# Final Exam

**June / 13 / 2007**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Fill in the blanks</th>
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</thead>
</table>
| 1) | The **powder-metallurgy** process consists of the following operations (in sequence):  
   1. Powder production  
   2. ________________  
   3. ________________  
   4. ________________  
   5. Finishing operation |
| 2) | produces a liquid-metal stream by injection molten metal through a small orifice. The stream is then broken by jets of inert gas, air or water. |
| 3) | When blending powders, the ideal mix is one in which all the particles of each material (and of each size and morphology) are ________________ uniformly. |
| 4) | ________________ wear occurs on the relief face. It is caused by rubbing the tool along machined surface and by high temperatures.  
   ________________ wear occurs on the rake face of the tool. It is influenced by temperature at tool-chip interface and by the Chemical affinity between the tool and workpiece materials. |
| 5) | ________________ are individual cutting tools with several cutting points. A square one has eight cutting points, and triangular one has six. |
| 6) | Tool coatings, generally in the thickness range of 2 - 15 µm, are applied on cutting tools and inserts by the following two techniques:  
   1. ________________ (CVD).  
   2. ________________ (PVD). |
| 7) | In machining, the usual procedure is to first perform one or more ________________ cuts at high feed rates and large depths-of-cut (high MRR) but with little consideration of dimensional tolerance and surface roughness.  
   These cuts then are followed by a ________________ cut, at a lower feed and depth-of-cut in order to produce a good surface finish. |
| 8) | is performed to enlarge a hole made previously by some other process (like drilling) or to produce circular internal profiles in hollow workpieces. |
| 9) | is an operation used to:  
   a) Make an existing hole dimensionally more accurate than can be obtained by drilling alone.  
   b) Improve the hole surface finish. |
| 10) | is to produce internal threads using a chip-producing threading tool with multiple cutting teeth. |
Q2 Select the most correct answer:

1) The principal variables in sintering are:
   a) Temperature
   b) Time
   c) furnace Atmosphere
   d) All the above
   e) (a) and (c) only.

2) As temperature increases, two adjacent particles begin to form a bond; as a result of this, the strength, density, ductility, and thermal and electrical conductivities of the compact increase. However, the compact shrinks. Hence, allowances should be made for shrinkage as are done for casting. This sintering mechanism is known as:
   a) vapor-phase transport
   b) diffusion
   c) liquid-phase sintering
   d) None of the above

3) Which of the following is acceptable during machining operations:
   a) The surface finish of the workpiece being cut is poor,
   b) The cutting tool wears rapidly and becomes dull,
   c) Discontinuous chips when machining brittle workpiece materials
   d) The tool begins to vibrate and chatter.

4) Conditions that would cause tool wear are:
   a) High localized stresses at the tip of the tool,
   b) High temperature, specially along the rake face,
   c) Sliding of the chip along the rake face, and
   d) Sliding of the tool along the newly cut workpiece surface.
   e) All the above
   f) (a), (b), & (c)

5) Consists of layers of material from the workpiece that are gradually deposited on the tool tip. As it becomes larger, it becomes unstable and eventually breaks apart.
   a) Continuous Chips
   b) Built-up edge Chips
   c) Discontinuous Chips
   d) Serrated Chips

6) Chip breaker features on inserts are not used for
   a) Increasing feed rate
   b) controlling chip flow during machining
   c) eliminating long chips, and
   d) reducing vibration and heat generated.

7) Lathes that are capable of performing multiple cutting operations, such as turning, boring, drilling, thread cutting, and facing; they are equipped with several cutting tools (as many as 6) are mounted and rotated after each specific cutting operation is completed.
   a) Tracer lathes
   b) Turret lathes
   c) CNC Lathes
   d) Engine Lathes
8) Which of the following is not true? To prevent the drill from walking on the workpiece surface at the beginning of the operation:
   a) The drill should be guided using fixtures to keep it from deflecting laterally.
   b) A small starting hole can be made with a center drill,
   c) Increase the roughness of the surface.
   d) Use a drill with S shape point, which has a self centering characteristic, or
   e) Use a centering punch to produce an initial impression.

Q3 Match definitions

<table>
<thead>
<tr>
<th>a) Particle size</th>
<th>It is a major and common hole making process.</th>
</tr>
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<tbody>
<tr>
<td>b) Shape factor (SF)</td>
<td>Metal powder is placed in a flexible rubber mold. The assembly then is pressurized hydrostatically in a chamber, usually using water.</td>
</tr>
<tr>
<td>c) Cold isostatic pressing (CIP)</td>
<td>a chunk, collet, face plate, or mandrel.</td>
</tr>
<tr>
<td>d) Sintering</td>
<td>is a measure of the ratio of the surface area of the particle to its volume – normalized by reference to a spherical particle of equivalent volume.</td>
</tr>
<tr>
<td>e) Because of their toughness and high resistance to fracture, HSS are especially suitable for</td>
<td>rotational speeds (N) of the workpiece clamped in a spindle, depths of cut, d, and feeds, f.</td>
</tr>
<tr>
<td>f) Workholding devices</td>
<td>is usually measured by screening – by passing the metal powder through sieves of various mesh sizes (screen analysis).</td>
</tr>
<tr>
<td>g) Drilling</td>
<td>is the process where green compacts are heated in a controlled-atmosphere furnace to a temperature below the melting point but sufficiently high to allow bonding (fusion) of the individual particles. Its temperatures are generally within 70% to 90% of the melting point of the metal or alloy.</td>
</tr>
<tr>
<td>h) the main turning parameters</td>
<td>(a) high positive rake-angle tools, (b) interrupted cuts, (c) machine tools with low stiffness that are subjected to vibration and chatter, and (d) complex and single-piece tools.</td>
</tr>
</tbody>
</table>

Q4 True or False:

1) Binders can be mixed with the powders to improve their flow characteristics:

2) It may be necessary to use multiple punches with separate movements, in order to ensure that the density is more uniform throughout the part.

3) The higher the pressing speed, the less the tendency for the press to trap air in the die cavity, thus, preventing proper compaction.

4) The green compact is ductile, and its strength (green strength) is low.
5) To maintain the same tool life, if the feed or depth of cut is increased, the cutting speed must be decreased (and vice versa).

6) Chips breakers increase the effective rake angle of the tool and, consequently, decrease the shear angle.

7) Cutting fluid may be a coolant, a lubricant, or both.

8) Positive rake angles improve the cutting operation by reducing forces and temperatures. However, positive angles result in a small included angle of the tool tip which may lead to premature tool chipping and failure.

Q5 Answer the following

1) Should green compacts be brought up to the sintering temperature slowly or rapidly? Explain your reasoning.

2) In the schematic illustration of the 2-D orthogonal cutting model, fill in the missing parts.

3) List at least 3 characteristics that the cutting-tool material must possess:
4) For the given cutting-tool materials and properties, indicate the increase or decrease of properties by drawing the arrow head on the given lines

<table>
<thead>
<tr>
<th></th>
<th>High-speed steels</th>
<th>Cast-cobalt alloys</th>
<th>Uncoated carbides</th>
<th>Coated carbides</th>
<th>Ceramics</th>
<th>Polycrystalline cubic boron nitride</th>
<th>Diamond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot hardness</td>
<td></td>
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<tr>
<td>Toughness</td>
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<td>Impact strength</td>
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<td>Wear resistance</td>
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<td>Chipping resistance</td>
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<td>Cutting speed</td>
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<tr>
<td>Thermal-shock resistance</td>
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<tr>
<td>Tool material cost</td>
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<tr>
<td>Depth of cut</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Very light for single-crystal diamond</td>
</tr>
</tbody>
</table>

5) On the schematic shown, indicate the cutting force ($F_c$), the thrust force ($F_t$), and the radial force ($F_r$).

6) To produce the most accurate holes, give the correct order of the following operations: Boring, Drilling, Centering, Reaming

7) List and explain the factors that contribute to poor surface finish in machining.
<table>
<thead>
<tr>
<th>Q6</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>An orthogonal cutting operation is being carried out under the following conditions: ( t_o = 0.1 \text{ mm} ), ( t_c = 0.2 \text{ mm} ), width of cut = 5 mm, cutting speed ( V = 2 \text{ m/s} ), rake angle ( \alpha = 8^\circ ), ( F_c = 500 \text{ N} ), and ( F_t = 230 \text{ N} ). Calculate the percentage of the total energy that is dissipated in the shear plane.</td>
</tr>
</tbody>
</table>

| 2) | A rod, made of high strength titanium alloy, is 6 inch long and 0.75 inch in diameter. It is |
being reduced in diameter to 0.70 inch by turning on a lathe. The spindle rotates at \( N = 800 \) rpm, and the tool is traveling at an axial speed (feed rate) of 8 inch/min. Calculate the cutting speed \( V \) (at outer \( D_o \) and machined \( D_f \)), the material removal rate MRR, cutting time \( t \), power dissipated, and cutting force. Take unit power (specific energy) for titanium alloy as 2 hp.min/in\(^3\).

3) A hole is being drilled in a block of high-strength aluminum alloy with a 10 mm drill bit, at a feed of 0.20 mm/rev, with a spindle running at \( N = 500 \) rpm. Calculate the material removal rate and the torque on the drill. Take unit power (specific energy) for aluminum alloy as 1 W-s/mm\(^3\).
### Section II (For those who did not take Midterm Exam or those that would like to improve their grades in Midterm Exam)

#### Q1 Fill in the blanks

1) _______________ is the capability of the molten metal to fill mold cavities.

2) A pure metal solidifies at a _____________ temperature. It has a clearly defined melting (or freezing) point.

3) Within the freezing range, the alloy is in a mushy or pasty state with columnar _____ _____________ that look like trees.

4) Because the cooling rate in regions with larger circles (larger amount of molten metal) is lower, they are called _________________. These regions can develop shrinkage cavities and porosity.

5) To ensure that the runners stay open, the fill time must be a ______ ________________ of the solidification time, but the velocity should not be so high to avoid _________________.

#### Q2 Select the most correct answer:

1) The surface of the dendrite has a higher concentration of alloying elements than does the core due to solute rejection from the core towards the surface during solidification of dendrite. This is called
   a) micro segregation
   b) Normal segregation
   a) Inverse segregation
   b) Gravity segregation

2) If you need only a few castings of the same design, which process would be the least expensive per piece cast?
   a) Dies casting
   b) Shell-mold casting
   c) Centrifugal casting
   d) Sand casting

3) Which of the following is not a casting defect:
   a) shrinkage cavities
   b) parting lines
   c) discontinuities (cracks, cold and hot tearing, cold shuts
   d) incomplete casting (misruns)

#### Q3 Match definitions

<table>
<thead>
<tr>
<th>a) Hot-Chamber Process</th>
<th>Mounted pattern made of ferous metal or aluminum is heated,</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### b) Centrifugal Casting:

Coated with a parting agent, and clamped to a box that contains fine sand, then the box is rotated. Sometimes referred to as expendable mold-expendable pattern processes.

### c) Shell Molding

Utilizes the inertial forces caused by rotation to distribute the molten metal into the mold cavities.

### d) Evaporative-pattern casting

It involves the use of a piston, which traps a certain volume of molten metal and forces it into the die cavity through a gooseneck and nozzle. The metal is held under pressure until it solidifies in the die. The shot chamber is continuously heated

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### Q4 True or False:

1) **True**

   Heavy parts are placed in the drag so that the buoyancy force on the cope is reduced. If the buoyancy force becomes high enough, the cope can separate from the drag, resulting in excessive flash in the casting.

2) **True**

   Cores are placed in the mold cavity to form the interior surfaces of the casting and are removed from the finished part during shakeout and further processing.

3) **False**

   Chills can be used to slow (speed) solidification of the metal in a particular region of a casting.

4) **False**

   The pouring of the metal should not be interrupted, since it can lead to dross entrainment and turbulence.

5) **False**

   Expendable (Permanent) molds are made of metals that maintain their strength at high temperatures and hence are used repeatedly.

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### Q5 Answer the following

1) Explain how you would go about avoiding hot tearing.

2) Arrange the following quenching media as for their cooling capabilities in increasing order: (slowest to fastest cooling media)
<table>
<thead>
<tr>
<th>Oil, water, Brine, Air, Synthetic polymers</th>
</tr>
</thead>
</table>

#### Q6 Calculations

1) The bottom of a sprue has a diameter of 10.175 mm and its length is 200 mm. It is desired to have a transition flow with Reynolds number of 14081. What diameter should be specified at the top of the sprue to prevent aspiration? What is the flow rate in m³/min. Consider the metal being cast is aluminum with a viscosity of 0.004 N.s/m² and density 2700 kg/m³.
Orthogonal Cutting Formulas

\[ r = \frac{t_o}{t_c} = \frac{\sin \phi}{\cos(\phi - \alpha)} \quad \tan \phi = \frac{r \cos \alpha}{1 - r \sin \alpha} \]

\[ r = \frac{t_o}{t_c} = \frac{V_c}{V} \quad \frac{V}{\cos(\phi - \alpha)} = \frac{V_s}{\cos \alpha} = \frac{V_c}{\sin \phi} \]

\[ R = \sqrt{F_c^2 + F_t^2} \]

\[ F = R \sin \beta, \quad N = R \cos \beta \]

\[ F_s = F_c \cos \phi - F_t \sin \phi \]

\[ F_n = F_c \sin \phi + F_t \cos \phi \]

\[ F_t = R \sin(\beta - \alpha), \quad F_t = F_c \tan(\beta - \alpha) \]

Power input in cutting = \( F_c V \)
Power for shearing = \( F_s V_s \)
Power for friction = \( F V_c \)

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**Turning Parameters and Formulas**

\( N = \) rotational speed (rpm)
\( f = \) feed (mm/rev, or in/rev)

feed rate,
\( v = f \cdot N \) (mm/min, or in/min)

Angular speed,
\( \omega = \frac{2\pi N}{2} \) (rad/min)

Cutting speed,
\( V = \omega \frac{D}{2} = \pi N \) (m/min, or ft/min)

Average diameter of workpiece,
\( D_{avg} = \frac{D_o + D_f}{2} \)

Depth of cut,
\( d = \frac{D_o - D_f}{2} \)

Material removal rate
\( MRR = \pi D_{avg} d f N \)

Cutting time
\( t = \frac{l}{f N} \) where \( l = \) length of workpiece to be cut (mm or in)

\( \text{Power} = \text{Torque} \cdot \omega \) (kW or hp), \[ \text{Torque} = F_c \frac{D_{avg}}{2} \] (N.m or lb.ft)

Power dissipated = (unit power or specific energy) * MRR
1 hp = 396,000 in-lb/min

For drilling
\[ MRR = \left( \frac{\pi D^2}{4} \right) f \ N, \quad N = \frac{V}{\pi D} \]

Bernoulli’s
\[ h_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = h_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + f \]

Continuity
\[ Q = A_1 v_1 = A_2 v_2 \]

Reynolds
\[ Re = \frac{\nu D \rho}{\eta} \]

Solidification time
\[ = C \left( \frac{\text{volume}}{\text{surface area}} \right)^2 \]