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ABSTRACT
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THERMAL IMAGE-BASED WHEEL-RAIL CONTACT CLASSIFICATION AND ANALYSIS USING CONVOLUTIONAL NEURAL NETWORKS

The increased wear of tram vehicle wheels and tracks in Polish cities poses a significant operational problem, leading to higher operating costs, reduced driving comfort, and increased undesirable vibration phenomena. Therefore, the study of wheel-rail interaction is crucial, particularly in the appropriate operational context, to enhance the efficiency of rail transport systems.

Undesirable contact phenomena, such as relative slippage (creepages) or multipoint contact, result in excessive wear and dissipation of frictional energy into heat, causing local temperature rises at the wheel-rail contact patch. Each type of contact has its own thermal signature by which it can be identified. Hence, there is the possibility of identifying a specific type of contact in a given exploitative context. By placing an infrared (IR) camera underneath the vehicle and directing it to observe the contact interface between the wheel and the rail, the measurement offers the possibility of detecting real-time temperature distribution within the relevant infrastructure and rolling stock context, while accounting for dynamic conditions. Convolutional Neural Networks (CNNs) have proven their utility in image classification tasks across various applications. Their operational concept, based on local dependencies between pixels, can be successfully implemented in addressing the issue of the interaction between a wheel and a rail, where thermal phenomena occur locally. Therefore the use of CNNs enables the automatic detection of contact situations (its location and type), along with statistics generation, playing a significant role in quantitative and spatial analysis. The classification process will also enable to rejection of false or heavily distorted images that do not present contact situations. Both of these techniques are employed in the development of the research methodology by a team in the INFRAIL project conducted at Poznan University of Technology.

The purpose of this paper is to outline the integration of thermal imaging measurements and Deep Learning in studying the characteristics of wheel-rail interaction under real operating conditions. The first part discusses the most important aspects of the mechanics of wheel-rail contact related to wear and heat generation in the context of vehicle operation and tram infrastructure. This is followed by a presentation of the methodology of quantitative thermal imaging measurement and the classification results on a material recorded on a tram during real operation. The subsequent section focuses on the potential of CNNs to detect contact situations in the tram wheel-rail interface, followed by a quantitative analysis. The experiment achieved satisfactory classification parameters. The research concludes with a presentation of the most significant research observations, such as the occurrence of intense frictional heating in the multipoint contact during curving, and backflange-type contact on the straight sections.

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