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Thermal model for bicycle tire internal temperature evaluation in various contact conditions

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Abstract:

Bicycle mobility has become increasingly popular as a sustainable and healthy means of transportation. Bicycles are not only a cost-effective mode of transportation but also help to reduce traffic congestion and air pollution. However, the efficiency and safety of bicycling largely depend on the optimization of bike components, such as the tires. The importance of bike tire optimization cannot be underestimated as it can affect both the bicycle dynamics and bicycle performance. In recent years, research has focused on improving the design and materials used in bike tires to enhance their efficiency and safety, mainly investing on empirical correlation activities (Steyn, 2014) and FEA models (Kumar, 2018).
Due to the lack of multi-physical mathematical models able to analyze and reproduce complex tire/road contact phenomena, useful to predict the wide range of working conditions, this research aims to the development of a bicycle tire thermal model. With the know-how gained in motorcycle applications (Farroni, 2020), the main outcome is to provide the full temperature local distribution inside the tire inner rubber layers and the inflation chamber. Such kind of information plays a fundamental role in the definition of the optimal adherence conditions, for both safety and performance maximization, and as an indicator of the proper tire design for various applications, each requiring specific heat generation and management.

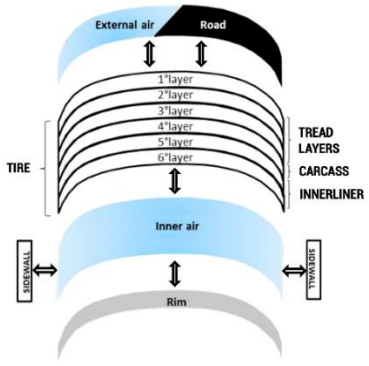

Figure 1. The conceptual scheme of the tire thermal model, and of its internal structure

The model, based on the thermodynamics Fourier Differential Equations applied to a three dimensional domain, has been parameterized measuring for a reference bicycle tire the variation of the footprint extension due to vertical load, camber and inflation pressure.

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Furthermore, the thermal conductivity and the specific heat of the various layers and materials constituting the tire was measured with a nondestructive procedure (Farroni, 2018). Data input and outputs are schematized in Figure 2.

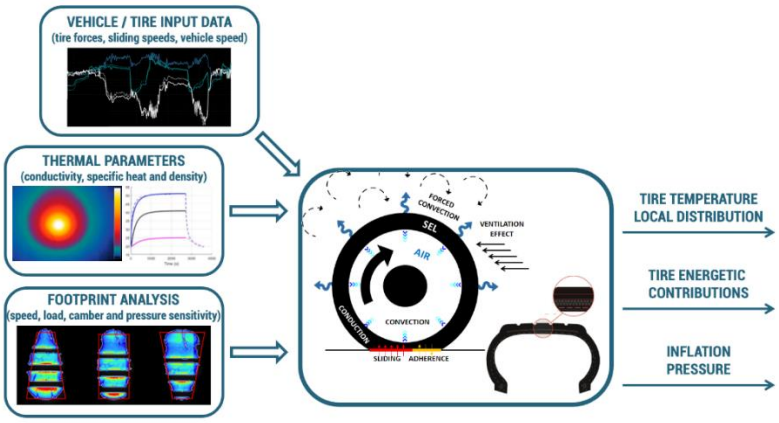

Figure 2. The tire thermal model parameterization principle and the input/output overview

The experimental validation has been carried out thanks to an innovative test-rig developed at Politecnico di Milano (Figure 3). It is the only test-rig for measuring the mechanical characteristics of bicycle tires complying to the standard ISO 9001-2015. It has been specifically instrumented for the activity, acquiring the external tire temperatures to be compared with the respective simulated ones, under various working conditions.

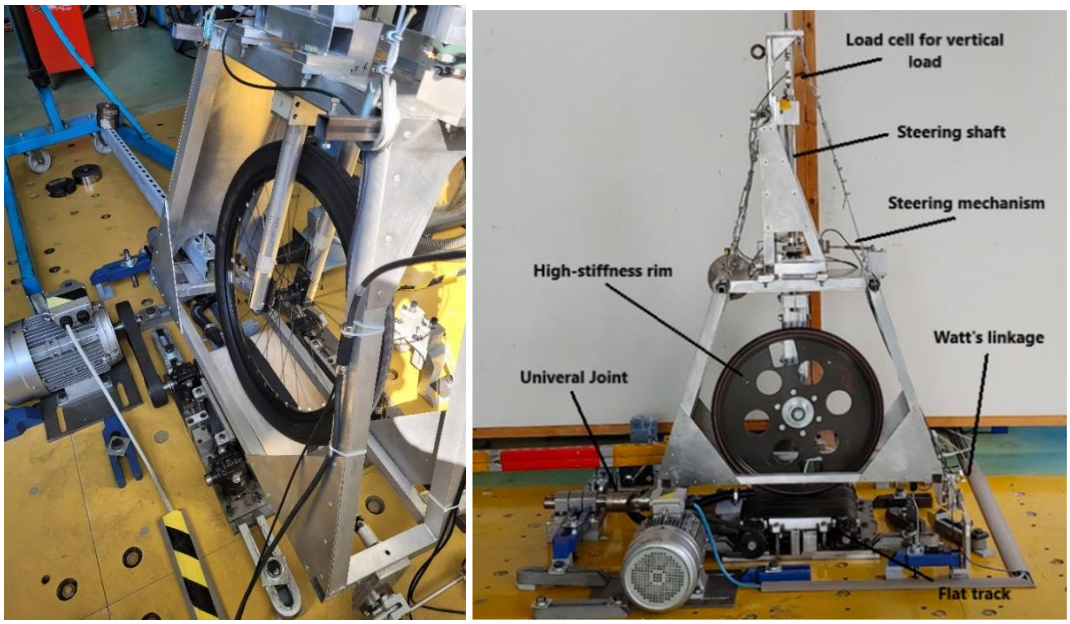

Figure 3. Test-rig used for the experimental validation of bicycle tyre thermal model (Dell'Orto, 2022).

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