Recent Research and Development Activities in Vehicle Technology

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RTRI was involved in approximately 280 research themes in the fiscal year 2017 to 2018. Among them, 46 were related to rolling stock technology, covering a wide range of themes, in practical, applied and fundamental research, such as: the increase in train running speed and improvement of ride comfort, the applied research such as the running stability and reliability of rolling stock, and elucidation of the mechanisms leading to wheel wear. Three topics from this research and described in this paper are: “Quantitative evaluation of wheel flats affecting vehicle bogie behavior,” “Development of a 3-Dimensional measurement device for wheel profiles” and “Evaluation of the running safety of railway vehicles in case of air spring deflation.”

Keywords: rolling stock, running safety, speeding up, riding quality

1. Introduction

As part of its long-term vision “RISING” (Research Initiative and Strategy - Innovative, Neutral, Global -) which sets the future direction to be taken by research, and in order to realize this vision, the Railway Technical Research Institute (hereinafter referred to as RTRI) drew up the 5-year basic plan “RESEARCH 2020 - Creating Innovative Technologies” for the fiscal years (FY) 2015 to 2019. During the third year of this five-year plan in 2017, each division/laboratory engaged in research linked to rolling stock reviewed their progress, with a view to prioritize work and target outcomes to meet railway operator needs. The change in the total number of Research & Development themes at RTRI, and change in the number of Research & Development themes undertaken by vehicle system laboratories in RTRI for the past 5 years are shown in Fig. 1. There are 9 vehicle system laboratories in total, including the Vehicle Structure Technology Division, Vehicle Control Technology Division and Railway Dynamics Division. Between them, they have engaged in about 40 themes at the beginning of each fiscal year. The total number of themes covered at RTRI shown by points joined by a line in Fig. 1 fluctuates between 270 to 290, and the vehicle system themes correspond to about 15% of the total number.

Fig. 1 Number of implementations of the themes researched in vehicle related laboratories (beginning of FY)

When classifying the number of vehicle related areas covered in FY 2017 (46 cases at the beginning of fiscal year) according to the directionalities of Research & Development, 40% involve “Improvement of safety,” as shown in Fig. 2, a trend generally reflected throughout RTRI, in particular, articles regarding improvement of running safety & collision safety, and diagnostic and assessment technologies. In vehicle systems research the number of themes related to “harmony with the environment” and “improvement of user convenience” was twice as high as in other RTRI research divisions, i.e. projects including topics such as energy saving measures or trackside noise reduction, and increasing running speeds and ride comfort, etc.

An example of this type of cross-cutting cooperation is in work relating to safety of vehicles against cross winds and fire prevention, where the vehicle systems division will communicate with the Environmental Engineering, Material Technology, Disaster-prevention Technology, Human Science, etc. divisions in the course of their work.

As examples of recent achievements in vehicle systems research in this regard, the following section gives a brief overview of the outcomes to: “Quantitative evaluation of impact of wheel flats on vehicle bogie behavior,”

Fig. 2 Classification of themes according to R&D directionality of 9 vehicle system laboratories in FY 2017

“Development of a 3-Dimensional measurement device for wheel profiles” relating to influence of damaged wheels on vehicles, and “Evaluation of the running safety of railway vehicles in case of air spring deflation,” on running safety.

2. Evaluating influence of damaged wheel treads on vehicles

2.1 Quantitative evaluation of impact of wheel flats on bogie behavior

Damage to wheel treads such as flats, can cause abnormal vibrations, and it may lead to complications such as the shaking loose of parts on vehicles etc. Accordingly, in order to understand the influence of wheel diameter and degree of damage exerted on bogie vibrations, the rotation tests on a test bench were performed, using a wheelset that had been given artificially generated wheel flats (Fig. 3 and Fig. 4).

Establishment of the correlation between peak values in vertical vibration acceleration on the axle box and running speed, confirmed that the maximum vibration acceleration appears at about 30 km/h, and demonstrated that the influence of wheel flat length was significant, whereas the influence of wheel diameter was not (Fig. 5). Furthermore, from time-series waveforms of vertical displacement and vibration acceleration of the axle box, it was confirmed that high vibration acceleration is generated by the impact of

Fig. 3 Rotation test of a wheelset on the test bench with artificially added wheel flats on the wheel tread

Fig. 4 Implementation state of rotation tests on the test bench

Fig. 5 Influence of wheel diameter and flat length

Fig. 6 Evaluation of time required for axle box to descend due to vertical vibration acceleration

the wheel as it rises, descends and collides with the roller surface due to the wheel flats (Fig. 6).

Furthermore, the relationship between the time required for the wheel to commence its descent to collision and running speed (Fig. 7), demonstrated that, as the running speed increased, collision occurred further back on the wheel flat, and then at certain speeds and above the vibration acceleration fell because vertical displacement (descent) of the axle box was smaller (Fig. 8).

These results confirm that wheel diameter only has a small influence on the maximum vertical vibration acceleration of the axle box generated by wheel flats, but increases with wheel flat length. The vibration acceleration of axle box vertical displacement (descent) of the axle box also show that the point of collision between wheel tread near the wheel flat and the roller (of the test bench) varies in the circumferential direction, depending on the running speed, it was confirmed that the vertical vibration acceleration of the wheelset peaks at a certain speed.

Based on this insight, the following sections in the paper determine the actual shape of damage, and elucidate the influence of wheel tread damage on bogies.

Fig. 7 Relationship between transit time and collision point

Fig. 8 Estimated descent of axle box and collision position (for a wheel flat length = 60 mm)

2.2 Development of a three-dimensional measuring instrument for wheel tread profiles

Based on the above, it is necessary to accurately determine actual wheel tread damage. Existing rotational roller contact type profile measurement instruments however, cannot measure small concavities and convexities such as peeling flaws, etc., making damaged wheels profile measurement difficult. A three-dimensional measuring instrument for wheel tread profiles was therefore developed, using a high-precision two-dimensional laser displacement gauge (Fig. 9).

This instrument can measure tread profiles for entire wheel circumferences, by rotating a wheelset while supporting the axle boxes with jacks, etc., and while measuring the rotating angle of a wheel by means of a roller encoder touching the wheel tread (Fig. 10). In addition, by changing the measurement jig, it is also possible to measure the local damaged wheel tread profile without rotating the wheelset by in situ inspection (Fig. 11).

By measuring the tread profile at a measurement intervals of 0.3 mm with an accuracy of ± 0.1 mm in the radial direction, and by displaying results on a 3D color screen, it is possible to detect and display the presence or absence of wheel flats as well as any visible damage, and to confirm the wheel tread profile as well as wheel deflection amount (roundness) of the position to be investigated. In addition, detailed display and dimensional measurement of the damaged tread portions are possible. Furthermore, detailed estimation of damage is possible by reproducing

Fig. 9 Three-dimensional measuring instrument for wheel tread profile

Fig. 10 Measurement sensor part (for measuring whole circumference)

Fig. 11 Measurement sensor part (for measuring local portions)

Fig. 12 Example of three-dimensional wheel tread profile data being applied

tread damage, etc., using a 3D printer (Fig. 12).

The developed instrument makes it possible to gain detailed information about the damaged tread profile, and thus, it can be used for investigating the influence of tread damage on vibrations in various vehicles parts, etc. It is proposed as a tool for daily management of tread condition and wheel profiles by railway business operators.

3. Running safety assessment method following puncture of air spring

Air springs between a vehicle bogie frame and its car body can suffer punctures due to accidental damage to equipment and/or piping. In some cases, the air release is intentional (blown out) to preventing vertical buckling. When air is release intentionally or through a puncture, the vertical supporting rigidity of the car body increases, making it more difficult for the vehicle to follow curves which results in a decrease of wheel load. A method was therefore developed to assess the running safety of a vehicle in such circumstances, in accordance with curve specifications.

Fig. 13 shows the analytical result combining a wheel elevation that does not exceed 2 mm, or cant and cant transition that do not exceed the derailment coefficient guideline value (modified arc wheel profile 0.95) on a transition curve with exit radius of 300 m. In the area where wheel elevation does not exceed 2 mm, there is no single point where the straight section of the wheel flange comes into contact with the rail - i.e. wheel climb has not commenced.

This suggests that, similarly to what is illustrated in Fig.13, when a puncture occurs in the air springs, even if the derailment coefficient exceeds the guideline value, a certain margin exists before wheel climb occurs. As a re-

Fig. 13 Comparison of running safety assessment using wheel elevation and derailment coefficient

sult, a proposal was made to use the wheel elevation value as the index to directly assess safety in relation to wheel climb.

Operators can then assess the running safety of a vehicle with an airspring puncture by inputting the relevant vehicle series, running conditions and other mechanical parameters into a graph such as Fig. 13. Fig. 14 is an example of such an assessment. Safety can be evaluated by plotting the specifications of curves found on the route along which the vehicle has to make a relief run following the puncture, and setting a maximum wheel elevation threshold of 2 mm.

On curves which gave a result indicating a low level of running safety, it was confirmed through trials on a test line at RTRI, that wheel elevation can be inhibited by applying or spraying a friction-relieving agent, such as water, etc. to the head of the inner rail of the transition curve towards its exit. This method can therefore be used to detect areas along a route that present a higher risk of derailment, and countermeasures should be taken, before sending a vehicle with a punctured air spring on a relief run.

Fig. 14 Example of running safety assessment

4. Conclusion

The findings presented in this article are examples of the results obtained from Research & Development conducted in the field of vehicle technology. Future work will continue focus on improving running safety as well as ride comfort, while other research will concentrate on themes clarifying railway-specific problems, improvement of non-destructive inspection accuracy, labor-saving in maintenance, etc., and deeper cooperation with relevant research divisions.

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