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Modeling of the Pantograph-Catenary Wire Contact Interaction

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Abstract

One of the problems appearing at creating of new pantographs designs is associated with the geometric parameters selection for the minimum wear of the coal insertion and the catenary wire. To determine the dynamic loads in the contact between the pantograph and the wire, there was performed the simulation analysis using MSC.ADAMS software. According to the computations the contact force-time dependence for the case of connected pantograph and wire was obtained. The simulation results were later used to analyze the stress-strain state of the coal insert. The finite element modeling of the pantograph-catenary wire contact interaction was performed in ANSYS. The created model included parts of wire, coal insert and steel lining. Taking into account the symmetry of the construction it was created the half-model of real construction. The total number of model finite elements was equal to 401 717. Longitudinal and vertical forces were applied to the wire part end points. These forces correspond to the interaction forces between the pantograph and a contact wire. The computational results demonstrate that the highest values of equivalent stresses appear at the lining corners, and, if for the case of the rectangular cross-section there is a phenomenon of graphite crumbling.

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Keywords: electric transport; pantograph; catenary wire; coal insert; contact interaction; finite element modeling.

1. Introduction

The specificity of electric transports is the energy supply through the sliding contact between the pantograph and catenary suspension. Design of pantographs and their characteristics are determined by the power and velocity of electric rolling stock (ERS), by the rolling stock overall dimensions and the proximity of buildings, by horizontal and

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vertical location of the catenary wires (Mikheev 2003). At vehicle movement it should be ensured the reliable contact between the pantograph runners (ski) and the catenary wire for its different height position (Belyaev 1976).

The quality of the pantograph-catenary wire contact is of great importance for the current collection process. Deutzer Technische Kohle company (DTK) carried out the contact pressing force measurements in order to determine the reasons for the contact quality decrease and for taking appropriate measures to improve it (Deutzer 2009).

The results showed that the poor mechanical contact can lead to the electric arc appearing and strong wear of the catenary wire as a result. Even in the case when an electrical arc does not appear, the insufficient pressing force causes an uneven fit of carbon inserts to the wire, the density of current in the contact local areas increases sufficiently and causes the fact of the catenary wire melting by heating and as a result the wire material can fall on the car roof or on the second carbon insert located in the nearby area. Besides, the mentioned problem leads to the deteriorating of the pantograph coal inserts fit to the wire and there can be the formation of the groove on graphite and copper plating of the adjacent zones as a result.

There is a great amount of investigations devoted to the pantograph-catenary wire contact interaction.

For example, to measure the contact force between a pantograph and contact wire Ikeda (2004) proposed to use a new inversion method, the distinct feature of which is to reduce restraints on the sensor arrangement to facilitate contact force measurement. To achieve sufficient levels of precision, high order vibration modes of the panhead have to be taken into consideration by applying a pseudo-inverse matrix. The author has confirmed the accuracy of this method by numerical calculations and an excitation test on a currently-used pantograph.

In the paper by Sergeev (2007) it was carried out an investigation of the vibrational dynamics of the discrete-continuous “overhead catenary – electric rolling stock pantograph” system. Based on the perturbation method the performed analysis showed that the mathematical description of the named system corresponds to the well-studied in the literature Mathieu equation with a periodic external influence. The analytical expressions describing the catenary – pantograph interaction were obtained. It is shown that the unwanted pantograph self-oscillating modes can disappear in the process of ERS movement by the result of selecting the optimal combination of the pantograph and catenary wire properties.

Arnold and Simeon (2000) have recently studied the interaction of pantograph and catenary in high speed trains. They formulated a simplified model problem that reflects basic parts of the nonlinear dynamics in the technical system pantograph/catenary. Following the method of lines the equations of motion are semi-discretized in space using finite differences. For time discretization, typical differential-algebraic equations techniques are applied such as index reduction, projection steps and handling of systems with varying structure.

Rauter (2007) presented a new methodology to study the dynamic behavior of the pantograph and of the interaction phenomena in the pantograph-catenary system. The catenary is described by a detailed finite element model while the pantograph is described by a detailed multibody model.

The work by Mpanda et al. (2011) demonstrates the results of the finite element modeling of thermal effects in the pantograph-wire contact at high-speed trains movement.

One of the problems appearing at creating of new pantographs designs is associated with the geometric parameters selection for the minimum wear of the coal insertion and the catenary wire. Bucca (2009) described experimental results of wear rate defining in the contact between the catenary wire and the pantograph. His paper demonstrates the analyzing technique including wear analysis of the wire at the dynamic interaction between the pantograph and catenary wire. The proposed method was applied to solve two problems. The first problem was to compare the wear of the contact wire for pantograph strips made of the copper and graphite. The second solved problem allowed to predict wire wear by variation of catenary wire mechanical tension.

However, in the literature there was found no information concerning stress-strain state determination for the coal insert at train movement.

The presented work demonstrates some investigation results devoted to the improvement of the pantograph – catenary wire contact mechanical characteristics.

2. Algorithm of the pantograph dimensions selection

The carried out analysis shows that it is necessary to solve a number of problems on kinematics and dynamics of mechanisms to create new pantograph configurations. The first problem to solve is to choose the structure dimensions