Prince of Songkla University

Faculty of Engineering

Midterm Examination: Semester 2 **Academic Year: 2010**

Date: December 27, 2010 **Time: 9:00-12:00**

Subject: 237-510 Powder Metallurgy **Room: A301**

ทุจริตในการสอบ โทษขั้นต่ำปรับตกในรายวิชานั้น และพักการเรียน 1 ภาคการศึกษา

Name... Surname ....Student ID...........................

Instruction:

1. ***There are 2 parts, 27 questions, 12 pages; 110 points***
2. ***Attempt all questions.***
3. ***Only a <u>hand-written note on two-sided A4</u>, <u>calculator</u>, and a <u>dictionary</u> are allowed.***
4. ***Borrowing things form other students is prohibited.***

Napisporn Memongkol

Instructor

Some important equations

$D_A = (4\,A / \pi)^{1/2}$ $D_V = (6\,V / \pi)^{1/3}$ $D_S = (S / \pi)^{1/2}$

A = projected area, V = volume, S = surface area, D_A = equivalent spherical projected diameter, D_V = equivalent spherical volume diameter, D_S = equivalent spherical surface diameter

$$\sigma = \sqrt{\frac{2Er}{D}} \qquad t = C\,d^2 / N^{1/2}$$

σ = impact stress require to fracture a brittle material, E = elastic modulus,
r = defect or existing crack tip radius, D = particle size, t = grinding time,
C = empirical constant depends on the process and desired level,
d = the grinding media, N = rotational speed

$$V = H/t = g\,D^2\,(\rho_m - \rho_f) / (18\,\eta)$$

V = terminal velocity, H = settling height, t = settling time, D = particle size,
g = acceleration (gravitational constant, 9.8 m/s^2) ρ_m = particle density,
ρ_f = density of the fluid, η = fluid viscosity

$$K = P_{H_2O} / P_{H_2} \qquad J = A \exp(-Q/RT)$$

K = the equilibrium constant, P_{H2} = the partial pressure of hydrogen,
P_{H2O} = the partial pressure of water, J = reaction rate, A = material constant,
R = gas constant, T = absolute temperature

$$D = \left(\frac{A}{\omega}\right)\sqrt{\frac{\gamma}{\rho_m R}} \qquad C_R = V_L/V_C = \rho_G/\rho_A$$

A = a process dependent constant, ω = angular velocity, γ = surface energy of the melt, ρ_m = density of the melt, R = radius of the electrode

PART I: Fill in the blank using the letter (a - ss) provided in the next page that is related to the questions (2 point each) 40 points

1. "A finely divided solid, smaller than 1 mm in its maximum dimension" is a definition of ....
2. The three main reasons for using powder metallurgy are a) ...., b) ...., and c) ....
3. One of the best tools available for observing the discrete characteristics of metal powders is ....
4. For a cubic particle with a size of 1 μm as measured on each edge, determine the equivalent spherical diameters.

   4.1) The equivalent spherical projected diameter D_A = ...μm

   4.2) The equivalent spherical volume diameter D_V = ...μm

   4.3) The equivalent spherical surface diameter D_S = ...μm
5. The buoyancy force or (F_B) is determined by ....
6. From the equation "$D = 0.9\ \lambda\ /\ B \cos(\theta)$" using in X-ray technique that applied to size analysis of very small particles. What is "B"? ....
7. In particle size analysis, the weight based distribution is skewed to the .... particle sizes in comparison to the population based distribution.
8. The two most important factors in gas atomization that affect the particle size are .... and ....
9. The two outstanding differences between gas atomization and water atomization are .... and ....
10. Particle size analysis by .... uses a predetermined settling height and places a dispersed powder at the top of the tube.
11. In electrical zone sensing, dispersed particles in the electrolyte are carried by the fluid flow into the .... and cause a decrease in conductivity.
12. The screening technique is usually applied only to particles larger than ......μm
13. The most straightforward descriptor of particle shape is the ...., defined as the maximum particle dimension divided by the minimum particle dimension.
14. .... measures the ability to densify a powder under an applied load

Answers for PART I

a) shaping	b) 1.18	c) economic
d) energy saving	e) smaller	f) 1.27
g) particle size	h) TEM	i) 1.24
j) gas type	k) apparent density	l) coarser
m) dispersant	n) compressibility	o) fluid velocity
p) captive	q) $g \rho_m \pi D^3 / 6$	r) $3\pi D V \eta$
s) 1.48	t) Light blocking	u) powder
v) maximum intensity	w) 38	x) intensity
y) surface contamination	z) $g \rho_f \pi D^3 / 6$	aa) atmosphere
bb) nozzle geometry	cc) 1.38	dd) 25
ee) 1.13	ff) peak broadening	gg) powder shape
hh) gas velocity on exit	ii) unique	jj) aperture
kk) sedimentation	ll) Light scattering	mm) diffraction angle
nn) 45	oo) SEM	pp) light microscope
qq) aspect ratio	rr) sample chamber	ss) melt superheat

PART II: Answer all the questions

1. (2 points) The applications for PM components fall into **two main groups**. The first group is ....

   ....

   and the second group is ....

   ....

2. (3 points) The PM industry divided into **three groups**, what are they?

   a) ....

   ....

   b) ....

   ....

   c) ....

   ....

3. (2 points) Comparison between **shaping** and **compaction**?

....

....

....

....

....

4. (2 points) Comparison between **Hall flowmeter** and **Scott volumemeter**?

....

....

....

....

....

5. (5 points) Give the meaning of these densities;

   Pycnometer density ....

   green density ....

   apparent density ....

   sintered density ....

   tap density ....

6. (3 points) What is the meaning of **debinding**? Give two options of debinding in the PM processes?

....

....

....

....

7. (3 points) How might mixed particles of copper and tin be separated from one another?

....

....

....

8. (10 points) Two different tungsten powders (theoretical density = 19.3 g/cm^3) are analyzed for particle size using a streaming technique and found to have an equivalent mean size of 5 μm. However, the other properties are quite different as noted below:

	Powder A	Powder B
Specific surface area, m^2/g	0.26	0.12
Apparent density, g/cm^3	2.3	4.5
Tap density, g/cm^3	4.6	8.1

a) Explain why there might be a difference in surface areas.

b) What equivalent spherical diameter would give the same surface areas for each powder?

c) What differences might explain the packing properties?

d) What additional information would be useful?

9. (5 points) A spherical nickel powder is analyzed for particle size using sedimentation. The powder is dispersed in water at the top of a settling column 100 mm high. If the settling time of this powder is **6 minutes** then what is the particle size of this powder? (ให้คำนวณหาขนาดอนุภาค)
(Ni density = 8.9 g/cm^3, water density = 1 g/cm^3, water viscosity = 10^{-3} kg/m.s)

10. (5 points) Iron powder is screened into -100/+200 mesh and -325 mesh fractions. The apparent density of the coarse fraction is 2.6 g/cm^3 and the fine fraction has an apparent density of 2.3 g/cm^3. When a blend is prepared using 20% fine particles in the coarse fraction, the apparent density is measured as 2.8 g/cm^3. Explain the effect. (อธิบายผลที่เกิดขึ้นว่าทำไมเป็นเช่นนั้น)

11. (5 points) A solid loading of 65 vol.% is sought from a powder mixture composed of 98% iron powder and 2% nickel. The binder has a density of 0.95 g/cm^3. What weight is required for Fe, Ni, and binder for the feedstock? (ให้คำนวณหาน้ำหนักของผงเหล็ก ผงนิกเกิล และสารยึด)

12. (5 points) The green density for a copper powder is to be 6.5 g/cm^3. The apparent density is 2.7 g/cm^3; what is the compression ratio (C_R) and what is the final compact height for a powder fill height of 10 cm? (ให้คำนวณหา C_R และ ความสูงหลังการอัด)

13. (20 points) Data are collected by screening for a nickel powder (theoretical density of nickel = 8.9 g/cm^3) as follow:

mesh size	Weight, g
-325	0
+325/-270	6
+270/-230	14
+230/-200	43
+200/-170	56
+170/-140	39
+140/-120	28
+120/-100	12
+100/-80	4
+80	0

a) (10 points) Complete the table (calculate for particle size, weight percent, cumulative weight percent finer, and cumulative weight percent larger)

b) (6 points) Plot the graphs of particle size distribution on page 11 (last page of this exam) showing the **cumulative weight percent finer** and **cumulative population percent finer** versus the $\log_{10}$ of the particle size.

c) (2 points) What is the mean particle size on a weight basis?

d) (2 points) Estimate the mean particle size on a population basis.

Table (Standard sieve sizes)

mesh size	Opening, µm	mesh size	Opening, µm
35	500	140	106
40	425	170	90
45	355	200	75
50	300	230	63
60	250	270	53
70	212	325	45
80	180	400	38
100	150	450	32
120	125	500	25

สูตรที่กำหนดให้ $$n = \frac{6W}{\rho_m \pi D^3}$$

Table for particle size distribution data

size (µm)	Weight (g)	% wt	weight cumulative % finer	population	% pop	Population Cumulative % finer
	0					
	6					
	14	**1=**	**2=**	**3=**	**4=**	**5=**
	43					
	56					
	39					
	28					
	12					
	4					
	0					

***Show your calculation on the next page**

<u>หมายเหตุ</u> ให้แสดงวิธีการคำนวณเฉพาะค่าของตัวเลขที่อยู่ในช่องหมายเลข **1, 2, 3, 4 และ 5** ในหน้าถัดไป (หน้า 11) ส่วนค่าตัวเลขอื่นๆ ไม่ต้องแสดงการคำนวณให้นำค่าที่คำนวณได้มาใส่ได้เลย

<u>From your plot, Answer these two questions</u>

c) The mean particle size of Ni on a weight basis = ... µm

d) The mean particle size of Ni on a population basis = ... µm

Show your calculation here

No. 1

No. 2

No. 3

No. 4

No. 5

Cumulative particle size distribution