

Elevated Temperature Mechanical Testing of Metals[†]

Robert J. Hufnagel,[‡] David T. Schmale,^{*,§} and Wendell B. Jones[¶]

Sandia National Laboratories, Albuquerque, New Mexico 87185, and EG & G, Kirtland AFB, Station A, Albuquerque, New Mexico 87110

Standard servo-controlled hydraulic mechanical test systems have been modified to conduct elevated temperature, strain controlled creep-fatigue tests. These modifications include the design of special grips, the use of quartz rod extensometry, and the use of induction heating. In addition, digital computer control and data acquisition allow greater test flexibility and more precise data analysis and interpretation.

Introduction

The mechanical testing systems and procedures described in this paper have been developed and refined to conduct elevated temperature, fully reversed strain controlled cyclic tests. In addition, these test systems are capable of performing all of the standard tensile tests. The need for this and similar (Slot et al., 1969) mechanical test systems has grown out of the structural design needs in such areas as advanced nuclear reactors, solar central receivers, and fusion devices. In all of these cases, piping components and pressure vessels must be resistant to failure from thermal fatigue. This is in addition to the traditional concerns of creep strength and tensile strength. Historical experience in chemical processing plants and fossil-fired power plants showed that failure of pressure containing components resulted from the effects of the environment (corrosion), of a high-pressure transient (tensile failure), or of steady-state operation for long time at high temperatures (creep rupture).

The current elevated temperature applications mentioned earlier also include a significant number of thermal cycles to and from the operating temperatures. The superposition of this cyclic component with the steady-state operation has been termed "creep-fatigue". These two aspects of the service history combine in synergistic form to produce failures that are neither pure creep nor pure fatigue (Conway et al. 1975). In order to design so that pressure-containing components do not fail by this creep-fatigue interaction mechanism, extensive testing must be conducted. Oak Ridge National Laboratory and several other laboratories (ORNL, 1982) have conducted extensive test programs on type 304 and type 316 stainless steel and on 2¹/₄Cr-1Mo steel in support of the Clinch River Breeder Reactor design.

Figure 1 shows the types of programmed signals which are used to control strain history during testing. The combination of the cycling and the hold periods at the peak strain values simulates the effect of service cycling of the power plant component. Although the cycling of the actual components is driven by thermal transients, the laboratory tests are most often conducted isothermally. Most often the strain histories given in Figure 1 are generated by a function generator used in conjunction with a feedback controlled servo-hydraulic test machine. The load and strain signals monitored during testing are usually plotted with an x-y recorder. A typical stress-strain hysteresis

loop taken from a creep-fatigue test is shown in Figure 2.

Several similar test systems are used for all testing in the high-temperature mechanical properties laboratory. However, techniques for elevated temperature mechanical testing vary with the material being tested. Temperature (up to 1300 K) must remain constant and be uniform within the gage length of the specimen. The specimen must be rigidly mounted to allow axial motion only. An accurate and sensitive method of strain measurement is needed to provide a clean signal at low strain levels. This report describes the techniques necessary to adapt standard equipment to meet these rearrangements.

Test Equipment

A. MTS Hydraulic, Closed-Loop System: Standard Components. The basic requirements of reversed loading elevated temperature fatigue testing are met with standard closed-loop MTS hydraulic system components. Figure 3 shows one of the test systems used in this laboratory. (See Appendix for names and addresses of manufacturers of equipment.) Two-post test frames with servo-actuated, push-pull rams are used with hydraulic pressure supplied by external pumps. An MTS 442 controller (with ac and dc conditioners and associated modules for servo-control) monitors stroke, strain, and load and provides feedback in the desired mode of operation. An MTS 410 digital function generator provides the test program any control mode. Additional computer control and 24-h data acquisition are possible with an MTS 433 computer interface along with the DEC PDP 11/34 computer.

Load, stroke, and strain voltages are monitored continuously with digital voltmeters during tests. A Sandia designed interlock circuit is used in addition to the MTS limit detectors to monitor temperature, flow of cooling water, and RF generator operation. An Elgar uninterruptable power source provides power for safely shutting down the equipment in the event of utility power failure. This enables 24 h testing while observing proper precautions in case of specimen failure or equipment malfunction.

B. Specimen and Grip Design. Grips used for reversed load testing, unlike those used for tensile testing, must rigidly support the specimen ends to prevent any deflection or bending stresses in the gage when the specimen is compressed. Specimens are button ended with a straight sided or hour-glass gage section machined to close tolerances. Split collet grips are used to rigidly fix the specimen and avoid any backlash in the load train. The grip assembly provided by MTS is shown in Figure 4. All surfaces which are perpendicular to the load train are held to close tolerances, typically less than 0.0005 in. The MTS-supplied water-cooled fixtures adequately cool the load train components and protect the load cell, but the collet grips as supplied became too hot during testing and

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[‡]Kirtland AFB.

[§]Sandia National Laboratories.

Elevated Temperature Testing Of Metals

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Elevated Temperature Testing Of Metals:

Short-time High-temperature Testing American Society for Metals,1958 *Short-time high-temperature testing : proceedings of the Symposium "Short-Time Elevated-Temperature Testing of Metals", Los Angeles, March 25 to 29, 1957 : presented by the ASM during the Tenth Metal Congress and Exposition* Alan V. Levy,1958 Elevated Temperature Testing Problem Areas American Society for Testing and Materials. Annual meeting,1971 Elevated Temperature Testing Problem Areas ,1971 **Elevated-temperature Testing of Metals** A. M. Borzdyka,1965 **Short-time High-temperature Testing** ,1958 **Elevated Temperature Testing Problem Areas** ,1971 *The Stability of Metals at Elevated Temperatures* Claude Lester Clark,Albert Easton White,1928 *Elevated Temperature Testing Problem Areas* H. R. Voorhees,1970 **Testing Technology of Metal Matrix Composites** N. R. Adsit,1988 **Short-time high-temperature testing: proceedings of the symposium "Short-time elevated-temperature testing of metals" presented to the ASM during the 10th Metal Congress and Exposition; H.V. Levy, panel chairman, Los Angeles, Mar** American Society for Metals, **Harmonization of Testing Practice for High Temperature Materials** M.S. Loveday,Judith L. Gibbons,2013-12-20 The present decade is opening new frontiers in high energy astrophysics After the X ray satellites in the 1980 s including Einstein Tenma EXOSAT and Ginga several satellites are or will soon be simultaneously in orbit offering spectacular advances in X ray imaging at low energies ROSAT J Yohkoh as well as at high energies GRANAT in spectroscopy with increased bandwidth ASCA J SAX and in timing XTE While these satellites allow us to study atomic radiation from hot plasmas or energetic electrons other satellites study nuclear radiation at gamma ray energies CGRO associated with radioactivity or spallation reactions These experiments show that the whole universe is emitting radiation at high energies hence we call it the hot universe The hot universe preferentially emitting X and gamma rays provides us with many surprises and much information A symposium The Hot Universe was held in conjunction with the XXIIIrd General Assembly of the International Astronomical Union at Kyoto on August 26 30 in 1997 The proceedings are organized as follows Synthetic view of the hot universe is discussed in Section 1 Plasma and Fresh Nucleosynthesis Phenomena Timely discussions on the strategy for future missions Future Space Program are found in Section 2 Then the contents are divided into two major subjects the compact objects and thin hot diffuse plasmas Section 3 is devoted to the category of compact objects which includes white dwarfs neutron stars and gravitationally collapsed objects stellar mass black holes or active galactic nuclei **The Evaluation of the Stability of Metals at Elevated Temperatures from Expansion and Short-time Tensile Test Data** CLAUDE LESTER CLARK,1928 **Elevated Temperature Testing of Metal Matrix Composites Under Rapid Heating Conditions** JG. Baetz,RS. Frankle,1988 The Atlantic Research Corporation has designed and built facilities for testing metal matrix composites at elevated temperatures The facilities are capable of performing tension or compression tests of sheet type specimens to 1927 C 3500 F at heating rates in excess of 38 C s 100 F

s Tension tests were performed on unidirectional and cross ply graphite aluminum unidirectional graphite copper and discontinuous silica carbide aluminum materials The continuously reinforced materials exhibited superior room temperature properties and elevated temperature property retention when compared with the matrix metals alone The elevated temperature response of the discontinuously reinforced SiC Al was comparable to that of aluminum These test results indicate the potential advantages of using metal matrix composites in rapid heating elevated temperature applications where the temperature may approach the melting point of the matrix material

Short-Time High-Temperature Testing, Proceedings of the Symposium Short-Time Elevated-Temperature Testing of Metals Presented by the American Society for Metals (ASM) During the Tenth Metal Congress and Exposition, Los Angeles, CA, March 27-29 1957, 1958 **Elevated Temperature Static Properties of Wrought Carbon Steel**, *Short-time High-temperature Testing*, 1958 *Metallic Materials. Tensile Testing. Method of Test at Elevated Temperature* British Standards Institute Staff, 1911-02-28 Metals Tensile testing Mechanical testing Thermal testing High temperature testing Mechanical properties of materials Test specimens Test equipment Testing conditions Measurement characteristics Yield strength Proof stress Tensile strength

Short-Time High-Temperature Testing, 1958 **Elevated-temperature Testing of Metals. 2nd Rev. Enl. Ed. Translated from Russian by A. Wald** A. M. Borzdyka, 1965

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