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NECESSITY OF VIBRATION ISOLATOR OR CONTROLLER FOR RAILWAY STRUCTURES

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ABSTRACT

This paper explains that the application of vibration isolation and control techniques for railway structures is more necessary than for road structures, according to the dynamic analysis simulations of running stability of a 3-dimensional Shinkansen vehicle model with perpendicular flanges on its wheels under 31-degree of freedom on time of an earthquake. However, this paper also explains that the application of these techniques for railway structures is not so easy as for road structures as a result of some simulations on running stability of a railway vehicle running on a structure with bent angle at its boundary with a neighbor one. Because, in railway system, it is most important to keep the system from derailment caused by bent angle at boundary of structures.

KEYWORDS

Railway structure; vibration isolation; vibration control; railway vehicle; running stability; numerical analysis; bent angle; Shinkansen.

DEALING SUBJECTS IN THIS PAPER

This paper deals with the following subjects:
(a) the results of numerical analysis simulation on running stability of a railway vehicle running on a vibrate structure, using the model of a 3-dimensional Shinkansen vehicle with perpendicular flanges on its wheels under 31-degree of freedom,
(b) the simulation results on running stability of a railway vehicle running on a structure with bent angle at its boundary with neighbor one, using the same model, and
(c) the especially considerable facts and the actual possibility concerning the application of vibration isolation and control techniques for railway structures, different from general structures, such as road structures.

BACKGROUND

The techniques concerning vibration isolation and control have been well-known since rather old days in the field of mechanics and architecture engineering. The other hand, in the field of civil engineering in Japan, the vibration control technique was introduced recently, because the build-up technique of structures against earthquakes has been most important. But these techniques have gradually become popular in the civil engineering, as becoming the problems of vibration of structures more serious, as a result of size-up, weight-down and flexibility-up of structures accompanied by the development of new materials of high-strength and excellent techniques of design, construction, simulation and analysis of structures.

In case of road structures such as large suspension bridges, the vibration control techniques have been actively adopted. In case of railway structures, however, while some bridges installed vibration isolation supports have been built up, they are not clearly defined as 'vibration isolated bridges'. It seems inactive in case of the latter.

Considering railway structures, it is most important to keep safety of running vehicle from derailment. The phenomenon of derailment is no need to be considered for road structures. On this viewpoint, vibration control techniques should be promoted for railway structures. But it is difficult to adopt these techniques unconditionally which have possibility of causing large bent angle at boundary between neighbor structures, because there are dangers of derailment caused by these deformations of structures.

This paper explains how to consider these techniques for railway structures, through the numerical simulation on dynamics of Shinkansen vehicle model running at 200 km/h.

SHINKANSEN VEHICLE MODEL

The values of critical amplitude of oscillating track and displacement of structure such as bent angle for safe running of Shinkansen vehicle were calculated by a 2-dimensional vehicle model (for example, MoT and RTRI, 1992). But this model cannot realize important phenomena, because it contains a simplified

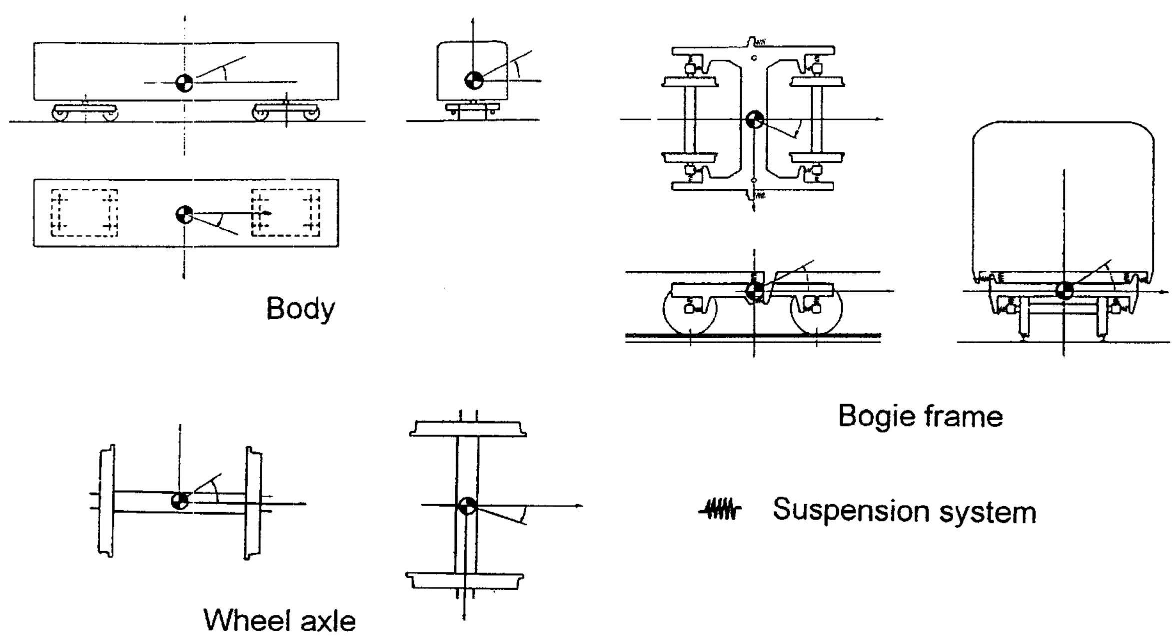


Fig. 1 3-dimensional Shinkansen vehicle model (31-degree of freedom) assumption that vehicle cannot lift its wheel from rail. Considerable factors which cause those phenomena are influences of a gap between wheel flange and rail, creep force and friction force between wheel and rail, elastic property of rail, yawing of wheel axle ,bogie frame and car body and so on.

Then, 3-dimensional Shinkansen vehicle model with perpendicular flanges on its wheel under 31-degree of freedom which enabled to reappear important real phenomena by inputting those factors was built. And some numerical simulations of dynamics were run by Runge-Kutta-Gill method (Fig. 1).

VIBRATION OF STRUCTURE AND STABILITY OF RUNNING VEHICLE

The values of critical amplitude of oscillating track for safe running was calculated on condition that the upper limits of the ratio of lateral load to wheel load Q/P=2, the ratio of lateral load to static wheel load Q/P_S=2 and the ratio of wheel lifting magnitude to wheel flange effective height $Z=(z_W-z_R)/0.025=1$ were kept. Investigated result is shown in Fig. 2. In this figure, result of 2-dimensional model which regulated existing running safety boundary is also shown.

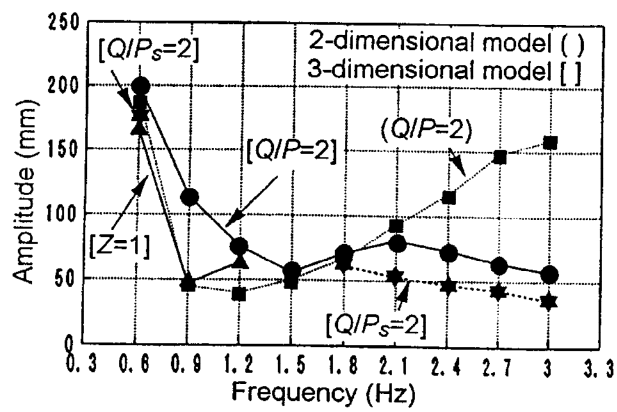


Fig. 2 Critical amplitude for safe running (V=200km/h)

In comparison with both results, boundary values of amplitude of vibration calculated by the 3-dimensional model are less than existing ones in the frequency region over 1.8 Hz. This is caused by the excess of lateral load. In this frequency region, there may be some cases that the necessity to make the grade of the displacement of a structure less than existing value or to consider some countermeasures of anti-derailment will occur.

BENT ANGLE ON BOUNDARY OF STRUCTURE AND STABILITY OF RUNNING VEHICLE

The numerical simulations on running stability of Shinkansen model passing over the point set up bent angle toward vertical and horizontal direction were run under various running velocity. The relation between vertical critical bent angle and horizontal one calculated on condition of the ratio of lateral load to wheel load Q/P=1.5 is shown in Fig. 3. The values of existing rule were calculated by 2-dimensional model on condition that the following: (1) Q/P=1.2, and (2) both vertical bent angle and horizontal one don't act at the same time. The existing rule is thought proper, as compared with the simulation result of 3-dimensional model. Fig. 3 clearly shows that both vertical bent angle and horizontal one are in relation of linear function of first degree, when both act at the same time. When the technique of vibration control is applied to existing structure, the possibility of occurrence of large bent angle at its boundary with neighbor one, especially at the boundary with non-applied neighbor one increases. Because the contrast of vibrate motions of them is emphasized. In this case, another countermeasure is necessary to discuss, as the next chapter.

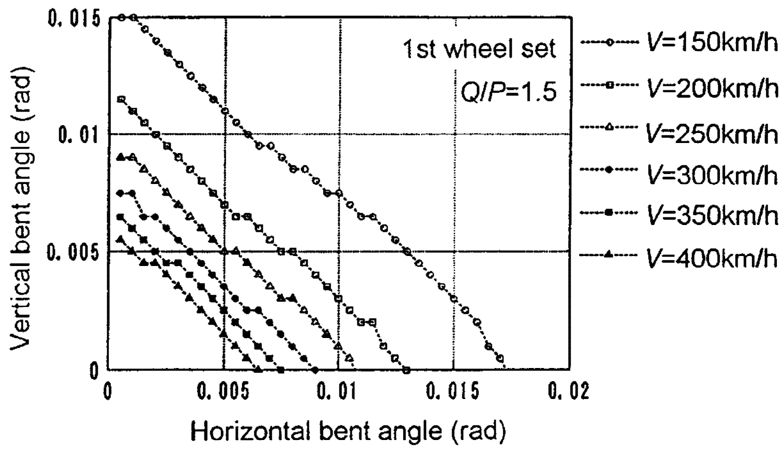


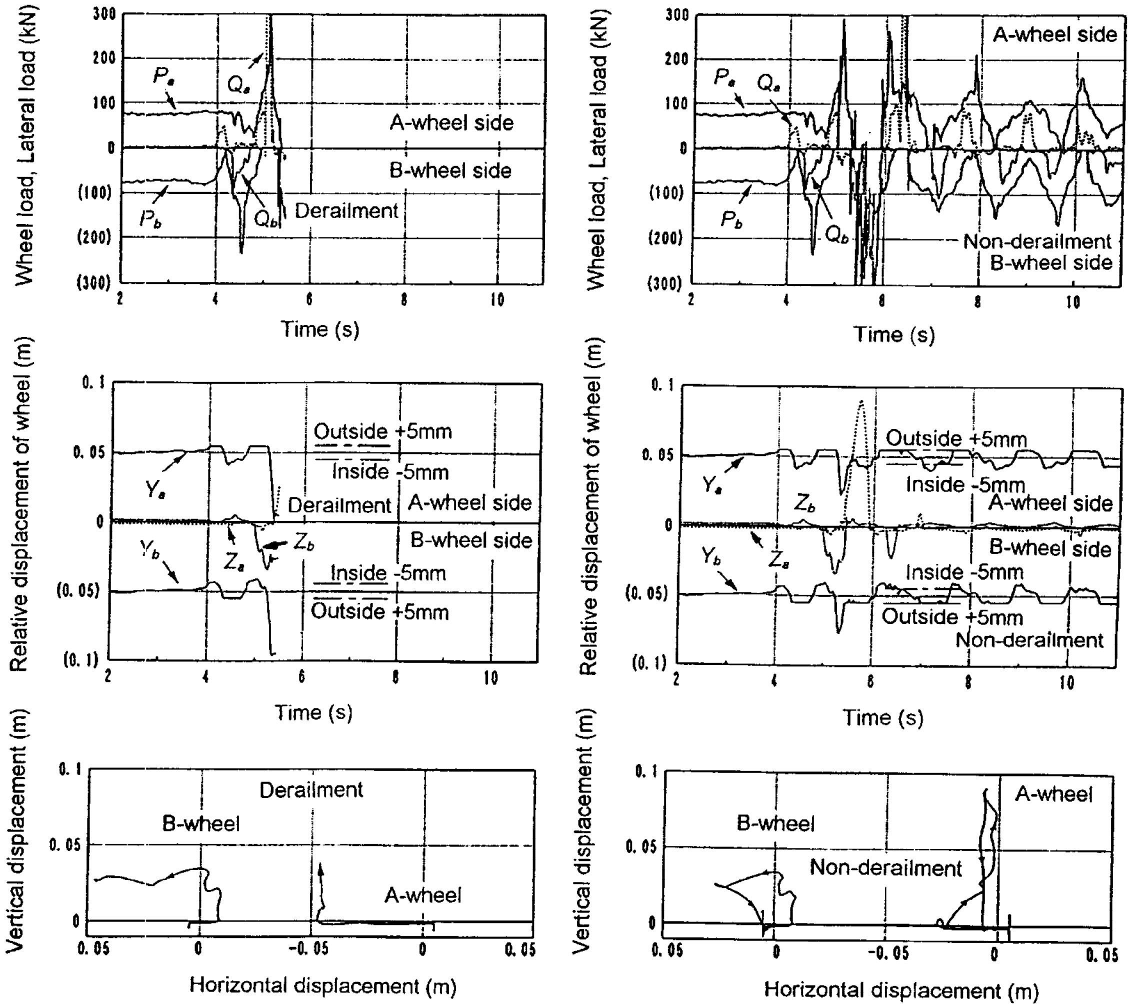
Fig. 3 Critical bent angle for safe running

A SUGGESTION ON APPLICATION OF VIBRATION ISOLATION AND CONTROL TECHNIQUES TO RAILWAY STRUCTURES

When vibration isolation and control techniques are applied to a part of continuous structure, the possibility that larger bent angle occurs at its boundary increases. In the case of railway structure, some countermeasures to keep the value of bent angle less than the ruled critical value are considered, for example setting up of buffer structure, anti-derailment guard rail and so on. But when a buffer structure such as a buffer beam is set up, reconsideration on the design of the main structure is needed, and it is not easy to cope.

On the other hand, anti-derailment guard rail is comparably easy to set up, and is effective as a preventive countermeasure of derailment of running railway vehicle by vibration of structure and bent angle which occur at boundary of structure. By the study of Matsuura (1996), it is shown that the anti-derailment guard rail laid at ordinary position cannot prevent derailment in case of rocking of vehicles being large, but the other one which is laid at nearby main rail have high preventive effect from derailment. Fig. 4 shows the simulation result using the earthquake wave of 1995 Hyogo-Ken-Nanbu Earthquake observed by Kobe marine meteorological observatory, and that the preventive effect from derailment is not obtained on the ordinary position at 45 mm of back gap of wheel flange but is obtained nearby main rail on the position at 25 mm of the same (Matsuura, 1996).

Thus, in the case that vibration control and isolation techniques are applied to railway structures and large bent angle value is supposed to occur at boundary of structure, the author suggests the necessity of juxtaposition of anti-derailment guard rail laid at nearby main rail. But on decision of laid position and extension of it, the numerical simulation by the proper model of dynamic analysis is needed.



(a) Laid at ordinary position

(b) Laid at closer position

1st wheel set V=200km/h

NS+UD wave of 1995 Hyogo-Ken-Nanbu Earthquake (by JMA)

Fig. 4 Effect of anti-derailment guard (Matsuura, 1996)

CONCLUSIONS

This paper explains how to consider these techniques for railway structures, through the numerical simulation on dynamics of Shinkansen vehicle model running at 200 km/h. Considering railway structures, it is most important to keep safety of running vehicle from derailment. The phenomenon of derailment is no need to be considered for road structures. On this viewpoint, vibration control techniques should be promoted for railway structures. But it is difficult to adopt these techniques unconditionally which have possibility of causing large bent angle at boundary between neighbor structures, because there are dangers of derailment by these deformations of structures. Conclusions are the following:

(a) The boundary values of amplitude of vibration calculated by the 3-dimensional model are less than

existing ones in the frequency region over 1.8 Hz. This is caused by the excess of lateral load. In this frequency region, there may be some cases that the necessity to make the grade of the displacement of a structure less than existing value or to consider some countermeasures of anti-derailment will occur.
(b) On the critical bent angle of boundary of structure, the existing rule is thought proper, as compared with the simulation result of 3-dimensional model. Fig. 3 clearly shows that both vertical bent angle and horizontal one are in relation of linear function of first degree, when both act at the same time.
(c) When the application of vibration isolation and control techniques to railway structures, the juxtaposition of anti-derailment guard rail is important. Because it is effective as a preventive countermeasure of derailment of running railway vehicle by vibration of structure and bent angle which occur at boundary of structure. But the anti-derailment guard rail laid at ordinary position cannot prevent derailment in case of rocking of vehicles being large, but the other one which is laid at nearby main rail have high preventive effect from derailment. It is advisable to apply appropriate vibration isolators or controllers to suitable positions of railway structures after anti-derailment guard rails are laid at nearby main rails.

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