# 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 $\sigma_d = \bar{Y}\varepsilon$.

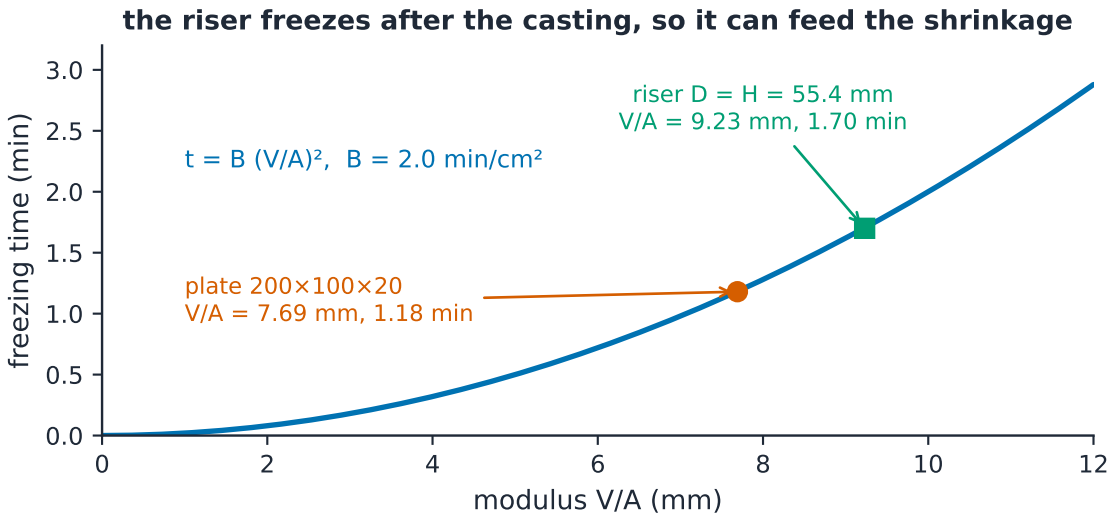
■ **Worked example. The plate and its riser**

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.



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## 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]



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**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 $\sigma_d$ 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]



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## Solutions

**2.1**

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

**2.2**

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

**2.3**

- $\varepsilon = \ln(A_0/A_f) = \ln(64/49) = \mathbf{0.267}$.
- $\bar{Y} = K\varepsilon^n/(n+1) = 500 \times 0.267^{0.2}/1.2 = \mathbf{320}$ MPa.
- $\sigma_d = \bar{Y}\varepsilon = 320 \times 0.267 = \mathbf{85.5}$ MPa.
- $F = \sigma_d A_f = 85.5 \times \pi \times 3.5^2 = \mathbf{3.29}$ 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 $= 1 - A_f/A_0 = 1 - e^{-1.2} = \mathbf{69.9}\%$.
- Friction and redundant work raise the real drawing stress, so passes are kept to about 20 to 45% reduction.



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