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Sustainable Development, Global Change & Ecosystem

D2.2 – Load time histories due to wheel and rail geometrical irregularities

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Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

D2.2.1 Report on stress/load/acceleration time histories when vertical acceleration excide high levels

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Date: *August 31st 2008*

1 Introduction

This report presents the work carried about stress, load and acceleration time histories when the vertical acceleration excides high levels.

As part of this work was carried out also for D2.1, this report will not detail the computation of load and acceleration time histories. These tasks will only be mentioned in the first two paragraphs.

The last paragraph presents the computation of stress time histories.

2 Detection of defects

As already explained in D2.1, defects in the rail are detected by the peaks in the vertical acceleration signal in the axle box. The signal is thus swept and when the acceleration exceeds a given value, it is a defects. The figures below show an example of one Pendolino vertical acceleration signal. (Figure 1)

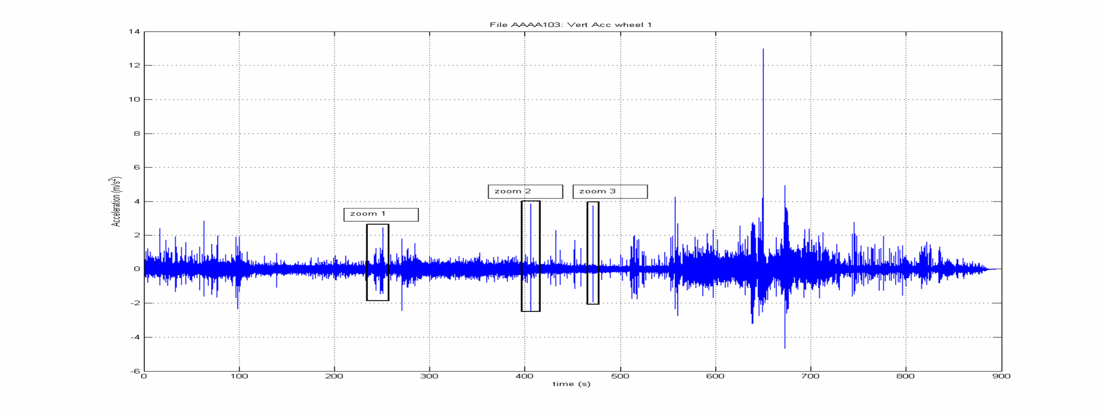

Figure 1: Vertical acceleration in data file AAAA103 for the Pendolino

3 Stress time histories

Time histories of the measured stresses are obtained by putting, one after the other, all parts of the strain signals contained between the “begin” and “end” times from the classification matrix.
Figure 2 presents the positions of the strain gages on the axle during the measurements on the Pendolino.

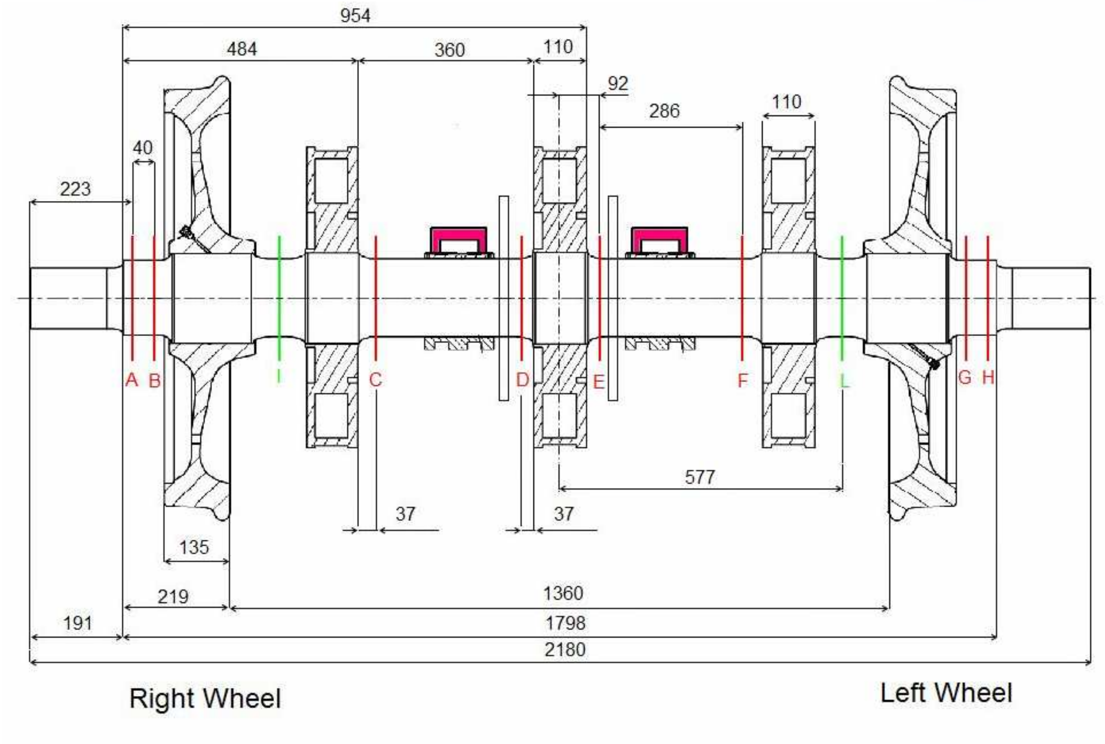

Figure 2: Positions of the strain gages on the axle

The time histories of strain are saved in a matrix where the rows are the time points and the columns are the different signals of strain on the strain gages.

4 Conclusion

In conclusion, the software is able to extract the stresses and classify them in different rolling conditions. Defects are detected when the vertical acceleration on the axle box exceeds a given value. A span of 4 s around this peak is taken to ensure that all the consequences of the defects are included in the time frame. These time frames are then classified according to the speed at which the vehicle is running. Time histories of the strains are reconstituted from these time frames.

These strain histories can then be used for axle design purposes.

D2.2.2 Report on stress/load/acceleration time histories due to different wheelflats

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1 INTRODUCTION

One of the most challenging trends in present railway research is the reduction of vehicle impact trough e.g. the reduction of axle loads, non-suspended masses, energy consumption. In this view, an efficient procedure for wheelset design is of critical importance. At present, wheelsets (axles and wheels) are designed based on the application of conventional loads that do not reflect the real service loads, and hence in some cases the final result may be over-conservative. New methods are presently under development, and are expected to bring significant reduction in the weight of wheels and axles, being based on the knowledge of the wheelsets' actual service loads.

Information concerning service loads can be derived either by a direct measure or by the numerical simulation of train-track interaction. Both these ways present however some drawbacks: the physical measure is not applicable at the design stage of a new vehicle, it is expensive and time consuming especially if all service conditions (full load/tare, new/worn wheel profiles etc.) are to be covered; furthermore, the pass-band of contact force measuring methods is currently limited to 20÷50Hz, which does not enable to measure the effect of impulsive loads taking place at line singularities (such as turnouts and rail joints) or in presence of wheelflats. On the other hand, mathematical models of train-track interaction and the related simulation software have been already demonstrated to be able to quantify with good accuracy the effect of "standard" loads related to the vehicle's running dynamics in tangent track and in curve [1], [2], but still need to be proved accurate enough in the prediction of extreme loads produced by singularities and concentrated defects on both wheels and rails. Of course, this calls for a validation against measurements, which is now made difficult by the limited pass-band of contact force measurements.

It is important to remark that extreme loads, although being only seldom experienced by the wheelset, can be particularly critical to the fatigue resistance of the wheelset, as they may produce crack initiation and accelerate the subsequent crack propagation in the axle [3] and may be responsible for surface or sub-surface damage in the wheels [4]. Aim of this work is therefore to investigate how the effect of exceptional loads can be accounted for in a numerical procedure for the prediction of wheelset load spectra, with special focus on the effect of turnout negotiation and wheelflats. To substantiate the modelling and simulation work, an extensive test campaign was carried out with an instrumented ETR680 Czech Pendolino train on the Czech Republic railway lines and on the VUZ test circuit located in Velim (CZ). The results obtained show that singularities in the line and wheelflats actually produce extremely high train-track interaction effects, although the stresses in the axle seem to be only marginally affected. A detailed description of track flexibility and train-track interaction appears then to be an essential ingredient for the accurate numerical prediction of impulsive loads.

2 DESCRIPTION OF EXPERIMENTAL TESTS

An experimental campaign was performed on two railway lines in Czech Republic and on the Velim circuit, using an ETR680 Czech Pendolino measuring train mounting an instrumented wheelset (see deliverable D1.1) and additional transducers to measure the dynamics of the railway vehicle.

The bandwidth of the measuring wheelset was assessed by FEA calculations performed considering the wheelset resting on a flexible track and by experimental impulsive tests performed on the instrumented wheelset placed on a ballasted track and pre-loaded with the nominal axle load. Figure 1 shows the numerically determined frequency response function of the bending deformation in bending measuring section n. 3 of the Pendolino wheelset caused by a vertical force applied on the left wheel: it is observed that the first bending resonance occurs at 73Hz, corresponding to the first bending mode of the wheelset. Accordingly, the pass-band of the measure was defined to be 0÷50Hz, the upper limit being well below the first resonance also to account for possible changes in the resonance frequency depending on the actual elastic and inertial properties of the track.

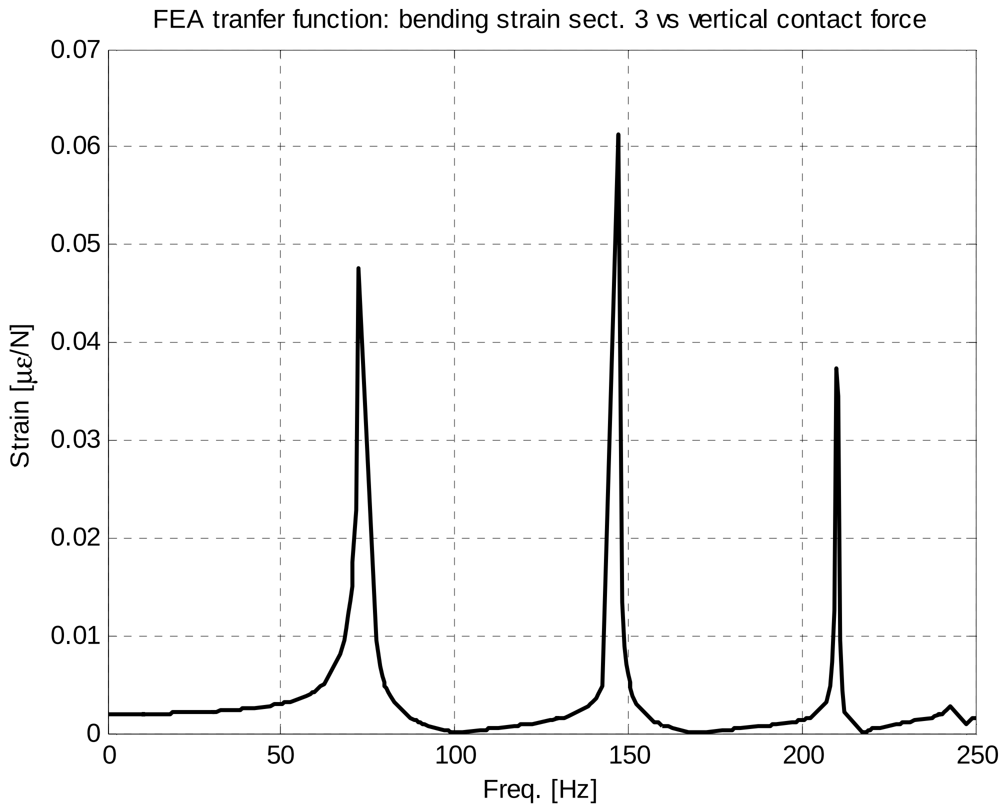

Figure 1- Frequency response of the bending deformation in section 3 produced by a vertical force applied in the contact point, as obtained from a calculation performed on a finite element model of the wheelset.

Additional transducers were mounted on the measuring train to characterise its dynamic behaviour under different running conditions, with particular attention to the effect of impulsive loads. In particular, the following measurements were taken:

vehicle speed;
left and right axle box vertical acceleration;
left and right axle box lateral acceleration;
left and right primary suspension deformation;
bogie lateral acceleration and yaw speed;
braking pressure;
GPS signals (longitude, latitude, altitude).

These channels were acquired together with bending and torsional deformations of the instrumented wheelset. The sampling frequency was set to 1000Hz (except for special test runs) and anti-aliasing filters were used. Since GPS channels were made available at 2Hz frequency, this signal was over-sampled to use the same acquisition system for all channels.

3 WHEELFLAT TESTS

Besides inline tests, additional tests were performed on the Velim test circuit, also in the Czech Republic, with the aim of investigating the effect of impulsive loading represented by switch crossing and by wheelflats. The Velim circuit is characterised by a high speed ring allowing the maximum speed of 200km/h and presenting two curves with radius 1400m, and by a low speed ring (maximum speed of 90km/h) presenting sharper curves with radius as low as 300m. Main advantages of performing these tests in a circuit instead than in a line open to service were that track geometry and rail irregularity were known with good accuracy, whereas rail profiles and track mechanical impedance in critical sections (especially on the turnout) could be easily measured. Furthermore, on the circuit it was possible to perform tests with artificial wheelflats produced on one of the two wheels of the instrumented wheelset.
Wheelflat effect was investigated by producing an artificial flat (figure 2) on the left wheel of the measuring wheelset, with an initial size of 30mm approximately, which was then increased to almost 60mm approximately (figure 3).

Figure 2- Execution of the artificial wheelflat on the measuring wheelset.

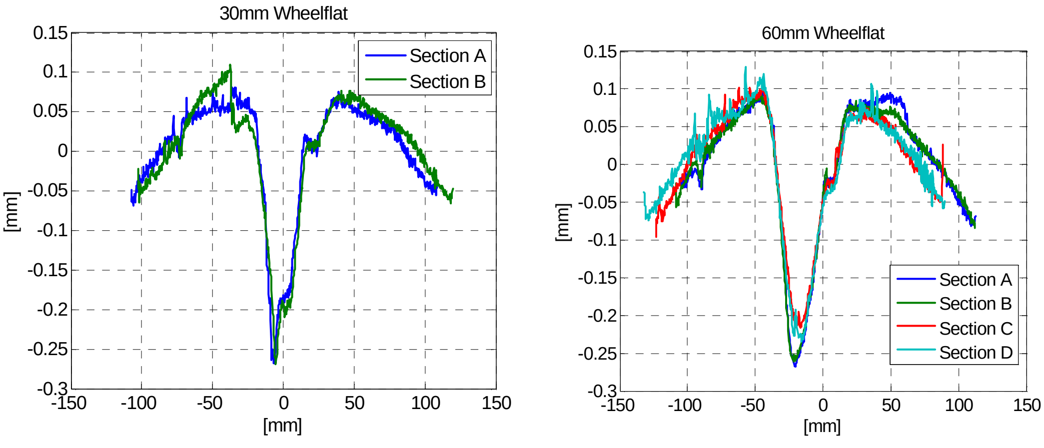

Figure 3- Circumferential measurements of the 30mm and 60mm artificial wheelflat.

The flat was located in the same angular position as one of the two instrumented diameters where strain gauges were installed in the axle; in this way, one of the two bending strain measurements performed in each bending measuring section is synchronised with the wheel passing over the flat. With the two defect sizes, circuit test runs were performed at speeds from 50km/h to 200km/h, to assess the influence of localised periodic defects on axle strains/stresses and on vehicle dynamics. Figure 4a shows the time history of the vertical axle box acceleration during straight track running at 50km/h with the 60mm wheelflat. Peak values in the range of 100m/s^2 are reached, with a frequency analysis (not shown) presenting relevant contributions in the frequency range above 50Hz. This indicates that large dynamic train-track interaction effects are produced also by a singularity located on the wheel profile. However, when considering the bending stresses in the axle (Figure 4b) only a slight effect of high frequency dynamics is observed, whereas the effect of rotating bending produced by the static load is predominant. This behaviour can probably be explained by the "mechanical filtering" effect provided by the large inertia of the wheel, although further research is ongoing to better clarify this point that has clear implications on the design of the axle: if confirmed, this experimental observation would suggest that impulsive loads mainly affect the resistance of the wheels and have only a marginal influence on axle fatigue resistance.

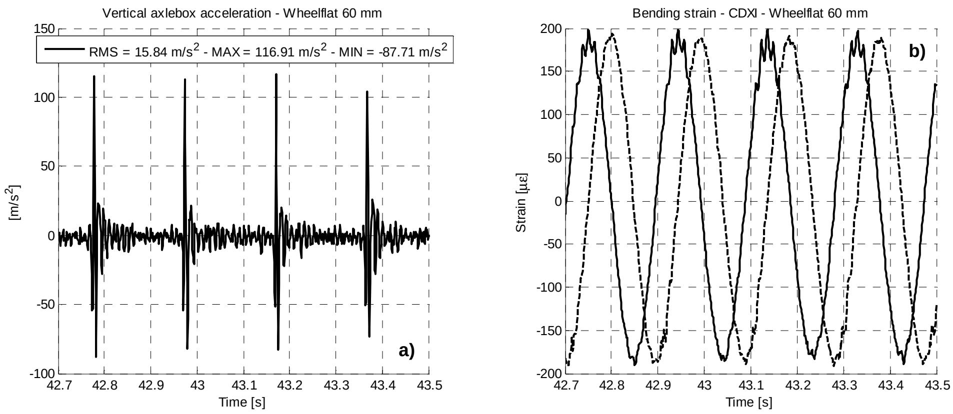

Figure 4- Effect of an artificial wheelflat at speed 50km/h, measured on the Velim test circuit. (a) Time history of the vertical axle box acceleration. (b) Time history of the bending strain measured in section 3 of the instrumented wheelset.

REFERENCES

[1] Bel Knani K., Bruni S., Ferrarotti G., Cervello S., Development of an integrated design methodology for a new generation of high performance rail wheelsets, World Congress of Railway Research WCRR ’01, Koln, Germany, 25-29 November 2001
[2] Chaar N., Berg M., Vehicle-track dynamic simulations of a locomotive considering wheelset structural flexibility and comparison with measurements, Proc.IMechE Part F: Journal of Rail and Rapid Transit, Vol. 219 (2005), pp. 225-238
[3] Beretta S., Carboni M. (2006), Experiments and stochastic model for propagation lifetime of railway axles, Engineering Fracture Mechanics 73, pp. 2627-2641
[4] Ekberg A., Kabo E., Andersson H., An engineering model for rolling contact fatigue of railway wheels, Fatigue & Fracture of Engineering Materials & Structures Vol. 25 (2002) no 10, pp 899–909.