Simulation of Thermal Management in Materials and Systems

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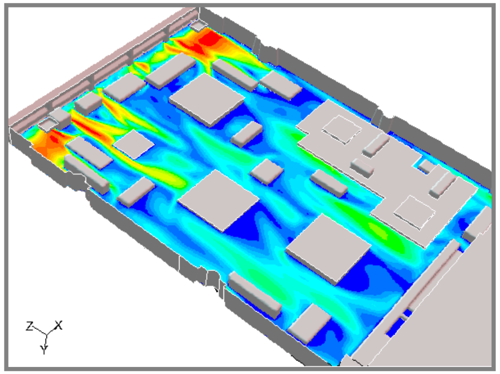
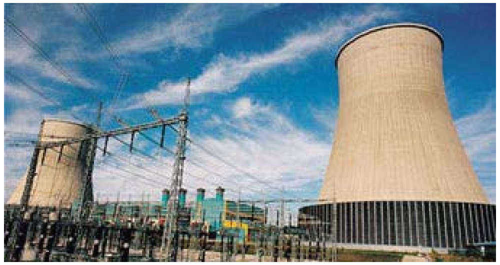
SYSTEMS AND ENGINEERING TECHNOLOGY

Presentation Outline

- Who are Frazer-Nash
- Technical capability
- Case studies
  - Electronics cooling
  - Hot box dome
  - Turbine lifing
  - Nuclear graphite
- Conclusions





Who We Are

FRAZER-NASH
CONSULTANCY

Frazer-Nash is a multidisciplinary systems and engineering consultancy that excels at solving some of today's most complex engineering challenges.

Our consultants apply their expertise and know-how to develop, enhance and protect our clients’ critical assets, systems and processes.

We use advanced engineering techniques to help clients improve safety, efficiency and performance.

And provide independent advice to provide assurance, minimise risk and reduce costs and liabilities

The Royal Institution of Naval Architects

Institute of Marine Engineering, Science & Technology IMarEST

Institution of MECHANICAL ENGINEERS

IET ccredited Scheme®

IOP Institute of Physics Accredited Company Training Scheme

Royal Aeronautical Society 1866

PROOF

UKAS QUALITY MANAGEMENT 001

INVESTORS IN PEOPLE

Technical Capability

Systems Technology

Structures, Fluids, Vibration

- How do I improve it?
- How do I extend it's life?
- How do I change it?
- How do I stop it breaking?

Systems Assurance

Safety, Environmental, Assurance

- How do I make sure it is safe?
- What about legislation?
- What documentation do I need?

Simulation

EC&I, Software, Modelling

- How do I control it?
- How do I add capability?
- How can I model its operation?
- How can I make it cheaper?

Systems Engineering

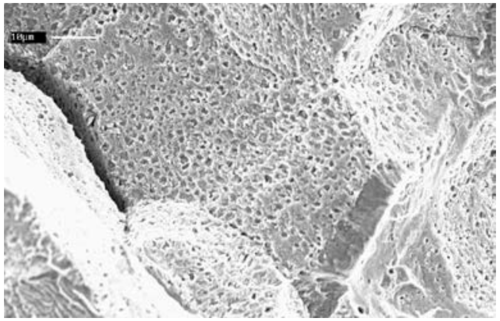
Requirements, Human Factors, Mechanical Design

- How do I operate it?
- How do I set the requirements?
- How do I validate it?
- How do I choose between alternative approaches?

Key Technical Skills in Thermal Management

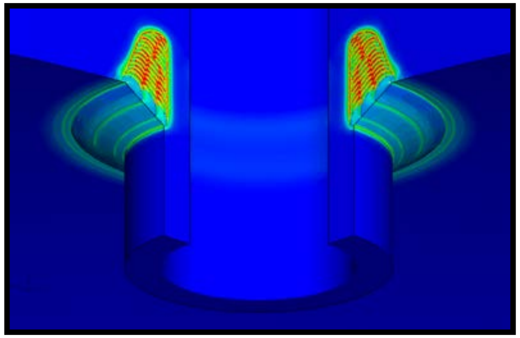
Materials

- Materials assessment and advice
- Constitutive modelling and implementation to FE
- Corrosion, Chemistry and EAC
- Asset Management
- Legislation - REACH



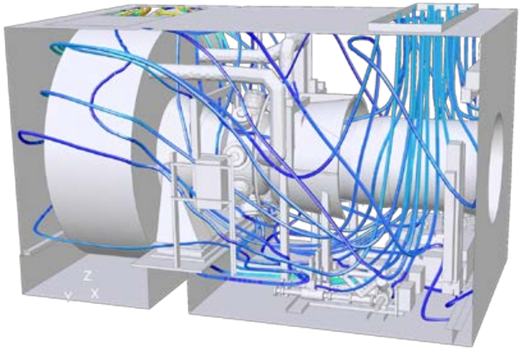
Structures

- Linear and non-linear FE methods
- Design code assessments
- Lifing assessments
- Modelling of manufacturing processes



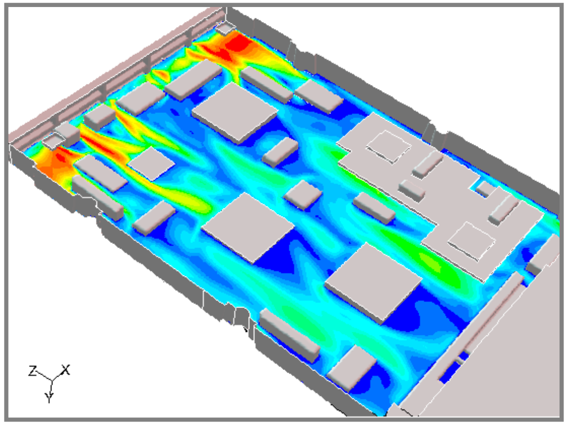
Fluid Dynamics

- Heat transfer analysis
- Fluid structure interaction
- Aerodynamics
- Gas dispersion and ventilation



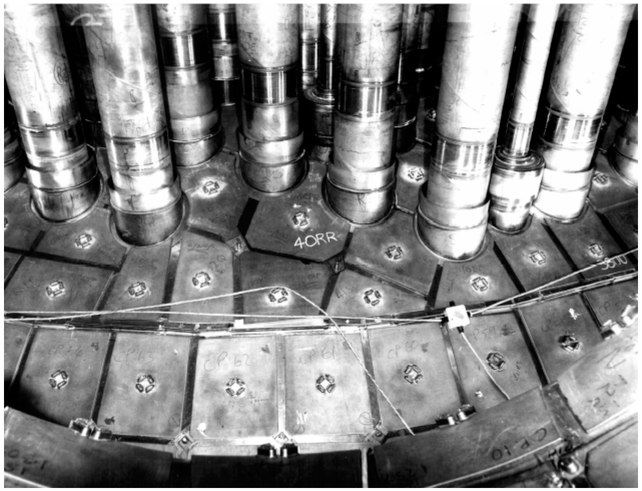
Case Study – Electronics Cooling

- Design of a novel outdoor telecommunications device
  - Small device was designed for extremely high levels of reliability, as mounted in inaccessible locations
  - Casing designed to dissipate heat from internal components without using fans
  - Two stage approach
    - Initial hand calculations and expertise
    - Detailed numerical model to refine concept
- We have also undertaken system level thermal calculations and CFD modelling to solve a number of electronic thermal issues



Case Study - HYA/HAR Hotbox Dome

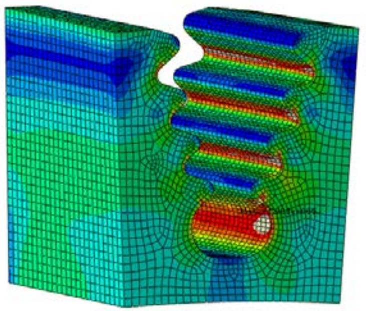
- Raised thermocouple readings on under-side of dome
  - Reduced operating power
  - Significant economic impact
- Large programme of work with 2 main aims
  - Restore lost output
  - Address issue to end of life

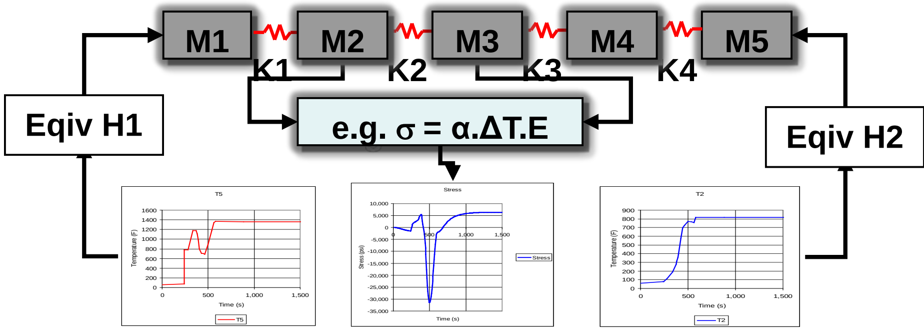


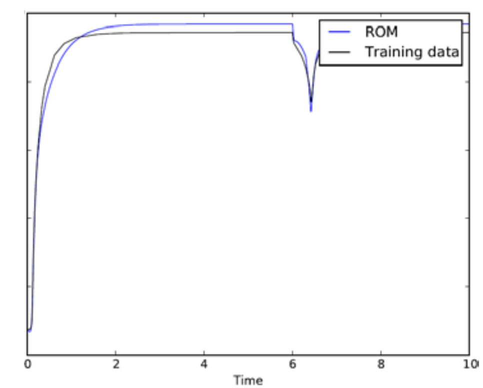
- Approach
  - Root-cause analysis
  - Thermal analysis
  - Reactor inspections
  - Physical mitigations
  - Safety case

Case Study – Gas Turbine Lifing

- Relevant to design, operation and life extension
- Transient Thermal Models
  - Matching predicted temperatures with engine test data Transient Stress Analysis
  - Identification of critical locations for creep-fatigue assessment
- Reduced Order Models for **real time** assessment at critical locations
  - Temperature transients and
  - Stress transients related directly to engine data
- Hot Gas Path Components
  - Discs, Blades, Seals, Dampers, Liners, Combustors, Exhaust Diffusers







Case Study – Nuclear Graphite

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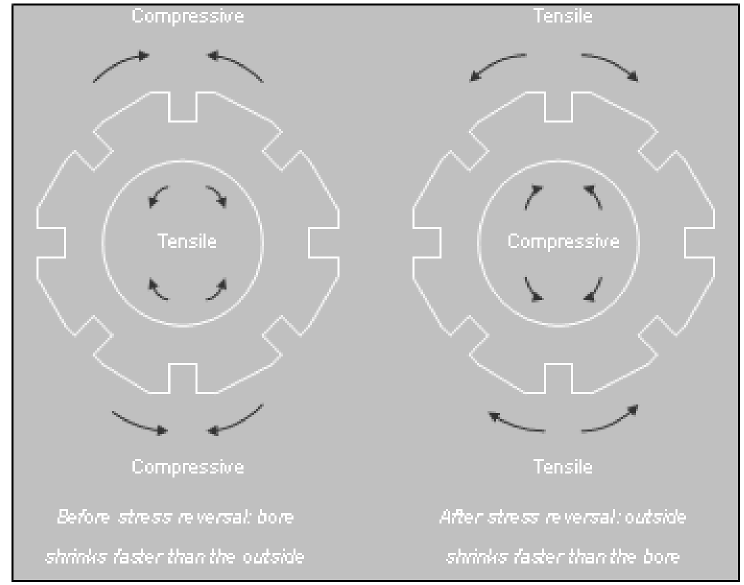
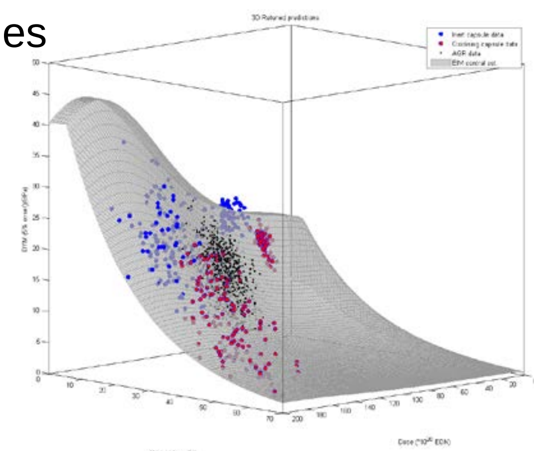
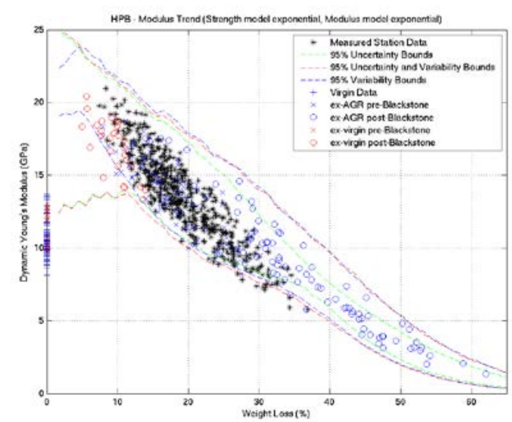
Understand Materials

- Through-life (Dose, Weight Loss, Temperature) prediction of properties
    - Dynamic Young's modulus (DYM);
    - Flexural strength;
    - Thermal conductivity;
    - Dimensional change strains;
    - Coefficient of thermal expansion (CTE).
- Experimental data form various sources
    - Materials Test Reactor Samples
    - AGR trepanning
- Probabilistic Analysis
    - Uncertainty
    - Variability







Case Study – Nuclear Graphite

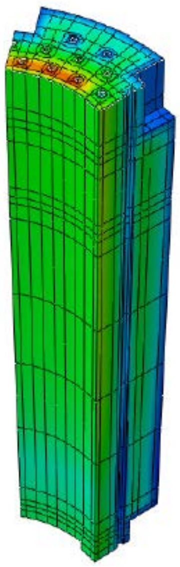
Model oxidation

Fixed inputs (specific to reactor and layer):
Dosimetry (McBEND)
Temperature (PANTHER)
Gas concentrations
Mesh
Virgin properties
Pressure boundaries (OCTANE)

Tunable scalar parameters
ARM (modifies oxidation rate)
Ascale (modifies shrinkage rate)
F (Channel power factor)

→

FEAT DIFFUSE



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Results
Mesh values for density and weight loss.

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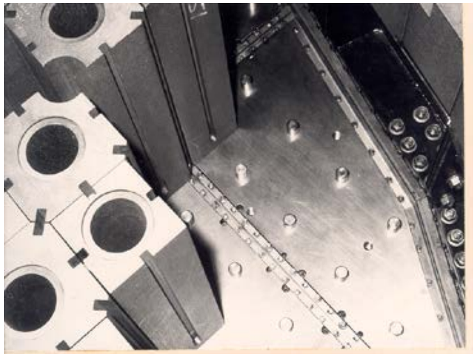
Extract quantities of interest
E.g. average density over specified control volumes; volume fraction of brick that exceeds a given weight loss threshold.

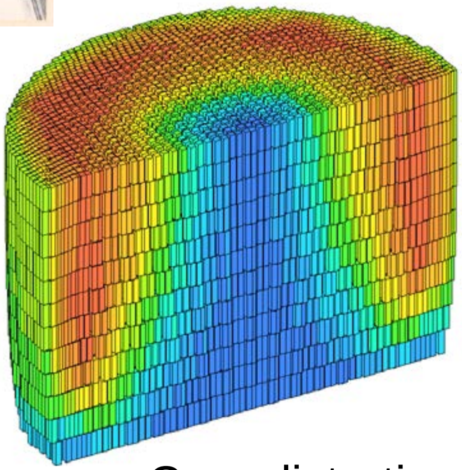
Case Study – Nuclear Graphite

Structural Analysis

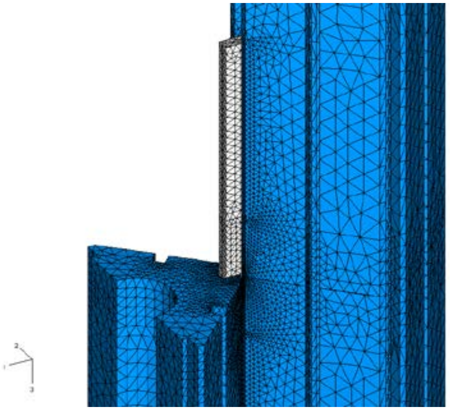
- Aim to predict stresses and likelihood of failure initiation in graphite core components during reactor normal operating conditions
- Stress contributions from:
  - Thermal (differential temperatures and CTE)
  - Irradiation (differential shrinkage, creep)
  - External loads (gas pressure, self weight, core distortion)
- Compare evolution of stresses with remnant strength and determine component fail probability



Core geometry



Core distortion



Contact modelling

Conclusions

- By combining technical services (fluids, materials and structures) and applying a systems approach we can optimise thermal management solutions of materials
- This approach can be used throughout the life cycle of a product of service:
  - In the design phase, supporting the customer
  - Solving problems during installation / operation
  - Enabling life extension
  - Underwriting decommissioning

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