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Validation of finite element models for temperature calculation in railway wheels and brake blocks using experimental data from a novel twin-disc rig

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1. Objective

During braking operations in railway vehicles, significant heat is generated as brake blocks press against the wheel tread, converting kinetic energy into thermal energy. This leads to increased temperatures in both the wheel and brake shoes. Additionally, the phenomenon known as "rail-chill", where the warm wheel transfers heat to the colder rail, and convection with the ambient air, contribute to thermal stresses in these components. Over time, such stresses can cause thermal cracks, compromising safety, structural integrity and requiring more frequent maintenance. To address these challenges, experimental campaigns play a crucial role in characterizing material properties and behaviour under thermal stresses.

The Politecnico di Torino railway research group has recently designed a scaled twin-disc test rig for the investigation of wear caused by the wheel-rail contact. Designed using Pascal's similitude model, the test bench replicates full-scale maximum contact pressure in scaled setup. Subsequently, a tread braking system was introduced to investigate the thermal behaviour of brake blocks during drag braking operations. This enhancement follows a novel thermal scaling rule which ensures that the temperature field on the scaled system is the same as for the full-scale wheels and blocks for drag braking operations.

As part of the activity, finite elements (FE) models of wheel and brake shoe were developed, to assess the effectiveness of the scaling method. The objective of this paper is to tune and validate the FE models based on the experimental temperature values recorded on the scaled twin-disc rig.

2. Methods

The thermal scaling rule was derived from a well-established approach in the literature. By analysing the governing partial differential equations of the diffusion phenomenon, non-dimensional groups were identified. Similitude between full-scale and scaled systems was achieved by ensuring these non-dimensional parameters are equivalent in both cases, leading to the derivation of scaling factors for the main thermal quantities of interest.

The effectiveness of the derived thermal scaling rule was further proved by means of FE models developed in ANSYS Mechanical APDL for the wheel and shoe, built considering simplified geometries. The simulations demonstrated that the final temperature distribution after drag braking is consistent between the scaled and full-scale geometries.

This technique was then applied to upgrade the test rig to run tread braking tests in 1Bg and 2Bg configurations. Pneumatic cylinders press the brake shoes against the wheel, which is set in motion through contact with a rail disc powered by a brushless motor. Dynamic parameters such as angular speed and torque are recorded using transducers in the motor, while thermal data for the brake shoes and wheels is captured using a thermal imaging camera and thermocouples.

The experimental temperature measurements are first used to calibrate the test bench and subsequently to refine the previously developed FE models.

3. Results

FE model simulations successfully validated the novel thermal scaling rule, thus confirming that experimental data from the twin-disc test rig can be reliably correlated to full-scale conditions. Additionally, the outputs of experimental tests of drag braking operations are used to tune and validate the FE models, improving their predictive capabilities for analysing thermal phenomena during tread braking operations.

4. Conclusions

This study employs thermal experimental data from tread braking tests to tune and validate numerical models of railway brake shoes and wheels. The validated models will enable more in-depth analyses of thermal behaviour, as well as investigations into thermomechanical damage, wear, and the interaction between dynamic and thermal effects. Future work will focus on extending tests to stop braking scenarios and developing more refined numerical models.

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