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The issue of uncertainty of visual measurement techniques for long distance measurements based on the example of applying electric traction elements in diagnostics and monitoring

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ABSTRACT

Rail transport is the most economical and energy-effective in the field of land transport, in particular electrified. In order to ensure efficient and reliable operation of electrified rail transport, the issues of monitoring and diagnostics of the traction infrastructure and vehicles are extremely important. The most critical point in the transmission of electric energy to the vehicle is the sliding contact of the current collector with the traction network. For this reason, work is currently being carried out on the possibility of monitoring the technical condition of current collectors at selected points of the railway lines, which makes it possible to detect the current collectors which do not work properly, and those in which the damage occurred after the train's departure. In order to make the diagnostic process at such point as complete as possible, it is necessary to develop new measurement methods and new applications for the existing methods. Evaluation of the technical condition of current collectors at the control point is carried out based on the analysis of displacements of the contact wire of the overhead contact line, caused by the impact of the current collector. The nature of these displacements, as well as the presence or absence of certain components provides the information on the correct adjustment of the current collector and the technical condition of its strips. Simultaneous measurement of vertical and horizontal displacements requires the application of innovative measurement techniques. The use of non-contact visual techniques for this purpose, which makes it possible to measure displacements in a two-dimensional plane using a fast 2D camera and advanced image analysis, is promising. This article presents the analysis of measurement uncertainty of visual measurement techniques for long distance measurements for application of electric traction element diagnostic and monitoring. The measurement verification at a laboratory test stand are also presented. The requirements concerning the measurement equipment have been determined and the factors affecting the uncertainty of the final measurement dependent on a given configuration of the stand have been specified.

1. Introduction

The increasing mobility of modern societies, as well as liberalization of the economic market are causing an increased demand for passenger and freight transport. Rail transport is the most economical and energy-effective in the field of land transport, in particular electrified. In order to ensure efficient and reliable operation of electrified rail transport, the issues of monitoring and diagnostics of the traction infrastructure and vehicles are extremely important. The most critical point in the transmission of electric energy to the vehicle is the sliding contact of the current collector with the traction network. Even a minor defect of any part of this contact (such as chipping of the shoe's contact strip) can often lead to severe damage of the infrastructure and/or vehicle, resulting in significant financial losses, as well as causing perturbations and disruptions in railway traffic. For this reason, work is currently being carried out on the possibility of monitoring the technical condition of current collectors at selected points of the railway lines, which makes it possible to detect the current collectors which do not work properly, and those in which the damage occurred after the train's departure. In order to make the diagnostic process at such point as complete as possible, it is necessary to develop new measurement methods and new applications for the existing methods. The principle here is that the measuring equipment should not interfere with the traction network parameters, or that such interference should be as small as possible.

Evaluation of the technical condition of current collectors at the control point is carried out based on the analysis of displacements of the contact wire of the overhead contact line, caused by the impact of the current collector. The nature of these displacements, as well as the presence or absence of certain components provides the information on

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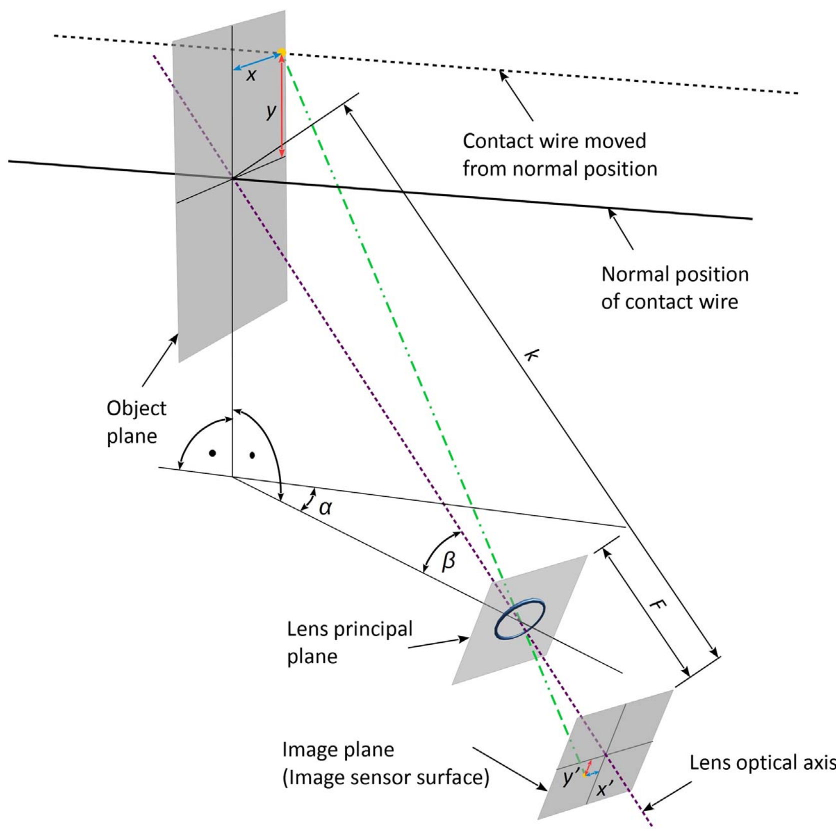

Fig. 1. Configuration of the measurement stand for testing the contact wire displacements of the overhead contact line in two axes using a 2D imaging camera, where: x, y – displacement of the contact wire in the horizontal and vertical axis respectively; x', y' – displacement of the image on the camera matrix in the horizontal and vertical axis respectively, k – distance between the central point of the object plane and the image plane, F – distance between the main plane of the lens and the camera matrix (plane of the image); α – angle between the vertical plane in which the contact wire lies and the vertical plane in which the optical axis of the lens lies; β – angle of inclination of the optical axis of the lens in relation to the horizontal one.

the correct adjustment of the current collector and the technical condition of its strips. For example, too low or too high vertical displacement of the wire indicates the incorrect adjustment of pressure, and the presence of horizontal displacements may indicate chipping or pitting in the shoe strip. Only vertical displacement measurements with the use of a short-range laser rangefinder, or other measurement techniques are performed at the currently functioning stands [1,2], which limits the functionality of such stands.

Simultaneous measurement of vertical and horizontal displacements requires the application of different measurement techniques. The use of non-contact visual techniques for this purpose, which makes it possible to measure displacements in a two-dimensional plane using a fast 2D camera and advanced image analysis, is promising [3]. Visual measurement techniques in traction applications have so far been applied in measuring the geometry of overhead contact lines [4–12], as well as in measuring the wear of the contact wire [4,13,14]. The evaluation of the technical condition of strips is carried out with the use of 3D laser scanning systems [15–18]. Therefore, the proposed use of a 2D camera and determination of the technical condition of the current collector based on the analysis of displacements of the contact wire is an innovative application of visual measurement techniques. Thanks to the proposed visual technique it is possible to measure the displacements not only of single contact wire, but also of the catenary wire. In the case of contact lines consisting of two contact wires, or other more complex configurations, displacements of each contact wire or catenary wire can be measured independently without any hardware upgrades. This is a great advantage of the proposed method, compared to the existing solutions, where each increase in the number of measurement elements required a corresponding increase in the number of sensors. In addition, the possibility of complex monitoring of the response of the contact line to the influence of the current collector will allow for a more accurate analysis of the correctness of cooperation of these elements.

Prior to carrying out measurements, it is necessary to perform an analysis of measurement uncertainty for such a stand, so as to determine whether the accuracy obtained is going to meet the requirements of the measurement object.

This article presents the above-mentioned analysis along with the measurement verification at a laboratory test stand. The requirements concerning the measurement equipment have been determined and the factors affecting the uncertainty of the final measurement dependent on a given configuration of the stand have been specified.

2. Object of measurement

The object of the measurement is to register the displacement of the contact wire of the overhead contact line in a two-dimensional plane, caused by the impact of the current collector of a passing traction vehicle. With regard to controlling the correctness of the current collector contact force regulation, and to monitoring the technical condition of its strips, the measurement point should be located half way along the suspension span. This is due to the fact that the degree of flexibility of the contact line is the highest at this point, and therefore the influence of the current collector will be the strongest there. Naturally, for such a configuration, the displacements measured at this point will be smaller when the current collector is at the end of the span than when it reaches its middle. However, the damage of the strip should always result in a measurable displacement in the horizontal axis. Such a displacement may be regarded as a signal that the damage has been detected. Values of these displacements do not normally exceed ± 10 cm, both in the vertical axis and in the horizontal axis in relation to the resting position. Since the contact wire is located at the height of about 5.5 m above the railhead, and because it is necessary to remain at a certain distance due to vehicle gauge, terrain configuration at the measurement site or other factors which prevent a close approach to the measured object, the distance from which the measurements are to be performed can be about a dozen or even a few dozen metres. This distance can therefore be several hundred times greater than the measured displacement