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Experimental tools for railway crossing condition monitoring (crossing condition monitoring tools)

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A R T I C L E I N F O

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A B S T R A C T

Two experimental tools to measure the railway crossing dynamic responses are presented. One system is ESAH-M equipped with a 3-D accelerometer and a speed detection sensor that featured for crossing instrumentation and characterised by fast installation/uninstallation, automatic data recording and processing. The other system is a Digital Image Correlation (DIC) based Video Gauge System (VGS) that record the dynamic displacements of the rail/sleepers. A number of measurements have been performed aiming to explore the feasibility of these experimental tools, establish the relation between the measured dynamic responses and condition of the monitored crossings and estimate the effectiveness of crossing maintenances.

The measurements based on crossing instrumentation show that the crossing degradation process can be described using the dynamic responses. The wayside monitoring in different problematic track sections have shown the capability of detecting and quantifying ballast conditions. Both systems will be further applied in long-term monitoring of railway crossings.

1. Introduction

In railway track system, a turnout is an essential component that is needed to guide a train when it is passing from one track to the other. However, rail discontinuity in the turnout crossing makes it a vulnerable part in the railway track system. The high wheel/rail impact forces due to this discontinuity accelerate the crossing degradation and lead to high costs of turnout maintenance. In the Dutch railway network, there are more than 7000 crossings, and about 100 crossings among them are urgently replaced every year. The service life of some crossings is only 2–3 years [1]. Moreover, the high impact forces can lead to other types of crossing damage, such as broken clips, geometry deterioration and ballast settlement, etc. (Fig. 1.1). Damage in the crossing may in turn result in further amplification of the wheel impact forces and accelerate the degradation of the track structure. Improving the performance of turnout crossing is very important in extending the crossing service life, reducing the maintenance cost, enhancing the track stability and guaranteeing the track safety.

Currently, turnout crossing maintenance in the Netherlands consists of two main activities: preventive check and damage repair. The former are periodic inspections, while latter is only performed when visible damage has occurred. The inspection trains are widely applied to collect railway track information, but with the constrained possession time and limited amount of the inspection trains, it is very difficult to get the real-time information on the condition of railway crossings. In this case, the inspection (preventive check) cannot fully eliminate potential damage risk with limited information and when it comes to damage repair, it often resulted in complete replacement of the crossing.

One solution for maintenance improvement is timely performing it in the predictive way based on the principles of Structural Health Monitoring (SHM). Typically, SHM consists of five levels of activities, namely detection, localization, assessment, prognosis and remediation [2]. Predictive maintenance requires the SHM developed to the level of assessment and prognosis. Nowadays, SHM systems are well developed and applied to various civil engineering structures, such as large bridges and buildings with sensors and other monitoring devices installed during construction [3–6]. In railways, the use of SHM systems is mainly in the stages of defects detection and localization. The main methods of detection/localisation are ultrasonic testing [7], image recognition [8,9], acoustic detection [10], guided wave inspection [11], manual inspections, etc. Regarding to railway crossings, most of the studies are numerical concerning crossing performance analysis and design optimization [12,13]. Experimental methods such as instrumented wheel [14–17] and rail [18] are mainly used for numerical model validation. Therefore, development of SHM Systems for railway crossings that include damage detection, localization and condition

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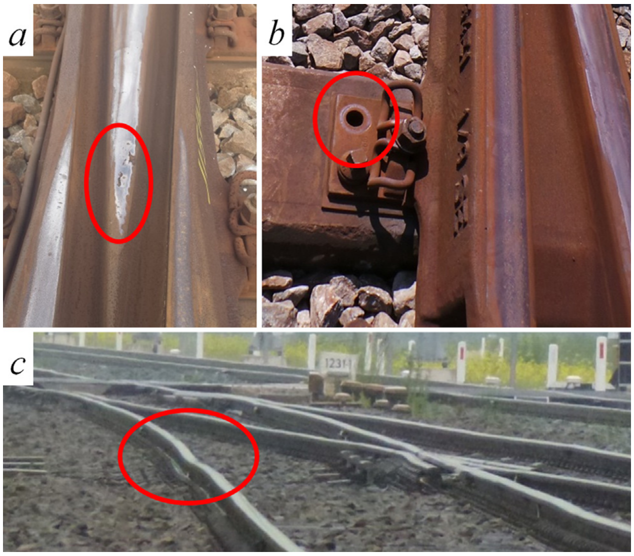

Fig. 1.1. Typical problems in railway crossings: Cracks in crossing nose (*a*), broken clips (*b*) and ballast settlement (*c*).

assessment, as well as damage prognosis and remediation is highly requested.

This paper presents two experimental tools for crossing condition monitoring and shows how the crossing structural behaviour and wheel-crossing interaction can be characterised based on the measured responses (Detection and Localization stages of SHM). In Section 2, a brief introduction of the wheel-rail interaction in the railway crossing is given. The experimental tools, accelerometer-based crossing instrumentation and Digital Image Correlation (DIC)-based wayside monitoring tool are described in Section 3. In Section 4, the performance of a crossing in various condition stages is analysed and relations between the dynamic responses and the crossing condition are determined. In addition, the effect of maintenance on the crossing nose is briefly discussed. Measurements and analysis of the performances of ballast in various conditions using wayside monitoring tool is presented in Section 5, followed by conclusions given in Section 6. The presented condition monitoring tools will be used as the basis of SHM system for railway turnout crossings.

2. Wheel-rail interaction in railway crossings

A standard right-hand turnout (Fig. 2.1) has four passing directions: the facing (from switch panel to crossing panel) and trailing (the opposite facing) directions in the through and divergent routes. In order to allow trains to intersect two tracks on the same level, there is a gap between the wing rail and the nose rail (Fig. 2.1). When passing the crossing nose, a significant amplification of the wheel force can occur due to the presence of this gap.

An example of wheel-rail interaction when the train runs in the through facing direction is given in Fig. 2.2, and the wheel-rail contact points along the track are shown as the yellow strips. The wheel firstly approaches the crossing from the wing rail ((*a*) and (*b*), looking from the right side, the same below), and then follows with the transition of the wheel from the wing rail to the nose rail (*c*), after which the wheel continues running over the crossing nose (*d*) and the through rail.

In section (*c*) (Fig. 2.2), the wheel load is transferred from the wing rail to the crossing nose, where impact occurs on the nose rail. This section is then referred to as the transition area. Apparently, the smoother the transition of the wheel from the wing rail to the crossing nose, the smaller the amplification of the wheel forces (impact forces) due to the rail gap.

The presence of the gap (and the resulting impact force) is the main cause of the fast degradation and failure of the railway crossing. The forces can be extremely high because of high train velocity (140 km/h as same as in normal track) when passing the crossings in the through direction. The high wheel (impact) forces ultimately lead to the crossing rail failure (cracks). As it was shown in the previous experimental studies [19–22] the geometry of the crossing deteriorates not only locally due to rail plastic deformations, but also overall due to the settlement of ballast that in turn results in further increase of the wheel forces. In the forthcoming sections, the link between the crossing condition/degradation and the measured responses will be established.

3. Experimental tools for condition monitoring

In order to timely detect and localise the possible crossing defects, proper experimental tools are highly required. To be suitable for crossing condition monitoring, these tools should satisfy the following requirements:

- Easy to install in and uninstall from the crossing;
- Able to measure the crossing condition related responses;
- Capable to perform the measurement continuously.

The increasingly strict railway safety rules in the Netherlands demand the measurements to be performed without track possession. Among the dynamic responses, accelerations and displacements are the major indexes for assessment of structural performance. The rail accelerations due to passing trains provide information on the track vibrations that can reflect the condition of the crossing; the rail/sleeper displacements on the other hand, mainly reflect the condition of the supporting structure of the track (mainly the ballast). Therefore, rail accelerations together with the rail and sleeper displacements can be used for crossing condition assessment.

Based on the above-mentioned requirements, two devices have been selected for crossing responses measurements. The one is an accelerometer-based ESAH-M (Elektronische System Analyse Herzstückbereich-Mobil) for crossing instrumentation. The other is the DIC-based displacement measurement device called Video Gauge System (VGS) for wayside monitoring. Both devices are described below.

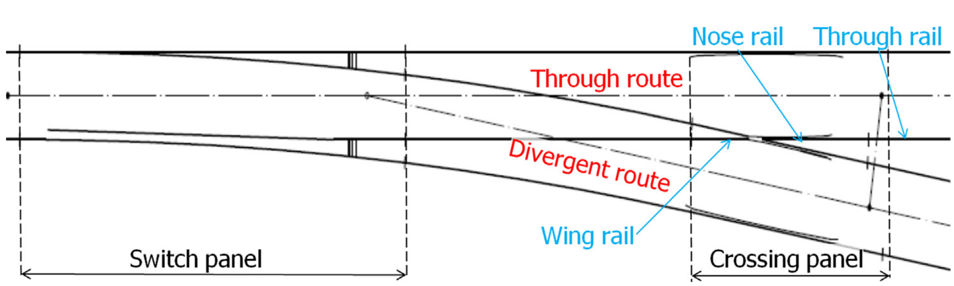

Fig. 2.1. Demonstration of a standard right-hand turnout.