UMR Acoustique Environnementale
(Université Gustave Eiffel-Cerema)

PHD THESIS PROPOSAL 2021

PhD thesis title

Fast Multipole Method for Tyre/Road Contact

Recommanded education

☒Master Science (M2)

Requested skills

Main specialty : Computational mechanics
Other concerned specialties : Acoustics and vibration

Description

Tyre/road contact plays a decisive role in the generation of rolling noise. Its physical modeling is an important issue to reduce the impact of road traffic on the Environment. During rolling, tyre/road interaction generates noise sources of mechanical origin (vibratory excitation of the tyre) and aerodynamic (air-pumping), which are then amplified by the dihedral formed between the tyre and the road surfaces [1].

In recent years, a multi-asperity approach for modelling tyre/road contact has been developed by UMRAE at IFSTTAR [2]. Combined with a two-scale iterative resolution method, this approach effectively introduces 3D pavement texture into rolling noise prediction models below 1000 Hz, originating from vibrations of the tyre carcass. However, improvements of the contact model are necessary at the micro-scale for the modelling of mechanisms at the origin of noise beyond 1000 Hz, such as air-pumping, self-oscillation of tyre tread blocks due to stick/slip or adhesion mechanisms.

The aim of the thesis is to improve the resolution of the contact problem by means of a Fast Multipole Method (FMM). As a first step, the candidate will perform a literature review on the FMM and its various applications in physics, with a particular interest on its use in elasto-dynamics and in contact mechanics.

Then, the work will mainly rely on the Boussinesq theory, which corresponds to the contact problem in static conditions at the surface of an elastic half-space. The interaction function of the problem will be approximated by solid harmonics, which will make possible to use a method of moments to speed-up the contact calculation at the micro-scale. This approach will be combined with the multi-asperity description of the surface indenting the half-space, namely the contacting points in the vicinity of the tip of an asperity will be grouped together and considered as a single source of displacement at the surface of the half-space. Next, an iterative algorithm will be used to solve the contact problem.

The MMR will first be validated by comparison with a reference method [4] in the case of surfaces composed of well separated asperities of simple shape (i.e. spheres, cones or cylindrical punches). The method will then be applied to an actual road surface sample, for which a multi-asperity reference method also exists [5]. In this more complex case, the MMR will have to integrate a criterion of separation between the asperities in order to ensure the convergence of solid harmonics. The error of the MMR results in comparison with the reference method will be evaluated and related to the order of the multipole decomposition. The possibility of parallel computing will also be studied in order to speed up the resolution of the contact problem.

In the last part of the work, assuming a good efficiency of the MMR, the method will be applied to the calculation of the variation of tyre/road contact forces during rolling. Coupling with a simplified model of tyre vibrations could be considered. This study will consider several road surfaces for which combined measurements of 3D texture and rolling noise have been carried out in the past [6]. The spectra of contact forces and of dynamic enveloped texture at the tyre/road interface could then be related to the measured noise spectra in order to improve the statistical hybrid noise prediction models developed within UMRAE [3, 7].

References :

[1] Heckl M. « Tyre noise generation ». *Wear* 113, n° 1 (1986): 157-70. https://doi.org/10.1016/0043-1648(86)90065-7.

[2] Dubois G. « Modèle de contact dynamique pneumatique chaussée par approche multi-aspérités : application au bruit de roulement ». Thèse de doctorat, École Centrale de Nantes, 2012. http://tel.archives-ouvertes.fr/tel-00755561

[3] Dubois G., Cesbron J., Yin H.P., Anfosso-Lédée F. et Duhamel D. « Statistical estimation of low frequency tyre/road noise from numerical contact forces ». *Applied Acoustics* 74, n° 9 (2013): 1085–1093. https://doi.org/10.1016/j.apacoust.2013.03.011.

[4] Cesbron J. et Yin H.P. « Contact analysis of road aggregate with friction using a direct numerical method ». *Wear* 268, n° 5 (2010): 686–692. https://doi.org/16/j.wear.2009.11.005.

[5] Dubois G., Cesbron J., Yin H.P. et Anfosso-Lédée F. « Numerical evaluation of tyre/road contact pressures using a multi-asperity approach ». *International Journal of Mechanical Sciences* 54, n° 1 (2012): 84–94. https://doi.org/10.1016/j.ijmecsci.2011.09.010.

[6] Cesbron J. et Klein P. « Une nouvelle base de données texture/bruit pour la prévision du bruit de contact pneumatique/chaussée ». In *Actes du Congrès Français d'Acoustique*, 1683–1689. Université du Maine, Le Mans: Société Française d'Acoustique, 2016.

[7] Klein P. et Cesbron J. « A 3D envelopment procedure for tyre belt radiated noise level prediction ». In *Proceedings of Inter-Noise 2016*, 2230-41. Hamburg, Germany, 2016.

Key-words : rough contact, multi-asperity approach, fast multipole method, tyre/pavement interaction, tyre/road noise

Expected skills and background

Master's degree in mechanics with a specialization in computational mechanics or acoustics and vibrations. A complementary experience in contact mechanics would be appreciated. Skills in numerical methods and programming (C/C++, Python, Matlab) are essential. Writing skills in French and/or English are expected. Dissemination of the work by publication of scientific articles in peer-reviewed journals is expected, as well as a communication to at least one international conference in mechanics or acoustics.

Doctoral school

The student will be enrolled at doctoral school « Sciences Pour l'Ingénieur » (SPI) (https://ed-spi.u-bretagneloire.fr/fr/11_presentation). The registration school will depend on the skills and background of the candidate.

Place of the thesis

☐ **Uni Eiffel, Campus Lyon** (25, avenue François Mitterrand, Case24, Cité des mobilités, F-69675 Bron Cedex)

☒ **Uni Eiffel, Campus Nantes** (route de Bouaye, CS4, F-44344 Bouguenais Cedex)

☐ **Cerema – Strasbourg** (11, rue Jean Mentelin, Strasbourg-Koenigshoffen, F-67035 Strasbourg)

Supervision

- PhD thesis supervisor : Julien CESBRON

Funding

- Cofunding Université Gustave Eiffel - Région des Pays de La Loire

Other information

The application procedure is detailed on https://www.ifsttar.fr/offres-theses/index.php. Prior application on the thesis platform, the candidate must send by email to Julien Cesbron (julien.cesbron@univ-eiffel.fr) the following documents before April 9, 2021:

- a resume;
- a motivation letter;
- his (or her) Master degree scores (with rank);
- possibly one or more letter(s) of recommendation.

An incomplete application will not be considered..

Contact

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