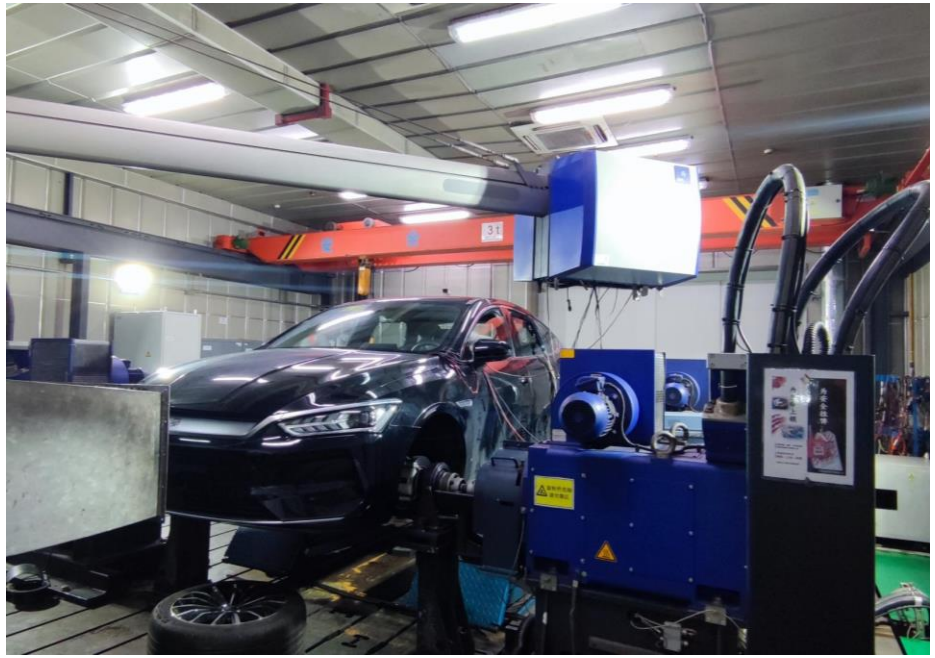
Determination of System Power of Hybrid Electric Vehicles and of Pure Electric Vehicles Having More Than One Electric Machine for Propulsion

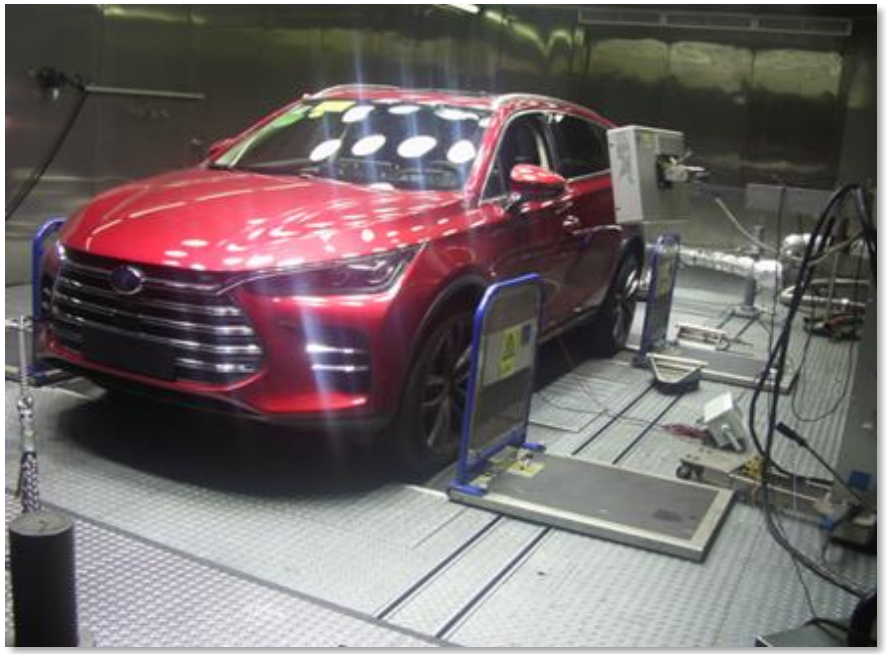
GTR21 Bench Test Validation

1、Test Bench

- The bench test validation is performed on two kinds of test benches.



Hub Dynamometer



Chassis Dynamometer

2、Test Sample

Test Sample		Hybrid(4WD) 
Powertrain	Front	Hybrid (476ZQC+EHS2)
	Rear	Electrified (Three in One)
Total Weight（kg)		2420
Test Weight（kg)		2584
Tire		265/45 R21
Target Road Resistance		A：184.88 B：1.8383 C：0.0449
Maximum Speed（km/h)		180
Engine	Info.	1.5T 139hp L4 Plug-in Hybrid
	Rating Revolution Speed (rpm)	5200
	Max Torque（N·m)	231
	Max Power（kW)	102
Front Motor	Max Power（kW)	160
	Max Torque（N·m)	325
Rear Motor	Max Power（kW)	200
	Max Torque（N·m)	350
Transmission		ECVT
Battery Pack Capacity (kWh)		45.8

Test Sample		Tang EV 
Powertrain	Front	Electrified
	Rear	Electrified
Total Weight（kg)		2660
Test Weight（kg)		2824
Tire		265/45 R21
Target Road Resistance		A：272 B：0.005 C：0.0444
Front Motor	Max Power @ 6000rpm	165
	Max Torque（N·m)	360
	Speed Ratio	10.75
Rear Motor	Max Power @ 6000rpm	210
	Speed Ratio	10.75
	Max Torque（N·m)	360
Maximum Speed（km/h)		180
Battery Pack Capacity (kWh)		108.8

3、Measurement Points of Vehicle

No.	Measured Parameters	Unit	Data Source	Remarks
1	Engine Speed	rpm	On-board Data	
2	Engine Intake Manifold Pressure	pa	On-board Data	Application of sensors may damage the vehicle
3	Fuel Flow Rate	g/s	Fuel Consumption Meter & On-board Data	
4	Voltage of Battery Pack DC bus	V	Power Analyzer & On-board Data	Measure each path if there are more than one output from battery pack
5	Current of Battery Pack DC bus	A	Current Clamp & On-board Data	Measure each path if there are more than one output from battery pack
6	Atmospheric Parameters(Temperature、Pressure、Humidity)		Meteorological Station	At least one record shall be done prior and at the end of the test
7	Speed of Dynamometer	km/h	Dynamometer	
8	Force of Dynamometer	N	Dynamometer	
9	Axle/Wheel Rotational Speed	rpm	Dynamometer	
10	Axle/Wheel Torque	N·m	Dynamometer	
11	Accelerator Pedal Command	%	On-board Data	
12	Engine Throttle	%	On-board Data	
13	Enigine Coolant Temperature	℃	On-board Data	Monitor parameter, shall be in the range specified by manufacture
14	Battery Temperature	℃	On-board Data	Monitor parameter, shall be in the range specified by manufacture
15	Oil Temperature of Transmission or Gerabox	℃	On-board Data	Monitor parameter, shall be in the range specified by manufacture
16	Battery SOC	%	On-board Data	Monitor parameter, shall be in the range specified by manufacture
17	Motor Winding Temperature	℃	On-board Data	Monitor parameter, shall be in the range specified by manufacture
18	Drive motor torque, speed, DC Voltage, DC current		On-board Data	
Note: All the above sample frequency shall be at least 10 Hz				

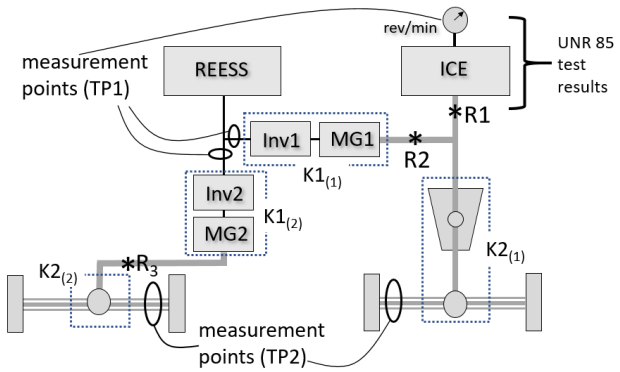
4、Info. Shall be Provided by Manufacture

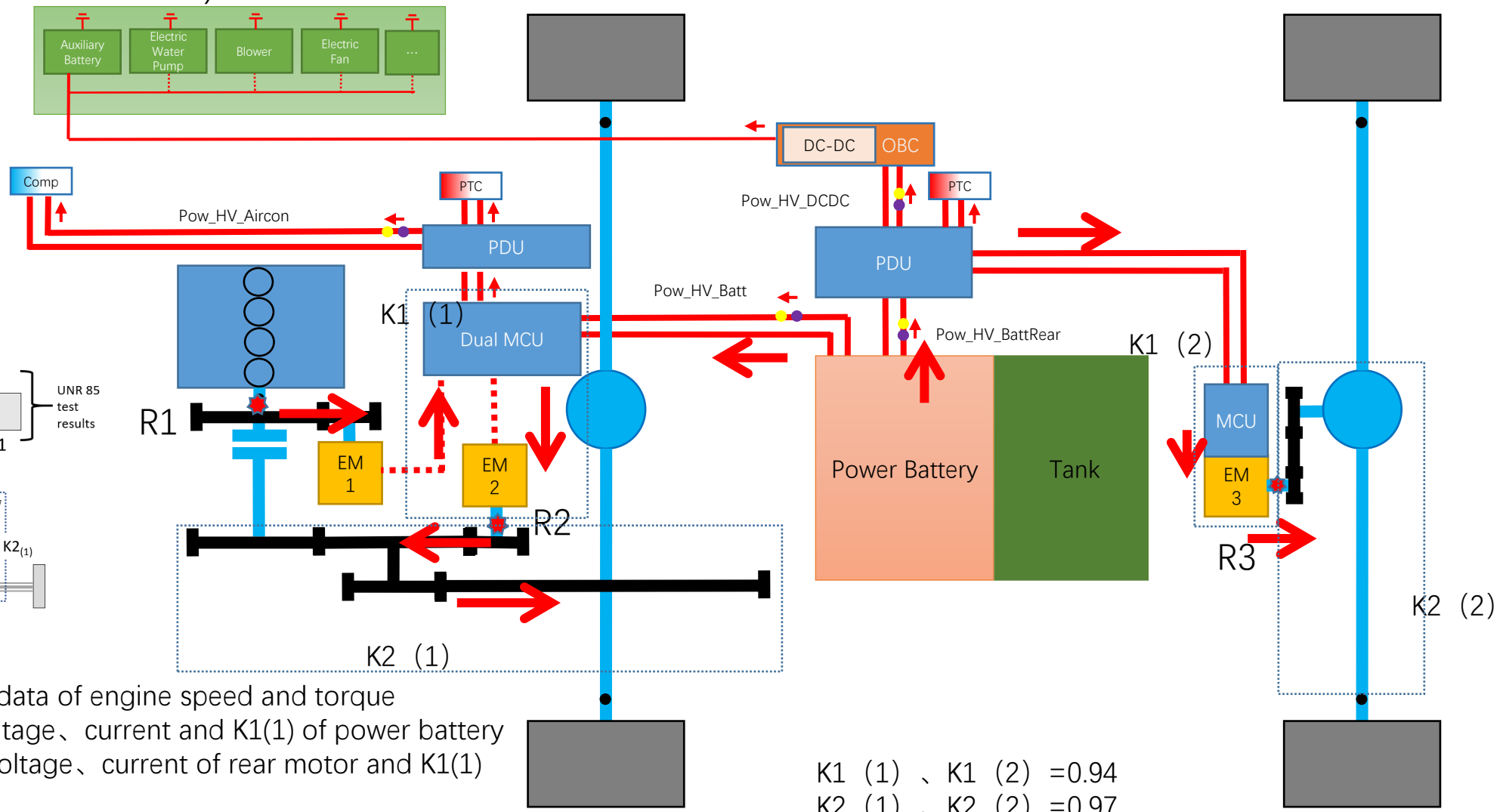
No.	Measured Parameters	Remarks
1	Vehicle Energy Flow Chart	Energy flow chart when the sample vehicle operates at maximum vehicle power
2	K1	Electrified Driven System Efficiency K1=Electrified Driven System Shaft End Power/Input Propulsion MCU Power
3	K2	K2=Half-axle Mechanical Power/Gerbox Input Mechanical Power

5、Test Sample

PHEV 4WD (Series Architecture)

- Torque Measurement Points
- Current Measurement Points
- Voltage Measurement Points
- Reference Points





R1-Determined by on-board data of engine speed and torque
R2-Determined by DC bus voltage、current and K1(1) of power battery
R3-Determined by DC MCU voltage、current of rear motor and K1(1)

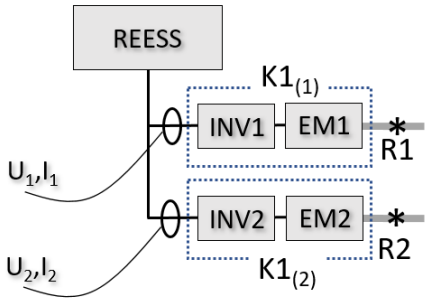
K1 (1) 、K1 (2) =0.94
K2 (1) 、K2 (2) =0.97

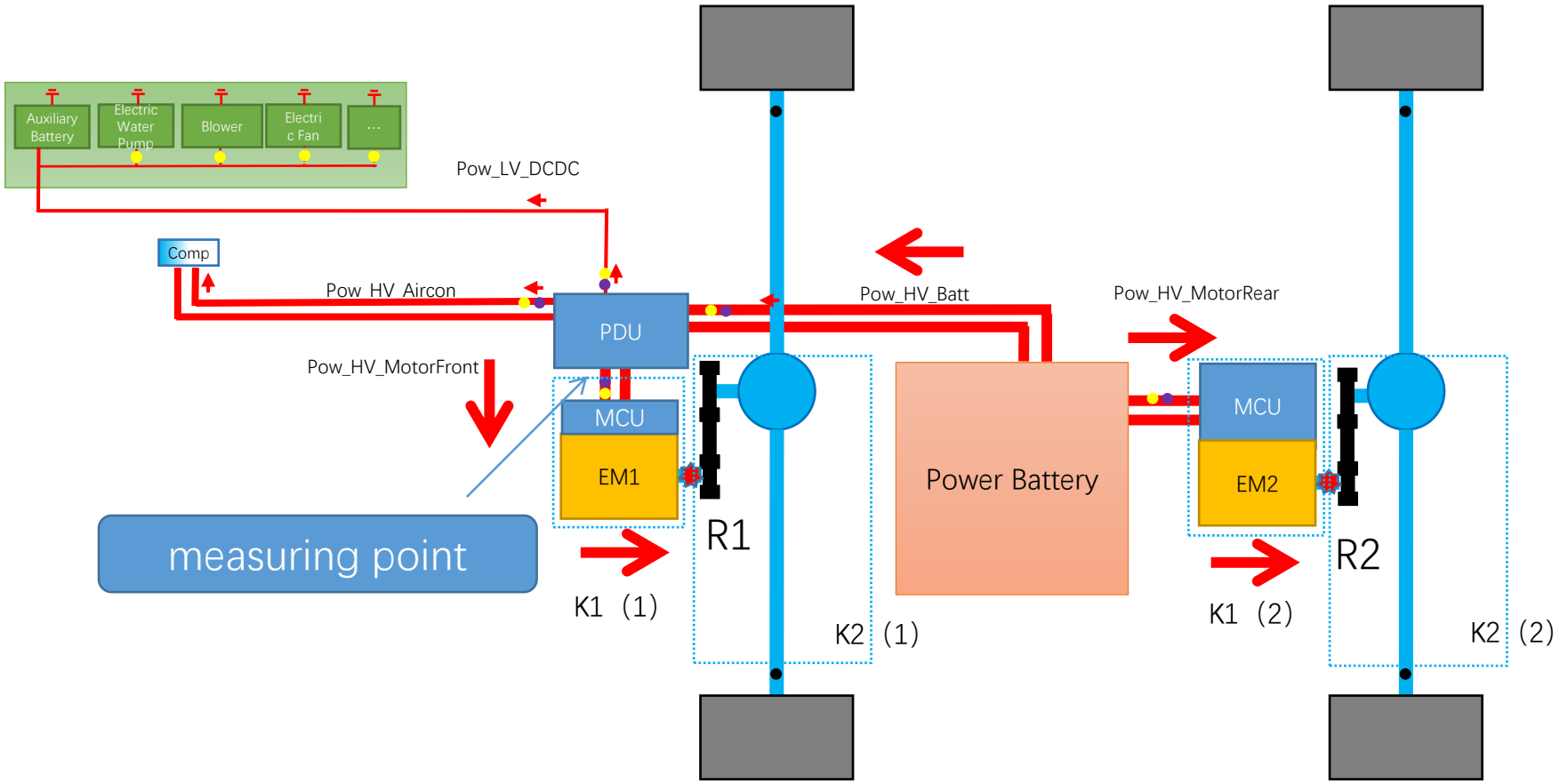
System Power=R1+R2+R3

5、Test Sample

PEV 4WD

- Torque Measurement Points
- Current Measurement Points
- Voltage Measurement Points
- Reference Points

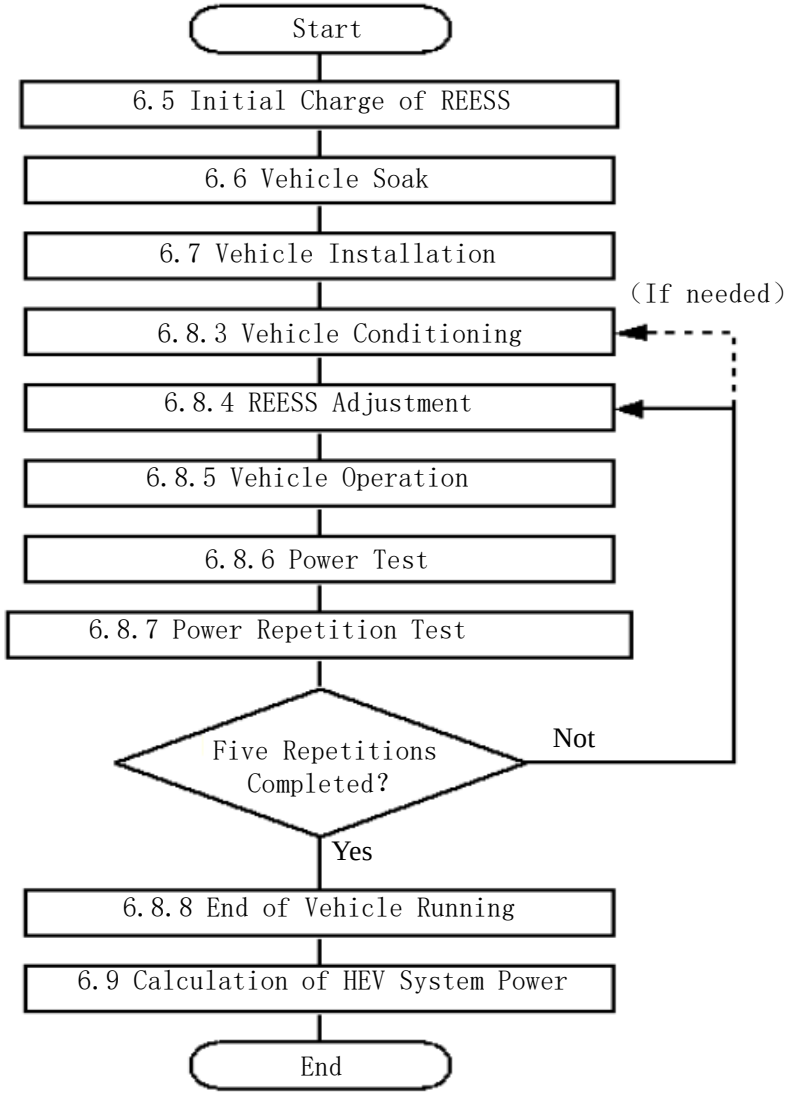




K1（1）、K1（2）=0.94
K2（1）、K2（2）=0.97

System Power=R1+R2
=Pow_HV_MotorFront*K1+Pow_HV_MotorRear*K2

6、Test Sequence

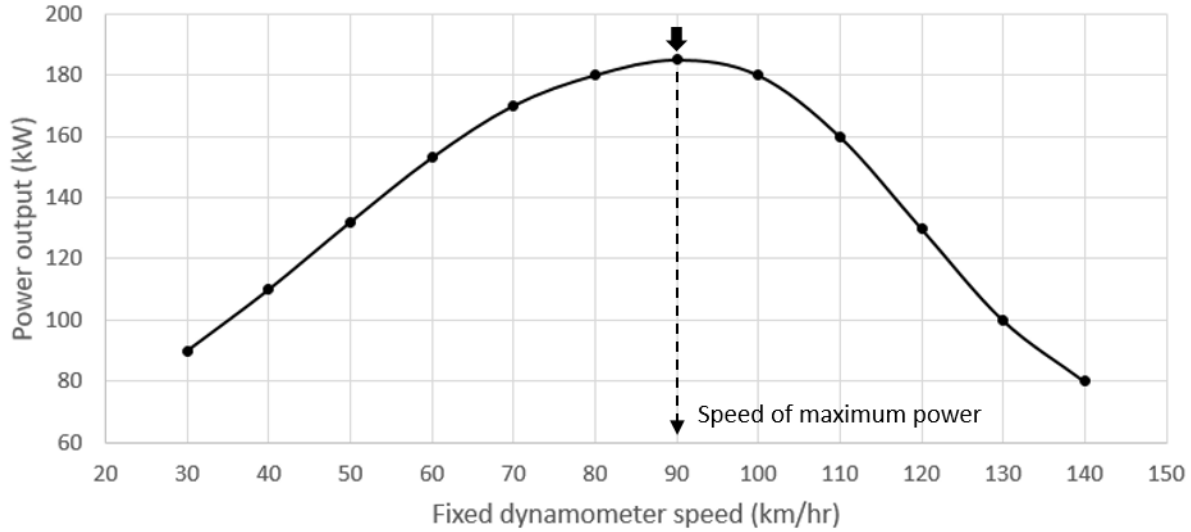


Run for 20 mins at 60km/h or as recommended by manufacture

SOC sustained at the range which can achive the maximum power, REESS can be adjusted by use of light regenerative braking, or by allowing the vehicle to coast

6、Test Sequence

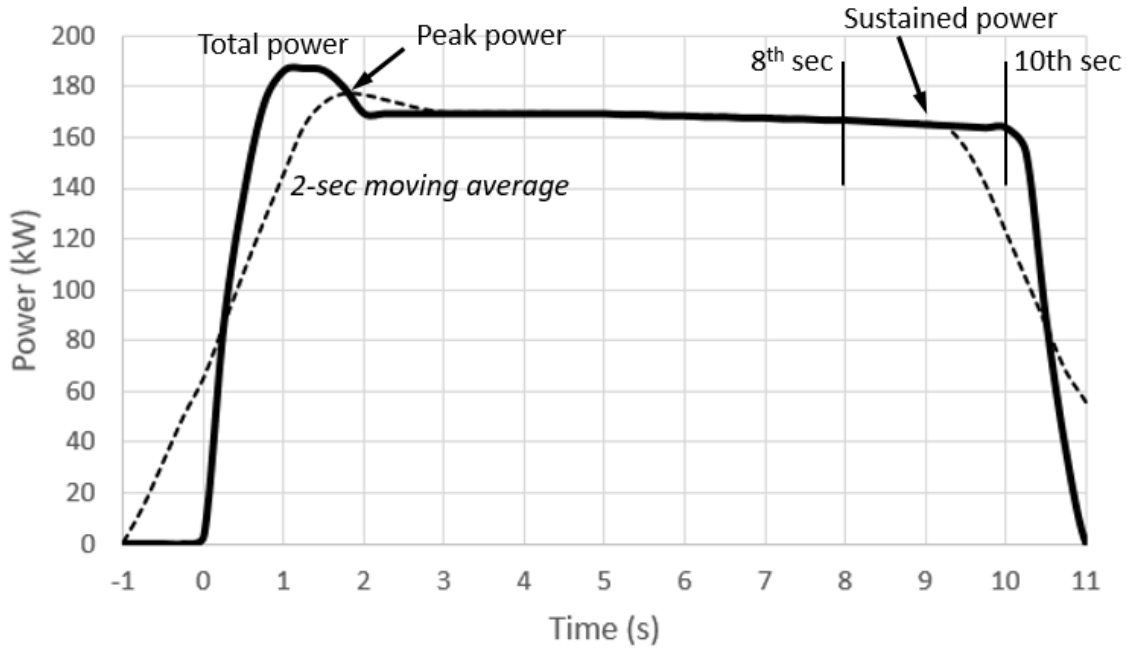
- Determination of maximum power
  -vehicle shall be at high SOC
  -selection of driver-selectable mode: sport mode
  -maximum accelerator command:command the accelerator pedal to 100% as fast as possible, and hold for 10 s while reach 100%
  -maximum power determination:determined by the measured shaft end(Hub Dynamometer) or wheel end(Chassis Dynamometer) maximum power of dynamometer



BYD Tang PHEV 4WD maximum power speed: 80km/h
BYD Tang PEV 4WD maximum power speed: 90km/h

6、Test Sequence

- Definition of peak and sustained power



Compute the peak and sustained vehicle system power ratings for the vehicle, as the mean of the respective individual results of the four analyzed repetitions.

The variation of each of the four analyzed repetitions shall be computed and recorded as a percentage of their mean.

7、Result Calculation

TP1

$$Vehicle\ system\ power\ [kW] = \sum_{i=1}^{n} R_i$$

where,
n is the number of power determination reference points
R_i is the power at the i[th] reference point [kW]

TP2

The vehicle system power is calculated as the sum of the power at each of the reference points:

$$Vehicle\ system\ power\ [kW] = \sum_{i=1}^{n} R_i$$

The power at each reference point is calculated as:

$$R_i\ [kW] = \left(\frac{P_{axle}}{K2} \right)$$

Where
P_{axle} is the power measured at the respective powered axle [kW]:

$$P_{axle}\ [kW] = (2\pi \times axle\ shaft\ or\ wheel\ speed\ [rev \bullet s^{-1}] \times axle\ shaft\ or\ wheel\ torque\ [Nm]) /1000$$

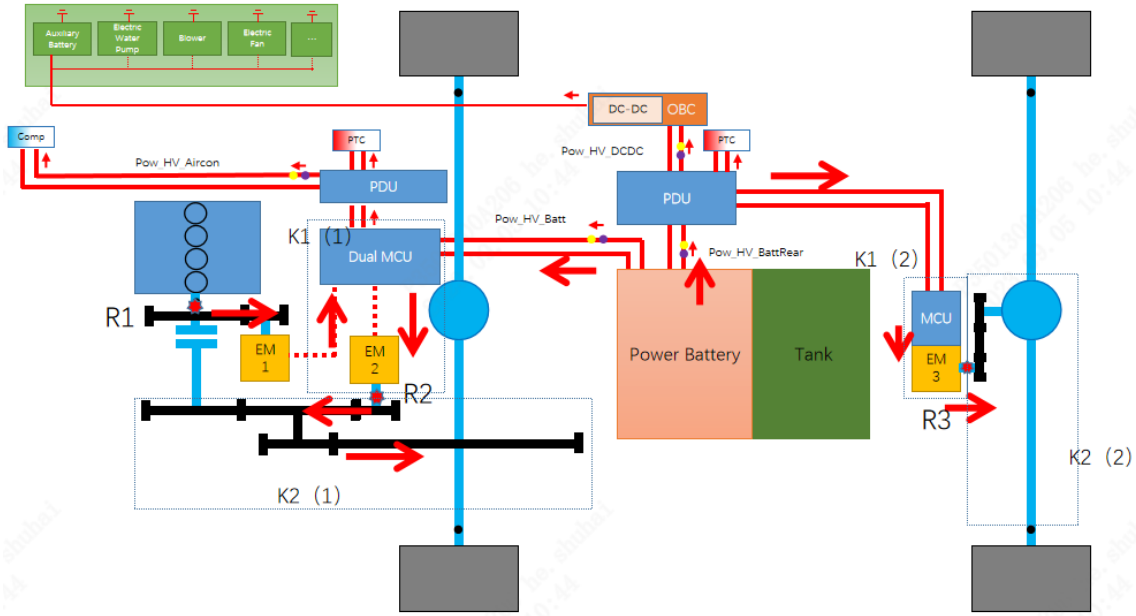
K2 is the mechanical energy conversion efficiency factor K2 applicable to the axle as described in 6.1.1.2. and 6.1.3.2.

7、Result Calculation

Hub Dynamometer Test Results-BYD Tang PHEV 4WD(Series)

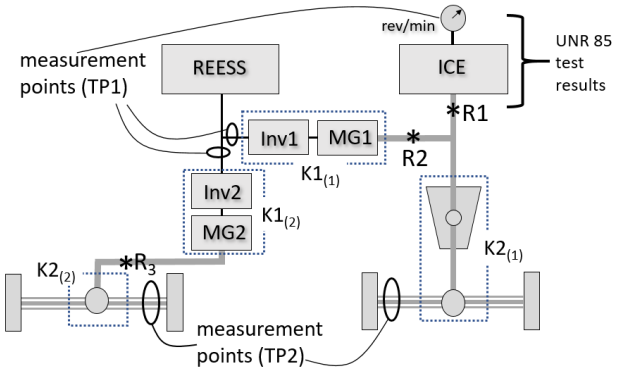
TP1 Measurement Results (kW):

Repetition	R1 Peak	R2 Peak	R3 Peak	R1 Sustained	R2 Sustained	R3 Sustained	System Power
1	48.959	135.322	162.954	46.957	129.237	154.687	330.882
2	47.452	135.034	162.847	45.467	128.798	154.148	328.412
3	47.082	135.088	162.841	46.569	127.255	153.658	327.482
4	47.265	135.598	161.004	44.093	127.963	153.096	325.152
5	48.272	135.903	160.618	45.970	128.533	153.028	327.530
Mean of Last 4 Repetitions	47.518	135.406	161.828	45.525	128.137	153.482	327.144



TP2 Measurement Results (kW):

Repetition	R1 Peak	R2 Peak	R1 Sustained	R2 Sustained	System Power
1	146.982	163.219	144.979	154.901	299.880
2	146.816	163.063	145.191	154.312	299.503
3	146.909	163.175	145.786	153.776	299.563
4	146.687	161.549	145.950	153.383	299.333
5	146.622	161.200	146.049	153.365	299.414
Mean of Last 4 Repetitions	146.758	162.247	145.744	153.709	299.453



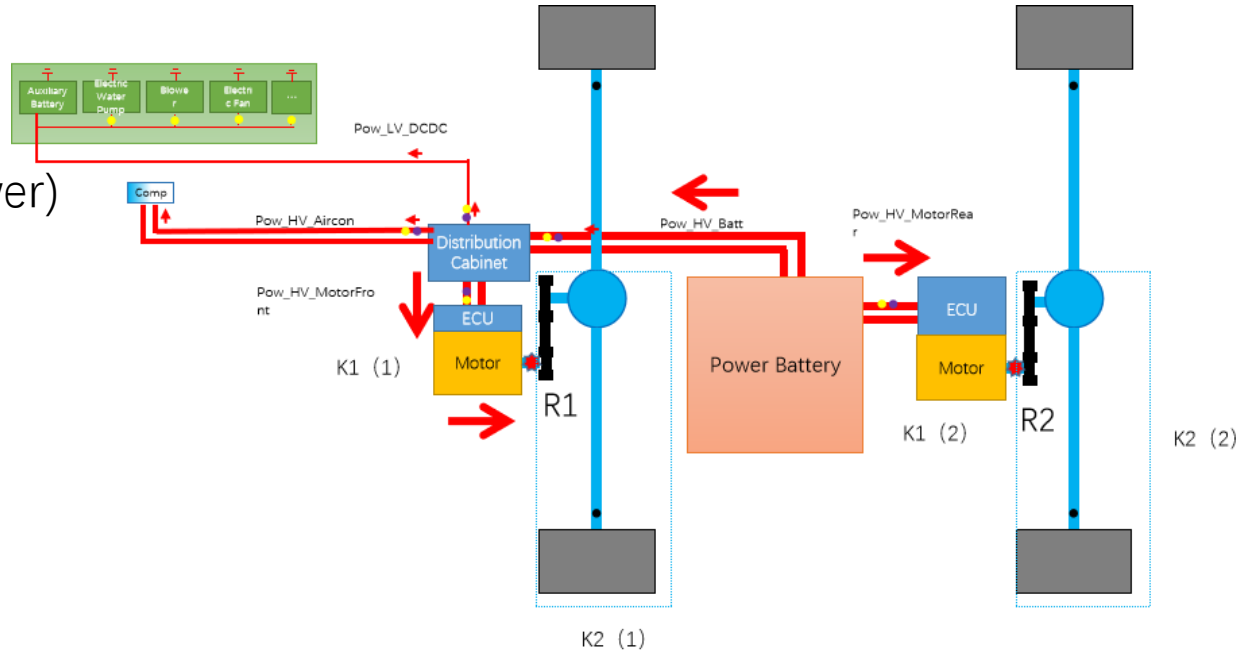
Note: R1 of TP1 is computed by on-board engine speed and torque

7、Result Calculation

☐ Hub Dynamometer Test Results-BYD Tang PEV 4WD

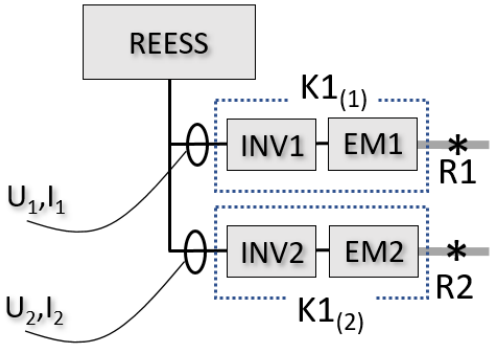
TP1 Measurement Results：(Computed at MCU DC end power)

Repetition	R1 Peak	R2 Peak	R1 Sustained	R2 Sustained	System Power
1	138.427	196.741	135.295	195.355	330.649
2	138.155	197.115	135.184	195.542	330.726
3	138.020	196.077	134.732	195.243	329.975
4	138.038	196.414	136.236	194.975	331.212
5	138.041	196.639	137.267	195.066	332.333
Mean of Last 4 Repetitions	138.063	196.561	135.855	195.207	331.062
Note: R1 of TP1 is computed at MCU DC end instead of the REESS start.					



TP2 Measurement Results

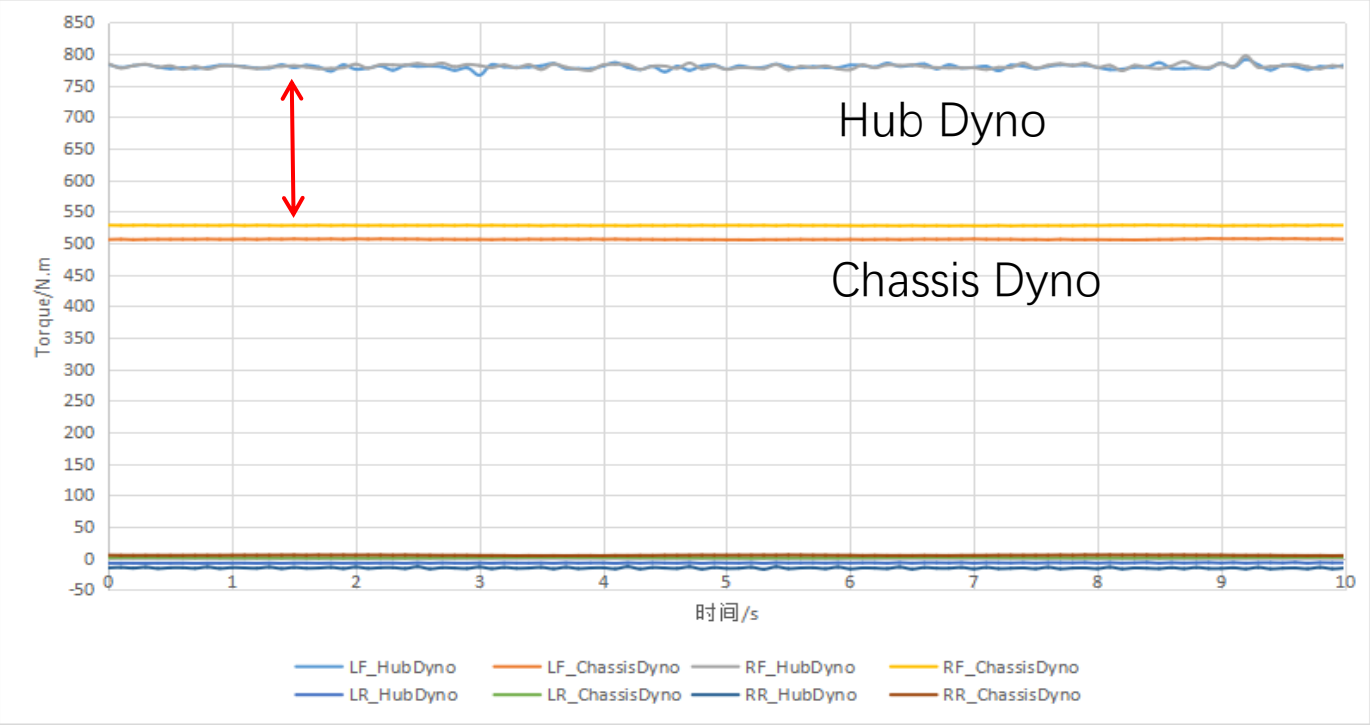
Repetition	R1 Peak	R2 Peak	R1 Sustained	R2 Sustained	System Power
1	136.799	196.058	133.545	193.671	327.216
2	136.378	196.409	133.329	193.902	327.231
3	135.851	194.863	132.551	193.017	325.568
4	135.853	195.119	133.656	192.756	326.412
5	135.780	195.299	134.334	192.824	327.158
Mean of Last 4 Repetitions	135.966	195.422	133.467	193.125	326.592



7、Result Calculation

- Data Comparison between Hub Dynamometer Test and Chassis Dynamometer Test

Note:Limited by the safety and torque of hub test bench, only performed the data comparison of 50 km/h at 40% throttle



Note：

Due to the tires on the vehicle, there are additional rolling resistance loss of wheel output torque on the chassis dynamometer than hub dynamometer, but the value of rolling ressistance is related to the rolling resistance coefficient and vehicle test weight, while it's not easy to get the real rolling resistance coefficient.

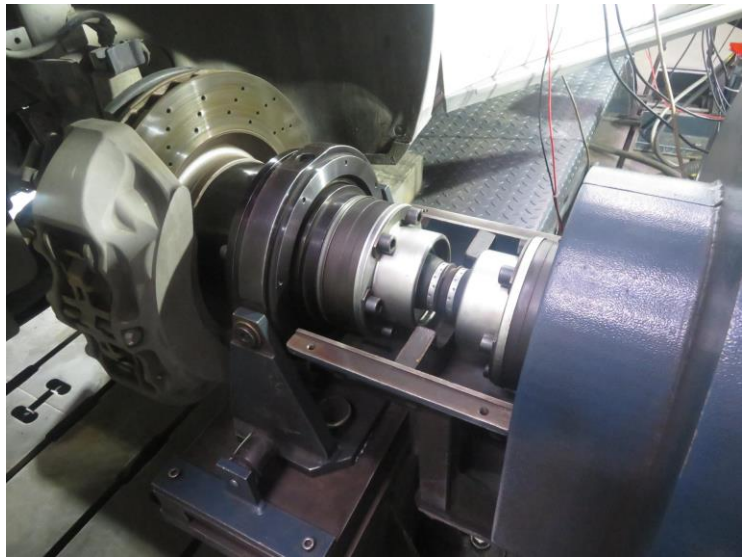
Output torque comparison of each wheel between the two Test Benchs:

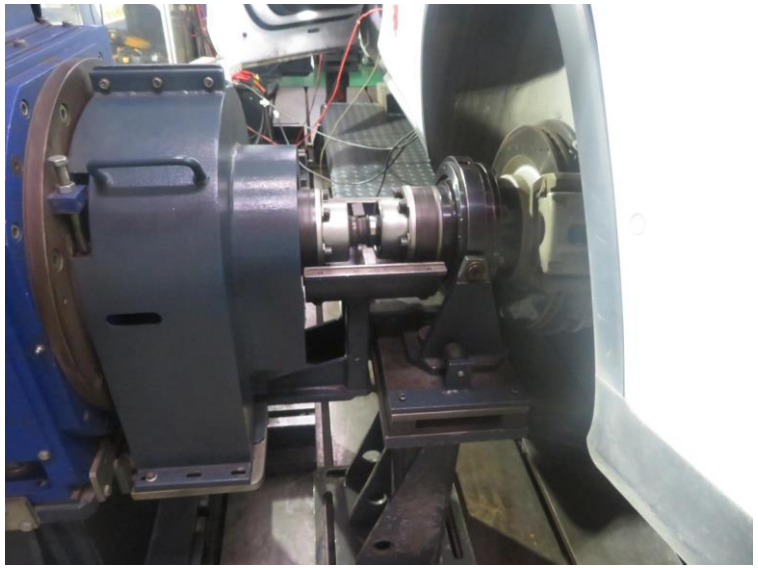
Test Bench	Left Front Wheel（N·m）	Right Front Wheel（N·m）	Left Rear Wheel（N·m）	Right Rear Wheel（N·m）
Hub Dynamometer	779.045	779.747	-7.199	-15.199
Chassis Dynamometer	505.741	527.690	1.371	5.070

8、Summary

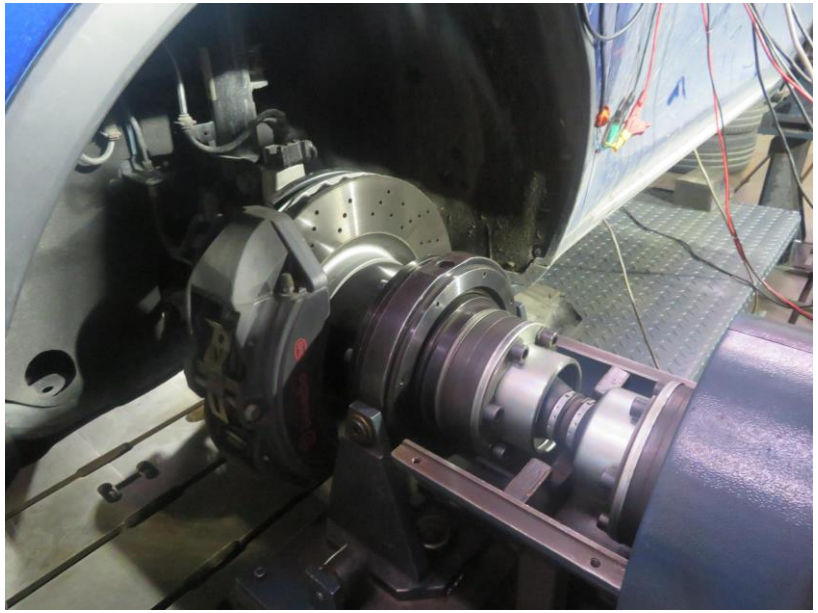
- There is no specific speed resolution in the process of maximum power identification. We recommend to set the speed resolution at 5km/h in determination of the maximum power, at which it's easier to identify the maximum power, because the power variation is not obvious under 1km/h speed resolution.
- For vehicles that have power distribution unit, the battery pack power is firstly delivered to the PDU, then delivered to the DC bus of the drive motor MCU, and the bus can be measured directly. In this case, is it acceptable to directly measure the power through MCU bus rather than by use the calculation of （P_{REESS}-P_{DCDC}-P_{Aux})?
- For highly intergrated multi-in-one system, it's difficult to determine the K2 fator of transimission system when performing TP2.
- When performing TP2 on a chassis dynamometer, due to the rolling resistance losses which account a large portion while it's hard to get the rolling resistance coefficient make it tough to deliver K2. So it's better to perform the TP2 test on a hub dynamometer.

9、Appendix-Tang PHEV





9、Appendix-Tang PEV



THANK YOU!

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