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Uni-axial and multi-axial creep behaviour of P91-type steel under constant load

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ABSTRACT

The uni-axial and multi-axial creep behaviour of P91-type steel under constant load was studied. The conventional, uni-axial, constant-load creep tests were performed at initial stresses ranging from 120 MPa to 240 MPa, and at temperatures from 625 to 675 °C, while the multi-axial, small-punch, constant-load creep tests were performed at loads ranging from 350 N to 550 N, and at temperatures from 650 to 690 °C. Both types of test can be considered as short-term creep tests because the maximum time-to-rupture was less than 500 h. Since it is well known that the creep behaviour of P91-type steel cannot be satisfactorily described by a simple, Arrhenius-type, power-law constitutive model, an improved stress-dependent, energy-barrier model was used for a description of the uni-axial as well as the multi-axial creep behaviour of the P91-type steel. It was found that the obtained values of the apparent activation energies Q_c during the uni-axial and multi-axial creep tests were very close, and in both types of test they were considerably higher than the activation energy for the lattice diffusion in iron.

1. Introduction

Creep tests can be conducted either at constant load or at constant stress. However, from the engineering point of view, constant-load creep tests are more important than constant-stress creep tests, because it is the load and not the stress that is normally kept constant in engineering applications. When studying the creep properties of materials, the most conventional tests are uni-axial creep tests using cylindrical specimens [1–3]. However, in some cases it is not possible to have available the large amount of material required for a conventional cylindrical specimen. Therefore, some new testing techniques are being developed: tests that are able to extract the mechanical properties from a specimen with a small volume [4,5]. One of these tests is the so-called miniaturised disc-bend test, also known as the small-punch test. This technique can also be used to measure the creep properties [6]. In the small-punch creep test a thin, circular disc is supported over a recessed hole and forced under constant load to deform into the hole by means of a spherically shaped punch or a ceramic ball. This gives rise to a rotationally symmetrical, multi-axially stressed state in the specimen, in contrast to the conventional uni-axial creep test, where a multi-axially stressed state occurs with the formation of the neck in the specimen. However, this happens during a very late stage of the creep test, just before the rupture. Thus, it has almost no influence on the time-to-rupture.

P91-type steel is widely used for the high-temperature pipework components in advanced power plants. It exhibits a considerable high-temperature creep strength, a high corrosion-cracking resistance, a low oxidation rate, and good weldability

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