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Bending capacity of girth-welded circular steel tubes

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ABSTRACT

In this paper, the buckling behavior of girth-welded circular steel tubes subjected to bending was investigated by numerical method. Finite element (FE) simulation of the girth welding process was first performed to obtain weld-induced residual stress and deformation employing sequentially coupled three-dimensional (3-D) thermo-mechanical FE formulation. Elastoplastic large-deformation analysis in which the failure mode, the ultimate moment capacity and the moment versus end-rotation behavior of girth-welded circular steel tubes under pure bending were explored incorporating weld-induced geometric imperfection and residual stress was next carried out. Results showed that the flexural behavior of girth-welded circular steel tubes always involves local buckling near the girth weld on the compression side, which significantly affects the moment versus end-rotation response.

1. Introduction

Circular steel tubes are increasingly used both in building and bridge structures due to their efficient geometry and to esthetic benefits that they offer over more traditional open cross sections. During their service life, these members are subjected to loading of various types such as axial loading, bending and torsion. In practice, girth welding of circular tubes is frequently needed due to the long geometry relative to the diameter and the wall-thickness. When two circular steel tubes are welded together, a non-uniform temperature field induced during the welding process produces undesired residual stress and deformation. The presence of welding residual stress and deformation can be a major concern in structural integrity assessment of girth-welded members [1]. Particularly, when combined with service loads, welding residual stress causes premature yielding and loss of stiffness and may lead to deterioration of load carrying capacity [2]. Moreover, welding deformation, i.e. weld depression induced by circumferential shrinkage of the weld region has been founded to have significant effects on the buckling behavior of cylindrical members [3]. Therefore, a good estimation of weld-induced residual stress and geometric imperfection, and an accurate prediction of the behavior of girth-welded members under loading are important for the production of an efficient and economic design and safety of the structure. This paper addresses the bending resistance of girth-welded circular steel tubes.

Recently, finite element (FE) method has emerged as a useful and powerful numerical analysis tool. It can be employed to simulate welding temperature field, welding residual stress field and welding deformation [4–9]. Over the last three decades or so, there have been significant research activities on the FE simulation focusing on the girth welding [10–14]. However, these studies have been limited to the axisymmetric condition which cannot reproduce the three-dimensional (3-D) features in the girth welding process [15]. On the 3-D FE simulation, limited works have been published due to the high computational cost [15–20].

Much work has been devoted to investigating the behavior of circular steel tubes under bending in the elastic range [21,22] and plastic range [23–31]. However, their works have been generally related to hot-rolled or cold-formed sections. In the literature available on welded circular tubes in bending, Chen et al. [32] presented a FE model for longitudinally stiffened large diameter fabricated steel cylinders in pure bending. The model incorporates both initial geometric imperfections and residual stresses resulting from the welding of stiffeners to the cylinder and verified through the experimental program. The geometric imperfections measured from the test specimen were mapped into the FE model and incorporation of the residual stresses into the model was done by applying a distributed fictitious temperature loading that produced the initial strains necessary to set up the required residual stresses in the cylinder and stiffeners. Kiymaz et al. [33] examined the structural response of seam-welded stainless steel circular hollow section (CHS) flexural members incorporating residual stresses produced by the seam welding. For the residual stress analysis, they proposed a simpler stress-block model based on the measurements taken by Chen and Ross [34]. Nevertheless, as described, they did not implement direct simulation of the welding process due to the truly complex analysis procedure. Moreover, in their works, girth welding of the tubes was not considered.

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