CONF-900474--1

An Internal/External Pressure, Tension/Compression Multiaxial Fatigue System*

SAND--90-1080C

DE90 009510

Roy J. Bourcier, Wendell B. Jones, David T. Schmale
Sandia National Laboratories
Albuquerque, New Mexico

ABSTRACT

As computers become increasingly powerful, the constitutive models used in structural analysis codes become increasingly sophisticated. With the current generation of supercomputers, it now seems reasonable to consider incorporating relatively detailed representations of the multiaxial deformation response of engineering alloys. To aid in the development of such models and to allow measurement of their constituent parameters, we have designed a complex multiaxial deformation test system.

The system to be described has been developed to perform non-proportional cycling of thin-walled metal tubes using internal/external fluid pressure and tensile/compressive axial loading. It has been added to an existing MTS 490 kN load frame with a PDP 11/34-based computer control system. Features of interest include: a) specimen grips, b) the high pressure chamber, c) the hydraulic intensifier and controller, and d) associated valving and switching. Initial software for this system has been written on the PDP 11/34 in the MTS MultiUser-BASIC language to perform simple proportional multiaxial cyclic deformation to a prescribed effective plastic strain limit.

The pressure vessel, specimen and grips are shown in Figure 1. The system is designed to accomodate 12.7 mm OD X 11.48 mm ID precision drawn tubing 127 mm long as the test specimen. The grips are made from 18 Ni 300 maraging steel heat treated to approximately RC 55. The pressure vessel slides over the upper grip and is held in place with a set screw which engages a groove in the upper compression fitting. Axial motion of the specimen is unrestricted. Pressure external to the specimen is contained by the specimen, pressure ring and the pressure vessel. Internal pressure is contained by a seal in the mandrel at each end of the gage section. No additional axial force is necessary to counteract force due to pressure inside or outside of the specimen.

* This work performed at Sandia National Laboratories supported by the US Department of Energy under contract no. DE-AC04-76-DP00789.

The lower compression fitting/grip arrangement is designed to allow the specimen to slide through a seal in the pressure ring while the grip slides through the positioning ring. Oil internal to the specimen enters through the upper mandrel which is sealed to the MTS housing with a metal C-ring. Oil external to the specimen enters the side of the vessel through an Autoclave fitting. The entire assembly is designed to fit into modified MTS 25.4 mm button end collet grips.

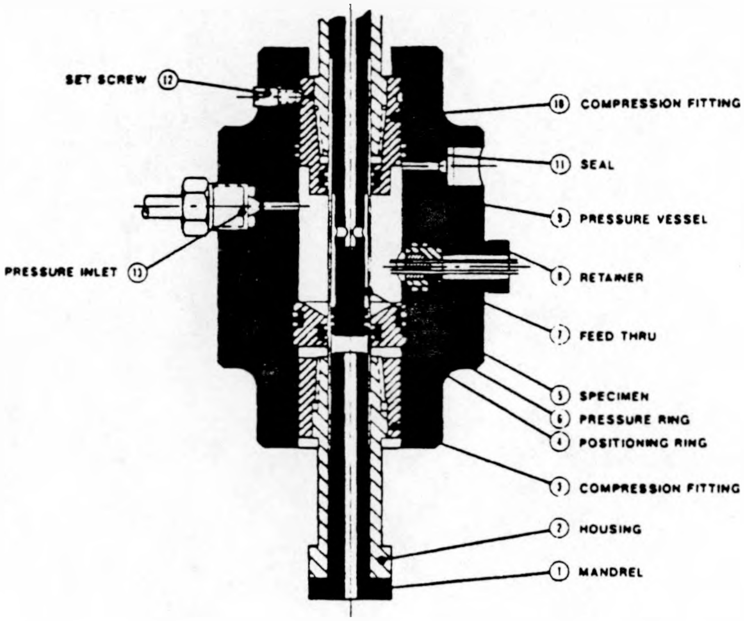

Figure1. Pressure vessel, specimen and grips for biaxial system

The specimen is instrumented with four 350 ohm strain gages; two measure axial, and two measure hoop strain. Since each bridge is wired with two opposite active gages, their resistance is in effect summed, thus giving amplified and average strain readings to minimize the influence of any small asymmetries on the test results. The completion resistors in the bridge are mounted directly outside the chamber on terminal strips. Eight leads from the signal conditioners are attached to the bridge; two for excitation, two for bridge output, and four for shunt calibration. Four wires are passed through each feedthrough on the side of the chamber.

Tests are run in load and pressure control. The load is feedback controlled using an MTS 442 controller with the control signal coming from an MTS 433 computer interface linked to the DEC PDP 11/34 computer. Pressure is also feedback controlled but through an MTS 406 controller with the control signal coming from one of the interface D/A's.

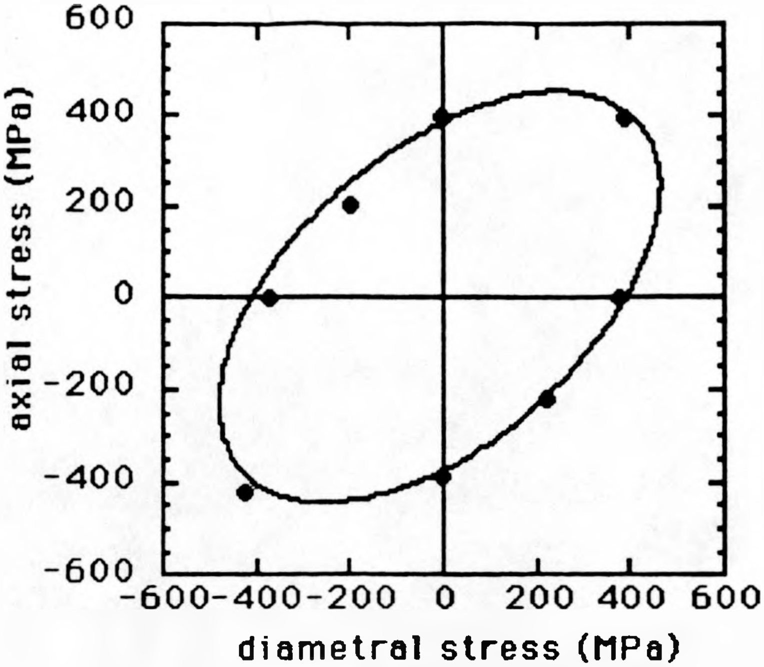

Figure 2. A 500 microstrain yield surface measured for 316 stainless steel

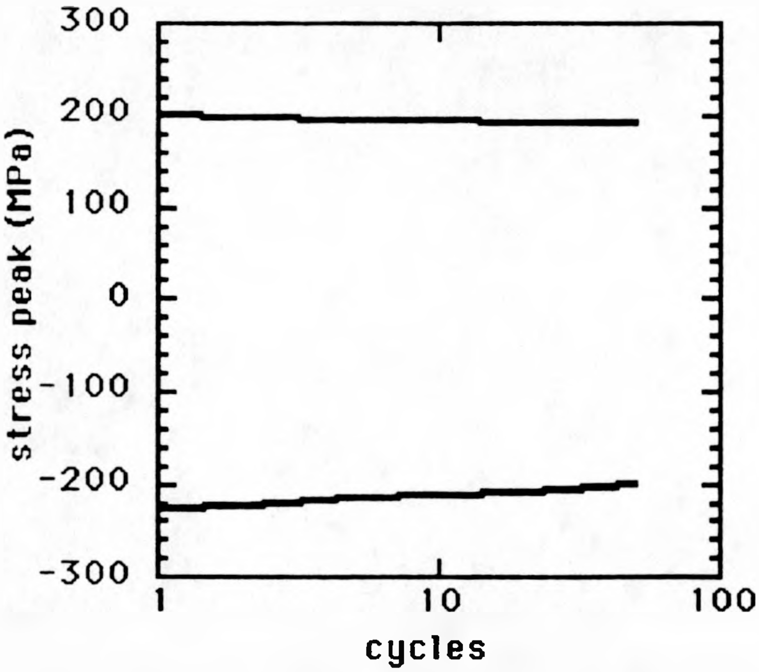

Figure 3. Stress peak history for a balanced biaxial test on 316 SS

Oil is supplied by one intensifier and is directed through 6.35 mm OD tubing rated at 414 MPa. A Marstan valve directs the pressurized oil (up to 69 MPa) internally or externally to the specimen. When pressure is directed to one side (internal or external) of the specimen, the other side is vented to atmospheric pressure, thus ensuring near zero resistance to expansion and compression of the tube. Axial loading is provided by a servo controlled hydraulic ram. Prior to testing, two test programs are run to remove air from the intensifier, lines, specimen and test vessel.

System capabilities have been demonstrated by a series of tests performed on precision drawn and annealed 316 stainless steel tubing. Determination of a 500 microstrain yield surface is shown in Figure 2. Four separate reversed cyclic paths were used to perform this test. The endpoints of these cycles define a good approximation of a vonMises yield ellipse, indicating simple isotropic deformation response typical of annealed FCC metal alloys. The capability to perform extended multiaxial cycling loading histories is demonstrated in Figure 3, where the stress peak history of 50 cycles of fully reversed balanced biaxial deformation to 500 microstrain is plotted. The results show uniform cyclic hardening response with no dropouts or glitches due to poor test control or geometric instability.

At present, this system is awaiting the acquisition and installation of a new 16-bit direct digital control system. The system will be based on a 33 MHz PC workstation (running OS/2) and a high speed multiprocessor controller. Plans are to program existing and future software using the C language and the Presentation Manager user interface. The improved resolution and control rate of this system should allow us to significantly enhance our test capabilities. We are currently developing a scheme to perform small strain yield surface measurements prior to cyclic testing so that anisotropic effective stress-strain criteria can be incorporated in the control of nonproportional biaxial cyclic tests. Such added complexity is not feasible with the current control system.