Journal of Traffic and Transportation Engineering(English Edition)
2014,1(3):209-220

Progress on wheel-rail dynamic performance of railway curve negotiation

Kaiyun Wang, Chao Huang, Wanming Zhai, Pengfei Liu, Shen Wang
Traction Power State Key Laboratory, Southwest Jiaotong University, Chengdu, Sichuan, China

Abstract: Recent advances on wheel-rail dynamic performance of curve negotiation are reviewed in this paper. There are four issues, the mechanism and calculation method of curve negotiation, the analysis and assessment of dynamic performance of vehicle, the effect of vehicle parameters on dynamic performance, and the influence of railway parameters on dynamic performance. The promising future development of wheel-rail coupled dynamics theory is analyzed in the research of curve negotiation. The framework and technique matching performance of wheel-rail dynamic interaction on the curved track are put forward for modern railways. In addition, the application of performance matching technique is introduced to the dynamic engineering, in which the wheel load is reduced obviously when the speed of train is raised to 200-250 km/h.

Key words: railway; curved track; dynamic interaction; wheel-rail system; performance matching

1 Introduction

Due to the change of alignment and geometric size, the moving path of wheelset and the state of wheel-rail contact will change obviously when a vehicle passes through a curved track, which can aggravate the wheel-rail interaction, intensify the wheel-rail vibration, and affect the running safety and comfort. On the small-radius curved track, this phenomenon would be more serious. Therefore, it is very important to carry out researches on mechanism and dynamic performance of curve negotiation. Since the wheel-rail dynamic performance on the curved track has been one of the focuses of vehicle dynamics, there are a large number of theoretical and experimental studies on the curve negotiation in the international and domestic domain. There are four issues, including the mechanism and the calculation method of curve negotiation, the analysis and assessment of vehicle dynamic performance, the effect of vehicle parameters on dynamic performance, and the influence of railway parameters on dynamic performance. However, because the curved track is a weak link on the railway and the mechanism of wheel-rail interaction on curved track is complex, there are many engineering problems closely related to the interaction, such as, the

* **Corresponding author**: Kaiyun Wang, PhD, Professor.
E-mail: kywang@swjtu. edu. cn.

rail corrugation appearing on the small-radius curves of existing railway and on the big-radius curves of high-speed railway, the rail side abrasion and the plastic flow appearing on the curved track of heavy-haul railway, etc. It can be seen that studies on the wheel-rail dynamic interaction of curved track are not deeply and systematically performed yet. It has not been investigated from the view of system engineering. More detailed researches, including theoretical models, principles and techniques of performance matching and so on, should be carried out. In this paper the advance and achievement in these studies are reviewed and discussed. From the view of system dynamics, the framework and technique matching performance of wheel-rail dynamic interaction on the curved track are put forward for modern railways.

2 Mechanism and calculation method of curve negotiation

A quasi-static method was introduced into the study on the mechanism of curve negotiation (Newland 1968; Boocock 1969). Subsequently, lots of studies on the steady-state curving performance of locomotives and rolling stocks have been performed (Wickens 1975; Elkins and Gostling 1977; Piotrowski 1988; Sheffel et al. 1993). The dynamic interaction between vehicle and curved track cannot be figured by means of quasi-static method. Then, the dynamic performance of curve negotiation was presented. A quasi-static model and a dynamic model of curve negotiation were established (Zboinski 1998), and the curving performance and stability of motion on curved track were analyzed. By establishing a bond graph model of curve negotiation, some dynamic rules which cannot be discovered by the conventional method were found (Banerjee et al. 2009). Two types of calculation method of wheel-rail contact were developed (Sugiyama and Suda 2009), one was the table look-up that can be effectively used for the tread contact, and the other was the real-time online when the contact point jumped to the flange region. If there are two contact points in curve negotiations, the latter method is used to determine the contact configuration. By means of the software SIMPACK, a dynamic model of metro vehicle passing through small-radius curved track was established (Kurzeck 2011). The relationship between wheel-rail dynamic interaction caused by the resonance and rail corrugation on curved track was analyzed. The wheel-rail longitudinal creep forces, lateral creep forces and spin creep moments were calculated when a vehicle passing through the curved track, and the formulas of the friction power were obtained (Tudor et al. 2009). Under traction condition, the characteristics of wheel-rail dynamic interaction on the curved track were analyzed (Grassie and Elkins 2005). Results indicated that, under the traction condition, the lateral wheel-rail dynamic interaction would be larger to certainly cause the rail oblique crack. In recent years, the stability motion on the curved track has been studied (Dukkipati and Swamy 2001; Cheng et al. 2009; Zboinski and Dusza 2010). The most prominent research was conducted (Cheng et al. 2009), in which, a vehicle model with 21 DOFs was established, and another model with fewer DOFs was obtained, and the stability motion of vehicle with different DOFs was analyzed by the simplified model.

At the domestic level, researches on the mechanism of curve negotiation have been performed relatively late. The study of steady-state curving performance began in 1970s. The formula to calculate displacement of the centre plate on curved track was deduced (Sha 1979). According to the safety running condition of vehicle, an integrated graph was given to describe the restricted relationship among the loading gauge, the goods, and the multi-oriented vehicle. Taking a locomotive with two bogies as an example, a simplified calculation method of nonlinear negotiation performance was proposed (Shen 1982). Formulas were deduced to calculate the longitudinal, lateral and spin creep rates. According to the principle of steady-state curve performance, the design principle of force-steering bogie was studied (Mao et al. 1985). The mechanism and calculation method of steady-state performance were analyzed by developing different simplified linear models (Huang 1981; Shen 1998; Shu 1999; Lu et al. 2002). Afterwards, with the evolution of the dynamic model and the computer technology, the investigation on the mechanism of curve negotiation was performed. Research on the ex-