Proposal from China on discussing k1 and k2 factors of GTR21

2023.5.29

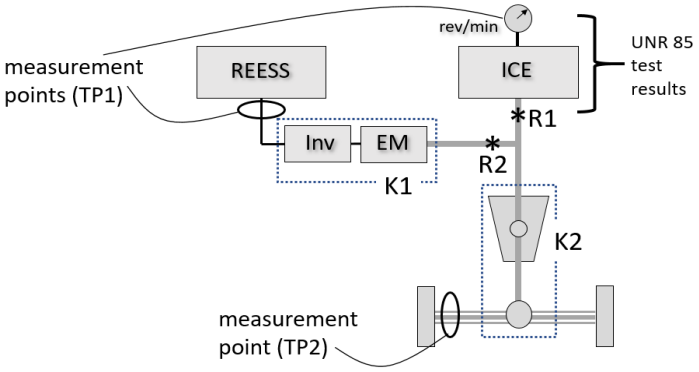
1. Background

■ A review of test results gained from vehicles of three power configurations is shown;

1) Parallel Hybrid Vehicle

■ A validation test was performed on a **parallel hybrid vehicle** by following the test procedure defined in GTR 21;

Vehicle information	The rated engine power : 118 kW (GB/T 17692,equivalent to ECE R85/00) The rated motor power : 85 kW (GB/T 18488)
Reference point	Reference points R1,R2 shown in Figure
Test procedure 1	1.The Voltage, current, engine speed, fuel flow rate and inlet manifold pressure obtained according to onboard CAN data; 2.The electrical energy conversion efficiency (K1) : 95% (tested according to GB/T 18488)
Test procedure 2	1.The speed and torque on wheel-side obtained from dynamometer reading; 2.The mechanical energy conversion efficiency (K2) : 90% (estimated value).



■ Results of the test

The maximum vehicle power occurred at 115 km/h vehicle speed (engine speed 4800 rpm);

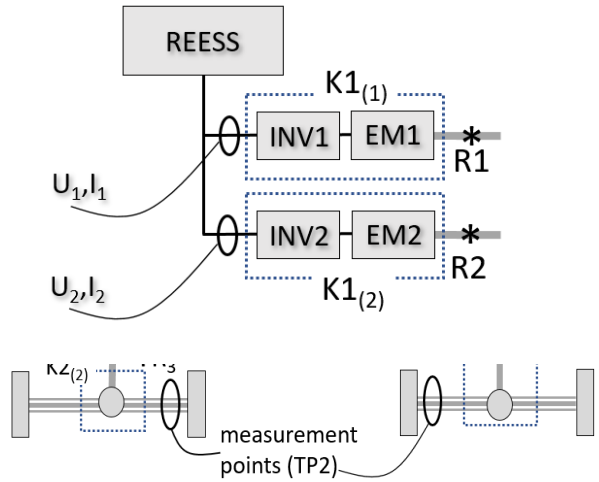
The indicated maximum vehicle power from TP1 was 201.6 kW, while the indicated maximum vehicle power from TP2 was 205.3 kW, 1.8% difference.

1. Background

2) Dual Motor Pure Electric Vehicle

■ A validation test was performed on a **dual-motor pure electric vehicle** by following the test procedure defined in GTR 21;

Vehicle information	The rated front motor power : 120 kW (GB/T 18488) The rated rear motor power : 150 kW (GB/T 18488)
Reference point	Reference points R1,R2 shown in Figure
Test procedure 1	1.The Voltage, current, obtained according to power analyzer and onboard CAN data; 2.The electrical energy conversion efficiency (K1): 89%(front),93%(rear) (tested according to GB/T 18488)
Test procedure 2	1.The speed and torque on wheel-side obtained from dynamometer reading; 2.The mechanical energy conversion efficiency (K2): 99% (estimated value).



■ Results of the test

The maximum vehicle power occurred at 87 km/h vehicle speed;

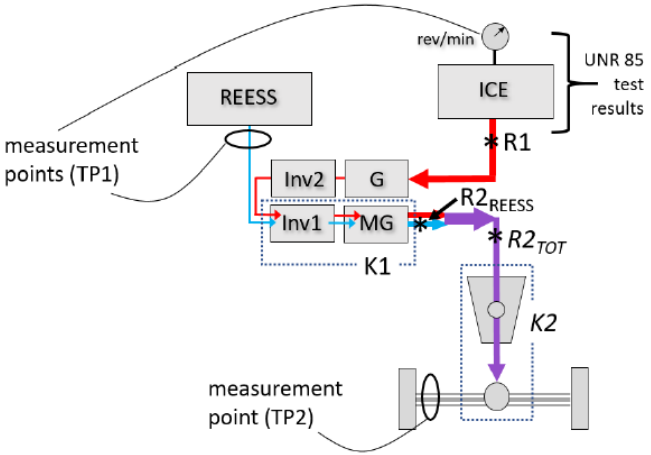
The indicated maximum vehicle power from TP1 was 242 kW, while the indicated maximum vehicle power from TP2 was 235 kW, 2.9% difference.

1. Background

3) Range Extending Hybrid Vehicle (Series Type)

■ A validation test was performed on **range extending hybrid vehicle (series type)** by following the test procedure defined in GTR 21;

Vehicle information	The rated engine power : 66 kW (GB/T 17692,equivalent to ECE R85/00) The rated motor power : 160 kW (GB/T 18488)
Reference point	Reference points R1,R2 shown in Figure
Test procedure 1	1.The Voltage, current, obtained according to power analyzer and onboard CAN data; 2.The electrical energy conversion efficiency (K1): 90% (tested according to GB/T 18488)
Test procedure 2	Not applicable



■ Results of the test

The maximum vehicle power occurred at 73 km/h vehicle speed (engine speed 1950 rpm);

The indicated maximum vehicle power from TP1 was 135 kW (2% discrepancy compared to simulation).

2. Issues for Discussion

Issue: K1,K2 Determination for highly integrated Electric Drive System (EDS)

1) Influence of K1,K2 on the accuracy of Power Determination

■ Taking the parallel hybrid vehicle as an example , every 0.5% change in K1 has the following impact on the test results.

Results from TP1 parallel hybrid vehicle

Max Battery Power minus 1kW (kW)	K1	R2 (kW)	R1 (kW)	R1+R2 (kW)
88	0.94	82.72	118	200.72
	0.945	83.16		201.16
	0.95	83.6		201.6
	0.955	84.04		202.04
	0.96	84.48		202.48

■ Similarly for K2 , every 0.5% change in K2 has the following impact on the test results.

Results from TP2 parallel hybrid vehicle

Dynamometer reading power (kW)	K2	R1+R2 (kW)
184.7	0.89	207.5
	0.895	206.4
	0.9	205.2
	0.905	204.1
	0.91	203.0

Conclusion: A 1% variation in K1,k2 yields a 0.9-2.3 kW variation in indicated power.

2. Issues for Discussion

Issue: K1,K2 Determination for highly integrated Electric Drive System (EDS)

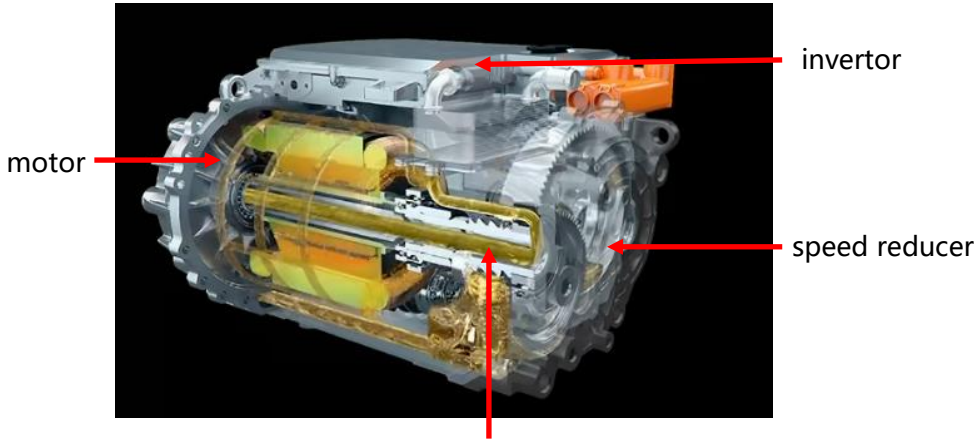
2) Difficulty of directly measuring K1,K2

- Figures below reveal three different types of Electric Driving System (EDS) at different integration level ;
  - ✓ Type 1: It is practically easy to measure K1, some dedicated mounting needed;
  - ✓ Type 2: For water cooled EDS (no fluid flows between motor and reducer/gearbox, the complexity of the dedicated mounting increases, but still OK to conduct experiment;
  - ✓ Type 3: For oil cooled EDS, oil flows between motor and speed reducer/gearbox, **which makes it difficult to measure K1**.
- Similar to K1, the determination of K2 would experience the same difficulty for highly integrated EDS;

Type1: 3 in 1

Type2: 7 in 1 (water cooled)

Type3: 7 in 1 (oil cooled)



oil flows between motor and speed reducer(cannot separate)

2. Issues for Discussion

Issue: K1,K2 Determination for highly integrated Electric Drive System (EDS)

3) Possible Solution – Adopting CAN data

- A 7 in 1 (water cooled) EDS has been selected to conduct a comparison: 1) tested on testbed with external transducers; 2) CAN data applied;
- As can be seen, a discrepancy in efficiency (K1) is 0.44% occurred;
- Noted: the accuracy of the CAN data to be requested.

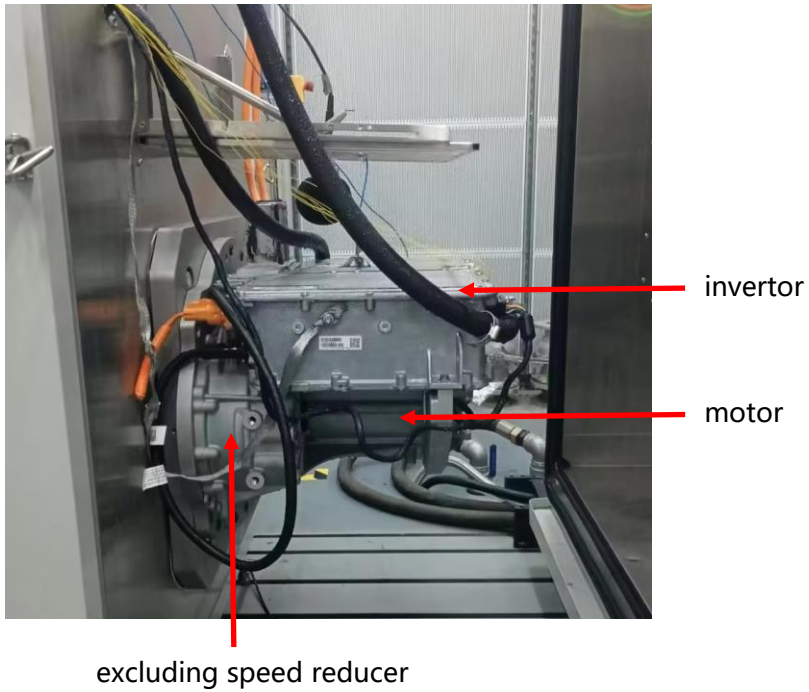
Testbed Data

Current	Voltage	Motor speed	Torque	Efficiency (K1)
457.3	296.5	6598	176.6	0.900

CAN Data

Current	Voltage	Motor speed	Torque	Efficiency (K1)
458.2	296.4	6598	176.1	0.896

Motor System Testbed



2. Issues for Discussion

Issue: K1,K2 Determination for highly integrated Electric Drive System (EDS)

3) Possible Solution – Adopting assembly efficiency instead

- A comparison of indicated power based on K1 from either assembly (motor, invertor and speed reducer) or motor system (motor and invertor): 1.2% difference;
- Noted: This approach is only valid for TP1 when K1 is needed.

Results from TP1 parallel hybrid vehicle

7 in 1 (water cooled) EDS	Max Battery Power minus 1kW (kW)	K1	R2 (kW)	R1 (kW)	R1+R2 (kW)
assembly	88	92.2	81.1	118	199.1
motor system	88	95	83.6	118	201.6

Assembly Test

Motor System

2. Issues for Discussion

Issue: K1,K2 Determination for highly integrated Electric Drive System (EDS)

4) Suggestion

- If it is not convenient (still possible) to implement external transducers, CAN data can be used to read the actual power; however, the manufacturer needs to supply a validation report showing the comparison of testbed results and CAN data;
- For oil cooled highly integrated EDS where it is impossible to directly acquire data via external transducers, the efficiency of the assembly can be used instead.