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Some key effects on the failure assessment of weld repairs in CrMoV pipelines using continuum damage modelling

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Abstract

Some typical results obtained from finite element (FE) creep and continuum damage mechanics analyses, for assessing weld repair performance, are presented. The work outlines some developments in failure analyses of repaired welds in pressurised, thick-walled, main steam circumferential pipe weldments made of CrMoV steels. Methods involved in determining the material properties for constitutive equations are briefly described. Results presented cover a range of analyses, taking account of the effects of repair profiles/dimensions, geometry change during creep, end (system) loading, reheating effects in the weld metal of partial repair welds and initial damage level, etc., on the failure life of the repaired welds. The potential uses and limitations of the damage analysis for weld repair performance assessment are discussed.

Keywords: Creep; Damage; Repair; Weld; Failure assessment

1. Introduction

There is often a need for carrying out weld repairs on components operating at elevated temperature in power plant in order to ensure their long term integrity [1]. Experience from the performance of repaired welds has shown that creep damage is often found in or close to the repair and this occurs earlier than would have been expected [2]. Extensive effort has been made to investigate the high temperature performance and to predict failure life of weld repairs, e.g. [3].

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A typical weld repair procedure includes mechanical removal of the damaged material and the restoration of the component geometry by welding followed by a post weld heat treatment, PWHT. This PWHT is intended to locally temper the hard heat-affected zone (HAZ) structure and weld metal and to minimise the residual stresses generated. The process of repair welding will create new HAZs, some of which will be in the original parent, some in the weld and some in the HAZ materials. Two typical procedures, i.e., full repair and partial repair, are commonly used.

The major factors which affect the creep failure behaviour of repaired welds are the relative material properties for the various zones, the repair profile/dimension, the material degradation (or initial damage) and the loading system, etc. Due to the complex nature of the problem, the finite element (FE) method is usually used to assess the effects of these factors, e.g. [2,4–6]. For example, continuum damage mechanics FE analyses can be used to predict the failure life of repaired welds, where the full creep stage, including tertiary creep, is considered. Before realistic modelling can be performed, the material properties for each material zone must be determined.

This paper focuses on the failure assessment using creep continuum damage FE analyses for pressurised, circumferentially welded CrMoV steel pipes. Weld repair models, creep and damage constitutive equations and methods used for determining the material properties are briefly described. Typical results related to the life prediction of the repaired welds are presented, covering a range of analyses, which consider the effects of repair profiles/dimensions, geometry change during creep, end (system) loading, reheating effect and initial damage level, etc., on the failure life of the repaired welds. The potential uses and limitations of FE modelling for predicting the performance of weld repairs are addressed.

2. Geometric and material models for repaired welds

2.1. Weld repair models

Schematic diagrams of some typical weld repair geometries are shown in Fig. 1. A typical weld in a component consists of parent material (PM), heat-affected zone (HAZ) and weld metal (WM), Fig. 1(a). The material models for a new and an aged weld are shown in Figs. 1(b) and (c). Figs. 1(d)–(f) show two

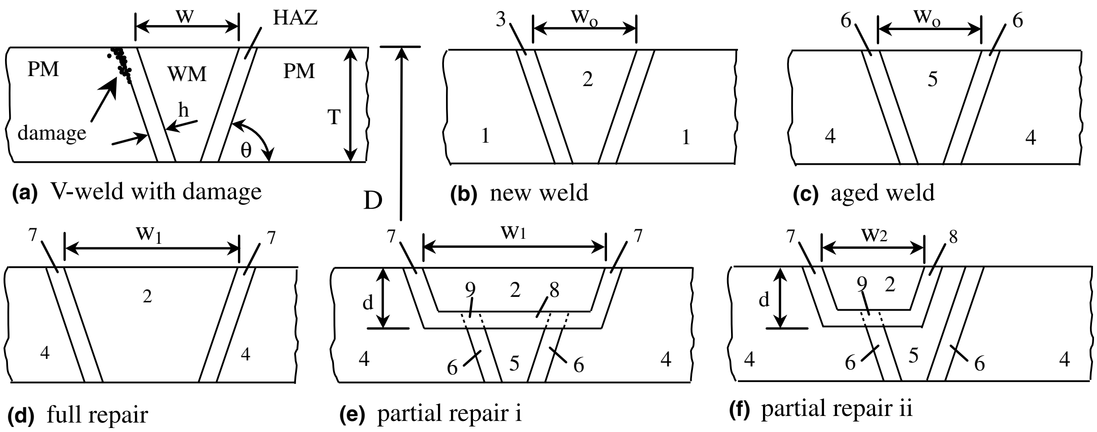

Fig. 1. Typical geometric models: material zones and repair profiles [6]. [1, new PM; 2, new WM; 3, new HAZ (in new weld); 4, aged PM; 5, aged WM; 6, aged HAZ (in aged weld); 7, new HAZ in aged PM; 8, new HAZ in aged WM; 9, new HAZ in aged HAZ] Dimension (mm): $D = 356$, $T = 63.5$, $w_o = 46$, $h = 4$, $\theta = 15°$.