ARTICLE IN PRESS

Engineering Fracture Mechanics xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Engineering Fracture Mechanics

journal homepage: www.elsevier.com/locate/engfracmech

# Damage mechanism of slab track under the coupling effects of train load and water

Shihao Cao [a], Rongshan Yang [a,*], Chengguang Su [a], Feng Dai [a], Xueyi Liu [a], Xiaoyu Jiang [b]

[a] *MOE Key Laboratory of High-speed Railway Engineering, Southwest Jiaotong University, Chengdu 610031, PR China*
[b] *School of Mechanics and Engineering, Southwest Jiaotong University, Chengdu 610031, PR China*

ARTICLE INFO

*Article history:*
Received 1 November 2015
Received in revised form 30 June 2016
Accepted 7 July 2016
Available online xxxx

*Keywords:*
Slab track
Crack
Hydrodynamic pressure
Hydro-mechanical coupling

ABSTRACT

The damage mechanism of slab track under the coupling effect of train load and water was studied in this research. Based on the law of mass conservation and momentum theorem, the hydrodynamic pressure expression was derived by using the control volume method. The effects of load characters, water viscosity, and crack shape were analyzed in this paper. In order to describe the stress field singularity of crack tip, the quarter-points elements at the crack tip were established, and the maximum tensile-stress criterion and mixed fracture criterion were used to analyze the coupled hydro-mechanical fracture of slab track. Through the presented analysis, it was determined that, the effect of water viscosity on hydrodynamic pressure is negligible when crack aperture is greater than 2 mm, and the value of hydrodynamic pressure depends linearly on axle load and is proportional to the square of train speed. The train speed is an important factor to affecting the crack propagation, and the crack propagation rate increases with the increasing train speed. It is concluded from the research that the mixed-model fracture criterion is more appropriate to analyze the coupled hydro-mechanical fracture of slab track than the maximum tensile-stress criterion.

© 2016 Elsevier Ltd. All rights reserved.

## 1. Introduction

Due to the superior performance of high stability, excellent ride quality, and low maintenance, the slab track as the main track form has been widely used for high-speed railway systems. However, the interfacial crack is ubiquitous because of the improper construction and maintenance, and its propagated deterioration under the repeated train load and temperature variations is a concern. The site investigation indicates that the crack propagation is faster in the rain rich and poor drainage areas relative to the arid areas. This demonstrates that the coupling effect of train load and moisture may play an important role in the process of crack propagation.

The essence of slab track damage under the coupling effect of train load and moisture is a coupled hydro-mechanical (HM) fracture, and an accurate calculation of hydrodynamic pressure is the crux of the coupling analysis. Due to the complexity of hydrodynamic pressure, it was studied preliminarily in the slab track field [1]. Similar studies have also been done in other engineering fields such as highway, airfield runways, or the concrete gravity dam subjected to high hydrostatic pressure and seismic load. Some studies indicate that the water flow in the crack meets Darcy's law [2–5]. Tinawi and Li [6,7]

* Corresponding author.
*E-mail addresses:* 531148108@qq.com (S. Cao), 120637647@qq.com (R. Yang), suchengguang@126.com (C. Su), 840898782@qq.com (F. Dai), xyliu@home.swjtu.edu.cn (X. Liu), xiaoyujiang8@sohu.com (X. Jiang).

http://dx.doi.org/10.1016/j.engfracmech.2016.07.005
0013-7944/© 2016 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Cao S et al. Damage mechanism of slab track under the coupling effects of train load and water. Engng Fract Mech (2016), http://dx.doi.org/10.1016/j.engfracmech.2016.07.005

ARTICLE IN PRESS



**Nomenclature**

| | |
|---|---|
| F | load acting on the rail supporting bed |
| F′ | first derivative of the loading function |
| F″ | second derivative of the loading function |
| $v_{cm}$ | velocity of the crack mouth |
| $a_{cm}$ | acceleration of the crack mouth |
| $L$ | crack length |
| $h$ | crack aperture |
| $\theta$ | angle between two crack surfaces |
| $x$ | distance between the monitoring point and the crack tip |
| $\delta_x$ | displacement of upper crack surface |
| $\omega_x$ | crack aperture after load |
| $P_x$ | water pressure |
| $P_L$ | absolute pressure of water at the crack mouth |
| $P_{max}$ | maximum pressure of water at the crack tip |
| $P_{min}$ | minimum pressure of water at the crack tip |
| $m$ | mass of the control volume |
| $\rho$ | density of the control volume |
| $A$ | area of the control volume |
| $\Gamma$ | boundary of the control volume |
| $\mathbf{u}$ | velocity vector of control volume |
| $\mathbf{n}$ | outward normal of the control volume |
| $\mathbf{M}$ | momentum vector of the control volume |
| $\mathbf{F}$ | force vector acting on the control volume |
| $\beta(x)$ | deformation coefficient |
| $v_{x,y}$ | water velocity |
| $v_{x,m}$ | maximum water velocity |
| $\tau_{x,y}$ | shear stress |
| $\mu$ | dynamic viscosity coefficient |
| $\sigma_1$ | first principal stress |
| $\sigma_b$ | strength limit |
| S | displacement of the train |
| $K$ | stress intensity factor |
| $K_{eff}$ | effective stress intensity factor |
| $K_C$ | fracture toughness |
| $G$ | shear modulus |
| $u_i$ | nodal displacement in the $x$ direction |
| $v_i$ | nodal displacement in the $y$ direction |

derived the hydrodynamic pressure expression which is a function of the relative crack-opening acceleration and velocity. Further studies show that the seismic hydrodynamic pressure inside the crack is higher than the corresponding hydrostatic pressure. The hydrodynamic pressure experiment under sinusoidal load was conducted by Javanmardi and Xu [1,2], and the positive and negative pressures are considered to correspond to the stages of crack closing and opening, respectively.

There are some literatures on HM fracture research. The wedge splitting tests were conducted to study the crack propagation under mechanical load and hydrostatic pressure [8–11]. The reinforced concrete structures subjected to the same loads were investigated experimentally and numerically [5]. In the theoretical research, micro-fracture mechanics was adopted to analyze the effects of pore water pressure on the crack propagation, and the free water in the cracks accelerated the crack growth [12]. A formulation for the coupled hydro-mechanical behavior of zero-thickness interface elements was proposed [4,13,14].

Up to now, either uniform load or sine wave load has been used to analyze hydrodynamic pressure in the crack. Since the hydrodynamic pressure is a function of the loading acceleration and velocity, the loading process should be considered in the analysis. Therefore, selecting an appropriate load pattern is a key to analyze the damage mechanism of slab track under the coupling effect of train load and water.

In the research described in the paper, the hydrodynamic pressure expression was derived, and the effects of load characters, water viscosity, and crack shape were analyzed. The quarter-points elements around the crack tip were used to model the stress field singularity. The maximum tensile-stress criterion and mixed-model fracture criterion were used to analyze the HM fracture of slab track.

Please cite this article in press as: Cao S et al. Damage mechanism of slab track under the coupling effects of train load and water. Engng Fract Mech (2016), http://dx.doi.org/10.1016/j.engfracmech.2016.07.005

Download English Version:

https://daneshyari.com/en/article/7169438

Download Persian Version:

https://daneshyari.com/article/7169438

Daneshyari.com