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HYBRID LIGHT DUTY VEHICLES EVALUATION PROGRAM

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ABSTRACT–A HEV evaluation program, funded by ADEME, was carried out by a group of Laboratories of different specialties in order to evaluate and compare consumption, emission and component technologies of the three first HEVs put on the market (Toyota Prius, Nissan Tino and Honda Insight). This paper presents the results obtained until now. These results show good consumption and emission performance of the tested vehicles compared to conventional ones. The energy management seems to be globally the same for the three vehicles excepting for cold starts where the Insight allows a very earlier stop of the engine compared to the Tino and especially to the Prius. A mapping of the engine consumption of the Prius and the Insight was performed in order to furnish data for the simulation models. The Permanent Magnet motors of the Prius and Tino have different number of pair poles and then different emf at a given speed. The low emf values of the Prius allow operation at high speed with less field weakening control than for the Tino. The inverters of the Prius and the Tino, controlled by a PWM at respectively 5 kHz and 7 kHz switching frequency, are made of IGBTs with high commutation performances.

KEY WORDS : HEV, I.C. engine, Energy consumption, Pollutant emissions, Vehicle component

1. INTRODUCTION

Hybrid Vehicles have now reached the market and are becoming widespread in Japan, United States and Europe, as illustrated by the sales of over 100,000 Toyota Prius since 1997. These vehicles are equipped with drivelines involving one or two electric motors and a high power battery, with the aim of significantly improve i.c. engine operating conditions. As a consequence, fuel consumption and pollutant emission of these vehicles have been dramatically reduced. However, it appears that these vehicles are very sensitive to their type of use (urban, extra-urban, highway), as our first experiments carried out on the Japanese Prius in 1999 have shown (Jeanneret 1999).

2. PROGRAM CONTEXT AND OBJECTIVES

A research program, EVALVH*, was set up in 2000 with the following objectives:

(1) Set up measurements method on chassis dyno, specific to HEVs;

(2) Evaluate consumption and pollutant emission of vehicles according to their usage conditions (actual and normative type use);

(3) Evaluate operating conditions of driveline components (engine, electric machine(s), electronic control, high power battery, auxiliaries);

(4) Evaluate energy management laws set in the vehicles;

(5) Evaluate technologies involved in driveline components;

(6) Develop and validate simulation software and corresponding databank for the vehicles tested.

This three-year research program (overall cost 0, 9 M EUROs) involves the following laboratories:

(1) INRETS, Lab of Transport and Environment (LTE) and Lab of New Technologies (LTN), for vehicle testing and simulation together with electronic control testing;

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(2) The Institut Français du Pétrole (IFP), for vehicle testing, engine mapping and simulation;

(3) The Ecole des Mines de Paris (ARMINES), for battery testing and evaluation;

(4) The Groupe de Recherche en Electronique et Electrotechnique de Nancy (GREEN) from the University of Nancy for electric motor testing and evaluation.

The first vehicle to be tested in the program was the Toyota Prius (Resp. 1: Japanese and 2: EEC version), the second the Nissan Tino and the third the Honda Insight, a fourth vehicle is planned but not already identified. These three vehicles were acquired from Japanese dealer and shipped to France. Evaluation of the two Prius has been carried out since 1998, the Tino and the Insight have been on test since 2001, and battery testing is now in progress.

The paper presents results obtained on the vehicles and highlights component operating conditions and energy management laws. A comparison of hybrid vehicles will be made, especially concerning engine and battery use. Comparison with fuel consumption and pollutants emission of conventional vehicles will be made using results recorded on INRETS's and IFP's chassis dyno based on the same vehicle driving schedules.

3. TESTED VEHICLES AND THEIR CHARACTERISTICS

The three tested HEVs characteristics and their drive train schemes are given in Annex 1.

4. OPERATING MODES AND ENERGY MANAGEMENT

For HEVs, consumption and emissions depend on the way the electric energy stored in the batteries is substituted to the chemical energy of fuel, or on the contrary, on the way the i.c. engine will have to provide extra energy to recharge the batteries. The global energy management is performed by the ECU first according to the Depth Of Discharge (DOD) of the batteries, but other parameters (like i.c. engine temperature) are also taken into account to define the best strategy.

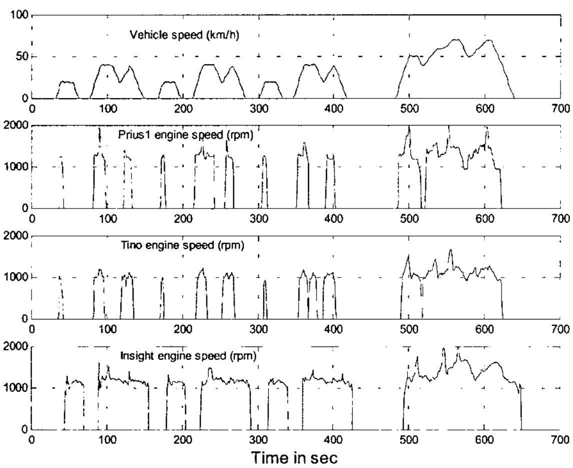

Figure 1. Vehicle and i.c. engine speeds during a 10-15 modes cycle.

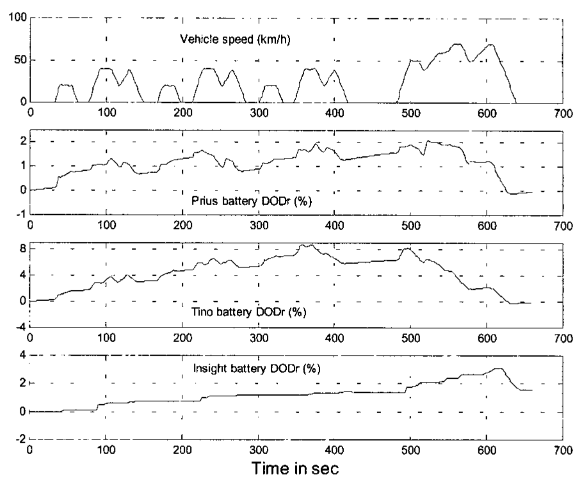

Figure 2. Vehicle speed and battery depth of discharge during a 10-15 modes cycle.

4.1. Warm Condition Functioning (Japanese Driving Schedule 10-15 Modes)

Among several 10-15 modes recorded cycles with different initial DOD, we selected the ones which lead to a battery balance close to zero, in order to compare the on/off strategies of the i.c. engine on the three tested vehicles (version 1 for the Prius). The Engine speed and the relative depth of discharge recorded during the cycle are given on the Figures 1 and 2.

One can see that for the three vehicles, the ICE is stopped when the vehicle stops. Nevertheless, for the Insight, the engine is always working when the vehicle is in motion. This is due to its drive train architecture which does not allow pure electric mode. The Prius 1 and the Tino have almost the same engine switching strategy with some minor differences as may be observed at time 370. The battery DOD management, in this case of balanced cycle, shows the same global behavior for the three vehicles (increasing then decreasing of the DODr). The beginning of the battery recharging phase occurs during the high speed part of the cycle. However, this phase may appear at the very beginning of the high speed part (Tino), at the middle (Prius1) or only during the regenerating phase at the end (Insight). We may also notice that the maximum depth of discharge amplitude,

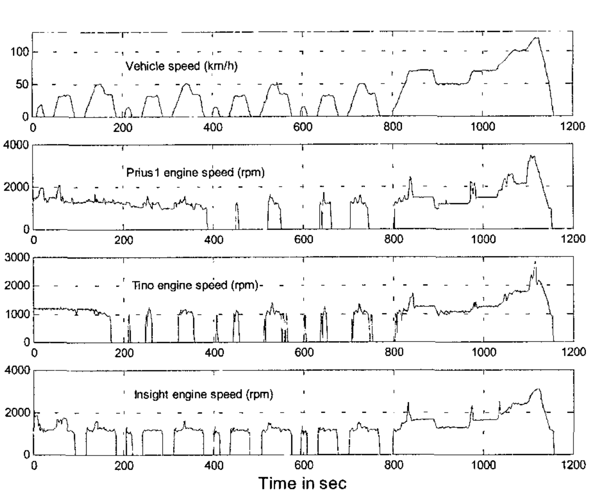

Figure 3. Vehicle and i.c. engine speeds during an NMVEG cycle.

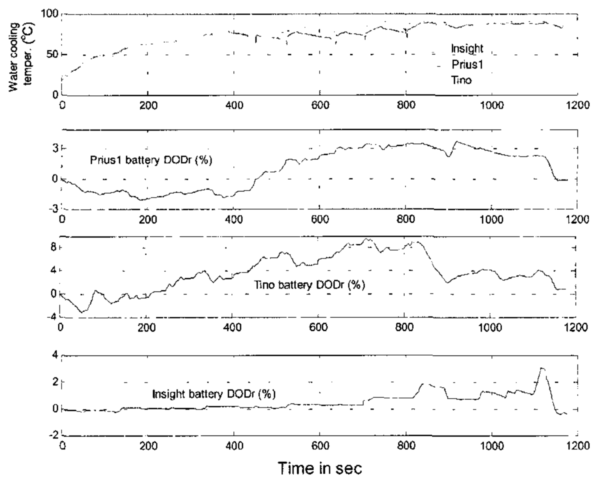

Figure 4. Batteries relative depth of discharge and water cooling temperature during an NMVEG.

recorded during the cycle, is quite different from one vehicle to another, mainly for the Tino for which the DODr reaches a maximum of 8 % of the nominal value, whereas recorded values for the Insight (3%) and Prius1 (2%) remain considerably lower.

4.2. Cold Start Functioning (NMVEG cycle)

The New European Driving Cycle NMVEG is a cold start cycle. In this case, it appears that the stop&go operation of the i.c. engine is usually delayed to allow engine and catalyst heating. The energy management strategy is consequently modified as shown on the Figures 3 and 4.

Indeed, compared to the warm start cycle (10-15 mode), we can observe that the engines of the three vehicles start and remain switched on during several minutes at the beginning (6.5 for the Prius1, 3 for the Tino and only 1.5 for the Insight). Meanwhile, we have to notice that Insight and Tino allow the engine to stop under relatively low coolant temperature (almost 40°C for the Tino and 50°C for the Insight). There might be a compromise between an early stop of the engine and a low consumption and emission.

If we analyze the DODr variation on the Figure 4, we can see that the Tino, and especially the Prius 1, profit from the Engine working at the beginning of the cycle to recharge the batteries. In this way the engine works at a higher load and so is more efficient. Whereas the Insight shows almost the same behavior than on a warm start cycle. This may be thanks to its very short heating period.

5. TESTED CYCLES CHARACTERISTICS

As with all other passenger cars, hybrid vehicles are approved for consumption and pollutants emissions on standard driving cycles (NMVEG in Europe, FTP in the USA, 10~15 modes in Japan...). However, previous studies showed that the real use driving schedules usually present higher consumption mainly because of more frequent variations of the speed [Badin 96]. That is why we consider, in addition to the normative cycles, some real use cycles recorded and classified by INRETS (André 1997). Some characteristics of the cycles used in our tests are given on the table in Annex 2.

6. CONSUMPTION AND EMISSION RESULTS

Instead of imposing the same state of charge range for all the tests, we calculate the global amount of electric charges provided by the batteries on the whole test and give test results according to DODr (relative Depth Of Discharge). The consumption at zero DODr is then obtained by a linear interpolation (Jeanneret 1999). However, for the emission results, we consider a mean value and its standard deviation of all the tests performed on the same cycle. Indeed, the linear interpolation in this case can lead to a low correlation factor as the pollutant emission level is not directly linked to battery DOD variation.

6.1. Fuel Consumption

Using the method described above, the fuel consumption of the 3 cars tested in our program is given for each of the cycles performed. The second column is the fuel consumption in l per 100 km and per ton, to take into account the vehicle weight differences.

Globally, more or less the same approach is used for reducing fuel consumption in the 3 vehicles:

(1) the downsizing of the i.c. engine in order to use higher load (so better efficiency);

Table 1. Fuel consumption results of the three tested vehicles.

	Prius 2 (European version)		Prius 1 (Japanese version)	
	Consum l/100 km	l/100 km per ton	Consum l/100 km	l/100 km per ton
10-15 modes	(1)	(1)	4.3	3.3
NMVEG	4.9	4.0	5.6	4.3
Urban	5.2	4.3	6.0	4.6
Road	(1)	(1)	5.5	4.2
Highway	(1)	(1)	6.3	4.9

	Tino		Insight	
	Consum l/100 km	l/100 km per ton	Consum l/100 km	l/100 km per ton
10-15 modes	5.8	3.9	3.1	3.6
NMVEG	6.8	4.5	3.5	4.1
Urban	6.8	4.5	(2)	(2)
Road	7.0	4.6	(2)	(2)
Highway	8.0	5.3	(2)	(2)

(1): test not to be done, (2): test not done yet

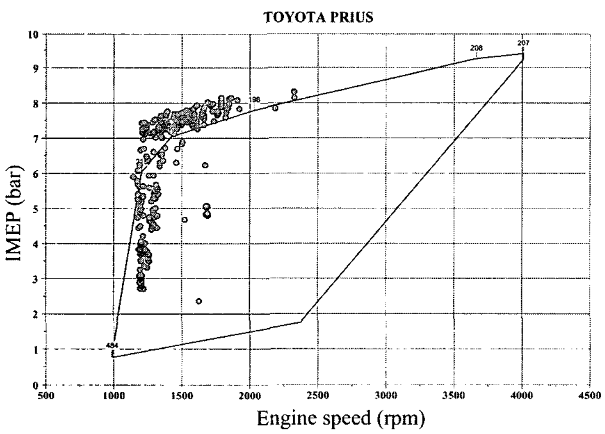

Figure 5. Operating points of the Prius 1 i.c. engine on a 10-15 modes standard cycle.

(2) the hybridization between the i.c. engine and an electric motor (that compensate part of the drawbacks of a high i.c. engine downsizing, and allows suppression of very low load points or use of specific strategies such as stop&go...);

(3) a specific transmission system that reduce the link between vehicle and engine speeds;

(4) the energy recovery during regenerative breaking.

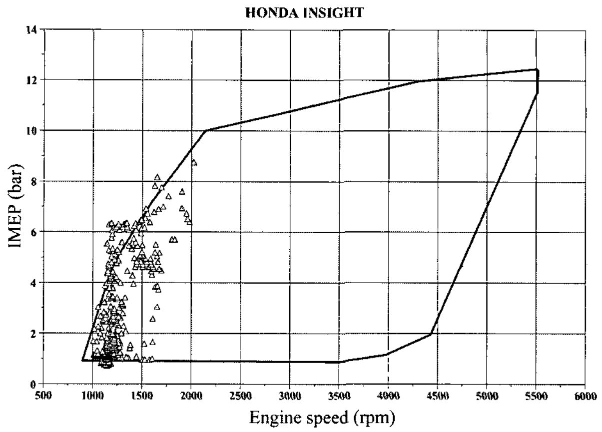

Figure 6. Operating points of the Insight i.c. engine on a 10-15 modes standard cycle.

According to the table given in annex 1, among the 3 vehicles, the Prius car follows the most completely the logical of downsizing and hybridization of the i.c. engine, whereas the Insight car uses only a slight hybridization (only engine-boost) and transfers its downsizing effort to the global vehicle (reduction of car weight) but keeps a quite powerful i.c. engine compared to the vehicle.

We can compare the use that the two extreme vehicles make of their i.c. engine on the 10-15 modes cycle, as illustrated on Figures 5 and 6:

Owing to the planetary gear of the Prius or to the CVT of the Insight tested, the engine speed of both vehicles is controlled over the whole standard cycle in order to reduce friction losses as much as possible. For both vehicles, there is a common strategy to modulate power first through the engine load (with engine speed maintained between 1000 and 1500 rpm), and then through the engine speed (up to 2300 rpm for the Prius 1) when the power available at low engine speed is not sufficient to meet the demand. We can observe that for the Insight, the i.c. engine downsizing is not intensive enough to impose such an engine speed variation on the 10-15 modes cycle.

On the other hand, when the Insight, due to its architecture, has to start its i.c. engine whenever the vehicle is in motion, the Prius is able to operate in full electric mode when very low power is required. This explains why during the cycle no point below 2.5 bar IMEP is required of the i.c. engine of the Toyota car. Thus, on the cars tested, specific transmission system and hybridization allow in-depth optimization in terms of fuel consumption. However, we must check whether these good results are specific to the standard cycle targeted (the 10-15 modes one for these 3 Japanese vehicles). To evaluate this point, we can compare the results obtained on the NMVEG and the 10-15 modes cycles for these 3

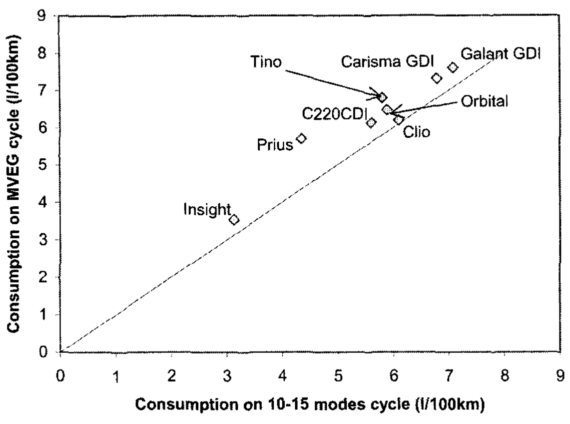

Figure 7. Comparison between fuel consumption on the NMVEG and the 10-15 modes standard cycles for several cars.

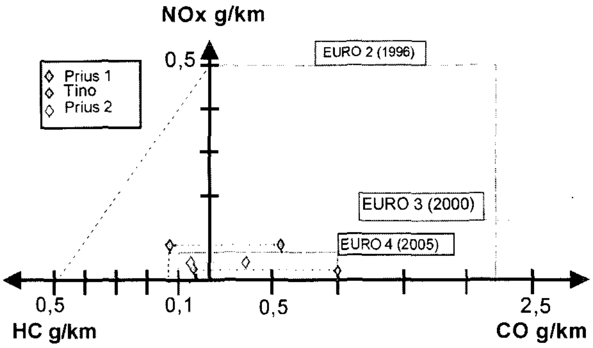

Figure 8. Position of the two Prius versions and the Tino on the European Normalized Pollutants area.

hybrid vehicles and for conventional cars also (Figure 7). For the Mitsubishi Galant and Carisma GDI, the Mercedes C220CDI or the Ford / Orbital cars, it appears that fuel consumption measured is 7 to 9% higher on the MVEG cycle than on the 10-15 modes one. For the Honda Insight, the Nissan Tino and the Toyota Prius 1, this over-consumption on the NMVEG cycle appears to be 12%, 15% and 24% respectively. This could indicate a better optimization of these 3 Japanese vehicles on the Japanese standard cycle, or a greater benefit brought by the hybridization in terms of fuel consumption on less severe standard cycles (higher possibilities in using the electric mode).

Table 2. Prius 1 emission values in g/km.

	CO		HC		NOx	
	Mean	S.D.[1]	Mean	S.D.	Mean	S.D.
10-15 modes	0.09	0.0609	0.02	0.005	0.05	0.035
NMVEG	0.60	0.15	0.12	0.033	0.09	0.018
Urban	0.29	0.112	0.02	0.005	0.18	0.035
Road	0.25	0.078	0.02	0.008	0.15	0.043
Highway	0.09	0.014	0.01	0.004	0.26	0.039

Table 3. Tino emission values in g/km.

	CO		HC		NOx	
	Mean	S.D.[1]	Mean	S.D.	Mean	S.D.
10-15 modes	0.35	0.070	0.00	0.004	0.02	0.005
NMVEG	1.02	0.181	0.06	0.011	0.02	0.009
Urban	0.74	0.421	0.02	0.033	0.05	0.035
Road	0.64	0.127	0.00	0	0.02	0.010
Highway	0.69	0.098	0.00	0	0.05	0.017

1: Standard deviation.

6.2. Emission

For the pollution measurement, the detailed tests today are only performed for the Prius 1 and the Tino. The results are given in the Tables 2 and 3.

In order to illustrate the position of these vehicles in the European normalized area, we have drawn the following figure 8 using the values in the Tables 2 and 3 for the normalized cycle NMVEG.

We can see that the Prius1 is largely inside the Euro 3 area and near the boundaries of the Euro 4. The Tino is inside the Euro 4 area for the HC and the NOx and almost on the boundary for the CO. The Prius 2 is completely inside the Euro 4 area.

7. COMPONENT SPECIFIC TESTS

7.1. IC Engine Tests

Usually, i.c. engines are characterized on engine test benches in order to obtain their global performances (versus engine speed / BMEP: Break Mean Effective Pressure or IMEP: Indicated Mean Effective Pressure). For engines used in hybrid vehicles, this would be difficult to put into practice, as many elements such as the complete drive train and batteries are necessary for the ECU to properly control the engine. For our tests, we preferred a far less intrusive technique consisting of measuring the i.c. engine response when the vehicle is running at constant speed on a chassis dynamometer. Thus, we have access to the mapping of steady operating points in accordance with the optimization strategies defined for the vehicle.

Measurements done on the vehicle during these tests are summarized below:

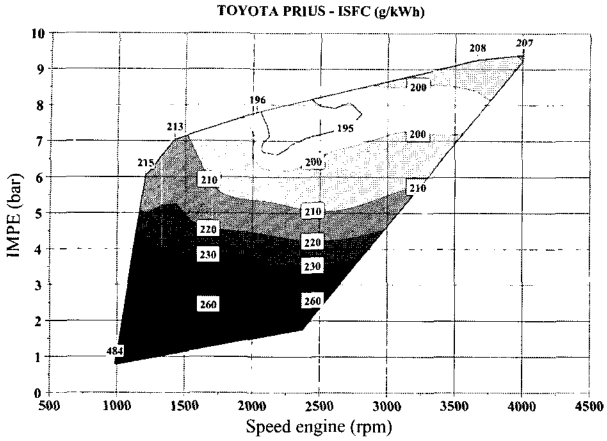

Figure 9. Measured Prius 1 indicated consumption maps according to engine speed and IMPE.

(1) I.C. engine: Speed, IMEP, air mass flow, intake throttle position, intake pressure, EGR, maxi cylinder pressure, crank angle of maxi cylinder pressure, VTEC (for the Honda Insight), coolant temperature, intake air temperature;

(2) Auxiliaries 12 V Battery and HP Battery: Currents and voltages;

(3) Vehicle: Speed and power absorbed by the brake of chassis dynamometer.

In order to evaluate the IMEP, an angular encoder, next to spark plug pressure sensors was installed and connected to an IFP device calculating IMEP cycle to cycle in real time. For the Honda Insight car, the 14 mm offset between cylinder and crankshaft axis should be handled with care as the kinematics of the piston is altered : TDC (resp. BDC) does not occur at 0 CAD (resp.180 CAD), but at 4.6 CAD (resp.188 CAD).

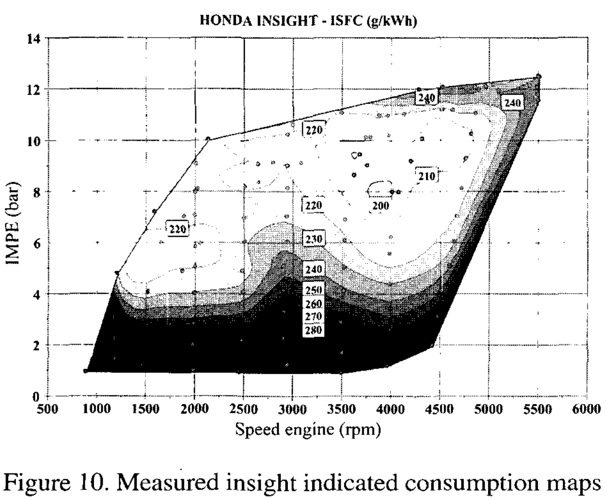

Figure 10. Measured insight indicated consumption maps according to engine speed and IMPE.

The testing method consisted of progressively opening the throttle while keeping a constant vehicle speed. On a vehicle equipped with a mechanical gear box, such a process would induce a variation of load on the engine. Because of the continuously variable transmission (CVT for the Insight and the Tino cars or planetary gear box for the Prius), the vehicle response is different : for low vehicle speeds, the increasing demand for power is met first through a variation of load, but beyond 8 bar IMEP, the ECU uses engine speed to increase power. Thus, the optimization of the operating point according to the power required does not allow the i.c. engine to run in high load / low speed or low load / high speed conditions.

The following Figures (9 and 10) show the engine mapping of ISFC (Indicated Specific Fuel Consumption) versus engine speed and IMEP for the two hybrid vehicles Toyota Prius 1 and Honda Insight.

7.2. High Power Batteries Tests

7.2.1. Objectives

The experiments have the objective to determine battery characteristics for simulation purpose, i.e.:

(1) Open circuit voltage according to the battery DOD for different temperatures;

(2) Internal charge and discharge resistance according to the battery DOD for different temperatures;

(3) Capacity according to battery current;

(4) Faradic efficiency according to the battery current, DOD for different temperatures.

7.2.2. Experiments

For each vehicle tested, battery pack is dismantled from the car and put on a test bench in order to perform the previously described tests.

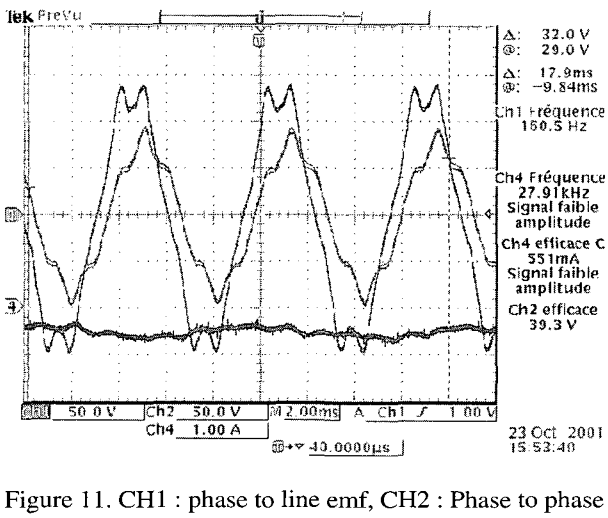

Figure 11. CH1 : phase to line emf, CH2 : Phase to phase emf, CH4 : DC current. (Tino electric motor)

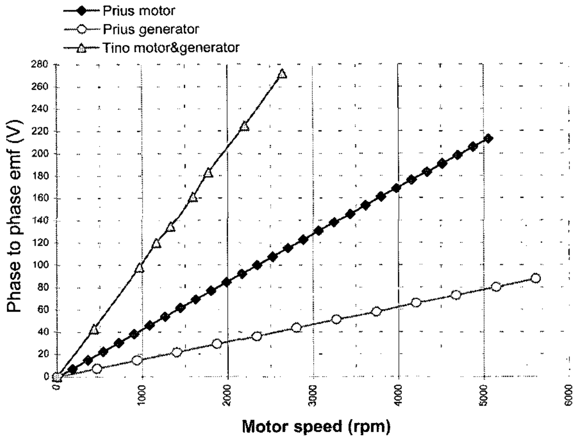

Figure 12. Phase to phase emf against motor speed motors and generators of Prius 1 and Tino.

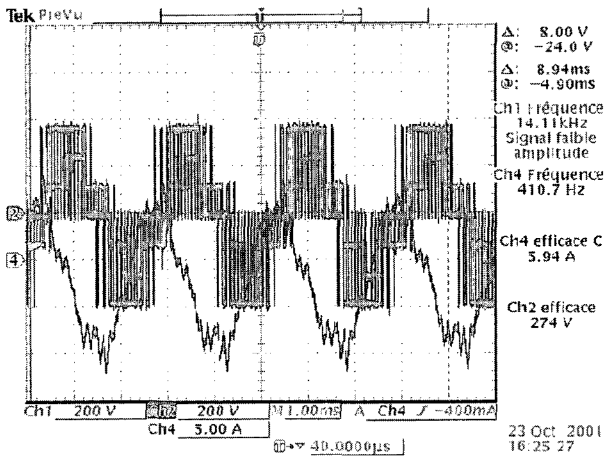

Figure 13. CH1: phase to line Voltage, CH2: Phase to phase Voltage, CH4: phase current.

Batteries are stored in an enclosed space and regulated with a pulsed air at specified ambient temperature. Specific thermistors are installed inside the battery pack. We therefore can accurately follow the temperature evolution during the whole test.

Up to now, experiments on the Panasonic NiMH 6.5 Ah battery, which equipped the Prius1, are in progress.

7.3. Electric Motors Tests

Some tests have been carried out on the Prius 1 and Tino electric motors and generators which are all Permanent Magnet Synchronous motors. This type of motor is now the most used in the field of electric and hybrid drive trains considering its good performance in terms of efficiency and Power/weight Power/volume ratios.

7.3.1. No load test

In this test, the wheels are pulled by the chassis dyno, the ignition key is put on its first position so that the inverter does not supply the motor yet. Consequently, we can measure emf with an rms value obviously proportional to the motor frequency. Figure 11 shows the emf waveforms of the Tino motor. On Figure 12, we make a comparison between emf amplitudes for the Prius 1 and Tino.

The phase-to-line voltages (CH1, Figure 11) are reconstructed using an artificial neutral of strong impedance assembled on the three phases, in parallel with the power supply of the inverter. The phase-to-line voltage has a correct lag of 30° with respect to the phase-to-phase voltage (CH2, Figure 11). As we can see, the emf waveforms show many space harmonic distortions. A spectral analysis revealed the existence of the harmonics 5, 7, 11 and 13.

We also observe a D.C. current (CH4, Figure 11), of low value, injected by the inverter and which might be used to detect if the motor is present.

During this test, and by measuring the motor speed and the emf frequency, one can calculate the number of pair poles using the following equation:

$$p = \frac{f \times 60}{N}$$

Where f is the emf motor frequency in Hz, and N is the motor speed in rpm.

We obtained: (Prius 1 motor: p=4, Prius 1 generator: p=4, Tino motor: p=10).

As this value is constant for each motor, we used it in the other tests (especially on cycles) to determine the instantaneous motor and generator speed. In this way we can estimate an overall transmission ratio and its

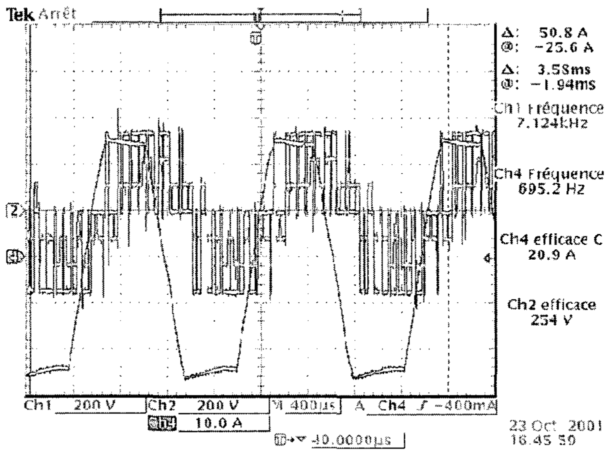

Figure 14. CH1: phase to line Voltage, CH2: Phase to phase Voltage, CH4: phase current.

instantaneous variation.

Concerning the rms emf values (Figure 12), they are usually related to the battery voltage, mainly during high speed operation. As we can see in the figure 10, the emf in the Tino motor and generator is significantly higher than the Prius ones, probably due to the high number of pair poles. The two dimensioning strategies (Tino/Prius1) of the motor voltage according to the battery one are quite different. Although the battery voltage of the Tino is higher than that of the Prius 1, it is not sufficient to accomplish motor operation at high speed without setting the direct current "id" at high negative values (in order to decrease the flux in the machine). This issue can justify, partly, the high consumption we recorded for the Tino under highway conditions.

7.3.2. Under load test

In this test (figures performed only for the Tino) the vehicle was normally operated on the chassis dyno. We have recorded Voltage and currents in the motor phases during two different operations:

(1) At steady state mode of 110 km/h of vehicle speed (Figure 13);

(2) During a large acceleration at 100 km/h (Figure 14).

A credible analysis of the first test is that electric motor does not contribute any significant power. The current is very low and is quite chopped. Indeed, at high permanent speed, the i.c. engine is on and has enough power to insure the driving demand and charge the high voltage battery thanks to the generator.

However, when we request much more power from the car, the control device engages the electric motor (second test case); it is the "boost" mode. In this case, captures reached the limits of the current probe (saturation). We can however see that the current is leading the phase-to-line voltage by approximately 28°. We note that this lag could be larger (we also noticed a value of 56°). At high speed, the PWM pattern is strongly reduced. A significant observation is that we do not see at any time the square waves appearing (1-Pulse Switching). The Prius 1 does not allow this kind of control neither. However, the Prius 2 uses it to improve the motor performance at very high speed (Shinko 2000).

7.4. Inverters Tests

Voltage and currents measurements were carried out on the Prius 1 and Tino Inverters (Electric circuits on Figure 15) to identify the commutation characteristics of the power electronic devices.

The following figures illustrate one of the Tino IGBTs voltage Vce and current Ic commutations during normal operation of the vehicle. W is the energy lost during commutation expressed in mJ.

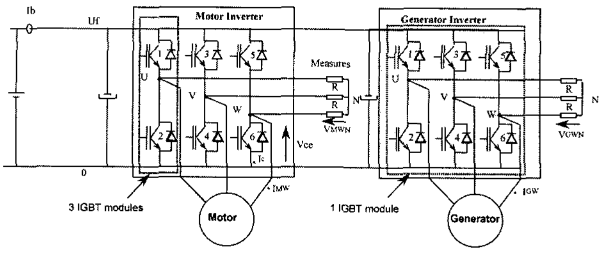

Figure 15. Electric scheme of the Tino motors and inverters. (The same circuit is valid for the Prius excepting that the motor inverter also has 1 IGBT module).

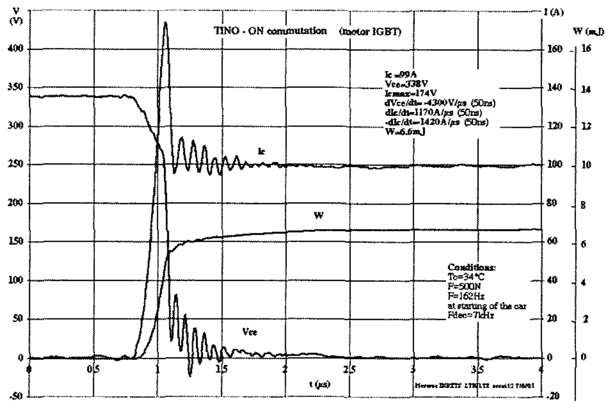

Figure 16. Commutation ON of a Tino IGBT during vehicle operation.

One can observe that the commutations are relatively hard. Indeed, the dV/dt (voltage variations of the electronic component) are significant; their values are between 3000 and 5000 V/µs. These fast variations create significant oscillations at the point of all the isolating parts whose capacitor currents are directly proportional to these variations. These fast commutations can also generate electromagnetic troubles.

The over-voltage (90 V) obtained during the commutation and in relation with the di/dt (1365A/µs) shows the care that has been taken while the electric circuit wiring (wiring inductance=60 nH). This value is sufficiently low, if we assume that, for such hard commutations, a good IGBT wiring inductance must be lower then 100 nH.

The following Figure 18, deduced from several commutation measurements, gives an evaluation of the commutations losses ON and OFF of the Tino IGBTs at a module temperature of 33°C (lower than permanent operating temperature which is about 50°C).

When multiplied by the commutation frequency of 7 kHz (5 kHz for the Prius 1) and then added to the conduction losses, the values shown on the figures 16 can

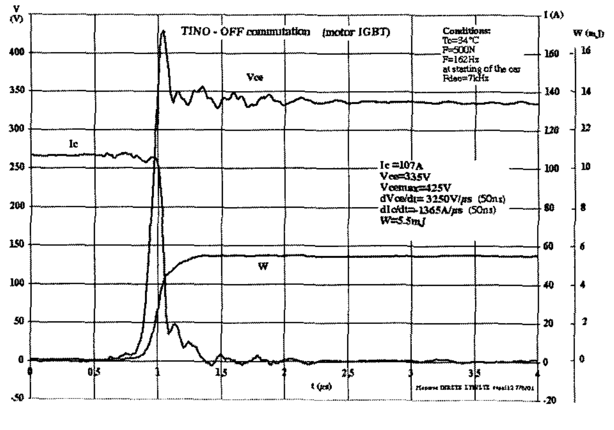

Figure 17. Commutation OFF of a Tino IGBT during vehicle operation.

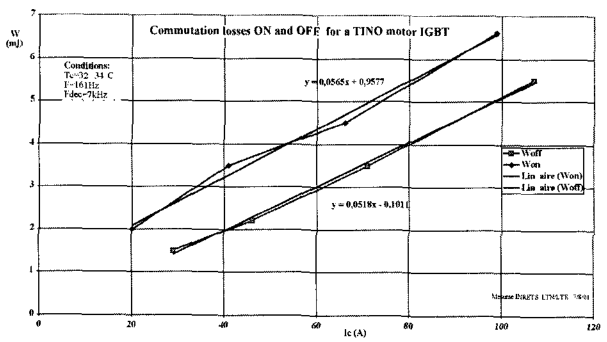

Figure 18. Commutation losses ON and OFF of a TINO IGBT at 33°C versus current.

lead to a calculation of the efficiency of the inverter and its variation with the current for simulation applications.

8. CONCLUSION

A hybrid vehicle evaluation program has allowed us to assess the advantages of the 3 first HEVs put on the market in terms of consumption and pollutants emission.

The results of this project also provided information on the following points:

(1) Evaluation of the hybrid solutions potential according to their use;

(2) Knowledge concerning various components of the vehicle and their management laws;

We can expect that these studies will be used for:

(3) Evaluation policies of the new technological solutions according to their consumption/pollutant balance (all type of VEHs, all type of uses);

(4) Future studies on the aging, dimensioning and optimization of the specific components and energy management laws for HEVs.

A simulation action was already initiated some years ago with the objective to build a complete simulation library (VEHLIB (Jeanneret 1999; Badin 2001)) made of component models and developed under Matlab-Simulink environment. The study described in this paper will allow us to collect data and to validate the component models as well as the whole vehicle models of the vehicles tested.

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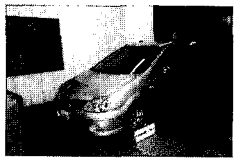
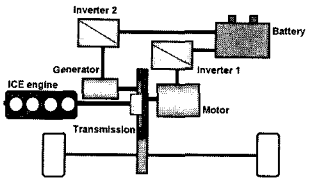
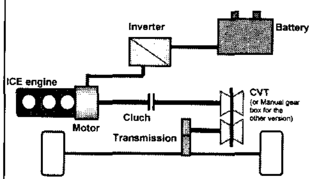
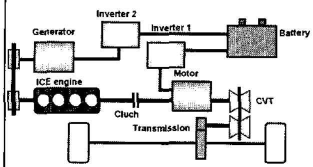
Annex 1. Tested vehicles characteristics.

Type	Toyota		Honda	Nissan
Photo				
Powertrain				
Model	Prius 1 Japan	Prius 2 CEE/US	Insight	Tino
Vehicle type	VP	VP	VP	Minivan
Drive train type	S/P	S/P	P	S/P
Year	1997	2000	1999	1999
Nb of seats	4/5	4/5	2	5
Cost in Euro	# 23000	# 25000	# 23000	# 34000
No load weight (kg)	1240	1220	820/850	1514
Cx	0.30	0.30	0.25	
Transmission	Cont, epi. Tr.	Cont, epi. Tr.	Manu. or CVT	CVT
ICE type	SI 4 cyl	SI 4 cyl	SI 3 cyl	SI 4 cyl
Displacement in l	1.496	1.496	0.995	1.8
Max Power kW @ tr/mn	43 @ 4000	53 @ 4500	49 @ 5700	73
Max Torque Nm @ tr/mn	102 @ 4000	115 @ 4200	92 @ 4800	
Electric motor type	SYN PM	SYN PM	SYN PM	SYN PM
Max Power kW	30	33	10	17
Max Torque Nm	305	350	49	
Battery Type	NiMH	NiMH	NiMH	Li-ion
Manufacturer	Panasonic	Panasonic	Panasonic	Shin Kobé
Nominal capacitance (Ah)	6.5	6.5	6.5 @ 3 h	3.6
Nominal Energy kWh	1.8	1.7		# 1
Nominal voltage in V	288	274	144	340
Max Power kW	21	34		25
Consumption l/100[1]	3.6	3.5	2.9	4.3
Cycle	10-15	10-15	10-15	10-15
Carburant	Gasoline	Gasoline	Gasoline	Gasoline
Performances en s	14.1[2]		12[2]	13.2
Acceleration en km/h	0-96		0-96	0-100

1: Manufacturer Data 2: PNGV evaluation

Annex 2. Tested cycles characteristics.

	Duration (sec)	Avg.Disp. speed* (km/h)	Distance (km)	Maximum acceleration (m/s^2)	Maximum deceleration (m/s^2)	Duration of stops (sec)	Start condition
10-15 modes	660	32.5	4.158	1.14	1.14	199	warm
NMVEG	1179	43.8	11.085	1.31	1.42	267	cold
Urban	560	29.5	3.478	1.60	1.94	134	warm
Road	843	51.7	11.262	1.96	2.50	58	warm
Highway	1804	95.4	46.210	2.29	3.46	62	warm

*without counting stops