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Proposal of a Portable Folding Electric Scooter Model and Manufacturing of the Prototype

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Abstract

In recent years, small mobile devices called personal mobility or smart mobility have attracted attention. Personal mobility refers to electric-driven personal transportation that can travel at close range and medium distance, including small electric vehicles, electric bicycles, electric motorcycles and electric scooters. Most of the electric scooters used in Korea are mainly imported from China. This is due to the fact that the price competitiveness of major components of electric scooters is owned in China. At this point, the domestic research direction is preferable for the composition and design of the electric scooter body rather than cost reduction for the components. In this study, we propose a new model of portable folding structure that is easy to use for electric scooters, which are personal vehicles using electric energy. We also made a prototype for practical use.

Keywords: *Foldable, Electric scooter, Personal mobility, Prototype, Foot-plate*

1. Introduction

The term personal mobility refers to personal means of electric driving that can travel at close range and medium distance, including small electric vehicles, electric bicycles, electric motorcycles and electric scooters. Unlike conventional motorcycles and automobiles, the driving method and body shape are completely different, and they are spreading mainly in young people. Personal mobility is becoming more and more utilized as a small means of transportation optimized for urban movement as urbanization progresses in many countries, and it can be a realistic, economical and convenient means of transportation before the era of electric vehicles. It is also used as a means of transportation in tourist attractions and public streets in conjunction with ICT(Information & Communication Technology). [1, 2]

Korea has an industrial structure that uses a lot of energy, and the government is trying to transform the industrial structure that uses eco-friendly energy. In the way to cope with such environmental factors, it is judged that it is the right direction to use the energy of the means of transportation as electricity. Most of the electric scooters used in Korea are mainly imported from China. This is due to the fact that China has price

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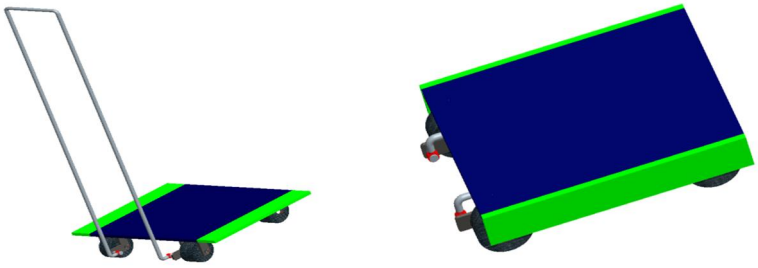
competitiveness for major components of electric scooters. At this point, the direction of domestic research is that it is desirable to construct and design the electric scooter body rather than cost reduction for components.[3,4,5]

This study suggests a new model of portable folding structure that is convenient to use for electric scooters, a personal means of transportation using electric energy. The proposed models are foldable, which makes it easy to carry, and the prototypes for commercialization are also produced.

2. Proposal of a portable folding model

The portable folding electric scooter model proposed in this study is a four-wheel structure. One of the top 100 inventions of mankind, and the Segway is made up of two wheels on both sides of the driving direction. In order to stand up to two wheels, a gyro sensor and an actuator must be used, and price increases due to the installation of parts are essential. In addition, the electric scooter, which consists of two wheels on both sides, is reluctant to ride because of the difficulty of getting on and off and fear of getting on and off. The first model proposed is the same as Fig. 1, which is a model of four electric scooters that are more stable than two electric scooters.



(a) driving mode (b) folding mode

Figure 1. The first model of a portable folding electric scooter

The proposed first portable folding electric scooter model is a folding structure on both sides of the footrests used during riding and driving. When the electric scooter is not operated, the scaffolding is folded on both sides and put in a backpack or a dedicated bag, so it can be stored or moved. The first portable foldable electric scooter model can be made of two steering axes and can be folded. The folding structure of the electric scooter is not only a structure that folds the left and right sides of the footrest of Fig. 1, but also a structure that folds the entire footrest into three equal parts. The second model proposed in this study is a three-step folding structure, like Fig. 2: (a) is a run in a unfolding state, and (b) is a folding form.

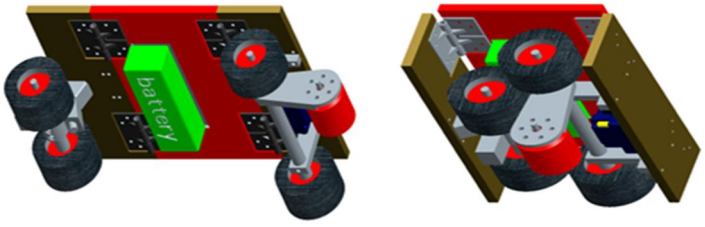


Figure 2. The second model of 3-steps folding structure

The second model above can be made of one steering axis, and when the body is folded in design and

production, the wheels before and after the body should not overlap.

3. Manufacturing of the prototype

Prior to manufacturing the prototype of the models presented, the specifications such as the maximum speed of the electric scooter to be manufactured, the riding capacity, tire diameter, and the gradient angle should be determined. You can calculate the required power, number of revolutions, and torque of the motor used in the electric scooter you want to manufacture using these specifications.

The resistance to the electric scooter that runs is the same as the following equation (1).[6]

$$R_D = R_r + R_{air} + R_g \tag{1}$$

Where, R_D : Driving Resistance
R_r : Rolling Resistance
R_{air}: Air Resistance
R_g: Gradient Resistance

The rolling resistance is expressed as follows.

$$R_r = \mu_r \cdot W \tag{2}$$

Where, μ_r: coefficient of rolling resistance
W: total vehicle weight

The coefficient of rolling resistance is 0.01 for asphalt, and the total weight of the vehicle is the sum of the weight of the vehicle and the weight of the passenger. In this study, the passenger is considered to be $70kg_f$ and the vehicle weight is $15kg_f$.[7,8]

$$R_{air} = C_\omega \cdot A \cdot \frac{\rho}{2} \cdot V^2 \tag{3}$$

C_ω: coefficient of air resistance
A: projection area
ρ: air density
V: vehicle speed

$$R_g = W \cdot \sin\theta \tag{4}$$

θ: gradient angle

Considering safety in the specification of the vehicle, the gradient angle was 10 degree and the maximum speed of the vehicle was 20km/hr . In addition, the size of the body, folding structure, and the diameter of the front and rear tires were 0.07m to apply the wheels being sold.
Each specification can be applied to equations (2, (3), (4), to calculate the resistance required for driving, which can be applied to equations (5) to obtain the necessary power for the motor.

$$P = R_D \cdot W^{[watt]} \tag{5}$$

$$V = \gamma \cdot \omega \times \frac{2\pi N}{60} \quad (6)$$

γ: radius of driving wheel
N: revolution number(rpm)

In the expression (6)

$$N = \frac{60 \times V}{2\pi\gamma} \quad (7)$$

You can calculate the number of rotations by assigning the specifications to the equation (7). The torque required for the motor can be calculated using the following expression.

$$T = R_D \times \gamma \quad (8)$$

T: Torque

The above equations allow you to calculate the power, number of rotations, and torque of motors applied to electric scooters, but you must custom-made motors to select motors that perfectly match the calculation results. In this study, we selected the ones that are close to the calculated specifications of the motors on the market and manufactured the prototype.

3.1 Fabrication of folding foot-plate structure

In order to manufacture the models proposed in Fig. 1 and Fig. 2, the first model was divided into one main footstep and two auxiliary footrests in the basic part, the scaffolding structure, and the second model was divided into three stages. The results are the same as Fig. 3.

(a) first model (b) second model

Figure 3. Manufactured main foot plates & side foot plates

The scaffoldings were made of industrial plastics and processed using a machinening center, which was processed by a step on the hinge where the main plate and the auxiliary foot plate were connected.

3.2 Bodywork

The results of the first model's prototype in this study are the same as Fig. 4. The steering shaft was not

able to enter the footrest during the production process, and was placed on the footboard, because the various parts under the footrest could not be installed under the footrest. In addition, it is a structure that fods the side of the footstep, and there are two steering axes, so the wheel rotation of the steering wheel is limited. In order to prevent such limited rotation, the steering wheel interval can be narrowed to free rotation, but narrowing the steering wheel interval can increase the ride feeling and anxiety during the operation.

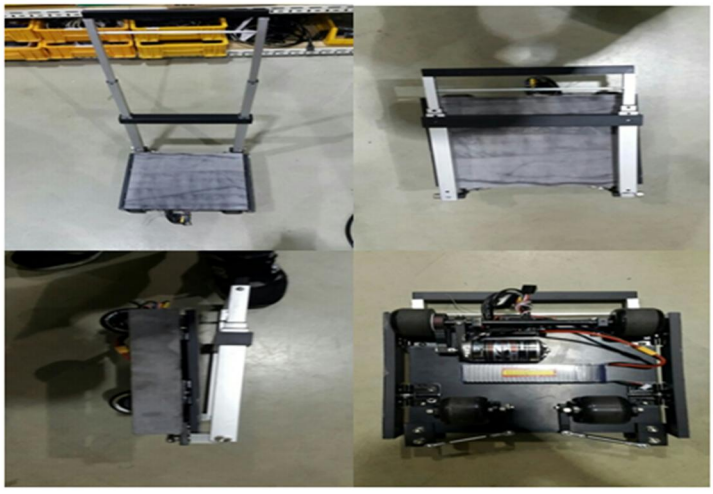


Figure 4. Prototype of the first model

The specification for the first model produced in Fig. 4 is the same as Table 1. In the production process, the motor was used to drive the rear wheel. Since most of the motors on the market are high-turn motors, we used a 5-1 timing belt to reduce the motor speed of high-turning. It is a rear-wheel drive, so it can have the advantage of not having to have a separate differential device, which has the effect of cost reduction.

Table 1. Specification of a manufactured first model of electric scooter

Items	Model or Specification
Motor	12V-22V, 2250W, 1,788(12V)∽2,086(14V)rpm
Controller	hobbywing 150A Brushless waterproof
Battery	14.8V, 4S(3.7V * direct 4EA) Lithium Polymer
Driving method	Timing belt(5:1), Remote control
Weight	13.5kg
Size	20×35×7(cm, folding mode)
Minimum turning radius	130 cm
Max. velocity	20 m/s

The results of the prototype of the second model proposed in Fig. 2 are as follows.

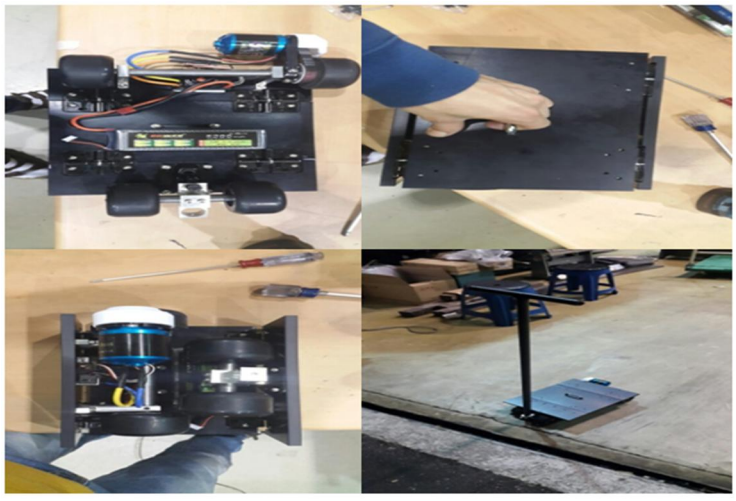


Figure 5. Prototype of the Second model

Table 2. Specification of the Second model

Items	Model or Specification.
Motor	24V, 1650W, 3,000rpm
Controller	CCPM SERVO CONSISTENCY MASTER
Battery	14.8V LiPo battery
Driving method	Remote Control
Weight	11.5kg
Size	16×35×10(cm, folding mode)
Minimum turning radius	110cm(1 Shaft steering) 120cm(2 Shaft steering)
Max. velocity	20 m/s

The first and second model proposed in this study consist of four wheels as a whole. In order to have a wide rotation angle of the steering wheel in the process of producing the proposed model, it is advantageous to have one steering axis. The second model is also lightweight and has a small size in the folding structure.

4. Conclusion

In this study, two types of portable folding electric scooters were proposed as a means of short-range transportation for the elderly and travelers, and the prototype products were made for commercialization of the proposed models. The following conclusions were drawn through the production of the proposed models

and prototypes.

(1) When folding the body, the wheels before and after the body should not overlap.

(2) In order to have a wide rotation angle of the steering wheel, it is advantageous to have one steering axis.

(3) Narrowing the steering wheel interval, which is the front wheel, can increase the ride feeling and anxiety during the operation process.

Acknowledgement

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