B-17.5 Analysis of the system for wide spreading electric vehicles in a special region and the model vehicle to be wide spreaded

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Abstract

A system design to use many electric vehicles in a midium sized city was made. The basic design of electric vehicles (EVs) to be used in the area was made also. The way of incentives and infrastructure is proposed.

A computer simulation program was produced to calculate the performance of an electric vehicle precisely. Range per charge, maximum velocity, acceleration and energy consumption rate can be calculated by the program. The calculated value of the performance by the program is coincided with the actual performance of the prototype passenger car within the error of 5%. A new drive system and a new frame structure were proposed. If these technologies are used, the space of a cabin and a luggage space can be increased in an EV. By using these technologies fundamental designs of EV were made by considering economies. In a taxi, as two rooms can be made within the same sized conventional taxi, the income of one taxi driver could be increased. In a light truck, as the height of the floor of the luggage space can be constructed much lower than a conventional light truck, it become very easy to load and unload luggages and it is possible to enlarge the size of the luggage space. It helps to make the efficiency of transportation higher. To spread these electric vehicle, it is convenient to be used for taxi then transportation field.

Key Words model electric vehicle, simulation program, driving system, frame structure

1.Background

As one of the way to spread electric vehicles widely, it is useful to set a model area and use many electric vehicles (EVs) in this area. To realize this, a system design of the model is required. It is required to estimate the performance, functions and economics of the EVs to be used in the model area.

2.Objective

The purpose is to make a system design to spread electric vehicles widely to a special area in a medium sized city. In the system design, the EV to be wide spread used will be analyzed technically and the infrastructure and incentives will also be taken into accounted.

3.Research method

To calculate the performance of an EV, a simulation program was developed. New technologies which increase the performance and function of an EV were proposed and their feasibility to be used in a practical uses were examined. By using these technologies, fundamental designs of an electric taxi and a light truck were made.

4.Result and Discussion

(1)Development of simulation program.

There are three factors which decide the performance of an EV. These are the battery system, the drive system and the body. The important performance in an EV is the rage per charge, maximum velocity, acceleration and energy consumption rate.

The structure of the simulation program is shown in Fig. 1. The program is composed of subroutines to calculate the performance of an EV, input the value of parameters,calculate the performance of each components in an EV, handle the data and output the calculated results. Several types of motors, driving systems and batteries can be selected in the program.

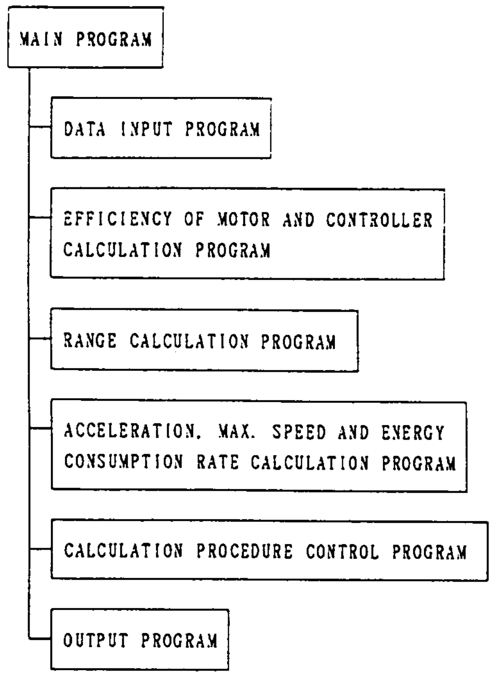

Fig.1 THE STRUCTURE OF THE SIMULATION PROGRAM

An example of the simulation calculation to examine the accuracy of the program is shown in Table 1. In the table the calculated values and the realized values of a prototype EV are shown. From the table each values are coincide within the error of 50%. This result shows that the performance of an EV can be expected precisely before it is constructed then the development of an EV become easier.

(2)New technologies in an EV

We showed that the performance of an EV could be increased greatly by adopting newer technologies, using new drive train and making whole of the vehicle as an EV. Standing on these fact, new technologies are proposed.

One is for a driving system. There are many types of driving system in an EV. In prototype EVs the system where driving motors are attached to each driving wheels and a differential gear is removed is also tested.And the system in which the driving motors are set into each driving wheels is possible. The system is named the direct drive system. There are

Table 1 THE RESULT OF THE SIMULATION CALCULATED BY THE DEVELOPED PROGRAM AND THE REALIZED VALUE

	CALCULATED	REALIZED
RANGE(km)		
40km/h	556	548
100km/h	272	270
0-400m ACCELARATION (sec)	17.92	13.05
MAX.SPEED (km/h)	183	176

merits and demerits in each driving systems. In the direct drive, the merits are that the transmission loss is minimized and the space in the body can be increased. The largest demerit is that the efficiency at the acceleration stage is low. To remove this problem, a system where a reduction gears are inserted between the shaft of the motor and the wheel was considered. The schematic diagram of the system is shown in Fig. 2. In the figure, M is a high speed motor, Be is a baring, G is a reduction gear and Br is a brake. This system will be called the new drive. To show the merit of the new drive the simplified equation of motor efficiency is shown in eq(1), where only cupper loss is considered,

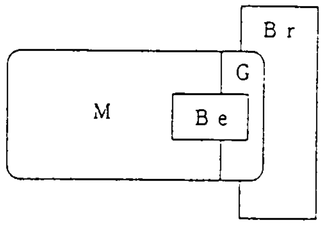

Fig.2 SCHEMATIC DRAWING OF THE NEW DRIVE SYSTEM

$$\eta_c = \frac{1}{1 + \dfrac{2\pi R T}{(\phi Z)^2 n i^2}} \qquad (1)$$

where η_c is the efficiency of the motor, ϕ is the total flux, z is the number of winding, n is the rotation speed, i is the gear ratio, R is the resistance and T is the torque. If the rotation speed and the torque is decided the efficiency is calculated. From eq(1), when the maximum velocity of the motor is high enough, efficiency of the motor increases with the gear ratio. In the eq(1), i=1 is the case of the direct drive.

In table 2, the effect of the new drive will be shown. The comparison is made between the direct drive and the new drive when they are applied to the prototype passenger car. In the direct drive, 4 permanent magnet motors with 42kgm maximum torque are assumed to be used, and 2 motors whose maximum torque is 20kgm with gear ratio of 4 are assumed to be used in the new drive. From table 2, although the range per charge at a constant speed is shorter it is much longer at a city drive in the new drive system. The

Table 2 THE SIMULATED PERFORMANCE OF A PROTOTYPE EV WHERE NEW DRIVE SYSTEM IS APPLIED

	DIRECT DRIVE	NEW DRIVE
RANGE AT 40km/h	557 km	566 km
RANGE AT 100km/h	272 km	264 km
RANGE AT 4 MODE PATTERN DRIVE	232 km	349 km
RANGE AT 10 MODE PATTERN DRIVE	198 km	306 km
0-50km ACCELERATION TIME	4.65 s	4.75 s
0-400km ACCELERATION TIME	17.9 s	17.4 s
MAX. SPEED	166 km/h	188 km/h

reason is that the efficiency at the acceleration is much better.

The second technique is on the structure of a frame. The biggest problem of an EV is believed that the weight of a battery is heavy. The volume of the battery is another problem. The volume of the battery have been limiting the space of a cabin or a luggage room. The safety when it is crashed and heat dissipation are problems of the battery also. To solve these problems a new frame which is named the battery builtin frame (BBF) is proposed. There are about 10cm height dead space under the floor in an ICE car to put a muffler and sometimes propeller shaft. A slab structure is made by using this space and thin type battery will be inserted in the space. The slab structure is made by an extrusion. By the BBF the space of a battery is prepared under the floor and total weight of the vehicle is decreased.

Table 3 EXPENSES OF TAXI AND TRANSPORTATION COMPANY (1989)

	TAXI	TRUCK
PRICE OF CAR	3.14	5.77
FUEL	4.94	5.34
REPAIR	2.33	3.52
PERSONAL EXPENSE	78.2	45.3
OTHERS	11.4	39.47

(3)The design of EVs considering economics.

The price of an EV is another problem which is preventing a spreading of EVs. The main reason of the high price is that the large amount production are not conducted. To solve this problem, it is required to be found a condition whe is decreased even if the price of the EV is re economical problem is decreased even if the price of the EV is expensive.

Table 3 shows the expenses of taxi and transportation companies. The table shows that the price of the car is much cheaper than the labour charge. Then if the income per driver will be inçreased total merit will become better even if the price of the car is high.

In an EV taxi, the two room cabin system is possible where two passenger space are prepared in a taxi. In Tokyo, the rate when passengers are riding is 60% for total driving rage, and in Seoul, the rate is 85%. The main difference between two cities is that the foreign passengers are permitted to ride in a taxi at one time in Seoul. Although Japanese people does not want to ride a taxi with a foreign people, if there are two separate rooms are prepared in a taxi, 2 groups can be ride at a time. In an EV, as more wider space can be prepared in a same sized can compared with ICE car, the two room cabin system as is shown in Fig.3 can be realized. In Fig.3, 2 seats are located at the side of the chauffeur seat and 3 seats are at the behind of the seats.

Suppose that the rate of passengers riding becomes to 72.5% when the two room cabin system is realized, and the rate of two rooms are occupied is 20% then the total income of the taxi will become 40% larger. If the half of the increased income will be used to buy the car the price can be

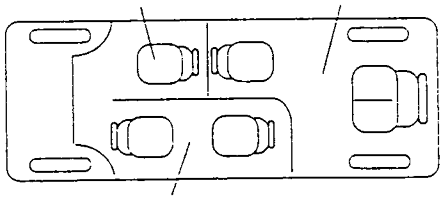

Fig.3 LAYOUT OF A TAXI WHICH HAS TWO CABINS

16 million yen at most when the life of the car is 5 years.

The same idea can be applied in light truck. In Japan, major light trucks are 2 tons types whose normal size are 1,700mm in width, 4,700mm in length and 2,500mm in height. The main reason why the 2 tons type trucks are used is that the size of the luggage space is suitable, nof load ot for the reason of load weight.

The averaged load weight was 870kg in a 2 ton truck when it is full loaded. This fact shows that it is important to increase the volume of luggage space to increase the efficiency of a light truck.

If the new drive system and the BBF is adopted in the light truck, the height of the luggage space can be make lower compared with that of the conventional truck. Then the volume of the luggage space will become larger about 20%. It helps to increase the income by a single driver.

Table 4 SPECIFICATION AND CALCULATED PERFORMANCE OF A ELECTRIC TAXI

SPECIFICATION	
LENGTH	4700 mm
WIDTH	1700 mm
HEIGHT	1400 mm
PASSENGERS	5
TOTAL WEIGHT	1860 kg
BATTERY WEIGHT	530 kg
AIR DRAG COEF	0.25
PERFORMANCE	
RANGE (10 mode)	275 km
MAX. SPEED	170 km/h
ACCELERATION (0-400m)	18.5 sec

Table 5 SPECIFICATION OF LIGHT TRUCK

SPECIFICATION	
LENGTH	4700 mm
WIDTH	1700 mm
HEIGHT	2200 mm
FRONTAL AREA	3.4 m²
AIR DRAG COEF	0.4
WEIGHT OF VEHICLE (WITHOUT BATTERY)	2000 kg
ROLLING DRAG COEF	0.008
ENERGY DENSITY	38 Wh/kg

(4)Fundamental performance of EVs which meet to the concept of new application

Fundamental performance of a taxi and a light truck which meet to new concept will be shown.

In table 4, the specification of the taxi is shown. The weight of battery is assumed 530kg. The result of the simulation of the performance is shown in table 4 also. As shown in the table, the maximum velocity and the acceleration is suitable for practical uses of taxi. The range is just 275km in city drive. Range of 400km is required to be used for a taxi. To increase the range per day, quick charging, high performance battery and hybrid system are the choices. If 80Wh/kg battery is used, the range will become 400km. In the hybrid system required power from the generator is 400W. In table 5, the specification of the light truck is shown. The size is assumed to be as same as that of the conventional 2 tons truck. The motor is the same one as that of the taxi.

The relation between the battery weight and the range is shown in Fig. 4. From Fig.4, the range is 100km in a city drive when the battery weight is 600kg. To achieve the range of 150km, 1200kg weight of battery is enough.

(5)The way to spread widely in a middle city.

The way to spread EVs widely in middle city, will be considered. As the drive system, a frame and a battery are common in the taxi and the

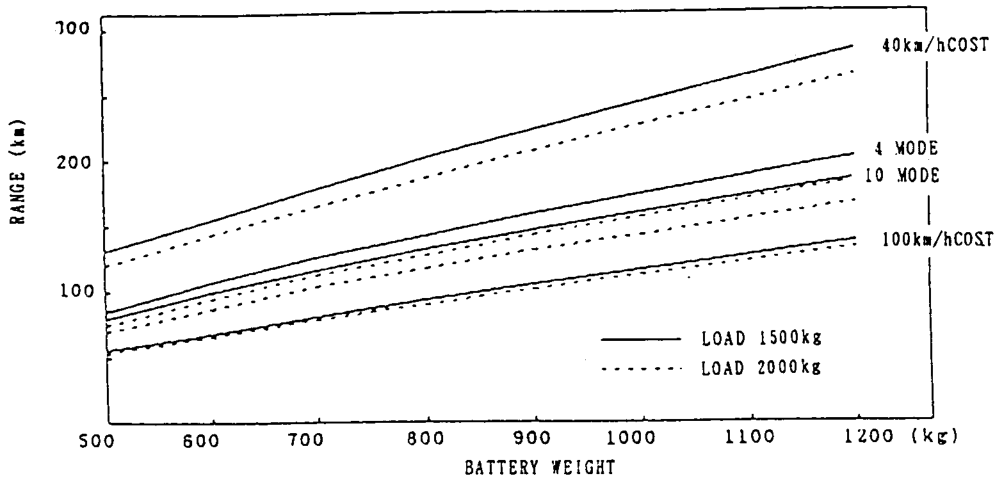

Fig.4 CORRELATION BETWEEN BATTERY WEIGHT AND RANGE IN A LIGHT TRUCK

light truck, the techniques which is used in one EV can be applied to the other type of EV easily. The price of a car is possible to make cheaper by producing one type of car in a large scale than when two types of a car is manufactured at a time. A taxi should be selected at first between two choices of the type of the cars because there is a possibility to add a large incentive to an EV taxi. In a medium sized city, major point where a taxi get a passenger is a railway station. If an indoor parking is prepared and if only an EV can get a passenger in the parking because it emit no exhaust gas, then passengers select an EV taxi more than an ICE taxi. To realize this, an EV to be used for a taxi should be developed at first then the indoor parking should be prepared by a public sector.

6.Conclusion

New technologies and function for EVs are discussed to spread EVs widely. By using these technologies, driving performances, which is the biggest problem to spread EVs widely, will increase greatly and economical problem also will be solved. As a result, these techniques and functions be used for a taxi in a medium sized city to be able to spread EVs widely.