Development of a High Speed Shinkansen Bogie




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Development of a new bogie targeting improved running safety and stability, riding comfort, and reliability is being performed in order to increase Shinkansen speed. New configuration elements such as driving device and axle bearings for the bogie are being used. A first prototype was made beforehand and its performance and long term durability were confirmed through bench tests. Currently they have been installed on a Shinkansen high speed test train and running performance confirmation is being pursued.

• **Keywords:** High speed Shinkansen bogie, driving device, axle bearing, brake disk, and brake lining

1 Introduction

In conjunction with the development of a high speed Shinkansen bogie, in addition to performance (running safety and stability, and riding comfort) compatible with great increases in driving speed, ensuring of reliability when running at high speeds, and use for service operation based on long term durability and ease of maintenance must all be considered. Therefore, configurations including use of new structural elements were reviewed for the main structural parts of the bogie. In addition to significant investigation of the strength and performance through numerical analysis at the investigation stage, a first prototype was built and performance tests and long term endurance tests through bench testing were performed for confirmation.

bogies for which development proceeded in this manner has been installed on a Shinkansen high speed test train and performance confirmation is being performed through actual running tests. Here, with regard to the development details and development process for the high speed Shinkansen bogie, the bogie and the main parts such as driving device, axle bearings, and brake components are mainly introduced.

2 Development details

2.1 Structure of bogie being developed

In order to achieve stable running at a maximum driving speed of 360 km/h, new parts must be used for the important structural components such as the driving device, axle bearings, and brake components. Furthermore, for the bogie in general, enhanced running safety and stability and riding comfort as well as enhanced reliability, durability and maintainability were targeted during development. In order for the target speed to greatly exceed the current operating maximum speed, the load conditions necessary for design were set based on data obtained using test train cars built in the past.

The primary characteristics of the bogie thus developed are the following items.

(1) In order to enhance running safety and stability, the stiffness of primary suspension was optimized.

(2) In order to enhance vertical riding comfort, the vertical rigidity of the primary suspension and secondary suspension was optimized.

(3) In order to enhance horizontal riding comfort, the horizontal rigidity of the secondary suspension was optimized.

(4) In order to enhance horizontal riding comfort, the bogie has been equipped with an electromagnetic active suspension control system.

(5) In order to increase permitted speed on curves, an air spring stroke type body tilting control system has been installed.

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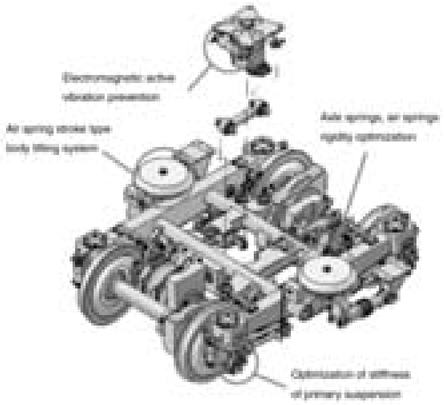

Fig.1: Bogie configuration

Even if the technical target are the same, as a unique thought process for achieving this can not be established, it was decided to build 3 types of bogies with different detailed structures for this development, install them on a high speed test train and perform comparative evaluations of them based on actual running tests.

2.1.1 Development A type bogie

This uses a method of linking the bogie frame and axle box using an arm integrated with the axle box (guide - arm - type) and a configuration of placing one electromagnetic actuator for active suspension control. (Fig. 2)

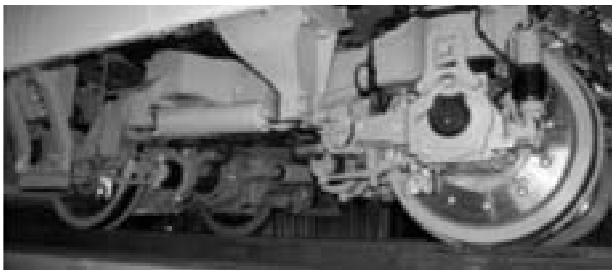

Fig.2: Development A type bogie

2.1.2 Development B type bogie

This uses a method of linking the bogie frame and axle boxes using plate springs (leaf - spring - type) and a configuration of placing one electromagnetic actuator for active suspension control. (Fig. 3)

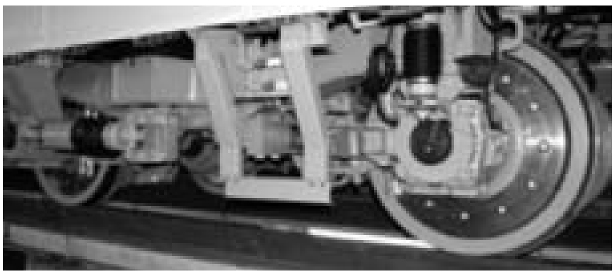

Fig.3: Development B type bogie

2.1.3 Development C type bogie

This axle box suspension uses the guide arm type suspension for the A type bogie and uses a configuration of placing 2 actuators for active suspension control. A section (bolster) of the conventional train car body construction materials were switched over for use as structural materials of the bogie (body supporting beam), which has enabled weight reduction for the train car as a whole and simplification of the work required for attaching and detaching of the bogie. (Fig. 4)

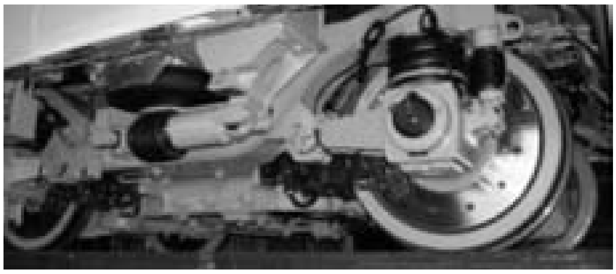

Fig.4: Development C type bogie

2.2 Driving gear unit

2.2.1 Gear unit

In conjunction with the increase in running speed, the load on the driving gear unit that transfers rotation of the motor to the wheels is intensified. Here with the targeting of enhancing reliability and reducing noise, double helical gears that do not generate force in the axial direction in conjunction with the transfer of torque to the gear unit were used. As conventional helical gears generate a force in the axial direction when torque is transferred, a taper roller bearing that requires fine clearance adjustment during assembly of the axle bearing was required. Through use of double helical gears the axle bearing was relieved of force in the axial direction enabling use of cylindrical roller bearings that do not require clearance adjustments.

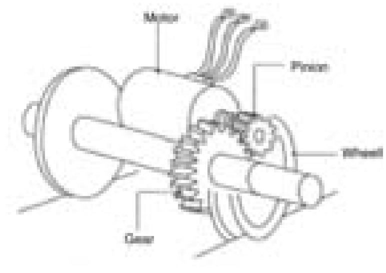

Fig.5: Configuration of the driving gear unit

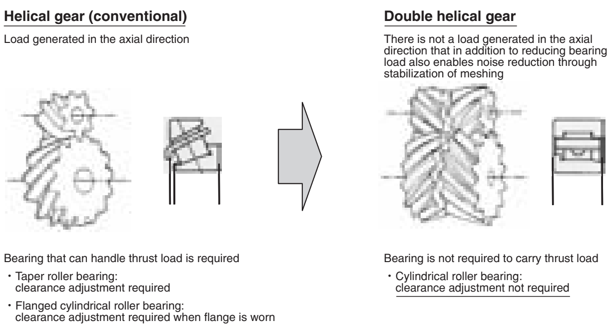

Fig.6: Gear configuration [1)]

2.2.2 Axle coupling

As described previously, the stiffness of the primary suspension for the bogie that has been developed has been reduced to improved vertical direction riding comfort; therefore, the displacement between the traction motor axle and the pinion axle has gotten large. Therefore, 2 types of axle couplings (gear type axle coupling and TD coupling) that have reduced rotation noise and that are compatible with this amount of displacement have been developed.

2.3 Axle bearings

The vibration acting on the axle bearing when increasing running speed from 275 km/h to 360 km/h roughly doubles. Therefore, because durability would be reduced through use of conventional bearings, enhance in reliability and durability of the bearing is essential for enabling increase in speed. In addition, it is important to confirm the performance beforehand.

Several types of bearings including oil lubrication type and grease lubrication type were created for this development and a performance test was implemented on a bench test device described later. As a result, because there are issues with temperature rise and sealing characteristic for the lubricating oil with the oil lubrication type, the grease lubrication type was selected and, in addition, a configuration that suppresses attack on the wheel axle was adopted.

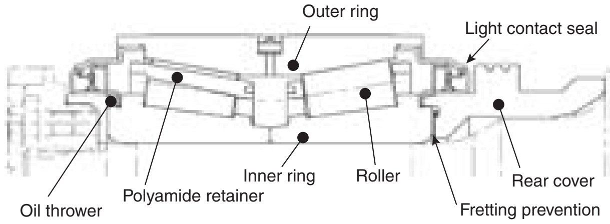

Fig.7: Axle bearing

2.4 Brake components

Brakes that can sufficiently absorb braking energy from high speed and that reduce heat generation and wear have been developed.

2.4.1 Brake disk

Central fastening structure that suppresses warping of disk due to brake heating and reduces stress applied to the fastening bolts was adopted.

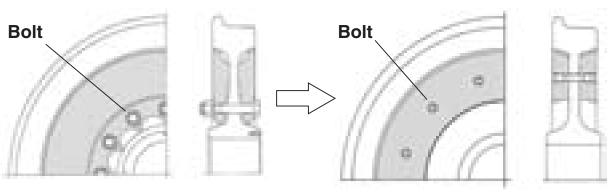

Fig.8: Brake disk configuration

2.4.2 Lining

In addition to enhancing the material, a segmentation configuration that enables uniform contact on the disk was selected.

3 Performance test

Conventionally, part based performance testing such as for driving gear unit and axle bearing were implemented using a bench test device; however, performance testing for the bogie has been performed through actual running in most cases [2]. However, in recent years, running performance confirmation (prior confirmation) that is implemented using bench tests [3] with a bogie or train car has increased. In this case, for the development of the bogie, as running speed will be increased greatly, a first prototype was built and focus on performance testing based on bench tests was pursued.

Performance testing results for bench tests are as shown below.

3.1 Bogie performance test results

The evaluation of bogie characteristics was primarily implemented on the rolling stock test rig at the Railway Technical Research Institute where running stability and riding comfort were confirmed.

As a result, it was confirmed that all of the developed bogies were able to run without stability issues at speeds higher than 400 km/h. Furthermore, confirmation concerning riding comfort was also obtained and items where improvement is needed were reflected in the specification of the bogie for the test train.

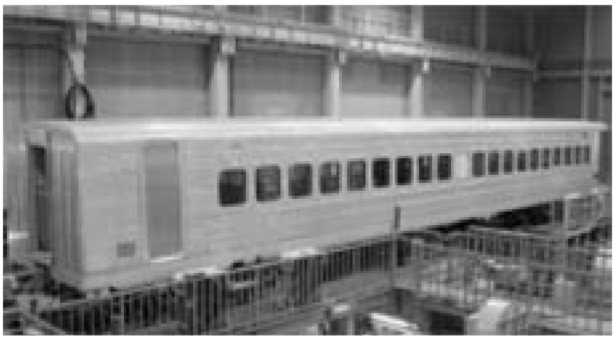

Fig.9: Test on rolling stock test rig
(Railway Technical Research Institute)

3.2 Driving gear unit performance test results

Tests related to temperature (high acceleration test at low temperature and driving test at room temperature) and surrounding area noise measurements were performed. It was found that the new train car has equivalent or better favorable characteristics than the driving gear unit of conventional train cars with respect to tests related temperature even at 360 km/h and with respect to surrounding area noise, it was found that a reduction effect compared to current levels had been achieved.

3.3 Axle bearing performance test results

As a result of comparing temperature characteristics for oil lubrication type and grease lubrication type, it was found that when running at 400 km/h the oil temperature for the oil lubrication type became 120℃ where the oil starts to deteriorate and on the other hand the grease lubrication type was roughly half of that temperature. Furthermore, in the case of oil lubrication type, there was an oil leak (after 30,000 km) showing that achieving compatibility of the seal structure with high speed traveling is difficult.

3.4 Brake components performance test results

As a result of performing emergency braking 80 or more times starting at 400 km/h, the following items were learned.

(1) Warping of disks has been reduced to approximately 1/4 that of current components and there was basically no wear, to the extent that the wearing depth was below capability of measurement.

(2) Segmented lining suppresses generation of hot spots on the disk and melting of the lining and maintains a coefficient of friction better than current components even for speeds exceeding 360 km/h. Furthermore, wearing depth was also reduced below 1/5 of current components.

4 Long term endurance test

In order to certainly achieve safe and reliable high speed traveling while the train car is being used over a long term of time, it is necessary to amply confirm reliability and durability for each of the components beforehand in addition to bogie performance. However, until recently test device that could implement long term testing with the loads seen during traveling did not exist except for a small subset, and durability evaluation required installation on an actual train car and driving it for a prescribed period.

Evaluation using existing train cars is not feasible with this level of increase in speed however, several new elements need to be installed on a development bogie to enable ample prior verification. Here, the research and development center used the bogie testing equipment equipped at the Omiya General Rolling Stock Center where a 600,000 km endurance test was implemented on a prototype bogie under the conditions of a traction motor drive that uses a load absorption mechanism and vibration excitation of actual railroad tracks and in the end traveling of 650,000 km was reached on the test device. This was a round the clock test with maximum speeds of 400 km/h for 124 days making it an extremely severe test.

Fig.10: Long term endurance test (bogie testing device)

The driving gear unit and axle bearings were disassembled and inspected after the completion of the endurance test and it was found that there were no non-conformances that would affect safety.

5 Conclusion

Development details related to a high speed bogie were introduced and this developed bogie has been installed on a high speed Shinkansen test train and running performance is currently being confirmed.

In the future, in order to create a bogie and bogie components that are safe and reliable, confirmation of high speed performance, durability, and maintainability through driving tests is planned to further enhance the level of completeness.

References

1) Mechanical Engineering Handbook, B application, B1 mechanical element design-Tribology pB 1-108

2) For example, Sasaki et al, Use of test stand for development of Shinkansen Bogie, Mechanism theory, No. 02-50 (2002) p 175-178

3) For example, Iwanami et al, riding comfort enhancement countermeasures testing using E2 series 1000 Shinkansen train car, Mechanism theory, No. 02-50 (2002) p. 169-170