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Analysis on the fatigue cracks in the bogie frame

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ABSTRACT

Aiming at the problem that some fatigue cracks occurred in the bogie frame of B-type metro vehicles and based on the actual stress and acceleration time history, it is found through the comparison between time and frequency domains that the main reason resulting in the fatigue cracks is that the low-frequency wheel–rail impact due to rail joints and the exceeded out-of-roundness of wheels excite the natural vibration modes of the frame structure, and produce the high-frequency resonance from the frame transoms, eventually lead to the occurrence of fatigue cracks. Based on this, the suggestions for maintenance of vehicles and track routes are put forward.

1. Introduction

In recent years, rail transit has greatly relieved the urban traffic pressure, and due to its speedy, efficient and pollution-free features, it is also called the green transportation. At the same time, as the construction of infrastructure facilities, rail transit plays an important role in promoting the stable growth of economy and gets the strong support from local governments. By the end of 2014, urban rail transit had gone into operation in 22 cities in China mainland and there had been 83 operating lines and 2699.6 km length in total. Among them, Beijing subway operation mileage is 520.3 km, totally 18 operation lines [1]. B type metro vehicles are used mostly due to their low running cost, as shown in Fig. 1.

The operation feature of subway is that the departure interval of vehicles is short, and the operation time is long. Subsequently, the fatigue fracture occurred in a large number of bogie's components [2–7]. In 2012, the cracks occurred in the motor bogie frames of Beijing subway vehicles, and the cracked location was mostly in the middle of the transom, where was the welding positions between transom and vertical stop, shown in Figs. 2 and 3. These vehicles have so far operated for more than 5 years and the mileage is over 400,000 km. In order to find out the ultimate cause of the frame fatigue crack, an on-track test is carried out. During the test, some acceleration sensors and strain gauges are mounted on the bogie frame and axle boxes to obtain the acceleration and stress response information of the bogie. Through the comparative analysis of time domain and frequency domain by nCode Glyphworks [8], the underlying causes of frame fatigue damage are investigated.

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Fig. 1. B type metro vehicle.

2. Stress analysis

2.1. Stress analysis in time domain

During the analysis, we find that the stresses of the measuring positions near the vertical stop in the middle of transom are relatively high. A stress time history section (between two stations) at the welding position of the vertical stop and transom was taken as an example, as shown in Fig. 4, the peak stress reaches about 70 Mpa. After zooming in the stress in time domain and selecting S1 time, the “beat” phenomenon in waveform is obvious, as shown in Fig. 5. According to vibration analysis theory [9], the displacement solution of the no-damping structure under external excitation loads is:

$$x(t) = \left(\frac{p}{k}\frac{1}{1-\beta^2}\right)(\sin \varpi t - \beta \sin \omega t) \tag{1}$$

where:

p	amplitude of the excitation load;
k	structure stiffness;
ϖ	excitation load frequency;
ω	natural frequency of the structure;
β	frequency ratio.

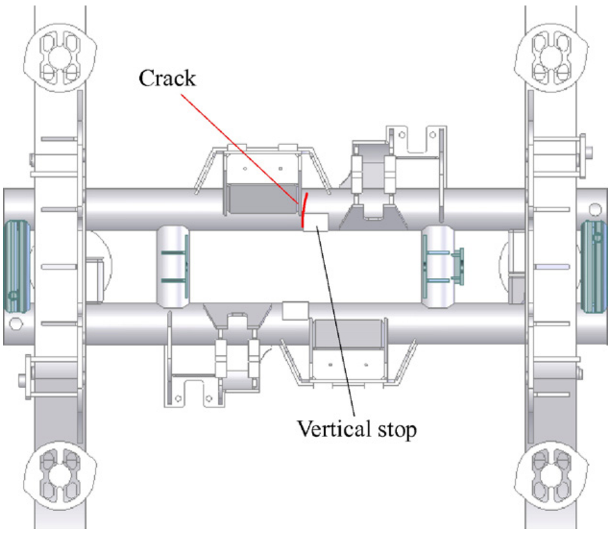

Fig. 2. Frame fatigue crack.