

Reproduction of chassis dynamometer drive cycles on the road using a 5 Hz GPS speed signal

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Efforts to reduce vehicle emissions, a prime source of air pollution in many metropolitan areas, require emissions measurements throughout the useful life of the vehicle. While some measurements can be accomplished in ordinary operation, repeatable tests are also necessary. Currently, repeatable tests are conducted on chassis or engine dynamometers. Transport of heavy-duty vehicles to chassis dynamometer facilities, or removal of their engines for engine dynamometer tests, are expensive and time-consuming tasks. As an alternative, chassis dynamometer driving cycles can be driven on a suitable test track, while emissions are measured with a monitoring system installed on board of the tested vehicle. To repeat the cycles, a vehicle speed signal with sufficient accuracy and update rate is necessary. Since the driver operates the vehicle in a closed-loop system, with immediate feedback of the vehicle speed, a transient response time on the order of tenths of a second is necessary. The vehicle speed signal can be sourced from the engine control unit, or various sensors sensing driveshaft or wheel rotational speed, or directly sensing the road speed. One option is to use a global positioning system receiver. Traditional GPS units with one-second update rate are, however, too slow to reproduce transient cycles.

The goal of this study was to evaluate the feasibility of using a speed signal from a fast-response, 5 Hz update rate GPS system to reproduce chassis dynamometer driving cycles on a test track.

The evaluation was carried on a Renault Master van with a 2.0-liter common rail turbodiesel engine and a 6-speed manual transmission, which was used as the test vehicle. The van was equipped with a commercially available 5 Hz GPS receiver, coupled with an in-house written software allowing replication of driving cycles. The tests were carried out on a former military airport near Ralsko, Czech Republic. The airport features a 2.4-km runway, with taxiways on both sides of the runway. The maximum speed at which the vehicle could be safely turned around was experimentally determined to be around 30 km/h. Three common driving cycles were selected: ECE light-duty vehicle cycle, and two transit bus cycles: Manhattan Bus Cycle and Orange County Bus Cycle (SAE J-2711). For heavy duty cycles, engine was operated at low rpm, to simulate characteristics of a six-speed intercity bus. These three cycles were selected because they could all be driven in their entirety within the constraints of the airport.

Emissions were measured by an impromptu simple and relatively primitive portable, on-board emissions monitoring system. Concentrations of CO and CO₂ were measured by two multi-gas NDIR cells taken from a garage-type analyzer and extensively calibrated in the laboratory, NO_x by electrochemical cells, and PM by dynamic low-angle laser beam scattering. Emissions of HC were not measured as power limitations did not allow for the use of a heated sample line. Exhaust mass flow was estimated based on engine characteristics and operating parameters.

For a series of four runs of the ECE cycle, the range ((maximum-minimum)/average) of total mass emissions per cycle were 10.2% for NO_x, 4.0% for CO₂ and 5.5% for PM, with coefficient of variance (COV) 4.8% for NO_x, 1.8% for CO₂, and 2.6% for PM. For a subsequent series of five runs of the ECE cycle, ranges were 6.0%, 7.8% and 21.0%, and COV were 2.4%, 2.9% and 9.2% for NO_x, CO₂ and PM, respectively.

Generally, the cycles were somewhat difficult to reproduce. This can be partly attributed to the time lag of 1-2 readings (0.2-0.4 s) of the GPS, but also due to the delayed throttle response of the vehicle, and due to the driver lacking day-to-day experience in cycle driving. Still, the overall cycle reproducibility was excellent, given the above conditions and the relatively primitive on-board emissions monitoring system used. (As with all field measurements using portable, on-board systems, the choice of equipment should be made carefully and thoughtfully, after thorough assessment of the needs of the project and resources available.)

The GPS system is universal for a virtually all vehicles, has a good absolute accuracy (no need to calibrate for actual tire diameter), is inexpensive, and is very easy to install and operate. Problems due to the time lag and noise on the order of tenths of km/h are expected, however, with some aggressive urban cycles with low-speed transients.

Overall, a fast-response GPS is not believed to be the best source of speed signal for this purpose, but offers a relatively good cost/performance ratio and can be used, with minimal efforts and costs, on all vehicles.

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Background

- Efforts to reduce vehicle emissions, a prime source of air pollution in many metropolitan areas, require emissions measurements throughout the useful life of the vehicle. While some measurements can be accomplished in ordinary operation, repeatable tests are also necessary. Currently, repeatable tests are conducted on chassis or engine dynamometers. Transport of heavy-duty vehicles to chassis dynamometer facilities, or removal of their engines for engine dynamometer tests, are expensive and time-consuming tasks.
- As an alternative, chassis dynamometer driving cycles can be driven on a suitable test track, while emissions are measured with a monitoring system installed on board of the tested vehicle.
- To repeat the cycles, a vehicle speed signal with sufficient accuracy and update rate is necessary. Vehicle speed signal can be sourced from the engine control unit, or various sensors sensing driveshaft or wheel rotational speed, or directly the road speed. One option is to use a global positioning system receiver. Traditional GPS units with one-second update rate are, however, too slow to reproduce transient cycles.



When replicating a drive cycle, the driver is operating a vehicle to match the actual speed to the cycle speed, just like on a chassis dynamometer.

Goal

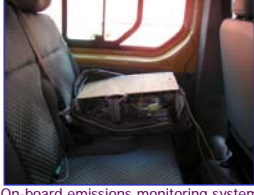
The goal of this study was to evaluate the feasibility of using a speed signal from a fast-response, 5 Hz update rate GPS system to reproduce chassis dynamometer driving cycles on a test track.

Experimental

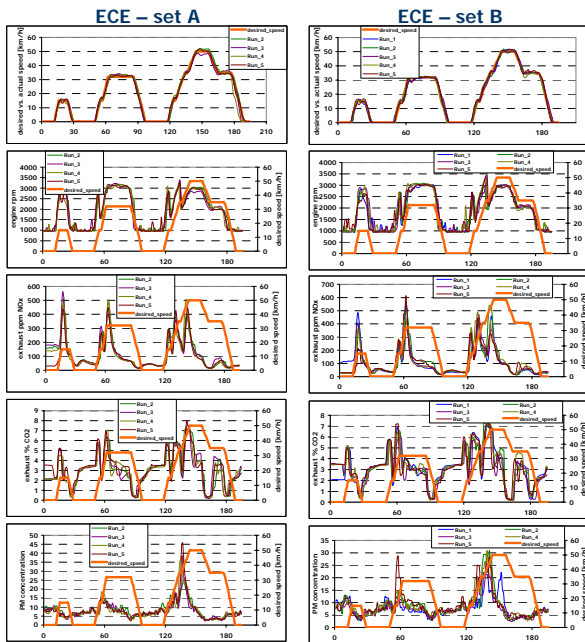
- A Renault Master van with a 2.0-liter common rail turbodiesel engine and a 6-speed manual transmission was used as the test vehicle.
- The van was equipped with a commercially available 5 Hz GPS receiver, coupled with an in-house written software allowing replication of driving cycles.
- The tests were carried out on a former military airport near Ralsko, Czech Republic. The airport features a 2.4-km runway, with taxiways on both sides of the runway. The maximum speed at which the vehicle could be safely turned around was determined to be 30 km/h.
- Three common driving cycles were selected: ECE light-duty vehicle cycle, Manhattan Bus Cycle, and Orange County Bus Cycle (SAE J-2711). These cycles were selected because they could all be driven within the constraints of the airport.
- Emissions were measured by a simple portable, on-board emissions monitoring system (CO, CO₂ – NDIR analyzer, NO_x – electrochemical cells, PM – dynamic laser beam scattering, HC not measured as power limitations did not allow for the use of a heated sample line).



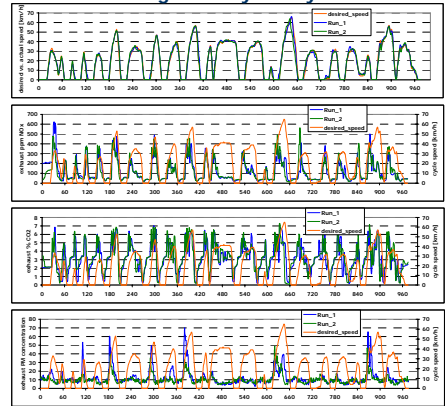
Non-heated exhaust gas sampling



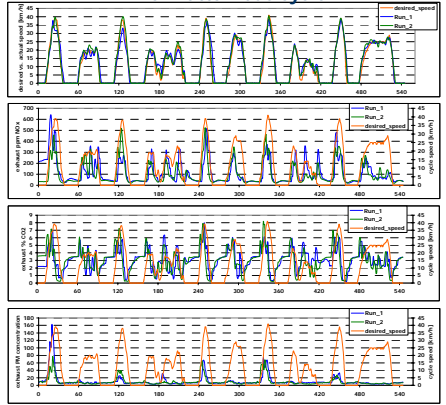
On-board emissions monitoring system



Orange County bus cycle



Manhattan bus cycle



Results

ECE tests summary results (per test)

Set	Nox [g]	CO2 [g]	PM [mg]
Run 1	0.6928	160.9	2.780
Run 2	0.6844	159.1	2.631
Run 3	0.6480	159.9	2.659
Run 4	0.6251	165.5	2.741
Average	0.663	161	2.70
95% C.I.	9.6%	3.5%	5.1%
Range	10.2%	4.0%	5.5%

Set	Nox [g]	CO2 [g]	PM [mg]
Run 1	0.6363	161.5	2.547
Run 2	0.6500	163.7	2.812
Run 3	0.6118	154.7	2.491
Run 4	0.6467	167.4	2.968
Run 5	0.6337	161.7	3.074
Average	0.636	162	2.78
95% C.I.	4.7%	5.7%	18.4%
Range	6.0%	7.8%	21.0%

ALL RUNS	Nox [g]	CO2 [g]	PM [mg]
Average	0.648	162	2.74
95% C.I.	8.1%	4.6%	13.8%
Range	12.5%	7.8%	21.3%

Range = (maximum-minimum)/mean
95% C.I. = 2 * standard deviation / mean

Discussion

- The 5 Hz GPS signal was observed to allow better replication than a 1 Hz GPS, but not quite as well as a 10 Hz road speed signal from the ECU. The GPS unit had a time lag of about 1-2 readings, which could pose a challenge in heavy low-speed transients (i.e., New York City Cycle).
- Generally, the cycles were somewhat difficult to reproduce, due to the delayed throttle response of the vehicle, and due to the driver lacking day-to-day experience in cycle driving.
- Still, the overall cycle reproducibility was excellent, given the above conditions and the relatively primitive on-board emissions monitoring system used.
- The GPS system is universal for a virtually all vehicles, has a good absolute accuracy (no need to calibrate for actual tire diameter), is inexpensive, and is very easy to install and operate.
- As with all field measurements using portable, on-board systems, the choice of equipment should be made carefully and thoughtfully, after thorough assessment of the needs of the project and resources available.

Conclusions

A speed signal from a fast-response GPS was used to reproduce chassis dynamometer driving cycles at a local airport. Emissions measurements, conducted with a relatively primitive on-board monitoring system, were reasonably reproducible. A fast-response GPS is not believed to be the best source of speed signal for this purpose, but offers a relatively good cost/performance ratio and can be used, with minimal efforts and costs, on all vehicles.

Acknowledgments

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