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Field measurement of coefficient of friction in rails using a hand-pushed tribometer

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ABSTRACT

The coefficient of friction (COF) on the rail of a commercial railway was measured in the field using a hand-pushed tribometer. Two different friction modifiers (FM), a flange lubricant and water were manually applied on the top of the rail and creep curves were obtained for contact pressures of 1.0 and 1.2 GPa. The coefficient of friction was between 0.42 and 0.55 for dry tests, between 0.39 and 0.44 for water lubricated tests, and ranged from 0.13 to 0.22 when the FMs or flange lubricant were added. Thicker layers and greater contact pressures led to lower values of COF. In comparison to the dry condition, the effect of contact pressure was much less significant when an interfacial product was applied.

1. Introduction

Wear of rails and wheels as a consequence of contact interaction is a major problem for the transportation industry. A widely used approach to deal with it is the application of lubricants and/or friction modifiers at the wheel/rail interface [1]. However, when an additional element is deliberately added to such an interface the coefficient of friction (COF) changes and many operational settings need to be adjusted. Accordingly, reliable assessment of COF at the wheel/rail interface is a key factor to control the available traction force and to improve the performance of the system. It is well known that the presence of friction modifiers and/or lubricants at the interface drastically changes the tribological response of the contacting pair and helps increase the durability of the components while it reduces prejudicial effects such as noise and rail corrugation.

Most studies carried out to measure the COF at the wheel/rail interface have been performed to identify the changes induced when an additional element (water [2,3], high positive friction modifiers [2], leaves [3], among others) is added to the contact. To do so, several methods have been developed to measure the COF. In the laboratory, typical instruments include pin-on-disc tribometer [2–5], twin disc machine [6,7], mini traction machines [8,9], and full scale roller rigs [10,11]. In pin-on-disc tests, typical values of COF for dry conditions are among 0.35 and 0.5 [2] and from 0.05 to 0.15 when a friction modifier or lubricant is added to the contact [4,5]. In tests done in a twin disc machine, the COF for dry conditions was around 0.6 [6], 0.2 for wet conditions and 0.07 for greases and friction modifiers [7]. When a mini traction machine was used, the values of COF were between 0.7 and 0.8 in dry conditions [8], 0.15 to 0.2 in wet conditions and 0.02 to 0.05 when a lubricant was used [9]. When the COF was measured in a full-scale roller rig the values ranged from 0.5 to 0.54 dry, 0.08–0.1 wet [10] and 0.05 in oil [11]. In summary, there are significant differences in the COF when it is measured in a laboratory using a rolling-sliding configuration or a pure sliding condition.

Harrison et al. [2] developed a hand-pushed tribometer to collect data from a small section of track. However, the equipment was not suitable for simultaneous COF measurements of top-of-rail and gauge-face and in order to overcome those issues the author also developed a TriboRailer allowing for simultaneous measurements of top-of-rail and gauge-face for the track, high-speed operation and automated data collection. Harrison measured the COF using the TriboRailer and compared the results with the hand-pushed tribometer. He found that the COF measured by the tribometer (0.7) was higher than the COF measured by TriboRailer (0.5) under dry conditions since the former uses lower contact pressure to perform the measurements. Later on, the same author [12] developed an improved version of the hand-pushed tribometer and studied the variation of the COF with pressure, velocity and lubrication conditions. He found that the COF in dry conditions depended on the dimensions of the wheel and the pressure and in all cases, when the contact pressure increased, the COF decreased.

Lewis et al. [3] developed an alternative method for the assessment of railhead traction by using a pendulum rig and they

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found good correlation with tribometer readings. The major advantage of this method is that measurements can be taken from around 0.3 m of the rail. Nevertheless, one disadvantage of the method is that, as the measurement pad wears, it must be swung over a calibration material in order to determine if the pad must be replaced. Magel and Liu [13] also developed an instrument for field measurements of the characteristic traction creepage based on lateral creepage and compared the results with those obtained with a hand-pushed tribometer. They found higher values of COF on tangent curve and lower values on curved track when comparing the data obtained with the hand-pushed tribometer.

Other authors calculate the COF by measuring the tangential and normal forces in the field by using strain gauges properly located in the rails. Recently, Popovici [14] developed an instrument to measure the COF on-line in an instrumented vehicle, but the measurements are carried out under sliding conditions. From the literature review, it can be said that several methods have been developed to measure the COF in the field, being the hand-pushed tribometer one of the most reliable methods for train operators to measure the COF because of its low cost, the relevant data and the reliable and quickly operation.

In this work, the coefficient of traction COT (friction force divided by normal force for every creepage value) is measured with the aid of a custom-made hand-pushed tribometer *(TriboMetro FR 101)* in contact with the rail, and the entire creep curve is reported for different interfacial products and two contact pressures. The maximum level of tractive force depends on the capability of the contact patch to absorb traction and is expressed in the form of the friction coefficient (COF). Two different Friction Modifiers (FM), a flange lubricant and water, were manually applied on the top of the rail and gauge prior to the tests and creep curves were obtained for contact pressures of 1.0 and 1.2 GPa. The results were compared with the values of COF found in the literature using different setups in the laboratory and in the field.

2. Materials and methods

COF measurements were performed in a commercial railway using a custom-made hand-pushed tribometer *(TriboMetro FR 101)*. The equipment was instrumented to measure the entire creep curve and calculate the Coefficient of Traction (COT) from the data obtained and store it in a personal computer. The position of the measurement wheel with respect to the rail can be changed to measure different contact zones either on the flange or the rail head.

The operating principle of the equipment is to progressively increase the braking torque on the wheel to induce longitudinal slip with respect to the rail. A normal force is applied by a helical spring to the rotating wheel and is kept constant during each test. During the measurements, the operator pushes the tribometer at a typical walking speed and the measuring wheel rotates due to the tangential force (friction force) generated at the wheel/rail interface. When the wheel is rotating, its angular velocity is measured with an encoder. The test starts once a constant angular velocity is reached. After starting the test, an increasing braking torque is applied with the aid of an electromagnetic device to promote creepage, and then the creep curve is obtained. The data are acquired and controlled by a data acquisition card and stored in a personal computer. Once the test is finished, the COT is calculated for every measurement point as the ratio of the tangential force (which is a function of the braking torque) to the normal force (measured with a load cell) for every creepage. The COF reported after the test is the average of 6 independent measurements, in which the COF reported is the maximum stable value of COT obtained for the entire creep curve once the saturation is reached. Fig. 1 shows the equipment in the field as well as a schematic of its principle of operation. The average relative sliding speed was 0.5 m/s in all cases and the contact pressure was either 1.0 or 1.2 GPa.

The COF was measured in the head rail of a 90 m radius curve located in a low-density traffic line with an average rail roughness (Ra) of $3.0 \pm 0.6\ \mu m$ (obtained after 30 measurements). The measurements were carried out using different conditions in terms of the presence of an interfacial element: dry, water, friction modifier 1 (commercial), friction modifier 2 (custom-made) and flange lubricant (commercial). The wheel was deeply cleaned using methanol and acetone after each measurement. In every test the data were taken from six independent measurements performed along 30 m of railway. The average COF was computed from at least 20 measurements using the same conditions and two main outputs were obtained:

1. The average value of the COF once saturation of the creep curve was reached, and
2. The entire creep curve (Creepage vs COF).

Fig. 2 shows the testing curve where the COF was measured. The arrows mark the specific locations where the interfacial products (shown in the inset) were applied to measure the coefficient of friction. The temperature and humidity were externally monitored

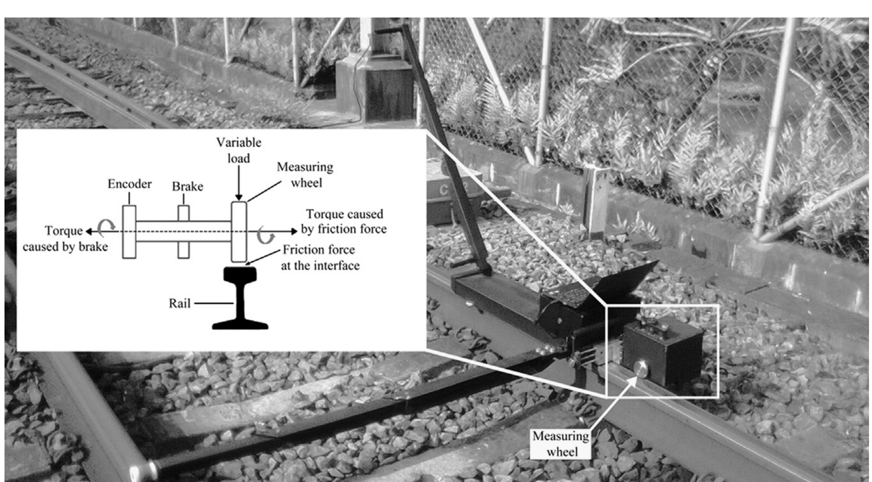

Fig. 1. Positioning of tribometer in the railway and schematic of measurement principle.