National Examination December 2018

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 the answer paper with a clear statement of any assumptions made.**

2. **Candidates may use one of two calculators, the Casio or Sharp approved model.**

3. **This is a *Closed Book* exam.**

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

I **(a total of 20 marks; each is worth of 2 marks)**

Select the best answer only from the multiple choices provided for each question or statement; or determine the statement given is "True" or "False".

I.1 **It is well known that γ iron has much bigger solubility of C than α iron, because**

(a) γ iron has a lattice structure that is less densely packed and thus the total "empty space" in the structure is bigger.

(b) γ iron has a lattice structure that is close-packed with a higher density and thus the total "empty space" in the structure is bigger.

(c) γ iron has a lattice structure that is close-packed with a higher density and thus the total "empty space" in the structure is smaller. However, there are individual empty sites in the structure that have bigger space.

(d) α iron has a bigger total "empty space" due to its smaller density.

I.2 **The major purpose of the end quench test of a Jominy specimen is to determine the _____ of a quenched steel.**

(a) hardness.

(b) hardenability.

(c) ductility.

(d) machinability.

I.3 **In terms of the nature of strengthening micro-mechanism, which mechanism in the following list does not contribute in any major way to martensite strengthening.**

(a) Solid state solution strengthening.

(b) Dislocation strengthening.

(c) Grain size strengthening.

(d) Dispersion hardening.

I.4 **It is well known that martensite transformation and deformation twinning are both diffusion-less process. But the two processes result in a number of differences. The most important difference between these two processes is that**

(a) Martensite transformation occurs only in steels.

(b) Deformation twinning happens only in HCP materials.

(c) Deformation twining is generally not a major strengthening mechanism and, unlike martensite transformation, it does not result in a different phase.

(d) Deformation twining is generally a major strengthening mechanism, although it does not result in a different phase.

I.5 **Which condition in the following list may promote deformation twinning in low C steel?**

(a) The strain rate is very high.
(b) The plastic strain accommodation is very small.
(c) The deformation temperature is high.
(d) **Deformation twinning may never form in low carbon steel.**

I.6 **In all cast irons, carbon always exists in the form of graphite.**
(True – False)

I.7 **Austenite in all steels can always be quenched into martensite provided that the cooling rate is high enough.** **(True – False)**

I.8 **Generally speaking, during tensile test of IF steels, one cannot detect any Luder's bands because there is no yield point phenomenon.** **(True – False)**

I.9 **Both pearlite and bainite are mixture of ferrite and cementite.**
(True – False)

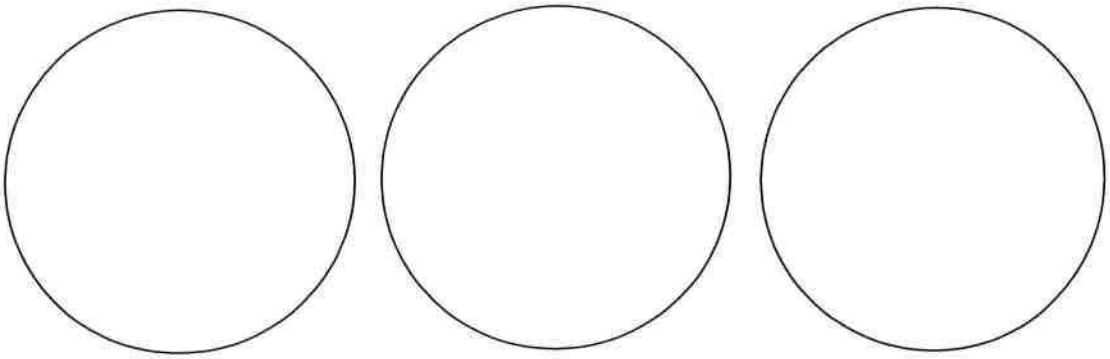
I.10 **For a given steel, the hardness of the steel after being quenched to the martensite structure depends mainly on the concentration of alloying elements in the steel.** **(True –False)**

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

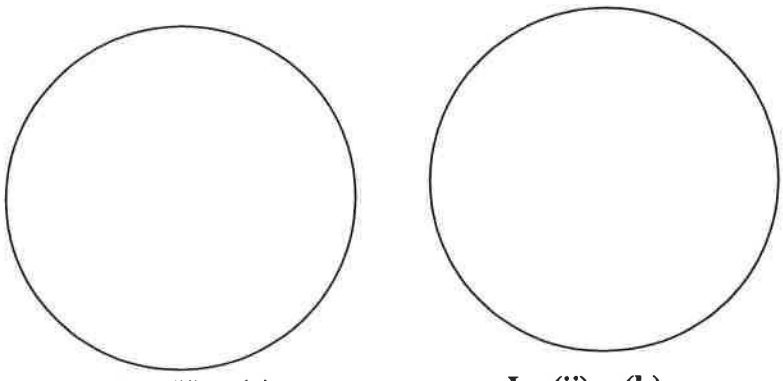
In the circles provided below,

(i) **Draw schematically the microstructure of SAE 1040 steel held at the following temperatures, respectively, for a relatively long period of time: (a) the microstructure at 1000°C, (b) the microstructure at 730°C and (c) the microstructure at 20°C after it is slowly cooled down from 730°C.**

(ii) **Draw schematically the microstructure of SAE 1090 steel held at the following temperatures, respectively, for a relatively long period of time: (a) the microstructure at 730°C, (b) the microstructure at 20°C after it is slowly cooled down from 730°C.**



I – (i) – (a) **I – (i) – (b)** **I – (i) – (c)**



I – (ii) – (a) **I – (ii) – (b)**

III. (i) 7 marks. (ii) 8 marks.

(i) Describe step by step how you would experimentally construct a *CCT* curve for a given steel, say AISI1045.

(ii) Explain the reason(s) qualitatively behind the "C" shape of a typical *TTT* curve, i.e. explain why a typical TTT curve has a "C" shape.

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

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

Chemical Composition of T1 in weight percent:
C(0.65–0.80), Cr(3.75-4.00), Mo(0.2-0.5), W(17.25-18.75), V(0.9-1.3), Mn(0.1-0.4), Co(0.1-0.15), Si(0.2-0.4)

the austenization temperature for a quenching operation is very high, such as 1250 to 1280 ^{0}C for T1 steel. Explain the reason.

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

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

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

(i) Conventional gray 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 gray 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.

VI. (i) 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?

(i) 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?

VII. (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?
