MEASUREMENTS AND CALCULATIONS RELATED TO CURVE SQUEALING IN THE RAILWAY SYSTEM

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Summary: Within a collaboration between the Federal Institute of Technology (ETH) and the Swiss Federal Railwys (SBB), the phenomenon of curve squealing is studied. The aim is to understand the phenomenon causing this noise. Therefore various measurements and studies have been done. These include long-term-measurements on regular railway traffic, test runs with a test train, lab tests and simulations. Results are discussed.

INTRODUCTION

Curve squealing in railway systems is an annoying phenomenon that railway operators and nearby residents have to deal with, when railway lines have curves with small radii. In particular urban locations are problematic, as the acoustic impact affects a large number of people. Therefore mainly urban railway and tramway operators go to huge efforts to get curve squealing under control. A resent newspaper article [1] shows the importance and the activities in this field.
Trial and error is the most common way to deal with curve squealing. Thus different kind of friction modifiers, including water or lubricants, or different wheel or rail dampers are used. Sometimes acoustic barriers are built, influencing the townscape. This aims more to combat the effects of the noise than to understand the phenomenon.
The focus in the research project between the Swiss Federal Institute of Technology (ETH) and the Swiss Federal Railways (SBB) is to understand the mechanism of curve squealing. This would probably give the possibility to eliminate the source of the phenomenon.

LONG-TERM-MEASUREMENTS

Studies of literatures and discussions with operators, showed that often only a distinction between wet, moist, smeared and dry conditions were made. Differentiations between different trains, wheels and speeds were not discussed.
Long-term-observations showed an important influence of these factors. The database consists of more then a thousand train passages of accelerating or passing by trains. Trains slowing down were not considered, as break noise could falsify the results. For this purpose specific measurement equipment was designed [2].
The equipment recorded: meteorological data (air temperature, rail temperature, air humidity), acoustic noise, rail vibrations, train speed, running direction and recording time. More over the composition of the single train was collected.
Rail traffic was quite homogeneous, consisting of mainly four types of suburban trains and a few freight trains crossed the automatic measurement plant.
Because suburban trains of one particular type were the loudest and at the same time the most frequently passing trains, four representative trains of this type were selected for further signal investigation, corresponding to 524 train passages.
The intuitive expectation has been to obtain a clear dependence of squealing on humidity and rainfall, but the recorded data didn't validate these expectations. Moreover some trains squealed during a period while others didn't. This meant that different trains, although consisting of the same type of vehicles, differed in a relevant way from each other.
By use of the Doppler effect, it could be established whether a wheel set squealed at the measurement location or not. The analysis showed that only a few wheels were subjected to squeal.
The analyses of the acoustic signals show that the considered trains commonly squealed at a frequency in the range from 4000 to 4700 Hz.

MEASUREMENT OF STRIKING ANGLE AND DISPLACEMENT VERSUS MOISTURE OF RAIL

The circumstance that only a few wheels of a large number of the same type of wheel fitted on the same type of vehicle generate curve squealing, encouraged the authors to do measurements of the relative position and the striking angle of each wheel during the passing by the measurement location [3].
A new set of measurements was performed to investigate how moisture on the rail influences the running behavior of trains in curves. Therefore a series of measurements with one suburban train was performed. Water was used to alter the friction coefficient, which strongly influences the train running behavior. The train ran back and forth on the rails which were periodically artificially moistened, in order to simulate drying of the rail surface after rain. To avoid a too rapid dry up, about 200 m of rail were moistened. Two high definitions lasers measured the distance of the wheel rim to a virtual plane perpendicular to the flange of rail (figure 1).
As a result it could be measured that train speed and moisture on rails have an important influence on the running behavior of railway trains. The lower the train speed, the higher the lateral displacement of the rear wheel towards the center of the curve. Moisture is able to influence the lateral displacement by up to 10 mm for a rear wheel set. The

lower the moisture, the lower is the lateral displacement. In addition, it influences considerably the occurrence of squealing.
The analysis of the data shows that, after a certain number of passages, lateral displacement becomes stable. The achieved values correspond to the values for dry rail. This phenomenon could be observed for each wheel set in all measurement series.
Curve squealing occurred only at a particular lateral displacement. This was related to a specific moisture on rail, train speed and running direction.
The test will be repeated to verify the reproducibility.

Figure 1: Setup for the measurement of striking angle (a) and lateral displacement (d). The setup consists of two high definition lasers attached directly on the flange of rail.

CHARACTERIZATION OF WHEEL PROPERTIES DEPENDING FROM WEAR PROGRESS

The eigenmodes of wheels and rails relating to the squealing frequencies, were analyzed. To this end a common FE-Analysis has been used. The data have been verified by full scale measurements on assembled and on disassembled wheels.
As the radius may have an important influence on the squealing phenomenon, the influence of the wheel diameter on the eigenfrequencies and eigenmode was studied [4]. The results showed an important shift in the eigenfrequencies of the eigenmodes during wheel lifetime (Figure 2 right).

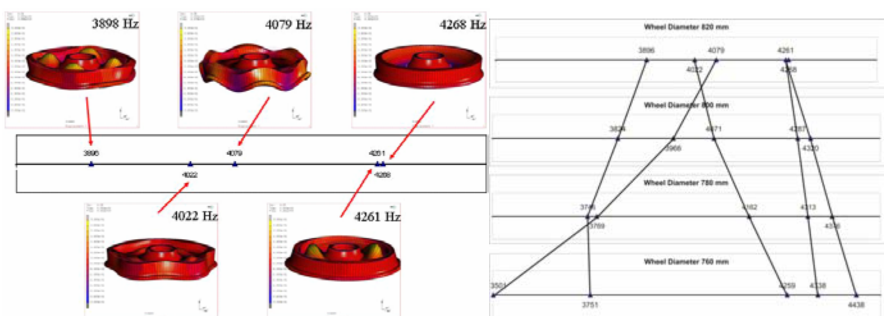

Figure 2: Left: Eigenforms of new wheels in the area of 4000 Hz. Right: Eigenfrequencies versus wheel radius for different eigenforms.

CONCLUSIONS

The occurrence of curve squealing is strongly associated to a particular wheel going around a curve. Train speed, moisture on the rail, running direction, wheel and rail profile influence the way the wheel goes around the curve and these factors are expected to play a fundamental role in the occurrence of squealing influencing the contact point and probably the mechanism of excitation. More over the wheel diameter influences the vibration characteristic of the wheel and its response, therefore it has also to be taken in account.
Only a model including all these factors can reproduce this phenomenon.

References

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