Georgia Institute of Technology

Manufacturing

PhD Qualifying Examination

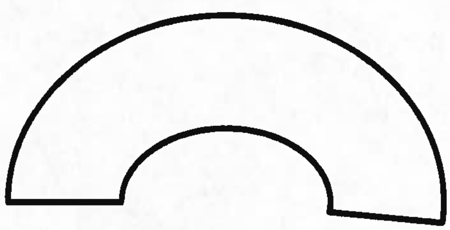
Fall 2011

ANSWER ALL PROBLEMS

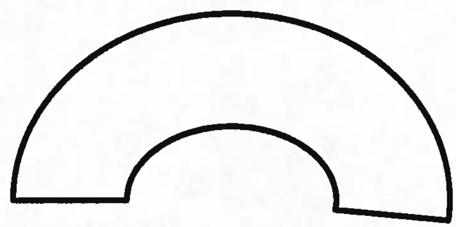
(A) There are four questions that must be answered as part of this problem.

(A-1) What factor limits the smallest radius to which a sheet can be bent? How is this limit affected by the previous processing (i.e., previous manufacturing step) of the sheet?

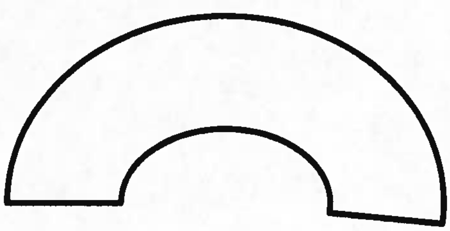
(A-2) Using the figures shaped like beams below, clearly draw/illustrate the stress distribution resulting from a bending moment being applied to the beam, for the condition specified below the figure (i.e., A-D). Fully label each diagram.



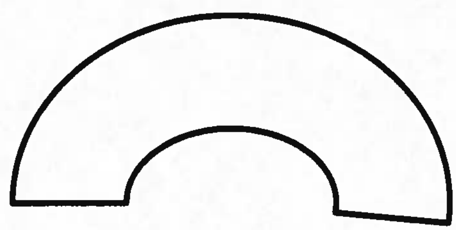
A. Elastic Bending



B. Fully Plastic Bending



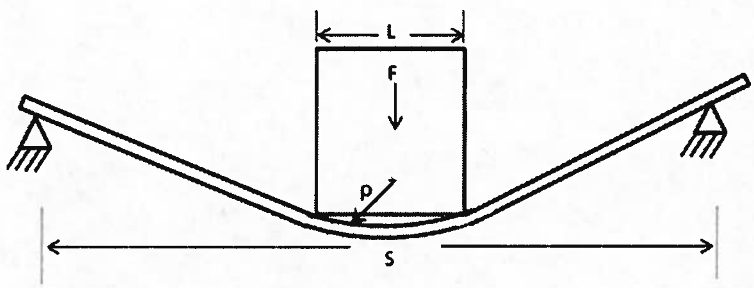
C. Elastic and Plastic Bending



D. Plastic Bending of a strain-hardening material

(A-3) For a beam under plastic bending with strain hardening, derive the resulting moment.

(A-4) For the beam shown below, where plate thickness = h and width = w, force = F, and the radius of curvature = ρ, determine the force and maximum stress as a function of geometry. Show your work.



(B) You are sand casting magnesium into a bottom-gated mold to make a part that is a cylinder with a diameter of 25 cm and a height of 15 cm. The gate is cylindrical with a diameter of 0.5 cm. The pouring basin has a height of 4 cm. You may assume that the gate, the runner, and the bottom of the sprue have the same diameters. There should be no aspiration. Room temperature is 20 °C.

Determine the following:

(B-1) The solidification time, if the part is poured at 50ºC above its melting point. Explain why you may assume that this is an insulating mold situation.
(B-2) The combined height of the sprue and pouring basin, based on Reynolds number criterion and avoidance of short shots.
(B-3) The diameter of the top of the sprue, based on "no aspiration" requirement.
(B-4) The entire time to cool from the pouring temperature to 100ºC, when it can be removed from the mold. Use h = 125 W/m^2-K for this part of the problem only.

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
Aluminum	0.90	2700	202

Nickel	0.44	8910	92
Magnesium	1.07	1700	156
Copper	0.39	8970	385
Gray cast iron	0.441	7125	42.7

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)
Aluminum	660	396	1.05	1.3
Nickel	1453	297	0.73	--
Magnesium	650	384	1.38	1.04
Copper	1083	220	0.52	2.1
Gray cast iron	1251	211	0.34	5.25

(C) Consider the problem of cutting AISI 1040 steel with a zero degree rake angle (α) High Speed Steel (HSS) tool on a shaping machine. The undeformed chip thickness (t_0) is 0.25 mm, the width of cut (w) is 2 mm, and the deformed chip thickness (t_c) is 0.75 mm. The coefficient of friction at the tool-chip interface is known to be approximately 0.5. In addition, the shear yield strength of the work material is 400 MPa, and is known to be approximately constant over the applicable range of strains, strain rates and temperatures.

(C-1) Sketch the orthogonal cutting process and on it illustrate via arrows the transport (or distribution) of heat generated in the primary (shear) and the secondary (tool-chip interface) zones. Clearly list the assumptions (if any) you make in your illustration of heat transport.

(C-2) If the fraction of primary shear zone heat that goes into the workpiece is given by Γ, where $\Gamma = 0.15 ln\left(\frac{27.5}{\frac{\rho c V t_0}{k} \tan\phi}\right)$, calculate the mean temperature at the tool-chip interface for a cutting speed (*V*) of 2 m/s. Note that ϕ is the shear angle (in degrees).

Also given:

ambient temperature is 40°C

density of work material, ρ = 7200 kg/m^3

specific heat of work material, *c* = 502 J/kg-°C

thermal conductivity of work material, *k* = 43.6 W/m-°C

(C-3) A common rule of thumb in metal cutting is that the tool hardness H_{tool} should be greater than 1.35 times but less than or equal to 1.5 times the work material hardness H_{work}. The hardness of AISI 1040 steel (H_{work}) is 350 HV (Vickers) and can be assumed to be fairly constant over the applicable range of strain rates and temperatures (due to the opposing effects of strain rate and temperature). The variation in hardness (in Vickers) of HSS with temperature is given as:

$$H_{tool} = 850\left[1 - \left(\frac{\theta}{700}\right)^{3.1}\right]$$

where θ is the temperature in °C. Estimate the highest cutting speed that can be used without violating the thumb rule.