Materials Assessment Services

ANSTO is a specialist materials assessment provider offering an integrated service concentrated on maximizing the performance of capital assets and infrastructure. With over 30 years experience in nuclear plant and specialised materials research, ANSTO has developed expertise in investigating service-induced deterioration of materials properties and how such changes may affect plant integrity, safety and operating decisions.

A dedicated multidisciplinary team of professionals provides specialist scientific and engineering services gained through our extensive experience in the assessment of Australia’s only nuclear reactor. Coupled with applied research, development and collaborative research projects with Australian industry, we have accumulated significant expertise in the areas of plant assessment and remaining life calculations.

**ANSTO has extensive expertise in:**
- Materials engineering and metallurgy
- Measurement and modelling mechanical performance (e.g. FEA, seismic modelling)
- Materials testing
- Microstructural characterisation of structural materials
- Plant life assessment
- Structural integrity and structural weld assessment
- Residual stress analysis

**Our market segments include:**
- Engineering services consultancies
- Minerals, mining and resources industries
- Power generation
- Oil extraction and refining
- Gas extraction and pipeline

A wide range of materials are routinely processed by the metallography laboratory to facilitate subsequent characterisation or processing. Preparation of polished/etched sections of carbon, low alloy and heat resistant steels, as well as non-ferrous alloys is performed routinely. Specialised preparation techniques for unusual or difficult materials, which may be porous, friable or extremely small, have also been developed and applied successfully.

Combined with a wealth of staff expertise, the laboratory is well equipped with a range of cutting and automated grinding/polishing equipment permitting rapid preparation of most metallic and ceramic materials. The microscopy suite features three modern optical microscopes as well as a state-of-the-art microhardness testing instrument. All these optical instruments are fitted with CCD cameras to permit digital image capture and image analysis.

As well as in-house materials preparation and characterisation, the group also has considerable experience in the area of on-site metallographic replication/examination of large industrial plant. Clients for whom such work has been performed include major power generation and petrochemicals companies.
Materials Assessment Capabilities

- Failure analysis
- Remaining life assessment
- Fatigue assessment
- Fracture mechanics
- Creep fatigue assessment
- FEA creep/ creep fatigue assessment
- Replication
- Portable hardness testing
- Mini sample removal and testing
- Conventional mechanical testing - tensile, impact etc
- Specialised mechanical testing at sub zero and elevated temperature.
- Creep testing in vacuum and argon.
- Stress relaxation testing.
- Full size sample testing up to 500kN
- Miniature testing
- Complex and non-standard testing specialists
- High temperature strain gauging
- Non-Destructive Evaluation

Design Codes Used

- ANSTO has ISO9001 accreditation and works to the following codes:
  - BS7910
  - British Power, BNFL R5 and 56
  - Full list of Australian Standards for example 1210, 1228 etc
  - ASME section 8 and section 3
  - ASME B31.1
  - ASME section NH (Code N-47)
  - BS5500

Computer Codes

- INVERTHERM (ANSTO) Inverse thermal calculation code
- HTRL (ANSTO) based on R5 and the ASME Code Case NH remaining life calculation
- HYDRO (ANSTO) Gas pipeline hydro test software
- CAESAR Piping code
- NISA Finite element code
- ABAQUS Finite element code
- CFX Fluid dynamics
Finite Element Capabilities and Experience

The finite element analysis area employs three high-end dedicated computers running ABAQUS and additional codes. For example a 150,000 element main steam pipe ‘T’ intersection including weld, HAZ and parent properties with full creep redistribution over 200,000 hours was analysed in 6 hrs. Types of analysis include:

- General static
- Nonlinear creep and plasticity
- Nonlinear coupled thermal elastic plastic analysis
- Nonlinear residual stress / weld modelling
- Transient dynamics (frequency, seismic, shock)
- Fracture mechanics and fatigue modelling
- Extreme dynamic modelling i.e.
- Impact and explosive modelling
- Mixed physics modelling
- Coupled fluid structure problems
- Fluid dynamic analysis

Recent Work - Creep, Creep-Fatigue and Structural Integrity of Industrial Plant

- Development of Creep-fatigue damage algorithms for superheater outlet headers.
- Finite element modeling of welded joints under creep conditions including assessment of different properties within the heat affected zone.
- Analytical modeling of high temperature component performance using Theta Projection analysis.
- Transient elastic-plastic finite element modelling of a superheater outlet header.
- Development of creep-fatigue damage assessment methodology for a number of power stations within NSW and Queensland for online damage assessment systems. System is currently installed at several NSW power stations.
- Development of miniaturised testing techniques for assessing elevated temperature creep and stress relaxation properties of steels.
- Remaining life assessment of numerous power plant components including turbine rotors, steam chests, high temperature fasteners, steam piping, headers, boiler tubing.
- Conventional and miniaturised toughness testing of power plant steels to assess extent of temper embrittlement. Components investigated include - turbine rotors, high temperature fasteners, steam piping and headers.
- Assessment of extent of degradation of turbine rotor steels using high resolution transmission electron microscopy.
- On-site replication of platformer reactor vessels and remaining life assessment – Petroleum refinery.
- Assessment of degradation in properties of 304 SS due to Sigma phase embrittlement.
- High temperature pressure vessel defect assessment using R5 methodology.
- Design of high temperature components using AS 1210 h.
Methodology

The principle used behind life assessment of high temperature components is based on adherence to the practices and guidelines contained within AS3788. This practice follows the typical staged approach contained within AS3788 based on the EPRI Guidelines. For plants with more than 100,000 hours service generally mixed stage 2 and 3 assessments are carried out.

Analytical assessment is carried out using detailed finite element analysis. On the turbine side this analysis would generally cover, but is not limited to, components such as rotor bores, outer groove, blade-groove shoulder, inner casing, nozzle block, turbine stop valves, throttle valves, steam chest and main steam termination points, etc.

Finite element analysis is carried out using programs such as ABAQUS, NISA, NASTRAN. Typical transients considered would include cold, warm and hot starts. Upset conditions are also analysed if required by the station. Analysis undertaken is typically thermal, elastic, creep relaxation and elastic plastic analysis based on the chosen transients.

Life assessment calculations are based in the first instance on simplified expressions contained within EPRI guidelines. These are generally based around linear fraction rules ASME Division NH and section 7 of BS PD6493. Allowable cycles are taken from codes such as AS1210 etc. Creep rupture properties are taken from NRIM, ISO and BS PD6525 as well as an extensive database of tests conducted at ANSTO.

Detailed life assessment calculations performed are based on the ductility exhaustion method using the R5 methodology. This is a structural integrity assessment procedures developed by British Energy, BNFL Magnox Generation and Serco Assurance. It incorporates, augment and where necessary replaces the provisions of ASME III subsection NH and the French Code RCC-MR.

This analysis is based on the following:
Creep rupture due to loadings which are primary or which have significant elastic follow-up. Fatigue which involves time-independent processes but which contribute to the overall damage accumulation. Local failure which is characterised by cyclic stress relaxation around peak stress regions and leads to the so-called creep-fatigue interaction.

At high temperatures, creep must be considered in addition to failure addressed by low-temperature modes such as fatigue. It is assumed that the usual stress limits against time-independent failure models have been satisfied. These are checked using shakedown analysis for excessive plasticity. The additional mechanisms of excessive creep deformation, creep rupture, cyclically-enhanced creep deformation, crack initiation and growth of defects under steady or creep-fatigue loadings are also addressed.

The concept of reference stresses is employed for creep whereas for cyclic loading shakedown is applicable. Shakedown analysis is explicit within the methodology that we use in contrast to codes such as N-47 which employ implicit shakedown limits. For creep damage calculations, ductility exhaustion methods are employed under stress relaxation conditions in contrast to other methods which employ life fraction. This approach is more difficult than the life fraction methods, however, it delivers results that are mechanistically justified and, although still conservative, are less so than the linear summation rules.

For more information please contact

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