Wear and Energy Saving Bogie Design with Rubber Primary Springs – Principles and Experiences

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Abstract: The traditional radial steering bogie with swing hanger links is known as track-friendly but heavy, expensive in investment- and maintenance-costs. Whereas the actual rigid axle bogies like Y25 cause severe wear on wheels and rails in curves and also need high traction forces in curves.

Bogies with rubbers springs like DRRS, LEILA and Gigabox are a new feature with good behaviour in curves and on straight tracks. Good experiences over many years with DRRS and 35 t axle load on the German RWE coal line prove the benefits. For the new designs LEILA and Gigabox, which are in market introduction now, even higher benefits can be demonstrated. The principle design features and the benefits regarding lateral track forces, wear and traction resistance are evident.

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1. DEMANDS OF BOGIE

Besides the general demands like low cost and high reliability from the dynamic point of view there are two main demands:

1. low dynamic forces
2. stable running

Low dynamic forces are reached by good uncoupling by soft springs and the avoidance of resonances by damping. There is a general difference between friction damping and hydraulic damping. The latter usually is combined with rubber springs.

2. DESIGN EXAMPLES

Figure 1
Leaf spring bogie with swing hangers of RWE Power for 35 t axle load, vmax 65 km/h

Figure 2
Wedge damping device of the three-piece bogie
The leaf-spring bogie has several friction mechanisms. At vertical deflections there is relative movement between the several spring leaves. Additionally the swing hangers rotate around the pins, which give additional friction damping. In lateral and longitudinal direction this kind of friction damping is the only damping method available.
mechanism. Most times the movements in all three directions of motion are coupled. For instance if a lateral track fault occurs the wagon does not move only lateral but it will tilt also and therefore vice-versa movements in the leaf-spring occur which also damp the lateral movement.

At the three-piece bogie a normal force \( N \) is applied by the spring-load on the wedge, which causes force \( R \) on the friction-surface, see figure 2. Of course this effect also occurs on the other, in figure 2 not sliced side of the bolster.

This friction mechanism does not only work in vertical direction but also in lateral direction as long as the slack admits this kind of movement.

At the Y25 bogie the friction damping is very similar to the tree piece bogie. An inclined link, so called Lenoir link causes a load relevant normal force \( N \) between an axle box and a piston. Between the piston and the axle box and also on the other side of the bearing between axle box and bogie frame a friction force occurs.

This friction force is not only working in vertical direction but also lateral.

The main advantage of friction damping is that load sensitiveness can be implied easily. But there are several disadvantages:

With friction always some kind of wear is implied. This always means maintenance costs. As the friction surfaces always are open to the surrounding environment there are huge influences whether it is dry or wet weather, whether there are some aggressive media like iron dust around or not.

But also the behaviour from principle has some problems, Figure 4.

The spring force and the friction force must be regarded together. For small forces and small displacements the arrangement is very stiff. The nominal stiffness of the spring is reached at huge displacements only which occur for instance at a twisted rail in situations prior derailments.

The much better damping mechanism is hydraulic damping. Figure 5.

The force amplitude is fixed with \( \pm 10 \) kN. The higher the excitation frequency is the smaller is the amplitude of movement and the higher the dissipated energy per cycle. The dissipated energy is equivalent to the surface in the ellipses of the graph.

This behaviour is very good as damping increases with higher speeds.

The older rubber spring design DRRS (double rubber ring spring), figure 6 still uses friction damping similar to figure 3. Because of this no significant longitudinal movement of the axle boxes and no significant wear reduction in the wheel-rail contact is possible. Nevertheless the behaviour is better than with leaf spring bogies.

Just the newer design of the LEILA[1] bogie with inside bearings enables a soft longitudinal rubber primary suspension, figure 7. It can be shown that with this design energy savings of up to 25 % compared to stiff bogie design can be achieved [2]. Damping is achieved with two vertical hydraulic dampers per axle box.

With the inside bearings there are huge advantages possible as more space for the application of rubber springs and dampers and also much simpler designs for the cross anchors. There is a significant reduction of the angle of attack between wheel and rail. Figure 8 shows measured results of the difference of the angle of attack of a Y25 bogie and a Leila bogie in a 300 m radius of a 180° tunnel “Leggistein” on the Gotthard Northramp in Switzerland. It is obvious that a reduction of more than 60 % is achieved. This means that the angle of attack is more than halved. This gives huge benefit not only regarding wear of wheel and rail but also in traction force reduction or speed increase with the same traction force.
At the primary spring design Gigabox, figure 9, there is a so-called hydro spring included: Inside the rubber spring there are hydraulic viscous damping systems which give damping forces in all three directions. With this design very few elements are used in the suspension system. Even the slack adjustment is integrated into the element.

3. CONCLUSION

Friction damping in bogies was used for one and a half century in rail-freight. Right now it seems obvious that there are many advantages regarding live cycle costs so that hydraulic damping will replace friction damping during the next decades.

Reference

