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Microstructure and mechanical behavior in dissimilar 13Cr/2205 stainless steel welded pipes

K. Bettahar [a,b], M. Bouabdallah [b], R. Badji [a,*], M. Gaceb [c], C. Kahloun [d], B. Bacroix [d]

[a] Welding and NDT Research Centre (CSC), B.P. 64, Cheraga, Algeria
[b] LGSDS, École Nationale Polytechnique, 10, Avenue Hassan Badi, B.P. 182, El Harrach, Algeria
[c] LFEPM, Faculté des hydrocarbures et de la chimie (UMBB), Algeria
[d] LSPM, CNRS, Université Paris 13, 93430 Villetaneuse, France

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ABSTRACT

This work aims to investigate the microstructure and the mechanical behavior of dissimilar 13Cr Supermartensitic/2205 Duplex stainless steel welded pipes. A wide variety of microstructures resulting from both solidification and solid state transformation is induced by the fusion welding process across the weld joint. The tensile tests show that the deformation process of the dissimilar weld joint is mainly controlled by the two base materials: the duplex steel at the beginning of the deformation and the supermartensitic one at its end. This is confirmed by the micro-tensile tests showing the overmatching effect of the weld metal. The fatigue tests conducted on dissimilar welded specimens led us to conclude that the weld metal is considered as a weak link of the weld joint in the high cycle fatigue regime. This is supported by its lower fatigue limit compared to the two base materials that exhibit a similar fatigue behavior.

1. Introduction

In the last decades, welding has continuously been an important field of interest since it is the most widely used process in assembling structural components. With the development of more and more innovative materials in several industrial domains, it is necessary to adapt material properties with service conditions. This leads in some cases to join materials having different alloy systems. In this context, dissimilar welding is a promising solution. The necessity of joining different grades of materials takes place in several fields nowadays such as oil and gas, petrochemistry, power plant and automobile industries among others [1–5]. However, the main disadvantage of dissimilar welding is the microstructural heterogeneity generated by the weld thermal cycles that can influence significantly the global and local mechanical behavior of the weld joint. Under optimal operating conditions, the welded components should transfer load on both sides of the structure without being gradually or unexpectedly damaged. Since the mechanical properties are directly related to the microstructure (mismatch effect), the presence of any microstructural heterogeneity causes local heterogeneity of the mechanical behavior of the weld joint. In practice, dissimilar welding of materials, such as 2205 Duplex stainless steel (DSS) and 13% Cr Supermartensitic stainless steel (SMSS), is widely used in gas transportation. DSS and SMSS have both high mechanical properties combined with an excellent corrosion resistance and good weldability despite their microstructures that are different from both morphology and phase constituent aspects. DSSs are known as austenitic–ferritic steels composed of two different phases ferrite and austenite with nearly equal proportions of each [6,7]. The SMSS microstructures consist mainly of martensite with a small amount of retained austenite. Ferrite phase is also frequently found in supermartensitic microstructures and can affect their mechanical behavior if it exceeds a certain proportion [8,9]. In piping industry, some DSS and SMSS components have particular geometries such as flanges, elbows and branch tees. When these regions contain dissimilar weld joints, the risk of crack initiation can be expected due to local microstructural heterogeneity. This difference in microstructure can cause the crack initiation near the fusion line, which is a factor that can increase the local stress concentration in the adjacent heat affected zone as reported in previous works [10]. These cracks can grow under given service conditions causing the fracture of the welded structure [11,12].

Recently, great efforts have been devoted to study the DSS and the SMSS weld joints separately. For the DSS welds, several research works have been carried out to examine the effect of weld metal chemistry and heat input [6], the corrosion behavior in aggressive environments [13], and the effect of post-weld heat treatments on their microstructure and mechanical behavior [14,15]. The strain heterogeneity that occurs during loading and the contribution of austenite and ferrite phases to the global mechanical behavior of the DSS weld joints in either static or dynamic loadings have been well discussed in the literature [16–19].

* Corresponding author.
E-mail address: riadbadji@gmail.com (R. Badji).

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