UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE : AAB3013 - JOINING OF METALS AND NON METALS

DATE : 5 AUGUST 2024 (MONDAY)

TIME : 9.00 AM - 12.00 NOON (3 HOURS)

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **EIGHT (8)** pages in this Question Booklet including the cover page and appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. Two carbon steel plates with a thickness of 10 mm will be joined by butt-join design using gas tungsten arc welding (GTAW) process. The process must be controlled properly to achieve specified welding quality. The chemical composition of carbon steel is presented in **TABLE Q1**. After the process is completed, the formation of martensite structure is observed.

TABLE Q1

	C	Mn	P	S	Si	Cr	Ni	Mo
Wt%	0.05	1.50	0.045	0.03	1	18	12	0.3

a. Describe the principle of GTAW by using appropriate sketches.

[8 marks]

b. Using the carbon steel plate's composition, determine the carbon equivalent (CE) of the material where CE is defined as

$$CE = \%C + \%\frac{Mn}{6} + \%\frac{(Cr + Mo + V)}{5} + \%\frac{(Si + Ni + Cu)}{15}$$

[5 marks]

c. Based on the value of CE in **part (b)**, propose the welding procedure to weld this material to achieve the desired welding qualities without any defects.

[6 marks]

d. Suggest a method to eliminate the presence of martensite that formed after the welding process. Justify your answer.

[7 marks]

2. **FIGURE Q2** demonstrates the utilization of resistance spot welding to connect two steel plates together. The welding operation is carried out with a current of 5000 A and a current flow time of 0.1 s. However, it has been observed that the weld's shear strength did not meet the minimum required strength due to the presence of weld defects.

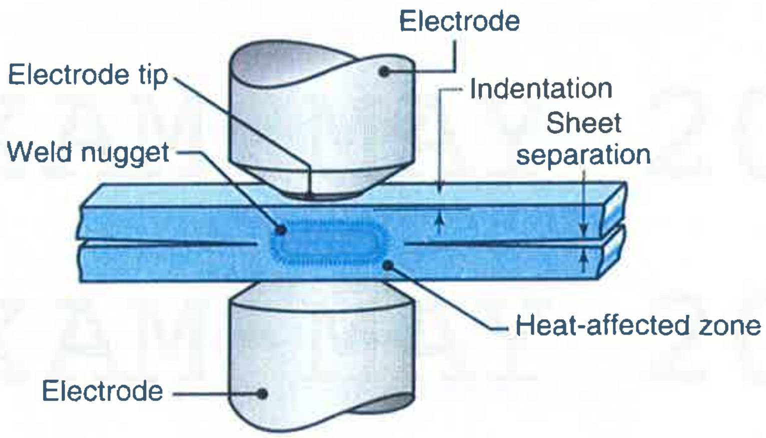

FIGURE Q2

a. Identify welding parameters applicable to the resistance spot welding procedure.

[5 marks]

b. Determine the heat generated if the effective resistance in the operation is 200 μΩ.

[7 marks]

c. Propose **THREE (3)** suitable non-destructive techniques (NDT) to assess the external and internal defects of the weld.

[12 marks]

3. a. The growing prevalence of polymer materials in structural and automotive applications because of their low weight, high specific strength, elasticity, and low cost has spurred research into the combination of polymers and metals in manufacturing. Parts made with metal-to-polymer joints are now in high demand in the automotive industries. As a material engineer, you are assigned to assemble a thermoplastic cover over a metal frame to fabricate an engineering component for automotive application.

i. Propose a suitable joining method that can be used to join the part. Justify your answer.

[10 marks]

ii. Assess the impact of surface preparation and environmental factors on joint quality.

[8 marks]

b. **FIGURE Q3** shows simple butt and lap joints of two different materials using epoxy and acrylic having minimum and maximum adhesive strength of 15.4 MPa and 25.9 MPa respectively.

FIGURE Q3

i. Determine the minimum and maximum tensile force that the lap joint can withstand if the area of the joint is 15 mm x 15 mm.

[4 marks]

ii. Determine the minimum and maximum tensile force that the butt joint can withstand if the area of the joint is 3 mm x 20 mm.

[4 marks]

4. As a material engineer, you are assigned to evaluate the effect of friction stir welding processing parameters on shear strength of the metal joints. A design of experiment (DOE) is conducted according to L_9 orthogonal array as shown in **TABLE Q4a**. In the study, interaction effects between processing parameters are considered insignificant and hence, not examined. Nine trials run with certain processing parameter level are carried out triplicate and the results are shown in **TABLE Q4b**.

TABLE Q4a

Run	Processing parameter			
	Time (min)	Temperature (°C)	Heating rate (°C/min)	Diffusion pressure (MPa)
1	5	570	5	40
2	15	570	10	80
3	30	570	30	120
4	5	600	10	120
5	15	600	30	40
6	30	600	5	80
7	5	620	30	80
8	15	620	5	120
9	30	620	10	40

TABLE Q4b.

	Shear strength (MPa)		
Run	R_1	R_2	R_3
1	1.035	1.035	1.034
2	1.102	1.102	1.102
3	1.691	1.691	1.690
4	1.710	1.710	1.711
5	1.006	1.004	1.004
6	1.750	1.750	1.752
7	1.163	1.164	1.163
8	1.802	1.800	1.800
9	1.610	1.611	1.610

a. Describe the friction stir welding process and its underlying principle.

[8 marks]

b. Determine the signal to noise ratio for each run of the friction stir welding process.

[8 marks]

c. Determine the average effect on shear strength of friction stir welded metal joints at each processing parameter's level.

[8 marks]

-END OF PAPER-

APPENDIX I

List of constant value, unit and formula

Universal Gas Constant, R = 8.314 J/(mol.K) 1 MPa = MegaNewtons per square meter (MN/m^2) 1 F = 96500 C/mole	
$MSD = \frac{\left(\frac{1}{R_1^2}+\frac{1}{R_2^2}+\frac{1}{R_3^2}\right)}{3}$	$S/N = -10\,log(MSD)$
$m_{D3} = 1/3\ (S/N_3 + S/N_4 + S/N_8)$	$H = I^2RT$
$\sigma = \frac{F}{A_o}$	$\nu = -\frac{\varepsilon_x}{\varepsilon_z}$
$\varepsilon = \frac{l_i - l_o}{l_o}$	$E = \frac{\sigma}{\varepsilon}$
$N_f = \frac{1}{AY^m \Delta\sigma^m \pi^{\frac{m}{2}}} \int_{a_0}^{a_c} a^{-(\frac{m}{2})} da$	$c = \frac{d}{2}$
$\mu_r \approx \frac{1}{2}\sigma_y \varepsilon_y$	$\sigma_T = \frac{F}{A_i}$
$\varepsilon_T = \ln(\varepsilon + 1)$	$\sigma_T = \sigma(\varepsilon + 1)$
$\varepsilon_x = \frac{d_i - d_o}{d_o}$	$N = \frac{\sigma_{YS/UTS}}{\sigma_{Design}}$
$\sigma = \frac{3FL}{2bd^2}$	$E = \frac{FL^3}{4bd^3\delta}$
$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$	$s = \left[\frac{\sum_{i=1}^{n}(x_i - x)^2}{n-1}\right]^{1/2}$
$\sigma = \frac{Mc}{I}$	$M = \frac{FL}{4}$
$\Delta G = \pm nFE$	$c = R$
$\sigma = \frac{FL}{\pi R^3}$	$E = \frac{FL^3}{12\pi\delta R^4}$
$I = \frac{\pi R^4}{4}$	$I = \frac{bd^3}{12}$
$I = \frac{\pi}{64}(d_o^4 - d_i^4)$	$V_m + V_f = 1$
$E_{cs} = E_m V_m + E_f V_f$	$\Delta K = Y\sigma\sqrt{\pi a}$