Measuring Acceleration in Vehicles using the AccBox System – Results and Discussion
Innehåll

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Abstract
The goal of the project was to measure accelerations in cars, buses and motorcycles. A cubic wooden box was built and three (two-axis) acceleration sensors were installed. A Matlab-program that filters the signal and calculates the acceleration components was developed.

Measuring the angular acceleration was more complicated than expected. With the current setup and software the box only measures the linear accelerations in three dimensions.

The accelerations of cars and buses tested never exceed 1 g under normal urban driving. The motorcycle tested reached 2 g accelerations in the x-y-plane and 4 g in the z-direction.

Results and discussion

Car tests

Test car
The car used for measuring is a 2004 Renault Clio with a weight of 1160 kg (with driver) and a 60 kW diesel engine. The box was placed according to figure 1.

![Figure 1: Placement of the box in the car](image)
Acceleration of a car

The maximum acceleration of a car in the x-y-plane is limited by the tires’ friction. A standard car can reach a deceleration of about 8 m/s² when braking¹, while the (forward) acceleration is rather limited by the power of the engine. In the x-direction two components are contributing to the acceleration – the centripetal acceleration and the rotation around the y-axis.

Car urban driving

According to figure 2 accelerations stay below 1 g under normal urban driving. Accelerations in y-direction seem to vary less than accelerations in the other directions.

![Graph of accelerations in different directions](image)

**Figure 2: Accelerations in all directions from urban car driving.**

The Fourier spectrum in figure 3 reveals a peak around 2 Hz that probably derives from the eigenfrequency of the chassis.

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Figure 3: Fourier spectrum from urban car driving.

Car in roundabout
The car was driven several turns around a roundabout. As expected, the only significant acceleration appeared in the x-direction with a value of about 5 m/s² according to figure 4. Maximum values of 9 m/s² for x-direction acceleration appeared during the testing of the box, when the car was driven harder through roundabouts. That was not possible in this test because of wet road.
Car over speed bumps

To reach a large acceleration in the z-direction the car was driven fast over a couple of speed bumps. The maximum modulus of acceleration in the z-direction was 14 m/s² according to figure 5.
Acceleration and braking of the car

The car was accelerated and braked both hard and soft to get an idea of the difference between the two cases. According to figure 6 the difference is quite big, especially when braking. The deceleration is 4 times bigger when braking hard compared to soft braking. Hard acceleration generates values of about 4 m/s² while soft acceleration gives 2 m/s², all according to figure 6. The first 100 seconds belong to the hard-driving part, while the next 100 seconds comes from soft driving. Acceleration figures can also be derived from theory. A 0-50 km/h run with 4 m/s² acceleration would take 3.5 seconds which is a result that corresponds to test car’s performance.
Figure 6: Lengthways accelerations when accelerating and braking the car.
Bus tests

Test bus
The bus riding took place in the city buses of Gamla Uppsala Buss. We rode both articulated buses (as the one in figure 7) and single buses. The bus in figure 7 takes 105 passengers of which 55 are seated. The maximum weight is 25 tons and it has got a 191 kW diesel engine. A single bus takes about 80 passengers of which 30 are seated. The maximum weight is around 17 tons and the engine power is about 170 kW.

Figure 7: The tests took place in buses like this around Uppsala city centre.

City bus riding
City bus riding generates fairly modest accelerations; according to figure 8 the x-y-plane acceleration did not even exceed 0.5 g. One thing to notice is that sideway accelerations (x-direction) are consistently bigger than lengthways accelerations. The explanation is probably that buses’ high center of mass make them rock quite a lot when cornering.
Figure 8: Accelerations in all directions from city bus riding.

According to figure 9, there are two peaks at 1.5 and 8.5 Hz. The 8.5 Hz peak probably comes from the eigenfrequency of the bus frame, while the 1.5 Hz peak is perhaps the eigenfrequency of the air suspension.
Figure 9: Fourier spectrum from city bus riding.
Motorcycle tests

Test bike
The motorcycle used for measuring is a 2005 Suzuki SV650S with a 54 kW petrol engine and a weight (without driver) of 190 kg. The actual bike with mounted box is shown in figure 10.

Figure 10: Placement of the box on the motorcycle.

Motorcycle urban driving
Motorcycle driving generates much bigger accelerations than bus and car driving. In figure 11 all frequencies above 20 Hz are filtered. Since a motorcycle is turned by tilting, have a stronger engine, shorter wheelbase and tires with better grip higher accelerations are expected, but peak values are suspiciously high.
A possible explanation is that the box was attached high and far back on the motorcycle, giving it a long lever arm with large movements as a result. It is particularly important to think about the placement of the box or a flywheel on a motorcycle because of its big pendulous motions. Also, the box was placed with a small forward tilt moving accelerations between y and z-direction as seen in figure 10.

According to figure 11 some part of the motorcycle’s chassis seems to have an eigenfrequency of around 5.5 Hz.
Figure 11: Fourier spectrum from urban motorcycle driving.