Nonlinear Stabilization of Hunting Motion of Railway Wheelset by Gyro-scopic Damper

Noriyuki Tamaki[*] and Hiroshi Yabuno[*]

[*] *Intelligent and Mechanical Interaction Systems, University of Tsukuba, Tsukuba, Ibaraki, Japan*

Abstract. Railway vehicles suffer hunting motion when the running speed exceeds a critical velocity against the small disturbance, which is obtained from the linear stability theory; the critical speed is called a linear critical speed. In contrast, the nonlinear critical speed is related to the stability against the finite magnitude disturbance. It has been clarified so far that the gyro-scopic damper increases the linear critical speed obtained by linear analysis. However, the effect of gyro-scopic damper on the nonlinear critical speed has not been examined. In this presentation, we clarified that the gyro-scopic damper increases the nonlinear critical speed.

Introduction

Railway vehicles suffer hunting motion when the running speed exceeds a critical velocity, which is a flutter-type self-excited oscillation, due to the creep force between the wheels and the rails [1]. This phenomenon does not only make passengers uncomfortable but also even causes a derailment. The linear critical speed of hunting motion against a small disturbance can be obtained by linear theory. Furthermore, the quintic order nonlinear analysis clarifies that nonlinear destabilization against a finite disturbance is induced through the subcritical characteristic of the Hopf bifurcation and a saddle-node bifurcation [2]. The saddle-node bifurcation point corresponds to the related critical speed called a nonlinear critical speed, which is lower than the linear critical speed in the range between the linear and nonlinear critical speeds, it has been theoretically and experimentally shown that the stability depends on the magnitude of the disturbance [3]. By the way, it has been theoretically and experimentally clarified that the gyro-scopic damper increases the linear critical speed [4]. However, the effect of the gyro-scopic damper on the nonlinear critical speed has not been examined. In this presentation, we investigate the effect of gyro-scopic damper on the nonlinear critical speed.

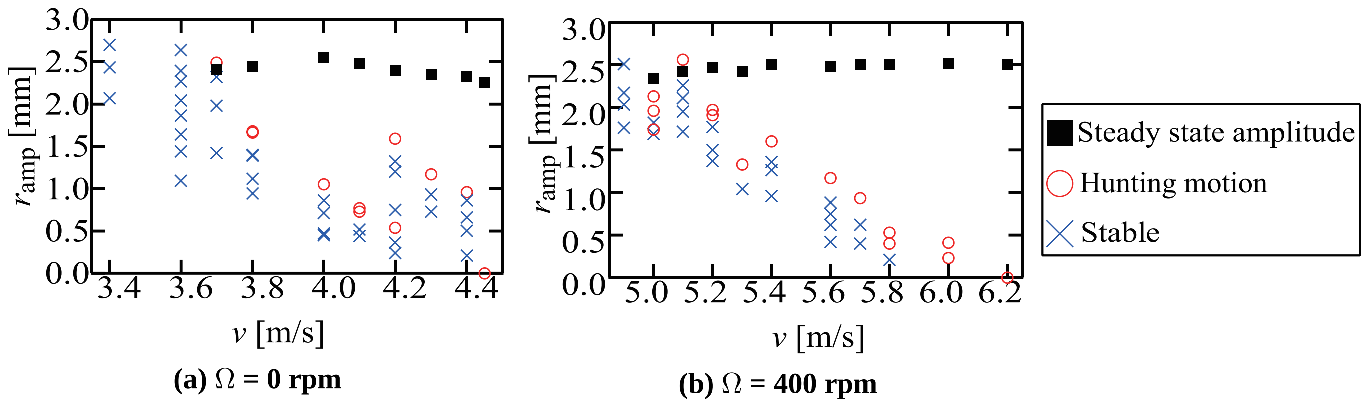

Figure 1: Effect of a gyroscopic damper: (a) rotational speed of gyro is 0; (b) rotational speed of gyro is 400 rpm.

Conclusions

This abstract shows the experimental using a roller rig. By using electromagnet device, we gave various initial disturbances r_{amp} to wheelset below the linear critical speed. The saddle-node bifurcation point in case (b) is produced at the running speed $v = 5.0$ m/s which is higher than $v = 3.7$ m/s in case (a). The gyro-scopic damper increased the nonlinear critical speed in compared with that in the case without effect of the gyroscopic damper. In addition, the nonlinear critical speed with rotating gyro-scopic damper is higher than the linear critical speed without rotating gyro-scopic damper $v = 4.5$ m/s.

References

[1] Wickens. A. H., THE DYNAMICS STABILITY OF RAILWAY VEHICLE WHEELSETS AND BOGIED HAVING PROFILED WHEELS, International Journal of Solids and Structures, 1(3), 319-341, 1965.

[2] Kaiser,I., Polach, O., Comparison of Methods Analyzing Bifurcation and Hunting of Complex Rail Vehicle Models, Journal of Computational and Nonlinear Dynamics, Vol. 7, 041005, 2012.

[3] Wei,W., Hiroshi,Y., Subcritical Hopf and saddle-node bifurcations in hunting motion caused by cubic and quintic nonlinearities: experimental identification of nonlinearities in a roller rig, Nonlinear Dynamics, 98(1), 657-670, 2019.

[4] Hiroshi,Y., Hirokazu,T., and Hirokazu,O., Stablization Control of Hunting Motion of Railway Vehicle Wheelset Using Gyroscopic Damper, Journal of Vibration and Control, 14(1-2), 209-230, 2008.