LOW-CYCLE FATIGUE OF É1612 AND É1437B HEAT-RESISTING MATERIALS AT NORMAL AND ELEVATED TEMPERATURES

A. E. Babenko

No investigation of the low-cycle fatigue of materials will be complete without a study of their stressed- and strained-state kinetics. For studying the laws of deformation and rupture at low numbers of load cycles, a special technique has been developed in the Strength of Materials Department of the Kiev Engineering Institute. The principal units of the apparatus used for this purpose are a loading device, an electromechanical device for recording stress–strain diagrams (maximum diagram size 480 × 850 mm), and an automatic system for maintaining a constant stress or strain amplitude. The apparatus makes it possible to conduct tests under "soft" or "hard" loading conditions, at normal or elevated temperatures (up to 800°C).

The loading device is based on the Lehr–Schenck cyclic-torsion testing machine. To this machine has been added a worm reduction gear to obtain lower deformation rates and a gear-type reduction mechanism to increase the angle of rotation of the active grip of the machine.

With the aid of the electromechanical system (Fig. 1), it is possible to measure and record the torque and the angle of twist of the gauge portion of the specimen. The unit is an automatic following system with two similar channels, one of which serves to measure and record the torque and the other, the angle of twist of the specimen. Torque measurements are performed with resistance strain gauges bonded to a dynamometer and angle-of-twist measurements with resistance strain gauges bonded to an elastic clamp. The latter is attached to rings mounted on the gauge portion of the specimen with the aid of three sharp spikes. A special device is used for fitting the rings onto the specimen. Two of the spikes on each ring are fixed, whilst the third is spring-loaded. The spike tips are made of Ti5K6 hard alloy* which has constant mechanical properties up to a temperature of 900°C and is much harder than any materials tested, as a result of which little force is required for driving the tips into the specimen and holding them securely in that position. Specimen rupture only very rarely occurs at the points of contact with the tips.

Each channel of the following system constitutes a measuring bridge composed of the resistance gauges bonded to a measuring element (dynamometer or clamp), which are incorporated in a temperature self-compensation circuit. The bridge arms consist of resistance gauges, bonded to a small elastic beam, for balancing the bridge, a differential condenser for balancing the reactive component, and a rheochord. The bridge is supplied with a 35 kc/sec alternating current, as a result of which interference can largely be eliminated. A UTS-12 strain-control unit generator is used as a bridge power-supply source, one of its channels acting also as the first amplification stage. After amplification in the strain-control unit, the signal passes to a UE-109 electronic amplifier, which is normally used in the EPP-09 potentiometer. Since the UE-109

*15% TiC + 6% Co + WC – Translator's note.

Fig. 1. Schematic diagram of apparatus: 1) demodulator; 2) cathode follower.

amplifier gives an amplified ac signal, the circuit is provided with a phase-sensitive rectifier, from which the signal passes to a cathode follower and then to the control windings of a dynamoelectric amplifier. From the dynamoelectric amplifier the signal proceeds to a dc slave motor with an independent excitation winding, whose armature is mechanically linked with the sliding contact of the rheochord. The rheochord contact is moved until the error signal disappears. To improve the dynamic characteristics of the system, use is made of a damping signal, which is proportional to the first derivative of the error signal received from the armature of the slave motor. The bridge is used to emit a signal proportional to the armature emf. From the bridge the signal passes to a filter which stops high-frequency oscillations and then to the UE-109 amplifier.

The automatic system consists of a circuit for reversing the motor once a given stress or strain has been reached and a specimen heating circuit (see Fig. 1).

The specimen is heated by passing a current through it or in a furnace. The heating system (see Fig. 1) is composed of a step-down transformer, an RNO-5 variable-ratio transformer, two starters, and an ÉPP-09 potentiometer. The transformer is connected to two adjustable windings of the variable-ratio transformer, which are set so that the voltage on one of them is slightly in excess of that required for heating the specimen to a given temperature, and on the other, slightly below that value. When the temperature reaches the upper limit, the ÉPP-09 potentiometer switches the transformer over to the lower voltage and the temperature falls; when the temperature drops to the lower level, the higher voltage is applied to the specimen. The temperature is measured with a Chromel-Alumel thermocouple, using a Class 0.5 ÉPP-09 potentiometer. The temperature can be regulated with an accuracy of ±5°C. In addition, the temperature is also measured with another thermocouple connected to a Class 0.2 PP-01 potentiometer. The thermocouple wires are 0.2 mm in diameter. The thermocouple is bonded to the specimen by percussion welding.

Cyclic tension tests are conducted on a thin-walled tubular specimen. Its outside and inside diameters are 11.5 and 10 mm, respectively, and its gauge length is 22 mm. These specimen dimensions ensure a virtually uniform stressed state in the specimen gauge portion, twist angle measurements being performed on a basis of 10 mm. From the point of view of temperature distribution over the specimen length, a longer specimen would be preferable. With materials of high ductility, however, this is impracticable because, to obtain rupture of a small number of cycles, large angles of twist would be required, at which longer specimens...