Study about the Application of LPB for the Propulsion System in Bimodal Tram

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Abstract

We are now developing the environmentallyfriendly public transportation system and more for disabled persons. Newly developed tram what is called Bimodal tram(BT) has adopted lithium polymer battery(LPB) for the propulsion system which is series-type of hybrid vehicle. BT use the range of 600~700Vdc as the applied voltage for the propulsion of vehicle. So LPB(80Ah) pack for BT consisted of 168 cells which has 705V as 4.2V of LPB cell voltage. This paper has investigated the characteristics of LPB cells and then the thermal distribution of battery module and completed LPB pack.

Keywords: Bimodal Tram, Lithium Polymer Battery

1 Introduction

Series hybrid type propulsion system of BT consists of CNG(compressed natural gas), generator, PWM converter, battery, inverter and traction motors. BT has three modes which are battery mode, engine mode and hybrid mode. In normal running, hybrid mode will be selected by driver. In case of battery fault, driver will run the vehicle with engine mode but it has the speed limitation because of the shortage of power. Battery mode will be used when engine is out of order or vehicle passes through tunnel. So battery plays a important role to run the vehicle. The objective of this paper is developing the battery system adequate to the propulsion system of BT. Among various battery, We adopted LPB as a propulsion battery which has high power and energy density comparing with any other conventional battery but need high cost[1~4]. Table 1 shows the specification of LPB cell .

Table 1. The specification of LPB cell and pack

Typical capacity		80.0Ah
Cell Nominal voltage		3.7V
Charge condition	Max. current	160.0A
	Voltage	4.2V±0.03V
Discharge condition	Continuous current	400.0A
	Peak current	500.0A
	Cut-off voltage	3.0V
Cycle life[@ 100% DOD]		>1,000 Cycles
Operating temp.	Charge	0 ~ 40°C
	Discharge	-20 ~ 60°C
Cell Dimension	Thickness [mm]	6.8±0.15
	Width[mm]	455±2.0
	Length[mm]	325±2.0
Cell Weight[kg]		2.03±0.03
Pack rated capacity(Ah)		80
Pack rated voltage(V)		650
cell/pack		168
Pack output power(kW)		200
Pack weight(kg)		600
Duration		5 년

This paper has investigated the temperature distribution of cell and module while driven with the BT driving cycles. We designed and constructed the module and pack with fan to cool conclusively.

2 Results and Discussion

Figure 1 shows the graphs charging on 0.5C(40A), 1.0C(80A), 2.0C(160A) respectively. Charging is done by CC(constant current) and CV(constant voltage) sequentially. 2.0C(1C=80A) had shorter time to charge the LPB than 1.0C or 0.5C reaching to 4.2[V]. By experiment in laboratory, even C-rate(for example, >3C) more than 2.0C had shown almost the same charging time for the LPB cell. Our goal is accomplishing of development of LPB having big charging current(> 2.0C) to make a shorter charging time in the future.

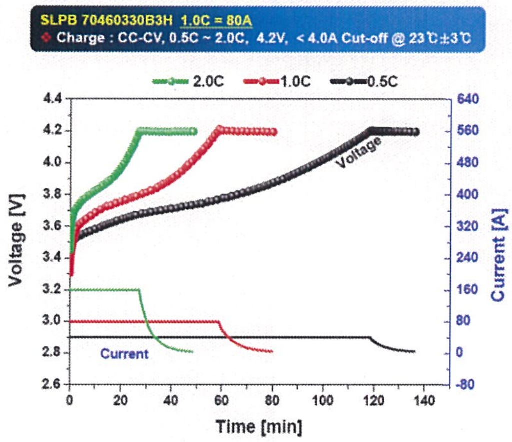


Figure1: Charging curves with C-rate

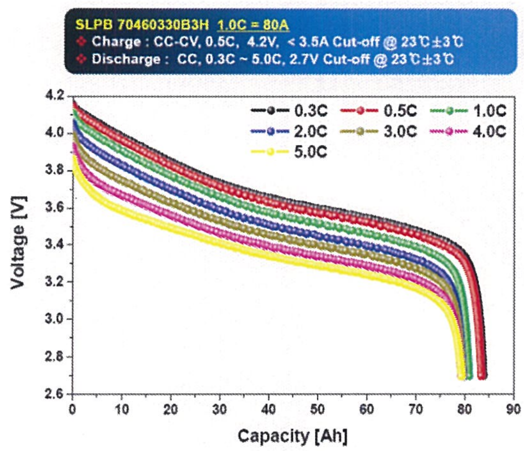


Figure2: Discharging curves with C-rate

Figure 2 has shown the variation of cell voltage during discharging on the different C-rate with 7 steps(0.3C ~ 5.0C) from 4.2[V] to 2.7[V]. The discharging voltage difference between 5.0C and 0.3C is about 0.36[V] per cell and 63.36[V] per the pack. However, capacity of battery had drop to less than 6% of 5.0C comparing to 0.3C, which is expected to be resulted from the internal resistance and overpotential drop by electrochemical reaction inside of LPB. Figure 3 illustrates the discharging characteristic curves of 0.5C according to variable temperatures of -20[℃] ~ 60[℃] through 2.7[V] to 4.2[V].

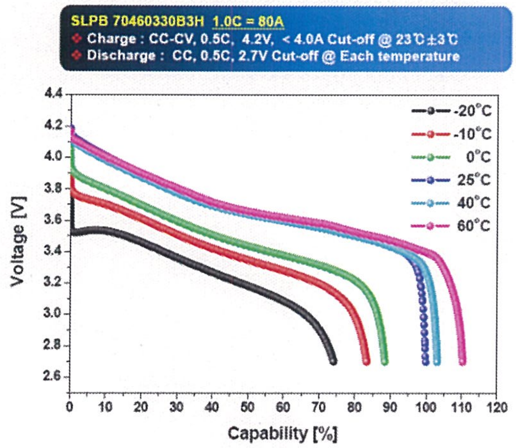


Figure3: Cell capability with variable temperatures

X-axis represents the capability(%) compared with 1C(80A) capability as 100[%]. In the range of 25[℃] ~ 60[℃], discharging curves showed no differences from 4.2[V] to 3.4[V] in y-axis but below 3.4[V], there was the difference of 10[%] in capability which is assumed to be caused by the activated electrochemical reaction in high temperature. Discharging curves of 0[℃] ~ 20[℃] has shown the voltage differences of 0.2 ~ 0.5[V] in the same capability(50[%]) comparing to 25[℃].

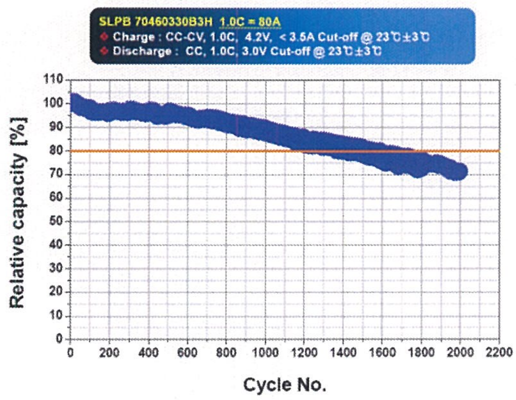


Figure4: Cycle lifetime of LPB

Figure 4 shows the cycle lifetime of LPB which is repetitively discharged and charged with 1C(3.0[V] cutoff) and 1C(4.2[V] full) respectively. The relative capacity has reduced below 80[%] at 1200cycle on DOD(depth of discharge) 100[%]. The expected cycle lifetime of LPB for bimodal tram is 1million cycle on our driving cycle(figure 5). However 1200cycle is not enough to be our needs and it is necessary to make more progression in the cycle lifetime of LPB. Initially we made 1 module in 8 series connection(8S1P) of LPB cell sand investigated the temperature distribution during charging and discharging over 101cycle (101minutes) according to vehicle driving profile(1 driving cycle = 1 minute).

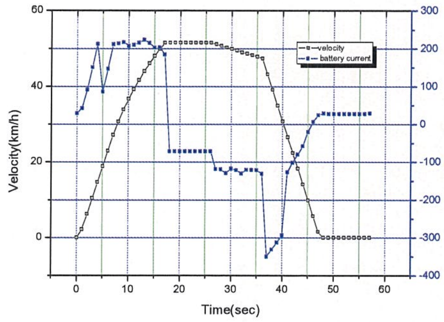


Figure5: Driving cycle of BT

Without cooling fan, LPB module(8S1P) reached at 70℃ until we cut off the load current. Figure 6 shows the temperature bar graph of each cell consisting of LPB module.

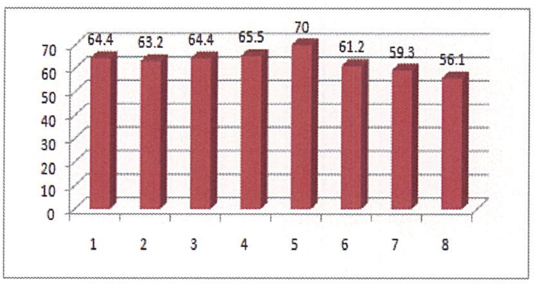


Figure6: Temperature distribution of LPB module

Normally LPB should be operated within appropriate temperature ranges such as 20~40[℃] to get longer lifetime and better efficiency which is directly related with the performance of vehicle and LCC(Life Cycle Cost). Figure 7 illustrated 2-dimensional temperature distribution pictured by infrared camera where made the effect of fan blown from one direction. We could find that the highest temperature position of stacked module was the cable joint which has high contact resistance. On proceeding of charging and discharging, heat generated from cable joint spreads to the other side of module plate. Even when we blew the wind by fan, It was not enough to decrease the temperature spreading to whole plate, which is resulted from the blowing direction of fan wrong.

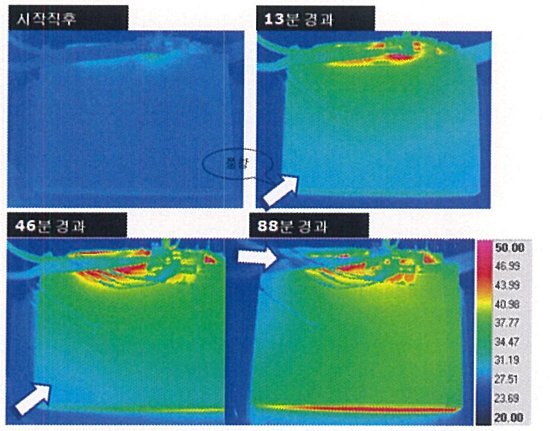


Figure7: Surface thermal illustration for LPB cell

According to the experimental result of temperature distribution for module charging and discharge of 101 cycles, we built module box with fan which is close to cable joint and blowing out them with wind. Figure 8 shows the temperature variation of each cell with elapsing time and results in saturated curves over temperature.

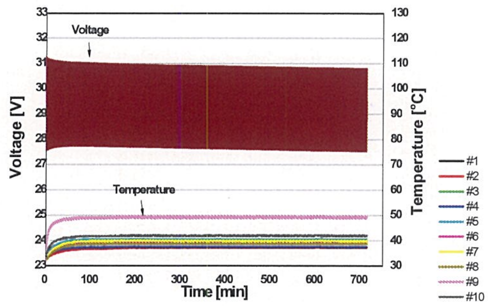


Figure8: Temperature distribution of module with fans

We used thermocouple(K-type) as a temperature sensor and 8 cells were stacked from the bottom inside of the module. #9 shows the bottom temperature and #10 shows the ambient temperature(26[℃]). #1 is the temperature for upper side of the bottom cell and #6 which is the temperature of the middle positioned cell showed the highest temperature among 10 temperature sensors. Figure 9 illustrated the completed module box which has two fans for intake and exhaust of air. Also we inserted aluminum plates on the gap between cells inside of module box to maximize the cooling of cells.

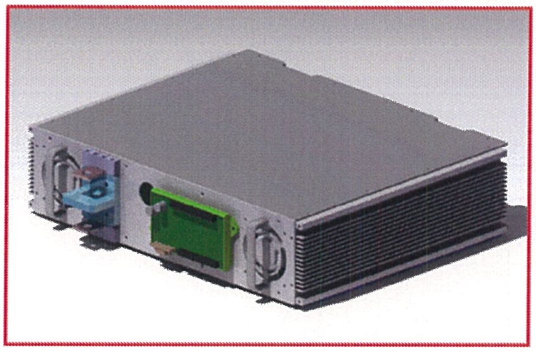
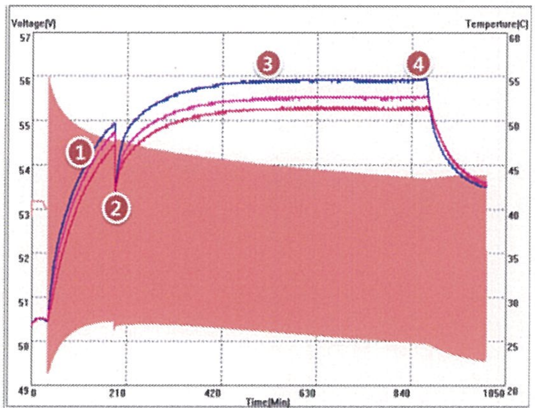


Figure 9: Designed module box



No	operation
1	Fan stop with openning of case cover
2	temporary test stop
3	Fan stop with closing of case cover
4	Fan running with closing of case cover

Figure 10: Temperature rising curves of designed module

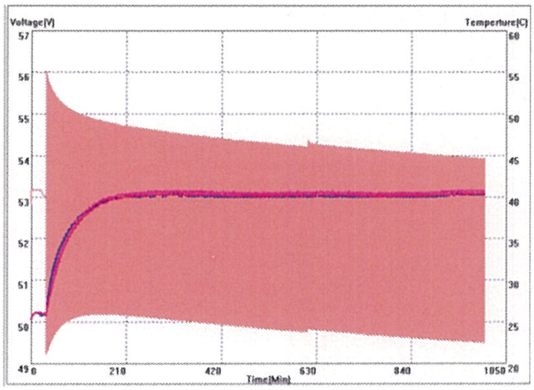


Figure 11: Temperature saturation curve

Figure 10 shows the temperature curves which was measured on the operation of fans. Blue curve represents for the temperature of cable terminal side installed with fans and pink one for the temperature of side cooling aluminum pins and red one for the temperature of the upper surface of module box in figure 9. During the operation of two fans, the highest temperature of the module box indicated upto 55[℃]. While the driving cycles lasted about 18hours with the ambient temperature of 26[℃], The temperature saturation(53[℃]) was kept up throughout after the initial rise(figure 11). Figure 11 illustrates the LPB pack(176cells 650V) consisted of 13 modules with 14S1P(12 modules) and 8S1P(1 module). LPB pack has its own 3 fans for the seperate use different with module fan. They are designed to circulate the air inside of pack from intake to exhaust by the conditioned air inside of bimodal tram.

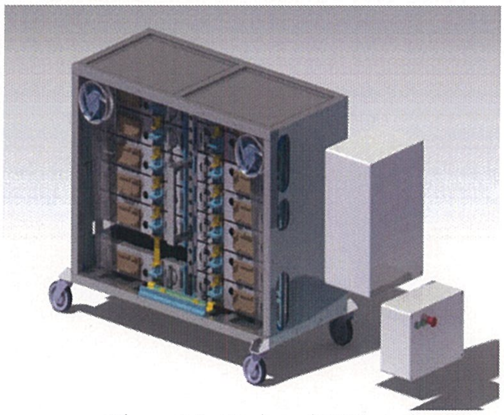


Figure 12: Designed LPB pack

3 Conclusion

In this paper, we have designed and constructed the LPB pack for bimodlal tram which is driven by series hybrid driving system. LPB pack consisted of 176 cells with 13 modules(8S1P. 14S1P) which represented good performances with the designed construction. Now we are struggling to test the LPB pack installed on the bimodal tram with real field driving situation and we are wishing to share the results with others in the future.

Acknowledgments

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