Research on Load Identification of Articulated Connector

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Abstract. With the further development of the piggyback transportation technology, the number of external loads, the action form and the effect of the articulated connector, which is a key component of the piggyback, are becoming more and more important references for strength design. Due to the complex and irregular structure of the articulated connector, it is particularly important to accurately identify the external load on the articulated connector structure during actual driving. Through the establishment of an eight-unit piggyback dynamic model, the longitudinal, lateral and vertical loads of the articulated connector under the excitation of the American five-level spectrum orbit were analyzed, and the identification schemes of the longitudinal, lateral and vertical loads of the articulated connector are proposed. It shows that each load identification scheme can identify the corresponding load more accurately.

1. Introduction
With the orderly progress of the construction of a powerful transportation country, the demand for the freight market is increasingly diversified, and piggyback transportation is a "door-to-door" mode of public-rail transportation, which can fully combine the advantages of railways and highways to improve transportation. Efficiency and service quality have good socio-economic advantages. China urgently needs to accelerate the research and development of key technologies for new transportation tools and promote the upgrading of equipment technology.

The new equipment piggyback has the advantages of saving the number of bogies used, making full use of axle load and shortening the connection distance of the vehicle. The articulated connector is a key component of the piggyback. Its structure is special and the stress is complicated. At present, there are few studies on load identification of the articulated connectors at home and abroad, so it is of great engineering significance to study the load identification of articulated connector.

Taking the load identification of the articulated connector as the research purpose, the short-group eight-pack piggyback dynamic model was established using SIMPACK software, and the longitudinal, lateral and vertical loads of the articulated connector under the excitation of the American five-level spectrum orbit were analyzed. And put forward the longitudinal, transverse and vertical load identification scheme of the articulated connector.

2. Structure and Principle
The articulated connector is mainly composed of a convex joint, a concave joint, a conversion sleeve, a slave plate, a slave plate pad, a wedge fast, a diagonal wedge, a traction pin, a support block, etc.
The convex joint composition includes a convex joint, a radial joint bearing, a block. The structure of the ring, shaft sleeve and articulated connector is shown in Figure 1.

Figure 1. Structure of articulated connector

Under the action of longitudinal tensile load, the transmission path of the longitudinal force of the articulated connector is: convex joint head-traction pin-conversion sleeve-concave joint large chamber end baffle-concave joint neck. The traction pin and the conversion sleeve restrict the rotation and movement of the concave and convex joints of the main parts of the articulated connector through the arc surface contact of the left and right sides; the upper surface of the support block and the convex joint head transmit the convex joint through the arc surface contact vertical force.

Under the action of longitudinal compressive load, the longitudinal force transmission sequence of the articulated connector is: convex joint head-pad from plate from plate-inclined wedge-wedge-recess of small joint cavity. A friction contact arc with a radius of 170mm is designed from the plate composition and the convex joint head. Due to the frictional contact with the arc surface, if there is relative motion between the two surfaces or tends to relative motion, then the corresponding will inevitably occur friction force, and this dynamic or static friction force can provide the corresponding friction torque, thereby limiting the relative movement of the two. The main function of the end baffle and conversion sleeve of the female joint head is to limit the rotation and movement of the female and male joints of the main connector when the articulated connector is deflected to the maximum position. Move upward from the inclined wedge between the plate and the wedge to reduce longitudinal impact.

3. Piggyback Dynamics Analysis

3.1. Eight-Unit Piggyback Dynamic Model

Because the built-in piggyback vehicle model has more degrees of freedom, if it is directly used as a calculation model without simplification, it will consume a lot of computer hardware resources, resulting in low calculation efficiency. Therefore, the piggyback model is simplified accordingly. Then, the piggyback model was established using the sub-structure method, which can truly reflect the actual situation of the eight-unit piggyback. The specific model is shown in Figure 2.

Figure 2. Piggyback model
3.2. Traction Formulation Simulation

Considering the complexity of the actual driving conditions, it is difficult to fully display the actual motion process using simulation software. Therefore, this simulation temporarily ignores the conditions such as turnouts and ups and downs, and sets up a track line with a length of 20 km. and this track line contains three typical curves with radii of 1000m, 1200m and 1400m respectively. Then the American quintuple spectrum is applied to the entire line to obtain the longitudinal, lateral and vertical load of the articulated connector. The longitudinal, lateral and vertical load are shown in Figures 3~5.

![Figure 3. Longitudinal load](image1)

![Figure 4. Lateral load](image2)

![Figure 5. Vertical load](image3)

It can be seen from the above figure: the longitudinal load obtained by simulation does not reflect the changing trend of longitudinal load during driving well. The lateral load is consistent with the data, and can roughly reflect the trend of lateral load changes during driving. The vertical load can not reflect the changing trend of the vertical load during driving, but it can reflect the time history of the actual vertical load of the plane track.

4. Load Identification of Articulated Connector

4.1. Longitudinal Load Identification Scheme

![a) Longitudinal stress](image4)

![b) Vertical stress](image5)

![Figure 6. Cloud image under longitudinal tensile load](image6)
As can be seen from Figures 6-7, the inner and outer rib regions of the upper and lower necks of the convex joint show a strong tensile stress response under the longitudinal tensile load, and a strong compressive stress response under the longitudinal compression. The surface of the actual environment is smooth, and it is convenient for patching, tooling and loading before the test. Therefore, the strain gauges are selected to be arranged on the ribs on the upper, lower, left and right sides of the neck of the convex joint. The longitudinal load identification scheme is shown in Figure 8.

![Figure 8. SMD bridge solution](image)

At the same time, the response at the load identification point when combined with other loads alone, the calculation results are shown in Table 1.

| Stress/MPa | Longitudinal tensile load | Longitudinal compressive load | Lateral load | Vertical load |
|------------|---------------------------|-------------------------------|--------------|--------------|
| e1         | 243                       | -249                          | 27           | -129         |
| e2         | -7                        | 12                            | 25           | -131         |
| e3         | 250                       | -261                          | 13           | 127          |
| e4         | -9                        | 5                             | -12          | 103          |
| e          | 509                       | -527                          | 27           | 26           |

It can be seen from Table 1 that the stress response of the selected load identification point under longitudinal tensile load and longitudinal compression load is 509MPa and -527MPa, which is much greater than the stress response of other loads at this load identification point, so the longitudinal load identification point can accurately identify the longitudinal load.
4.2. Vertical Load Identification Scheme

It can be seen from Figure 9 that the stress response of the upper and lower regions of the neck of the convex or concave joint is strong. In theory, they can be used as load identification points, but in order to improve the accuracy of the vertical load identification scheme, we need to choose a suitable location.

![Figure 9. Longitudinal stress cloud under vertical load](image)

Figure 9. Longitudinal stress cloud under vertical load

It can be drawn from Figure 10 that the stress values at the upper and lower edges of the convex joint neck have a small difference, but the stress values at the upper and lower ribs of the concave joint neck have a large difference. This shows that the neck of the concave joint is more suitable for the determination of the vertical load identification scheme, and it is convenient for patching, tooling and loading before the test. Therefore, the strain gauges are arranged on the upper and lower sides of the neck of the convex joint. The vertical load identification scheme is shown in Figure 11.

![Figure 10. Longitudinal stress cloud under longitudinal load](image)

Figure 10. Longitudinal stress cloud under longitudinal load

![Figure 11. SMD bridge solution](image)

Figure 11. SMD bridge solution

At the same time, the response at the load identification point when combined with other loads alone, the calculation results are shown in Table 2.
Table 2. Response at load identification point

| Stress/MPa | Longitudinal tensile load | Longitudinal compressive load | Lateral load | Vertical load |
|------------|---------------------------|-------------------------------|--------------|---------------|
| h1         | 275                       | -328                          | -5           | -125          |
| h2         | 260                       | -285                          | 2            | 121           |
| h3         | 258                       | -275                          | -7           | -148          |
| h4         | 281                       | -330                          | 3            | 139           |
| h          | -8                        | 12                            | -17          | -533          |

It can be seen from Table 2 that the stress response of the selected load identification point under vertical load is -533 MPa, which is much greater than the stress response of other loads at the load identification point, so the vertical load identification point can accurately identify the vertical load.

4.3. Lateral Load Identification Scheme

![Figure 12. Longitudinal stress cloud under lateral load](image1)

It can be seen from Figure 12 that both the medial side of the upper and lower side ribs of the concave joint neck are subjected to compressive stress, and both lateral sides are subjected to tensile stress and the stress response is strong. The surface of the actual environment is smooth, and it is convenient for patching, tooling and loading before the test. Therefore, the strain gauges are arranged on the upper and lower ribs of the neck of the concave joint. The lateral load identification scheme is shown in Figure 13.

![Figure 13. SMD bridge solution](image2)

At the same time, the response at the load identification point when combined with other loads alone, the calculation results are shown in Table 3
Table 3. Response at load identification point

| Stress/MPa | Longitudinal tensile load | Longitudinal compressive load | Lateral load | Vertical load |
|-----------|--------------------------|-------------------------------|--------------|---------------|
| k1        | 253                      | -32                           | 85           | -129          |
| k2        | 251                      | -35                           | -79          | -135          |
| k3        | 279                      | -123                          | 142          | 131           |
| k4        | 268                      | -109                          | -164         | 127           |
| k         | 13                       | -11                           | 470          | 10            |

It can be seen from Table 3 that the stress response of the selected load identification point under the lateral load is 470 MPa, which is much greater than the stress response of other loads at the load identification point, so the lateral load identification point can accurately identify the lateral load.

5. Conclusion
Based on the dynamics, the identification schemes of longitudinal, lateral and vertical loads of articulated connectors are proposed, and the patch positions and bridge assembly methods are explained. Then the response of each load at each load identification point is analyzed, which shows the accuracy of each load identification scheme.

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7. References
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