Ph.D. Qualifier Examination – Manufacturing
Fall 2008

Closed book examination
Attempt all three questions

Question #1

Consider the cold heading of a large, cylindrical wire nail (see figure below). The material is a low carbon steel that can be modeled by the following expression:

$$\sigma_{flow} = K\varepsilon^{n}$$

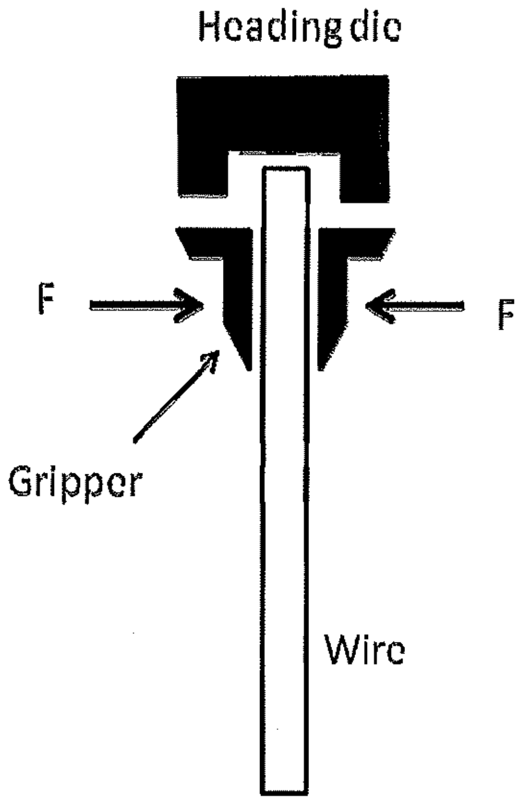
where K = 965 MPa and n = 0.14.

The wire's diameter is 10 mm. The head of the nail should have a 12 mm diameter and a 5 mm thickness.

The wire is held by a gripper below the point at which the head is formed. The gripper is 25 mm long and has five teeth on each of its two jaws to grip the wire. The gripper looks similar to a pair of pliers. Each tooth can develop 30,000 N of gripping force for each 1 mm that it penetrates into a side of the wire. You may assume that gripper is much stronger than the wire.

The coefficient of friction between the heading die and the wire is zero. The coefficient of friction between the top of the gripper, which forms the counter face for the heading die is also zero. No flash is formed during this impression die operation, but the die-work piece interaction produces a pressure-multiplying effect of 3.

Determine the force on the gripper, *F*, needed to prevent slippage of the wire during the heading operation.



Nail with formed head

Question #2

The use of sand molds to cast garden ornaments yields parts that have rustic surfaces, which seem weathered. Bird baths, stepping stones, wall copings, bench seats, wall ornaments, and shallow planters are all good candidates for sand casting. You are tasked with casting a solid copper garden ornament that is 6 cm by 5 cm by 4 cm in a sand mold.

(a) What are the process steps required to make an ornament?
(b) At what point in time can you extract your ornament from the mold, if the molten metal is pour at 75°C above its melting temperature?
(c) Your ornaments are large sellers. To maximize production of your ornament, such that it is enjoyed by customers all over the world, what is its solidification time?
(d) Select another material from which your ornaments can be made. Describe the benefits of using this material and how it impacts the processing of your ornaments.

Specify all major assumptions. Show all work.

Material properties:

Data for solid materials (room temperature)

Material		Specific heat (C) (kJ/kg-°C)		Density (ρ) (kg/m^3)		Thermal conductivity (k) (W/m-°C)	
Sand		1.16		1500		0.60	
Copper		0.39		8970		385	

Data for liquid materials

Material		Melting point (°C)		Latent heat of solidification (fusion) (H_f) (kJ/kg)		Specific heat (C) (kJ/kg-°C)		Viscosity (μ) (mPa-s)
Copper		1083		220		0.52		2.1

Question #3

Consider an orthogonal cutting operation with a zero rake angle tool.

a) Derive an expression for the shear strength of the work piece material, τ_s, in terms of the specific cutting energy u_c, the mean coefficient of friction at the tool-chip interface, μ, and the cutting ratio, r_c.

b) Given the following quantities, calculate the shear angle *and* the shear strength of the work piece material:

Width of cut, $w = 2.0$ mm
Undeformed chip thickness, $t = 0.2$ mm
Deformed chip thickness, $t_c = 0.8$ mm
Cutting force, $F_c = 800$ N
Thrust force, $F_t = 800$ N