Structure of an Independent-wheel-system Bogie with a DDM and its Performance at High Speed

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We have developed a new-concept bogie for gauge-changeable trains that is applicable to both standard gauge 1,435-mm line and meter gauge 1,067-mm line. The bogie must therefore feature good running stability at high speeds on standard gauge lines as well as high running performance on the curves of meter gauge line. It adopts a direct-drive motor system to enable the motor to be mounted directly to the wheels, an independent wheel system and a wheel-set steering system. The independent wheel system provides the bogie with good running stability at high speeds with a short wheelbase. We tested the model on our rolling stock test machine, and confirmed that no stability problems occurred at speeds of up to 500 km/h. We also conducted high-speed performance testing at the Transportation Technology Center Inc. in Pueblo, Colorado, USA, and on the Sanyo Shinkansen line in Japan at speeds of over 200 km/h.

Keywords: independent wheel system, high-speed performance, direct-drive motor system, gauge-changeable bogie, steering system

1. Introduction

In Japan, standard gauge lines are used for Shinkansen tracks, while other lines adopt the meter gauge type. This means that, for trains operating on both Shinkansen and meter gauge lines, a gauge-changeable bogie applicable to both types is needed.

We began development of the type A bogie, which adopts the cardan drive system. The purpose of developing the type B bogie was to enable comparison of the performance between independent and non-independent wheel systems.

This paper discusses the high-speed performance of the type A bogie and its construction.

2. Construction of the bogie

The type A bogie is characterized by an independent wheel system and wheel sliding on the axle in the axial direction. In the interests of simplifying its construction, we selected a direct-drive motor system to enable the
motor to be mounted directly to the wheels (Fig. 1). The independent wheel system provides the bogie with good running stability at high speeds with a short wheelbase (2,200 mm). However, the lack of a self-steering function on this system may result in large lateral forces, and the wheel flange may wear when negotiating small-radius curves on meter gauge line (1,067 mm). To address this problem, the bogie is designed with a forced-steering system that steers the wheelset with links according to the relative angle of yaw between the car body and the bogie (Fig. 2).

3. High-speed performance

3.1 Test on a rolling test machine

We tested the first prototype bogie, the RT-X5, on our rolling stock test machine. The bogie’s wheelbase is 2,100 mm, and the spring stiffness of the axle box is almost the same as that of a commercial Shinkansen bogie (Table 1). No stability problems causing hunting were found at 450 km/h, but the temperature of the bearing at 450 km/h was over its allowable limit. This is because its dN value exceeds 500,000 at 450 km/h, and the bearing size was designed for an axle load of 12.5 t. For comparison, we then connected the wheels on both sides with a sleeve and tested it. The speed limit for hunting was 150 km/h. At high speed, small amounts of high-frequency vibration were observed as a result of the small clearance between the axle box and the axle box beam (Table 2).

We tested the next prototype bogie, the RT-X7, on our rolling stock test machine. For this model, the bearing was miniaturized, and an oil seal was attached to the bearing to improve lubrication performance. There was no clearance between the axle box and the axle box beam, and the wheelbase and spring stiffness of the axle box were the same as those of the RT-X5. No stability problems causing hunting were found at a speed of 500 km/h (Table 3).

Based on the test results of the RT-X5 and RT-X7 bogies, we designed RT-X9 and RT-X10 bogies for running with a test train on a commercial line. The basic construction of the wheelset in the RT-X9 and RT-X10 bogies is the same, but for negotiating small-radius curves on meter gauge line (1,067 mm), their forced-steering systems were different.

The difference between the RT-X9 and RT-X10 bogies is in the layout of the link between the Z-shape link and the car body. The RT-X9 bogie has links directly connecting the car body with the Z-shape link, while the RT-X10 has a steering beam in the same way as a bogie with a bolster, and links connect the steering beam with the Z-shape link.

For the steering system, the longitudinal spring stiffnesses of the axle boxes in the RT-X9 and RT-X10 bogies were made lower than those of the RT-X5 and RT-X7. We tested both bogies on our rolling stock test ma-
No stability problems causing hunting were found at a speed of 350 km/h. This test was limited to 350 km/h in line with the allowable limit of the motor's rotation speed. We judged that running stability can be maintained at speeds of over 350 km/h, and testing without a steering link confirmed that there were no stability problems causing hunting. When we tested the RT-X9 bogie without one yaw damper, rolling vibration was observed, but was not seen with the RT-X10. It can therefore be concluded that this vibration came from the coupled vibration of the bogie's yawing movement and the rolling movement of the car body.

### 3.2 Running test

We conducted high-speed performance and endurance testing at the Transportation Technology Center Inc. in Pueblo, Colorado, USA. The maximum speed for the test of the RT-X9 and RT-X10 bogies was 243 km/h (Fig. 3). In testing without one yaw damper, rolling vibration was observed on the RT-X9 bogie.

We then conducted high-speed performance testing on the Sanyo Shinkansen line in Japan at over 200 km/h, and confirmed stability at high speeds. The results of running tests on the RT-X9 and RT-X10 bogies confirmed that the independent-wheel-type bogie with a steering system offers good stability at high speed, and that the RT-X10 bogie with a steering beam is more stable than the RT-X9 model.
4. Improvement of the bearing system

We improved the lubricating performance for bearings, which are the most important mechanical parts of high-speed bogies. The dN value (diameter x number of rotations) indicates the high-speed performance of bearings, and the value for commercial Shinkansen models is almost 220,000. However, for the type A bogie, the inner diameter of the bearing is over 200 mm because the diameter of the axle and sleeve is large, giving it a dN value of almost 340,000. Table 4 shows the relevant specifications. Additionally, the wheel rotates with the motor, so the outer race of the bearing also rotates. Grease in the bearing is therefore pushed out by centrifugal force, and lubricating performance decreases.

Figure 4 shows the bearing temperature in the bench test. At 270 km/h, it reached the limit value of 120°C in one hour. The mechanical performance of the bearing thus had no problems at speeds over 300 km/h, but as its temperature is limited by the dN value, the speed limit of the bearing for commercial use is 240 - 270 km/h.

To improve the lubricating performance, we tried an open-type bearing followed by a sealed-type bearing, and then developed a new type of bearing with an internal grease pocket (Fig. 5) that has a lubrication life five times longer than that of the open-type bearing.

We then tried a structure lubricated with oil (Fig. 6). The lubricating condition of the bearing’s roller is favorable, with oil pressed to the outer race by centrifugal force. As the temperature of the seal becomes high, we developed a system to reduce pressure in the oil pan.

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5. Conclusions

We tested two types of bogie with an independent wheel system and a steering system for a gauge-changeable train with an axle load of 12.5 t. The results obtained are outlined here:

6. References