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PHOTOMICROGRAPHIC STUDY OF TEMPERATURE DISTRIBUTION IN A PULSE-HEATED SPECIMEN

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IN GENERAL, temperature gradients exist in a specimen heated by the passage of electric currents through it. If the specimen is heated from room temperature to high temperatures (above 2000 K) in short times (less than 1 s) the gradients are very sharp and are confined to the regions close to the end clamps.

This note presents a photomicrographic technique to study the region of sharp temperature gradients in a molybdenum specimen pulse heated to high temperatures in a vacuum environment.

The specimen was placed in series with a battery bank (28 V), a standard resistance (0·001 Ω), and a fast-acting switch. An electronic timer controlled the length of the current pulse. The details of the measurement system was given in an earlier publication [1]. The specimen was a tube of the following nominal dimensions: length 4 in. (102 mm), o.d. = 0·25 in. (6·3 mm), wall thickness = 0·02 in. (0·5 mm). A small rectangular hole (1 × 0·5 mm) was fabricated in the wall at the middle of the specimen to approximate blackbody conditions. A schematic diagram of the specimen and the end clamps is shown in Fig. 1. Specimen temperature was measured with a high-speed photoelectric pyrometer [3]. Potential difference across the middle portion (50 mm) of the specimen and current flowing through it were also measured. Recordings of temperature, voltage, and current were made with a high-speed digital data acquisition system [1] which had a full-scale signal resolution of approximately one part in 8000 and a time resolution of 0·4 ms. The specimen was heated from room temperature to 2800 K for several times with pulses ranging from 0·38 to 0·75 s in duration. The clamps were water cooled and stayed approximately at 20°C during the experiments.

At the end of the entire set of experiments a photomicrograph of the specimen was prepared which is shown in Fig. 1. The pertinent locations on the photomicrograph are identified with respect to the specimen. Two distinctly different grain structures may be seen. The portions of the specimen which were in the clamp or close to it have retained the original "drawn" pattern, while the portion which was heated to high temperatures shows a considerable grain growth. It is interesting to note a clear boundary between the two patterns which correspond to a plane (P1) approximately 3 mm from the plane (P2) of the end clamp.

In order to have a crude estimate of the specimen temperature at the plane P1, the transient heat conduction equation [2] is solved assuming constant properties for a pulse heating period of 0·38 s. The results indicate that temperature at the plane P1 was approximately 2100 K, while the midpoint value was 2800 K.

A difference between the actual temperature gradient and that indicated by the photomicrograph is that the latter does not show any uniformly changing grain pattern between room temperature and high temperature regions. Also, no appreciable difference is observed between grain size at plane P1 and at a plane closer to the midpoint of the specimen.

Various methods, such as thermoelectric (thermocouples), pyrometric, photographic, etc. may be used to study temperature distribution in a specimen. All of these techniques require the performance of the measurements during the actual experiment. Temperature indicating paints, although useful at moderate temperatures, cannot be used at high temperatures. The advantage of the photomicrographic technique is that, although crude, it provides a means to map the region of sharp temperature gradients in the specimen after the completion of the experiment, and is ideally suited for high temperature studies. This is particularly attractive in experiments belonging to the following classes: (1) high-speed (submillisecond) experiments in which the resolution of most measuring equipment is not sufficient to follow the event, (2) in experiments in which the system does not permit the installation and operation of transducers for the detection of temperature gradients. An excellent example to item 2 is the high pressure systems designed for studying the behavior of matter at high temperatures and at very high pressures.

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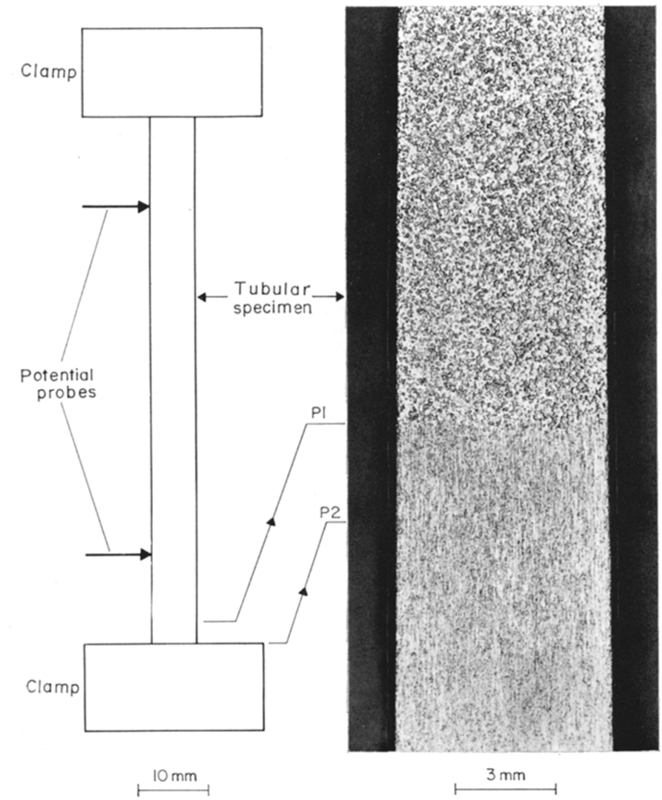

FIG. 1. Schematic and photomicrograph of the specimen.