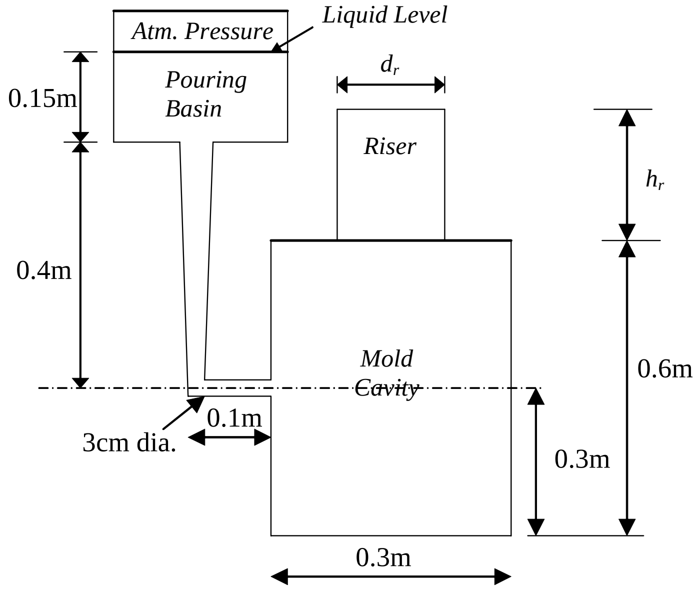
Manufacturing PhD Qualifying Examination – Written Part

Answer All Questions

1. Consider the sand mold shown in the figure below for casting a cylindrical block of metal.

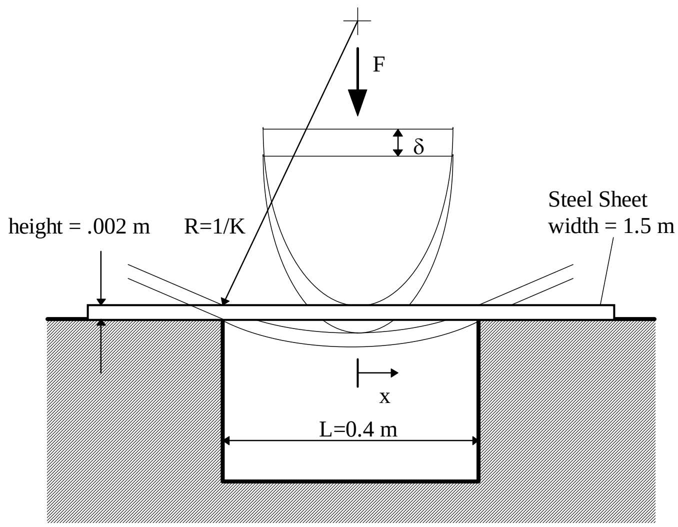


(a) Estimate the time it will take to fill the 0.3m diameter cylindrical mold cavity. Neglect the time required to fill the runner and riser and assume that throughout mold filling the height of molten metal in the pouring basin is kept constant. Clearly state all assumptions you make in arriving at the answer. Note: the dashed line in the above figure serves to indicate the location of the gate relative to the entire mold cavity.

(b) Determine the minimum required dimensions of the cylindrical riser (located on top of the mold cavity) such that no shrinkage cavities form in the mold cavity. It is given that the height-to-diameter ratio of the riser is 1.

(c) The sprue in a top-gated sand mold is generally tapered to prevent aspiration of gases into the molten metal, which leads to porous castings. Use Bernoulli's principle to derive a relationship between the cross-sectional area at the top of the sprue (A_t), area at the bottom of the sprue (A_b), the combined height of the sprue and pouring basin (h_t) and the height of the pouring basin (h_p). Clearly list all assumptions you make in deriving this relationship.

2. Die bending (shown schematically below) has been identified as a possible low cost alternative to match die forming for the manufacture of simple automotive body panels. The lower cost follows since match die forming requires two matching dies while die bending requires a single contoured punch to perform bending operations. As a manufacturing engineer your project centers around characterizing the bending process. Typical body panels are made of low carbon steel (modulus of 200 GPa and yield strength of 220 MPa)



(a) Determine the maximum curvature, K achieved for a punch load of F = 3000 N.

(b) Given parameters such as the modulus, E, the area moment of inertia, I, the yield strength, σ_y, etc., sketch a general moment-curvature (M vs. K) curve for the body panel sheet and identify on the sketch the yield moment and curvature, perfectly plastic moment, M_{load} and K_{load} of part (a), and the slope of the purely elastic recovery region.

(c) What is the unloaded curvature of the sheet originally subjected to the load of part (a).

3. The Brinell Hardness (BHN) is defined in Equation 1; the units of BHN are kg/mm^2. Equation 2 defines BHN in terms of the diameter (d) of the resulting indentation. Equation 3 defines BHN in terms of the depth (t) of the resulting indentation. The figure shows the geometry. The test consists of applying a 3000 kg load to a 10-mm diameter steel ball, which serves as the indenter.

(a) Derive an equation that relates the indentation force of the indenter shown in the figure to the yield stress of a perfectly plastic material, σ_y. Be sure to justify any approximations made.

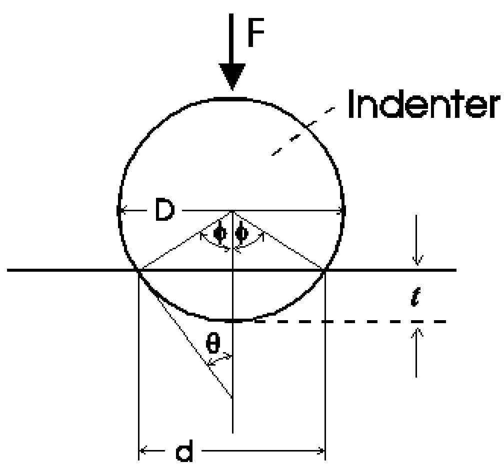
(b) Derive an equation that relates the Brinell hardness to the yield stress of a perfectly plastic material, σ_y, using the geometry in the figure below, the equations provided, and the results of (a). Be sure to justify any approximations made.

(c) Discuss your results to (a) and (b).

$$\text{BHN} = \text{Load / Area of Indentation} \tag{1}$$

$$BHN = \frac{F}{\left(\frac{\pi D}{2}\right)\cdot\left(D-\sqrt{D^2-d^2}\right)} \tag{2}$$

$$\text{BHN} = F / \pi\, D\, t \tag{3}$$



4. In the single point turning of cast iron with HSS tool the tangential cutting force and the thrust force are measured to be 250 lb and 48 lb respectively at a radial depth of cut of 0.05 inch and a spindle speed of 600 rpm. The workpiece has a diameter of 2.5 inch and a total length of cut of 6 inch to be completed in 1 minute time. Estimate the apparent shear strength of the workpiece material. Note that the major cutting edge angle of the tool is 90^o and the process configuration can be considered as orthogonal machining.