COMPUTATIONAL MECHANICS 2023
38th conference with international participation
Srní
October 23 - 25, 2023

Assessment of solid lubricants for the wheel–rail interface

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1. Introduction

One of the key concepts of railway transport mechanics is adhesion, which means the ability to transmit tangential forces at the wheel–rail interface under normal loading. Tangential forces can act as traction or braking forces, and they take part in the guiding of a vehicle on the track. They cause stress in the material and influence the wear of wheels and rails.

The ratio of tangential force to normal force is limited by the coefficient of friction, which constitutes the main characteristic of the tribological conditions of the wheel–rail interface. There have always been methods to influence the tribological conditions, such as sanding in case of low adhesion. Today, the problem is treated in a complex way and referred to as friction management (see e.g. [3]), and its tools can be generally characterized as friction modifiers. This paper is focused on friction modifiers designed to cause low coefficient of friction (LCF), i.e. lubricants of the flange/gauge corner zone, specifically in the solid state.

Information on the performance of the lubricants is important for the evaluation of their suitability for use in railway operation and also serves as an input for the simulation of vehicle dynamics and wear of wheel/rail profiles.

2. Test methodology

The methodology for comparative testing of solid lubricants using a twin-disc machine is defined in the standard EN 15427-2-1 [1], adopting the procedure of the previous standard EN 16028. The procedure can be briefly described as follows: after mounting the test discs and setting the load, the machine runs at the required speed without lubrication of the discs. When the coefficient of friction (COF) reaches the initial level of 0.4, a solid lubricant sample (stick) is applied and loaded against one of the discs. If the lubricant is effective, the COF drops. After 200 s, the lubricant sample is removed without stopping the machine and the COF gradually rises again. The test ends when the COF reaches the reference dry level of 0.4. The lubricant sample is weighed to assess the lubricant consumption.

The standard recommends keeping creepage at 10–20 %, rotational speed 230–400 rpm (without indication of the disc diameter) and pressure in the contact of the discs 800–1200 MPa (without specifying whether this is mean pressure or maximum Hertzian pressure). The lubricant stick loading is not prescribed in the standard. The discs should be cooled by air flow.

The following outputs are evaluated:

- rate of COF decrease after applying the lubricant,
- steady COF value during lubrication of the discs,
- duration of COF increase up to the reference dry level after the lubricant is removed,
- consumption of the lubricant during the test.

The test discs should be manufactured from real wheel and rail materials (cut from wheels and rails) and shaped so that the required Hertzian pressure is reached by applying the force by the twin-disc machine. The lubricant sample is obtained by cutting the supplied sticks to dimensions suitable for a small-scale applicator.

3. Results

After the start of the test, the COF usually starts to increase and soon reaches the dry reference value. When the lubricant is applied, the COF drops. Depending on the lubricant performance, the lubricated COF levels as well as the general shape of the COF history during the test can differ considerably; examples for two different materials are shown in Fig. 1 (the bottom example shows better performance than the top one).

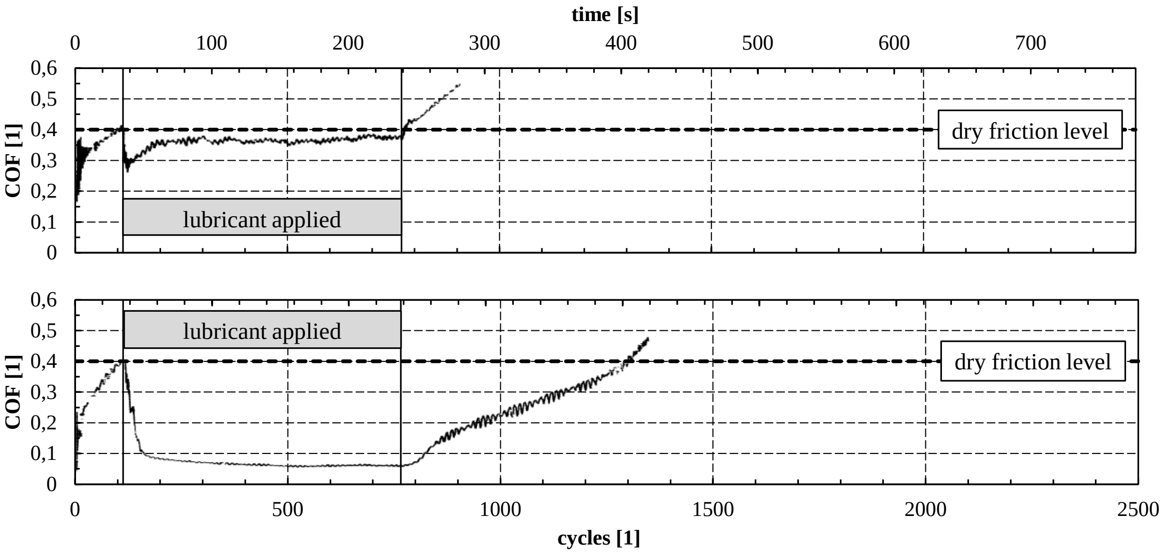

Fig. 1. Measured time histories of COF during twin-disc tests of two different solid lubricants

Evaluation of lubricant sample consumption, required by the standard, appears impracticable: weight loss after 200 s is extremely difficult to measure. If a particle is accidentally separated from the sample during manipulation or if a piece of metal debris from the disc is embedded in the stick, the result is significantly affected. It is suitable to depart from the standard and perform an additional test just to evaluate the lubricant consumption, where the weight loss is measured in multiple stages of a run taking about 100 000 cycles. The discs can be weighed during this test as well to find the effect of the lubricant on disc wear.

The methodology is designed for comparative testing, serving for comparison of various lubricant materials on a given test apparatus. Comparability of results obtained on different testing machines is not guaranteed. In the authors' experience, the methodology is not sufficiently specified and the results are not always consistent even with a single testing machine.

The study [2] shows that the performance in terms of COF may not be consistent with the effect on the wear of the discs (the wear can be sometimes reduced even if the COF stays quite high).

4. Factors influencing the results

Unsuitable thermal conditions (high temperature at the disc interface) can cause structural changes of the interface layer with the lubricant. It is also important that the discs should be cut out of such parts of wheels and rails that are not affected by plastic deformation of the surface layers. Care must be taken to have high geometrical quality and surface roughness. Furthermore, loading of the lubricant sample is an important factor that influences lubricant performance and consumption. The standard requires a run-in shape of the stick end (conformal contact), but an alternative option has also been discussed that uses a flat end (line contact) which leads to more consistent conditions of transferring the lubricant particles to the disc surface.

5. Conclusions

The standardized testing methodology should be improved, which is the objective of the current research. A methodology that would produce absolutely valid and universally comparable results may not be possible to find. What can be done, however, is to provide such a test setup that the solid lubricant, together with the steel disc surfaces, operates in a mode relevant to real operation.

References

[1] EN 15427-2-1, Railway applications – Wheel/Rail friction management – Part 2-1: Properties and Characteristics – Flange lubricants, CEN, 2022.

[2] Evans, M., Lewis, R., Alternative twin-disc assessment of solid stick flange lubricants, 10th International Conference on Contact Mechanics, Colorado Springs, 2015.

[3] Tomeoka, M., et al., Friction control between wheel and rail by means of on-board lubrication, Wear 253 (1–2) (2002) 124–129.