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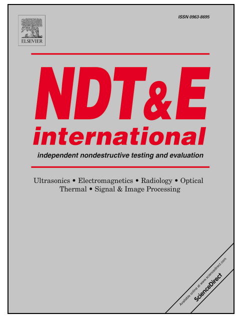

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3D Simulation and Experiment on High Speed Rail MFL Inspection

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Abstract

Magnetic Flux Leakage (MFL) method is widely used in non-destructive testing of ferromagnetic specimens such as steel pipes, ropes and rails. Inspection velocity is a critical factor in online rail track evaluation due to specific inspection conditions. As the speed increases the distribution of magnetic induction inside rail becomes inhomogeneous primarily under the influence of eddy currents. This complicates MFL signals interpretation and reduces the ability to detect deep subsurface defects in the rail head. In this paper we explore the speed limitations of the traditional MFL rail inspection and contemplate the ways to overcome the said limitations. To investigate the dependence of flux leakage data on inspection velocity two different methods were applied. The first one is 3D computer simulation of interaction between the fixed rail and the moving magnetizing system. The second method is the set of field measurements in which an experimental setup consisted of electromagnets and sensors moved along rail with artificially made defects. The results of both methods indicate to detect defects located in the center of the rail head at speeds over 80 km/h the distance between magnetizing system poles should exceed conventional 3 m or some alternatives should be employed such as MFL remote field analysis.

Keywords: Magnetic Flux Leakage, MFL, rail NDT, high-speed inspection, Finite Element Analysis

1. Introduction

The magnetic flux leakage (MFL) method is widely used in non-destructive testing of ferromagnetic objects. This method presupposes magnetizing the test object with sources of static magnetic field (magnetizing system), which allows detecting flaws inside the object due to field distortions around it. Generally, the magnetizing system executed in the form of a U-shaped magnet is moving along the object ensuring continuous control of its surface. The MFL is used to control reservoirs [1], piping, steel ropes [2].

Another important sphere of the MFL application is the evaluation of the rail track condition. The magnetizing system and the sensor system are installed on an inspection vehicle going along the rails. As a rule, magnetic control means are integrated in the combined systems for the rail track condition evaluation, implementing other control methods based on different physical principles, namely ultrasonic, eddy-current methods, etc. There are also methods for the magnetic rail evaluation based on the analysis of residual magnetization arising in weak magnetic fields under the conditions of periodic mechanical loads, and thus, not requiring a magnetizing system for the inspection vehicle. However, the said methods prove to be of little use in order to detect rail defects [3].

A critical parameter for evaluating the track rails is the maximum speed of the inspection vehicle which allows for an acceptable level of defect-detecting. This is related to the operation specifics: a low inspection velocity leads to a delay in the train circulation due to the need of rail track evaluation. In theory, the inspection velocity must correspond to the regular train speed at a given railway section. Unfortunately, none of the currently used methods provides for the necessary inspection velocity for different reasons.

The limitations of the inspection velocity using MFL are caused by eddy currents arising in the conducting medium when the magnetic field level is changing in time. Vast areas of eddy currents appear near the magnetizing system poles preventing the magnetic field from penetrating inside the rail and reducing the MFL ability to detect deep subsurface defects.

In order to diminish the negative impact of eddy currents, it is necessary to increase the time of the exposure of the evaluated rail area to the magnetic field. This can be achieved due to an increase in the pole distance within the magnetizing system. Currently, the rail defect detection actively uses a new magnetizing system, where the pole distance equals 3 m [4], which exceeds the pole distance in the previously used systems by more than three times. A more efficient injection of the magnetic field into the rail through the trolley wheel maintains the rail magnetization intensity and the electromagnet energy consumption at the established levels.

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