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The Effect of Tempering Duration on the Creep Behavior of the P91 Steels at 600℃

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ABSTRACT

High performance martensitic heat resistant steels are widely used in fossil fuel power plant industry due to because of their good creep resistance at high temperatures. In-depth understanding of the high temperature inelastic deformation mechanism of such steels is crucial to ensure the reliable, safe and efficient operation of the power plant [1]. The martensitic steels have a complex microstructure with a hierarchical arrangement, including a collection of packets in the prior austenite grain, blocks in the packet and laths along with dispersed nanoscale strengthening phases (e.g., MX precipitates and carbides). The purpose of this paper is to study the creep mechanisms with regard to the microstructure of the P91 martensitic steel at high temperature by means of experimental characterisation and finite element simulation.

In the present paper, the effect of tempering duration on the creep response of the P91 steel at 600 oC was experimentally examined with the precipitate size identified. Apart from the standard heat treatment (holding at 1060℃ for 40 min and then at 760℃ for 2 h) for the as-received P91 steels, secondary tempering treatment has been applied with different tempering time periods, e.g., 0 h (T0), 10 h (T10) and 20 h (T20) at 780℃. In order to simulate the creep response, crystal plasticity based micromechanical finite element model was developed based on the measured microstructure [2]. The crystallographic slip at the block level is accounted for using an exponential type of constitutive flow rule and the precipitate size effect is represented in the crystal plasticity model through the use of an internal variable in association with the slip resistance. The results show that the secondary tempering duration can significantly affect the creep behavior of the martensitic steel (see Fig. 1). It is found that with increasing tempering time period the precipitate size increases, which could lead to detrimental effect on material's creep resistance. Similar effect of the precipitate size on the creep response has also been shown in literatures [3]. The measured creep response of the P91 steels with different heat treatments at different stress levels can be predicted by the developed micromechanical model. The micromechanical modelling results show (see Fig. 2) that the accumulated equivalent plastic strain during the creep is strongly heterogeneous and the levels of the strain localization depend on the tempering duration.

KEYWORDS

P91 steel; heat treatment; microstructure; crystal plasticity; creep

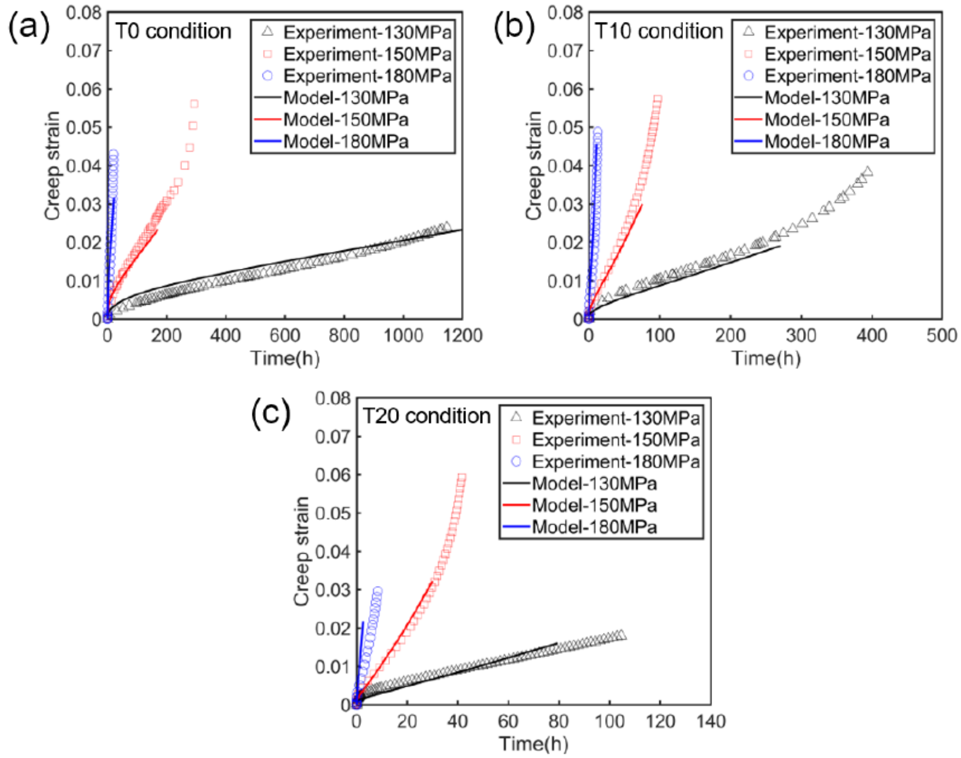

Figure 1: Comparison of creep strain between the experimental data and the modelling predictions at 600°C for the materials with different heat treatments (a) T0, (b) T10 and (c) T20

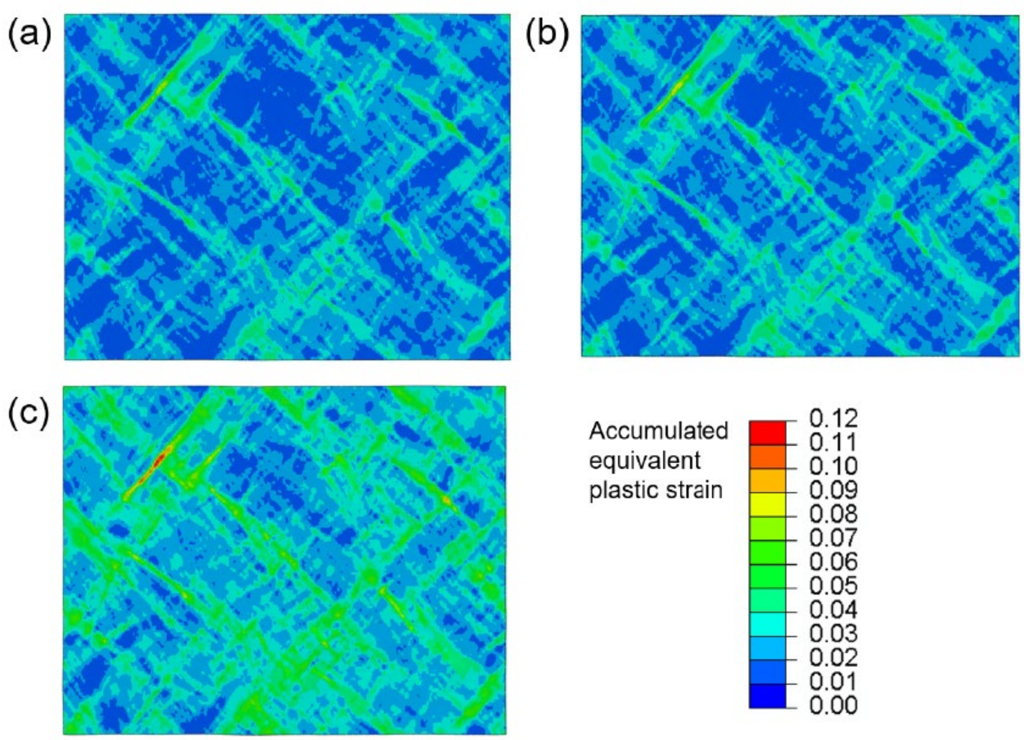

Figure 2: The accumulated equivalent plastic strain distributions for (a) T0, (b) T10 and (c) T20 at 130 MPa and 80 h

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