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Influence of climatic conditions on adhesion in the wheel-rail contact

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ABSTRACT – The goal of this study was to investigate the effect of climatic conditions on adhesion in the wheel-rail contact. For this purpose, a ball-on-disc tribometer was utilized which enables to precisely control climatic conditions, mainly temperature and air humidity. Apart from these conditions, the influence of leaf layer on adhesion was investigated. The special attention was paid to water condensation which can cause a further adhesion decrease. Obtained results showed that a combination of high relative humidity and a presence of leaf layer can significantly reduce adhesion in the contact, even below a value 0.1 which is needed to traction and braking.

1. INTRODUCTION

Transmission of tangential force from the wheel to the rail represents a crucial parameter for traction and braking performance of railway vehicles. This transmission is usually expressed as the ratio of tangential and normal force acting in the contact. In railway field, this ratio is usually called the adhesion coefficient which is typically in the range from 0.2 to 0.7 for dry conditions dependently on an experimental apparatus [1]. However, an actual value of adhesion coefficient is considerably affected by both operating and environmental conditions. In the case of environmental conditions, the most significant natural contaminants are humidity [2-3], water [4-8], and leaves on the track [9-10]. These conditions can result in the adhesion coefficient less than 0.1 [5,9] which can cause traction and braking difficulties. Although, there are many papers dealing with the influence of environmental conditions on adhesion in the wheel-rail contact, only little has been reported yet about the effect of water condensation on adhesion. In addition, previous studies mainly used apparatus where the contact operates under pure sliding conditions. This experimental approach can avoid some adhesion drops because of high contact temperature. With respect to these facts, the effect of water, temperature, and air humidity on adhesion was studied under rolling-sliding conditions in the present study. Furthermore, these experiments were carried out with "clean" and contaminated disc (by leaf extract) to evaluate the critical scenario occurring during autumn.

2. METHODOLOGY

A ball-on-disc tribometer was employed to achieve typical rolling-sliding conditions occurring in the wheel-rail interface. Both the ball and the disc were independently driven; thus, the slip could be accurately set and controlled. A material of both contact bodies was a bearing steel AISI 52100 with an initial roughness of Ra 0.01 µm and 0.2 µm for the ball and the disc, resp. The tribometer is equipped by the climatic chamber enabling to set various values of temperature (1–50 °C) and relative humidity (7–100%).

Each particular experiment was started by a run-in in order to remove all oxides and a residual friction layer adhered on contact surfaces. This run-in was stopped when a stable and dry level of adhesion was reached. Immediately after this run-in, the main part of the test was conducted. During this measurement, the adhesion coefficient was recorded at a frequency of 1 Hz. All experiments were performed under following operating conditions: contact pressure of 0.8 GPa, entrainment speed of 1 m/s, and slip of 5%. These experimental parameters were chosen with respect to the typical operating conditions for light rail systems. As was mentioned above, "clean" and contaminated discs were used in this study. Besides air humidity and temperature, the effect of various quantity of water on adhesion was investigated where an applied quantity was changed from 1 µl for tens of milliliters to achieve fully-flooded conditions.

3. RESULTS AND DISCUSSION

Figure 1 shows the example of time test with the clean disc where the effect of relative humidity on adhesion was investigated at a constant air temperature of 24 °C. The same sets of measurements were conducted for various temperatures. After completing of all these experiments, an average value of adhesion was evaluated for each particular measurement. The average adhesion value was calculated from last 30 seconds where the adhesion coefficient was certainly stabilized.

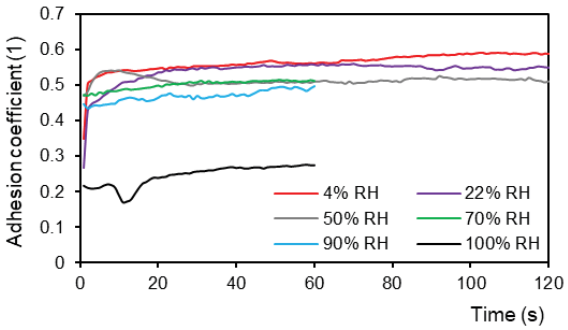

Figure 1 Effect of RH on adhesion for clean disc at air temperature 24 °C.

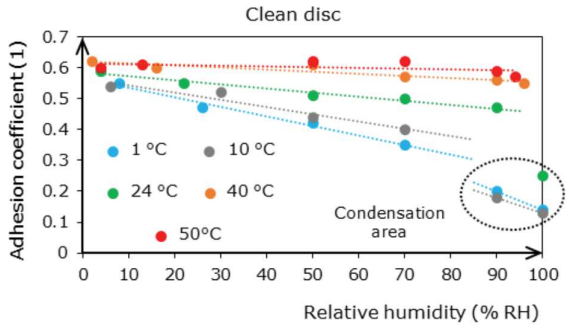

Figure 2 Influence of relative humidity and temperature on adhesion for clean disc.

The results of adhesion measurements with the clean and contaminated disc for various values of relative humidity and temperature are depicted in Fig. 2 and Fig. 3. In the case of the clean disc, it is apparent that the adhesion coefficient is significantly reduced with increasing relative humidity. Moreover, this effect is much more significant for lower temperature e.g. 1 °C. These results are in a good correlation with a previous observation [2]. It should be highlighted that a further adhesion drop occurs if water condensation was identified, see the condensation area in Fig. 2 and Fig. 3. In that case, a small amount of water together with wear debris may form an enough viscous paste, which can partially or completely separate contact surfaces, as was previously reported by Beagley et al. [11]. A presence of this viscous paste/layer with a low shear strength results in low adhesion values.

The similar trend was also found for measurements with the contaminated disc. In this case, the adhesion coefficient generally reached lower values, due to the presence of leaf extract, compared to the experiments with the clean disc. This combination of leaf and high relative humidity results in insufficient adhesion for traction and braking because the adhesion coefficient was less than 0.1. This critically low adhesion can be explained as a result of softening of leaf layer due to the presence of water.

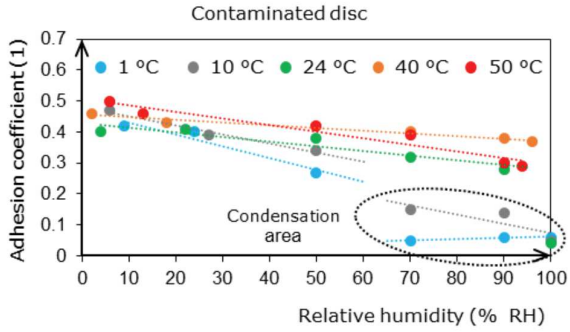

Figure 3 Influence of relative humidity and temperature on adhesion for contaminated disc.

4. CONCLUSIONS

The present study was focused on the effect of climatic conditions on adhesion in the wheel-rail contact. Experimental research was conducted using a ball-on-disc apparatus which enables to achieve the typical rolling-sliding conditions occurring in light-rail systems. The obtained results showed that adhesion was considerably reduced with increasing value of relative humidity, especially at lower temperatures. Furthermore, the significant drop in adhesion was found if water condensation occurred. The critical case was observed for a high relative humidity and the disc contaminated by the leaf extract. In this case, the adhesion coefficient reached critically low values leading to traction and braking difficulties. This critical scenario can especially occur during mornings where a low temperature and a high humidity can be expected.

ASKNOWLEDGEMENT

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