8.2 Casting and forming

Name: _____ Class: _____ Date: _____ **Total: 16 marks**

KEY WORDS Chvorinov's rule • casting modulus • riser • flow stress

Objective

Estimate solidification time with Chvorinov's rule, size a riser that freezes last, and find the stress and force to draw a wire.

1 Key knowledge and worked examples

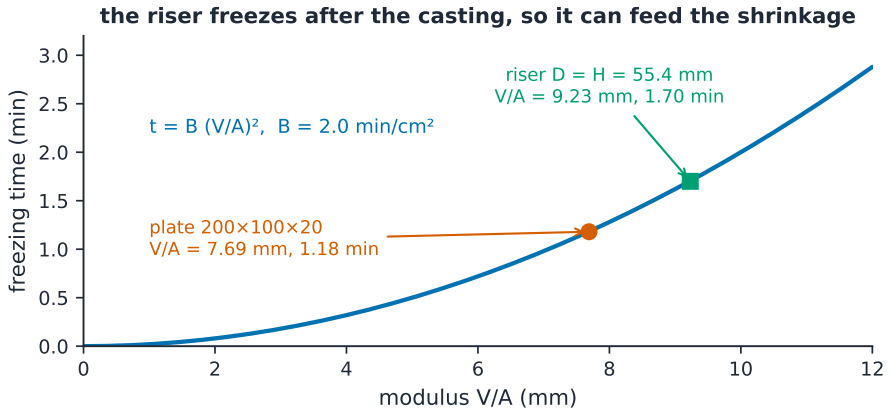
■ **Freezing time and forming force**

- **Chvorinov's rule** : $t = B(V/A)^2$; V/A is the **casting modulus** .
- A **riser** must freeze after the casting: give it a larger modulus. A cylinder with $D = H$ has $V/A = D/6$.
- Drawing: true strain $\varepsilon = \ln(A_0/A_f)$; mean **flow stress** $\bar{Y} = K\varepsilon^n/(n{+}1)$; ideal drawing stress $\sigma_d = \bar{Y}\varepsilon$.

■ **Worked example. The plate and its riser**

A steel plate $200 \times 100 \times 20$ mm, $B = 2.0$ min/cm^2.

- $V = 400\,000$ mm^3, $A = 52\,000$ mm^2, so $V/A = 7.69$ mm $= 0.769$ cm.
- $t = B(V/A)^2 = 2.0 \times 0.769^2 = \mathbf{1.18}$ min.
- Riser 20% larger in modulus: $D/6 = 1.2 \times 7.69$, so $D = \mathbf{55.4}$ mm, freezing in 1.70 min.



2 Practice

Use $B = 2.0$ min/cm^2 for steel.

2.1 A steel cube casting has 60 mm sides. Find its casting modulus (cm) and its solidification time (one decimal, min). [3]

2.2 Size a cylindrical riser ($D = H$) whose modulus is 20% above the cube's. Find D (nearest mm) and its freezing time (two decimals, min). [3]

2.3 Wire of 8 mm is drawn to 7 mm ($K = 500$ MPa, $n = 0.2$). Find the true strain (three decimals), the mean flow stress (nearest MPa), the drawing stress (one decimal, MPa) and the drawing force (two decimals, kN). [5]

3 Exam-style questions

3.1 In ideal drawing the wire breaks when σ_d reaches the drawn wire's flow stress $K\varepsilon^n$. Show that this happens at $\varepsilon = n + 1$, and find the largest area reduction in one pass for $n = 0.2$ (one decimal, %). Why is real practice well below it? [5]

Solutions

2.1

- $V/A = a^3/(6a^2) = a/6 = 60/6 = 10$ mm $=$ **1.0** cm.
- $t = B(V/A)^2 = 2.0 \times 1.0^2 =$ **2.0** min.

2.2

- $D/6 = 1.2 \times 10$, so $D =$ **72** mm.
- $t = B(V/A)^2 = 2.0 \times 1.2^2 =$ **2.88** min.

2.3

- $\varepsilon = \ln(A_0/A_f) = \ln(64/49) =$ **0.267**.
- $\bar{Y} = K\varepsilon^n/(n+1) = 500 \times 0.267^{0.2}/1.2 =$ **320** MPa.
- $\sigma_d = \bar{Y}\varepsilon = 320 \times 0.267 =$ **85.5** MPa.
- $F = \sigma_d A_f = 85.5 \times \pi \times 3.5^2 =$ **3.29** kN.

3.1

- Set $\sigma_d = K\varepsilon^{n+1}/(n+1)$ equal to $K\varepsilon^n$: $\varepsilon/(n+1) = 1$, so $\varepsilon = n + 1$.
- $\varepsilon = 1.2$: reduction $= 1 - A_f/A_0 = 1 - e^{-1.2} =$ **69.9**%.
- Friction and redundant work raise the real drawing stress, so passes are kept to about 20 to 45% reduction.