

Master examination

„Materials Science of Steel“ Pt. 1

31.03.2016

Name:

Matriculation number:

Signature:

Task	Points:	Points achieved:	Points after review (additional Points)
1	7		
2	6		
3	10		
4	7.5		
5	6		
6	3		
7	4		
8	5		
9	7		
10	3.5		
11	8		
12	8		
13	8		
14	8		
15	5		
16	4		
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 testing****7 Point(s)**

- a) Sketch the stress-strain-curve for an IF-steel (Steel without solute interstitial atoms) and indicate characteristic values. Furthermore, indicate the regions of homogenous and inhomogenous deformation. (4,5 Points)
- b) What is the maximum load that can be applied on a specimen before permanent deformation occurs? What is characteristic for this load? (2,5 Points)

Task 2**true stress – true strain****6 Point(s)**

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 in the same 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? (1 Point)
- d) For which steels is the occurrence of a discontinuous yield strength adjusted by a technical heat treatment? (1 Point)

Task 3**Considère-criteria****10 Point(s)**

"True stress"- "true strain"-curves do not have a maximum force which can be correlated with the beginning of necking. The uniform strain can be calculated using the Considère-criteria.

- a) Derive the equation for the Considère-criteria to calculate the uniform strain.
(6 Points)

b) Sketch the Considère-criteria. (4 Points)

Task 4**hot tensile test****7,5 Point(s)**

- a) Figure 1 and Figure 2 show the mechanical properties as a function of the testing temperature determined from several hot tensile tests for two different steels. Label both Y-Axes for both figures. Which material is more suitable for strip casting? Explain your choice briefly. (3 Point)
- b) Explain the minimum of the curves at temperatures between 800 and 900°C. (1 Point)
- c) What is the name of the characteristic temperatures which are at 1300°C and 1400°C for Material B? What is the consequence if the temperature difference ΔT between this temperatures is too big? (2 Points)

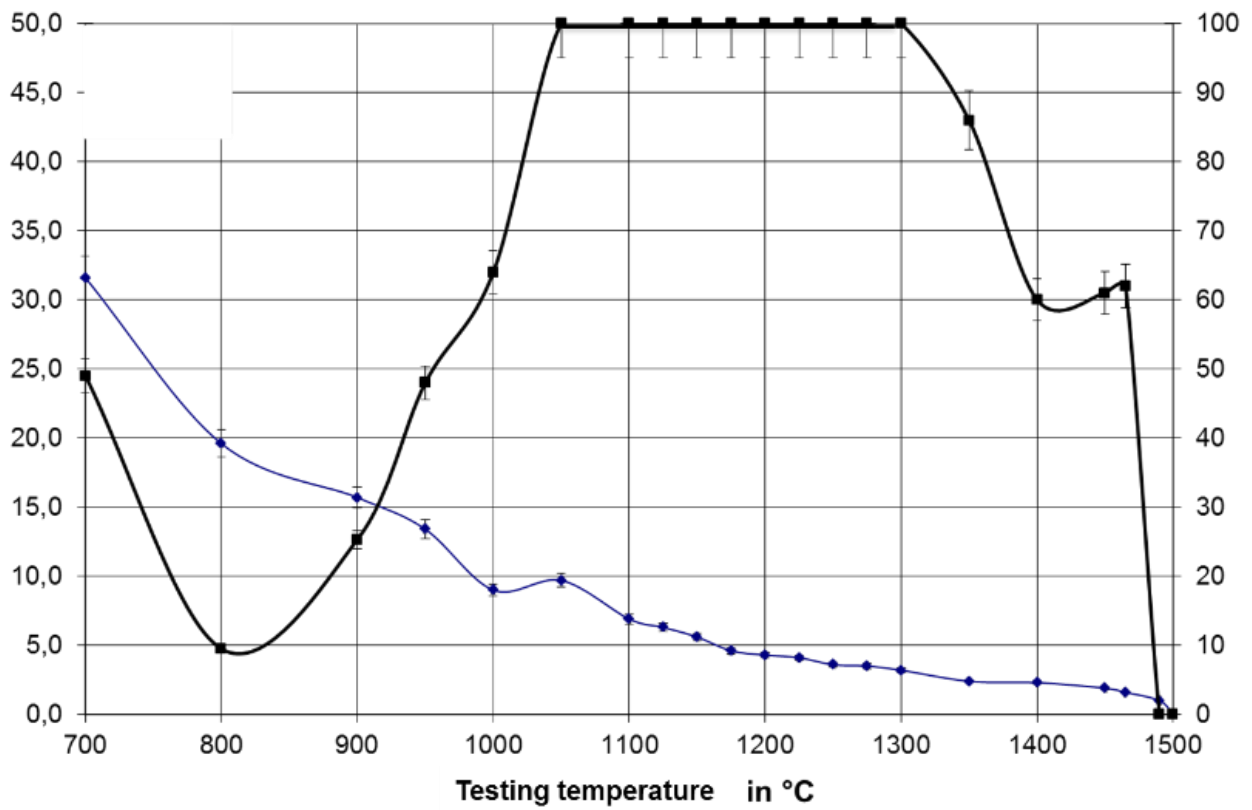


Figure 1: Material A

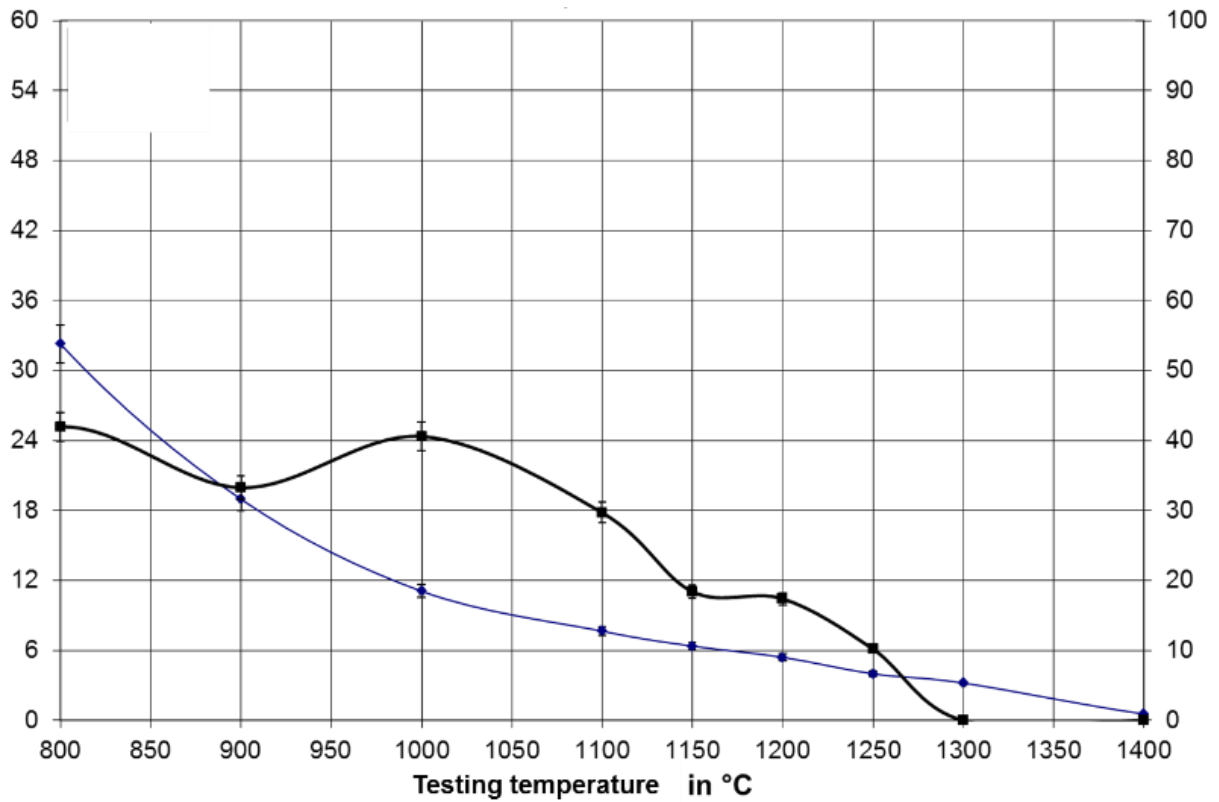


Figure 2: Material B

- d) Figure 3 shows three specimen after testing at 950°C, 1200°C and 1500°C of material A. Which specimen belongs to the previous mentioned testing temperatures? (1,5 Points)

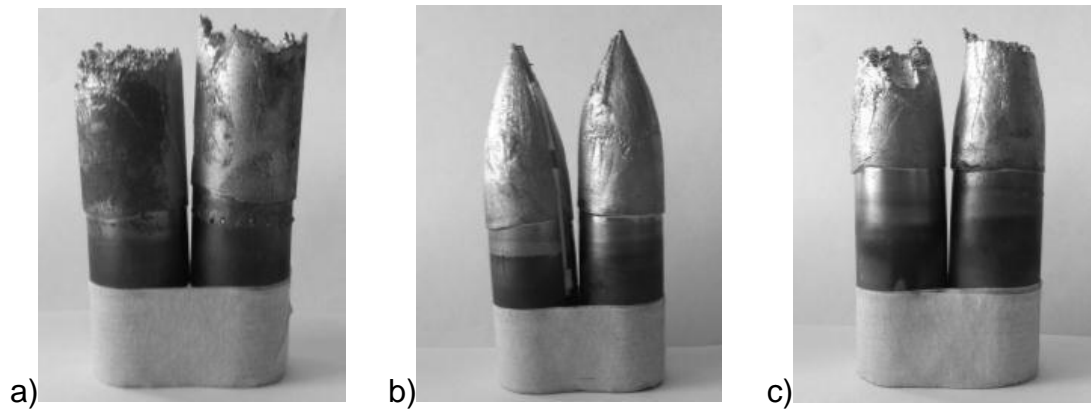


Figure 3: hot tensile test specimens after different testing temperatures

Task 5**Strain rate dependency****6 Point(s)**

The deformation behavior of steels is significant dependent on the strain rate and the temperature.

- Sketch a stress-strain curve for a ferritic-pearlitic steel in the three given diagrams in Figure 1. Consider the temperature related effects during the plastic deformation. (3 Points)
- Add a stress-strain curve for a specimen tested with a higher strain rate in each diagram and indicate the difference of the higher strain rate. (3 Points)

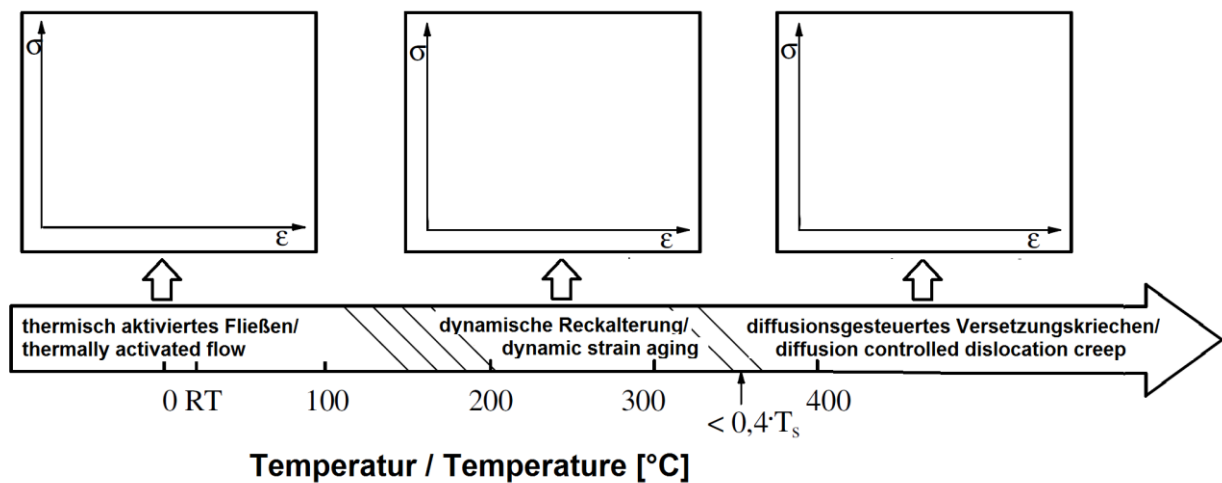
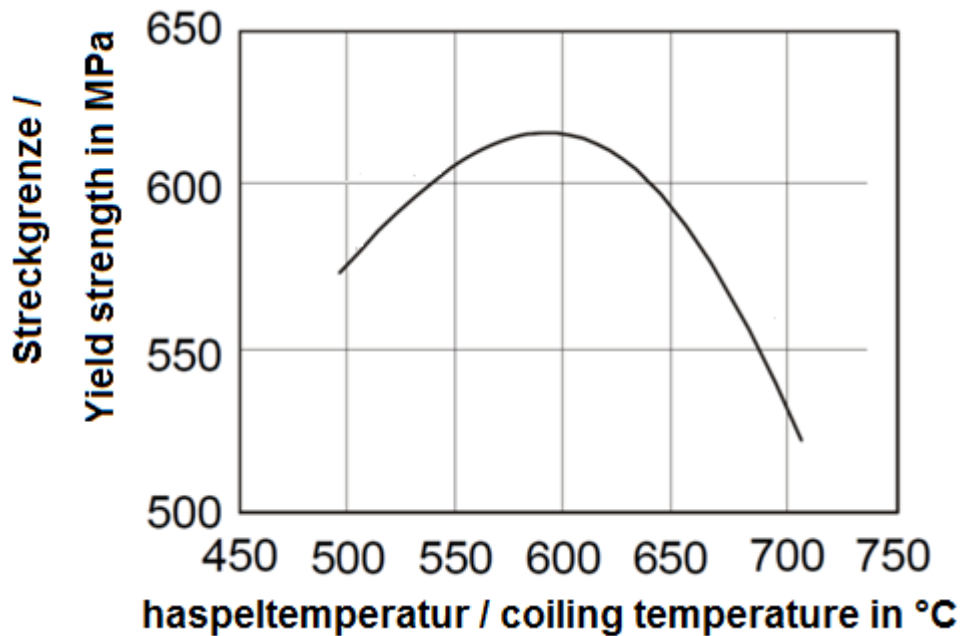


Figure 1

Task 6**Thermomechanical processing I****3 Point(s)**

Figure 1 shows the effect of the coiling temperature on the yield strength of a thermomechanically treated steel. Which microalloying element has been added to the steel? Explain the maximum of the yield strength at 600 °C briefly. (3 Points)



Task 7**Thermomechanical processing II****4 Point(s)**

- a) What is the typical content of microalloying elements in thermomechanically treated steels? (1 Point)
- b) What is the influence of each of the microalloying elements Ti, Nb and V on the toughness of thermomechanically treated steels? Explain your answer briefly. (3 Points)

Task 8**Strengthening of Steel****5 Point(s)**

- a) What is the relationship between the yield point of mild steel and the ferrite grain size (name and formula)? Which impact factors are relevant for the constants in this formula? (2.5 Points)
- b) Calculate the yield strength increase when the grain size is changed from $G=8$ to $G=11$. Use reasonable values for the required constants. (2.5 Points)

Hint:

$$d[\text{mm}] = \frac{1}{\sqrt{8 \cdot 2^G}}$$

Task 9**Fracture mechanisms****7 Point(s)**

- a) Name the 3 different steps of slip fracture. (3 Points)
- b) Explain the difference between transcrystalline and intercrystalline crack configuration (2 Points)
- c) Describe the macroscopic fracture appearance of slip- and cleavage fracture (2 Points)

Task 10**Fracture mechanics****3,5 Point(s)**

The toughness of structural parts can be described quantitatively by fracture-mechanics analysis.

- a) Describe the difference between the fracture-mechanics properties i) stress intensity factor and ii) fracture toughness. (2 Points)
- b) Do you need plane stress or plane strain to calculate the fracture toughness? Explain your answer briefly. (1,5 Points)

Task 11**Impact testing****8 Point(s)**

The time-force diagram of an Instrumented impact testing of a high strength construction steel (S690Q) using ISO-V-notch specimens ($10 \times 10 \times 55 \text{ mm}^3$) can be seen in **Diagram 1**. The impact velocity of the pendulum is 7.72 m/s (impact energy 1471 J, mass of pendulum 49,368 kg).

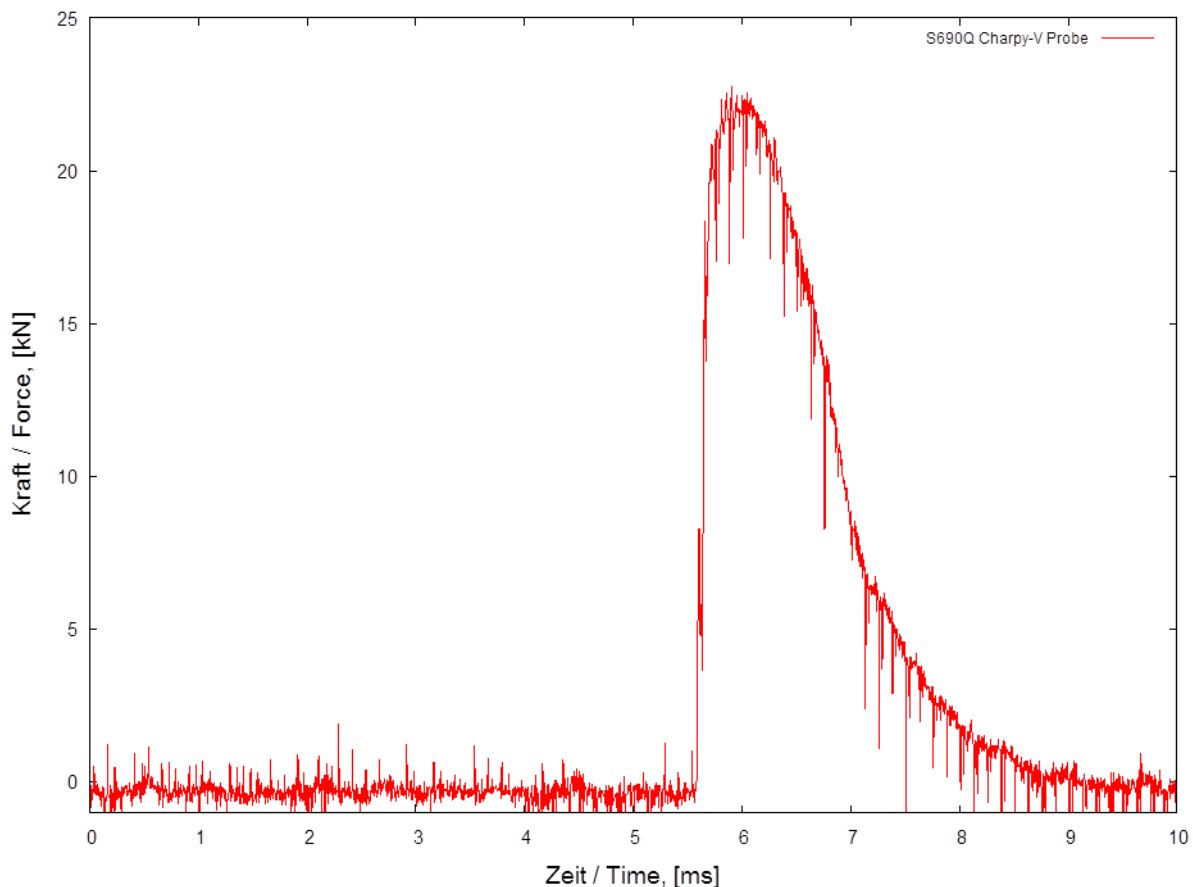


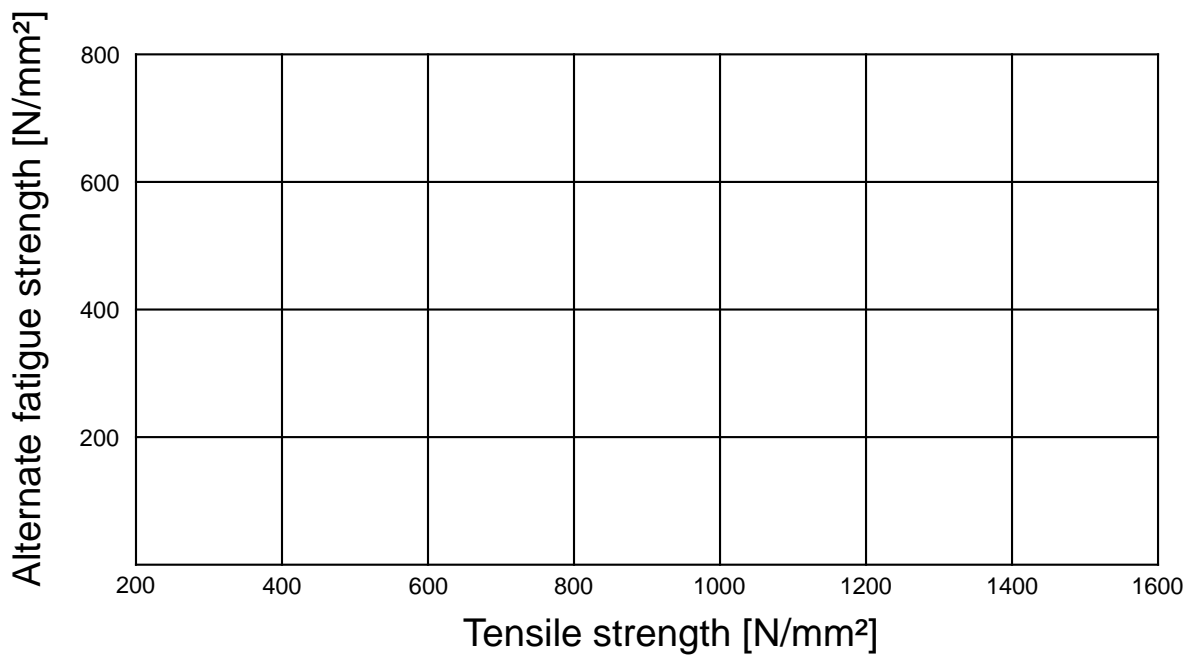
Diagram 1 force-time diagram of an instrumented charpy impact test, steel S690Q, Charpy-V-notch specimen

- a) Which equations are necessary to calculate the notch impact energy based on the force-time-diagram? (2 Points)

- b) Describe qualitatively the pendulum velocity change during the fracture of the sample. Is the energy change relevant when a typical structural steel with an impact energy of ~ 300 J is tested? (2 Points)
- c) Simplify the equations of task a) based on the additional information derived from task b). (2 Points)
- d) Estimate the charpy impact energy based on the equations from task c). Describe all necessary assumptions which are therefore necessary. (2 Points)

Task 12**Cyclic testing****8 Point(s)**

- a) In low-alloyed and alloyed steels a correlation between alternate fatigue strength and tensile strength can be observed. Moreover there is a strong influence of the load type (bend loading, tensile-compression alternate loading, torsion) on the alternate fatigue strength. Sketch the correlation of alternate fatigue strength and tensile strength for each load type. (4 Points)

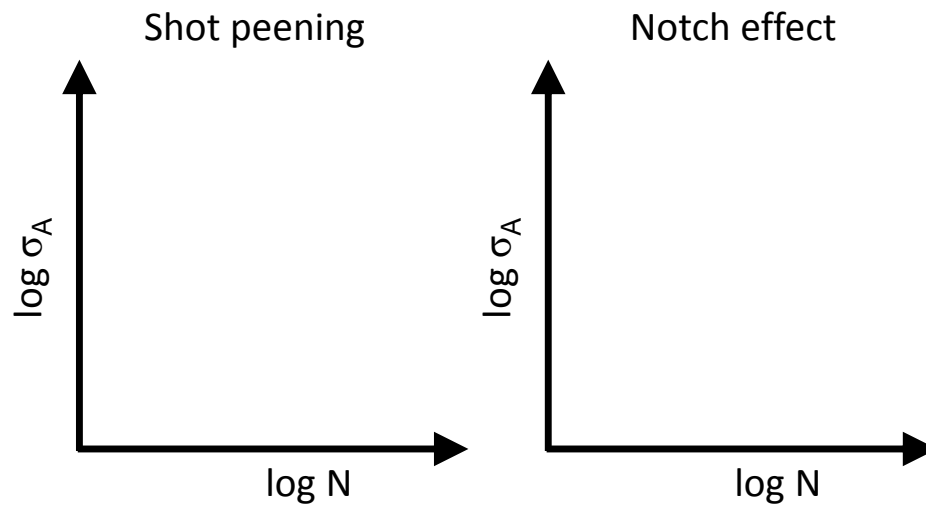


b) Sketch a woehler diagram for the following conditions in the given diagrams:

i) with and without shot peening

ii) with and without notch effect.

Explain the difference for the different testing conditions briefly. (4 Points)



Task 13**Sheet testing****8 Point(s)**

- a) The flow behavior of flat tensile tests is influenced by the characteristic values r , n and m . Define these properties and explain their importance. (3 Points)
- b) What are the equations to calculate the r_m and Δr . What do you expect if a material has the characteristic values $r_m=1$ und $\Delta r=0$? (2 Points)

c) What would be the optimum conditions for r_m and Δr for a material which is used for the production of beverage cans? Explain your choice briefly. (2 Points)

d) Two materials with the same yield strength and ultimate tensile strength have been tensile tested. The difference between them is the m value, which is:

Material 1: $m = - 0.1$

Material 2: $m = + 0.1$

Sketch the stress strain curves for both materials in one diagram. (1 Point)

Task 14 **High temperature properties** **8 Point(s)**

- a) The high temperature behavior of materials is strongly controlled by diffusion controlled processes. Sketch the plastic strain- time diagram which can be determined from creep tests in the upper diagram of **Appendix 1**. Furthermore add the areas of i) stationary creep, ii) accelerated creep and iii) transient creep. (2.5 Points)
- b) Sketch the corresponding creep rate in the lower diagram of **Appendix 1**. (1.5 Points)

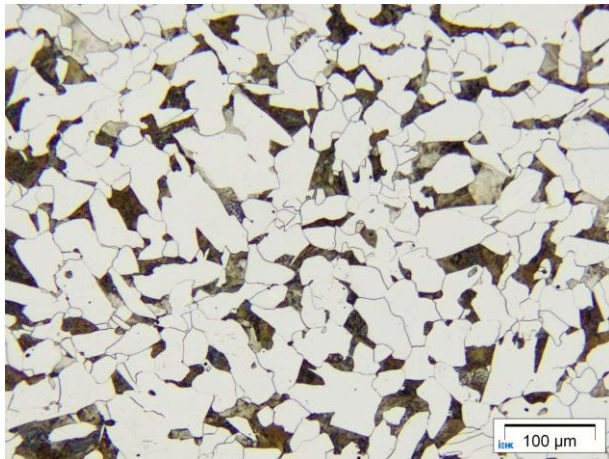
Appendix 1

- c) Name 4 metallurgical phenomena which occur during creeping (4 Points)
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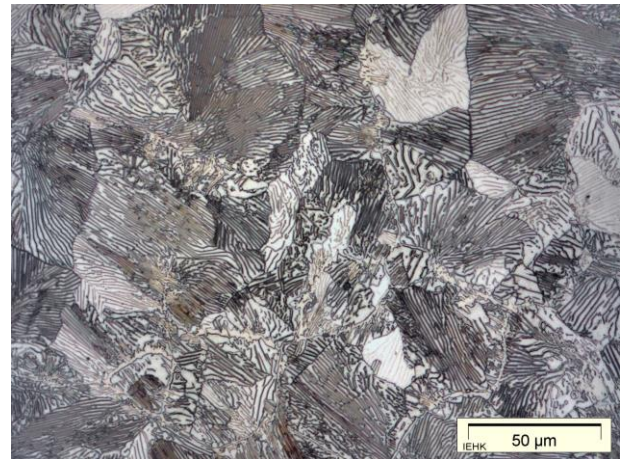
Task 15**Metallography****5 Point(s)**

Microstructural analysis is commonly carried out using light optical microscopy.

- a) Two different microstructures which have been cooled using near-equilibrium cooling rate can be seen in **Appendix 1**. Name both microstructures and label the different phases of each micrograph. (3 Points)

Appendix 1

1)



2)

- b) What is the approximate C content in wt.% for each steel? (2 Point)

Task 16**Electron microscopy****4 Point(s)**

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