Field Measurements on Curve Squealing - The Influence of the Wheel Diameter

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Introduction

Curve squealing is an annoying phenomenon in curves with small radii. The noise is characterized by a narrow frequency band and high intensity. Thus railway operators have to adopt counteractive measures where curves are located in areas with high population density.

The subject of a project between Swiss Federal Railways (SBB) and the Federal Institute of Technology is to study this phenomenon to understand the phenomenon so that suitable counteractive measures can be applied.

Long term observations

In the first stage long term observations on regular train traffic were adopted [1]. On a rail track where the traffic mainly consisted of homogeneous rolling stock, acoustic and vibration measurements where performed (Figure 1). Rail traffic consisted of suburban trains which regularly crossed the measurement point. In addition to the acoustic and vibration data, information about weather conditions and train configurations were collected.

As expected weather had an influence on the occurrence of squealing, but was not quantifiable.

Data analysis was restricted to one type of suburban train to get homogeneous spot tests. It was observed that only a few trains were particularly loud. A detailed analysis on the squealing trains showed that only single wheels were responsible for the squealing. This was an indication that small differences in the wheel properties might strongly influence the squealing behaviour.

Trial test runs

In trail test runs [2] interest was focused on the dependence of curve squealing in dependence on the amount of moisture on the rail surface. Therefore one test train had to drive back and forth. Rail surfaces were moistened artificially at the beginning of each test series consisting of several runs. The test was designed to simulate increasing friction coefficient due to rails drying out.

Besides acoustic measurements, speed and lateral displacement of each wheel set passing by the microphones was recorded. After a certain number of runs the lateral displacement based on the rail location stabilised and a new test series was started.

As observed in the long term observations only single wheels squealed. The squealing behaviour was depending on train speed (also reported in [3]), running direction and lateral displacement of the wheel sets. The frequencies which occurred were characteristic for a specific combination of squealing wheel, speed and friction coefficient induced by moisture on rail. A test repetition is planned.

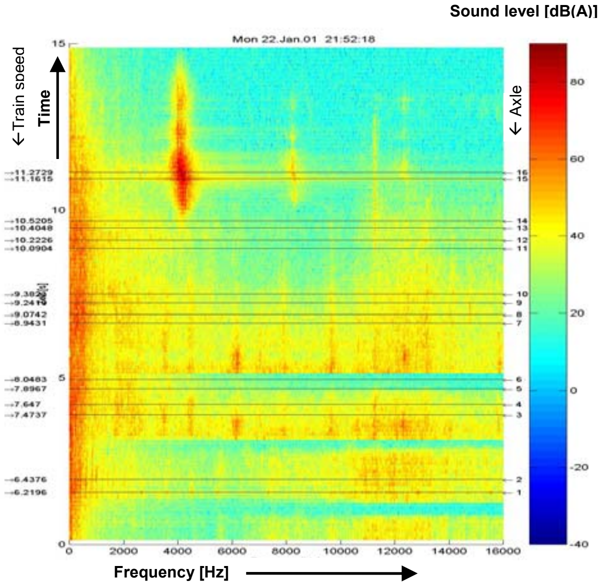

Figure 1: Time dependent frequency plot. Frequency (horizontal) versus time (vertical). Colour specifies intensity. Left numbers show speed of the train. Black lines and right numbers show wheel set crossing measurement point.

Resulting questions

Long term observations [1] and test runs [2] showed a wheel dependent squealing behaviour. Thus it is not possible to examine the squealing phenomenon by modelling new wheels with ideal wheel and rail profiles. Wear induced property variation in diameter and profile have to be taken into account.

Variations in diameter (new 820 mm, worn 760 mm) and mass (new 260 kg, worn 190 kg) have an important influence on the vibration behaviour of wheels.

Wheel or rail profile variations influence the point of contact and the direction of the forces acting on the wheel.

The friction coefficient between wheel and rail determines the amount of tangential contact forces which can be transmitted and where the stable contact point is located.

The observation that not every wheel squeals shows that only in critical situations wheels are subjected to squeal. What influence has the vibration behaviour in this circumstance? Are only single eigenmodes the origin of squealing or are almost all eigenmodes potential sources for squealing? Is the diameter change influencing the vibration behaviour the fundamental parameter or the profile influencing the point of contact?

Squealing Eigenmodes

To determine which eigenmodes are involved in curve squealing, field measurements of squealing frequencies and wheel diameters were compared to the results of Finite Element Analysis and Vibrometer measurements (figure 2).

The monitoring setup consisted of one microphone on each railway side and two lasers fixed on one flange of the rail. Besides the primary object to measure the relative distance between the rail and the wheel, the lasers were used to establish the moment in time at which the wheels were in line with the lasers. At this moment, no frequency shift due to Doppler Effect is present and the recorded frequency corresponds to the vibration frequency of the squealing [2].

This frequency and the wheel diameter were compared to the results of Finite Element Analysis for different radii [4].

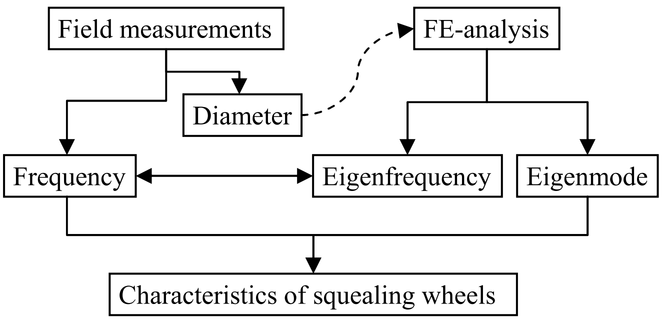

Figure 2: Schematic procedure to determine eigenmode of squealing wheels.

Measurements show on one hand squealing frequency of 3 kHz for a wheel with a diameter of 814 mm on the other hand 4 kHz for a wheel with a diameter of 797 mm. The results are introduced in Figure 3. No single eigenmode with its respective frequency band covers the observed range. As a result, more than one eigenmode is involved in the squealing phenomenon. More field measurements will show which eigenmodes are involved.

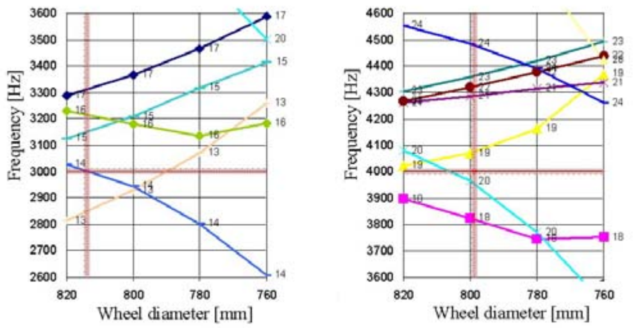

Figure 3: Eigenfrequencies of different eigenmodes versus wheel diameter.

Results

Curve squealing was caused in our test location by single wheels on certain trains. Comparisons show that more than one eigenmode is involved in the occurrence of curve squealing.

First data show that each wheel has in own characteristic squeal frequency in a restricted time. The observation window was too short to observe long term variation due to wear, but a natural frequency shift, new appearance or disappearance of curve squealing is expected.

Outlook

An ongoing study of the involved eigenmodes is now possible. The data base has to be improved so that a complete map of what eigenmodes are involved can be created. The study of this eigenmode will be an important key to the phenomenon.

Acknowledgements

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