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IDENTIFICATION OF WHEEL PROFILE IRREGULARITIES BY MEANS OF THE MEASURED VIBRATIONS DUE TO THE PASSAGE OF A TRAIN

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ABSTRACT
Vibrations produced by the passage of a train have their main source in the wheel-rail contact, producing annoyances to the surroundings when the wheel profile presents wheel flats or another kind of irregularities. Railway transport companies are pointing to the need of using monitoring techniques and predictive maintenance, in order to identify wheel flats and take the suitable measures before the active worsening and the wear in the wheel-track system can be considerable. In this work, a technique for the wheel flats and wheel profile irregularities detection, based on vibrations measured in the rail and related to the passage of a train, is presented. The vertical vibration time history was measured using two accelerometers located at the bottom of the rail. The strain signal of the rail web, produced by the passage of a single wheel, was also measured. Wheel flat detection is made by means of a time domain analysis of the vibration velocity signals. The time history analysis allows the knowledge of which wheels show a persistent irregularity. The identification methodology presented constitutes the base for the future development of an algorithm capable to detect automatically wheel flats and other profile irregularities.
Keywords: wheel flats, wheel profile irregularities, rail web strain, monitoring.

1. INTRODUCTION
In order to maintain the vibration produced by irregularities in the wheel profile under acceptable levels, railway companies are considering the use of monitoring techniques to carry out a suitable predictive maintenance. The main objective is to detect wheel profile irregularities just when they appear, before they become the main cause of significant levels of vibration and severe damage in the wheel-track system.
Monitoring techniques usually consist of a data acquisition system and a signal analysis procedure for detecting the irregularities. In this work, a study of the signals to be acquired at the passage of a train is presented, as well as the location of the sensors along the track, in order to achieve the development of a monitoring technique. Some examples of acquired signals, and their analysis, are also presented.

2. VARIABLES TO BE MEASURED
The acquisition system chosen for monitoring signals is the Pimento system by LMS [1,2]. This selection has been made on the basis of their portability and the properties of their acquisition software.
Velocity and acceleration vertical components of vibration have been measured for a single rail at a straight section of the track, placing piezoelectric accelerometers at the bottom of the rail, because the

vertical vibration component is the main one. Moreover, it is considered that the measured vibration is due only to the wheel-rail contact force. Acceleration and velocity signals are both registered simultaneously.

In order to carry out this measures, two accelerometers are placed along the rail at a distance of 1,2 m. In this manner, the transient vibration generated by the passage of a wheel can be registered, without loss of fundamental information, while the wheel is doing a whole rotation. It has been shown that the distance between two contiguous bogies is long enough and the attenuation factor of the track is high enough, to avoid the superposition of transient vibrations generated by wheels of different bogies. But this is not the case of vibrations produced by both wheels of the same bogie. The signals captured by both accelerometers are the superposition of transient vibrations from these wheels.

The rail web strain signal produced by to the passage of each wheel is also registered as an auxiliary measurement. This signal is acquired by means of an strain gauges sensor fixed to the rail web at the same location of the first accelerometer. The strain signal is used as an indicator of the passage of each wheel just over the first measurement point, because it depends mainly on the static load due to the coach weight which supports each wheel, and therefore the influence of the dynamic component of the contact force can be neglected.

Figure 1 shows the accelerometer and the strain gauges sensor locations in the rail.

Figure 1. Accelerometer placed at the bottom of the rail and strain gauges sensor placed in the rail web.

3. SIGNAL PROCESSING AND ANALYSIS

Chosen signals to be analyzed correspond to the vertical vibration velocity. At the top of Figure 2, the time signal of the rail vibration vertical velocity due to the passage of a train is shown. Additionally, at the bottom of Figure 2, it is shown the same signal filtered with a band pass filter with a frequency band between 200 and 500 Hz. This interval is chosen with the purpose of rejecting the low frequency wheel-track dynamic response, and standing out the mid frequency components associated to the wheel profile irregularities to be detected.

In the filtered signal, can be observed not only the passage of each bogie, indicated with a spot, but also the passage of both wheels of each bogie over the measurement point, as short time transient signals. In addition, other transient signals that would be attributed to wheel profile irregularities can be identified. Therefore, it is concluded that the filtered signals will be the base for the development of a method to identify the wheel profile irregularities.

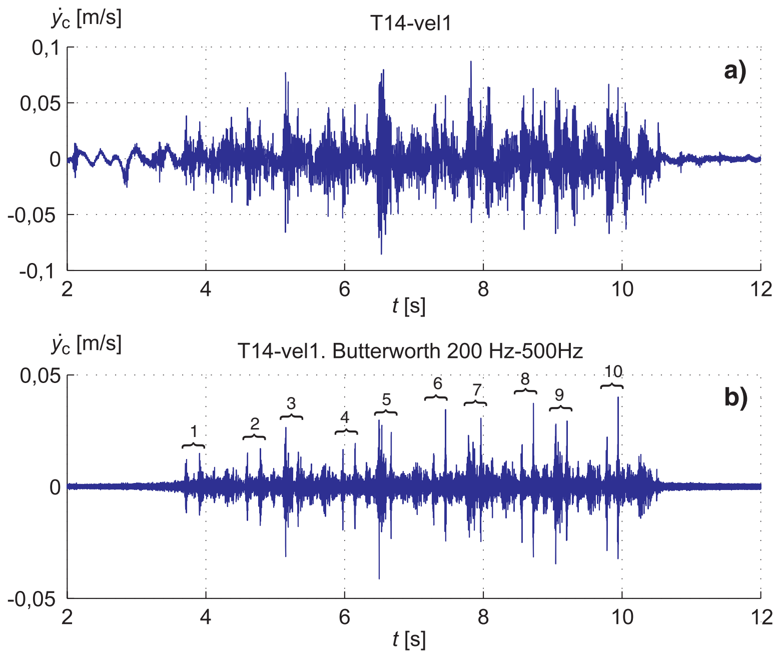

Figure. 2. Vertical vibration velocity signal due to the passage of a train. a: Signal acquired. b: Signal filtered with a band pass filter between 200 Hz and 500 Hz

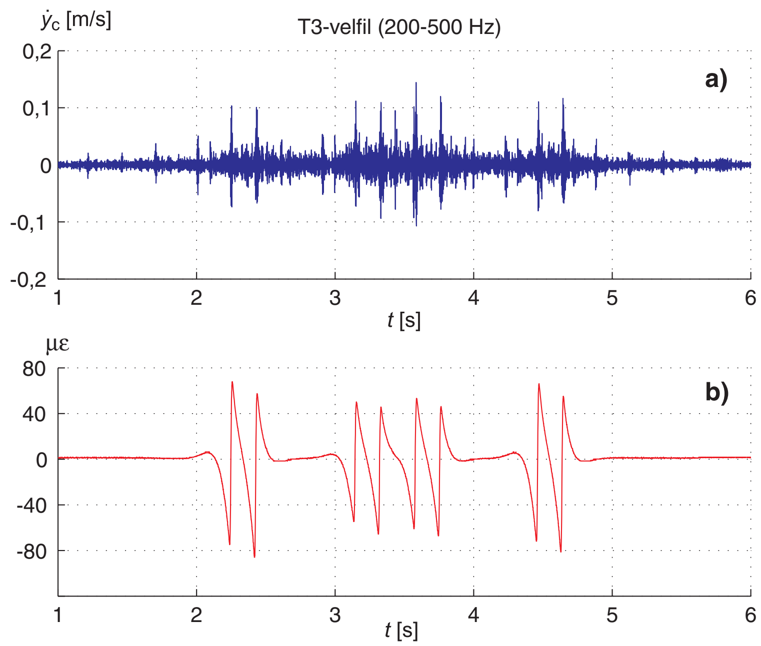

Figure 3. a. Filtered vibration velocity signal due to the passage of a train. b. Rail web strain signal corresponding to the same passage

Figure 3 shows the filtered vibration velocity due to the passage of a light train and the corresponding rail web strain signal acquired with the strain gauges sensor, and expressed in microstrains (με). The concordance between the transient vibration associated to the passage of a single wheel over the measurement point and the sign shift of the rail web strain is clear. This light train is composed of two coaches and therefore only four bogies can be identified in the signal registers. It is obvious that using

the strain signal as a reference signal, is possible to identify easily the location of each wheel along the vibration register, and so differentiate between transient vibrations due to the passage of wheels and transient vibrations due to profile irregularities.
Figure 4 shows the zoomed register corresponding to a filtered vibration velocity signal due to the passage of a train. It can be seen a periodic distribution of transient vibrations (pointed by the inverted triangles). The period shown by the transients is equal to the time spent in one wheel rotation, so these transients can be attributed to profile irregularities. The same contact force pattern repeats in each wheel rotation, so the transient vibration produced by the contact force also repeats, with its amplitude affected by the distance between the wheel and the measurement point.
In order to identify these transient vibrations, a time windowing applied to the filtered vibration signal is used. The window width is adjusted to 0,01 s and moved along the signal register. The energy level of the signal fraction inside the window, compared with the mean energy of the whole register, leads to the transients identification.

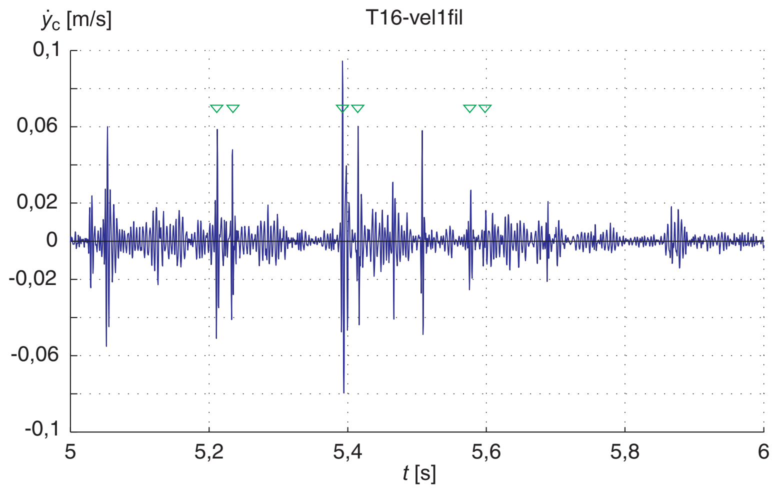

Figure 4. Zoomed register of the filtered vibration velocity signal due to the passage of a train

4. CONCLUSIONS.

A method for the detection of wheel profile irregularities, based on the acquisition and analysis of velocity vibration signals due to the passage of a train and the associated rail web strain signals, has been presented. The proper location of accelerometers and the strain gauges sensor in the track has been discussed, and a time domain analysis applied to filtered vibration signals has been proposed.
This methodology will be the base of an algorithm for the automatic detection of wheel profile irregularities, before such irregularities could cause significant vibration problems.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] Pimento. Time Data Acquisition Tutorial. 2004, pp. 1 – 27.,

[2] Pimento. Time Data Analysis Tutorial. 2004, pp. 1 – 34.,

[3] McHutchon, M.A., Staszewski, W.J., Schmid, F. Signal processing for remote condition monitoring of railway points. Strain 41(2), 2005, pp. 71 – 85.,

[4] Lanza di Scalea, F., McNamara, J. Measuring high-frequency wave propagation in railroad tracks by joint time-frequency analysis. Journal of Sound and Vibration 273(3), 2004, pp. 637– 651.