B-55.3 Estimation of environmental load generated by urban traffic (Final Report)

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Abstract: The energy spent by actual urban traffic is usually estimated by the simulation based on the result of mode economy test conducted under pre-determined special conditions. The test results have two drawbacks; one is resultant error caused by test methods, and the other is the gap between the test conditions and actual driving conditions.

Concerning test errors, following facts are clarified: Due to the light road load and heavy weight of EVs, inertia simulation error of chassis dynamometer affects the total accuracy of the scheduled-mode-driving test. And, newly developed hybrid electric vehicles require new test mode with braking conditions similar to actual driving conditions to simulate the regenerative braking effect in its intelligent braking system.

Concerning test conditions, it is clarified that the test procedure should be modified to estimate the influence of air conditioner on vehicle total economy. And we also clarified the effect of road gradient on energy economy of 3 type EVs, namely pure EV, parallel HEV and series HEV, by numerical simulation.

Key Words Electric Vehicle, Energy Economy, Hybrid Vehicle

Introduction Amount of energy spent in transportation sector, especially the energy spent by vehicle, is common problem among developed country. Energy spent by vehicles is not only huge but also is increasing rapidly. So, improvement of energy efficiency of vehicle is one of the key subjects in this field, and estimation of energy efficiency is also the key subject.

Evaluation of Energy efficiency of the vehicle on the actual traffic usage is important to estimate the amount of energy spent in transportation sector. Energy efficiency evaluation test is usually conducted by simulation test run on chassis dynamometer. These test is conducted by tracking the predetermined driving mode such as 10 ·15 mode prepared for certification test, and is conducted under the pre-determined conditions such as on flat road, without wind or with no air conditioner operation. Concerning even conventional internal combustion engine vehicle (ICEV), it is well known that the resultant efficiency of such evaluation test much differs from the efficiency in actual traffic usage. Electric vehicle (EV) or hybrid electric vehicle (HEV) is usually designed to improve energy efficiency, and their traction system is completely differs from conventional ICEV. So, the disparity between test result and actual energy efficiency of such vehicle will be grater than that of ICEVs.

In this report, following two subjects are discussed to make a proper scale for estimating actual energy efficiency of such energy efficient vehicles. Firstly, errors caused in chassis dynamometer test (including test conditions error) are discussed. Secondly, test procedure for evaluating the effect of regenerative brake designed to improve vehicle energy efficiency.

2. Factors to cause significant errors in conventional fuel economy test

2.1. Inertia simulation errors in chassis dynamometer simulation

Chassis dynamometer test is one of the simulation tests that simulate conditions similar to actual driving conditions. Namely, road load of the vehicle is generated by dynamometer and is controlled by dynamometer current. Vehicle inertia (vehicle mass) is simulated by inertia of rotating part of chassis dynamometer (including the drum) and flywheels connected to drum axis.

Amount of inertia was adjusted by selecting the flywheels so that total inertia be equal to or near to vehicle mass. As the minimum inertia value of the flywheel is limited, inertia value can be realized only discretely. So, every certification test defines fixed inertia value to be realized. They classify the vehicle mass, and define corresponding inertia value. So, simulated inertia has usually some amount of error.

Although the recently developed chassis dynamometer can simulate inertia electrically and it is possible to adjust inertia value continuously, every certification test requires to set corresponding predetermined value. This fact makes high specification of the recent chassis dynamometer void.

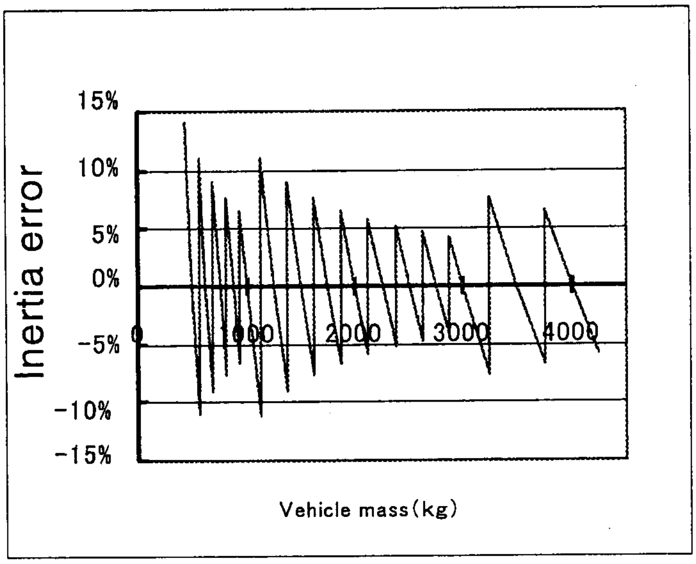

Fig. 1 Inertia simulation errors in TRIAS

Figure 1 shows inertia simulation error of TRIAS (certification test in Japan). Maximum error is about 12%. Assume that inertia and road load affect energy efficiency equally, this error makes 6% error in energy efficiency.

2.2 Simulation accuracy in regenerative braking operation

EVs and HEVs have re-generative braking feature, and quantity of the re-generative energy, which is fed to traction battery, is important value to evaluate the efficiency of EVs and HEVs. As newly developed EVs expect about 20% additional "Range" by regenerative energy today, effect of regenerative brake can not be neglected. Furthermore, newly developed HEVs expect more recovery energy to accomplish high total energy efficiency.

Energy efficiency of EVs/HEVs is usually estimated by driving cycle tests conducted on single roller chassis dynamometer (designed for testing 2WD conventional vehicle). As single roller chassis dynamometer can't simulate the behavior of service brake on non-traction axle, there is some possibility to have some amount of error in the resultant efficiency obtained by the test on single roller chassis dynamometer. One of the most difficult problems is that an amount of the error caused by single roller chassis dynamometer test can't be estimated, and the error depends on vehicle type and driving pattern. So, it is impossible to compensate the resultant errors.

To put the service brake on non-traction axle into operation, chassis dynamometer designed for 4-WD vehicles is required. But, taking account of facility cost, test method on 2-WD chassis dynamometer is expected, and compensation method to obtain the results similar to one obtained on 4-WD chassis dynamometer is also expected. The ultimate target of this study is to find the test method on 2-WD chassis dynamometer with the compensation procedure.

3. Effect of off mode conditions

One of the another problems in actual energy efficiency is that the condition in test differs from actual driving condition or not.

3.1. Effect of air conditioner operation

Usually, certification test is conducted without air conditioner operation. But, in actual use, air conditioner will be operated in many cases. As compressor of conventional air conditioner works independent to thermal load (it works so that pressure in accumulator is kept high), a drop of energy efficiency caused by air conditioner work will be 10% to 15% for all thermal loads. So, some certification test in USA requires one to consider that the drop is 15% if actual measurement is not conducted.

Concerning energy efficient air conditioner designed for EV use, load will be changed in proportion to the thermal load. To clarify this effect, test is conducted using EV that has EV air conditioner. No useful result can be obtained due to lack of our test rig. But it is clarified that energy efficiency is affected thermal load.

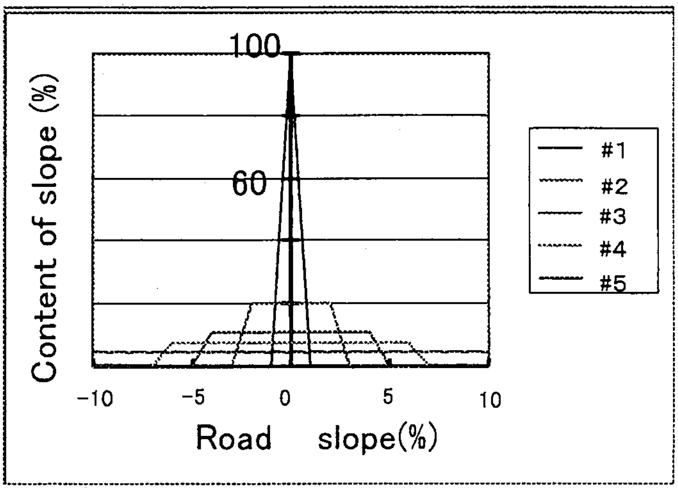

Fig. 2 Distribution of component-slopes in test mode

3.2. Effect of road inclination

To estimate the effect of road inclination on energy efficiency, numerical simulation of energy efficiency of EV, series HEV and parallel HEV. Energy efficiency in 10/15 mode travel on different slope conditions are calculated. Five slope conditions shown in Fig. 2 are used to calculation. Resultant consumed energies on different road inclination conditions are shown in Fig. 3. This figure shows that effect of road inclination differs in each vehicle type.

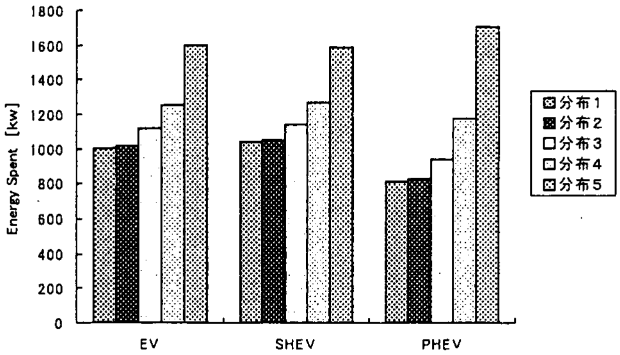

Fig. 3 Effect of slope on consumed energy

4. Behavior of regenerative braking in actual driving conditions (1)

It is useful to conduct the evaluation test of re-generative energy on single roller chassis dynamometer and compensate the resultant data to obtain true value. As the ratio of re-generative (electrical)/ mechanical brake is varies dynamically according to vehicle conditions, it is difficult to compensate the resultant data or to estimate true value.

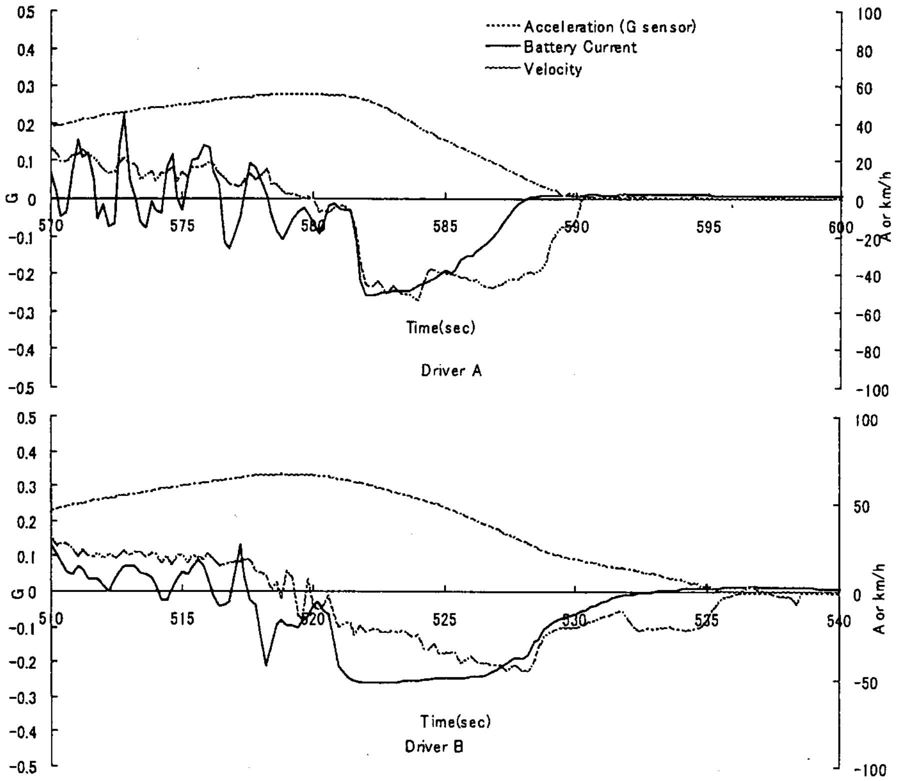

Fig. 4 Variation of Battery Current in Actual Urban Driving

Some newly developed HEV (TOYOTA PRIUS) applies re-generative brake only, in normal braking conditions (low deceleration conditions). As this HEV has ABS function and TRC (TRaction Control) function, it is impossible to conduct said vehicle test on single chassis dynamometer under the condition that vehicle is set in normal operating condition. The test of this HEV is usually conducted on single roller chassis dynamometer under the condition that the HEV is set "maintenance mode."

To clarify the operating circumstances of the HEV system and to clarify the amount of re-generative energy, it is necessary to conduct a test on the two-roller chassis dynamometer that can simulate braking period exactly.

To obtain typical data in urban driving conditions, current, voltage and power of storage battery pack are monitored in actual driving situations in Tsukua district. Velocity and acceleration/deceleration are also monitored.

Figure 4 shows the variation of battery current corresponding vehicle velocity variations in actual urban driving situations. Figure 5 shows the effect of deceleration magnitude on regenerative current. Due to the little sample data, it is not clear whether re-generative value is saturated or not, in high deceleration conditions. But, it is clear that there are some patterns for the same deceleration situations (different regenerative effect for the same conditions.)

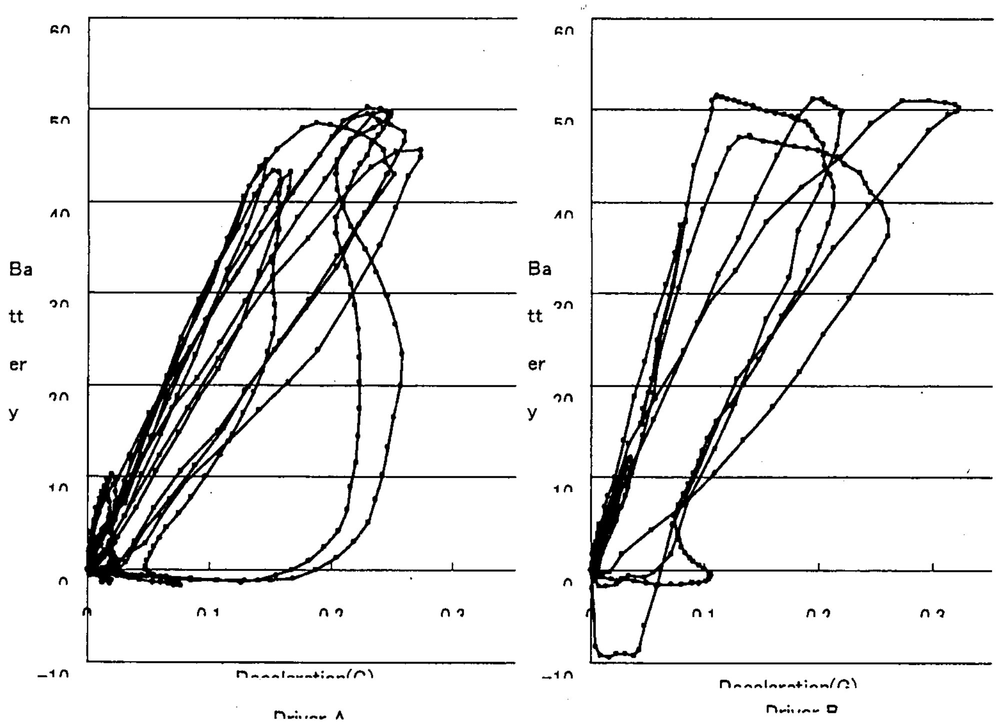

Fig. 5 Effect of Deceleration on Battery Current Regenerated

References

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