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A Self-Acting Radial Bogie with Independently Rotating Wheels

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As the independently rotating wheels can individually rotate around its axle while the axle itself not rotated, so its axle can be made into cranked axle and thus the floor height of the vehicle can be lowered, therefore the independently rotating wheels are generally adopted in low-floor light rail vehicles. As known, the longitudinal creep force plays a key role in the guidance of wheelset, whereas the independently rotating wheels can't generate longitudinal creep forces, so it has a poor guidance capability: on the tangent track, the independently rotating wheels usually run to one side of the track and can't restore the center of the track; on the curved track, the independently rotating wheels have larger attack angle, which usually causes the flange contact rail. Therefore, the independently rotating wheels not only causes serious wheel-rail wear but also increases the risk of derailment.

In order to solve the guidance problem of independently rotating wheels, a self-acting radial bogie with independently rotating wheels has been put forward in this paper. Its sketch map is shown in the broken line frame of figure 1. The bogie is made up of two single-axle bogies linked by a flexible coupled machine, so it also is called as the flexible coupled bogie with independently rotating wheels.

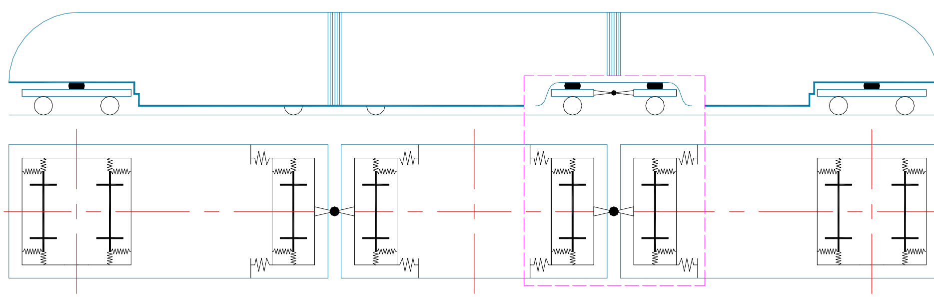

Figure 1: the sketch map of flexible coupled bogie with independently rotating wheels

According to the contrastive conditions of figure 2, the radial capability of the flexible coupled bogie with independently rotating wheels can be intuitively understood.

Figure 2(a) shows the two-axle bogie with independently rotating wheels running on a curved track. Since the No. ́ñand No. ́òwheelsets are constrained by the same frame, so the No. ́ñwheelset come into being a positive attack angle and

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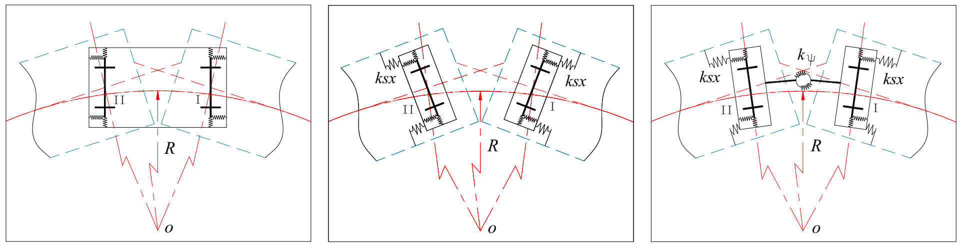

(a) Two-axle bogie (b) Single-axle bogie (c) Flexible coupled bogie

Figure 2: Conditions of the three types of bogie with independently rotating wheels running on curve track

No.£òwheelset has a negative attack angle on the curved track, which indicates that the No.£ñand No.£òwheelsets can not outspread enough to achieve the radial position on the curved track.

Figure 2(b) shows the case of single-axle bogie with independently rotating wheels running on a curve track. Since the No.£ñand No.£òwheelsets are not constrained by the same frame but by the respective car bodies, so the No.£ñwheelset come into being a negative attack angle and No.£òwheelset has a positive attack angle on the curved track, which indicates that the No.£ñand No.£òwheelsets outspread too much to achieve the radial position on the curved track.

By further analyses, it is known that the reason why the front and rear wheelsets of the two-axle bogie can not outspread enough to achieve the radial position on the curved track is that the constrain on wheelsets applied by the rigid frame is too great, while that of the two single-axle bogies outspread too much to achieve the radial position on the curved track is the absence of some necessary constrain between the two wheelsets. However the flexible coupled bogie can make up for the drawbacks of the former two types of bogies. When a appropriate coupling stiffness for the coupled bogie is chosen, the No.£ñand No.£òwheelsets would advisably outspread to achieve the perfect radial position on the curved track(showed in figure 2(c)), which is just the intention of the flexible coupled bogie with independently rotating wheels put forward in this paper.

How to choose the appropriate coupling stiffness for the flexible coupled bogie with independently rotating wheels? Some theoretical analysis are done as follows:

Since the primary suspension stiffness of single-axle bogie is far greater than its secondary suspension stiffness, therefore in theoretical analysis, the frame and the wheelset can be considered as a whole and the yaw motion equation of bogie can be written as follows:

$$I_{\mathrm{B}z}\left[\ddot{\psi}_{\mathrm{B}i}+v\frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{1}{R_{\mathrm{B}i}}\right)\right]=M_{\mathrm{W}zi}+M_{\mathrm{S}zi}+M_{\mathrm{C}zi} \tag{1}$$

Where: i= 1, 2, 3, 4; I_{B_z} denotes the yaw inertia of single-axle bogie; ψ_{Bi} is the yaw angle of single-axle bogie; v is the vehicle running speed; R_{B_i} is the radius of curved track; $M_{\mathrm{W}zi}$ is the yaw deflection torque produced by the wheel-rail forces; $M_{\mathrm{S}zi}$ is the yaw deflection torque produced by secondary suspension forces; $M_{\mathrm{C}zi}$ is the yaw deflection torque produced by flexible coupled machine.

When a train steady-state running on curved track, the left side of the equation (1) is equal to zero, while on the right side, the yaw deflection torque $M_{\mathrm{W}zi}$ which mainly generated by the the longitudinal creep force is very small and it can be ignored. So the equation (1) can be written into:

$$M_{\mathrm{C}zi} + M_{\mathrm{S}zi} = 0 \tag{2}$$

$$M_{\mathrm{S}zi} = -2k_{\mathrm{S}x}b_{\mathrm{S}}^2[\psi_{\mathrm{B}i} - \psi_{\mathrm{C}} + (-1)^i\frac{l}{R}] \tag{3}$$

$$M_{\mathrm{C}zi} = (-1)^i k_\psi[(-1)^{i+1}\psi_{\mathrm{B}i} - (-1)^{i+1}\psi_{\mathrm{B}(i\pm1)} + \frac{2b}{R}] \tag{4}$$

Where: i= 1, 2; $k_{\mathrm{S}x}$denotes the one side secondary suspension longitudinal stiffness; K_ψ is the yaw angle stiffness due to the coupled machine; $k_{\mathrm{C}x}$ is the one side longitudinal coupling stiffness between the front and back bogies; b_{S} is half of the secondary suspension lateral span ; b_{C} is half of the coupled machine lateral span ; l is half of the nominal distance between front and back bogies centers; b is half of the coupled bogie wheelbase; R is the radius of the circle curve; ψ_{B} is the yaw angle of bogie; ψ_{C} is the yaw angle of car body.

Considering the displacement of the wheelsets and the deformation of the suspensions system are far shorter than the length of the nominal distance between front and back bogies centers$2l$, thus the central part of the car body is approximately tangential with the circle curve, i.e.$\psi_{\mathrm{C}} \approx 0$. When a train steady-state running on a circle curve track, in order to let the front and rear wheelsets of the coupled bogies achieve radial position completely, must have$\psi_{\mathrm{B}i} = \psi_{\mathrm{B}(i+1)} = 0$. So that, based on equations (2) $\sim$ (4), we can obtain:

$$k_\psi\frac{2b}{R} = 2k_{\mathrm{S}x}b_{\mathrm{S}}^2\frac{l}{R} \tag{5}$$

Reduces to

$$k_\psi = b_{\mathrm{S}}^2\frac{l}{b}k_{sx} \tag{6}$$

It is known from the equation (6) that the coupling stiffness k_ψ is only relational with the inherent configuration parameters (such as l, b, b_{S}, b_{C}) of the train system and the secondary suspension longitudinal stiffness $k_{\mathrm{S}x}$, yet irrespective to the external condition parameters(such as speed of the train and curve radius of the track), which means that as long as the coupling stiffness $k_{\psi}$is selected according to equation (6), whatever external condition(curve radius and speed)change, the leading and trailing wheelsets of the coupled bogie can run automatically to radial location by the coordinated operation of the flexible coupled machine and the secondary suspension systems of the vehicle. So the coupled bogie is also called as the self-acting radial bogie with independently rotating wheels.