MFG1 - PhD Qualifying Exam
Jan 2022

Duration: 3 hrs **Max. Marks: 100**

Instructions

1. This is an open-all (book, internet, notes etc.) exam.
2. Please note that this exam **has 7 questions** and all the questions account for the total marks for this exam.
3. Make assumptions wherever necessary and state them.
4. All the steps of any calculation must be shown clearly.
5. Start a new answer on a new page.

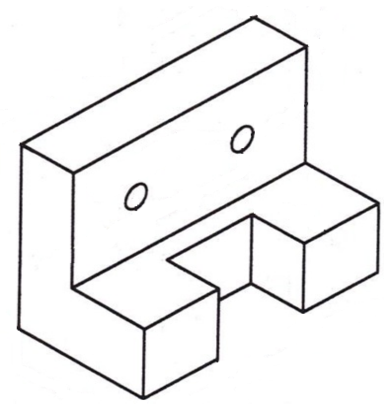
Questions

1. Using appropriate mathematical expressions and neatly labeled schematic diagram(s) justify that for extrusion a tapered die is recommended. [20]

2. Determine the minor axis of yield curve for plane stress condition by using von Mises criterion. [10]

3. Using detailed derivations related to compression of a disc of radius R, determine the critical radius r_s below which ($r \leq r_s$) the disc material deforms with sticking friction. The disc height is $h \ll R$. Assume that von Mises criterion of yield is followed. Draw neat schematic diagram(s) as needed and clearly describe your assumptions and variables. [20]

4. Sketch and briefly describe the most appropriate parting plane location (also show cope and drag) that minimizes the core volume for the geometry shown. [5]



5. Which casting process would you choose for the following and why? [3]

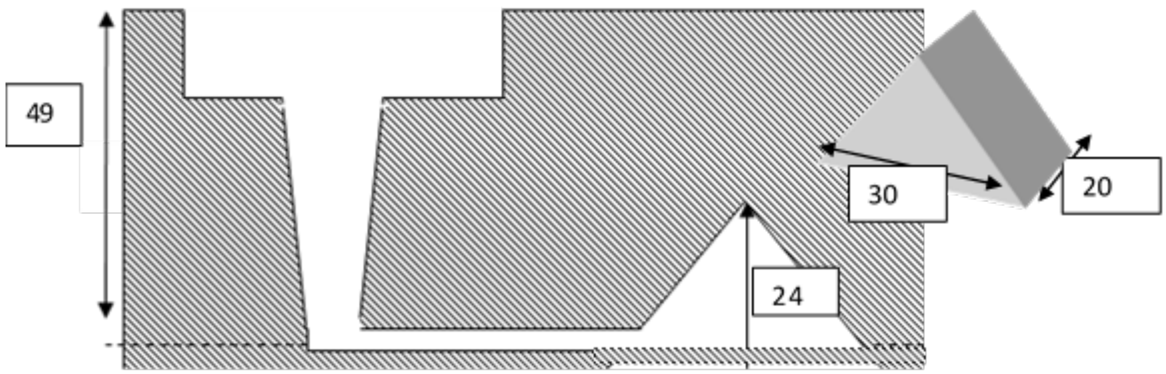
   a. Engine block b. Steel pipes c. Carburetor

6. A triangular prism is to be produced via the sand-casting arrangement shown in the picture below (figure in the next page).

   (a) Calculate the pouring time for the casting (assume the pouring cup is always full and the gate area is $\sqrt{5}$ cm^2). The width of the prism is 20 cm. g = 10 m/s^2 [8]

   (b) Now, verify if an amount of superheat of 20 K is sufficient. Assume that primary heat loss is ONLY through the bottom surface of the prism (and all other surfaces insulated). What is the average temperature drop in the <u>superheated</u> liquid after the pouring time has elapsed?

Consider simple energy balances between the total heat in the volume of the prism and the conductive heat losses from the bottom surface. [8]



(b) Calculate the solidification time. Consider that solidification initiates only after the complete filling. Heat transfer assumptions are as stated in (b) above. The sand and metal properties are as follows: [5]

DATA: The mold is initially at a temperature of 100 ºC. Melting point of the metal is 1100 C. The metal is poured at 1120 ºC. The density, specific heat, latent heat of melting, and conductivity of metal are 7000 kg/m^3, 600 J/kg/K, 100 kJ/kg, and 80 W/m/K respectively. Similarly, the density, specific heat, and conductivity of the sand are 1600 kg/m^3, 1000 J/kg/K, and 1 W/m/K

(c) Show the grain structure of the sand casting, considering it as an alloy, for situations when (a) all the 3 sides are cooled, and (b) only one-side is cooled as in (c). [3]

(d) Sketch an expected compositional profile (C vs distance) of an alloying element (having a partition coefficient *k*<1) along the height (20 cm) of the slab, connecting the base to the vertex/edge as shown, and briefly describe the trend. [3]

7. In a butt welding process using arc welding, the arc power is found to be 3 kVA, having an arc heat transfer efficiency of 80%. The process is used to weld two steel plates, each of 4 mm thickness, having grooves at 45º inclination.

(a) Consider the balance of the available heat (assume 2D or 3D source) with the minimum heat input necessary for maintaining a given width of the weld. Determine the maximum possible welding speed.

DATA: thermal diffusivity of steel: 10^{-5} m^2/s. conductivity: 40 W/m/K, Melting point: 1800 K, and room temperature 300 K. [9]

(b) Sketch approximate temperature variation with time as one moves away from the heat source, indicating 3-4 distances along the transverse direction. [3]

(c) How would you define heat affected zone, and how this can be identified? Also sketch an indicative microstructure along a transverse cross section that can represent such a welding process [3]

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