Market Analysis for HDV Battery Deterioration

28 Feb. 2024

Note; (prior explanation)

Note:
In August last year, we explained based on UBE,
but we currently recommend UBC is a better method
(the difference between discharging and charging is small).
The concept which we will explain this time is the same
for UBE and UBC, so we will explain it based on the past data.

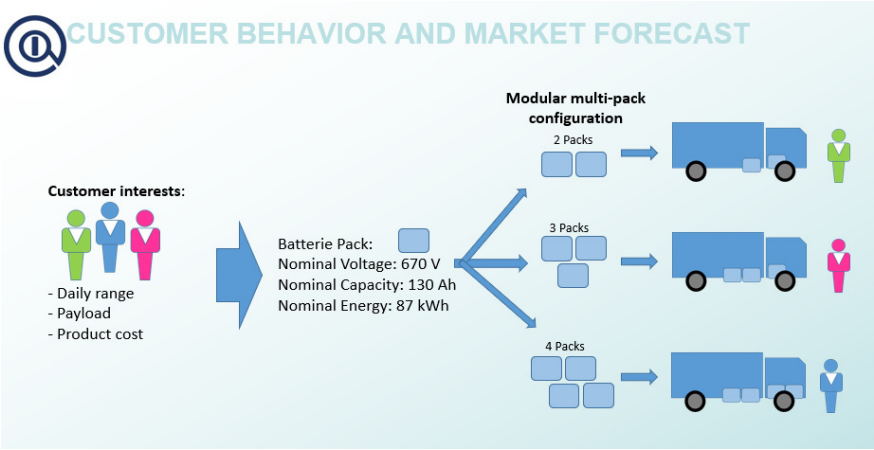
Furthermore, even if CP wants to keep UBE,
the FCE approach reflects the market more than the mileage for HDV.
We think it's easy for customers to understand about the battery deterioration.

Note; (prior explanation)

We believe that MPR should be evaluated based on
"Year" and "FCE" whichever comes first.

Originally, the purpose of this GTR was to eliminate inferior quality batteries.
We think PC(passenger car) will not consider replacing the basic battery unless there is a problem.
Also, we think it is rare for a single vehicle model to have several types of battery charging capacities.

On the other hand, HDV is required a myriad of battery charging capacity specifications depending on the customer's usage concept (requirements).There are also many cars that do not cover long distances but use PTO frequently. For example; Aerial work vehicles, Concrete pump vehicles, etc.
Additionally, HDV has long lifetime, and HDV manufacturers are considering replacing HDV batteries.



Backgrounds

In GTR22, SOCE (%) MPR criteria are “Year” and “Mileage”.
It was created with reference to Geo-TAB market data and the JRC TEMA model.
<GTR22> MPR metrics: 5 years 100,000 km_SOCE80% or 8 years 160,000 km_SOCE70% <Backstop:10%>.

Figure I/1
Example of a capacity retention curve generated from JRC TEMA modelling for two different BEV configurations

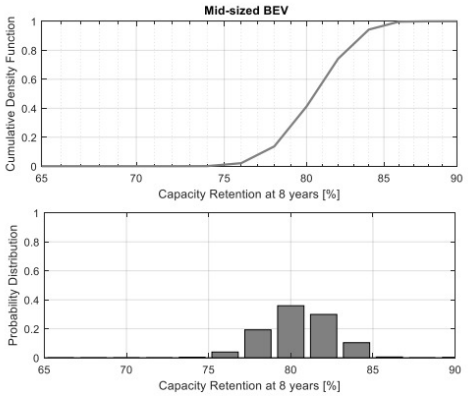
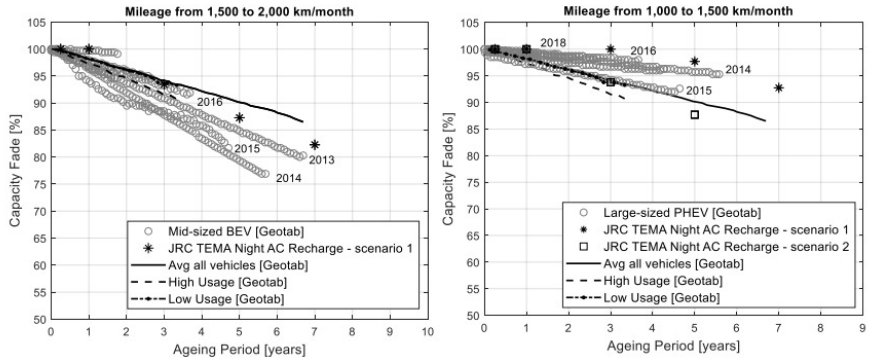


Figure I/2
Example comparison between estimated results from the TEMA model with in-use data from Geotab



<HD New GTR >
HD Commercial vehicles (N2/N3, M2/M3) which is a GVW exceeding 3.5ton generally have various energy consumption structures other than running such as refrigeration and cabin air conditioning .
And, for PEV/OVC-HEV HD commercial vehicles, we believe that “energy consumption” is more appropriate than “mileage” as an MPR metrics.
Therefore, we investigated the difference in the degree of correlation between SOCE and "mileage" or "energy consumption".

CUSTOMER BEHAVIOR AN

Example: Truck & Bus prioritizes reducing initial cost and securing load capacity and number of passengers
(battery replacement is acceptable before vehicle replacement)
【Main group】

Even for vehicle cab chassis (incomplete vehicle) with the same specifications, the amount of batteries installed differs because customer requirements differ.

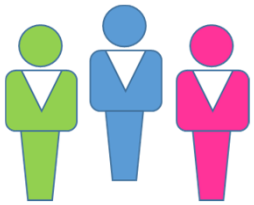
Modular multi-pack configuration

minimum Packs

( ) medium Packs

maximum Packs

Customer interests:



- Daily range
- Payload/Passengers
- Product/running cost

Battery Pack:

Example: Truck & Bus where battery deterioration progresses quickly due to high C-rate operation due to high loading/PTO/vehicle speed/gradient operation
(battery replacement is acceptable until vehicle replacement)
[Substitute group]

Example: Luxury Bus, which has plenty of GVW like P/C, carries less people/cargo, and has high profits per operation
(no battery replacement as it is a short-term vehicle replacement)
[Extremely rare group]

Objective

Reported at EVE meeting in August 2023

<Objective>
The purpose of this study is to analyze the significance of the correlation between SOCE and “Mileage" or "energy consumption" of PEV/OVC-HEV HDVs from the market data of a certain HD-OEM in Japan.

<Sample Specifications>
- Number of samples: 10
- Vehicles: PEV trucks from GVW 3.5ton to 7.5ton
- Body work: Cargo van / 2 cases, with electric fridge and without electric configuration
- Customers: 2 cases, small deliveries and store deliveries
- Charging method: 2 cases, normal charging and first charging
- RESS: 2 cases, one with single pack and the other with double pack
- UBE measurement: On-Board CAN value

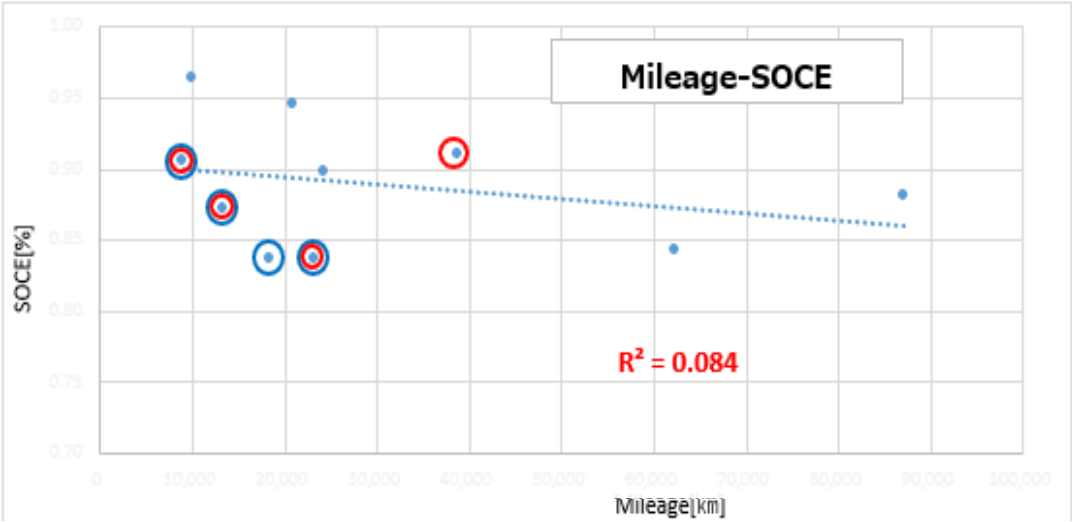
<Definitions>
- Energy Throughput: Lifetime discharge electric energy [kWh] or electric capacity [Ah]
- Full Cycle Equivalent (FCE): Equivalent full discharge cycle [cycle]

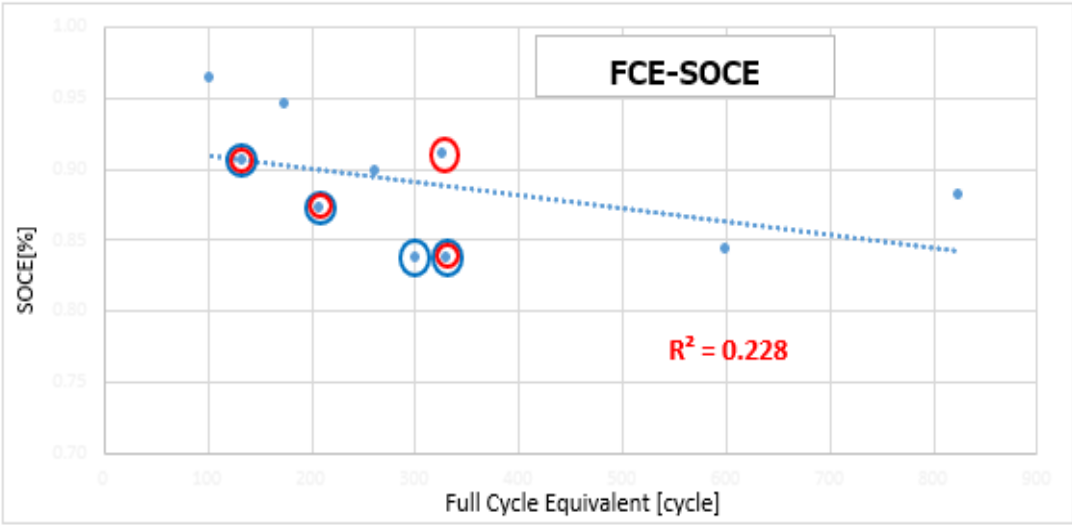
$$\text{FCE [cycle]} = \frac{\text{Energy Throughput}_{\text{on-board memory}}\ [\text{kWh}]}{\text{UBE}_{\text{certificated}}\ [\text{kWh}]} \quad \text{or} \quad \frac{\text{Capacity Throughput}_{\text{on-board memory}}\ [\text{Ah}]}{\text{UBC}_{\text{certificated}}\ [\text{Ah}]}$$

Results

Reported at EVE meeting in August 2023

Veh. No	Customer	Numbers of Pack	Fridged Truck	Duration [months]	Mileage odo [km]	Energy Throughput [kWh]	FCE Full Cycle Equivalent [cycle]	SOCE [%]
1	BB1	2	+					
2	BB2	2	+					
3	AA1	1	-					
4	BB3	2	+					
5	BB4	2	+			*1		
6	BB5	2	-					
7	AA2	1	-					
8	AA3	1	+					
9	BB6	2	+					
10	AA4	1	-					





*1; JAMA would like to disclose the actual figures for SOCE until the data for other regions become available.

<Results>
"FCE (R^2=0.228)" is higher than "Mileage (R^2=0.084)" in terms of correlation with SOCE.

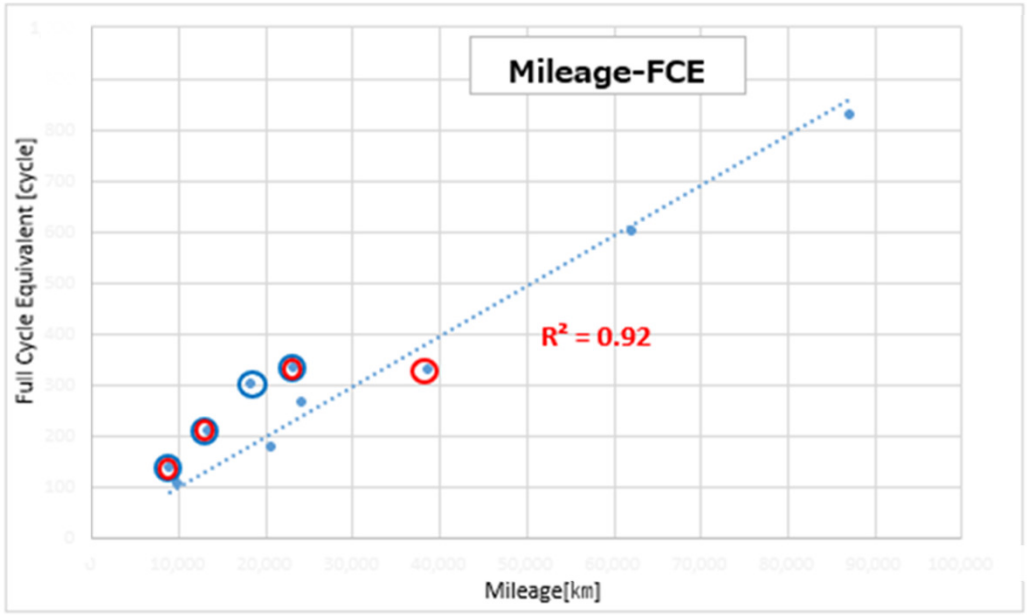
Conclusions

Reported at EVE meeting in August 2023

<Results>
"FCE (R^2=0.228)" is higher than "Mileage (R^2=0.084)" in terms of correlation with SOCE.

- **For the SOCE characteristics, "FCE" was more significantly correlated than "Mileage" for the PEV HDVs in this market sample.**

  However, since the correlation between "Mileage" and "FCE" is high (R^2=0.92), it is important to use one of them as the MPR metrics to avoid multiple correlations, "FCE" which has a significant correlation, seems to be appropriate.



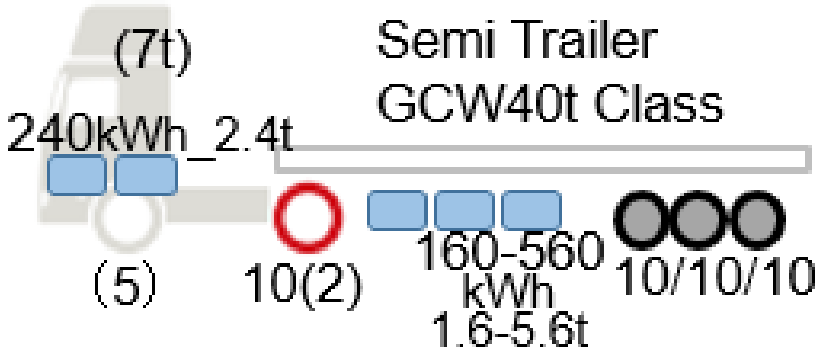
Conclusions

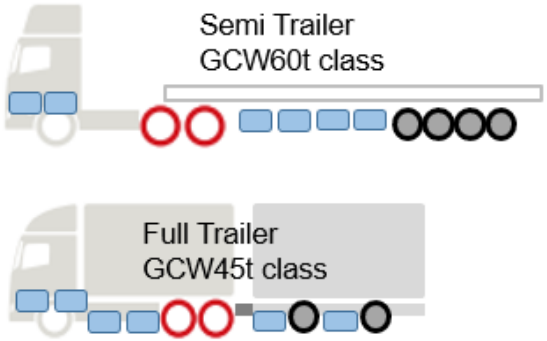
Proposal;

- This time, the results are based on limited market data, and data from a wider range of vehicle classes (over 7.5 tons, garbage trucks, etc.) need to be included. Therefore, for the new HD GTR, we would like to ask to set up a market monitor for Part A, just like GTR22. and we would like to set “Energy Consumption (FCE)” as a collection factor, collected data similar to “Mileage”, and evaluated the correlation with changes in SOCE and SOCC.
- Since it is not possible to discuss the MPR judgment threshold setting of 10% backstop based on this data at this time, we request that it be reserved until after the analysis of the market monitor in Part A.
- We believe that the “Energy Throughput (lifetime value)” registered in SAE for GTR22 will also be collected for the new HDV GTR.
- We believe that the newly defined "FCE cycle" also needs to be registered with SAE.

$$\text{FCE [cycle]} = \frac{\text{Energy Throughput}_{\text{on-board memory}}\ [\text{kWh}]}{\text{UBE}_{\text{certificated}}\ [\text{kWh}]} \quad \text{or} \quad \frac{\text{Capacity Throughput}_{\text{on-board memory}}\ [\text{Ah}]}{\text{UBC}_{\text{certificated}}\ [\text{Ah}]}$$

Concerns ; HDEV RESS @ Semi Trailer (1/2)





Ex.）GCW40t class Semi Trailer

Battery Capacity _ Wt. 3cases：240kWh_2.4t(City),400kWh_4t（Urban）, 800kWh_8t（H/W）

30min. System PWR　2cases：245kW(Current Nominal ICE), 415kW(Current Maximum ICE)

Mode ： WHVC for electrical vehicles, which is the base of the endurance degradation emission test mode WHTC set in GTR4. <20.072km/1mode>

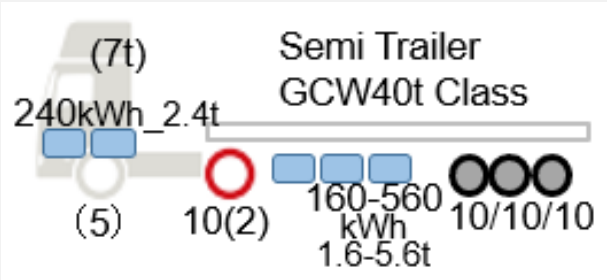
【Calculation : FCE & C-rate @160,000 km】

30min. System PWR		Capacity ; On-Board Battery		
		240kWh	400kWh	800kWh
245kW	FCE	1104	662	331
	Ave C-rate	0.35	0.21	0.11
415kW	FCE	1666	1000	500
	Ave C-rate	**0.53**	0.32	0.16

<Concerns : Polarization>

Concerns ; HDEV RESS @ Semi Trailer (2/2)

The replacement life of a vehicle in this class, including the used car market, is well over 1 million km, so battery replacement is essential in all cases.
Battery replacement => Lifetime battery capacity is the same.
(Maximum vehicle replacement life for H/W use...Head: 3 mil. km, Trailer: 5 mil. km)
Energy Throughput @WHVC 1mil. Km => 30.231kWh*1,000,000km/20.072km=1,506,128kWh @System PWR 245kW
50.174kWh*1,000,000km/20.072km=2,499,701kWh @System PWR 415kW
Case1) Number of battery replacements and total battery capacity @ System PWR 245kW
240kWh:(1,000,000/160,000*1104)/1100⇒6…1,680kWh
400kWh:(1,000,000/160,000* 662)/1100⇒3…1,600kWh
800kWh:(1,000,000/160,000* 331)/1100⇒1…1,600kWh
Case2) Number of battery replacements and total battery capacity @ System PWR 415kW
240kWh:(1,000,000/160,000*1666)/1100⇒9…2,400kWh
400kWh:(1,000,000/160,000*1000)/1100⇒5…2,400kWh
800kWh:(1,000,000/160,000* 500)/1100⇒2…2,400kWh



By the time the vehicle is replaced at 3~5 million km, it will need to be replaced several times more than the above.

Battery arrangement : Head: vehicle weight 7t (front axle 5t/rear axle 2t), Trailer: towing weight 33t
400kWh Battery increment of 240kWh : 1.6t = Head Ft. axle Capa. 32% ⇒ 160kWh_1.6t on a trailer
800kWh Battery increment of 240kWh : 5.6t = Head Ft. axle Capa. 112% ⇒ 560kWh_5.6t on a trailer
This arrangement can carry 28t-load_marine container even at 400/800kWh => However, trailer (Category O) no Odo record, MPR metrics needs FCE.
In addition, since RESS with Trailer is required to have a charge/discharge function, the capacity can be measured by Method2.

Additional comments

Additional Proposal;

- About MPR
  Based on Battery Capacity (SOCC)
  From start of life to [X] years or [XXXX] cycles,
  whichever comes first and [Ah in monitoring].

This is FCE value.

- HDV battery packs have a long vehicle lifetime,
  so they will be basically designed to be replaced.

Addition: O category is scheduled to be considered in Phase 2.
However, isn't it necessary to consider the below condition when deciding on the MPR and Method for Phase 1 (now)?

1) No km (mileage) record
2) Not being able to drive on its own
3) Deterioration occurs independently of the Tractor's on-board battery
   (not always connected to the same trailer)