Experimental characterization of elastomer deformation using x-ray tomography: application to the study of contact with a road surface

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Abstract

The grip and rolling resistance of car wheel tires on a road surface is strongly influenced by the mechanical properties of the rubber and especially by the deformation of this rubber during indentation by the road asperities. Rubber deformation due to the macro texture of the roadway is cited as an important rolling resistance phenomenon. Numerous experimental and simulation studies have been carried out (1-3). However, recently Sun et al. (4) showed that better specifying the texture parameters associated in the indentation of rubber remains an important and timely subject.The phenomena involved are difficult to observe using conventional techniques such as optical microscopy, due to the opaque nature of the elements concerned. The spatial scale of the order of a millimeter is the relevant one to study for rolling resistance (5).

The aim of this work was to develop a new methodology to measure the deformations, in the bulk, of a rubber exposed to indentation-type stresses. To this purpose, advanced techniques such as X-ray computed tomography (XRCT) combined with Digital Volume Correlation (DVC) were used. Numerous studies have shown that XRCT, based on X-ray absorption, can be used to obtain quantitative data (6) on non-transparent bodies. The ability of XRCT to provide directly and non destructively three dimensional (3D) images of various materials makes it a valuable tool to study quantitatively the deformation mechanisms during in situ deformation (6). The main difficulties are linked to the attenuation of the materials used (i.e. high attenuation for the soil and much lower for the rubber), the large deformations to be achieved, and the complexity of a road surface. In addition, DVC requires the presence of a speckle in the material's microstructure. In order to validate our approach, an in-situ indentation test using a low X-ray absorbent plastic ball was first conducted to evaluate the performance of DVC algorithm. Analytical rubber samples, specifically produced for this study, made of a SBR type rubber (Styrene Butadiene Ruber) and representative of a tread of a commercial passenger vehicle tire were used. Silica large particles were added to serve as markers and reinforcement of the rubber. The experimental results were compared with numerical simulations in Abaqus.

The results of these analyses will be presented first. Next, research carried out in order to better reproduce the real conditions of contact between the rubber of a passenger car tire

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and the road will also be discussed.

(1) Xueliang Gao, Yi Xiong, Weiping Liu, and Ye Zhuang. Modeling and experimental study of tire deformation characteristics under high-speed rolling condition. Polymer Testing, 99:107052, 2021.

(2) J. A. Cabrera J. Castillo, A. Pérez De La Blanca and A. Simón. An optical tire contact pressure test bench. Vehicle System Dynamics, 44(3):207–221, 2006.

(3) Filip Feldesi, Theunis R. Botha, and P. Schalk Els. Full-field strain measurements of the inside of an agricultural tyre using digital image correlation. Journal of Terramechanics, 91:309–318, 2020.

(4) Zhaojie Sun, W. A.A.S. Premarathna, Kumar Anupam, Cor Kasbergen, and Sandra M.J.G. Erkens. A state-of-the-art review on rolling resistance of asphalt pavements and its environmental impact. Construction and Building Materials, 411, 2023.

(5) William Levesque, André Bégin-Drolet, and Julien Lépine. Effects of pavement characteristics on rolling resistance of heavy vehicles: A literature review. Transportation Research Record, 2677(6):296–309, 2023.

(6) E. Maire and P. J. Withers. Quantitative x-ray tomography. International Materials Reviews, 59(1):1–43, 2014.