On-track Tests for the Running Stability of a Metro Trainset

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Abstract. A field test on-track was conducted to verify the running stability of a metro train according to UIC 515 through measuring the lateral acceleration on the bogie frame. In this test, various running speeds, load case, running directions and three track lines were examined. The test scope, method and specification are presented as well as the test instruments and data processing. It is found that the running stability in bogies of the trainset are quite different on various track segments. The stability performances of each bogie for a specific train under various load cases and running directions on various track segment are suggested to be examined.

1. Introduction

With the fast spreading of Chinese railway vehicle business, it is of great importance to verify the running stability through field test for future opportunity and reputation building. Running stability is critical to the ride comfort and safety of metro trains. Moreover, the operation companies are located worldwide, and they have constantly growing expectation for better dynamic performance. Thus, a field test is in need. Field test and service monitoring are common for high-speed trains [1-4], and lots of field test are carried out metro either.

2. Test scope and method

It is a 4-car train as illustrated in Fig.1 with car number and vehicle type (motor and trailer) declared. The trainsets were made by the CRRC Changchun Railway Vehicles CO., LTD in China. Test runs covers the whole Network of a metro railway. For verification purposes, the measurements were recorded at each test for both driving directions. In accordance to UIC 515 [5], a bogie is stable if the maximum lateral acceleration on the bogie frame measured over 6 consecutive cycles is lower than 8 m/s². Data are filtered with a band pass filter of 0.5 - 8 Hz before analysis. The velocity signal of the train was measured with a GPS, one part of the Data Acquisition & Recorder System. The signals of the acceleration sensors arriving on the recorder were checked and calibrated prior to the first test run. All sensors come with a calibration certificate provided from the manufacturer.

![Figure 1. Configuration of the tested metro trainset.](image-url)
High accuracy accelerometers were used to measure the accelerations of the bogie frame above the axle boxes and it would turn analog quantity into digital signals, which would be recorded by the data acquisition and recorder (HBM-eDAQ), as shown in Fig. 2. All the test equipment has been working well for long time service monitoring of high-speed trains, thus they would be qualified the test \cite{3,4}.

![Figure 2. Data Acquisition and Recording System on board.](image)

### 3. Test specifications

#### 3.1. Configuration of the accelerometers

The accelerometers were mounted on the top of frame end directly above the axle box and the cover of axle box as shown in the following Figure 3. All bogies of the tested train were equipped with accelerometer sensors. And the accelerometers were mounted respectively on the both two sides of the train. All record sheets for each single trip were analysed in accordance with UIC 515, the maximal acceleration amplitude exceeding 8 m/s² measured over 6 cycles should be detected.

![Figure 3. Configuration of the accelerometers on the bogie frame and axle box.](image)

#### 3.2. Pass/Fail Criteria

In accordance to UIC 515, a bogie is stable if the maximum lateral acceleration amplitude of the bogie frame measured over 6 consecutive cycles is lower than 8 m/s². If there is any deviation to these requirements, corrective actions such as measurement of the wheel profiles, rail profiles and the gauge have to be made, and the test has to be repeated under specified condition.

#### 3.3. Test cases

As required by the stability analysis specifications in UIC515, the test was done for the trainset in AW0 (tare load) and AW4 (crush load, 8 persons/m²) loading condition. The ATO means the vehicle running speed is controlled by the track operation speed according to the curves and superelevation. Whereas lines A and B are two separated lines that represent a newly built track and used for years track, respectively. The maximum operation speed is restricted by the track operation speed on different segments, in which in the limit is about 70 km/h. Additionally, a tangent track was chosen to have the trainset running with its maximum operation speed at 88 km/h. This case was to examine the running stability of vehicle for further higher operation speed condition.

### 4. Results and discussions

After the original signals were measured and recorded, the data was transferred from the electric signal to the acceleration. Then the data was filtered with a band pass filter of 0.5 - 8 Hz (Butterworth filter with 4 orders). As a result, a filtered time history of the bogie frame acceleration was obtained, and the amplitude is compared with the limit. The maximum acceleration of all eight bogie frames of the test trainset under Line A, Line B and Tangent track is plotted in Figs.4-5, Figs.6-7 and Fig.8, respectively.
Through the comparative analysis between load case, running direction, track segments, bogie types and positions among a trainset, several observations can be summarized. As depicted in Figs.4 and 5,

1) the lateral vibration on the bogie frames under AW4 load case is slightly higher than that under AW0 load case by approximately 25% regarding the averaged maximum value.

2) Moreover, the vehicle experiences a relatively better stability when it is downwardly operated (from segment S12 to S1) compared to the upward running case (from segment S1 to S12). This is explained that a different running stability was observed on the trainset when it runs on different directions along the railway line.

3) Furthermore, the running stability of bogies among a trainset is quite different, in which the leading bogie of a vehicle may experience a severe lateral vibration than that of a trailing bogie.

4) Additionally, the motor bogie suffers a heavy vibration than the trailer bogie for the tested trainset. It can be concluded that it is needed to examine the stability performances of each bogie for a specific train under various loading cases and running directions on track.

5) It is also noticed that, the track segments S1 ~S5 may have a poor irregularity than that of S6 ~ S12.

6) For all the tested cases on Line A, the trainset has a redundant running stability, which means the maximum acceleration always maintains smaller than 8 m/s². An exception is noticed on certain section from S7 to S8 (see Fig.5(a)), in which the acceleration exceeds the limit was observed once. However, the local time history plot Fig.5(c) shows that only one cycle is bigger than 8 m/s², less than the limits of 6 consecutive cycles, and the test results still meet the criteria.

Similar results can be found for the tests on Line B and Tangent track, as shown in Figs.6-7 and Fig.8, respectively. For line B, it has the same running stability behaviour as that on track Line A. Again, all the previously mentioned trends and finds out on line A can be observed on Line B. While for the tangent track case, as shown in Fig.8, the bogies of the trainset experience a relatively reduction on the lateral vibration by roughly 20% with respect to that on Lines A and B with curved tracks.

Figure 4. Maximum of the lateral acceleration on the bogie frames on Line A under AW0 when operating along (a) up and (b) directions.
Figure 5. Maximum of the lateral acceleration on eight bogie frames on Line A under AW4 when operating along (a) up direction, (b) down direction, (c) time history of the lateral acceleration on BG1 on S8.
Figure 6. Maximum of the lateral acceleration on eight bogie frames on Line B under AW0 when operating along (a) up and (b) down directions.

Figure 7. Maximum of the lateral acceleration on eight bogie frames on Line B under AW4 when operating along (a) up and (b) down directions.
Figure 8. Maximum of the lateral acceleration on eight bogie frames on tangent track segments under (a) AW0 and (b) AW4 cases.

5. Conclusions
The lateral vibration on the bogie frames under AW4 load case is slightly higher than that under AW0 load case by approximately 25%. A different running stability was observed on the trainset when it runs on different directions along the railway line. Furthermore, the running stability of bogies among a trainset is quite different, in which the leading bogie of a vehicle may experience a severe lateral vibration than that of a trailing bogie. Additionally, the motor bogie suffers a heavy vibration than the trailer one for the tested trainset. It is needed to examine the stability performances of each bogie for a specific train under various loading cases and running directions on track.

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