Mixed Mode Fatigue Crack Propagation Mechanism of the Diaphragm Cutout Detail in Steel Bridge Deck

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Abstract

Based on the extended finite element method (XFEM), finite element model of a typical steel bridge deck was established to analyze the fatigue crack propagation of diaphragm cutout detail. It was considered the parameters of welding residual stress, vehicle load and initial crack in the fatigue mechanism analysis. Residual tensile stress in the cutout edge of the diaphragm of two types of cutout was calculated. Cutout with higher residual tensile stress provided the welding residual stress field for calculation of fatigue crack propagation. Under coupling action of vehicle load and welding residual field, the fatigue crack in diaphragm cutout edge was mixed mode crack of Modes I, II, dominated by Mode I.

Keywords: steel deck; welding residual stress; fatigue crack; crack growth simulation; XFEM.

1 Introduction

Steel bridge deck has been widely used due to its characters of high capacity, light weight, and fast fabrication [1]. However, fatigue damage is found in welded connections of steel bridge decks due to long-term traffic load, residual tensile stress, and environmental corrosion [2, 3]. Fatigue cracks appearing in weld connections will further expand as time goes by, which seriously threatens the safe operation of the bridge.

Cut holes are placed in the diaphragms of modern steel decks, so that the U-ribs pass through the diaphragm continuously and the fatigue stress at the connection between the longitudinal ribs and the diaphragm can be significantly reduced. However, the cut hole reduces the stiffness of the diaphragm. Under the out-of-plane stress and in-plane stress, the stress concentrating at the edge of the cutout is large, plus influenced by factors such as the welding residual stress and initial crack. More research is need to investigate the fatigue performance at diaphragm cutout.

Extensive fatigue test of this detail has been carried out. For example, Haibach performed fatigue tests on the fatigue strength of various types of cutout and applied a new type of cutout[4]. Fryba et al. carried out tests on the type of cutout for open rib diaphragms and suggested that circular and apple shape cutouts should be used in OSD [5]. Wang et al. studied the influence of the shapes of cutout and geometry on the stress distribution at cutouts by static test and finite element analysis of a full-scale steel bridge [6]. The results showed that the stress distribution of the Haibach and circular shape cutouts were rational. Wang et al. carried out full-scale fatigue tests for OSD. The result showed that due to the welding residual stress, cracks were found in the compressive zone, which indicates that welding residual stress plays an

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