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Abstract

Analytical Solutions for Residual Stresses in Cold-Formed Steel Circular Hollow
Sections due to Cold Rolling

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The manufacturing process of cold-formed steel sections can modify the mechanical properties of the material and affect their structural behavior. Such effect can be assessed and quantified by means of residual stresses and equivalent plastic strains induced by the manufacturing process. However, laboratory measurements of residual stresses in cold-formed sections are difficult, time consuming and of limit accuracy. The measurement of equivalent plastic strains is even problematic. Moreover, a clear relationship between residual stresses and various stages of the manufacturing process cannot be established by an examination of the measurement results. Due to these limitations of laboratory measurements, theoretical predictions of residual stresses and equivalent plastic strains in cold-formed sections become necessary for an accurate assessment of the effect from forming on the mechanical and structural behavior of cold-formed members. This requires the accurate modeling of each stage of the manufacturing process.

Residual stresses in cold-formed circular hollow sections are derived from three sources: (1) the coiling-uncoiling process, (2) the cold bending of the roll-forming process and (3) the thermal effect of welding. This thesis is concerned with the theoretical modeling of the manufacturing process of cold-formed carbon steel and stainless steel circular hollow sections for the prediction of the resulting residual stresses and equivalent plastic strains due to cold rolling. In the present study, only the deformationally-induced residual stresses due to the first two stages (i.e. the

coiling-uncoiling process and the cold bending of the roll-forming process) of the manufacturing process have been considered and the thermally-induced residual stresses due to welding have not been taken into account. Analytical solutions for the deformationally-induced residual stresses are verified using finite element simulations of cold bending of steel sheets. The limitation of the analytical solutions is also discussed.

A parametric study is also presented for an investigation into the effects of various forming parameters, including coiling curvatures and tube diameters, on residual stresses. Based on results from the present study, it can be concluded that the through-thickness variations of residual stresses in cold-formed circular hollow sections are highly nonlinear. The magnitudes and distributions of residual stresses depend on the coiling curvature and the tube diameter. The development processes of residual stresses in the cold-formed circular hollow section are also illustrated through the analytical results.