

A railway vehicle fault detection system

I. Persson

AB DEsolver, Optand 914, S-831 92 Östersund, SWEDEN

M. Asplund

Trafikverket, Box 809, S-971 25 Luleå, SWEDEN

ABSTRACT: Many different type of faults on track and vehicles may occur, which can cause a bad ride comfort. Passengers are normally no experts in vehicle dynamics and can therefore not tell the cause of the bad ride of the vehicle. What they can do is to complain for the staff working in the train, telling there is a problem, and it doesn't feel normal. The crew working in the train is also no experts in rail vehicle dynamics. For them it can be difficult to describe the vibrations to make it easy for the workshop to find the problem. In the workshop there are limited possibilities to make test runs. Workshops do not normally have access to a test track. Example of possible faults:

- The fault can be in the vehicle. Different faults in different suspension components can occur. E.g. oil leakage in hydraulic dampers, ice and snow blocking the motion in different suspension parts.
- The fault can be in the contact points between vehicle and track. Unfavorable shapes of wheel and/or rail profiles can lead to instabilities.
- The fault can be in the track. When looking at track quality according to UIC 518 and EN 14363 only wavelengths in the range of 3-25[m] are considered. The vibration frequencies can be outside this frequency span.

The bad ride comfort can be a combination of more than one single fault. E.g. a tight gauge in combination with hollow wheel profiles and ineffective yaw dampers. In some cases it can take long time to find the fault(s). It can happen the vehicle needs to go to the workshop more than one time before the fault(s) have been corrected.

1 ACCELEROMETER SETUP

Three 3-axis accelerometers are mounted in a vehicle. The accelerometers are mounted in the axlebox, in the bogie frame and in the car-body. Measurements are made in longitudinal, lateral and vertical direction. Also a GPS navigation device is mounted at the same longitudinal position as the accelerometers, giving the location of the vehicle along the track. The measured results are uploaded to the cloud via a 3G or WiFi-network.

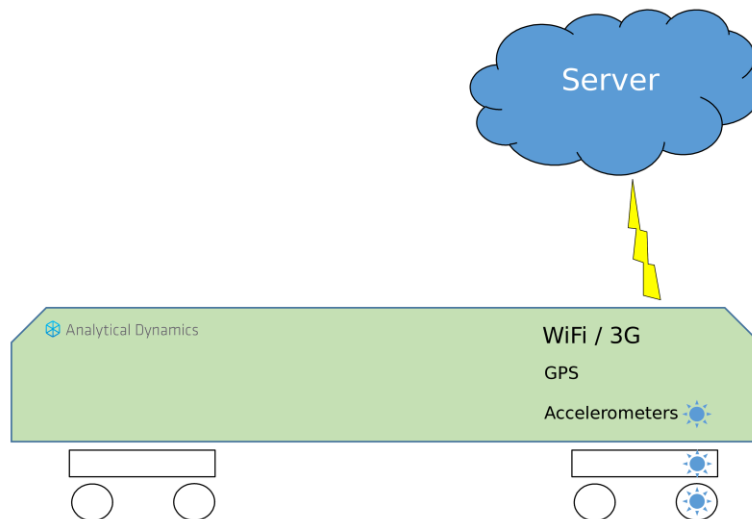


Figure 1. Accelerometer setup.

2 ESTIMATED GAIN FUNCTIONS

To give the staff in the workshop better information about the vibration problems a fault detection system is suggested. It is based on the measured accelerations made with the accelerometers above plus track irregularities made by an inertia based track data recording machine. From the measurements, Fourier spectra are created. The shapes of the Fourier spectra are filtered and divided with each other to form “estimated gain functions”, in this paper abbreviated to “EG-functions”. The EG-functions work like simplified transfer functions. Since the primary and secondary suspension are relatively linear. The EG-functions are not affected very much of the excitation amplitude. The EG-functions only change when there is a change in the properties of the suspension. The EG-functions are in this paper used in a fault detection system to give suggestions on possible fault(s) that are the reasons for the bad ride comfort. The EG-function is calculated according to:

$$\text{EGF_acc1_acc2}(f) = \text{FFTacc1}(f) / \text{FFTacc2}(f)$$

Where:

$\text{EGF_acc1_acc2}(f)$ = EG-function from accelerometer 2 to accelerometer 1

$\text{FFTacc1}(f)$ = Fourier spectra accelerometer 1

$\text{FFTacc2}(f)$ = Fourier spectra accelerometer 2

2.1 Estimated gain functions of the reference vehicle

Knowing the properties of a reference vehicle is important in the proposed fault detection system. We must be able to distinguish between a normal and an abnormal behavior of the vehicle, within certain tolerances. Current work is still in an early stage. Until now only simulated results have been used. The studied model comes from KTH's course in vehicle dynamics.

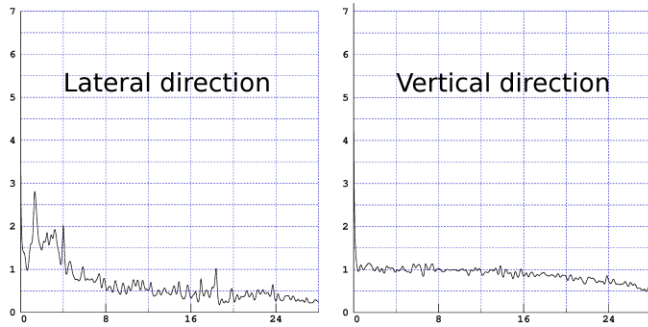


Figure 2. EG-functions between track and axlebox for the reference vehicle.

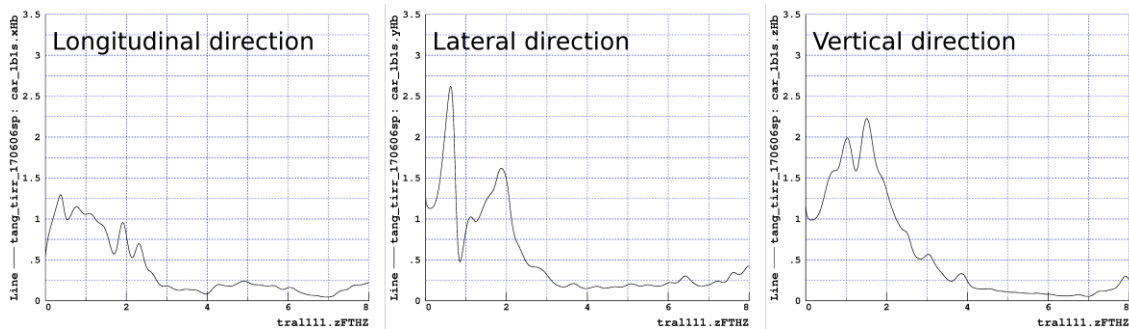


Figure 3. EG-functions between bogie frame and car-body for the reference vehicle.

2.2 Normalized EG-functions

In order to simplify the comparisons with the EG-functions for the reference vehicle the EG-functions has been normalized in the following equation:

$$NEGF_acc1_acc2(f) = (EGF_acc1_acc2(f) - 1) / (EGF_acc1_acc2(f) + 1)$$

In this paper the “Normalized EG-functions” has been abbreviated to “NEG-functions”. If $NEGF_acc1_acc2$ is equal to zero, i.e. $EGF_acc1_acc2 = 1$. Means that the amplitudes in the two spectra $FFTacc1$ and $FFTacc2$ are the same. If $EGF_norm_a1_a2$ is positive the amplitude in $FFTacc1$ is bigger than $FFTacc2$, and if $EGF_norm_a1_a2$ is negative the amplitude in $FFTacc1$ is smaller than $FFTacc2$.

2.3 Example 1: Snow packing, or the airbags are resting on the emergency springs

When snow gets hard packed between bogie and car-body. The suspension cannot work normally and the effective stiffness gets very high. Mainly in vertical direction, but it depends on the design of the vehicle. In the studied model only stiffness is added in vertical direction.

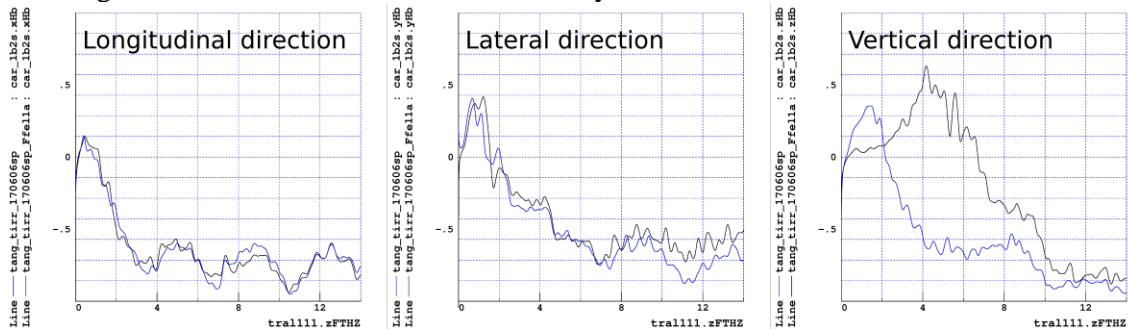


Figure 4. NEG-functions between bogie and car-body. Black line is the vehicle with the fault. Blue line is the reference vehicle.

2.4 Example 2: High conicity hollow worn wheel profiles

In case the fault is in between vehicle and track. The NEG-functions over primary and secondary suspension agrees quite well with the reference vehicle. Instead this type of fault can be detected by looking at the NEG-functions between track and wheelsets.

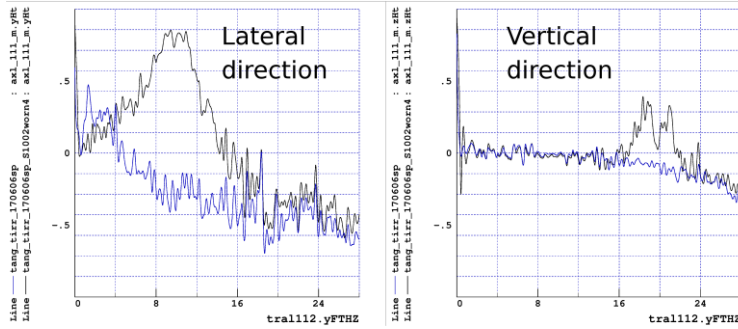


Figure 5. NEG-functions between track and axlebox. Black line is the vehicle with the fault. Blue line is the reference vehicle.

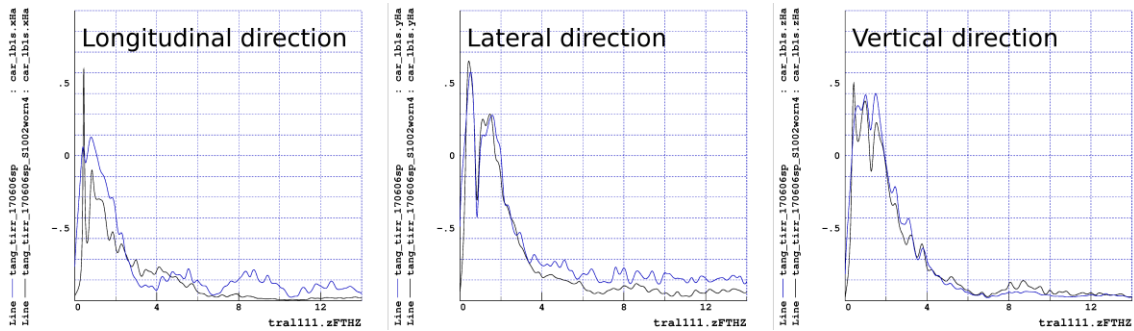


Figure 6. NEG-functions between axlebox and car-body. Black line is the vehicle with the fault. Blue line is the reference vehicle.

3 FLOWCHART OVER SUGGESTED FAULT SEARCH SYSTEM

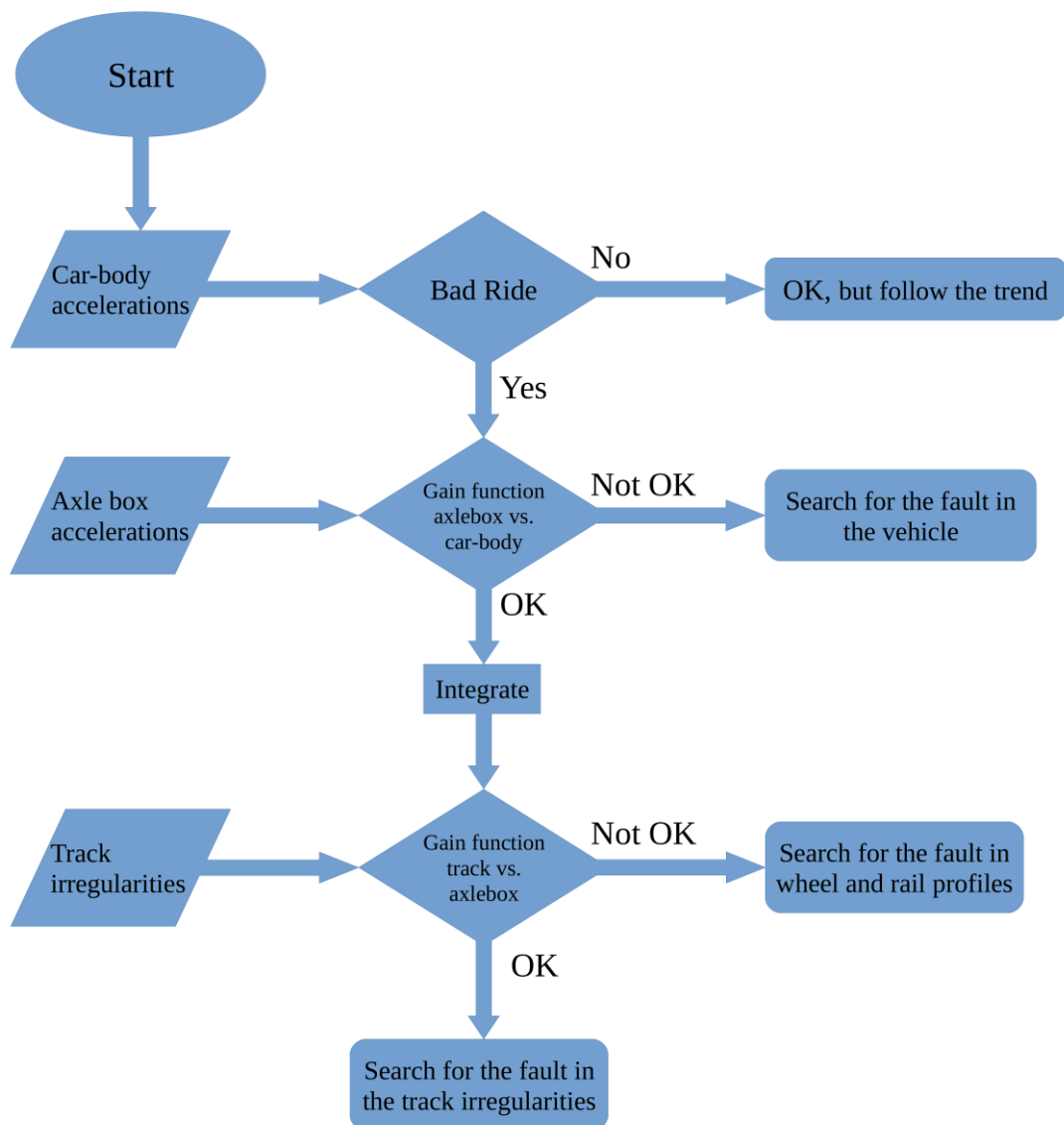


Figure 7. Flowchart over suggested fault search system.

4 SUMMARY

The main advantages of the proposed system are:

- Early fault detection reduces maintenance downtime costs and increase the availability of the vehicle. Repairs can be planned in advance.
- The estimated gain functions give more information of the problem for the vehicle- and/or track maintainer, which speeds up the time searching for faults.
- Avoiding bad goodwill for the train. There is a risk that some passengers may choose another type of transportation in the next trip.

In relation to the maintenance costs and risk for bad goodwill, the prices of accelerometers, GPS and data storage are low.