National Examination, December2017

10-Met-B6, Physical Metallurgy of Iron and Steel

3-Hour Duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper with a clear statement of any assumptions made.

2. Candidates may use one of two non-programable calculators, the Casio or Sharpe approved models.

3. This is a *Closed Book* exam.

4. There is a total of 7 questions with a total of 100 marks possible.

I. (i) 5 marks, (ii) 5 marks

(i) In steel, when austenite transforms to martensite, there is a change in volume. The following equations are usually used to calculate the lattice parameters of phases involved in such transformation in which x is the carbon concentration in the steel.

In martensite:

$$c = 0.2866 + 0.0166x$$

$$a = 0.2866 - 0.0013x$$

In austenite:

$$a_o = 0.3555 + 0.0044x.$$

Calculate the *relative change* in volume in a steel of 1.0% C concentrations.
Hint: the volume of austenite unit cell = (1/2) $a_o^3$ and that of martensite = $ca^2$

(ii) With some assumptions, the lattice length change, or the strain, due to the aforementioned volumetric change is related to the volume change as follows.

$$\Delta l/l = \Delta v/3v$$

Calculate the strain caused by such phase transformation.

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II. (i) 5 marks, (ii) 5 marks (iii) 5 marks

(i) Conventional grey cast irons are generally considered brittle materials as they have very limited potential for plastic deformation. What is the micromechanism that reduced the ductility of the iron matrix in the material to a very low level?

(ii) Name three practical examples of parts or components whereby grey cast irons are still commonly employed, knowing that they have very limited ductility. Explain the reason.

(iii)Provide a practical method and explain the mechanism(s) of your method for producing ductile cast irons so that the ductility of cast irons could be considerably improved.

III. 5 marks, (ii) 5 marks

(i) By quenching a steel with a given C concentration, martensite can be obtained which gives rise to a high hardness of the steel. Upon tempering the steel at certain temperature, however, the hardness of the steel will decrease.
Explain why the hardness of martensite will decrease upon tempering?

(iii)Two grades of steels are quenched to obtain martensite. One of them has a C concentration of 0.3% and the other 0.7%. It was found that, after quenching, samples of the two steels obtained their respective hardness of HV510 and HV840, with a difference of HV330 between them. After tempering them both at 540°C for 1 hour, their respective hardness became HV190 and HV 230, with a HV40 difference. What is the reason that has made the HV difference to such small level after tempering at the same temperature for the same period of time?

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IV. (i) 7 marks. (ii) 8 marks. (iii) 5 marks.

Answer the following questions:

(i) Explain why a typical TTT curve has a "C" shape?

(ii) Explain why the addition of some alloying elements such as Cr in a carbon steel, say SAE1045, can move its TTT curve towards right-hand, i.e. increase the "gap" between the C-curve nose and the vertical axis.

(iii) Explain why the addition of a relatively large amount of some alloying elements such as Cr in a steel can change its TTT curve from a single "C" curve to two "C" curves?

V. (i) 7 marks, (ii) 8 marks.

When manufacturing heavy duty steel strapping, the strapping steel sheet (usually 1 to 2 mm in thickness), say SAE1032 steel, needs to be heat-treated with a procedure whereby the strapping, on a continuous processing line, is heated to its austenitization temperature and then quenched very quickly into a molten lead bath of $380^0$C and then kept at this temperature for a while before it is cooled down to the ambient temperature.

(i) What kind of microstructure should be expected after such treatment? Why?

(ii) In one case, many long-stringer-shaped ferrite grains were detected by metallographic investigation after the above processing (i). Such a structure decreases the strength of the steel and is therefore detrimental to the applications of the strapping. Can you figure out the reason for the formation of such a stringer ferrite structure?

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VI. (i) 5 marks, (ii) 5 marks, (iii) 5 marks.

(i) For many tool steels, such as high speed steel T1, see its chemistry in the table below

| Grade | C | Cr | Ni | W | V | Cu | Mn | S | P |
|---|---|---|---|---|---|---|---|---|---|
| T1 | 0.65–0.80 | 3.75–4.00 | 0.3 | 17.25–18.75 | 0.9–1.3 | 0.25 | 0.1–0.4 | 0.03 | 0.03 |

for austenization the heating temperature must be as high as 1250°C(+/-). Explain the reason.

(ii) For this kind of steels, often the cooling for the quenching operation can be done either in still air or simple by a slow fan cooling in air. Why is such a processing procedure recommended and workable?

(iii) In addition, for these steels, especially for T1 or D2 steel, there is a general requirement to temper the steel a minimum of three times after quenching. Why?

VII. (i) 8 marks, (ii) 7 marks.

(i) In the modern manufacturing, especially auto-manufacturing, industry, the following newly developed steels are being used more and more frequently for their respective special properties.
Please provide the full names for these steels, and briefly explain the significance of these names, respectively.

(i) TRIP steels,
(ii) DP steels,
(iii) IF steels,
(iv) HSLA steels.

(ii) How is the projected microstructure obtained in DP steel during processing, and what are the major strengthening mechanisms in DP steel?