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Residual stress distributions in welded stainless steel sections

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ABSTRACT

Residual stress magnitudes and distributions in structural stainless steel built-up sections have been comprehensively investigated in this study. A total of 18 test specimens were fabricated from hot-rolled stainless steel plates by means of shielded metal arc welding (SMAW). Two grades of stainless steel were considered, namely the austenitic grade EN 1.4301 and the duplex grade EN 1.4462. Using the sectioning method, the test specimens were divided into strips. The residual stresses were then computed by multiplying the strains relieved during sectioning by the measured Young's moduli determined from tensile and compressive coupon tests. Residual stress distributions were obtained for 10 I-sections, four square hollow sections (SHS) and four rectangular hollow sections (RHS). Peak tensile residual stresses reached around 80% and 60% of the material 0.2% proof stress for grades EN 1.4301 and EN 1.4462, respectively. Based upon the test data, simplified predictive models for residual stress distributions in stainless steel built-up I-sections and box sections were developed. Following comparisons with other available residual stress test data, the applicability of the proposed models was also extended to other stainless steel alloys. The proposed residual stress patterns are suitable for inclusion in future analytical models and numerical simulations of stainless steel built-up sections.

1. Introduction

Residual stresses in structural stainless steel sections may differ significantly from those in carbon steel sections, owing to distinct differences in material and thermal properties [1,2]. For cold-formed sections, residual stresses are mainly attributed to the coiling–uncoiling of the sheet material and to the press-braking or cold rolling operations [3,4], whereas in fabricated sections the localised welding heat input and uneven cooling are the key sources of residual stresses [5]. The residual stresses in structural sections can be determined by both destructive and non-destructive methods [6]. However, the non-destructive measuring techniques, such as X-ray diffraction, ultrasonic and magnetic methods, are often not practical for examining structural members. The sectioning method, due to its accuracy and simplicity, has been widely used to evaluate residual stresses in structural steel members. It was successfully used to determine residual stresses patterns in carbon steel sections [7], high strength steel sections [8] and cold-formed stainless steel sections [9]. This sectioning technique is based upon the measurement of residual strains that are relieved when cutting test sections into small strips [10].

Measurements of residual stress in structural stainless steel sections have been reported in a number of previous experimental programmes. Young and Lui [11] presented measurements in two cold-formed RHS by means of the sectioning method, whereas Jandera and Gardner [12] examined residual stresses in cold-rolled stainless steel box sections by X-ray diffraction. A comprehensive experimental programme carried out by Cruise and Gardner [9] involved the measurement of residual stresses in hot-rolled and press braked stainless steel angles, as well as cold-rolled box sections, using the sectioning method. For fabricated structural stainless steel sections, residual stress measurements using the sectioning technique have been made on four I-sections by Bredenkamp et al. [13], two I-sections by Lagerqvist and Olsson [14] and six I-sections by Wang et al. [15]. Overall, with relatively few residual stress measurements on welded stainless steel I-sections and none on welded stainless steel hollow sections, coupled with an increasing use of stainless steel in heavier load-bearing applications, the focus of this study is to carry out comprehensive measurements on fabricated sections and to develop simplified models for predicting the magnitudes and distributions of their residual stresses.

A total of 18 structural stainless steel built-up sections, including 10 I-sections, four SHS and four RHS were examined to acquire the level and distribution of residual stresses present in such sections. The sectioning method, using the wire-cutting technique,

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