Running Test of Contactwire-less Tramcar Using Lithium Ion Battery

Letter

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The basic specification of lithium ion battery type tramcar was established using DC 600V type tramcar with weight of 40t. 45kWh of manganese type lithium ion battery was used. The running test was carried out for the first time in Japan in the business line. The relation between running time and voltage, current and integrating watt was investigated in detail. The tramcar was run when the lithium ion battery module was discharged between 660V and 480V. On one charge, the tramcar could run for about 25km. The mileage of contactwire-less tramcar improved two times of that of tramcar. The running performance of contactwire-less tramcar was equivalent to the tramcar.

Keywords : lithium ion battery, tramcar, contactwire-less, vehicles, energy-saving, emergency power source

1. Introduction

Recently, as the energy-saving and global warming countermeasures, the use of new energy system such secondary battery, fuel cell, super capacitor is expected for reduction measures of carbon dioxide discharge. A transportation section occupies in particular 24% of energy consumption and also 20% of carbon dioxide discharge. Lead and nickel hydrogen batteries have been used for HEV and EV. The problem of these batteries was that both of low power and energy density and very heavy. The energy and power density of the lithium ion battery are the highest in the secondary battery and the lithium ion battery is the lightest in the secondary battery. Therefore, lithium ion battery is suitable as a power source of transportation such as EV, electric bus. In the railway, it is possible to raise enerrgy-saving effect by using secondary battery. In addition, some following effects are expected[(1)-(3)]. 1) The townscape is improved because the overhead contact wire is not necessary. 2) It does not need to maintain the overhead contact wire. 3) It is possible to utilize as an emergency power source in the overhead contact wire supply failure by accident. 4) The discharge of nitrogen oxides and sulfur oxides can be drastically reduced except for the carbon dioxide.

The aim of this work is development of the contactwire-less tramcar which is driven with the lithium ion battery and examination of the energy-saving effect. We have been succeeded in running of railroad using lithium ion battery for the first time in Japan in the business line of Fukui railway. In this work, the running performance on the tramcar was examined using DC600V type train with 45kWh lithium ion battery and then the energy-saving effect was investigated. We have been also reported that lithium manganate cathode materials derived from aerosol process lead to rapid diffusion of lithium ion from cathode and then shows excellent high power density[(4)] compared with conventional commercial lithium manganate cathode materials. In this paper, the performance of lithium ion battery used for the running of the tramcar was described.

Fig. 1. 45kWh lithium ion battery module

2. Results and discussion

2.1 Lithium ion battery Homogeneous lithium manganate ($Li_{1.09}Mn_2O_4$) cathode materials were large produced by aerosol process[(4)] (The flame type spray pyrolysis equipment, ChugaiRo Co., Ltd.) using spray pyrolysis technique. The mixture of hard carbon and graphite (1:1) were used as an anode. Micro porous polypropylene sheet was used as a separator. 1 mol/dm^3 $LiPF_6$ in EC/DME was used as the electrolyte. Laminate sheet type lithium ion cell was assembled in a globe box under an argon atmosphere. The discharge capacity of lithium manganate cathode was 105mAh/g at 5C and 90% of its discharge capacity was kept after 2000th cycle at 5C. The energy and power density of laminate sheet type lithium ion cell were about 120Wh/kg and

Fig. 2. Lithium ion battery type tramcar

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2240W/kg, respectively. These values was improved from the desired value of energy density (70Wh/kg) and power density (1800W/kg) for power source of transportation which the country determined[(5)]. Lithium ion battery submodule (200mm x 150mm x 700mm, 30kg) was consisted of 108 lithium ion cells, in which 12 cells connected in 9 series were connected in parallel. The aluminum case was used for the case of submodule in order to release a heat during the charge and discharge.

2.2 Performance of tramcar Figure 1 shows the photograph of the 45 kWh module with a weight of 540kg which was consisted of eighteen lithium ion battery submodules. The electric capacity and weight of lithium ion batttery used in RTRI (Railway Technical Research Institute) was 33kWh and 1000kg, respectivly. Therefore, this module lightened about 50% than that used in RTRI. The electric capacity of module was also higher than that used in RTRI about 1.3 time. This means that it is very advantageous for practical running of tramcar with lithium ion battery. Overcharge and overdisarge protection circuit were installed at all submodules in order to ensure the safety. Table 1 shows the specification of the module. The output voltage range of the module was from 480 to 660V. Average output voltage was about 620V. The output current of module was 72A.

Figure 2 shows the photograph of a train (Nagoya Railroad, 602 type) in which the lithium ion battery module was set up. The weight of the tram was about 30t. The module was fixed in the exclusive rack to stand the vibration in the running. The module was directly connected with the motor of the tramcar. The running test was carried out at fukubu business line in Fukui railway. Each change of voltage, current and temperature in the running was incorporated in personal computer through the data logger.

Figure 3 shows the relation between running time and voltage, current and integrating watt. The tramcar was run when the module was discharged between 660V and 490V. The electric power of 43kWh was consumed for 8300s. It was confirmed that a current of 580A flowed to the module when the tramcar was accelerated up. Afterward, the current drastically decreased to few A and the current of 580A flowed again in the module after the tram had accelerated. The tramcar ran while repeating this behavior. After 8300s, the temperature of the module reached up to 43°C. On one charge, the tramcar could run for about 25km. It was found from the running test that the mileage and the maximum speed of tramcar was 0.58km/kWh and 65km/hr, respectively. On the other hand, the integrating watt of contactwire type tramcar was obatined after the running of 25km without battery. The mileage of tamcar was 0.3km/kWh. It was found from running test that lithium ion battery type tramcar has the performance which is equivalent to the train and the mileage was improved about two times.

Table 1. Specification of lithium ion battery module

Item	Type
Average output voltage	620V
Operation voltage range	490 - 660V
Capacity	72Ah
Output current	72A
Weight	540kg

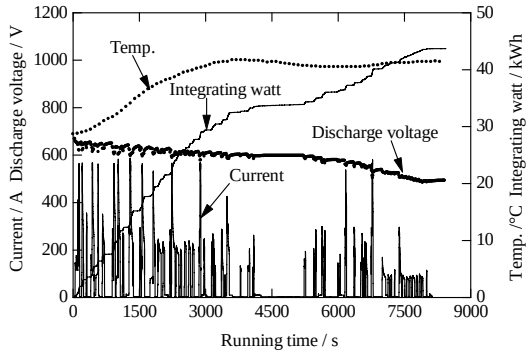

Fig. 3. Relation between running time and voltage, current, integrating watt, temperature

3. Conclusion

The tramcar driven by lithium ion battery was developed. 45kWh manganese type lithium ion battery was utilized in a tramcar. The running of contactwire less tramcar was examined for the first time in Japan in the business line of Fukui railway. The contact-wire less tramcar ran for about 25km on one charge. The mileage of tramcar was improved about two times by using lithium ion battery. It was found that the running performance of contactwire-less tramcar was equivalent to the tramcar.

Acknowledgement

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