Electric Wheelchair Using Ni-MH Battery Aided by Fuel Cell

Shizuo Yamaguchi [1], and Tomohiro Ikemoto [2]

[1] *Department of Mechanical and Electronic Systems Engineering, Kyushu Kyoritsu University, yama1217@kyukyo-u.ac.jp*
[2] *Department of Information Science, Kyushu Kyoritsu University, ikemoto@kyukyo-u.ac.jp*

Abstract

This paper proposes the extend mileage of electric wheelchair using a hybrid system consisting of Ni-MH battery aided by fuel cell as its drive source. Driving power sources in the trial electric wheelchair using Ni-MH battery with a 24V, 6.7Ah and fuel cell with a 24V, 300W is aided by hydrogen storage material filled-up to capacity of 70NL with a pressure of 1MPa. At present, running characteristics of electric wheelchair using in-wheel brushless dc motor as the drive system measures the current and voltage supplied to it, and investigates the mileage when that is run at a specific speed. As a result, at a speed of about 4.3km/h, averaging values of generating current and voltage of hybrid system are 2.7A and 24V, respectively. Mileage of electric wheelchair using a hybrid system is improved to about 1.5 times comparing with Ni-MH battery only.

Keywords

electric wheelchair, Ni-MH battery, fuel cell, metallic alloys for hydrogen storage, in-wheel brushless dc motor, environmental protection

1. INTRODUCTION

Recently, there have been many proposals and countermeasures concerning the rapid development of aging society and welfare society. Especially, many kinds of supports are required for handicapped people and people of advanced age (senior citizens) in order to live a normal life in any given society. Various functions of assistive equipment for welfare from the point of view of users have been realized and the safety of such equipments has been improved greatly.

Wheelchair, as one of the assistive equipment for welfare is familiar to many people and has been utilized by handicapped as well as senior citizens all over the world. Furthermore, with the introduction of electric wheelchair, its safety and functions has improved considerably along with its performance [Ikemoto, 2005]. However, as the mileage of electric wheelchair with Ni-MH battery is about 8-10 km, a better mileage is expected by users.

On the other hand, as validity of fuel cell for the purpose of global environmental protection has been demonstrated as the drive source of electric vehicle [Tamura et al., 2000; Yamaguchi et al., 2003; Yamaguchi et al., 2004; Yamaguchi et al., 2005]. Thus, it has been adopted as drive source of electric wheelchair.

This paper proposes the extend mileage of electric wheelchair using a hybrid system consisting of Ni-MH battery aided by fuel cell as its drive source.

Running characteristics of electric wheelchair operating the hybrid system using in-wheel brushless dc motor as the drive system measures the current and voltage supplied to it, and investigates the mileage when that is run at a specific speed.

2. MANUAL WHEELCHAIR

A basic manual wheelchair is driven by human power to move them. Most basic manual wheelchairs can be folded for storage or placing it in a vehicle for the purpose of carrying it from one place to another. General view of manual wheelchair used for trial construction of electric wheelchair is shown in Figure 1. This manual wheelchair incorporates a seat and backrest, two small front wheels and two large rear wheels, two armrests and two footrests, respectively. This wheelchair is made by MATSUNAGA SEISAKUSHYO, and its model number is MW-10F. The strong points of this wheelchair are it is small, light-weight and it can be folded for carrying and storage purpose. Outline of the manual wheelchair used for trial construction is shown in Table1.

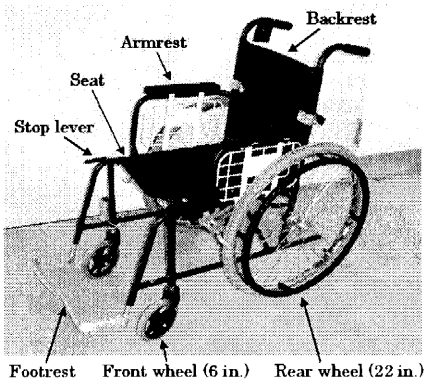

Fig. 1 General view of used manual wheelchair

Table 1 Outline of used manual wheelchair

Model	MW-10F
Full size	(Width) (Length) (Height) 61 cm × 101 cm × 88.5 cm
Folding width	31cm
Seating width	38 cm
Seating depth	40 cm
Foot supporting length	44 cm
Height of headrest	41 cm
Height of backrest	40 cm
Height of armrest	23.5 cm
Wheel size	Front wheel (6 in.) Rear wheel (22 in.)
Weight	12.5 kg

3. HYBRID SYSTEM

The block diagram of electric wheelchair using Ni-MH battery aided by fuel cell is shown in Figure 2.

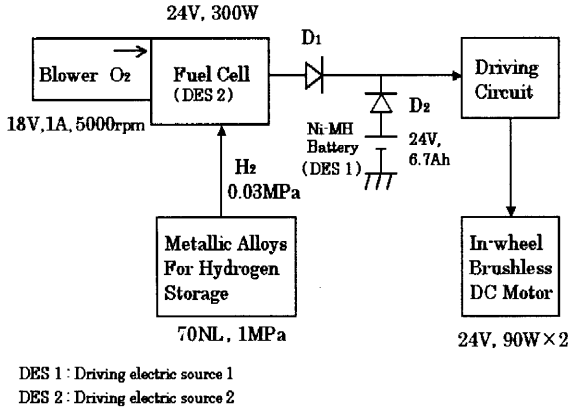

Fig. 2 Block diagram of electric wheelchair using Ni-MH battery aided by fuel cell

Driving electric source 1 is consisted of Ni-MH battery with a capacity of 6.7Ah. Driving electric source 2 with a 24V, 300W of fuel cell is generated by chemical reaction between H_2 and O_2 when passing through a proton exchange membrane (PEM). Diodes D_1 and D_2 with 25NC12 are used to protect the fuel cell and Ni-MH battery against the reverse current from themselves. Pressure of H_2 gas is adjusted to 1MPa using a gas regulator, and H_2 gas is charged in the hydrogen storage material for about 10 minutes. A blower is used to send O_2 in air into the fuel cell and the amount of air is adjusted automatically corresponding to generated output power. Gas pressure of H_2 sent to fuel cell is adjusted to 0.03-0.035MPa. Driving motors are used as in-wheel brushless dc motor rating 24V, 90W×2. Generating voltage of fuel cell and supplying current, and voltage of Ni-MH battery to drive system including the in-wheel brushless dc motor are monitored by using voltmeter and ampere meter of analog type.

Rating of drive system for the electric wheelchair is shown as follows.

(1) Driving motor: in-wheel brushless dc motor 24V, 90W×2, 2kg×2.
(2) Driving electric source 1: Ni-MH battery 24V, 6.7Ah, 2.9kg.
(3) Driving electric source 2: polymer electrolyte fuel cell (PEFC) 24V, 300W, 0.03MPa, 2.6kg.
(4) Hydrogen storage material: metallic alloys for hydrogen storage 70NL, 1MPa, 0.9kg.
(4) Blower: frequency control type 18V, 1A, 5000rpm.

4. GENERAL VIEW OF ELECTRIC POWERED WHEELCHAIR USING HYBRID SYSTEM

The rear view of electric wheelchair using Ni-MH battery aided by fuel cell is shown in Figure 3. As electric wheelchair can be simply folded when the placing it into a vehicle, the fuel cell is fixed by pulling up the belt to the rear side of backrest. Metallic alloys for hydrogen storage filled-up to capacity of 70NL with a pressure of 1MPa is mounted on the handlebar and fixed by a strong elastic band. In-wheel brushless dc motors rating of 24V, 90W are built-in rear wheels with electromagnetic brakes, and is operated as manual or electric wheelchair simply by using a changeover lever. Running of electric wheelchair for forward, backward, left and right side can be done by operating a joystick which also functions as an accelerator. Running speed of the electric wheelchair is selected to about 2.5km (low speed) and about 4.3km (high speed) by a changeover switch. The Ni-MH battery with a capacity of 6.7Ah can be charged in about three hours using a charger.

Outline of electric wheelchair using a hybrid system with Ni-MH battery aided by fuel cell is shown in Table 2. The main points of outline when changed from manual to electric wheelchair are as follows: its width gets larger; from 31cm to 43cm and its weight gets heavier; from 12.5kg to 32kg, because of various electrical equipments

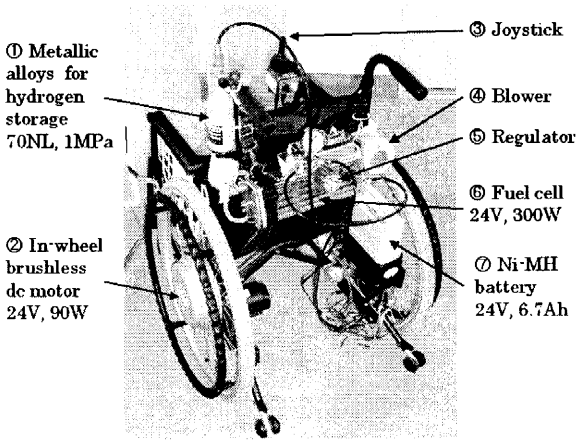

Fig. 3 General view of electric wheelchair using Ni-MH battery aided by fuel cell

Table 2 Outline of electric wheelchair using a hybrid system with Ni-MH battery aided by fuel cell

Full size	(Width) (Length) (Height) 61 cm × 101 cm × 95 cm
Folding width	43cm
Seating width	38 cm
Seating depth	40 cm
Foot supporting length	44 cm
Height of headrest	41 cm
Height of backrest	40 cm
Height of armrest	23.5 cm
Wheel size	Front wheel (6 in.) Rear wheel (22 in.)
Weight	32 kg

mounted on the wheelchair. However, compactness of the electric wheelchair is kept similar to that on the market.

5. CHARACTERISTICS OF ELECTRIC WHEELCHAIR USING HYBRID SYSTEM

Measurement of supplying currents to left wheel and right wheel are done by a terminal voltages of two current sensitive resistors with a value of 50mV/15A that are installed between the fuel cell and driving system including in-wheel brushless dc motors. The terminal voltages are supplied to Memory Hi-Corder while the electric wheelchair is running and the data obtained is downloaded to a flash card. Then, the data is processed by using a personal computer, and their characteristics based on Excel software are printed out.

5.1 Characteristics of supplying current and generating voltage while running by fuel cell only

Firstly, as supplying currents to left wheel and right wheel are I_L and I_R, supplying current I_S of total is $I_S = I_L + I_R$. Characteristics of supplying currents $I_S = I_L + I_R$ and generating voltage E_G while running a distance of about 139m consisting the following route on a flat ground at a speed of about 4.3km/h is shown in Figure 4. The data shows that the wheelchair ran a route on a flat ground to 38m in section (1) turned right and ran 65m in section (2) A turned left and ran 36m in section (3).

Figure 4 shows the voltage generated by the fuel cell at an idling state of the electric wheelchair which is 33.5V corresponding to 1.4 times compared with 24V of rated voltage while running. Measuring switch of Memory Hi-Corder is closed (ON) at $t = 0$ and electric wheelchair is started at $t = 3$s. Supplying currents $I_S = I_L + I_R$ to two in-wheel dc motors at $t = 6$s after the start is about

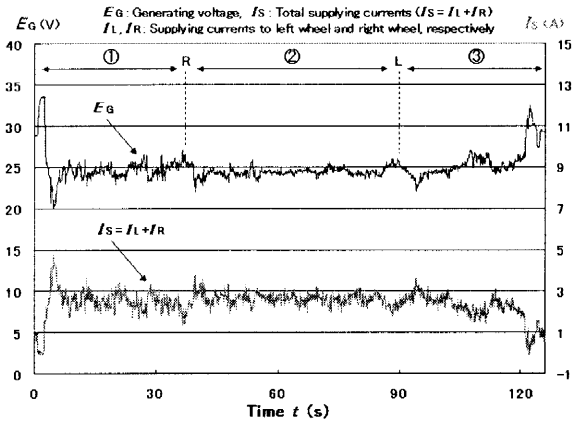

Fig. 4 Characteristics of supplying currents $I_S = I_L + I_R$ and generating voltage E_G at a running speed of 4.3km/h

4.7A corresponding to about 1.7 times compared with 2.7A at speed of about 4.3km/h. Output power ($E_G I_S$) of two in-wheel dc motors at $t = 6$s after the start is 99W (21V×4.7A) corresponding to about 1.5 times compared with 65W (24V×2.7A) of static state at $t = 60$s.

Characteristics of supplying currents I_L, I_R and generating voltage E_G at a running speed of 4.3km/h is shown

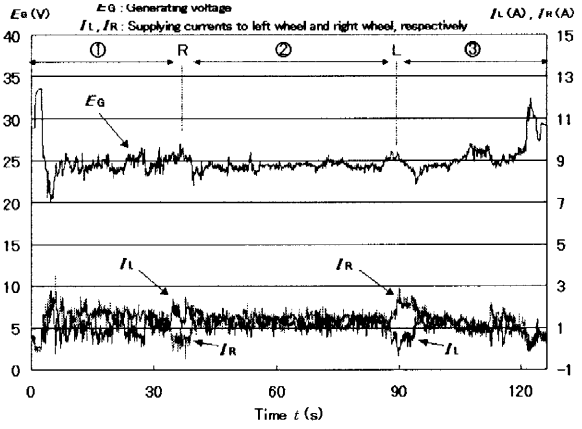

Fig. 5 Characteristics of supplying currents I_L, I_R and generating voltage E_G at a running speed of 4.3km/h

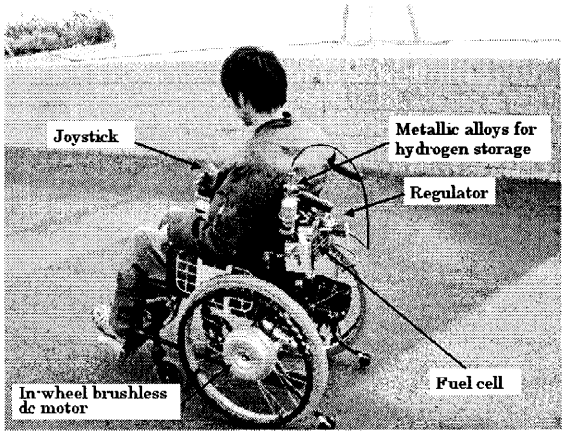

Fig. 6 Measurement view of running characteristics

in Figure 5. As rating of I_L and I_R, I_L is about 25 times larger than I_R for turning right and I_R is about 30 times larger than I_L for turning left. The mean values of supplying currents of I_L, I_R based on static state on flat ground is about 1.35A. Measurement view of running characteristics while the mileage of about 139m is showed in Figure 6. Data of supplying currents $I_S = I_L + I_R$ and generating voltage E_G are supplied to Memory Hi-Corder.

5.2 Characteristics of mileage using hybrid system

Characteristics of mileage is measured with the hybrid system consisting of Ni-MH battery aided by fuel cell, and it is set to 24V, 2.7A at 65W corresponding to speed of 4.3km/h by connecting to a load consists of variable slide resistors of 30Ω, 2A and 34Ω, 1.8A in a laboratory. Measurement view of characteristics for mileage is shown in Figure 7. Pressure of H_2 gas in metallic alloys for hydrogen storage is charged to 1MPa, and gas pressure of H_2 sent to fuel cell is adjusted to 0.035MPa. The metallic alloys for hydrogen storage is mounted in water using a circulating bath (low temperature bath), and its temperature is kept constant at 15°C. Memory Hi-Corder is used for measuring the mileage. Characteristics of mileage corresponding to speed of 4.3km/h using a hybrid system is shown in Figure 8. Figure 8 shows generating voltage E_G of hybrid system, supplying current I_S from a hybrid system to load and supplying current I_F from a fuel cell to load. Measuring switch of Memory Hi-Corder is closed (ON) at $t = 0$. Generating voltage, supplying current and pressure of H_2 at $t = 0$ are E_G = 25.2V, I_S = 2.63A, I_F = 0.41A and 0.035MPa. As time passed, E_G = 23.1V, I_S = 2.3A, I_F = 0.49A and 0.03MPa at t = 120min later. The current /F of fuel cell is increased from 0.41A to 0.49A as the voltage of Ni-MH battery is decreased. It shows the generating voltage of fuel cell compensated for decrease of the voltage with a Ni-MH battery. Furthermore, the current I_F of fuel cell showed the maximum value of 0.94A at t = 170min later. It's estimated that electric wheelchair is stopped when the generating voltage E_G by hybrid system is decreased to less than 19-20V. In consequence, mileage of electric wheelchair using a hybrid system is about 13km corresponding to t =180min with E_G = 19V. On the other hand, the mileage based on a Ni-MH battery only is about 8.6km corresponding to t = 120min. That is, mileage of electric wheelchair using a hybrid system is improved to about 1.5 times comparing with Ni-MH battery only.

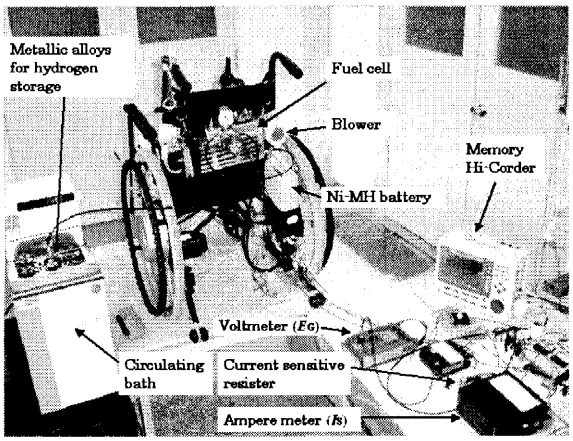

Fig. 7 Measurement view of characteristics for the mileage in laboratory

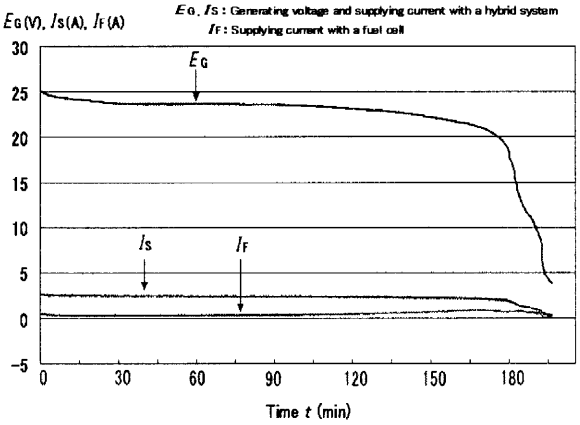

Fig. 8 Characteristics of the mileage corresponding to speed of 4.3km/h using a hybrid system

6. CONCLUSION

This paper proposes the extend mileage of electric wheelchair using a hybrid system consisting of Ni-MH battery aided by a fuel cell as its drive source. Driving power sources in the trial electric wheelchair using Ni-MH battery with a 24V, 6.7Ah and fuel cell with a 24V, 300W is aided by hydrogen storage material filled-up to capacity of 70NL with a pressure of 1MPa.

As a result, we have obtained the following.

(1) The trial electric wheelchair using a hybrid system is consisted with strong points of compact, lightweight and simple folding type.

(2) Mileage of electric wheelchair using a hybrid system is improved to about 1.5 times comparing with Ni-MH battery only.

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