Analysis of Fatigue Crack Propagation on Orthotropic Bridge Deck Based on Extended Finite Element Method

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Abstract: Due to stress concentration as well as welding residual stress, fracture due to vehicle fatigue loads is easy to occur in the weld and its adjacent position of long-span bridge, especially at the toe of weld between the U-rib and orthotropic steel bridge deck. In order to investigate the fatigue crack propagation mechanism of the toe of weld in long-span bridge, a multi-scale finite element model including the whole bridge, local components, the welding details and cracks was established firstly. And then, based on birth and death element technology, the welding heat and structural coupling process simulation was carried out in order to investigate the effect of welding residual stress on fatigue performance. Finally, based on the extended finite element method, the static analysis and the dynamic crack propagation analysis for the semi-elliptical crack in the established multi-scale finite element model were conducted. The welding process shows that the peak value of residual tensile stress in weld zone between the U-rib and top deck could reach the material yield strength, while the regions far away from the weld are in the state of compression. A 32ton standard fatigue vehicle specified in British Standard BS5400 was applied for the fatigue crack static analysis. The results show that when the vehicle is acting on different lanes, the fatigue crack initiating from the toe of weld between U-rib and top deck is mainly under compression in most cases. Only in several cases the fatigue crack is in the state of tension, however, the tensile stress required by the fatigue crack propagation has not be reached. Under the 50ton vehicle, the fatigue stress only at the toe of weld of U-rib can meet the requirements of the fatigue crack propagation. The dynamic analysis on fatigue crack reveals that the crack in the toe of weld of U-rib is in tensile stress state, and the fatigue crack is the mixed mode crack of Mode I, II and III. When the residual stress field was introduced, the stress state at the region where fatigue crack initiates will change and the angle of fatigue crack propagation will increase. The crack at the toes of weld of top deck under the 32ton and 50ton fatigue vehicles is mainly under compression. When the residual stress field was introduced, the crack will be subjected to be a tensile state. It will become mixed mode crack of Mode I, II and III and be dominated by Mode I.