A methodology for the detection of rail irregularities and defects based on the vehicle dynamic response

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The intense development of high speed railways in the recent years, together with a constant increase of passenger comfort standards have led to a considerable rise in quality requirements for the railway infrastructure. In this regard, if the rails are not perfectly aligned and smooth, such irregularities will induce extra vehicle oscillations and an increase of dynamic loads. In consequence, passenger comfort might be threatened and maintenance costs of both track structure and rolling stock may significantly rise [1, 2].

The measurement of rail irregularities has been traditionally done manually by maintenance workers; and more recently with the help of special machinery (*e.g.*, inspection cars and multiple tampering machines), which implies high maintenance costs [3]. Therefore, intense research has been carried out over the past decade in order to develop different techniques for an indirect detection of rail defects, where the dynamic response of the running vehicle is used instead of a direct measurement on the rail [4]. In this sense, this paper presents a methodology for the assessment of rail defects and irregularities based on acceleration registers measured on the vehicle.

To this purpose, the time history of accelerations is registered on the vehicle body by means of tri-axial accelerometers; while its position on the track is constantly recorded with a GPS. Then, the measurements are processed and transformed into 3D rail geometry data along the line, according to the algorithm described below and presented in Fig. 1.

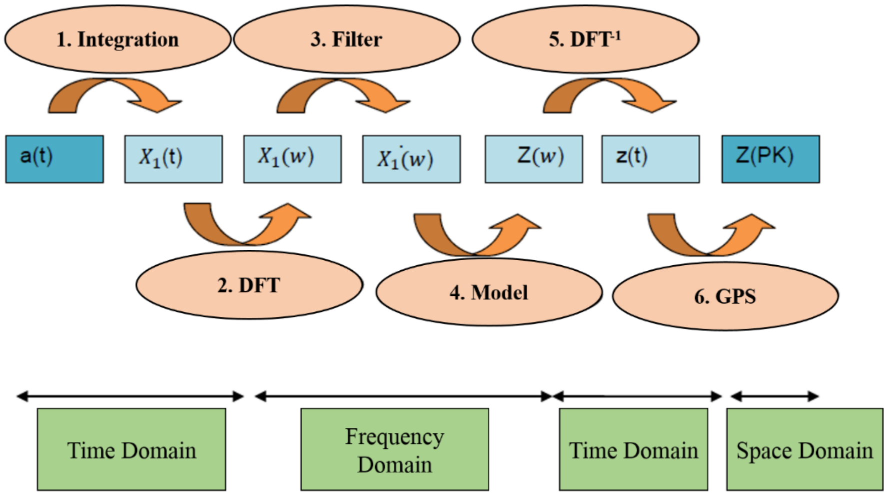

Fig. 1. Scheme of the data processing algorithm

First, the time history of accelerations is double-integrated over time through eq.(1) in order to obtain the time history of vehicle displacements.

$$x(t) = x_0 + v_0 \cdot t + \int \int_0^t a(t) \cdot dt \cdot dt \qquad (1)$$

Where *x(t)* and *v(t)* are the displacement and acceleration time histories, respectively; and x_0, v_0 are the initial values of vehicle displacements and velocities. Once the vehicle displacements have been calculated in the time domain, they shall be transformed into the frequency domain in order to allow a subsequent filtering of the data. This process is carried out by means of the Fourier transform in a discrete form (DFT, eq.(2)).

$$x(\omega) = \sum_{r=1}^{n} x(t) \cdot e^{\frac{2\pi i (r-1)(s-1)}{n}} \qquad (2)$$

Where coefficients *r* and *s* vary from 1 to *n*; and *n* is the total number of points in the data series. The high-pass filtering of the signal is then performed with the aim of removing low frequencies (*i.e.*, long wavelength components), since they do not correspond to rail irregularities or alignment defects, but to track geometry regular variations such as cant and slope changes. The fourth step of the algorithm deals with the vehicle-track interaction; and consist of calculating the displacements on the wheel-rail interface by means of the equations provided by the two-masses model of the vehicle (eq. (3)).

$$\begin{aligned} & m_2\ddot{x}_2 + c_2\left(\dot{x}_2 - \dot{x}_1\right) + k_2\left(x_2 - x_1\right) = 0 \\ & m_1\ddot{x}_1 - c_2\dot{x}_2 + c_2\dot{x}_1 - k_2x_2 + \left(k_1 + k_2\right)x_1 - k_1 z = 0 \end{aligned} \tag{3}$$

Where m_1 is the unsprung mass (*i.e.*, wheelset); m_2 is the sprung and semi-sprung mass (*i.e.*, car body and boogie, respectively); k_1 is the track stiffness; and k_2, c_2 are the stiffness and damping coefficients of the primary suspension, respectively. Once the rail geometry is known in the frequency domain, the data shall be transformed back to the time domain, which is performed by means of the inverse discrete Fourier transform shown in eq. (4).

$$z\left(t\right) = \frac{1}{n}\sum_{r=1}^{n} Z\left(\omega\right)\cdot e^{-2\pi i\frac{(r-1)(s-1)}{n}} \tag{4}$$

Finally, the geometry dataset in the time domain is transformed into the space domain by correlating its values with those provided by the GPS.

References

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