UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
SEPTEMBER 2022 SEMESTER

COURSE : AAB2033 - MATERIALS PROCESSING II

DATE : 5 DECEMBER 2022 (MONDAY)

TIME : 2.30 PM - 5.30 PM (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 **THIRTEEN (13)** pages in this Question Booklet including the cover page and appendices.

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

1. A manufacturing company is to mass produce torque clutch component as shown in **FIGURE Q1**. As a trainee engineer for manufacturing selection process you are asked to fabricate the component from thermoplastic material using plastic injection moulding process.

FIGURE Q1

a. With the aid of sketch, outline the injection moulding cycle for producing the torque clutch component.

[7 marks]

b. If the torque clutch component is to be made from thermosetting material, propose the process modification that need to be implemented and highlights the drawback associated with this change.

[6 marks]

c. The company is considering of using powder metallurgy process (PM) to fabricate the component (**FIGURE Q1**) from metallic powder in order to be used for high temperature wear resistance application. For the preparation of the feedstock, the stainless steel powder (SUS 316L) and binder of volume fraction 0.58:0.42 were initially mixed at 130°C using z-blade mixer for one hour. An organic compound which consists of 60 wt% paraffin wax (PW), 35 wt% polyethylene (PE) and 5 wt% stearic acid (SA) are used as binder. Another binder composition consists of 70 wt% polyethylene glycol (PEG) and 30 wt % polymethyl methacrylate (PMMA) are used as water-based system. The densities of the metal powder and binder is shown in **TABLE Q1**.

TABLE Q1

Material	Density (gcm^{-3})
Stainless steel powder (SUS 316L)	7.900
Polyethylene (PE)	0.910
Paraffin Wax (PW)	0.910
Stearic Acid (SA)	0.845
Polyethylene glycol (PEG)	1.130
Polymethyl methacrylate (PMMA)	1.180

i. Determine the amount of SUS 316L powder, PW, PE and SA required for the preparation of 1 litre mixture of feedstock if the theoretical density of the binder is given by:

$$\rho_{Binder} = \left(\frac{1}{[ratio/\rho_{PE}] + [ratio/\rho_{PW}] + [ratio/\rho_{SA}]} \right)$$

[8 marks]

ii. Assess the environmental impact if the binder composition of PW/PE/SA is replaced with PEG/PMMA system.

[5 marks]

2. a. A manufacturing company is to manufacture turbine blade as shown in **FIGURE Q2a** using 304 stainless steel slab having melting temperature of 1600°C. The initial manufacturing process starts with a fully annealed 304 stainless steel slab of 300 mm wide and 30 mm thick, which is rolled to a thickness of 20 mm in one pass at process temperature of 1050°C. The roll radius is 400 mm, and the rolls rotate at 200 rpm. The true stress-true strain diagram is presented in **FIGURE Q2b.**

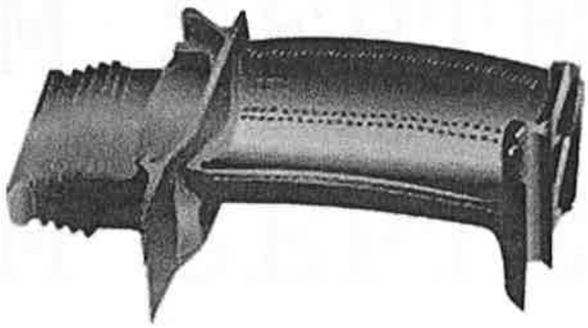

FIGURE Q2(a)

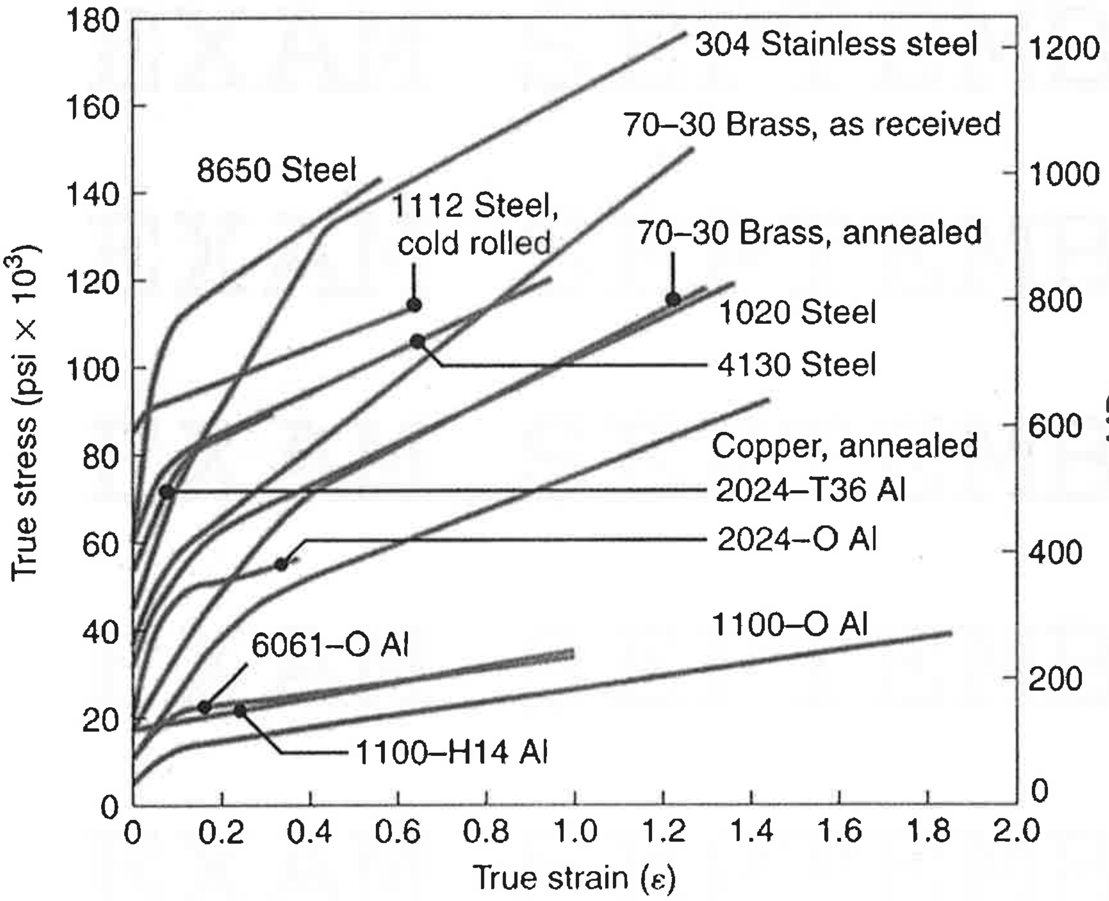

FIGURE Q2(b)

i. Describe the type of the work process and its advantages.

[3 marks]

ii. Sketch the microstructure and describe the mechanical properties of the rolled slab which is resulted from the process.

[5 marks]

iii. Determine the roll force needed and power required in the operation.

[5 marks]

b. After the rolling process, the round rod made of 304 stainless steel is used as the blank (bar stock) for producing turbine blade as in shown in **FIGURE Q2a**. The blank is drawn from a diameter of 10 mm to 8 mm at a speed of 0.5 ms^{-1}. Assume that the frictional and redundant work together constitute 40% of the ideal work of deformation. By referring to true stress – true strain diagram in **FIGURE Q2b**,

i. Determine the power required in this operation.

[4 marks]

ii. Evaluate the die pressure at the exit of the die.

[3 marks]

iii. If the inclusion of sulphur was present in round rod of annealed 304 stainless steel before the drawing process was performed, interpret on the quality of the final drawn product produced.

[4 marks]

3. a. XYZ company is a producer of pinion gear for automotive industry. **FIGURE Q3** describes the process flow of pinion gear production, which includes five assembly operations and three inspection and sortation stations. **TABLE Q3** shows the defect rate percentage at each assembly operation. The cost of each assembly operation, C_{pr} is RM1.00. The cost of each inspection and sortation operation, C_s is RM2.00.

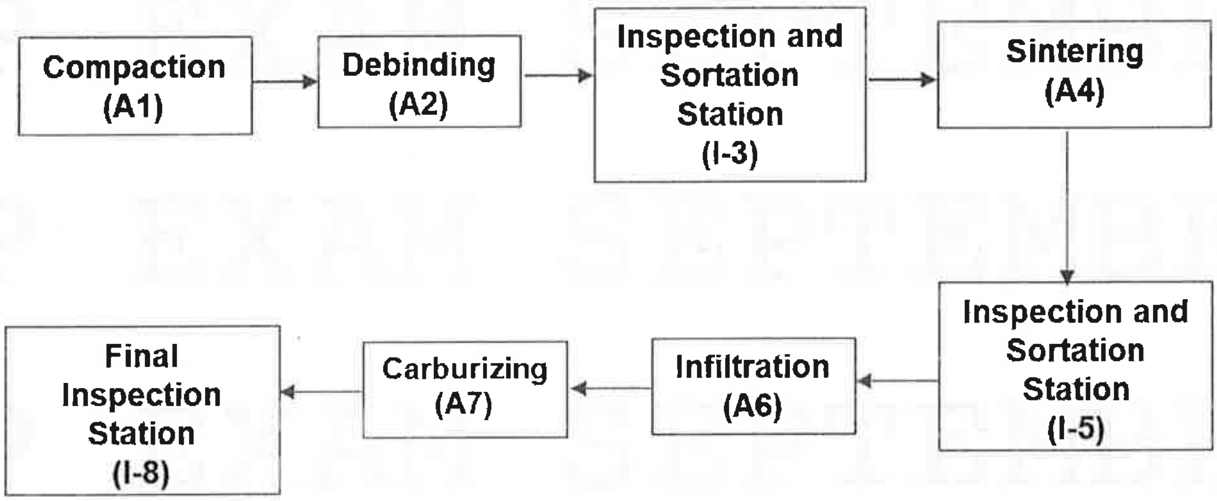

FIGURE Q3

TABLE Q3

Process Operation	Compaction	Debinding	Sintering	Infiltration	Carburizing
Defect rate %	0.5	0.6	1.0	1.5	0.9

i. If a batch of 10,000 pinion gears is loaded into the production line, determine the number of defects segregated at the inspection station I-5, final batch quantity (Q_f) and total processing and inspection cost per batch (C_b).

[10 marks]

ii. The company proposes to reduce the cost by having only one final inspection (I-8) for a batch of 10,000 pinion gears which is loaded into the production line. The inspection and sortation cost, C_s for I-8 will increase due to increase in defect types. Determine the maximum C_s for I-8, for this proposal to be cost effective.

[4 marks]

b. Company ABC is producing camshaft. Lately, the customer is complaining that there is a severe problem with camshaft length being out of specification, which causes poor fitting assembles, resulting in high scrap and rework rates. A random sample of 100 camshafts are measured before shipping out to the customer. The average and standard deviation of the camshaft length are found to be 599.6 mm and 0.8 mm respectively.

i. If the specification of the camshaft length is 600 ± 2 mm, determine the process capability index (C_{Pik}) and percentage of camshafts expected to be rejected at the customer level.

[7 marks]

ii. Appraise the significant of Taguchi loss function concept in the manufacturing environment and how it relates to process capability index.

[5 marks]

4. XYZ is a manufacturer of optical transceiver, device used for transmitting and receiving digital data which is modulated into the light source. There are 5 main processes during product assembly activities as depicted in **FIGURE Q4**. Each of the process is performed by one operator at a workstation. The process cost and percentage of defect contributed by each process as shown in **TABLE Q4**. Starting quantity of parts into the WS1, Q_0, is 5000.

FIGURE Q4

TABLE Q4

Workstation (WS)	Process cost /part (RM)	Defect %
1	1.00	0.5
2	1.20	1.7
3	1.00	0.3
4	1.40	1.9
5	1.10	0.3

To ensure product leaving the plant is free from defect, a final Inspection station is set up after the last process to sort defective parts. The inspection cost for this final inspection station is RM 1.20 per part.

a. Determine the operation costs for these processes with a final inspection station.

[5 marks]

b. To further improve the operation costs, process engineer is considering adding one more inspection station between the processes. Determine where is the best location to put this additional inspection station. The inspection cost for this in-between process inspection station is RM 0.10 per part. Show your calculations.

[13 marks]

c. The engineer also plans to convert most of its single-station manned workstation to a single-station automated cell, to reduce number of defective parts. Propose **THREE (3)** design features needed for automated cell to be successfully implemented.

[6 marks]

-END OF PAPER-

APPENDIX I

List of formula

Roll force equation:

$$F = LwY_{avg}$$

Roll-strip contact length:

$$L = \sqrt{R(h_o - h_f)}$$

Where *L* is the roll-strip contact length, *w* is the width of the strip, and Y_{avg} is the average true stress.

True strain for rolling process:

$$\varepsilon = \ln(\frac{h_o}{h_f})$$

The *total power* (for two rolls) in S.I. units:

$$Power = \frac{2\pi FLN}{60{,}000}\ \text{kW}$$

Where *F* is in Newton, *L* is in meter, and *N* is the revolutions per minute of the roll (rpm)

The forging force:

$$F = Y_f A_f (1 + \frac{2\mu r_f}{3h_f}) = Y_f \pi r_f^2 (1 + \frac{2\mu r_f}{3h_f})$$

$E_{cl} = E_m V_m + E_f V_f$	$\frac{F_f}{F_m} = \frac{E_f V_f}{E_m V_m}$
$F_c = F_f + F_m$	$LDR = \frac{D_o}{D_p}$

True strain for drawing process:

$$\varepsilon = \ln\left(\frac{A_o}{A_f}\right)$$

$\bar{Y} = \frac{K\varepsilon_1^n}{n+1}$	$F = Y_{avg} A_f \ln\left(\frac{A_o}{A_f}\right)$
$P = FV$	$Y_f = K\varepsilon_1^n$

$\sigma_d = \dfrac{F}{A_f}$	$P = Y_f - \sigma_d$
$C_b(0\%inspection) = QqC_d$	$q_c = \dfrac{C_s}{C_d}$
$FOHR = \dfrac{FOHC}{DLC}$	$COHR = \dfrac{COHC}{DLC}$
$MLT = n_o\ (T_{su} + QT_c + T_{no})$	$T_p = \dfrac{T_b}{Q}$, $T_b = T_{su} + QT_c$, $R_p = \dfrac{1}{T_p}$
$PC = \dfrac{nSHR_p}{n_o}$, $U = \dfrac{Q}{PC}$	$WIP = \dfrac{AU(PC)(MLT)}{SH}$
$WL = \sum_j Q_j T_{cj}$	$n = \dfrac{WL}{AT}$, $AT = TAU$
$Q = \dfrac{Q_o}{(1-q)}$	$WL = \dfrac{QT_c}{E_w(1-q)}$
$n = \dfrac{T_m + T_s}{T_s + T_r}$	$n_{of} = PQn_p n_o$
$n_1 = \max\text{int} \le \dfrac{T_m + T_s}{T_s + T_r}$	$Z = \dfrac{x-\mu}{\sigma}$
$Cp = \dfrac{USL - LSL}{6\sigma}$	$Q_f = Q_o \prod_{i=1}^{n} (1-q_i)$
$Cpk = \dfrac{USL - x}{3\sigma}, \dfrac{x - LSL}{3\sigma}$	$C_b = Q_o(C_{pr1} + C_{s1}) + Q_o(1-q_1)(C_{pr2} + C_{s2}) + Q_o(1-q_1)(1-q_2)(C_{pr3} + C_{s3}) + \ldots\ldots\ldots + Q_o\Pi(1-q_i)(C_{prn} + C_{sn})$
$C_b = Q_o\left(\sum_{i=1}^{n} C_{pri} + C_{sf}\right)$	$C_b(100\%Inspection) = QC_s$ $C_b(NoInspection) = QqC_d$ $q_c = \dfrac{C_s}{C_d}$

APPENDIX II

Standard Normal Probabilities

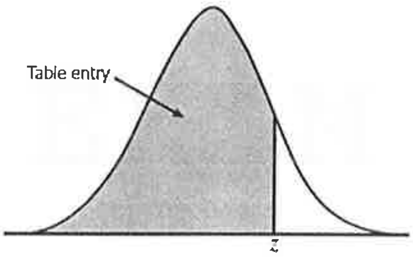

Table entry for z is the area under the standard normal curve to the left of z.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998