High-Temperature Materials Testing

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» MTS Systems GmbH
Who is MTS?

» MTS Systems Corporation helps researchers, engineers and manufacturers improve their products and grow their testing capabilities

» Our expertise is in physical simulation and measurement equipment and services, and linear position sensing

» MTS: 45 years strong
  – Over 2000 employees*
  – Over $400M annual revenue*

* Year ending 3 October 2009
Why do we perform high temperature fatigue tests?

- In many aerospace and power generation applications, critical components or structures are subjected to repeated loading (pressure) at high temperature (e.g. jet engine)
Why do we perform high temperature fatigue tests?

- In many aerospace and power generation applications, critical components or structures are subjected to repeated loading (pressure) at high temperature (e.g. gas turbine engine).

- Fatigue damage is critical.

- Zero failure tolerance.
Why do we need high temperature fatigue data?

High quality fatigue data at service temperature conditions are needed for:

- Designing with high temperature materials
- Fatigue life prediction of critical components
- Qualification of materials or critical components for high temperature applications
What fatigue tests do we do at high temperature?

» **Standard Specimen Fatigue Testing at High Temperature**
  - Load-Controlled Axial Fatigue (ASTM E466)
  - Strain-Controlled Axial Fatigue (ASTM E606)
  - Thermomechanical Fatigue (ASTM E2368)

» **Non-Standard Fatigue Testing**
  - Spectrum Loading
  - Variable Amplitude Loading
How do we generate high quality fatigue data?

» High Temperature Fatigue Testing Solutions include
  - Load Unit
  - Test Specimen
  - Gripping
  - Load Train Alignment
  - Heating & Cooling
  - Strain Measurement
  - Controls & Software
MTS Landmark® Servohydraulic Test System

Innovative MTS 370 load frames feature:

- Extremely stiff and lightweight crossheads
- Precision-machined columns
- Fatigue-rated MTS actuators
- Low-friction Annular Step Bearings
- Co-axially mounted LVDTs
- Best-in-class MTS load cells
- Smooth-ramping hydraulic service manifolds
  (57, 114, 228, 684 l/min)
Specimens (Low Cycle & Thermomechanical Fatigue)

» Gage Section

Round almost always preferred

» Stress concentration and corner damage

» Tubular specimens minimize radial thermal gradients for TMF

» Gripping advantages
Specimen – Grip Interface

» Threaded
  • Specimen removal – corrosion/galling
  • Backlash – threads must be preloaded

» Button head
  • Well suited to heated grips
  • No backlash when preloaded

» Smooth end
  • Collet friction grips
  • Simple geometry; no backlash
  • Good alignment/repeatability
  • Well suited to axial-torsion applications
HCF / LCF Grips

» Grip extension into furnace
  – Use with furnace
  – Grip body with water cooling
  – Nickel-based superalloy

» Threaded or Button head specimens
  – Preloaded through pushrod in extension rod

MTS 680 Grips
Collet Grips

» Entire grip outside furnace
  – Use with induction heating
  – Options with extension bar
  – Short load train

» Grip cooling (water)
  – Grip body cannot accommodate high temp due to hydraulics/seals (max. 65°C)
Load Frame Alignment – Why?

» Very crucial for uniaxial fatigue loading - alignment affects fatigue life significantly

» Good alignment practice
  – Reduces the variability in test data
  – Eliminates sources of uncertainty
  – Creates repeatable conditions

» ASTM standard E1012 , E606
Load Frame Alignment - Principle

Two Types of Misalignment:

Aligned

Misaligned

Specimen

Angular

Concentric

Metric is induced bending strain. Twelve strain gages for uniaxial specimen.
Load Frame Alignment - Tools

1. Strain gauged specimen
2. Alignment fixture
3. Data acquisition system
4. Computer/Software

MTS 609 Alignment Kit
Load Frame Alignment - Tools

Following software prompts, adjust concentricity and angularity to bring all bending strains within envelope.
Heating – Multiple Zone Furnace

» 2 or 3 independent heating elements
   – Independent control, or
   – Single channel control with manual ratio

» Potentially more uniform temperature distributions across specimen

Temperature profile test, MTS 653.03 three zone furnace
Induction Heating

» Heats by inducing eddy currents in specimen
  – Specimen must be conductive; better if ferromagnetic

» Heats specimen, not surroundings

» No enclosure; faster cooling possible than with furnace

» Well suited to thermomechanical fatigue testing
Forced Air Cooling

» Used with induction heating

» Compressed air, directed with nozzles

» Solenoid valve control, adjusting air flow towards the specimen, to achieve desired cooling rate (important in thermo-mechanical fatigue testing)
Strain Measurement – High Temperature Extensometer

» Direct Contact Extensometer
» Various Contact Forces, various Gage Lengths
» Air / Water Cooling Option
» Extensometer Rods – Quartz, Ceramic or Silicon Carbide Materials
» Various rod end geometries
» Feedback used for Strain Control
Controls & Software – FlexTest® Digital Controls

Controllers conduct reliable single and multi-channel material and component testing across multiple stations.

- Scalable
- Easy-to-use
- High-speed closed-loop control
- Data acquisition
- Function generation
- Transducer conditioning
Controls & Software – MTS TestSuite™ Software Platform

» Designed with extensive user input
» Well suited for both sophisticated and simple testing
» Visually intuitive, common interface to streamline and simplify the development of calculations and test workflows
Controls & Software – MTS TestSuite™ Software Platform

» Versatile foundation for a growing set of easy-to-use materials test templates
  - Low-Cycle Fatigue
  - High-Cycle Fatigue
  - Thermomechanical Fatigue
  - Advanced (Elevated Temperature)
  - Fatigue Crack Growth
  - Fracture Toughness
Controls & Software – MTS TestSuite™ Software Platform

» New tools to extend testing power and increase productivity:

- **Virtual Specimen** allows you to accurately simulate specimen behavior before breaking any real test articles.

- **Point-by-point monitoring** allows users to perform calculations and make decisions on every data point rather than making decisions once per cycle.

- **Multichannel** is used to create multi-axial loading conditions with enforced phase relationships between multiple channels.

- **Analyzer** is used to glean new insight from post-test data; available for both fatigue and fracture modules.
Thank you