The Study of the Installation Angle of Anti-hunting Damper on Bench Test

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Keywords: Anti-hunting damper, Installation angle, Roller rig, Dynamic performance.

Abstract. In this paper, the effect of the installation angle of anti-hunting damper on the hunting stability and the ride index of high-speed trains was verified through tests on roller rig. Firstly, the roller rig and related test methods were introduced, and then the changes in the dynamic performance of the vehicle were analyzed based on the test results. The results show that the vehicle has a higher nonlinear critical speed when the anti-hunting damper is installed horizontally. The installation angle of the anti-hunting damper has a great influence on the vertical ride index of the vehicle. With the increase of test speed, the difference of vertical ride indexes of vehicles under the two installation angles increases, and the vertical ride index of the vehicle is poor when installed at an angle.

Introduction

The anti-hunting damper is a rotary damping device installed longitudinally between the car body and the bogie, which is crucial for improving the stability, ride performance and critical speed of the vehicle. A lot of researches have been carried out on the anti-hunting damper at home and abroad. The literature [1] studied the influence of the damper rubber joint stiffness on the critical speed of the vehicle; the literature [2] and [3] studied the influence of anti-hunting damper on the train stability; the literature [4] studied the relationship between the anti-hunting damper and the ride quality of vehicle; the literature [5] and [6] studied the influence of the installation position and installation method of the anti-hunting damper on the dynamic performance of the train.; the literature [7] studied the problems related to the installation angle of anti-hunting damper through simulation. At present, there is little research and experimental verification on the relationship between the installation angle of anti-hunting damper and the dynamic performance of the high-speed trains. Therefore, this paper takes the EMU with two types of anti-hunting dampers as the objects, and testing on the rolling rig to study the influence of installation angle of the anti-hunting damper on the dynamic performance of the high-speed train.

The Roller Rig and Test Method

The Roller Rig

Chengdu roller rig was built by the State Key Laboratory of Traction Power, Southwest Jiaotong University in 1995, and is mainly used for research and development of new railway vehicle. After renovation for high-speed vehicle test in 2014, the highest test speed of the Chengdu roller rig is 600 km/h, the amplitude of the excitation can reach ±10 mm in the lateral direction and ±15 mm in the vertical direction. The rolling vibration test bench consists of five parts: test cell, drive system, hydraulic system, data acquisition and processing system, and supporting infrastructure. The test unit and data acquisition and processing system will be briefly introduced in this paper.

The test bench consists of six test cells, each with a separate roller unit and drive system, as shown in the Figure 1(a). The drive system provides different speed and torque to the respective roller unit. The two rollers of the unit can achieve six degrees of freedom motion independently at different rotational speeds. The forward movement of the vehicle along the track can be simulated by the rolling of the roller. Through the lateral and vertical excitation input of the track wheel, the test
bench can simulate the irregular input of the track to realize various working conditions. The data acquisition and processing of the test bench test are completed in the central control room. As shown in the Figure 1(b), the main instruments used are: dynamic data acquisition system, computer, laser printer, plotter and so on.

![The test bench](image1)

(a) The test bench

![The center control room](image2)

(b) The center control room

Figure 1. The roller rig.

**Test Method**

Hunting stability and ride index are often used to measure the dynamic performance of high-speed trains. The items of hunting stability test are the linear critical speed without track disturbance and the actual critical speed disturbance. After the stability indexes are qualified, the ride indexes are evaluated by testing the acceleration and absolute displacement of multiple parts of the vehicle. Methods as below:

**Hunting Stability.**

*The Leaner Critical Speed.* The linear critical speed of vehicle can be defined as the speed at which the lateral movement of the wheelset relative to track roller occurs a vibration with relatively regular amplitude. When the roller rig rotate purely without excitation, the linear critical speed can be obtained by measuring and observing the lateral displacement of the wheelsets by gradually increasing the test speed with a small acceleration (less than 0.5 km/h/s).

*The Actual Speed.* The actual critical speed of the vehicle system corresponding to the track excitation is the speed at which the wheelsets still have lateral movement when the excitation of the roller rig is cancelled. This speed can be obtained by increasing the test speed at a specific acceleration (5 to 10 km/h), adding the corresponding track spectrum to the roller rig, and measuring the lateral movement of the wheelset.

**Ride Index.** In the range of 80~380km/h, the speed is graded, and the ride index test with the sampling time of not less than 180s is performed for each speed stage. The quantities to be tested are the lateral and vertical accelerations and absolute displacement of the car body and bogie, and the lateral and vertical relative displacement of suspensions.

**Influence of Installation Angle on Vehicle Dynamic Performance**

Taking the EMU which is equipped with powered bogie, and has a distance between two bogies of 17.375 m and wheelbase of 2.5 m, and the actual service speed on track is 250 km/h as the test objet, two anti-hunting damper A and B are installed respectively to compare the influence of horizontal installation and angled installation on the train dynamic performance. In order to avoid the sudden change of the critical speed of the vehicle system caused by the vertical relative motion between the car body and the bogie is too strong, the installation angle of the anti-hunting damper is 10°. The
installation angle is changed by fixing the connection point of the damper to the bogie and adjusting the connection height of the other point to the car body [7].

**Hunting Stability**

According to the test method, the stability test with Wuhan-Guangzhou track spectrum excitations was carried out on the roller rig in the speed range of 80~380 km/h.

The actual critical speed and the speed of the first stable limit cycle of the vehicle are shown in Table 1, it can be seen that both speeds of the vehicle are affected by changes in the installation angle of the anti-hunting damper. According to the scheme A, when the anti-snake damper is installed horizontally or at an angle, the nonlinear critical speeds of the vehicle system are 216 km/h and 188 km/h, respectively, and the speed is relatively reduced by about 13%; the actual critical speed of the vehicle system when the anti-hunting damper installed horizontally is 330km/h, 300 km/h for angled installation, and the speed is reduced by 9 %. The results show that for scheme A, the angular installation of the anti-hunting damper may reduce the hunting stability of the vehicle. It can be seen from the scheme B that the angular installation of the anti-hunting damper also reduces the critical speed of the vehicle.

<table>
<thead>
<tr>
<th>Testing Program</th>
<th>Actual critical velocity (km/h)</th>
<th>Nonlinear critical velocity (km/h)</th>
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</thead>
<tbody>
<tr>
<td>Anti-hunting Damper A</td>
<td>Horizontal Installation</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>Angled Installation</td>
<td>300</td>
</tr>
<tr>
<td>Anti-hunting Damper B</td>
<td>Horizontal Installation</td>
<td>&gt;380</td>
</tr>
<tr>
<td></td>
<td>Angled Installation</td>
<td>&gt;380</td>
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</table>

Figure 2 and 3 shows the comparison of the lateral movement of the axle box at each speed grade when the anti-hunting damper is installed at different angles. As shown in the Figure 2(a-b), the anti-hunting damper under the two installation angles has the similar influence rules on the lateral movement of the axle box when the test speed is 200km/h, and the difference is not big. The amplitude of lateral movement of the axle box increases gradually with the increase of test speed. In comparison, the lateral movement when the anti-hunting damper is installed at an angle is significantly larger than that at the horizontal installation, and the difference becomes larger as the speed increases. As shown in the Figure 3(a-b), the difference of the lateral movement of the axle box in the two installation modes of the anti-hunting damper presents out obviously when the test speed starts from 220 km/h, and the amplitude of the lateral movement is larger when the anti-hunting damper is installed at an angle, and the difference increases as the speed increases.
The anti-hunting damper is regarded as a hydraulic damper with two rubber joints, i.e. Maxwell model when analyzing its characteristics in this paper, and damping characteristics, spring stiffness and dynamic characteristics of liquid should be considered at the same time. When the end of the angularly installed anti-hunting damper is subjected to sin displacement input, the displacement and acceleration of the end position moving along the axial direction generate sin and cosine components respectively in the vertical and longitudinal directions, i.e. less than the damping value in horizontal installation. Therefore, the critical speed of the vehicle when the anti-hunting damper is installed at an angle is less than that when during horizontal installation.

Ride Index

The ride index of the vehicle directly reflects the running quality of the vehicle and is closely linked to the comfort of passengers. In this paper, the Sperling index is used to evaluate the ride index of the vehicle by bench test method. The effects of each damper on the vehicle ride index under different installation angles are shown in the figures below.

The stability indexes of anti-hunting damper A and B under different installation angles are compared respectively, and the trends are basically the same. It can be seen from the Figure 4(a) that when the test speed is less than 160 km/h, the lateral ride index of anti-hunting damper A is basically the same under the two installation angles, and the difference between the two starts to appear with the increase of speed, and when installed horizontally, it is slightly larger than when the damper A is installed at an angle, so is damper B. That is, the lateral ride index of the vehicle is slightly better when the anti-hunting damper is installed at an angle. As can be seen from the Figure 4(b) and 5(b), the vertical ride index of the vehicle is obviously affected by the installation angle of the anti-hunting damper, and the vertical ride index when the damper A or B is installed at an angle is greater than that when it is at a horizontal installation. With the increase of test speed, the difference of vehicle vertical ride index under the two installation angles of anti-hunting damper increases, reaching about 8% when the vehicle reaches the critical speed.

Figure 3. The Lateral Movement of Axle Box With Damper B.

Figure 4. The Ride Index of The Vehicle With Damper A.
When the vehicle is running, the vibration force generated by the longitudinal or nodding vibration of the bogie can be transmitted to the car body through the anti-hunting damper to excite the bending vibration of the car body, that is, to change the vertical acceleration of the car body [8]. According to Sperling index, the running quality of the vehicle is related to the vibration acceleration and frequency. Changing the installation angle of the anti-hunting damper will have an impact on the transmission of vibration force and torque, i.e. changing the bending vibration of the car body and further changing the vibration acceleration and frequency. Therefore, the ride index of the vehicle is affected by the installation angle of the anti-hunting damper, and the vertical influence is greater.

Conclusion

By installing different anti-snake dampers on the EMU, the bench tests of each anti-hunting damper under horizontal installation and angled installation were carried out on the rolling test rig. The results of comparative analysis are as follows:

i. The installation angle has an influence on the nonlinear critical speed and the actual critical speed of the vehicle, and the increase of the installation angle reduces the critical speed of the vehicle. When the anti-hunting damper is installed at an angle, the end part is subjected to sine displacement input, and the displacement and acceleration of the end part moving along the axial direction respectively generate sine component and cosine component in the vertical direction and the longitudinal direction, i.e. the damping value is less than that when the anti-hunting damper is installed horizontally.

ii. According to the results of the test, the change of anti-hunting damper has an effect on the ride index of the vehicle. The lateral ride index of the vehicle is better when installed at an angle, but there is little difference between the two. Due to the change of the installation angle of the anti-hunting damper, the damping has a attenuation in the vertical direction. Therefore, the vertical ride index in horizontal installation is better than that in the angled installation, and the difference between the two is obvious. As the test speed increases, the difference can be up to 8%.

Acknowledgment

This project is supported by National Natural Science Foundation of China (Grant No. 11790282) and National Key R&D Program of China (Grant No. 2018YFB1201702)

References


