QUALIFYING EXAM – MANUFACTURING

Spring 2024

Instructions

Answer 5 of the 6 following questions.

Question 1.

The motor housing shown below will be die cast. Your customer, a design engineer who is not familiar with design rules for casting, has provided design specifications as shown below.

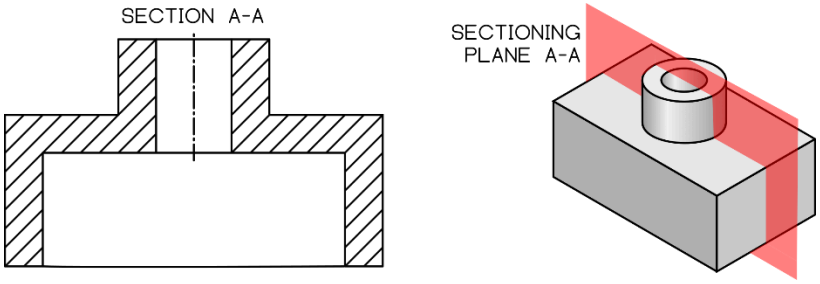


Fig. for Question 4 – Motor housing. For reference, the overall size of the workpieces is approximately 100 x 50 x 50 mm. The wall thickness is approximately 5 mm. Drawing not to scale.

Applying design-for-casting principles, provide a design with improved manufacturability. Indicate critical features you recommend adding such as the parting line location, draft, and machining allowances where necessary. Your design should be conducive to a two-plate mold design. In your answer provide the following:

(a) A cross-sectional drawing of the part with recommended modifications. Label the above-mentioned features and draw them in an exaggerated manner to make them clear.
(b) Provide one or two sentences describing the reason for each modification.
(c) Name two defects that can occur in the die casting process. Describe the nature of the defect and its cause..

Question 2.

Laser powder bed fusion (LPBF) is a prevalent metal additive manufacturing (AM) process. Although there are many process variables in the LPBF process, power P [W], laser scan speed v [mm/s], layer thickness t [mm], and hatch spacing d are four key variables often considered when modeling the process.

(a) Draw a plot showing P on the vertical axis and v on the horizontal axis. Label regions of the plot where there is high and low energy input to the powder bed. You should draw boundaries to help distinguish these regions.
(b) Develop an equation that describes linear energy density of an LPBF process, i.e., the amount of energy per linear unit of material.
(c) What are some advantages/disadvantages to high energy input? What are some advantages/disadvantages to low energy input? Consider the effect of these parameters on part quality, process productivity, etc.

(d) So far you have considered just P and v as process variables. Discuss how process variables t and d may affect the LPBF process as well.

Question 3.

Heat treatment of iron-carbon alloys is heavily utilized to alter workpiece properties. Considering an iron-carbon alloy, provide details on the following;

(a) What is the net effect of quenching and the expected resulting microstructure?
(b) What does a tempering heat treatment entail, and how does it affect the material properties?
(c) Explain the limitations of an iron-carbon phase diagram (or indeed any metal alloy phase diagram).

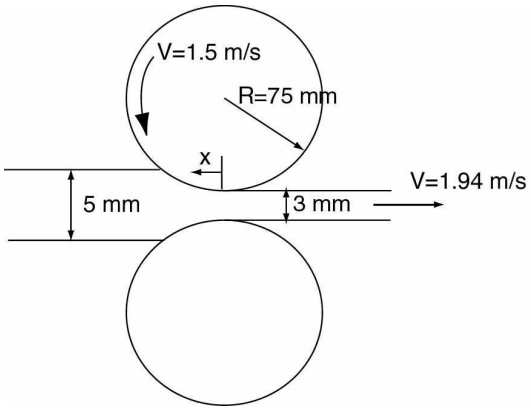
Question 4.

For thermoplastics, explain the effects of changing the following environmental parameters and material characteristics on the viscosity of the material.

(a) temperature
(b) pressure
(c) strain rate
(d) molecular weight
(e) the presence of side branches

Question 5.

A rolling operation takes place under the conditions shown. What is the velocity of the metal in the inlet zone? What is the position, x_n, of the neutral point? Note that there is a front and back tension that has not been specified! Sketch the pressure distribution on the work rolls.



Additional Data:
Material: 5052-O Aluminum
μ=0.1
Hardened Steel Rolls
Roll surface roughness=0.02 μm
Workpiece surface roughness = 0.15 μm
Temperature = 210°C
V_f=1.94 m/s
V_r=1.5 m/s
y_i=5 mm
y_f=3mm
R=75 mm

Question 6.

Consider alternative manufacturing processes such as casting, forging, powder metallurgy, additive manufacturing and machining.

(a) Explain the major differences of machining processes compared to the others.

(b) Explain the effects of the selected primary shaping process, e.g. casting, forging, additive manufacturing, powder metallurgy, on the subsequent machining process in terms of the part geometry, machinability, cost, selection of cutting tools.
(c) Explain the important considerations and constraints if you happen to develop a machining process.