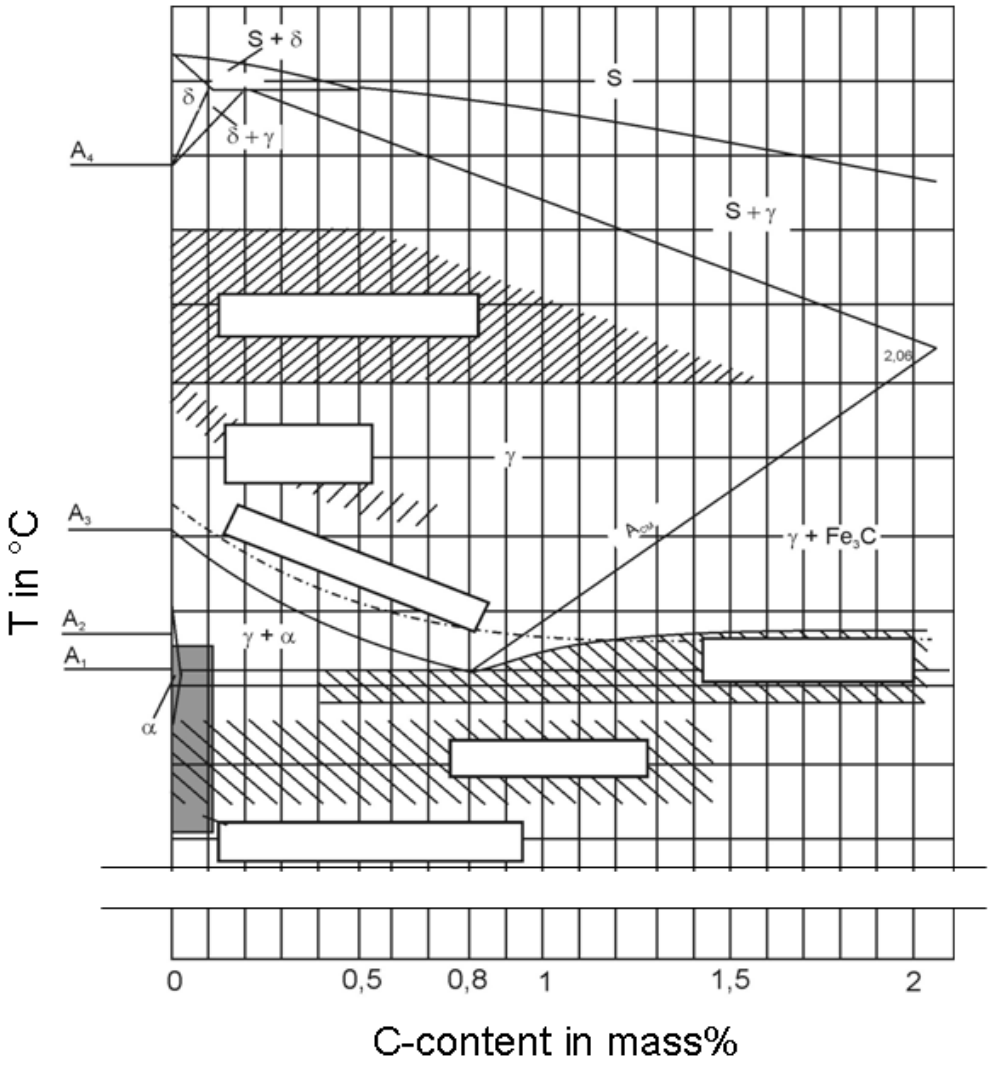

Figure 1: Section of the Fe-Fe3C-diagramm

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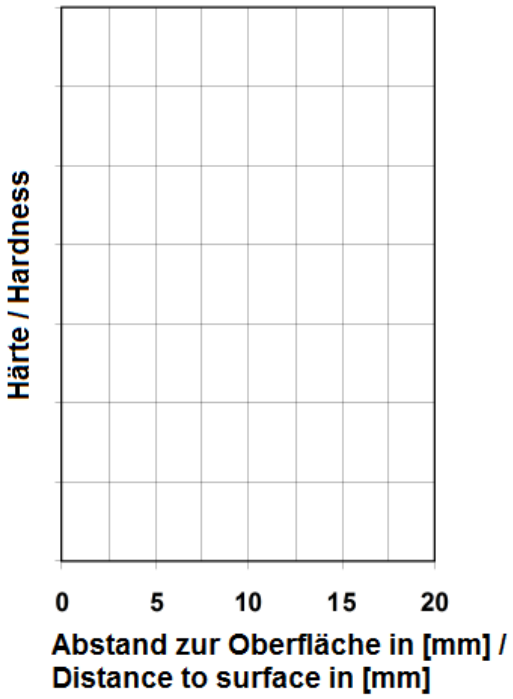
Task 16 Quench and Tempering 9 Point(s)

A shaft with a diameter of 40 mm has to be quenched and tempered to adjust the desired mechanical properties. Available materials are

- C35
- 44Cr2
- 42CrMo4

a) Sketch the hardness after quenching as a function of the distance to the surface for each steel in figure 1 (*3 Points*).



b) Explain the differences in the curves! Use the terms „hardenability“ and “critical cooling rate”! (*2 Points*)

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c) What is the purpose of tempering? (1 Point)

d) Tempering is divided into different temperature ranges based on the metallurgical phenomena occurring at these temperatures. Give the temperature ranges for 3 different tempering levels and name the most important phenomena at each tempering level. (3 Points)

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