French Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes one of the PhD subjects proposed by the French Polytech network. The network is composed of engineering schools/universities. The document also provides information about the supervisor.

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PhD information	
Title	**Advanced Numerical modeling of dynamic response of train-track ground system for high speed ballastless tracks**

Main topics regards to CSC list (3 topics at maximum)	Engineering science: VI-5) High speed railways and intelligent control, VI-3) Sustainable development engineering and lower cost manufacturing
Required skills in science and engineering	Numerical modeling in soil structure interaction problems, dynamic analysis, Matlab and Python programming

Subject description (two pages maximum including biblio)

Over the last decade, the expansion of high-speed lines has grown significantly. Conventional ballasted tracks are widely used due to their low investment cost. However, the use of this type of tracks becomes disadvantageous due to their limited service life (15-20 years), their costly maintenance and the problem related to high speed levels. As an efficient alternative, the ballastless tracks becomes more and more popular worldwide where very high speed levels are reached (more than 300 km/h). As a matter of fact, their service life is double to triple compared to ballasted track construction. The ballastless tracks were firstly introduced in Japan between 1960 and 1970, then in Germany in the 1991. More recently several thousands of kms were used in China where the speed trains may exceed 300 km/h. Although a major technological innovation, the high speed lines can constitute an important source of environmental disturbance (airborne and ground-borne noise and vibrations) to nearby residents and even damage for adjacent structures. The vibrations generated at the wheel/rail level arises from the train mass, the rail irregularities increasing with time, the wheel defects and the non-uniform stiffness due to the discrete supports of rails. At high speed levels, theses vibrations can be significantly amplified leading to real damage on both vehicle components and track components.
In order to understand the dynamics of these systems it is important to develop advanced theoretical and experimental methods that can correctly reproduces the mutual dynamic interactions between the system components (vehicle, tracks, sub-soil..). Several numerical approaches were proposed in the frequency domain but they are limited to linear behaviour. Some recent time modeling approaches were proposed in the case of standard ballasted tracks in a straight line at a constant speed.

The main purpose of the PhD research is to develop reliable numerical models in the time domain that aim to correctly simulate the complex dynamic interactions for the train/track/ground system in ballastless tracks with high speed velocities. With the fast increase in computing power, the numerical modeling techniques are very attractive for an efficient simulation of soil structure

interaction problems in time domains. However, including nonlinear behaviour requires a significant computational effort especially when dealing with high speed and frequency ranges. Both 1D and 3D approaches were recently developed (2015-2021) in previous dissertations within our research team (see references, Mezeh et al.). There were successfully applied to real scale experiments on ballasted tracks within the frame of a National French research project (BPL, Bretagne-Pays) that gathered several academic and industrial partners (The French SNCF national railway network company, EIFFAGE Infrastructures, IFSTTAR, SETEC Ferroviaire and the Lille University). In this project, located in the West of France (Bretagne-Pays), a good performance of the developed models was observed for various traveling speeds (162 to 342 km) of passenger High speed trains.

In the proposed PhD research, numerical developments will focus on the case of ballastless tracks for both sub-Rayleigh and super-Rayleigh velocity range. The developed model will be an efficient tool to define the strategies (mitigation techniques) leading to acceptable vibration levels in urban areas. On the other hand, the numerical model coupled with machine learning algorithms like the Genetic Algorithm (GA) should allow the determination of dynamic impedances that are very useful for engineering design applications.

Selected references:

- Bian, Xuecheng & Jiang, Hongguang & Chang, Chao & Hu, Jing & Chen, Yunmin. (2015). Track and ground vibrations generated by high-speed train running on ballastless railway with excitation of vertical track irregularities. Soil Dynamics and Earthquake Engineering. 76. 10.1016/j.soildyn.2015.02.009.

- Jin, Zihao & Zhang, Wei & Li, Yixin & Geng, Xueyu. (2025). Numerical studies of ballastless track-embankment vibrations considering the track irregualrity. Transportation Geotechnics. 51. 101536. 10.1016/j.trgeo.2025.101536.

- Mezeh R., SADEK M., Hage Chehade F., Shahrour I. (2017) “Adaptive analysis of infinite beams dynamics problems using the periodic configuration update method in the time domain”, International Journal for Numerical and Analytical Methods in Geomechanics, Wiley, 42(4), pp. 618-635; DOI: 10.1002/nag.2757.

- Mezeh R., SADEK M., Hage Chehade F., Mroueh H. (2018) “Adaptive meshing scheme for prediction of high-speed moving loads induced ground vibrations”, Computers and Geotechnics, Elsevier, 100, pp. 188-202; DOI: 10.1016/j.compgeo.2018.03.014.

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- Mezeh R., Mroueh H., Hosseingholian M., Sadek M. (2021) “Fully-coupled numerical model for ballasted track analysis – Field measurements and predictions” Transportation Geotechnics, Elsevier, Volume 27, 100483. https://doi.org/10.1016/j.trgeo.2020.100483.

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- Steenbergen M.J.M.M , A.V. Metrikine, C. Esveld (2007) Assessment of design parameters of a slab track railway system from a dynamic viewpoint, Journal of Sound and Vibration 306 (2007) 361–371.
- Ying Wu, Haoran Fu, Xuecheng Bian (2024). Comparative study on dynamic responses of ballasted and ballastless tracks at critical velocity. Transportation Geotechnics. 48. https://doi.org/10.1016/j.trgeo.2024.101354.
- Zhai, Wanming & Wei, Kai & Song, XL & Shao, Minghe. (2015). Experimental investigation into ground vibrations induced by very high speed trains on a non-ballasted track. Soil Dynamics and Earthquake Engineering. 72. 10.1016/j.soildyn.2015.02.002.