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System identification of a railway pantograph using a stepped sine sweep for evaluating accelerometer position

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Abstract

Identifying the fundamental frequencies and modal parameters of a system is of great importance for understanding it, and to analyse its behaviour. It is also very important for knowing and acknowledging the limitations of numerical models of the structure. The pantograph is such a structure. It is a quite complex dynamic system which configuration is of great importance for the dynamics of the pantograph-catenary interaction. To better understand the behaviour a pantograph has been put in a laboratory, instrumented with many accelerometers attached at carefully chosen positions, and using experimental system identification by a stepped sine sweep excitation. The first aim is to do a full system identification using this method. The second is to optimize the procedure by reducing the number of accelerometers or channels according to wanted output. The study has important findings regarding the frequency content of the pantograph, which components that are being influenced by which frequency, and procedure for telling how many accelerometers to use and where to place them in a similar study.

Keywords: railway catenary systems, pantograph-catenary interaction, modal analysis, structural dynamics, system identification, laboratory investigation, pantograph.

1 Introduction

The pantograph plays a significant role in the pantograph-catenary interaction. Numeric models are necessary to study phenomena in this interaction more closely than field tests allows. It is thus important to describe each part, the catenary and the pantograph, as close to reality as possible. To date most models used are based on information given by the pantograph manufacturer or by modelling the parts of the pantograph as good as possible.

To better understand the behaviour a pantograph has been put in a laboratory, instrumented with many accelerometers attached at carefully chosen positions, and excited using a stepped sine sweep procedure. This give the possibility to find all natural frequencies of the pantograph. It gives the opportunity to find which frequencies are important for which part of the pantograph. And, it shows which frequencies that are important for the whole pantograph. The sensitivity of the accelerometers at the collector strips to different frequencies is the most important for the pantograph-catenary interaction.

This paper uses experimental system identification by a stepped sine sweep excitation. The first aim is to do a full system identification using this method. The second is to optimize the procedure by reducing the number of accelerometers or channels according to wanted output.

2 Methods

A Dozler pantograph has been mounted in the laboratory with 13 accelerometers attached to it. The pantograph is a pantograph previously used on a diagnostic vehicle used for checking the stagger, it has therefore only one collector strip in aluminium. An actuator has been placed so that it excites the pantograph at the top of the collector strip, slightly to the side of the middle. Several stepped sine sweep excitations has been performed primarily between 5 and 200 Hz, but with some to 600 and 950 Hz as well.

Reference system: all the sensors are mounted with the cable plug towards the back of the pantograph, in order to have Z axis pointing upwards, X axis longitudinal to the pantograph pointing forward and Y axis lateral pointing left.

The equipment used are listed below, and can be seen mounted in Figure 1.
- 14 triaxial accelerometers of type Dytran 3583BT
- National Instruments CompactRio
- B&K Permanent Magnetic Vibration Exciter Type 4808
- B&K Power Amplifier type 2712
- Labworks Inc. SC-121 Sine Servo Controller

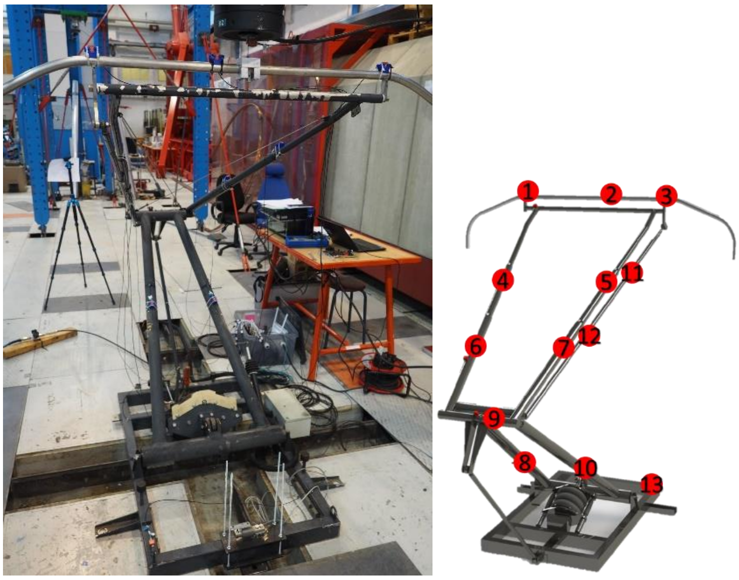

Figure 1: Laboratory pantograph set up, and accelerometer positions.

3 Results

The acceleration time series from the sine sweeps has been analysed primarily by power spectral density analyses using Burg spectra’s. The peaks in the Burg spectra’s are then the systems natural frequencies. A selection of time series from one test is shown in Figure 2, and the corresponding Burg spectra’s in Figure 3. As expected this technique is good for finding the important frequencies, one can even locate some of them directly from the time series. The first important frequencies in the different axis are for this pantograph, x-axis, 5.9 Hz, 10 Hz, 21 Hz, y-axis, 11 Hz, 12 Hz and 16.7 Hz, z-axis, 5.6 Hz, 11 Hz, 16.8 Hz and 22 Hz. Some of these frequencies are close to each other and is expected to highly influence each other. Figure 4 show that there is still a lot of natural frequencies in the area 0-200 Hz. Not all of these are important for the pantograph-catenary interaction, but the one at around 36 Hz might be important to include because of the size of the response.

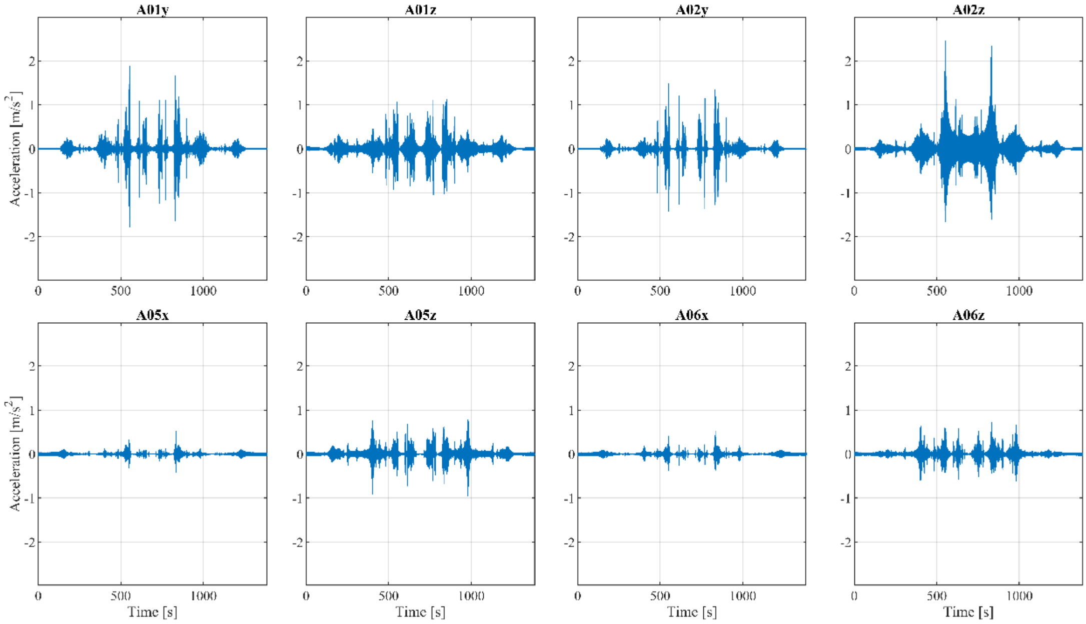

Figure 2: Acceleration time series from one sine sweep at selected locations.

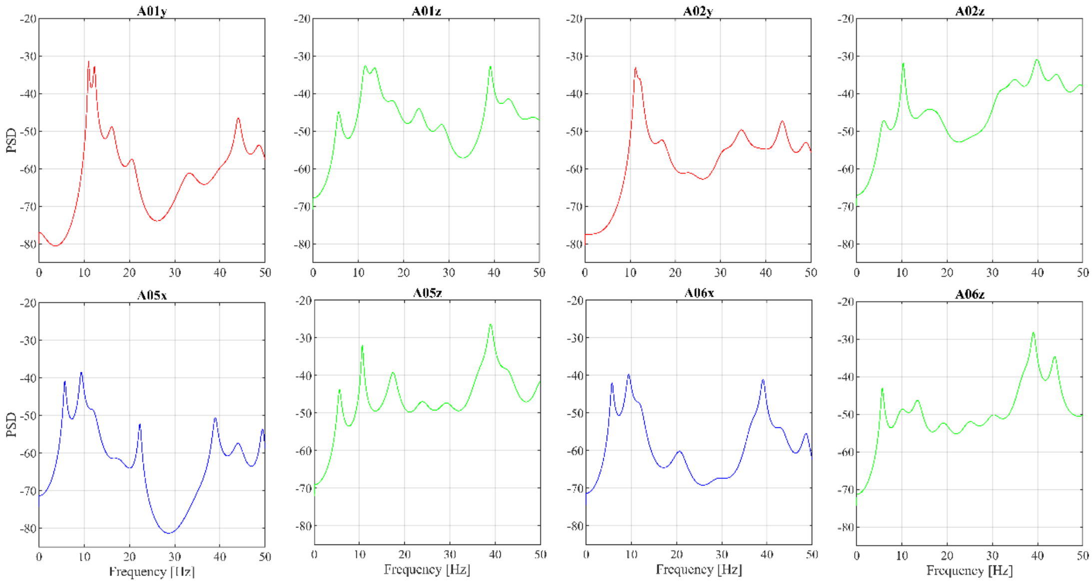

Figure 3: Logarithmic power spectral density of acceleration time series from one sine sweep at selected locations, 0-50Hz.

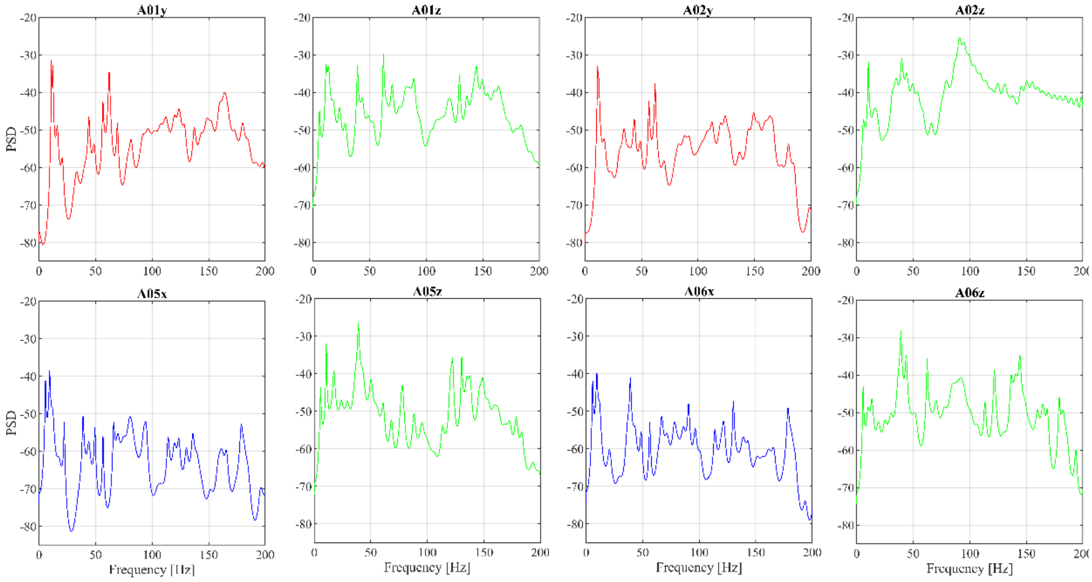

Figure 4: Power spectral density of acceleration time series from one sine sweep at selected locations, 0-200Hz.

4 Conclusions and Contributions

Evaluating the results from several sine sweeps has given a good insight in what frequencies are important for each component. It is also possible to find how many accelerometers, and where they should be placed to do a dynamic assessment of a pantograph. For finding the important frequencies below 50 Hz it looks like one need at least 4 accelerometers distributed on the pantograph. One on each collector strip preferably not in the middle, one at the next bar (for example at sensor 4), and one at the lowest bar (for example at sensor 10). It has also been seen that there are many frequencies up to 200 Hz that were quite easily excited, and one for the collector strip at 350 Hz.

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References