QUIZ MS203

Casting and Flow Stress

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PROBLEMS - CASTING

Problem 1

In the casting of steel under certain mold conditions, the mold constant in Chvorinov's rule is known to be 4.0 min/cm², based on previous experience. The casting is a flat plate with length = 30 cm, width = 10 cm and thickness = 20 mm. Determine how long it will take for the casting to solidify.

A) t_s = 1.33 min.

B) t_s = 2.49 min.

C) t_s = 3.61 min.

D) t_s = 4.80 min.

Problem 2

A rectangular casting having the dimensions 3 cm × 5 cm × 10 cm solidifies completely in 12 minutes. Compute the mold constant.

A) B = 10.1 min/cm²

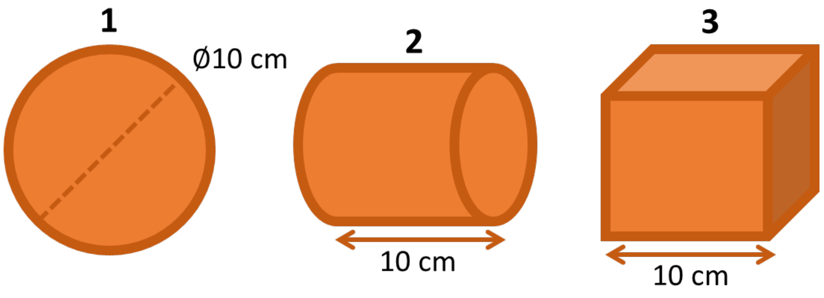
B) B = 14.5 min/cm²

C) B = 19.3 min/cm²

D) B = 22.2 min/cm²

Problem 3 (Groover, 2013)

Total solidification times of three casting geometries are to be compared: (1) a sphere with diameter 10 cm; (2) a cylinder with diameter and length both 10 cm; and (3) a cube with side 10 cm. The same casting alloy is used in all three cases. Which geometry would completely solidify faster?



A) The sphere.

B) The cylinder.

C) The cube.

D) None of the above.

Problem 4 (Groover, 2013)

A riser in the shape of a sphere is to be designed for a sand casting mold. The casting is a rectangular plate with length = 200 mm, width = 100 mm, and thickness = 18 mm. If the total solidification time of the casting itself is known to be 3.5 min, determine the diameter of the riser so that it will take 25% longer for the riser to solidify.

A) D = 34.4 mm

B) D = 47.5 mm

C) D = 59.6 mm

D) D = 67.4 mm

Problem 5 (Groover, 2013)

A steel casting has a cylindrical geometry with 4.0 in. diameter and weighs 20 lb. The casting takes 6.0 min to completely solidify. Another cylindrical-shaped casting with the same diameter-to-length ratio weighs 12 lb. This casting is made of the same steel, and the same conditions of mold and pouring were used. The density of steel = 490 lb/ft³. True or false?

1.( ) The mold constant for either casting is greater than 10 min/in.²

2.( ) The lighter casting has diameter greater than 3.5 in. and length greater than 5 in.

3.( ) The solidification time for the lighter casting is greater than 5 minutes.

PROBLEMS - FLOW STRESS

Problem 6

The strength coefficient = 550 MPa and strain-hardening exponent = 0.22 for a certain metal. During a forming operation, the final true strain that the metal experiences = 0.85. Determine the flow stress at this strain and the average flow stress that the metal experienced during the operation.

A) σ_f = 531 MPa and $\bar{\sigma}_f$ = 341 MPa

B) σ_f = 531 MPa and $\bar{\sigma}_f$ = 435 MPa

C) σ_f = 572 MPa and $\bar{\sigma}_f$ = 341 MPa

D) σ_f = 572 MPa and $\bar{\sigma}_f$ = 435 MPa

Problem 7

A metal has a flow curve with strength coefficient = 850 MPa and strain-hardening exponent = 0.30. A tensile specimen of the metal with gage length = 100 mm is stretched to a length = 157 mm. Determine the flow stress at the new length and the average flow stress that the metal has been subjected to during the deformation.

A) σ_f = 669 MPa and $\bar{\sigma}_f$ = 515 MPa

B) σ_f = 669 MPa and $\bar{\sigma}_f$ = 581 MPa

C) σ_f = 731 MPa and $\bar{\sigma}_f$ = 515 MPa

D) σ_f = 731 MPa and $\bar{\sigma}_f$ = 581 MPa

Problem 8 (Creese, 1999)

The strength coefficient = 35,000 lb/in.² and strain-hardening exponent = 0.40 for a metal used in the forming operation in which the workpart is reduced in cross-sectional area by stretching. If the average flow stress on the part is 20,000 lb/in.², determine the amount of reduction in cross-sectional area experienced by the part. In the following answers, A_o and A_f denote initial and final cross-sectional area, respectively.

A) A_f = 0.331A_o

B) A_f = 0.442A_o

C) A_f = 0.565A_o

D) A_f = 0.689A_o

Problem 9 (Groover, 2013)

Determine the value of the strain-hardening exponent for a metal that will cause the average flow stress to be 3/4 of the final flow stress after deformation.

A) n = 0.143

B) n = 0.215

C) n = 0.333

D) n = 0.416

Problem 10 (Groover, 2013)

In a tensile test, two pairs of values of stress and strain were measured for the specimen metal after it had yielded: (1) true stress = 217 MPa and true strain = 0.35, and (2) true stress = 259 MPa and true strain = 0.68. Based on these data points, determine the strength coefficient and the strain-hardening exponent.

A) K = 201 MPa and n = 0.135

B) K = 201 MPa and n = 0.271

C) K = 290 MPa and n = 0.135

D) K = 290 MPa and n = 0.271

SOLUTIONS

P.1 ■ Solution

The volume of the casting is V =30×10×2 = 600 cm³ and the surface area is A = 2(30×10 + 30×2 + 10×2) = 760 cm². Appealing to Chvorinov's rule, we obtain

$$t_S = B\left(\frac{V}{A}\right)^2 = 4.0\times\left(\frac{600}{760}\right)^2 = \boxed{2.49\text{ min}}$$

The casting should require about 2 and a half minutes to solidify.

♦ The correct answer is **B**.

P.2 ■ Solution

The surface area of the casting is A = 2(3×5 + 5×10 + 3×10) = 190 cm² and the volume is V = 3×5×10 = 150 cm³. The solidification time is 12 min. The mold constant can be established by substituting these data in Chvorinov's rule, namely

$$t_S = B\left(\frac{V}{A}\right)^2 \rightarrow 12 = B\times\left(\frac{150}{190}\right)^2$$

$$\therefore 12 = B\times 0.623$$

$$\therefore \boxed{B = 19.3\text{ min/cm}^2}$$

♦ The correct answer is **C**.

P.3 ■ Solution

For the sphere, the volume is $V_1 = 4\pi R^3/3 = 4\pi \times 5^3/3$ = 524 cm³ and the surface area is $A_1 = 4\pi R^2 = 4\pi \times 5^2$ = 314 cm². The time required for solidification is calculated to be

$$t_{S,1} = B\left(\frac{V_1}{A_1}\right)^n \rightarrow t_{S,1} = B\times\left(\frac{524}{314}\right)^2$$

$$\therefore t_{S,1} = 2.78B$$

For the cylinder, the volume is $V_2 = \pi R^2 L = \pi \times 5^2 \times 10$ = 785 cm³ and the surface area is $A_2 = 2\pi R^2 + 2\pi RL = 2\times\pi\times 5^2 + 2\pi\times 5\times 10$ = 471 cm². The time required for solidification is then

$$t_{S,2} = B\left(\frac{V_2}{A_2}\right)^n \rightarrow t_{S,2} = B\times\left(\frac{785}{471}\right)^2$$

$$\therefore t_{S,2} = 2.78B$$

For the cube, the volume is $V_3 = L^3 = 10^3$ = 1000 cm³ and the surface area is $A_3 = 6L^2 = 6\times 10^2$ = 600 cm². The time required for solidification follows as

$$t_{S,3} = B\left(\frac{V_3}{A_3}\right)^n \rightarrow t_{S,3} = B\times\left(\frac{1000}{600}\right)^2$$

$$\therefore t_{S,3} = 2.78B$$

Given that B is the same for all cases, we conclude that the solidification time will be approximately the same for all three geometries.

♦ The correct answer is **D**.

P.4 ■ Solution

The casting volume is V = 200×100×18 = 360,000 mm³ and the surface area is A = 2(200×100 + 200×18 + 100×18) = 50,800 mm². Given the solidification time t_S = 3.5 min for the casting, we can easily determine the mold constant,

$$t_S = B\left(\frac{V}{A}\right)^2 \rightarrow B = t_S \times \left(\frac{A}{V}\right)^2$$

$$\therefore B = 3.5 \times \left(\frac{50,800}{360,000}\right)^2 = 0.0697 \text{ min/mm}^2$$

Now, the riser volume is $V = \pi D^3/6 = 0.524D^3$ and the surface area $A = \pi D^2 = 3.14D^2$, so that $V/A = 0.524D^3/3.14D^2 = 0.167D$. Appealing to Chvorinov's rule again, we have

$$t_S = B\left(\frac{V}{A}\right)^2 \rightarrow 1.25 \times 3.5 = 0.0697 \times (0.167D)^2$$

$$\therefore 4.38 = 0.00194D^2$$

$$\therefore \boxed{D = 47.5 \text{ mm}}$$

♦ The correct answer is **B**.

P.5 ■ Solution

1.True. The density of steel is $\rho = 490/12^3 = 0.284$ lb/in.³ The volume of the casting follows as

$$\rho = \frac{m}{V} \rightarrow V = \frac{m}{\rho}$$

$$\therefore V = \frac{20}{0.284} = 70.4 \text{ in.}^3$$

Equipped with V, we can determine the length L of the casting,

$$V = \frac{\pi D^2 L}{4} \rightarrow L = \frac{4V}{\pi D^2}$$

$$\therefore L = \frac{4 \times 70.4}{\pi \times 4.0^2} = 5.60 \text{ in.}$$

The surface area is determined next,

$$A = \frac{2\pi D^2}{4} + \pi DL = \frac{2\pi \times 4.0^2}{4} + \pi \times 4.0 \times 5.60 = 95.5 \text{ in.}^2$$

We now have all the information necessary to determine the mold constant B,

$$t_S = B\left(\frac{V}{A}\right)^2 \rightarrow B = t_S \times \left(\frac{A}{V}\right)^2$$

$$\therefore B = 6.0 \times \left(\frac{95.5}{70.4}\right)^2 = \boxed{11.0 \text{ min/in.}^2}$$

2.False. We first require the volume of the lighter casting. Since weight is proportional to volume, we can write

$$\frac{V_1}{W_1} = \frac{V_2}{W_2} \rightarrow V_2 = W_2 \times \frac{V_1}{W_1}$$

$$\therefore V_2 = 12 \times \frac{70.4}{20} = 42.2 \text{ in.}^3$$

We were told that the lighter casting has the same diameter-to-length ratio as the heavier one, namely

$$\frac{D_1}{L_1} = \frac{4.0}{5.60} = 0.714$$

This means that the relation $D_2 = 0.714L_2$, or, equivalently, $L_2 = 1.40D_2$ holds for the lighter casting. Thus,

$$V_2 = \frac{\pi D_2^2 L_2}{4} \to V_2 = \frac{\pi D_2^2 \times 1.40 D_2}{4}$$

$$\therefore V_2 = 0.35\pi D_2^3$$

$$\therefore D_2 = \left(\frac{V_2}{0.35\pi}\right)^{\frac{1}{3}}$$

$$\therefore D_2 = \left(\frac{42.2}{0.35\pi}\right)^{\frac{1}{3}} = \boxed{3.37 \text{ in.}}$$

Finally,

$$L_2 = 1.40 D_2 = 1.40 \times 3.37 = \boxed{4.72 \text{ in.}}$$

3.False. From Part 2, we know that the volume of the lighter casting is V_2 = 42.2 in.³ The surface area is calculated as

$$A_2 = \frac{2\pi D_2^2}{4} + \pi D_2 L_2 = \frac{2\pi \times 3.37^2}{4} + \pi \times 3.37 \times 4.72 = 67.8 \text{ in.}^2$$

Lastly, the solidification time is determined to be

$$t_{S,2} = B\left(\frac{V_2}{A_2}\right)^2 = 11.0 \times \left(\frac{42.2}{67.8}\right)^2 = \boxed{4.26 \text{ min}}$$

P.6 ■ Solution

The flow stress is simply

$$\sigma_f = K\varepsilon^n = 550 \times 0.85^{0.22} = \boxed{531 \text{ MPa}}$$

The average flow stress is, in turn,

$$\bar{\sigma}_f = \frac{K\varepsilon^n}{n+1} = \frac{550 \times 0.85^{0.22}}{1.22} = \boxed{435 \text{ MPa}}$$

♦ The correct answer is **B.**

P.7 ■ Solution

The true strain in the specimen is

$$\varepsilon = \ln(157/100) = 0.451$$

The flow stress is then

$$\sigma_f = K\varepsilon^n = 850 \times 0.451^{0.30} = \boxed{669 \text{ MPa}}$$

while the average flow stress is calculated as

$$\bar{\sigma}_f = \frac{K\varepsilon^n}{n+1} = \frac{850 \times 0.451^{0.30}}{0.30+1} = \boxed{515 \text{ MPa}}$$

♦ The correct answer is **A.**

P.8 ■ Solution

With recourse to the equation for average flow stress, we write

$$\bar{\sigma}_f = \frac{K\varepsilon^n}{n+1} \to 20{,}000 = \frac{35{,}000 \times \varepsilon^{0.40}}{0.40+1}$$

$$\therefore \varepsilon = 0.572$$

Since $\varepsilon = \ln(A_o/A_f)$, it follows that

$$\varepsilon = \ln\left(\frac{A_o}{A_f}\right) \to 0.572 = \ln\left(\frac{A_o}{A_f}\right)$$

$$\therefore A_o/A_f = 1.77$$

$$\therefore \boxed{A_f = 0.565 A_o}$$

♦ The correct answer is **C**.

P.9 ■ Solution

In accordance with the problem statement, we must have $\bar{\sigma}_f = 0.75\sigma_f$. Therefore,

$$\bar{\sigma}_f = 0.75\sigma_f \to \frac{K\varepsilon^n}{n+1} = 0.75 \times K\varepsilon^n$$

$$\therefore \frac{1}{n+1} = 0.75$$

$$\therefore 1 = 0.75n + 0.75$$

$$\therefore n = \frac{0.25}{0.75} = \boxed{0.333}$$

♦ The correct answer is **C**.

P.10 ■ Solution

Using logarithms, the flow stress equation can be adjusted as

$$\sigma_f = K\varepsilon^n \to \ln\sigma_f = \ln\left(K\varepsilon^n\right)$$

$$\therefore \ln\sigma_f = \ln K + \ln\varepsilon^n$$

$$\therefore \ln\sigma_f = \ln K + n\ln\varepsilon$$

Substituting the first data point, we have

$$\ln 217 = \ln K + n\ln 0.35$$

$$\therefore 5.38 = \ln K - 1.05n \text{ (I)}$$

Substituting the second data point, we have

$$\ln 259 = \ln K + n\ln 0.68$$

$$\therefore 5.56 = \ln K - 0.386n \text{ (II)}$$

Subtracting equation (II) from (I) brings to

$$5.38 - 5.56 = \ln K - 1.05n - \left(\ln K - 0.386n\right)$$

$$\therefore -0.18 = -0.664n$$

$$\therefore \boxed{n = 0.271}$$

Inserting this result into equation (I) yields

$$5.38 = \ln K - 1.05 \times 0.271$$

$$\therefore 5.38 = \ln K - 0.285$$

$$\therefore \ln K = 5.67$$

$$\therefore K = e^{5.67} = \boxed{290 \text{ MPa}}$$

♦ The correct answer is **D**.

ANSWER SUMMARY

Problem 1	B
Problem 2	C
Problem 3	D
Problem 4	B
Problem 5	T/F
Problem 6	B
Problem 7	A
Problem 8	C
Problem 9	C
Problem 10	D

REFERENCES

- CREESE, R. (1999). *Introduction to Manufacturing Processes and Materials.* New York: Marcel Dekker.
- GROOVER, M. (2013). *Fundamentals of Modern Manufacturing.* 5th edition. Hoboken: John Wiley and Sons.

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