Institute of Refractories Engineers

Online Training Event 2020

Transient Thermal Conditions

Contents

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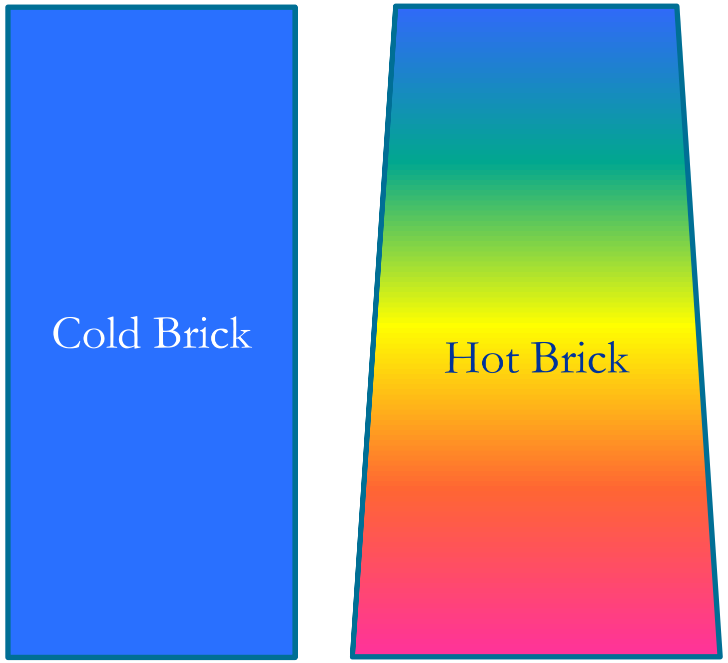
- What are Transient Conditions
- Heat Flow Modelling
- Thermal Shock

Transient Conditions

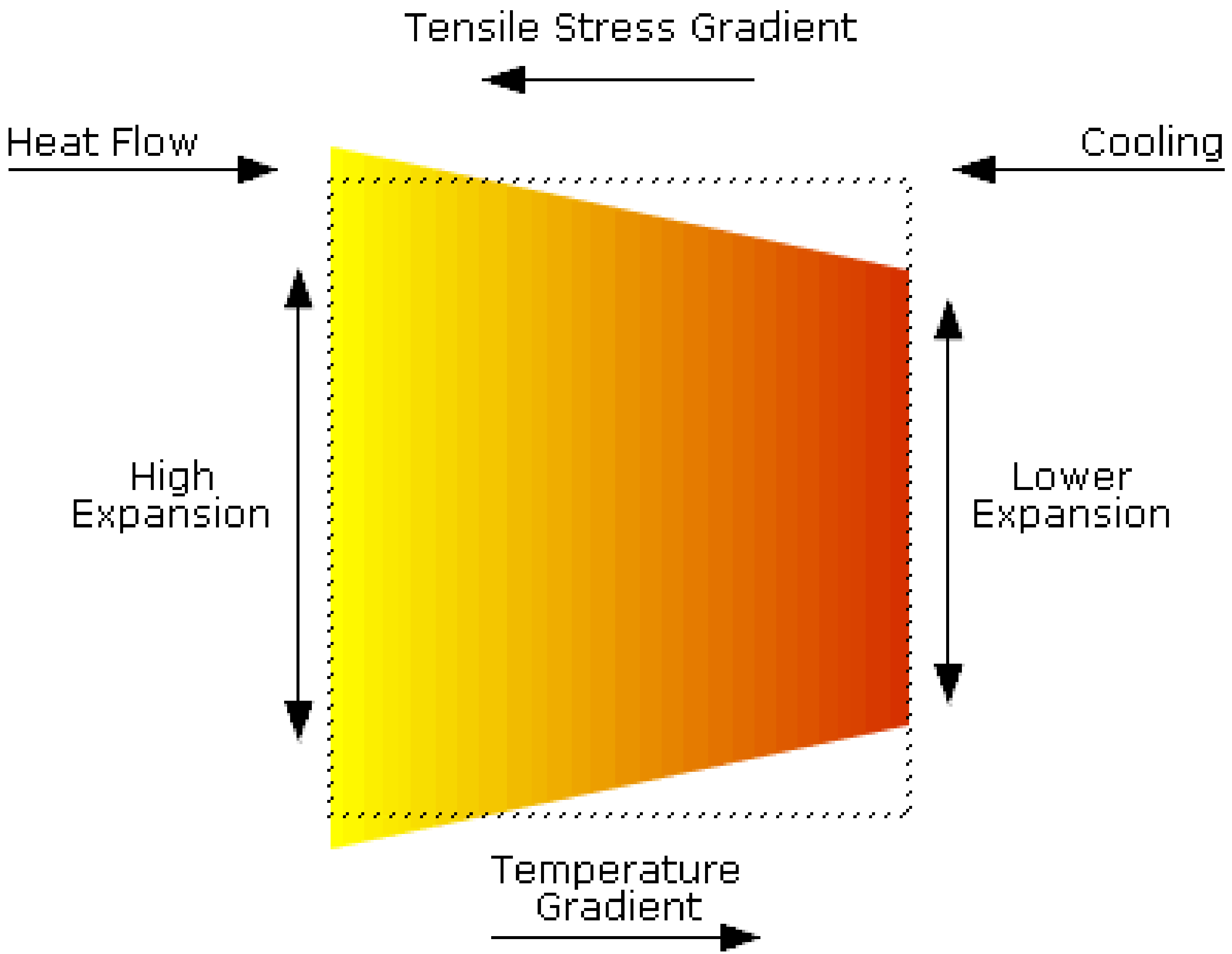
- Temperature changes over time
- Warm up
- Cool down
- Process stoppages
- Heating Processes
- etc

Thermal Stress

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

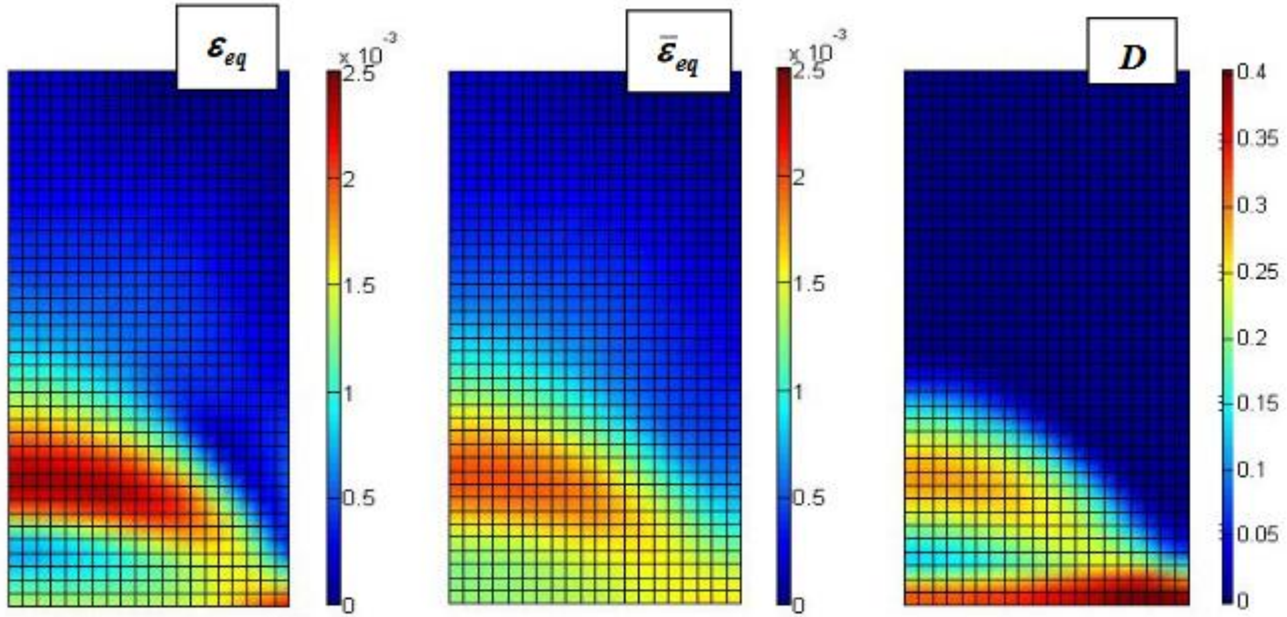


Thermal Stress



Rapid Heating

- Temperature gradient is non uniform
- Hot face wants to expand – constrained by cooler parts
- Stress develops.
- Cracking if stress > strength



Rapid Cooling

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- 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 e
- e = ΔL / L = α ΔT
- This strain results in a stress, s
- s = e E = E a ΔT
- Where E is the Elastic Modulus

How Much Change is Rapid

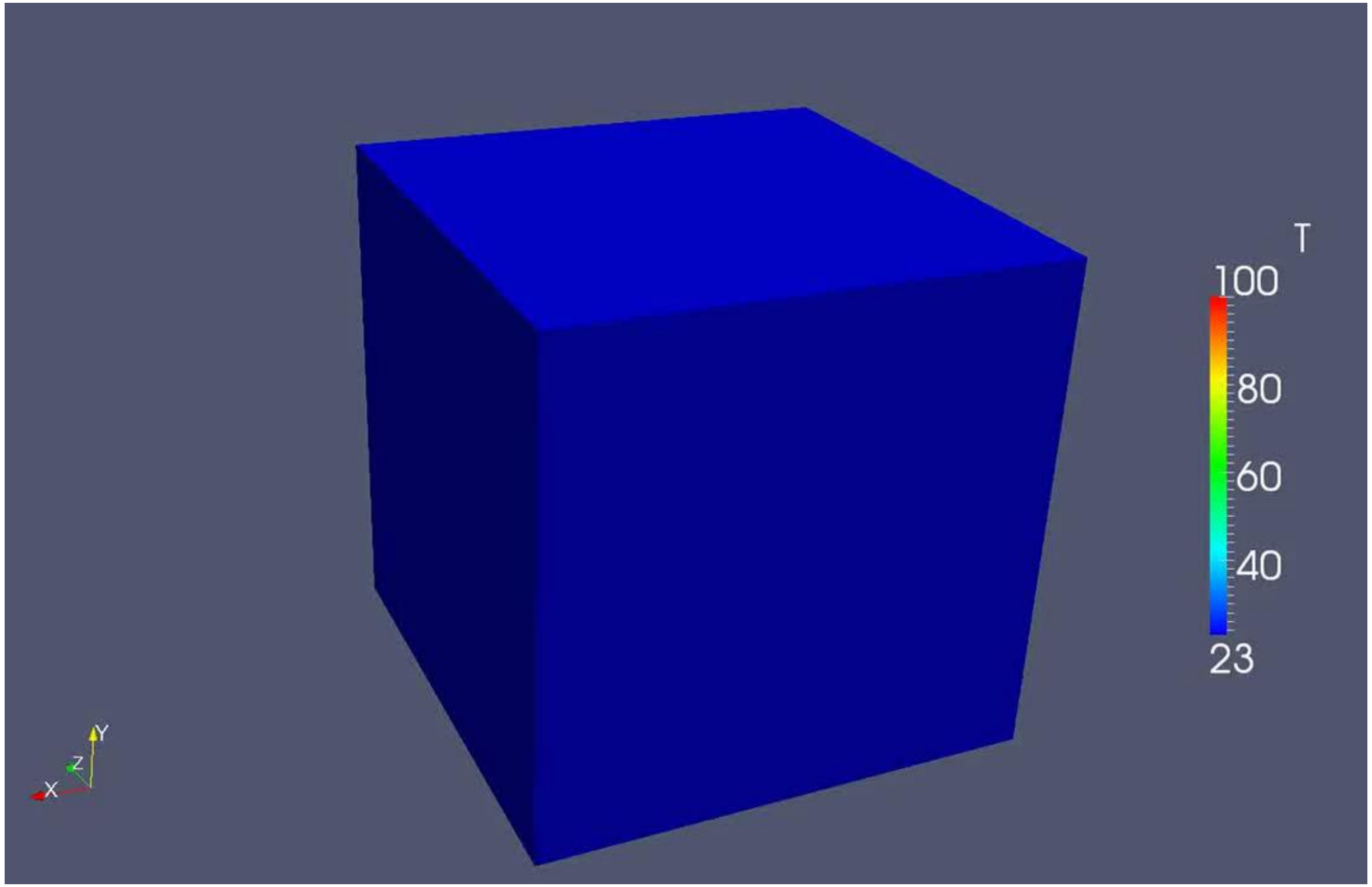
- The material fails is this stress is higher than the failure stress (strength) . This gives a critical temperature rise, R
- $R = s_F / (E \alpha)$
- R is called the Thermal Shock Parameter and indicates the failure under ‘ideal conditions’

- 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, Cp
- The heat energy needed to increase the temperature of a substance by 1°C
- Thermal Diffusivity, h
- Measure of how heat energy spreads through a material
- $H = \dfrac{k}{\rho\, Cp}$.
-

Temperature Distribution changes with time



What About Linings

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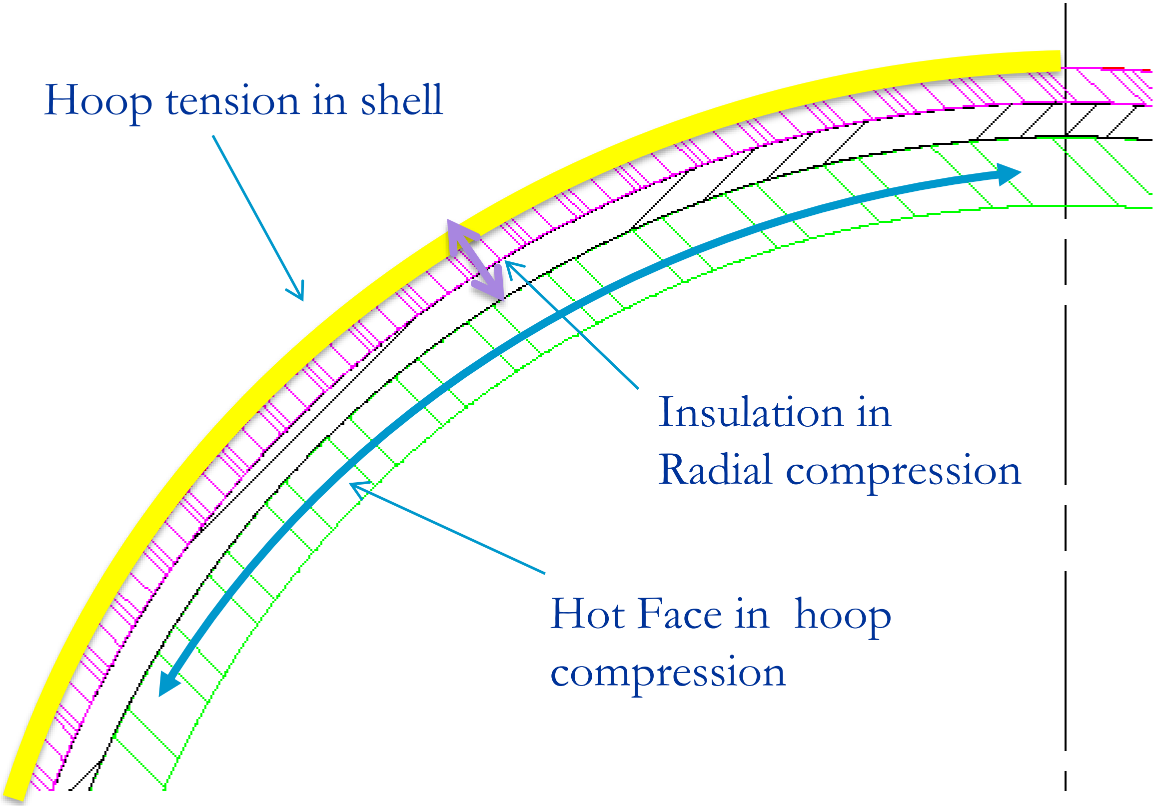
- In a lining, adjacent bricks interact



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

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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Thank you
Any Questions

https://irengineers.co.uk/