

Comparative Study of Measurement Methods for Engine Efficiency

Benchmarking in Hybrid Vehicles

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1. Introduction As emission regulations tighten, plug-in hybrid electric vehicles (PHEV) and extended-range electric vehicles (EREV) are expanding rapidly, and engine development has shifted from a power-oriented to an efficiency-oriented approach. Quantitative benchmarking of such high-efficiency engines is therefore becoming increasingly important. The engine torque that has to be measured for efficiency benchmarking, however, is difficult to acquire accurately. The torque available on the vehicle CAN bus is not a measured value but an estimate derived from internal ECU maps, and strain gauges bonded to the flywheel are sensitive to temperature and other external factors, so that a reliable absolute torque is hard to obtain.

2. Experimental method A multi-mode PHEV, selected as a high-efficiency vehicle, was installed on a four-axis chassis dynamometer with its original control strategy retained, and a precision in-line torque flange was fitted to the shaft between the engine and the dynamometer to obtain a robust brake torque measurement. Fuel consumption was measured with a Coriolis mass flow meter and in-cylinder pressure with a piezoelectric transducer, while the engine speed, indicated torque, lost torque and engine power were logged simultaneously from the CAN bus. The battery state of charge was held at 15 % so that the vehicle stayed in charge-sustaining mode; the dynamometer speed was fixed and the load was swept with the accelerator pedal. Brake thermal efficiency was evaluated from three torque sources: the direct measurement, CAN1 (indicated torque minus lost torque) and CAN2 (converted from the CAN engine power).

3. Results The CAN1 brake torque agreed with the measured value within -1 to 2 N·m at medium load (70-100 N·m) but deviated by up to 4 N·m at low and high load, whereas CAN2 overestimated the torque over almost the entire operating range, with a maximum deviation of 11 N·m. Fig. 1 (a) shows that the measured brake thermal efficiency peaks at about 42 % at 3000 rpm and 80 N·m, which follows the typical trend of a gasoline engine. The CAN1-based map, Fig. 1 (b), reproduces this shape but gives a wider 42 % region, and the difference between the two, Fig. 1 (c), is -0.5 to 1 %pt at medium load, 2 %pt at 110 N·m and 3 %pt at 50 N·m. The CAN2-based map placed its peak of 45.5 % in the high-speed and low-load region, which is inconsistent with the general characteristics of a gasoline engine and is attributed to the CAN engine power being a modelled or target value. The maximum efficiency measured with the engine installed in the vehicle was about 42 %, against 46.08 % quoted in the public material of the engine developer for bench testing.

4. Conclusions The brake thermal efficiency obtained from CAN data differed from the directly measured value by about 3 %pt, and by up to 10 %pt when the CAN torque information was unreliable. Since accurate torque information is rarely available from the CAN bus, the proposed in-line torque measurement is expected to provide a more reliable engine brake thermal efficiency for vehicle benchmarking.

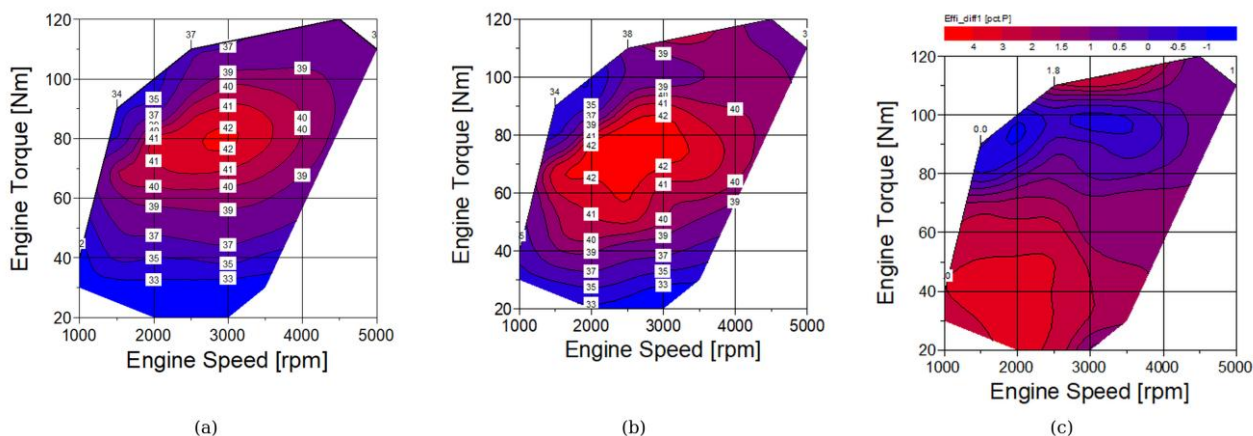


Fig. 1 Engine brake thermal efficiency maps ; (a) directly measured, (b) calculated from CAN1, (c) difference between (a) and (b)