Journal of Traffic and Transportation Engineering(English Edition)
2014,1(6):448-456

Rail temperature rise characteristics caused by linear eddy current brake of high-speed train

Xiaoshan Lu[1], Yunfeng Li[2], Mengling Wu[1], Jianyong Zuo[1,*], Wei Hu[3]

[1] *Institute of Railway Transit, Tongji University, Shanghai, China*
[2] *CSR Qingdao Sifang Locomotive Co., Ltd., Qingdao, Shandong, China*
[3] *École Nationale Supérieure d'Arts et Métiers, Angers, Pays de la Loire, France*

Abstract: The rail temperature rises when the linear eddy current brake of high-speed train is working, which may lead to a change of rail physical characteristics or an effect on train operations. Therefore, a study concerning the characteristics of rail temperature rise caused by eddy current has its practical necessity. In the research, the working principle of a linear eddy current brake is introduced and its FEA model is established. According to the generation mechanism of eddy current, the theoretical formula of the internal energy which is produced by the eddy current is deduced and the thermal load on the rail is obtained. ANSYS is used to simulate the rail temperature changes under different conditions of thermal loads. The research result shows the main factors which contribute to the rising of rail temperature are the train speed, brake gap and exciting current. The rail temperature rises non-linearly with the increase of train speed. The rail temperature rise curve is more sensitive to the exciting current than the air gap. Moreover, the difference stimulated by temperature rising between rails of 60 kg/m and 75 kg/m is presented as well.

Key words: high-speed train; linear eddy current brake; thermal load; rail temperature rise

1 Introduction

The traction and the braking are two main issues for a high-speed train (Zhu and Zhang 1996). As the drastic increasing in operation velocity of trains during recent years, the adhesion coefficient between the wheel and the rail at high speed decreases greatly as well as the coefficient of friction between the brake shoe and wheel. Therefore, it is necessary to use a non-adhesive braking system for a supplementary braking force (Chen 2008; Yan et al. 2010). The linear eddy current brake is such a non-adhesive form of non-contact brake system which has been already put into application on ICE3 (Chen 2001; Graber 2003; Kunz 2005; Treib 2013), shown in Fig. 1. The linear eddy current brake has distinguished advantages including no wear, no pollution, low maintenance, quick response and so on (Ding et al. 2012; Dong

* **Corresponding author**: Jianyong Zuo, PhD, Associate Professor.
E-mail: zuojy@tongji.edu.cn.

2007; Xu 2011). Thus, its application will greatly enhance the safety of train operation.

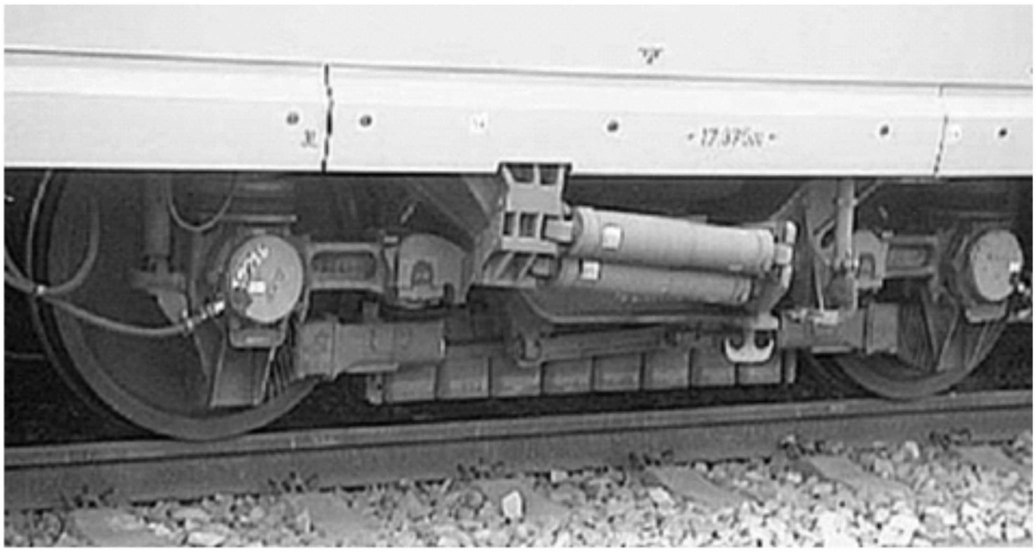

Fig. 1 LECB installed on ICE3

However, due to the energy conversion principle of train braking, the kinetic energy of the train is converted to other forms of energy and dissipated (Zhi et al. 1983; Zhu 1994; Zhang et al. 2011). The linear eddy current brake (LECB) achieves this by using eddy current effect converting the kinetic energy of the train into thermal energy of the rail. Based on the fact that the thermal energy on the rail caused by the eddy current effect can not be dissipated instantaneously, it will have a significant impact on the mechanical and electromagnetic performances of the rail and the effect of eddy current brake (Li et al. 2011). Therefore, a research on the rail temperature rise is necessary.

In fact, LECB is still in the experimental stage, which means it is not be widely commercially applied and there exist several problems itself. As to research on the rail temperature rise caused by LECB, some results have been obtained by German researchers and Japanese researchers respectively and lead the world in this domain (Hendrichs 1986; Kashiwagi et al. 2009). Both of them are based on the experiment. Other papers usually focus on the thermal characteristics on a magnet pole (Jung 2003). Nevertheless, a systematic research on thermal characteristics of rail affected by LECB is deficient, which is the main focus in the paper.

The study is set out based on simulation and a 3D-FEM model of LECB and rail is established. According to electromagnetic theory, the heat load on the rail is calculated before simulation so that the complex electrical-thermal coupling calculation can be avoided. The main factors of LECB that affect the rail temperature rise are studied.

2 Modeling for thermal simulation

Figure 2 (Schöpf 2008) illustrates the working principle of LECB in which F represents magnetic force, F_B represents braking force and F_A is attractive force. A LECB consists of the yoke, pole cores and coils. The magnetized directions of pole cores change alternatively. The LECB and the rail maintain a certain air gap (called brake gap). When the train is running, there is a relative movement between the LECB and the rail, which generates an unsteady magnetic field on the head of rail. According to Faraday's law of electromagnetic induction, eddy currents are generated on the head of rail, shown in Fig. 3. The eddy currents generated on the rail interfere in the original magnetic field and distort it. The electromagnetic force between the rail and LECB has a horizontal component along the direction of the train speed (direction Y) in addition to a vertical component (direc-