Institute of Refractories Engineers

Transient Conditions

Training Day 2016

Sheffield
13 October 2016

Contents

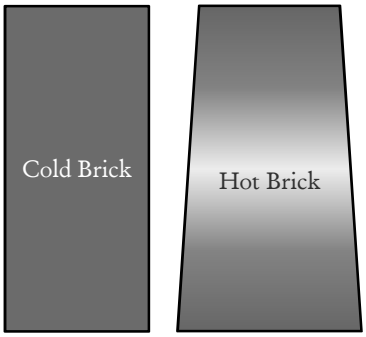
- What are Transient Conditions
- Heat Flow Modelling
- Thermal Shock

Transient Conditions

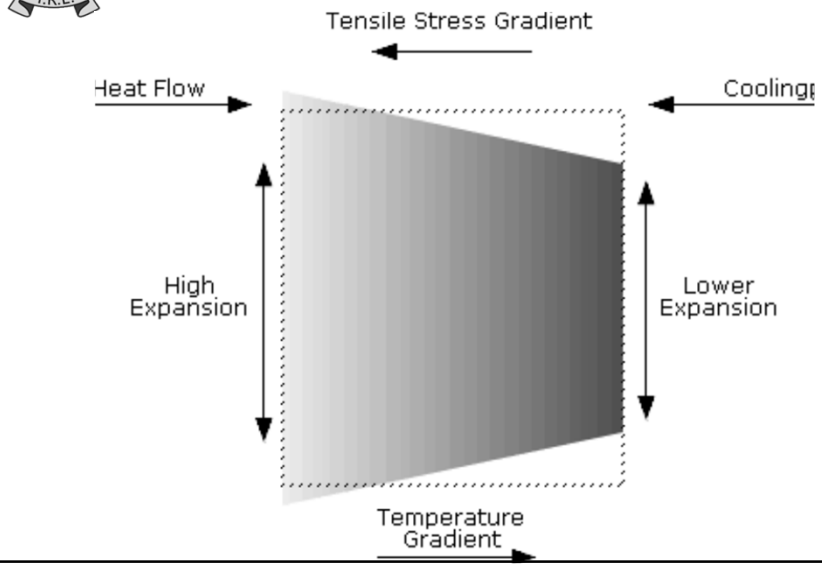
- Temperature changes over time
  - Warm up
  - Cool down
  - Process stoppages
  - Heating Processes
  - etc

Thermal Stress

- Thermal Expansion
  - Materials expand on heating and shrink on cooling
  - If gradient is uniform, this is stress free



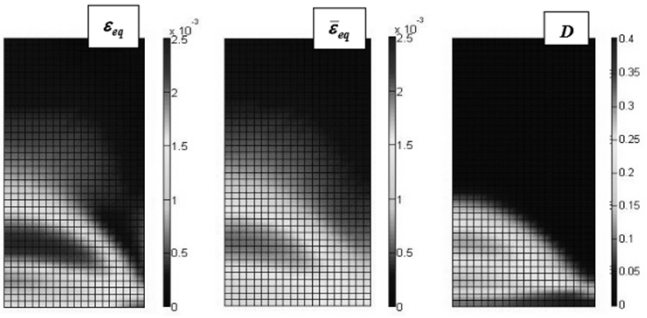
Thermal Stress



Rapid Heating

Temperature gradient is non uniform

- Hot face wants to expand – constrained by cooler parts
- Stress develops.
- Cracking if stress > strength



Rapid Cooling

- Similar effect – hot face in tension

- Cooling – cracks thru lining thickness
- Heating – cracks parallel to hot face
- Cycling - both

How Much Change is Rapid

On heating a material expands

$$\Delta L = \alpha . L . \Delta T$$

Where α is the thermal expansion coefficient

If the expansion is stopped by the cooler parts, this leads to a strain ε

$$\varepsilon = \Delta L / L = \alpha \, \Delta T$$

This strain results in a stress, σ

$$\sigma = \varepsilon \, E = E \, \alpha \, \Delta T$$

Where E is the Elastic Modulus

How Much Change is Rapid

The material fails is this stress is higher than the failure stress (strength) . This gives a critical temperature rise, R

$$R = \sigma_F / (E \alpha)$$

R is called the Thermal Shock Parameter and indicates the failure under 'ideal conditions'

Better thermal shock happens if

Strength is higher

Expansion is lower

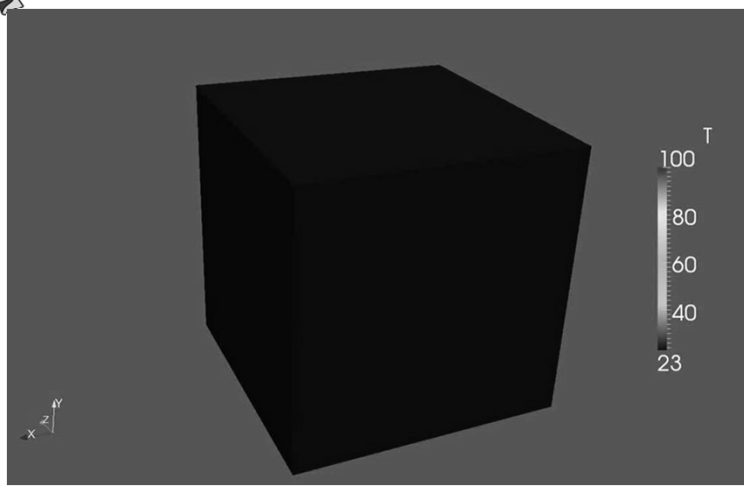
Stiffness is lower

Turns same strain into smaller stress

Thermal Diffusivity

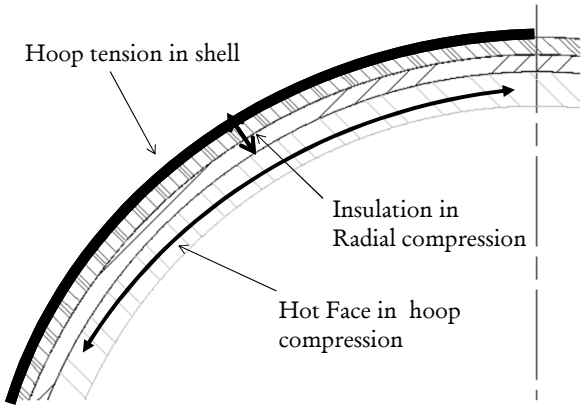
- How quickly does heat spread
- How much energy is needed to heat the material
  - Specific Heat Capacity, C_p
    - The heat energy needed to increase the temperature of a substance by 1°C
  - Thermal Diffusivity, α
    - Measure of how heat energy spreads through a material
    - $\alpha = \frac{k}{\rho C_p}$.

Temperature Distribution changes with time



What About Linings

In a lining, adjacent bricks interact



Effect on Heating

- Weaker insulation layers compressed to give 'room'
  - Cracks at corners – pinch spalling

On Cooling

- Gaps can open in lining
  - Slag or metal penetration stops gaps closing on reheat
  - Successive damage

Any Questions

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Closing Comments

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Course Aim

- To give an appreciation of how heat flows through a lining and how thermal gradients are calculated and used
- To give an appreciation of thermal expansion and how thermal expansion allowances can be made.

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Course Feedback Form

Heat Flow and Expansion Training Course — Sheffield, October 2015

Name (Optional)……..

		1	2	3	4	5
	COURSE CONTENT	☹		😐		☺
1	Did you find the course informative?					
2	Was all the material covered relevant?					
3	Did the course fulfil your needs?					
4	Did the content of the course reflect what advertised?					
5	Was the length of the course adequate?					
6	Would you recommend this training to others?					
7	Will you do any part of your job differently as a result of this training? If yes, please explain					
8	What was the most useful part of the course?					
9	What was the least useful part of the course?					