Safety Analysis of Coupler Buffer in Heavy Load Locomotive when Emergency Braking on Long Steep Slopes

Xi-hong JIN¹, Yan-jun ZENG¹, Hai ZHANG²*, Qian XIAO² and Ji-ru XU²

¹The State Key Laboratory of Heavy Duty AC Drive Electric Locomotive Systems Integration, Zhuzhou, Hunan, China
²The Ministry of Education Key Laboratory of Conveyance and Equipment, Nachang, Jiangxi, China

Keywords: Heavy load locomotive, Emergency braking, Coupler buffer, Long steep slopes.

Abstract. With the rapid development of national economy, the heavy load transportation has become an important means in the field of railway freight transportation, and the heavy load locomotive equipment has also developed rapidly. However, in the actual operation, some road bureaus found that the elastic cement buffer QKX100 used on the heavy-duty locomotive would leak some cement when locomotive encountered long steep slopes. In this paper, on the basis of structure analysis of cement buffer, the heavy-duty train longitudinal dynamics model is built, and the longitudinal dynamic calculation is realized under the emergency braking of heavy duty locomotive. Combining the structure principle of cement core, the paper analyzes the causes of hook slow system’s failure and puts forward: in order to improve the buffer work state, the appropriate locomotive operation, the reasonable train Marshall and the stringent buffer production control should be adopted.

Introduction

Since the 1980s, countries, such as the United States, Brazil and Australia, have been developing heavy-duty transport technology, ushering in a new era of heavy-duty transport. In China, since 1992, since the first special electrified heavy load transport line -- Daqin line was finished, the high-power locomotive equipment has been developed rapidly[1; 2]. With the rapid development of the national economy, in order to meet the increasing requirements of the railway transportation market, the high-power electric locomotive, which is standardized, serialized, modular and information-based, has become the locomotive equipment which adapt to the heavy load transportation of China's trunk railway. HXD1 electric locomotive has been widely used in the heavy freight of railway trunk lines since it was finished in 2007. In actual operation, the HXD1 electric locomotive can meet the transportation needs of heavy load long marshalling freight trains at long-distance section and long ramp traction.

In the actual operation, with the longer online service time of HXD1 electric locomotive and the difference in actual operation lines, some road bureaus found that the buffer device QKX100 used on some individual locomotives had leaked cement, and this fault occurred frequently on several long steep slope sections in Lanzhou, Ankang and Urumqi.

Therefore, in this paper, according to this typical line condition, the longitudinal dynamics simulation software of CARS LCRI is used to conduct the longitudinal dynamics calculation of the heavy-duty freight train under emergency braking, to analyze the causes of the fault of the hook and relief system, and to propose the suggestions of application and maintenance based on the analysis results.

The Calculation Model and Simulation System of Train Longitudinal Dynamics

The Locomotive and Vehicle Model

The HXD1 in-depth homemade locomotive is a new heavy-duty locomotive with 8 shafts, double engine reconnection, 9600kW power and 2(B0-B0) axle.
(1) Basic requirements for locomotive power utilization
Under the pressure of network voltage from 22.5kV to 29kV, the locomotive wheel cycle power is 9600kW; If the network voltage increases from 22.5kV to 19kV, the wheel cycle power will decrease linearly from 9600kW. When the network pressure is at 19kV, the locomotive wheel cycle power is 8064kW; If the network voltage decreases from 19kV to 17.5kV, the cycle power will decrease linearly from 8064kw to 0; If the network voltage increases from 29kV to 31kV, the cycle power will decrease linearly from 9600kW to 0, as shown in Fig. 1.

(2) Traction characteristics
The traction characteristic curve and regenerative braking characteristic curve are shown in Fig. 2 and Fig. 3.

(3) The vehicle model
The truck used in the calculation is C70 gondola, with 25t axle weight and 70t load.

**QKX100 Buffer Model**
The QKX100 buffer is the elastic cement buffer, and the key component of the elastic cement buffer is the elastic cement core (the elastic cement core is the finished product imported from Poland). The structure diagram of the elastic cement core is shown in Fig. 4. The elastic cement core compresses the elastic cement in the core through the reciprocating motion of piston rod and dissipates energy through the internal friction between the elastic cement molecules and the friction generated by the intermediate damping hole [6; 7]. When the piston rod is compressed by external forces, the piston rod moves to the left and the one-way valve is locked, causing the elastic cement pressure on the left side of the piston rod to rise, and the elastic cement flows to the right through the annular gap, which enables the buffer to withstand pressure. When the external force is withdrawn, the one-way valve
opens, and the elastic cement flows to the left through the annular gap and damping hole, and the piston rod returns to its original position automatically under the internal pressure of the cement [8]. Characteristic curve of QKX100 shows in Fig. 6.

![Figure 4. Structure of QKX100 buffer.](image)

Figure 4. Structure of QKX100 buffer.

![Figure 5. Characteristic curve of QKX100.](image)

Figure 5. Characteristic curve of QKX100.

**Route Model and Train Marshalling**

The 291 km route between JingHe and HuoErGuoSi is used to calculate. The length of the line with slope over 15‰ is 116.6km, accounting for 40% of the whole line.

Formation: HXD1 locomotive dual engine reconnect 4500 ton train (46 C70 open cars).

**The Longitudinal Dynamic Calculation of Emergency Brake under Long Steep Slope and Analysis of Hook Buffer System**

**The Longitudinal Dynamic Calculation**

1. **Calculating Settings**
   Selecting the long steep slope of the line from 0 to 104 kilometers, and the slope of this section of the line with a slope of more than -15‰ is 68 kilometers, accounting for 65%. Operating mode is the emergency brake under the different initial braking speed from 100km/h to 40km/h.

2. **Analysis of calculation results**
   Table 1 shows the maximum hook force of emergency braking under different initial braking speeds, and table. 2 shows the value and position of the maximum acceleration of emergency braking under different initial braking speeds. Based on the analysis of the previous operating conditions, it can be concluded that when braking, the maximum pressure hook force of the train appears in the middle and rear of the train, and with the reduction of the initial braking speed, the maximum pressure hook force tends to gradually increase, while the maximum pressure hook force first increases and then decreases. When braking, the maximum acceleration at the rear of the train changes obviously, with positive and negative acceleration changes, and the longitudinal impact of the vehicle is huge.

<table>
<thead>
<tr>
<th>Initial braking speed (km/h)</th>
<th>Maximum hook force(kN)/Position</th>
<th>Percentage (%)</th>
<th>Maximum pull force(kN)/Position</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>184/40</td>
<td>0</td>
<td>249/28</td>
<td>0</td>
</tr>
<tr>
<td>80</td>
<td>198/44</td>
<td>7.61</td>
<td>265/28</td>
<td>6.43</td>
</tr>
<tr>
<td>60</td>
<td>179/47</td>
<td>-2.72</td>
<td>269/28</td>
<td>8.03</td>
</tr>
<tr>
<td>40</td>
<td>152/2</td>
<td>-17.39</td>
<td>271/19</td>
<td>8.84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Initial braking speed (km/h)</th>
<th>Maximum acceleration (m/s²)/Position</th>
<th>Percentage (%)</th>
<th>Maximum deceleration (m/s²)/Position</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1.86/47</td>
<td>0</td>
<td>-2.38/41</td>
<td>0</td>
</tr>
<tr>
<td>80</td>
<td>1.96/47</td>
<td>5.38</td>
<td>-2.82/45</td>
<td>18.49</td>
</tr>
<tr>
<td>60</td>
<td>2.06/47</td>
<td>10.75</td>
<td>-1.77/37</td>
<td>-25.63</td>
</tr>
<tr>
<td>40</td>
<td>1.89/28</td>
<td>1.61</td>
<td>-1.86/47</td>
<td>-21.85</td>
</tr>
</tbody>
</table>
The Analysis of Coupler Buffer System

The elastic cement in QKX100 buffer is a semi-fluid and compressible medium between fluid and solid. In normal operation, the sealing structure between elastic cement core piston rod and cylinder can fully meet the requirement of buffer. However, high pressure dynamic seal of over 35MPa hydraulic oil is still a worldwide problem.

On the other hand, when slight leakage of hydraulic cylinder dynamic seal occurred, supplement from pipes can be obtained, so trace leakage will not produce obvious problems, and still can be used normally. Management is need when large leakage occurs. However, due to the constraints of structure space, when leakage occurs, cement couldn't be added, which makes the dynamic seal of the QKX100 elastomer buffer much tougher than the hydraulic cylinder.

Combined with the structural principle of the cement core, the more complicated and harsh the circuit conditions, the more frequent the QKX100 elastic cement buffer will be used. However, the higher the frequency of the piston rod of the buffer, the greater the wear of the buffer seal ring and the greater the possibility of leakage of cement. The movable seal ring disassembled from the buffer can be found with wear in size and shape, as shown in Fig. 6.

![Figure 6. Photo of seal components in the buffer.](image)

According to the actual application data and leakage failure of QKX100 elastic cement buffer, the continuous long ramp is one of the external reasons for QKX100 elastic cement buffer to have more leakage failures.

Summary

In order to ensure the safety of QKX100 cement buffer under the condition of long steep slope, the following aspects should be started.

1. When braking, the maximum pressure hook force of the train appears in the middle and rear of the train, and with the reduction of the initial speed of braking, the maximum tension is gradually increased, while the maximum pressure hook force first increases and then decreases. When braking, the maximum acceleration at the rear of the train changes obviously, with positive and negative acceleration changes, and the longitudinal impact of the vehicle is huge.

2. There are many uncertain factors in the seal itself of the buffer, such as the material of the seal, the fitting size of the seal, the surface state of parts, surface roughness, internal pressure, etc. When they reach a critical point, they can also cause an abnormal leak of the buffer. Therefore, from the characteristics of the buffer itself, the quality control of the buffer production process should be

89
strengthened to ensure the quality of the product itself. If you follow the “checklist” your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

Acknowledgement
This research was financially supported by Research and Design project of the CRRC Zhuzhou locomotive co., Ltd. (2017KJ37); Qingdao Post-doctoral applied research project funding.

References