Thermal-Mechanical Analysis of a Bridge Deck to Determine Residual Weld Stresses

Authors : Evy Van Puymbroeck, Wim Nagy, Ken Schotte, Heng Fang, Hans De Backer

Abstract : The knowledge of residual stresses for welded bridge components is essential to determine the effect of the residual stresses on the fatigue life behavior. The residual stresses of an orthotropic bridge deck are determined by simulating the welding process with finite element modelling. The stiffener is placed on top of the deck plate before welding. A chained thermal-mechanical analysis is set up to determine the distribution of residual stresses for the bridge deck. First, a thermal analysis is used to determine the temperatures of the orthotropic deck for different time steps during the welding process. Twin wire submerged arc welding is used to construct the orthotropic plate. A double ellipsoidal volume heat source model is used to describe the heat flow through a material for a moving heat source. The heat input is used to determine the heat flux which is applied as a thermal load during the thermal analysis. The heat flux for each element is calculated for different time steps to simulate the passage of the welding torch with the considered welding speed. This results in a time dependent heat flux that is applied as a thermal loading. Thermal material behavior is specified by assigning the properties of the material in function of the high temperatures during welding. Isotropic hardening behavior is included in the model. The thermal analysis simulates the heat introduced in the two plates of the orthotropic deck and calculates the temperatures during the welding process. After the calculation of the temperatures introduced during the welding process in the thermal analysis, a subsequent mechanical analysis is performed. For the boundary conditions of the mechanical analysis, the actual welding conditions are considered. Before welding, the stiffener is connected to the deck plate by using tack welds. These tack welds are implemented in the model. The deck plate is allowed to expand freely in an upwards direction while it rests on a firm and flat surface. This behavior is modelled by using grounded springs. Furthermore, symmetry points and lines are used to prevent the model to move freely in other directions. In the thermal analysis, a mechanical material model is used. The calculated temperatures during the thermal analysis are introduced during the mechanical analysis as a time dependent load. The connection of the elements of the two plates in the fusion zone is realized with a glued connection which is activated when the welding temperature is reached. The mechanical analysis results in a distribution of the residual stresses. The distribution of the residual stresses of the orthotropic bridge deck is compared with results from literature. Literature proposes uniform tensile yield stresses in the weld while the finite element modelling showed tensile yield stresses at a short distance from the weld root or the weld toe. The chained thermal-mechanical analysis results in a distribution of residual weld stresses for an orthotropic bridge deck. In future research, the effect of these residual stresses on the fatigue life behavior of welded bridge components can be studied.

Keywords : finite element modelling, residual stresses, thermal-mechanical analysis, welding simulation
Conference Title : ICSEVAE 2018 : International Conference on Structural Engineering, Vibration and Aerospace Engineering
Conference Location : San Francisco, United States
Conference Dates : June 06-07, 2018