Frequency and hold time influence on crack growth behavior of a 9 - 12% Cr ferritic martensitic steel at temperatures from 300 °C to 600 °C in air.

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Frequency and hold time influence on crack growth behavior of a 9 - 12 % Cr ferritic martensitic steel at temperatures from 300 °C to 600 °C in air.

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Abstract

Due to an increase of renewable energies proportion, e. g. wind power and photovoltaics, which cannot supply energy constantly, modern power plants must be able to be operated flexibly in order to compensate the residual load. As a consequence of increasing alternating load, fatigue damage becomes more and more important, while creep damage caused by ever shorter holding times at high operating temperature decreases. In this study a turbine bypass valve, one of the most fatigue loaded power plant component, manufactured from widespread standard 12 % Cr ferritic/martensitic steel X20 was investigated. Fatigue crack growth experiments showed that the crack growth rate increases slightly with decreasing frequency (20 Hz → 5 Hz). In hold time tests (300 s → 600 s, effective frequency 3.33×10^{-3} Hz → 8.33×10^{-4}), larger crack propagation rates per cycle occur than in the fatigue crack growth experiments with 5 and 20 Hz. In comparison to pure cyclic loading maximum load holding time further required significantly higher ΔK values to start crack growth.

Keywords: Fatigue, Creep-Fatigue, Crack growth, Frequency, Hold time, 9 - 12 % Cr steels

1. Introduction

Recently the requirements for conventional power plants changed fundamentally: Modern power plants must be capable of flexible operation (frequent start-ups and shut-downs, load following operation) to compensate for power requirements caused by fluctuating renewable sources of energy, what causes by far greater temperature and pressure fluctuations during operation. For this reason the applied materials face by far more demanding loading scenarios than in the past. As a consequence of increased cyclic operation fatigue damage becomes more dominant, whereas diminishing base load operation decreases the importance of creep damage.

In this respect thick-section components of the feed water and live steam systems, e. g. spheroidal forgings, fittings, collectors, pumps and turbine bypass valves (TBV) are of particular importance. In the current study material from two ex-service TBVs (operation duration ~ 21 years) was investigated. The TBV was chosen because it is subjected to the most demanding cyclic loading profile during plant start-up and shut-down and thus represents the most fatigued component. Technically, the TBV is a separation between the steam systems of differing pressure. The TBV was manufactured from German X20CrMoV12-1 grade, a tempered 12 % Cr ferritic-martensitic steel largely used especially in the German power industry [1, 2].

The aim of the study, carried out in the framework of the joint national “THERRI” (German: THermisches ERmüdungsRIsswachstum, engl.: Thermal fatigue crack propagation; grant number: 03ET7024A) project under funding of the German Federal Ministry of Economic