PHD QUALIFYING EXAM – Autumn 2022

MANUFACTURING PROCESSES - I

Maximum marks: 100 **Time: 3 hours**

- Only handwritten notes are allowed
- Make suitable assumptions, if required, and clearly mention them.

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1. In order to reduce shrinkage-related defects, risers are used in metal casting. In one such case, a regular hexagonal prism-type mould cavity is used on which an open-type cylindrical riser is attached. The side of the hexagonal cavity is 50 mm, while its width is 100 mm (as shown in Figure 1.Q2). A cylindrical core of diameter 25 mm, and length of 40 mm is kept inside the cavity to create an internal feature. Neglecting the core-print/chaplets, find the dimensions of the riser if the ratio of diameter to height (D:H) is 3:4. Ignore the foot print area of riser on the mould cavity. [10]

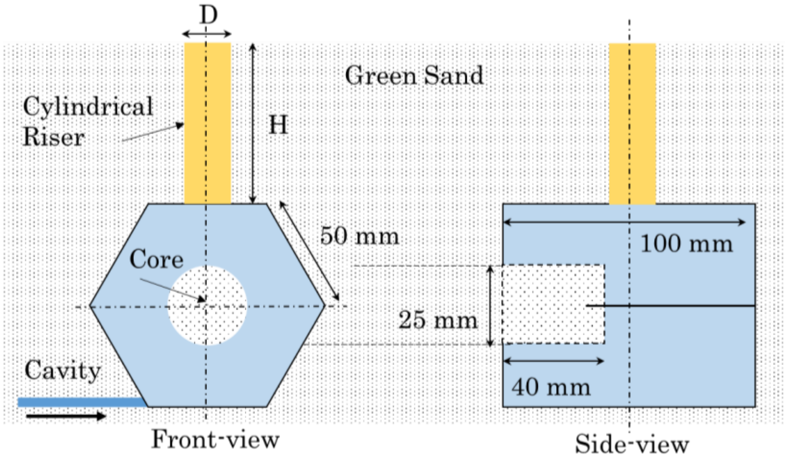

Figure 1. Q1

2. We need to find out the filling time for the following mould cavity having square cross-section. The geometric features of the casting are given as follows: size = 10 cm, height *h*= 4 cm. Sprue height H = 20 cm, g =10 m/s^2. Both top and bottom gates have same cross-sectional area (Ag = 5 mm^2), a) when only top gate is open, b) when only bottom gate is open, c) when both gates are open.

[4 + 4 + 7]

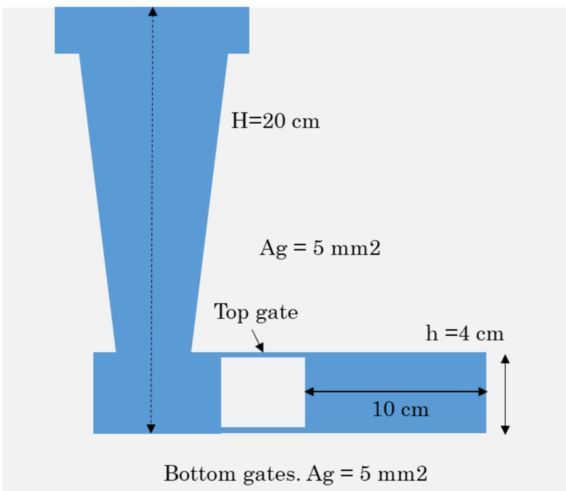

Figure 2.Q2

3. In the metal casting process, holding forces are often required to keep the cope and drag in the same place during the metal pouring. Find out the weights kept to compensate for the forces during the metal pouring in a horizontal sand-casting of a hollow cylindrical pipe (Outer size: 12 cm, Wall thickness: 1 cm, Length 100 cm). The metal head is 20 cm, while the molding flask used for the sand-casting purpose is 200 x 25 x 20 cm in size. The density of liquid metal and sand is 0.08 N/cm^3 and 0.02 N/cm^3. Only consider the static forces in the calculations. [10]

4. [6+6]

a. During the welding process, the cross-section area of the weld was observed to 30 mm^2. Welding was carried out at a speed of 0.5 m/min. The input current and voltage used were 175 A and 25 V, respectively. The unit energy required to melt the metal is 6 J/mm^3. What would be the melting efficiency if arc heat transfer efficiency was 90%?

b. Two plates with symmetrical V joint penetration of V-angle 60 degrees are to be arc welded in a single pass. The power P(kW) and length l(mm) characteristic are given by $P = 4 + 0.8l - 0.1l^2$. The top surface of the weld is flat, while the energy losses are 20%. The density of the filler material is 8 gm/cc, and the energy required to melt 1 gm is 1400 joules. The plate dimensions are 1000 mm in length and 5 mm in thickness. What will be the maximum welding speed?

5. [8+8]

a. The strain-hardening behavior of an annealed low-carbon steel is approximated by $\sigma = 700\epsilon^{0.2} MPa$. Estimate the yield strength after the bar is cold worked 50% via thickness reduction using simple forging process. Suppose another bar of this same steel was cold worked by an unknown amount and then cold worked 15% more and found to have a yield strength of 525 MPa. What was the unknown amount of cold work?

b. It is known that a certain material yields under uniaxial compression at 610 kN/mm^2. If the material is subjected to compression (σ_1) with additional compressive loading along other 2 principal axes such that the stresses along those 2 axes are 150 kN/mm^2 and 300 kN/mm^2. Using Von mises yield criteria, calculate the stress (σ_1) required to cause yielding.

6. For a wire drawing operation, consider a friction coefficient of 0.1 and a die with $2\alpha = 10°$. Ignore redundant work while answering following questions:

(a) Find the draw force needed for a 30% reduction of a 2 mm diameter annealed aluminum wire with $K = 180$ MPa and $n = 0.2$.

(b) If the wire is travelling at 2 m/s through the die, find the power required for the process described in (a).

(c) Find the smallest diameter die that can be successfully used to draw the 2 mm diameter annealed wire described in part (a) accounting for friction. [10]

7. For a direct extrusion process, in addition to the extrusion pressure, energy is required to overcome friction at the billet/container interface (Refer to Figure 3.Q7). Use the slab method to find an expression for the maximum contribution of friction alone to the extrusion pressure as a function of the extent of ram travel or instantaneous billet length, *L*.

Assume the yield strength in uniaxial tension as *Y* and the *k* is the shear yield stress.

Use von Mises yield criterion. Ignore any dead zone formation and redundant work.

(Hint: Construct a free body diagram of the slab element clearly showing the various stresses acting. Maximum contribution of the friction happens under sticking conditions. The boundary condition, at $x = 0$, the longitudinal (axial) stress $\sigma_x = 0$ can be taken in order to account for contribution of interfacial friction.) [10]

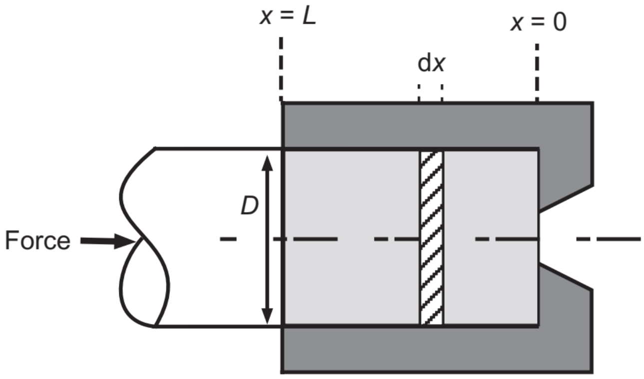

Figure 3.Q7

8. [6+4+6]

a. A 42 mm thick slab made of low carbon steel is to be reduced to 34 mm in one pass in a rolling operation. As the thickness is reduced, the plate widens by 4%. The entrance speed of the plate is 15.0 m/min. The roll radius is 325 mm and the rotational speed is 8 rev/min. Determine (i) the minimum required coefficient of friction that would make this rolling operation possible using limiting friction condition for rolling action, (ii) exit velocity of the plate, and (iii) forward slip.

b. Figure 4.Q8b shows defects after rolling a strip. Discuss the possible causes and propose measures to avoid such defects.

c. A bracket shown in Figure 5.Q8c to be fabricating using sheet metal. List sequence of sheet metal operations required using a progressive die and show a strip layout.

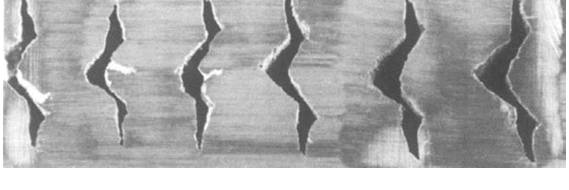

Figure 4.Q8b

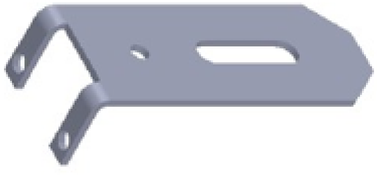

Figure 5.Q8c

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