Experimental Performance of a Model River Cruising Electric Boat Electric-powered by a Fuel Cell

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Abstract

This paper will describe the characteristics of an electric-powered cruising boat used in an experiment. One of the advantages of electric-powered vehicles is their high energy-efficiency, while one of the disadvantages is their level of stored energy density, which is much lower in comparison to the level of petroleum. For this reason, further improvement in the efficiency of electric-powered vehicles themselves are essential, in order to raise electric-powered vehicles' performance level to match that of an internal-combustion vehicle. The advantages of electric-powered boats and ships are described in another paper [Minami, 2003]. When the size, travel distance and speed of a boat are to be included in the characteristics of the performance of an electric-powered boat, it becomes important to learn the size of motors and batteries. The goal is to have a fluvial cruising-boat, of 20-meters in length and 20-tons in displacement volume, which travels at a speed of 5-10km/h. In order to obtain the necessary parameters of this performance, experiments using two model-ships of one-meter and two-meters long have been conducted [Minami, 2003], and data from an experiment using a model ship of approximately five-meters length was obtained. This ship was equipped with fuel batteries, and its performance was also checked.

Keywords

electric boat, fuel cell, energy efficiency

1. INTRODUCTION

In the second half of the twentieth century, the industrial world developed significantly and this development helped humans to realize an affluent civilization and rich cultural life. Cars, TVs, cellular phones, personal computers and other products essential to a modern society were developed one after another, and this development made life very convenient. But a civilization which greatly relies on a limited oil-resource needs to ensure new types of energy resources. Electric-powered cars are an example; this is a product developed to face up to the twenty-first century. Electric-powered vehicles have better efficiency compared to internal-combustion vehicles, and they produce less pollution [Minami, 2003a]. The development of products that ignore the problems of fossil-fuel exhaustion and the problems of the global environment, which are affected by global warming and aerial pollution, is impossible today. In short, the twenty-first century is the era in which products are developed while facing up to environmental issues.

However, product development following this concept often troubles developers. Developing new products while remaining concerned about environmental issues limits the efficiency of products and, as a result, the newly developed products have a lower level of performance than that of existing products. The electric-powered car is a typical case. In comparison to conventional gasoline-powered cars, recently developed electric-powered cars have lower performance in mileage per charge, production costs and many other points, including difficulties of maintenance, and they have not penetrated far into the market yet.

Nevertheless, exhaustion of gasoline (fossil fuel) in the near future is inevitable, and an alternative energy to replace gasoline will be needed. When this happens, the modes of transportation will be electric trains and other vehicles using electric power. Though electric-powered cars have low performance abilities in most ways, they can perform better environmentally and economically than conventional cars in such situations as commuting, where the travel distance in a day is set. Electric charging, which is equivalent to refueling, is more cost-efficient if it is done during the night when the electricity-rate is one-third of daytime. Furthermore, in terms of environmental issues, electric-powered vehicles can operate without vehicle emission. Likewise, if the electric-powered vessel in the process of being developed and described in this paper uses electric energy, and if the range of its usage and performance abilities is confined, then high-efficiency vehicles which utilize the merits of electric-powered vessels can be realized. In order to do so, products for specific purposes have to be developed, and more importantly, the users have to recognize the necessity of developing the electric-powered vehicles. This study aims to determine an electric-powered vessel's performance experimentally, and to make it fit for practical use.

What makes an electric-powered vessel better than a gas-electric-powered boat is not merely the diversification of necessary energy resources. The conventional internal-combustion boat emits gas and pollutes the properties of water. Electric-powered vessels travel with no emission and no water pollution. Also electric motors produce very little noise while operating, and this is of great merit, especially for cabin cruisers. These merits can produce a new impetus to demand for electric-powered vessels. This study aims to give commercial viability to this sort of electric-powered boat and to demonstrate to the general public the attractiveness of electric-propulsion in boats for river cruising. Its final goal is to reduce energy consumption by promoting a modal shift from land traffic to marine traffic.

2. EXPERIMENTAL DEVICE

What has to be considered in designing a boat of which the source of power is electric batteries is the mileage per charge; in short, how efficiently the boat can be operated. In general, the resistance which occurs while a boat travels on the surface of the water can be categorized into three types: viscosity resistance of water against the movement of the boat; wave resistance, which is caused by the boat itself; and air resistance on the water's surface. This experiment with a model is conducted in order to gather data on resistance, and to apply the data to actual boats.

An electric-powered experimental boat of approximately five meters in length (which is a quarter-size of a twenty-meter, full-size boat) was conducted, and the motor output, speed and fuel-consumption needed for a full-size boat were studied.

Figure 1 is a picture of the model boat used in this experiment. It is a catamaran of approximately 1.6-meters in width.

Fig. 1 Picture of a 1/4-size electric-powered model boat

Table 1 Specifications of experimental boat

Length	4.6 meters
Width	1.6 meters
Type of boat	Catamaran
Beam Width	0.25m (each Hull)
Motor	Permanent magnet-type direct-current motor 300Wx2
Propeller	2 Blades, 30cm in diameter
Power Source	75AH Lead-acid battery x 2 or 1.2KW Fuel Cell: NEXA (made by Ballard Co.)
Displacement	140kg

Table 2 Specifications of the fuel cell (NEXA™)

Performance	Rated net power	1200 W
	Rated current	46 A
	DC output voltage	22-50 V
	Operating lifetime	1500 hours
Fuel	Composition	99.99% dry gaseous hydrogen
	Supply Pressure	10 ~ 250 PSIG
	Consumption	<18.5 SLPM
Operating Environment	Ambient temperature	3℃ to 30℃
	Relative humidity	0 % to 95 %
	Location	Indoors and outdoors
Physical	Length	56x25x33 cm
	Weight	13 kg
Emissions	Liquid water	0.87 liters maximum /hour
Others	Interface	Full duplex RS485
	Number of Cells	48
	Sub Battery voltage	24V

Table 1 shows the specifications of the model boat used in the experiment.

Fuel cells used in the experiment are NEXA™, made by Ballard. Table 2 displays their specifications.

3. EXPERIMENTAL RESULTS

Figure 2 is one example of the results of the experiment. The energy requirements increase as the speed of the boat accelerates. Energy requirements were also studied in a towing experiment. The graph in Figure 3 shows the results of the experiment when the propeller is not under the water, and Figure 4 shows results when the propeller is under the water. Energy consumption increased. Figure 5 shows the propeller efficiency which was obtained based on the data from Figure 4. Efficiency per speed is obtained by dividing the energy consumption in Figure 5 by the energy consumption in Figure 3. The difference in consumption of electricity between Figure 3 and Figure 4 indicates the resistance when the propeller is under the water. It indicates about 250W of propeller resistance at a speed of 3.5km/h, and the consumption of electricity by the boat increases as the speed accelerates. Propulsion efficiency appears to be 90% at a speed of 5km/h. This is because the data from the towing experiment contains excess energy caused by the propeller, which actually is not rotating. In any case, it was found that a 50-60% energy transfer efficiency is obtained by this propeller. This is very important for making estimates for the total efficiency of the boat in a modal shift.

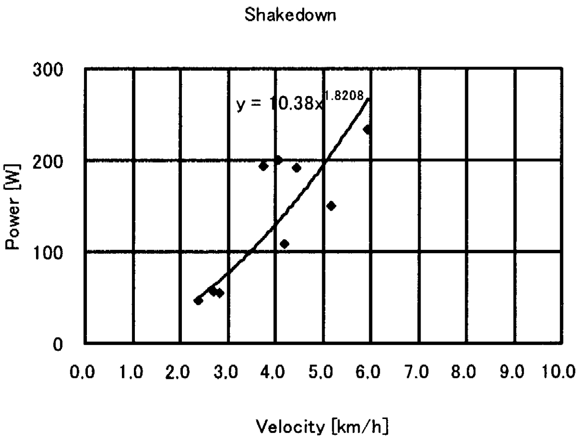

Fig. 2 The characteristics of energy consumption in shakedown

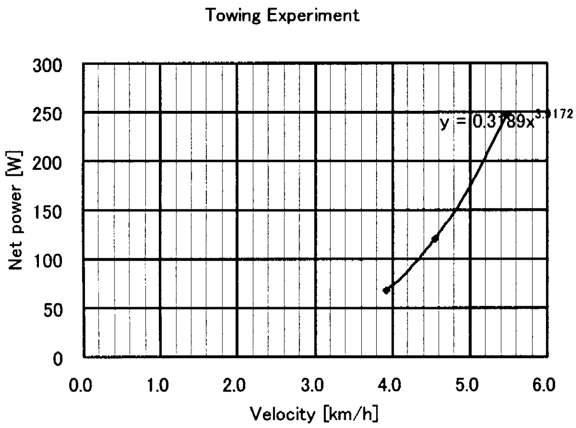

Fig. 3 The relation between electricity requirements and vessel speed learned from a towing experiment (when propeller was in the air)

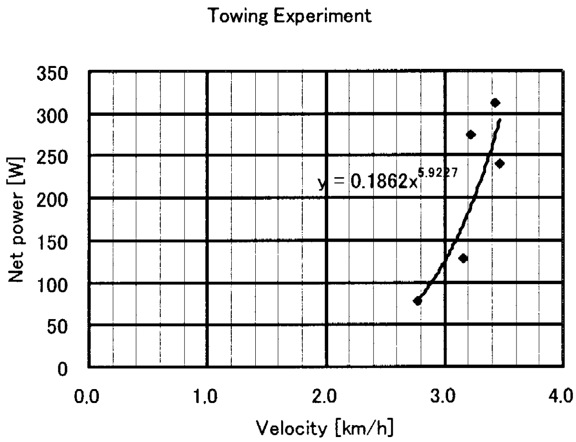

Fig. 4 Relation between electricity requirement and vessel speed learned from a towing experiment (when propeller was under the water)

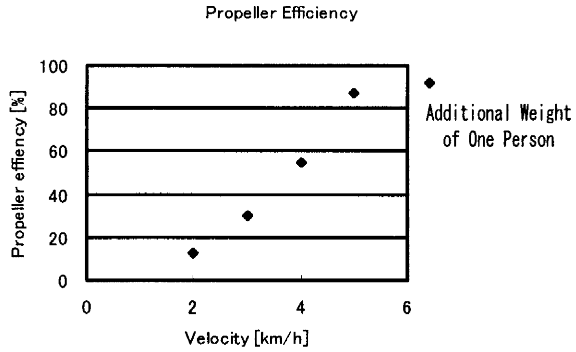

Fig. 5 Speed Characteristics of Propeller Efficiency

4. CONCLUSION

This experiment was conducted for the purpose of demonstrating that current issues regarding cuts in CO2, energy-saving and providing a comfortable means of transport can be resolved by developing electric-powered vessels. In this paper, as part of a study with an experimental boat for the development of a 20-meter demonstration boat, for the first time a performance experiment was conducted with a quarter-size catamaran model boat, which is the same type of ship as the eventual demonstration boat. A fuel-cell system which uses hydrogen gas as its main power-source was applied to this experiment, and it produced a good performance. Also, the possibility of a modal shift to the electric operation of boats and ships was studied in numerical terms.

References

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