Technical Review

Nippon Steel Corporation's Characteristic Technology and Future Prospects of Product Technology for Railway Parts

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Abstract

Nippon Steel Corporation began manufacturing tires for railway parts in 1919, and has been manufacturing railway parts such as wheels, axles, and bogies for more than 100 years. Those products manufactured by Nippon Steel have greatly contributed to the safety and running performance of rolling stock, and we have been developing highly functional products while ensuring safety. In this paper, we report the products we have developed and present our future prospects.

1. Introduction

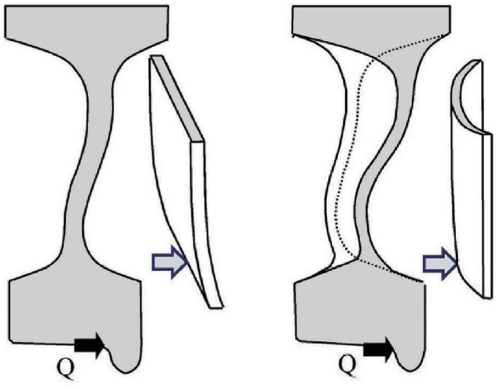
The Railway, Automotive & Machinery Parts Unit of Nippon Steel Corporation has been developing and manufacturing railway parts, such as wheels, axles, and bogies, contributing to railway services in Japan. Although the characteristics that railway parts require should vary according to product type, safety is the only commonly demanded performance element. Nippon Steel has been developing highly functional products that are lightweight and have excellent high-speed stability while ensuring safety. This paper introduces Nippon Steel's proprietary products and presents its future prospects.

2. Nippon Steel's Proprietary Products

2.1 Wheel axles

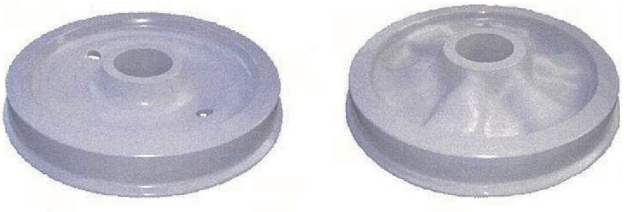
Wheels and axles are critical safety parts and they greatly contribute to the safety of railway operations. Nippon Steel has also been developing wheels and axles as its main railway parts. Nippon Steel's proprietary wheels are corrugated wheels developed for weight reduction.[1] As shown in **Figs. 1** and **2**, making the web wavy in the circumferential direction can enhance the rigidity against lateral force. Thanks to the enhanced rigidity, the plate thickness can be reduced by approximately 30%, which achieves weight reduction.

Regarding the other critical product, we developed induction hardened axles for the operation start of Shinkansen and then developed hollow-bored axles considering the needs for speedup and weight reduction of such trains. Induction hardening the surface of axles can impose compressive remaining stress. The given compres-



(a) Normal wheel (b) Corrugated wheel

Fig. 1 Concept of web design of the corrugated wheel



(a) Solid wheel (b) Corrugated wheel

Fig. 2 Corrugated wheel

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sive remaining stress works to reduce occurrences of fretting cracks, which are the main cause of damage on axles. Regarding hollow-bored axles, as the name indicates, holes are bored at the center of axles to reduce the weight. A general hollow-bored axle that is currently used in Shinkansen is lighter by approximately 50 kg.

We design wheels and axles based on the JIS and JRIS standards. As described above, wheels and axles are critical safety parts; if they become cracked or damaged, this may directly result in a derailment and other serious accidents. Specifications that were determined based on past experience have been used. Recently, evaluation techniques (e.g., stress analysis, fatigue testing, and flaw detection techniques) have advanced, which is making precise design possible. We will propose reviewing the design specifications in the future as well and develop wheels and axles with higher functions (lighter and more reliable) while ensuring safety.

2.2 Brake discs

Nippon Steel manufactures brake discs for high-speed rolling stock (mainly for Shinkansen). Shinkansen has adopted wheel-side discs for which discs are fastened to both sides of a wheel with bolts. When the service of Shinkansen first began, cast iron was used as the material. As the train speed increased, the use of forged steel began because it is stronger than cast iron. In addition, the disc structure has changed significantly in recent times. At first, the inner connection type was adopted; in the structure, a disc is fastened at the inner circumference section. Currently, the center connection type is the mainstream; in the structure, a disc is fastened at the center section of the sliding surface so as to reduce the weight and enhance the reliability of the engaged section. Nippon Steel has been developing both inner connection and center connection types, contributing to the safety of Shinkansen. **Figure 3** compares the inner connection and center connection types. The weight of a single center connection type brake disc is lighter by approximately 20 kg than that of an inner connection type disc. In addition, the shape of center connection type discs differs significantly from that of inner connection type discs. Accordingly, when the brake is applied, thermal deformation on the center connection type disc is smaller and thereby more braking force can be applied, which makes it possible to shorten the braking distance. Another advantage is that the reliability of sections fastened with bolts is significantly higher. The actual application of the center connection type to Shinkansen began in 2011.

To further enhance the reliability, we have been developing brake pads in addition to brake discs and have developed flexible pads (refer to “Development of New Brake Pads for Shinkansen” in this issue).

(a) Inner connection type (b) Center connection type

Fig. 3 Brake disc

2.3 Driving devices

Our other main products since the company’s founding are gears for rolling stock. The current mainstream is cardan driving devices in which large and small gears are put into a gear box, it is installed onto an axle, and a motor and the gear unit are coupled with gear-shape flexible couplings. There are two types of cardan driving devices: Right-angle cardan driving device in which a motor is placed at a right angle to the axle and parallel cardan driving device in which a motor and the axle are coupled in parallel. Considering maintainability and other factors, parallel cardan devices are used for Shinkansen and narrow-gauge trains in general. As their gears, helical gears are used.

As the speed of rolling stock increased, the noise of peripheral equipment was reduced, and people living along train lines became more aware of the environment, and therefore, there were greater needs for noise and vibration reduction. Accordingly, in 2004, we developed and introduced a loading rotating test rig installed in an anechoic chamber to evaluate the quietness and vibration characteristics of driving devices. We used this testing machine to invent tooth surface modification that can reduce gears’ meshing vibration greatly and thus can improve the quietness significantly, and we obtained a patent for the invention. This technology has reduced the noise of actual rolling stock and a wide variety of users have adopted these low-noise driving devices, valuing those highly.

In addition to noise reduction, to further enhance the reliability, we have developed double-helical gear units. The product is now used for in-service Tokaido, Sanyo, and Nishikyushu Shinkansen. As shown in **Fig. 4**, the conventional helical gear unit involves tapered roller bearings because a thrust force (load in the axial direction) occurs. To prevent excessive loads from working on such bearings, the clearance needs to be periodically adjusted. On the other hand, Nippon Steel’s proprietary double-helical gear unit eliminates the need for adjusting the clearance. In addition, the elimination of thrust force reduces loads to be applied to the bearings by approximately 20%, which in turn leads to higher reliability and longer service life of the bearings. However, double-helical gears cannot be manufactured by simply applying conventional manufacturing technologies. Accordingly, to mass produce such gears, we developed processing technologies and introduced special finishing machines and machining tools.

2.4 Bogies

All damping devices, such as springs and dampers, are installed on railway bogies. Accordingly, the performance of bogies determines most of the running performance. When rolling stock runs a curve, the wheels move along the rails. The wheels have been inclined at the sections (wheel treads) at which the wheels come into contact with the rails. This makes the radii of the wheels larger at the sections at which they are in contact with the outer rail of a curve and those of the wheels smaller at the sections at which the wheels are in contact with the inner rail. This allows the rolling stock to turn the curve (**Fig. 5**). Even for a curve in which a wheel set can smoothly turn thanks to the difference in the diameters between the inner and outer wheels, a bogie passes such a curve with the wheel flanges guided by the rails; because the wheel axles have been joined to the bogie frame with high rigidity springs, the rotation direction of the wheels becomes different from the travel direction of the rolling stock (attack angle). At this time, a load (lateral pressure) occurs between the wheel flanges and the rails in the direction to derail the wheels. For subway rolling stock that runs many

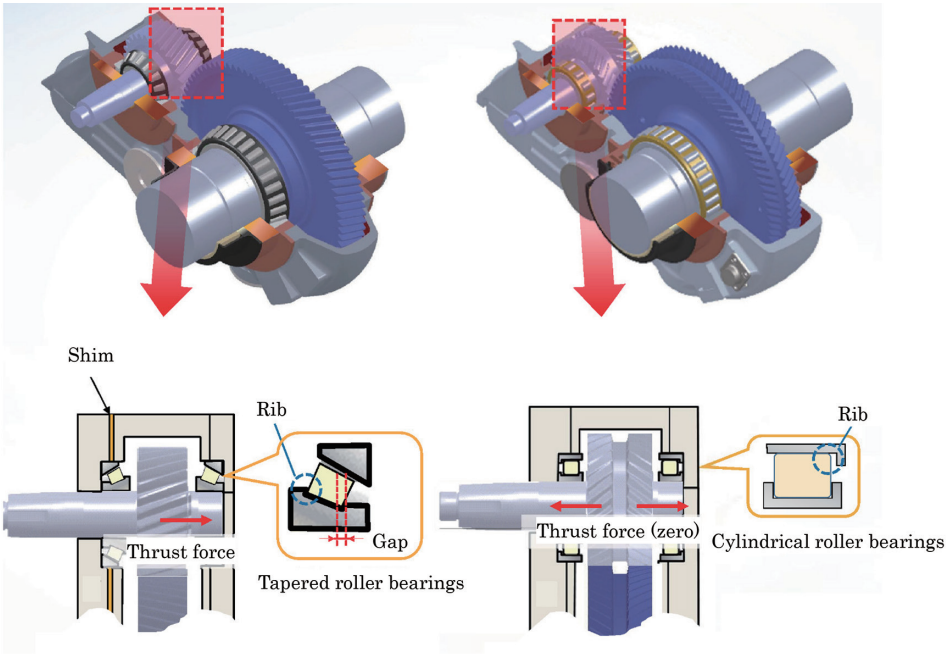

Fig. 4 Gear unit for railway

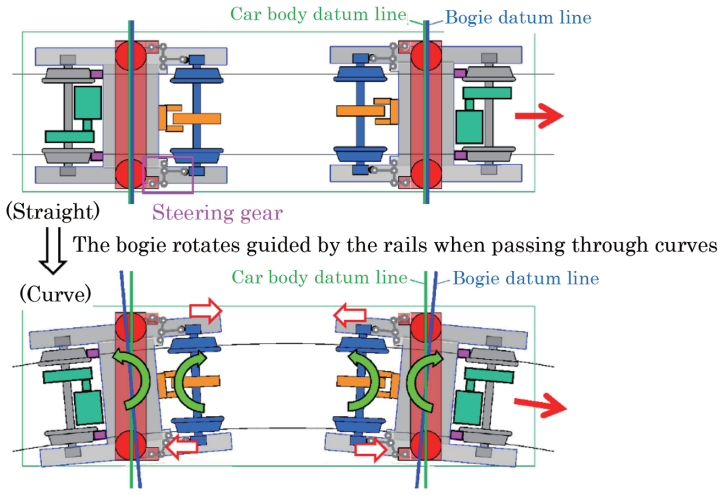

Fig. 5 Concept of steering bogie

curves, conditions for lubrication between wheels and rails have been considered to reduce lateral pressure. To further reduce lateral pressure, Nippon Steel developed steering bogies (**Fig. 6**). Nippon Steel's bogie-angle linked steering bogies have a link function added to conventional bogies. When rolling stock runs a curve, the link mechanism transmits the bogies' rotation (behavior) against the rolling stock to the wheel axles so as to turn the wheel axles. Compared to the conventional bogie, when rolling stock with the steering bogie passes a curve, the attack angle is smaller and thereby the lateral pressure applied to the wheel flanges is also smaller. Accordingly, the noise from the contact of the wheels with the rails is smaller. In addition, the running resistance when rolling stock runs curves is also lower (according to Nippon Steel's verification results, the use of steering bogies can reduce the electric power consumption when rolling stock runs curves by approximately 42%) and CO_2 emissions are expected to be reduced by 1 100 tons per year.

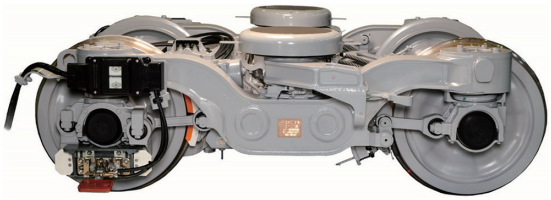

Fig. 6 Steering bogie for railway vehicle

3. Summary and Future Prospects

This paper introduced the main proprietary products of Nippon Steel. Although safety comes first when rolling stock products are designed and developed, we are planning to review the design standards and specifications going forward while ensuring safety. Using new design specifications makes it possible to develop more new products. Nippon Steel has been contributing to reducing environmental stress through the weight reduction of wheels and axles and the noise reduction via the development of double-helical gears and steering bogies. We will continue to develop new products in the future as well in anticipation of the next 100 years of railway operations.

Reference

1) Okagata, Y.: Design Technologies for Railway Wheels and Future Prospects. Nippon Steel & Sumitomo Metal Technical Report. (105), 26–33 (2015)

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