



DETERMINATION OF ELECTRICAL RESISTANCE OF RAIL FASTENING SYSTEM ACCORDING TO THE STANDARD EN 13146_5-2012

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Abstract

Since the rails serve as a current conductor from the vehicle to the electrical substation, the rail fastening system must have a certain electrical resistance to prevent current from leaking from the rail to the sleeper. The resistance can be determined using a laboratory test described in the standard EN 13146_5-2012. This standard specifies a test procedure for determining the electrical resistance of the fastening system and sleeper under wet conditions. The test uses a multimeter to record current and voltage over time. One rail is connected to the positive pole of the laboratory rectifier and the other rail is connected to the negative pole. The current from the rectifier flows into the rail and through the fastening system and sleeper to the other rail and back to the source. This paper describes the laboratory measurement of electrical resistance performed on a W-14 fastening system and a concrete sleeper. The measurement was performed at the Faculty of Civil Engineering, University of Zagreb, within the project “Development of the elastic fastening system DIV”.

Keywords: rail fastening system, electrical resistance, rail-to-earth resistance, stray current

1 Introduction

The requirements for the fastening system for concrete sleepers in ballasted track include longitudinal rail restraint, torsional resistance, attenuation of impact loads, effect of repeated loading, electrical resistance of the fastening system and sleeper, effect of exposure to severe environmental conditions, overall dimensions, effect of fastening system tolerances on track gauge, clamping force, cast-in fastening components, and in-service testing [1-3]. The requirements that the fastening system must meet are listed in the standards EN 13146 and EN 13481. For modern railways, which are using direct current (DC) or alternating current (AC), the fastening system must have a certain electrical resistance to increase the resistance between the rail and the ground, especially in wet conditions, and to prevent stray current. Since rails are used as return conductors, the electric current can deviate from its main path and create a path in the ground if sufficient resistance between the rail and the ground is not provided [4]. This current is referred to as stray current. In ballasted track, the electrical resistance depends on the type of fastening system, the type of sleepers and the properties of the ballast. Each fastening system provides a spot resistance to earth and “discharge points” for stray currents. Depending on the number of fastening systems in a traction system, the resistance between track and ground can be calculated [5]. When steel sleepers are used on ballasted tracks, it is very difficult to ensure adequate resistance between the rail and the ground. In this case, the electrical resistance depends mainly on the type of fastening system.

On the other hand, high electrical resistance is achieved when concrete sleepers are used because concrete sleepers have an insulating effect when dry, but their electrical resistance decreases when wet [6]. In the dry state, the electrical resistivity is $10^{12} \Omega\text{mm}$, but in the wet state, concrete behaves like a semiconductor and has a resistivity of $10^5 \Omega\text{mm}$ [7]. The electrical resistivity of concrete depends on the w/c ratio, pore size distribution, pore fluid conductivity and temperature [8].

According to [9, 10], the electrical resistance of the W14 fastening system on the B70 2.6 W-60 concrete sleeper is greater than 5 k Ω . For the Nabla fastening system, the electrical resistance is 15 k Ω because this system has better electrical insulation [11]. The W14 fastening system for concrete sleepers is the most widely used fastening system in the world. This fastening system consists of sleeper screws, SKL 14 clips, angled guide plate, rail pad and plastic dowels [12]. Rails are laid directly on the concrete sleeper, separated only by an elastic rail pad, and fastened with the clip and sleeper screw. The clips are laid on guide plates and the screw dowels are set in concrete (Figure 1).

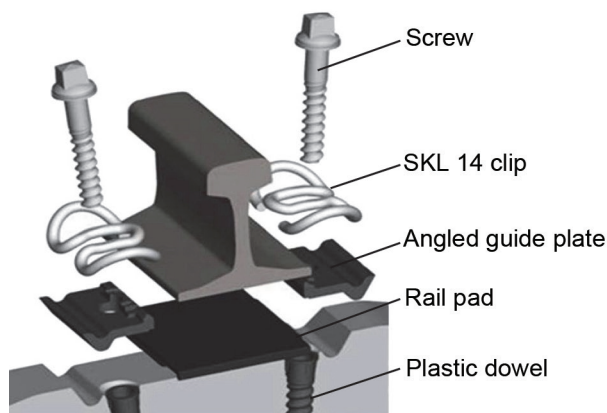


Figure 1 W14 fastening system [13]

The electrical resistance of this fastening system is determined by the electrical resistance of rail pad, plastic dowel, and sleeper. Rail pads should have certain value of electrical resistance to stop the current from leaking from the rail through the pad to the sleeper. The resistance of elastic pad depends on the fillers added to the rubber during vulcanization. The most used filler today is soot, whose electrical resistivity can vary from 0.44 to 150 Ωcm [14, 15]. According to IEC 62631-3-1:2016 [16], the electrical resistivity of the rail pad must be greater than $10^8 \Omega\text{cm}$. The resistance of the fastening system measured in wet condition will also depend on the water conductivity, which is defined by the ion concentration in the water and the temperature. To illustrate, salty water has a conductivity of 50-70 mS/cm, and the conductivity of drinking water is less than 1 mS/cm [17, 18].

The measurement of electrical resistance described in this article was carried out as part of the project "Development of the elastic fastening system DIV". To define the properties of the new fastening systems, various tests of the properties of W14 fastening systems were carried out to establish a test methodology described in the standard EN 13146.

2 Measurement of electrical resistance according to the EN 13146_5-2012

2.1 Electrical resistance of the fastening system and sleeper measured according to the standard

According to this standard EN 13146_5-2012 [19], the test must be performed under cover and protected from rain and draughts in a room with an air temperature of 15 to 30°C. Since the sleeper must be sprayed with water during the test, four nozzles should be placed above the sleeper. Each nozzle should spray 7 ± 1 liters of water in one minute. Before the measurement, the electrical conductivity of water must be determined according to the standard EN 27888. It should be 50 ± 5 mS/m. In [20] it is stated that the electrical conductivity of water should be measured at a reference water temperature of $25 \pm 0.1^\circ\text{C}$. The temperature is important because the conductivity of water increases with temperature and can affect the results of the electrical resistance of fastening system [21]. If it is not possible to measure conductivity at the reference temperature, the temperature correction factor defined in the standard EN 27888 can be used, but according to [22], a conductivity measurement made with the sample at the reference temperature is always more accurate than a temperature compensated measurement made outside the reference temperature.

In this paper, the laboratory measurement of electrical resistance was performed on a concrete sleeper B70 2.6 W-60. Rails of type 60 E1 with a length of 50 cm were used for the test. The rails were placed on an elastic pad and fastened to the sleeper with the SKL-14 clip and screw.

To perform the test, the sleeper is placed on two electrically insulating blocks to prevent leakage current from the sleeper. An AC power supply of 30 ± 3 V RMS and 50 ± 15 Hz was used for the measurement. The voltage during the test was 31 V and the current depended on the electrical resistance of the sleeper and fastening system. Voltage and current were measured using Multimeter GWInstek GDM9061 and data were recorded directly on computer. The specimen prepared for the test and the equipment used for the measurement are shown in Figure 2.



Figure 2 Specimen prepared for testing the electrical resistance (left), equipment used for the measurement (right)

One rail was connected to the positive pole of the current source and the circuit was closed by connecting the second rail to the negative pole. The current entering the rail connected to the positive pole flows through the fastening system and sleeper to the other rail and returns

to the current source (Figure 3). The spraying of water from the nozzles must continue for 2 minutes and the measurement must be taken at least 10 minutes after the water spraying has stopped. This measurement should be repeated two more times on the other two similar test specimens. If this is not possible, the same specimen can be used for all three measurements. In this case, the next measurement can be performed after 120 hours. The measurement described in this article was performed three times with the same specimen.

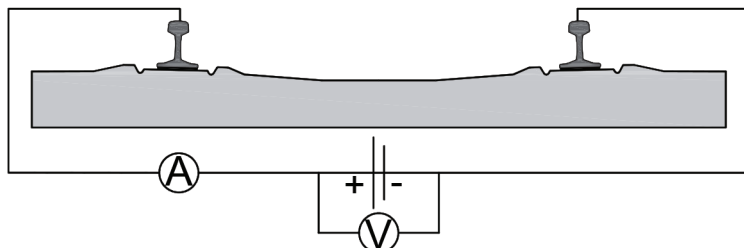


Figure 3 Current circuit for detecting the electrical resistance of the fastening system

Prior to the measurement, the electrical conductivity of the water was measured using the SI Analytics Lab 945 conductometer (Figure 4). Since the water temperature was 15.8 °C, the temperature of the water sample taken for the electrical conductivity measurement was increased to 25 °C. The measured electrical conductivity was 775 $\mu\text{S}/\text{cm}$. Since the conductivity of the water was too high, deionized water was added and the conductivity measurement was repeated until the conductivity of the water was in the range of 50 ± 5 mS/m as recommended in [19]. The measured value of water conductivity before the test was 492 $\mu\text{S}/\text{cm}$ (49.2 mS/m).



Figure 4 Measuring the electrical conductivity of water using the conductometer SI Analytics Lab 945

2.2 Rail pad electrical resistance testing

The electrical resistance of rail pads used in the specimen shown in Figure 2 was tested with the same equipment as for measurement the resistance of the fastening system. Rail pad was placed between the steel plate and the rail. The rail was connected to the positive pole of the current source and steel plate was connected to the negative pole (Figure 5). Since the resistance of the rail and the steel plate is very low, the only resistance in this circuit is the resistance of the rail pad.

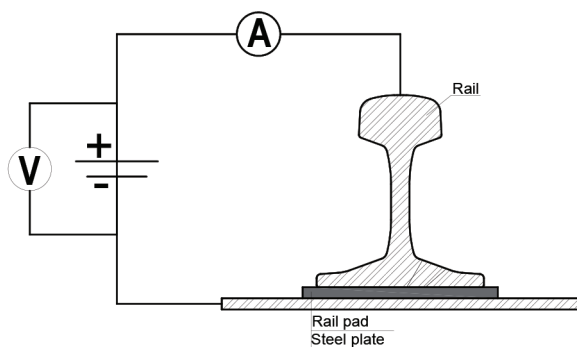


Figure 5 Measurement of electrical resistance of the rail pad

Current was measured using the multimeter and the electrical resistivity was calculated by the equation 1.

$$\rho = R \cdot \frac{S}{l} \quad (1)$$

Where:

R - the calculated resistance based on the measured current and voltage,

S - the area of the elastic pad,

L - the length of the elastic pad.

In this measurement area of elastic pad that is 180 cm² and the length is 0.5 cm. Average value of measured resistance is 58.67 kΩ and average resistivity of rail pads is 0.2110⁸ Ωcm.

3 Results analysis

Using the measured values (current and voltage), the electrical resistance of fastening system and sleeper was calculated for all three measurement cycles. The resistance was plotted as a function of time and is shown graphically in Figure 6.

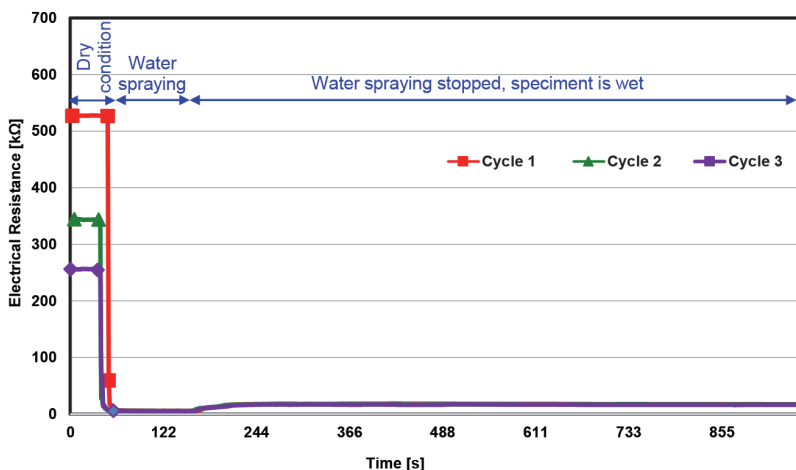


Figure 6 Electrical resistance of W14 fastening system, plotted in time for all three measured cycles

As it can be seen from Figure 6, the electrical resistance of the fastening system and sleeper is very high in the dry state. The average value of the resistance in all three measured cycles is 375.47 k Ω . After the nozzles start spraying the water, the electrical resistance decreases drastically. The minimum value of resistance in cycle 1 is 5.81 k Ω , in cycle 2 the minimum value is 5.69 k Ω and in cycle 3 is 5.32 k Ω . The spraying with water lasted for 120 seconds and after the spraying stopped, the electrical resistance started to increase. The average value of the maximum measured resistance detected in the wet state after the water spraying ended was 17.83 k Ω .

The minimum electrical resistance of the fastening system and the sleeper was calculated as the arithmetic mean of the minimum values from all three measured cycles. In this case, the minimum average value is 5.61 k Ω . The minimum electrical resistance determined in this laboratory test must be greater than the electrical resistance defined in the fastening system specifications - for the W14 fastening system this is 5 k Ω . Since in the W14 fastening system, the rail is in direct contact with the clip and the clip is in contact with the screw, measured resistance depends on the electrical resistance of the plastic dowel and the concrete sleeper. The reduction in resistance when water is sprayed is the result of the reduction in electrical resistance of the concrete sleepers when they are wet.

4 Conclusion

Electrical resistance is one of the characteristics that a fastening system must meet. The value of electrical resistance varies among fastening systems and depends on the type of fastening, the insulating materials and type of the sleeper. Electrical resistance can be measured using the test method described in the standard EN 13146_5-2012. It is important to note that electrical resistance changes over time due to the deterioration of the fastening system and the sleeper. Therefore, it is important to control the electrical resistance of the fastening system during the monitoring of track construction through various types of field measurements.

The measurement described in this paper was carried out to prepare the equipment for the measurement of electrical resistance of the new fastening system "DIV", which will be the result of the project "Development of the elastic fastening system DIV". Performing measurements on existing fastening systems, whose properties are known, is crucial for developing a test methodology that can be used to define the properties of the newly developed system.

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