REMOTELY OPERATED CREEP TESTING

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ABSTRACT

A creep machine was designed for hot cell use that minimized the profile so that a maximum number of units could be lined up per cell. To cut costs, as many of the necessary operations as possible are performed with master-slave manipulators.

Minimum profile was achieved by using a tubular furnace **MASTER** upper section of the specimen stringer. By placing the weight pan in front of the specimen stringer, a master-slave manipulator could be used for most operations on the machine.

Careful placement of machines allowed minimum separation and complete manipulator service without interfering with adjacent units.

INTRODUCTION

Reactor designers need to know how rapidly a component under stress at high temperatures and in a nuclear environment will deform plastically and the amount of deformation which will occur prior to failure of the component. The material parameters normally measured are, strain (defined as percent change in length), the rate at which strain occurs, and the total strain to failure.

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Creep-rupture testing, the most common technique for determining these material parameters, consists of applying a constant uniaxial tensile stress to a specimen, held at constant temperature, while measuring the strain which occurs as a function of testing time.

Standard creep machines, with modifications had been used with four in each of two 182 cm by 335 cm hot cells. As the need for much faster accumulation of data became evident the number of machines had to be increased.

DESIGN OBJECTIVES

Our approach to the design of a creep machine was to put as many machines in the hot cells as possible, to make them easy to use, with low maintenance, low operating cost and low unit cost. With these objectives in mind, we did as many of the necessary operations as possible with the Model 8 master-slave manipulators that were available. The operations included specimen loading into the machine, changing specimen stringer assemblies, removing the furnace, loading the weight pan, making the necessary electrical and mechanical connections and adjustments. We also located the machines in relation to each other and the manipulators in as dense an array as possible so that any machine could be worked on without interfering in any way with the operation of adjacent machines. The shock produced by the load dropping onto the load jack when a specimen ruptured, had to be eliminated so that tests in nearby machines would not be terminated prematurely.

The use of full size wooden models in a hot cell mock-up equipped with master-slave manipulators was of major importance in the original design and location of the creep machines. Since installation of the machines in 1967, there have been many improvements as a result of operating experience.

The specimens have been standardized at 50 mm long with 6.3 mm diam. heads, a 25.4 mm gage section, 3.2 mm in diameter, and a flat specimen with a gage section of 4.8 mm by 1.05 mm. Specimens have been tested at temperature up to 750°C and with loads up to 42.186 kg/sq cm.

At present 23 machines have been installed, with load to stress ratio of 6 to 1, 10 to 1, or 20 to 1 in the cells mentioned earlier. Each cell window has a pair of master-slave manipulators and there are two windows per cell; each manipulator pair can service six creep machines.

DESIGN

The novel feature of our creep machine design is the placement of the load in front of rather than behind the specimen and support column, Fig. 1 and 2. All operations behind the specimen stringer are eliminated with this arrangement, and the load can be applied to the weight pan with manipulators. The load, weight pan and load jack can be removed so that the manipulator can be used to raise or lower the furnace, insert specimens or remove the entire specimen stringer and furnace assembly. After a test is completed and the weights, weight pan and jack are removed, long nosed pliers are used to remove the broken specimen. If the specimen cannot be removed with the pliers, a punch and hammer are used to get the specimen out of the specimen grips by tapping lightly into the radius of the specimen shoulder.

The furnace design determined the width of the machine and how close adjacent machines could be placed. Clam shell furnaces required too much space. Tubular furnaces caused difficulties in stringer removal if they were supported off the column. In the final design, a tubular furnace was hung on the upper specimen stringer. A handle and catch were put on top of the furnace so that the manipulator could be used to lift the furnace and the catch could lock on to a shoulder on the upper stringer. A thermocouple well on the stringer keeps the furnace from rotating.

A very careful adjustment before installation must be made to obtain a uniform temperature across the specimen. Once the adjustment is made it is quite stable.

The upper specimen stringer, Fig. 3, is supported in a socket that in turn is connected to a clevis block that hangs from a pivot on the cantilever arm. The dial-gage-actuator arm is connected to this clevis block. A ring just above the upper specimen clamp supports two rods that move the core of a Linear Variable Differential Transformer (transducer) which is supported near the base of the specimen stringer, a core adjustment is provided on this support. A ring just below the lower specimen clamp supports two tubes each of which are concentric with the rods from the upper ring; these tubes in turn support the body of the LVDT mentioned above. Linear ball bearings keep the tubes and rods concentric. The lower section of the specimen stringer is held in a socket and supported by a spring within the socket. The socket is threaded into the base of the machine. Since the lower portion of the specimen stringer is supported, adjustments for its load are eliminated. After the machine has been loaded with a specimen the cantilever arm is adjusted by screwing the lower socket up or down. The dial gage is supported off the frame of the machine, the gage tip is up and contacts the actuator arm that was mentioned previously.

The load jack is directly beneath the weight pan and is used to support the weight pan while weights are put on, applying the load to the specimen, and catching the load when the specimen breaks. The jack is adjusted during the run so that it is only an inch to an inch and one half from the load stringer. The screw of the jack is threaded into a long nut that is connected to the base with a molded rubber sleeve. The early jacks did not have this feature. The rubber "energy absorber" reduces the shock wave of the load impact to the point that the effect on adjacent machines is insignificant.

The placement of the creep machines in one of the hot cells is shown in Fig. 4. A considerable effort went into the placement of each machine. Sketches, and the use of a mockup were helpful but the final placement of each machine was made only after all the necessary manipulator operations were made with adjacent machines in place. Fig. 5 is a photograph taken through a cell window.

INSTRUMENTATION

The furnace temperature is sensed by a thermocouple placed close to the specimen midplane. The temperature is regulated by a chart recorder controller combination; current to the furnace is adjusted with a variable transformer to lengthen furnace life. Running timers for each test are located on the same panel as the transformers. The control panel for the creep machines in one cell are shown in Fig. 6. The furnace controls are shown in the middle of the figure.

Strain is monitored with a dial gage and a LVDT (transducer). All the LVDT demodulators are located near the top of the second panel from the left in Fig. 6. The output of each demodulator is recorded every three minutes on a 12 point recorder located on the second panel.

The first panel shown in Fig. 6 has a digital temperature readout, to one tenth degree centigrade, and switches so that all furnace temperatures can be monitored. Also on the first panel is a two speed continuous chart recorder that is used to monitor strain during the first half hour of a new creep test to insure data regardless of rupture life of specimen.

PROCEDURES

Each furnace is adjusted under test condition by shunting the heating elements so that the specimen will be at a uniform temperature. Every LVDT demodulator pair is adjusted to give a linear output with the proper slope. These tests are made periodically after the contaminated parts have been removed to a contamination controlled area set aside and equipped to complete this task. The entire specimen stringers are checked after each test and rebuilt if there is any roughness in their motion.

Preparations for a test include inserting the specimen, lowering the furnace loading the weight pan and lowering the jack just enough to make sure that the specimen is seated in the stringer specimen grips.

The furnace is then brought up to temperature and allowed to stabilize for one and one half hours. The LVDT is adjusted to its null position by turning the armature adjustment screw with a manipulator held motorized socket wrench with a 45 cm extension. When the load pan is in place the master-slave manipulators cannot be used to make adjustments on the specimen stringer. After all adjustments are made the jack is lowered quickly to avoid strain other than full load without shock loading. A switch in the head of the jack starts the timer and the recording of data as soon as the load is released and stops the time when the specimen ruptures driving the recorder full scale.

COMMENTS

Plans have been made to collect data on magnetic tape in addition to the present method. This will allow much faster data transfer to a computer for analysis, giving a week-by-week progress report of test progress.

There have been improvements in the equipment eliminating misaligned stringers and making maintenance easier. Some of the tools and techniques have also been improved.

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CAPTIONS FOR REMOTELY OPERATED CREEP TESTING

Fig. 1. Schematic of the Creep Machine.

Fig. 2. Creep Machine. The load jack shown here has been replaced by the jack that can be seen in Fig. 5.

Fig. 3. Specimen Stringer.

Fig. 4. Plan View Showing Creep Machine Location in Front of One of the Cell Windows.

Fig. 5. View of Creep Machines Through a Cell Window. The second machine from the right has the load jack and the weight pan removed.

Fig. 6. Control Panel for the Creep Machines in one Cell. Controls for the machines in the second cell on the right facing the panel shown.

STRINGER SUBASSEMBLY FOR FLAT CREEP SPECIMENS