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Design of a twin-disc rig for the investigation of the thermo-mechanical behaviour of wheels, rails and brake shoes of railway freight wagons

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1. Objective

The wheel-rail contact represents the most critical aspect for the safe and reliable operation of railway vehicles. In particular, the wear process, caused by the rail-wheel interaction, modifies their profiles, negatively impacting the running performances and safety of the vehicle. For this reason, it is crucial to characterise accurately the tribological properties of steels commonly used in the railway industry. These investigations are usually performed using tribometers, such as "pin on disc", "ball on disc"or "twin-disc"tribometers. To tackle this problem, the Politecnico di Torino railway research group designed an innovative scaled twin-disc test rig, capable of simulating faithfully the full-scale scenario, thanks to the Pascal's similitude model adopted. As an upgrade to the initial design, a tread braking system was subsequently conceived, along with a novel similitude model, capable of replicating the thermal behaviour of brake blocks. The objective of this paper is to describe in detail the design of the bench and its final configuration, with great focus on the specifications, characteristics and capabilities of the new twin-disc rig.

2. Methods

The original configuration of the bench was designed using Pascal's similitude model, which ensures that the contact pressure at the wheel-rail interface is the same in both scaled and full-scale systems. As a further novelty, the discs are shaped to the actual rail and wheel profiles, with an additional correction on the rail profile to compensate for the non-zero curvature in longitudinal direction, thus ensuring the proper scaling of the contact patch.

The discs of novel test bench are independently powered by brushless motors, to run tests at different angular speeds and creep levels. The normal load, which presses the discs against each other, is adjusted through a system of compressed helical springs, whose stiffness keeps the pressure constant throughout the tests. The bench can replicate the contact occurring during common conditions of both freight and passenger wagons. The quantity of material removed due to wear is measured trough a laser system. This measurement is then used to tune wear coefficients for different wear laws.

As an improvement to this initial configuration, a tread braking system that can be installed on the twin-disc test bench was designed. As the bench was originally conceived to investigate wear, following Pascal's similitude model, the adaptation also required the definition of a different scaling rule for investigating thermal phenomena. Therefore, an ad-hoc thermal scaling rule was derived, through the identification of a set of non-dimensional numbers from the thermal equations. The thermal similitude model was validated with finite elements models of the shoe and wheel, thus confirming that it is possible to obtain the same temperature field in the full-scale and scaled systems. Whilst the thermal scaling rule is suited for drag braking operations, it cannot be extended to stop braking operations, as it would clash with the existing limits imposed by Pascal' s scaling strategy.

Based on the derived drag braking thermal scaling rule, the main components of the scaled tread braking system were designed. The brake blocks, made of materials commonly used in the railway industry, are pressed against the wheel disc by pneumatic cylinders, strong enough to perform both 1Bg and 2Bg test configurations. Design choices such as the drilling of slotted holes and the use of a self-aligning ball-bearing allow the brake block to adapt to the profile of the wheel. Furthermore, a cooling system based on air fans and a nozzle was conceived, to adjust the air flow speed and hence properly scale the convection coefficient.

3. Results

The design activity led to the construction of a novel twin-disc test rig, capable of performing both wear and tread braking experiments. For both types of tests, a dedicated similitude model is implemented, and this allows to relate the test results to the full-scale counterparts.

4. Conclusions

The bench is currently being used for preliminary tests and calibrations. Future developments of the activity will deal with the identification of a non-linear correlation between the data obtained from experimental tests, run with Pascal's similitude model, and finite element models of stop braking operations.

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