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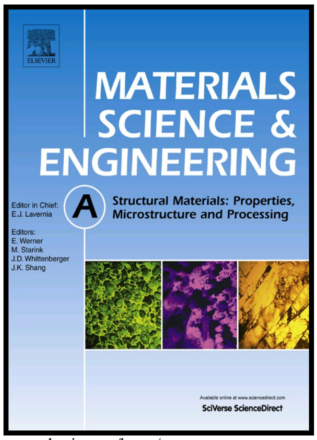

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In-situ synchrotron X-ray study of microstructural evolution during creep deformation in Grade 91 steel

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Abstract

Creep deformation mechanism of Grade 91 steel at 650℃ was investigated in-situ via wide-angle X-ray scattering (WAXS). WAXS peak broadening and a modified Williamson-Hall analysis provided information on evolution of dislocation densities in the primary $\alpha-$Fe phase, while WAXS peak shifts provided lattice strains in the $\alpha-$Fe matrix, $M_{23}C_6$ and MX precipitates. Load transfer was not evident during in-situ creep deformation, suggesting that precipitates did not significantly strengthen the matrix during creep deformation. Peak broadening results illustrated an increase in average dislocation density during primary stage creep. After onset of secondary creep, there was a decrease in dislocation density, attributed to annihilation and re-ordering of dislocations in the subgrain structure, followed by a relatively constant average dislocation density with increasing strain.

Keywords: Grade 91 steel; Creep; High-energy X-ray diffraction; Dislocation Density

1. Introduction

The Generation IV reactor concept is designed to operate at much higher temperature and for a longer service lifetime than currently operating boiling water reactors (BWRs) or pressurized water reactors (PWRs) [1, 2]. The design of high-temperature structural components must consider time-dependent effects, such as creep, creep fatigue, and environmental effects. 9Cr-1Mo-VNb ferritic/martensitic (F/M) steel (i.e. Grade 91) is a promising candidate for structural applications in advanced sodium-cooled fast reactors. The creep strength of a material depends on several metallurgical factors, e.g. the grain and subgrain size, precipitate size and density, etc. The carbide-forming precipitates in Grade 91 steel provide the material with its high temperature creep strength by preventing the motion of dislocations and delaying plastic deformation by inhibiting grain boundary sliding [1, 2, 3-11]. Grade 91 steel exhibits a 10^5-hour creep rupture strength of 100 MPa at 600℃ [3]. Commercial Grade 91 steel can be used up to 590℃ [4, 5]. In addition, Grade 91 steel has a better corrosion and erosion resistance than traditional steels [2].

F/M steels with 9—12 wt. % Cr were originally developed for fossil fuel power plants in the 1960s [1, 2]. The addition of Nb and V increased the creep strength of the material and