Journal of Sound and Vibration 413 (2018) 79–100

Contents lists available at ScienceDirect

Journal of Sound and Vibration

journal homepage: www.elsevier.com/locate/jsvi

On the non-proportionality between wheel/rail contact forces and speed during wheelset passage over specific welds

Nekane Correa, Ernesto G. Vadillo*, Javier Santamaria, Julio Blanco-Lorenzo

Department of Mechanical Engineering, University of the Basque Country UPV/EHU, Escuela Técnica Superior de Ingeniería, Alda Urquijo s/n, 48013 Bilbao, Spain

A R T I C L E I N F O

Article history:
Received 22 November 2016
Received in revised form 17 October 2017
Accepted 19 October 2017
Available online 16 November 2017

Keywords:
Wheel-rail contact
Rail defects
Welds
Wheel-rail forces

A B S T R A C T

This study investigates the influence on the wheel-rail contact forces of the running speed and the shape and position of weld defects along the track. For this purpose, a vertical dynamic model in the space domain is used. The model is obtained from the transformation between the domains of frequency and space using a Rational Fraction Polynomials (RFP) method, which is modified with multiobjective genetic algorithms in order to improve the fitting of track receptance and to assist integration during simulations. This produces a precise model with short calculation times, which is essential to this study. The wheel-rail contact is modelled using a non-linear Hertz spring. The contact forces are studied for several types of characteristic welds. The way in which forces vary as a function of weld position and running speed is studied for each type of weld. This paper studies some of the factors that affect the maximum forces when the vehicle moves over a rail weld, such as weld geometry, parametric excitation and contact stiffness. It is found that the maximum force in the wheel-rail contact when the vehicle moves over a weld is not always proportional to the running speed. The paper explains why it is not proportional in specific welds.

© 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

In recent years, studies have been conducted on the dynamic interaction between the rail vehicle and the track, when the former moves over irregularities on the latter, such as rail welds [1–5], corrugation [6–10], rail joints [11–13], general defects [14] and other general or special geometric flaws on the tracks [15,16]. Specifically, the presence of welds (Fig. 1) on track rails causes irregularities on the surface of the rail, which significantly affect the dynamic interaction between the rail vehicle and the track. These irregularities lead to fluctuations in the wheel-rail contact forces as the vehicle moves over the rail, and this can lead to detachment and impacts. This can induce rolling contact fatigue, causing cracks to initiate in the weld defects [17]. Defects on the rail can also be instrumental in the development of corrugations [18]. In fact, the presence of weld defects is a common trigger for rail corrugation [19]. All this makes it necessary to study the wheel-rail interaction that occurs when a vehicle moves over this type of defect on a rail surface.

* Corresponding author.
E-mail address: ernesto.garciavadillo@ehu.es (E.G. Vadillo).

https://doi.org/10.1016/j.jsv.2017.10.031
0022-460X/© 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

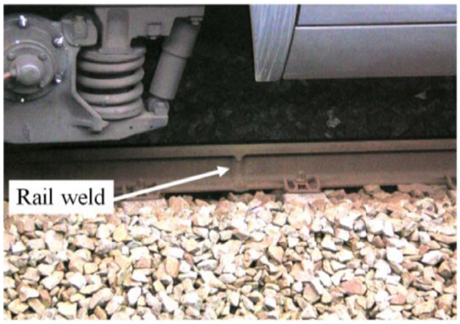

Fig. 1. Rail weld on a ballast track in Bilbao.

A time-domain model, which is capable of considering the nonlinearities in the wheel-rail contact force as the vehicle moves over the weld on a track with discrete supports, is required to carry out this study. In addition, the calculations have to be extremely rapid because the number of cases to be examined is considerably high (over 5000).

This study employs a time-domain model obtained by applying the Rational Fraction Polynomials (RFP) method [20]. This method enables a time-domain model to be developed from track information, which is in the frequency domain, such as track receptances. The RFP method can be used to fit the transfer functions in such a way that their associated receptances match the actual track receptances of different sections along the span. This setup is based on the Wu/Thompson model [21,22], which is modified to provide greater accuracy in the fittings of receptances at low frequencies. The low frequency range is precisely where the sleeper passing frequency is located, and this frequency is most important to the study carried out in this paper. The improvement is made using optimisation methods with multiobjective genetic algorithms. This produces a rapid and accurate wheel-track model, which has been validated and described in detail in Ref. [23]. The integration time of a wheelset passing over the weld is roughly 1 s. This enables an extremely rapid analysis of the contact forces between the wheelset and the rail. This model will be described in more detail in Section 2.1.

The consequences of the presence of welds on rail surfaces have been studied previously by other authors.

Steenbergen and Esveld [1] performed a study aimed at obtaining a new weld acceptance regulation. They proposed analytic expressions to calculate the contact forces when passing over rail welds. The assessment criterion for weld acceptance was based on the calculation of a quality index (QI) to determine whether the post-grinding weld geometry was acceptable. In order to assess the maximum contact forces, this criterion considers the first or second derivative of the geometry of the defect. This has proved to be more accurate in determining the validity of a weld than employing the criterion that the amplitudes of the defect should not exceed a certain value, which is the usual procedure in weld acceptance regulations. In Ref. [2] Steenbergen calculated the forces by an analytical expression, representing the welds as a sequence of discrete slopes. He also calculated the values of the P1 and P2 forces applied to rail welds.

In Ref. [5], Grossoni continues on the line of work of Steenbergen and Esveld through a series of parametric studies, and she also proposes to use a standard based on first-derivative based methods instead of the current zeroderivative methods.

In Ref. [4], Wen et al. showed the values of contact forces produced by wheelset passage over idealised rail welds, at high speeds only. They found that the trend of the maximum forces during wheelset passage over welds was practically linear, and that they increased as speed increased. These researchers, however, only analysed one type of defect (the one having the shape of a cosine function). This means that the welds are idealised, and although the authors of [4] modified the wavelengths and amplitudes of the cosines, they did not present any results for real welds, the shapes of which are more complicated.

This study analyses wheel-rail contact forces during wheelset passage over welds. It may initially be thought that, as the ride speed over a weld defect increases, the maximum wheel-rail contact forces would increase linearly. This does occur with some rail defects, such as rail dipped joints [11,13,24], where both P1 and P2 show a linear increase with speed. However, this is not always the case with rail welds. In some situations, the maximum contact forces during wheelset passage over welds do not increase linearly; instead, the maximum force may remain constant or even diminish as the running speed increases, as it was shown in Ref. [25]. It was found that the maximum contact forces increased up to a certain speed, at which the curve reached a maximum. Subsequently, it decreased and then increased again.

Similar results were obtained in Refs. [26–30] for the scenario of a wheel flat defect in the interaction between the wheel and rail. Fig. 2 shows the results of the maximum contact force obtained from the experiments [28] for a wheel flat. It can be observed that, at low speeds, the maximum contact force increases as running speed increases. However, above speeds of approximately 40 km/h, a higher ride speed does not produce a higher maximum contact force, which in fact falls to a relative minimum at around 95 km/h. After the relative minimum, it appears that the maximum force/speed curve recovers its initial upward trend.

In this study, an in-depth analysis is conducted on the different types of the most representative welds that have been used throughout the paper. Some of them have been measured in the vicinity of Bilbao – all of which are aluminothermic welds – and the others have been taken from the studies mentioned in the bibliography. If the bibliographic source has specified

Download English Version:

https://daneshyari.com/en/article/6754184

Download Persian Version:

https://daneshyari.com/article/6754184

Daneshyari.com