A new simplified approach to deal with conformal contact in railway dynamics

Filipe Marques[1], Hugo Magalhães[2], Binbin Liu[3], João Pombo[4],
Paulo Flores[1], Jorge Ambrósio[2] and Stefano Bruni[3]

[1] *MIT-Portugal Program, CMEMS-UMinho, Departamento de Engenharia Mecânica, Universidade do Minho, Campus de Azurém, 4804-533 Guimarães, Portugal, {fmarques,pflores}@dem.uminho.pt*

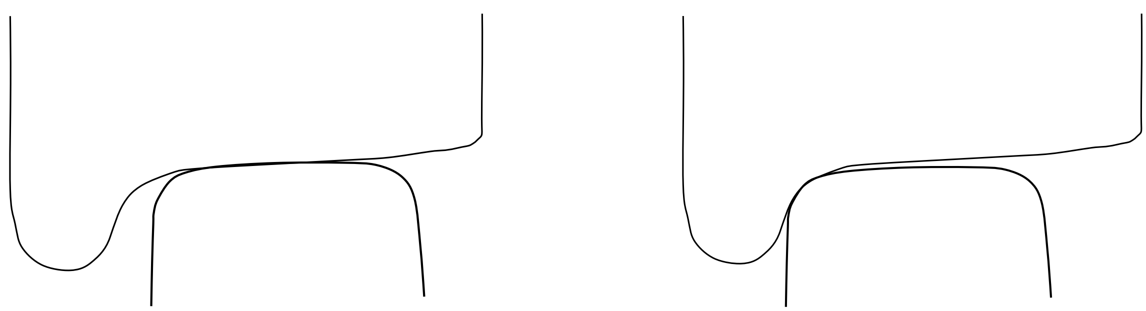
[2] *LAETA, IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Avenida Rovisco Pais 1, 1049-001 Lisboa, Portugal, {hugomagalhaes,jorge.ambrosio}@tecnico.ulisboa.pt*

[3] *Dipartimento di Meccanica, Politecnico di Milano, Via La Masa 1, Milano 20156, Italy, {binbin.liu,stefano.bruni}@polimi.it*

[4] *School of Energy, Geoscience, Infrastructure & Society Heriot-Watt University, Edinburgh, EH14 4AS UK; ISEL, IPL, Lisboa, Portugal; and Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal, j.c.pombo@hw.ac.uk*

The dynamic simulation of railway vehicles based on multibody methodologies is nowadays a reliable approach to prevent derailment, design components, study the vehicle performance for a certain track, among others. In this context, the wheel-rail contact interaction is fundamental not only in the study of the vehicle dynamics, but also in the prediction of rolling fatigue or wear, profile optimization, just to mention a few. For these purposes, the shape and size of the contact patch need to be properly determined, as well as the normal pressure and tangential tractions. Several authors have proposed different methodologies to deal with wheel-rail contact interaction [1-7]. Different strategies have been explored, from fast and approximate methods [1,5] to more complex and realistic models [2]. Naturally, the degree of complexity of the applied method is intimately linked with the required computational cost which implies always a tradeoff between accuracy and efficiency.

Most of the wheel-rail contact theories rely on some simplified assumptions, such as that a single normal direction can be considered for the entire contact patch and the validity of the half-space approach. Notwithstanding, these assumptions are often violated during the vehicle operation, namely when conformal contact occurs. In most of the cases, when the rail contacts the wheel's tread, the contacting surfaces have a non-conformal geometry, as represented in Fig. 1(a). However, in sharp curves or due to worn profiles, the conformality between contacting surfaces tends to occur, as shown in Fig. 1(b).



(a) (b)

Fig. 1: Wheel-rail contact interaction: (a) non-conformal and (b) conformal scenarios

The study of conformal contact is not yet a very deepened topic, although some researchers have been paying attention to this issue in the last few years [7-10]. The main distinction on the conformal contact is that the contact patch is no longer flat, as in the non-conformal contact represented in Fig 2(a). In the conformal contact, there is no plane where the contact patch can be projected and, therefore, the concept of normal and tangential forces is not applied. Figure 2(b) shows that the deformed profiles are in contact under a curved area. Moreover, in these conditions, the spin creepage is not constant through the contact region.

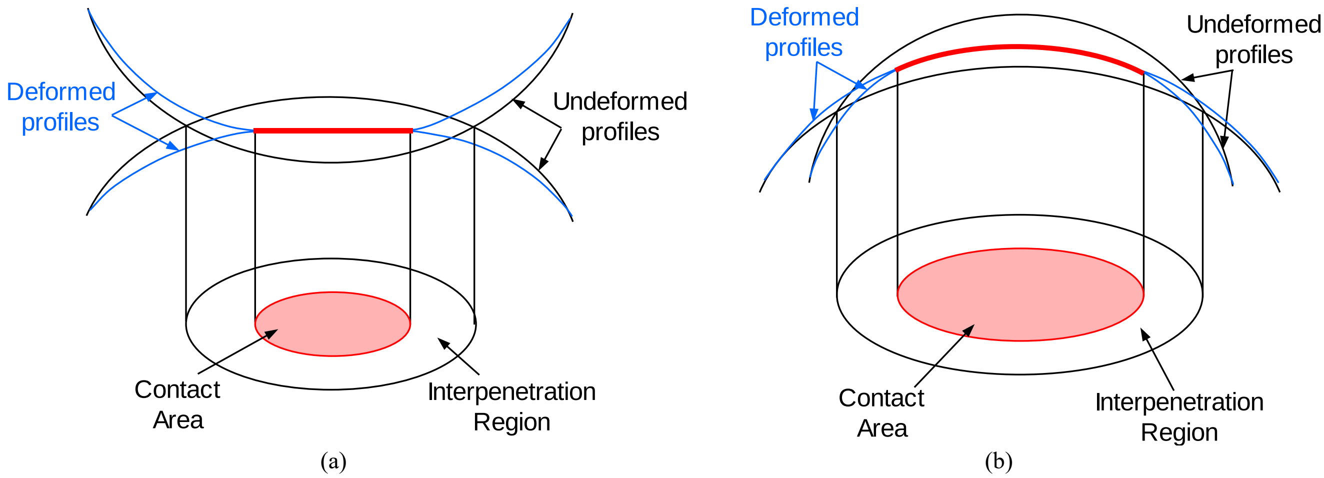


Fig. 2: Schematic representation of the contact region for (a) a non-conformal case (plane contact patch) and (b) conformal case (curved contact patch)

Thus, based on Kik-Piotrowski contact model [3,4,7], a new simplified approach to deal with conformal contact scenarios is proposed in this study. The contact patch is partitioned into strips along the rolling direction, and each strip is treated considering a variation of the contact angle. Therefore, the discretization of the contact patch is not only related to its width, but also with the variation of the contact angle through the patch. The elastic half-space assumption is kept since it can be valid for smaller variations of the contact angle. The preliminary results show that this simplified method is a faster and reliable alternative to the use of more computationally intensive approaches as the boundary or finite element method [8,9].

References

[1] J.J. Kalker, "A fast algorithm for the simplified theory of rolling contact," *Vehicle System Dynamics*, vol. 11, no. 1, pp. 1-13, 1982.

[2] J.J. Kalker, *Three-Dimensional Elastic Bodies in Rolling Contact*. The Netherlands: Kluwer Academic Publishers, 1990.

[3] W. Kik, and J. Piotrowski, "A fast, approximate method to calculate normal load at contact between wheel and rail and creep forces during rolling," in: I. Zabory (Ed.) *Proceedings of 2nd Mini Conference on Contact Mechanics and Wear of Rail/Wheel System*, pp. 52-61, TU Budapest, Hungary, 1996.

[4] J. Piotrowski, and W. Kik, "A simplified model of wheel/rail contact mechanics for non-Hertzian problems and its application in rail vehicle dynamic simulations," *Vehicle System Dynamics*; vol. 46, no. 1,2, pp. 27-48, 2008.

[5] J. Pombo, J. Ambrósio, and M. Silva, "A new wheel–rail contact model for railway dynamics," *Vehicle System Dynamics*, vol. 45, no. 2, pp. 165-189, 2007.

[6] M.S. Sichani, R. Enblom, and M. Berg, "A novel method to model wheel-rail normal contact in vehicle dynamic simulation," *Vehicle System Dynamics*, vol. 52, no. 12, pp. 1752-1764, 2014.

[7] B. Liu, S. Bruni, and E. Vollebregt, "A non-Hertzian method for solving wheel–rail normal contact problem taking into account the effect of yaw," *Vehicle System Dynamics*, vol. 54, no. 9, pp. 1226-1246, 2016.

[8] E. Vollebregt, and G. Segal, "Solving conformal wheel–rail rolling contact problems," *Vehicle System Dynamics*, vol. 52, pp. 455-468, 2014.

[9] J. Blanco-Lorenzo, J. Santamaria, E.G. Vadillo, and N. Correa, "On the influence of conformity on wheel-rail rolling contact mechanics," *Tribology International*, vol. 103, pp. 647-667, 2016.

[10] J.-P. Pascal, and B. Soua, "Solving conformal contacts using multi-Hertzian techniques," *Vehicle System Dynamics*, vol. 54, no. 6, pp. 784-813, 2016.