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CONFIDENTIAL

SET A

UNIVERSITI KUALA LUMPUR

MALAYSIA FRANCE INSTITUTE

FINAL EXAMINATION

SEPTEMBER 2013 SESSION

SUBJECT CODE	:	**FTB22203**
SUBJECT TITLE	:	**WELDING METALLURGY 1**
LEVEL	:	**BACHELOR**
DURATION	:	**2 ½ HOURS**
DATE / TIME	:	

INSTRUCTIONS TO CANDIDATES

1. **Please read the instructions given in the question paper CAREFULLY.**
2. **This question paper is printed on both sides of the paper.**
3. **Please write your answers on the answer booklet provided.**
4. **Answer should be written in blue or black ink except for sketching, graphic and illustration.**
5. **This question paper consists of TWO (2) sections. Section A and B. Answer ALL questions in Section A. For Section B, answer TWO (2) questions only.**
6. **Answer all questions in English.**

THERE ARE 4 PRINTED PAGES OF QUESTIONS, AND 1 PAGE OF FORMULA EXCLUDING THIS PAGE.

SECTION A (Total: 60 marks)

INSTRUCTION: Answer ALL question.

Please use the answer booklet provided.

Question 1

In welding experiment to joint 50 mm thick steel SA 516, using shielded metal arc welding (SMAW) and submerged arc welding (SAW) process. The current, voltage and welding speed for both process were 200A, 25V and 1.5mm.s^{-1} respectively. Data collected for SMAW and SAW are shown in the table below.

Process	Heat lost by Water cooled copper shoes (cal.s^{-1})	Heat lost radiation (cal.s^{-1})
SMAW	600	50
SAW	940	30

(a) State the formula for heat source efficiency.

(4 Marks)

(b) Calculate the machine efficiency for both of the welding process.

(12 marks)

(c) Choose which welding process is better and briefly explain your reason?

(6 Marks)

(d) Calculate the cooling rate at 800°C along the *x* axis for SAW process. Assume melting point = 1773 K, room temperature = 28°C, α = 5.3 x 10^{-6} m^{2}s^{-1}, ρC = 4.7 x 10^6 Jm^{-3}K^{-1}, and K = 24.9 Jm^{-1}s^{-1}K^{-1}

(8 Marks)

Question 2

(a) There are several metallurgical factors that contributed to solidification cracking such as primary solidification phase, grain structure at fusion zone and freeze temperature range.

i. Define the freeze temperature range.

(2 Marks)

ii. Discuss the relationship between freezing temperature range and solidification cracking.

(6 Marks)

iii. Refer to figure 1, explain why region II is a critical region for crack susceptibility.

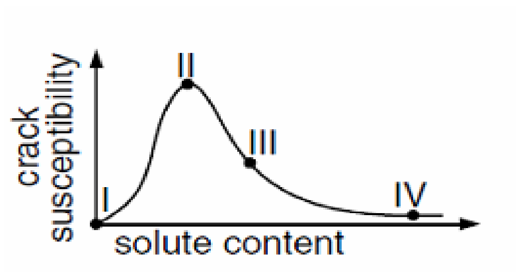

Figure 1: Solidification crack susceptibility vs solute content

(4 Marks)

(b) Partially melted zone (PMZ) cracking can occur in the mushy zone (S +L) during the solidification of the liquated material.

i. Sketch the PMZ and clearly state the boundary.

(4 Marks)

ii. List **THREE (3)** test methods to evaluate the susceptibility of partial melted zone (PMZ) cracking.

(6 Marks)

iii. Explain the general mechanism of liquidation cracking in PMZ.

(8 Marks)

SECTION B (Total: 40 marks)

INSTRUCTION: Answer TWO (2) questions only.

Question 1

Heat affected zone (HAZ) is a region has been metallurgical effected by heat but not fused. Many problems associated in this region.

(a) By aided of phase diagram sketching, explain the formation of partial grains refining in HAZ region for carbon steels.

(10 Marks)

(b) Briefly explain why the strength of work hardened material decrease as fusion zone is approached.

(6 Marks)

(c) Based on data given below for mild steel. Sketch detail a possible heat affected zone (HAZ) region.

Melting Point = 1530°C

A_3 Line = 900°C

A_1 Line = 723°C

(4 Marks)

Question 2

A wide range of microstructures can be developed in fusion zone (FZ) and heat affected zone (HAZ) of weldment. The properties of weldments depend upon the characteristics of the microstructure occur in HAZ and FZ.

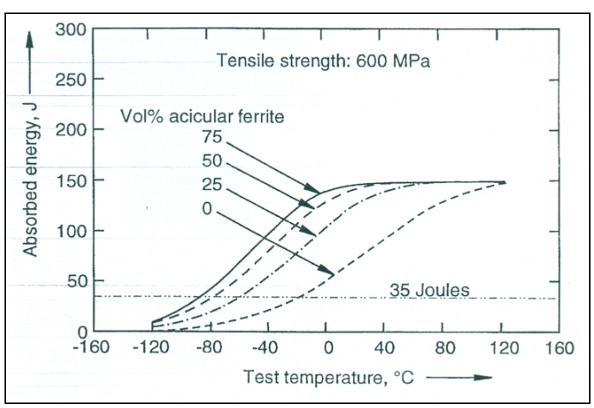

Figure 2: Effect of acicular ferrite volume to the fracture strength.

(a) Based on Figure 2, fracture strength of weldment increase as the percentage of volume of acicular ferrite increase. Discuss how acicular ferrite able to increase fracture strength.

(6 Marks)

(b) Explain how to increase the percentage of acicular ferrite volume in FZ.

(6 Marks)

(c) Discuss the effect of grain structure to fracture strength

(4 Marks)

(d) Explain why weld microstructure contain 5 -10% ferrite is better than fully austenitic in stainless steels.

(4 Marks)

Question 3

(a) Explain the effect of coarser grains in partial melted zone (PMZ) in the terms of resistance of cracking.

(8 Marks)

(b) Discuss the effect of peak temperature in relation with grain size in HAZ and mechanical properties of weldment.

(8 Marks)

(c) Breifly discuss the effect of grain boundary ferrite in mechanical properties of weldment.

(4 Marks)

END OF QUESTIONS

Appendix 1: Formula

$$Q = \eta EI \qquad H_{net} = \frac{Q}{U}$$

$$\int_0^\infty WC(T_{out} - T_{in})dt = \eta \mathrm{EIt}_{\mathrm{weld}}$$

$$\left.\frac{\partial \mathrm{T}}{\partial \mathrm{t}}\right|_x = \left.\frac{\partial \mathrm{T}}{\partial \mathrm{x}}\right|_t \bullet \left.\frac{\partial \mathrm{x}}{\partial \mathrm{t}}\right|_T = 2\pi k_s U \frac{(T - T_o)^2}{Q}$$

$$\frac{2\pi(T - T_o)k_s g}{Q} = \exp\left(\frac{Ux}{2\alpha_s}\right)K_o\left(\frac{Ur}{2\alpha_s}\right)$$

$$\frac{2\pi(T - T_o)k_s R}{Q} = \exp\frac{-U(R - x)}{2\alpha_s}$$

$$Cooling \quad rate = 2\pi k\rho C\left(\frac{h}{H_{net}}\right)^2 (T_c - T_o)^3$$

$$\text{Cooling Rate} = \frac{2\pi k_s (T_c - T_o)^2}{H_{net}}$$

$$\frac{1}{T_p - T_o} = \frac{\sqrt{2\pi e}\,\rho Chy}{H_{net}} + \frac{1}{T_m - T_o}$$

$$D = \frac{dU}{2\alpha}$$

$$n = \frac{QU}{4\pi\alpha^2 \rho C(T_m - T_o)}$$

Definition of symbols

Q = Energy

E = Voltage

I = Current

η = efficiency

H_{net} = Net energy input

T = temperature

t = time

C = specific heat of water

W = mass flow rate of water

k_s = Thermal conductivity of solid

g = Thickness of the workpiece

U = welding speed

α_s = Thermal diffusivity of solid

K_o = modified Bessel function of the second kind and zero order.

ρC = Volume Thermal capacity

k = Thermal conductivity

T_c = Temperature at which the cooling rate to be calculated, °C

T_o = initial plate temperature

r = radial distance from origin $(x^2 + y^2 + z^2)^{1/2}$

h = thickness for the base metal

e = constant value (2.718)

G = Temperature gradient

R = Growth rate

D_L = diffusivity of the solute in the liquid

ΔT = equilibrium freezing range

d = weld penetration

n = dimensionless operating parameter