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Development of Auxiliary Wheel Unit Mechanism for Overcoming Obstacles

Jae-Oh Han* and Kwang-Wook Youm†

Dept. of Mechanical Engineering, Chung-Ang University, Korea
Dept. of Mechanical and Automotive Engineering, Hanyaang cyber University, Korea
youmkw@hycu.ac.kr

Abstract

Recently, the spread of personal mobility has been rapidly increasing due to the development of environmentally friendly alternative transportation means. In addition, the level of battery technology is also rapidly developing, accelerating the popularization of personal mobility. Such personal mobility has convenience of location transfer, amusement, and high portability compared to other transportation devices. Most personal mobility, however, is made up of small wheels, which cannot overcome obstacles such as rugged roads or obstacles on the road. In this paper, to solve these problems, we tried to devise a device that can easily overcome obstacles by combining wheels with small moving means. The wheel size can be mounted on the front wheel of the small moving means in a protruding manner so that obstacles can be encountered before the front wheels and the safety and ride comfort of the running can be improved.

Keywords: *Auxiliary wheel unit, Overcoming obstacle, Electric vehicles, Personal mobility*

1. Introduction

The main problem with internal-combustion-engine (ICE) vehicles is pollution. We thus need to find an appropriate substitute for them, with a much lower impact on the environment. Electric vehicles (EVs) is one of appropriate substitutes. Nevertheless, due to the past low energy storage capacity of electric batteries, EVs have not gained popularity[1-5]. In recent years, people have begun commercializing vehicles that use electricity due to environmental problems, and have also created personal mobility that can be moved around[6-10]. In addition, the level of battery technology is also rapidly developing, accelerating the popularization of personal mobility[11]. Such personal mobility has high portability as well as other transportation facilities, as well as mobility and amusement. Moreover, it has also evolved in such a simple new a motorized wheel as a form of public care for elderly and disabled people[12-13]. It is well known that safety has always been a main topic in the developing process of vehicle[14-15]. Most personal mobility, however, is made up of small wheels, which can't overcome obstacles such as unevenness on the road or obstacles. To, solve this problem, a device has been developed which can easily move the obstacle by

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Corresponding Author: youmkw@hycu.ac.kr
Tel: +82-2-2290-0844, Fax: +82-2-2290-0601
Department of Mechanical and Automotive Engineering, Hanyang cyber University, Korea

connecting the auxiliary wheel unit to the moving means driven by the small wheel. The auxiliary wheel unit is coupled to the front of the front wheel. The auxiliary wheel unit meets the obstacle ahead of the front wheel and overcomes the obstacle, allowing the front wheel to overcome the obstacle without a shock. As a result, the stability of the driving can be obtained, the accident can be prevented, and the ride quality can be improved.

2. Development of auxiliary wheel unit mechanism

2.1 Conceptual design of auxiliary wheel unit

Figure 1 is a conceptual diagram for developing a device for overcoming obstacles. The wheel is fixed so as to protrude from the front wheel shaft of the small moving means and the obstacle comes into contact with the front wheel ahead of the front wheel. In this process, the wheel axle fixing frame is raised and the mechanism is designed to lift the front wheels together to overcome obstacles.

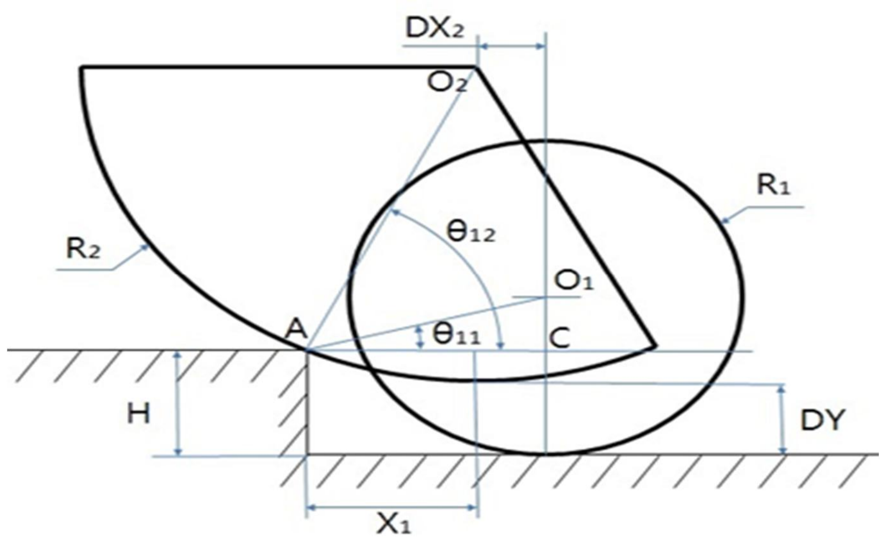

Figure 1. Conceptual design of auxiliary wheel unit

2.2 The driving mechanism of auxiliary wheel unit

Figure 2 shows the driving mechanism of the auxiliary wheel unit. The first figure shows the auxiliary wheel unit first touching the edge of the obstacle. In figure 2 (b), while the contact surface is maintained, the auxiliary wheel unit is rotated, so that the front wheel mounted with the auxiliary wheel unit moves forward and the front wheel is lifted. In the figure 2 (c), the auxiliary wheel unit overcomes the obstacle completely, and the lower part of the front wheel comes into contact with the corner of the obstacle and moves forward by the rotational force. The figure 2 (d), shows that it is returned to the front by the spring formed on the axis of the auxiliary wheel unit. Therefore, in this study, the auxiliary wheel system is designed to have the mechanism as shown in Fig. 2.

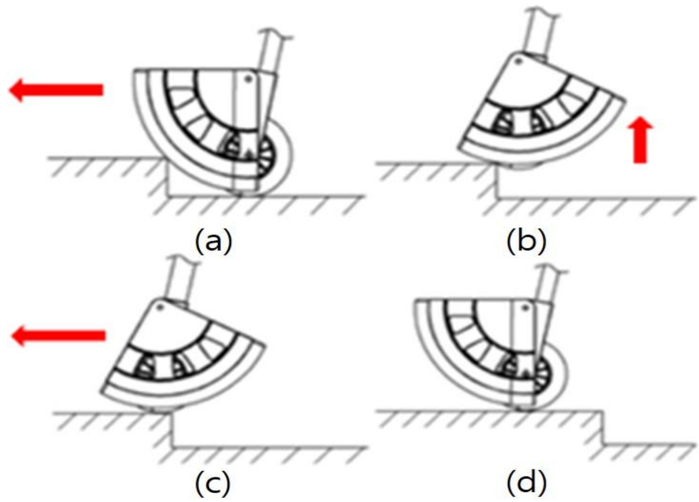

Figure 2. The driving mechanism of the auxiliary wheel unit

2.3 Verification of the driving mechanism of the auxiliary wheel unit

In order to verify the mechanism of the auxiliary wheel unit, the numerical value of the difference between the horizontal and vertical impact amounts according to presence or absence of the auxiliary wheel unit is shown by using a simple formula. First, each symbol and formula are as follows.

r_1: diameter of the main wheel

r_2: Radius of the auxiliary wheel unit

dx_2: offset distance between the center of the main wheel and the center of the auxiliary wheel unit

dy : Distance between the auxiliary wheel unit and the floor

h : height of the obstacle

dy_1: the distance between the auxiliary wheel unit and the floor at the height of the obstacle

$$\theta_{12} = sin^{-1}\frac{R_2 - DY}{R_2} \quad (1)$$

$$X_1 = R_2 cos\theta_{12} \quad (2)$$

$$\theta_{11} = tan^{-1}\frac{R_1 - H}{X_1 + DX_2} \quad (3)$$

$$\theta_{21} = sin^{-1}\frac{R_1 - H}{R_1} \quad (4)$$

Impact calculation fixed the contact point between the auxiliary wheel unit and the obstacle, the radius and offset of the auxiliary wheel unit were varied the radius of the front wheel is calculated based on the 8-inch wheels most commonly used for personal mobility. The height of the obstacle is 60% of the front wheel and the normal wheel cannot exceed it. Tables 1 and 2 calculated the offset change of the front wheel and the auxiliary wheel unit according to the change of the length of the radius of the auxiliary wheel unit using

Equation 1. Table 1 assumes that the length of the auxiliary wheel unit radius is less than or equal to the diameter of the front wheel. Table 2 is calculated assuming a large case as opposed to Table 1. And the impact amount in the horizontal direction vertical direction according to the presence or absence of the auxiliary wheel unit was obtained by using this.

Table 1. When the radius of the auxiliary wheel unit is shorter than the radius of the front wheel, the offset distance variation due to the change of the auxiliary wheel unit radius

	r_2	dx_2	x_1
1	100	134.355957	80
2	105	131.893845	82.46211251
3	110	129.503144	84.85281374
4	115	127.177978	87.17797887
5	120	124.913238	89.4427191
6	125	122.704443	91.6515139
7	130	120.547642	93.8083152
8	135	118.439327	95.91663047
9	140	116.376368	97.97958971
10	145	114.355957	100
11	150	112.375567	101.9803903
12	155	110.432909	103.9230485
13	160	108.525905	105.8300524
14	165	106.652661	107.7032961
15	170	104.811446	109.5445115
16	175	103.000670	111.3552873
17	180	101.218872	113.137085
18	185	99.4647047	114.8912529
19	190	97.7369198	116.6190379
20	195	96.0343620	118.3215957
21	200	94.3559577	120

Table 2. When the radius of the auxiliary wheel unit is longer than the radius of the front wheel, the offset distance variation due to the change of the auxiliary wheel unit radius

	r_2	dx_2	x_1
1	200	94.355957	120
2	210	91.067677	123.288280
3	220	87.864851	126.491106
4	230	84.741143	129.61481
5	240	81.690966	132.664991
6	250	78.709358	135.646599
7	260	75.791893	138.564064
8	270	72.934601	141.421356
9	280	70.133906	144.22205
10	290	67.386573	146.969384
11	300	64.689662	149.666295
12	310	62.040495	152.315462
13	320	59.436623	154.919333
14	330	56.875800	157.480157
15	340	54.355957	160
16	350	51.875189	162.480768
17	360	49.431732	164.92422
18	370	47.023952	167.332005
19	380	44.650330	169.705627
20	390	42.309452	172.046505
21	400	39.999999	174.355957

Table 3 and Table 4 calculate vertical force and horizontal force when the radius of the auxiliary wheel unit is smaller than the diameter of the front wheel. The calculation method is calculated by substituting the data of Table 1 into Equation 2 and Equation 4. The horizontal and vertical impacts were determined by the presence or absence of auxiliary wheels. The range of $r_2$is between 100 mm and 200 mm. As shown in the table, in the absence of the auxiliary wheel unit, the horizontal impact is about 0.9165, which is close to 1. On the other hand, in the case of the auxiliary wheel unit, as the value of r 2 increases, the horizontal direction impulse amount is decreased by about 0.6% and about 30% when the radii of the front wheel and the auxiliary wheel unit are the same. In the case where the vertical direction component degree auxiliary wheel unit is not provided, a value of about 0.4115 is shown. When the auxiliary wheel unit is present, the value is between 0.6 and 0.8. This is about twice the value when the diameter of the front wheel is equal to the radius of the auxiliary wheel unit.

Table 3. When the radius of the auxiliary wheel unit is shorter than the radius of the front wheel, impact of horizontal component

r_2	Horizontal component			
	After mounting: $\cos(\theta_{1\,2})$	After mounting: $\theta_{1\,2}$	Before mounting: $\cos(\theta_{2\,1})$	Before mounting: $\theta_{2\,1}$
100	0.8	0.64350	0.91651	0.41151
105	0.78535	0.66752	0.91651	0.41151
110	0.77138	0.68977	0.91651	0.41151
115	0.75806	0.71044	0.91651	0.41151
120	0.74535	0.72972	0.91651	0.41151
125	0.73321	0.74776	0.91651	0.41151
130	0.72160	0.76468	0.91651	0.41151
135	0.71049	0.78059	0.91651	0.41151
140	0.69985	0.79560	0.91651	0.41151
145	0.68965	0.80978	0.91651	0.41151
150	0.67986	0.82321	0.91651	0.41151
155	0.67047	0.83595	0.91651	0.41151
160	0.66143	0.84806	0.91651	0.41151
165	0.65274	0.85959	0.91651	0.41151
170	0.64437	0.87058	0.91651	0.41151
175	0.63631	0.88108	0.91651	0.41151
180	0.62853	0.89112	0.91651	0.41151
185	0.62103	0.90073	0.91651	0.41151
190	0.61378	0.90995	0.91651	0.41151
195	0.60677	0.91879	0.91651	0.41151
200	0.6	0.92729	0.91651	0.41151

Table 4. When the radius of the auxiliary wheel unit is shorter than the radius of the front wheel, impact of vertical component

r_2	Vertical component			
	After mounting: $\cos(\theta_{1\,2})$	After mounting: $\theta_{1\,2}$	Before mounting: $\cos(\theta_{2\,1})$	Before mounting: $\theta_{2\,1}$
100	0.6	0.64350	0.4	0.41151
105	0.61904	0.66752	0.4	0.41151
110	0.63636	0.68977	0.4	0.41151
115	0.65217	0.71044	0.4	0.41151
120	0.66666	0.72972	0.4	0.41151
125	0.68	0.74776	0.4	0.41151
130	0.69230	0.76468	0.4	0.41151
135	0.70370	0.78059	0.4	0.41151
140	0.71428	0.79560	0.4	0.41151
145	0.72413	0.80978	0.4	0.41151
150	0.73333	0.82321	0.4	0.41151
155	0.74193	0.83595	0.4	0.41151
160	0.75	0.84806	0.4	0.41151
165	0.75757	0.85959	0.4	0.41151
170	0.76470	0.87058	0.4	0.41151
175	0.77142	0.88108	0.4	0.41151
180	0.77777	0.89112	0.4	0.41151
185	0.78378	0.90073	0.4	0.41151
190	0.78947	0.90995	0.4	0.41151
195	0.79487	0.91879	0.4	0.41151
200	0.8	0.92729	0.4	0.41151

Tables 5 and 6 use the data in Table 2 to calculate the case where the radius of the auxiliary wheel unit is equal to or greater than the diameter of the front wheel. The calculation method is calculated by substituting the data of Table 2 into Equation 2 and Equation 4. First, the horizontal component is about 0.9165 when there is no auxiliary wheel unit. When the radius of the auxiliary wheel unit is twice the diameter of the front wheel, the value is about 0.4358, which is less than 50% of the case where there is no auxiliary wheel unit. The vertical direction component also shows a value between 0.8 and 0.9. The calculation shows that the numerical value is more than twice the numerical value in the absence of the auxiliary wheel unit and that the larger the radius of the auxiliary wheel unit, the more the obstacle can be overcome. The following graph is used for a more authentic contrast.

Table 5. When the radius of the auxiliary wheel unit is longer than the radius of the front wheel, impact of horizontal component

Horizontal component				
r_2	After mounting: $\cos(\theta_1\ {}_2)$	After mounting: $\theta_1\ {}_2$	Before mounting: $\cos(\theta_2\ {}_1)$	Before mounting: $\theta_2\ {}_1$
200	0.6	0.92729	0.91651	0.41151
210	0.58708	0.94334	0.91651	0.41151
220	0.57495	0.95824	0.91651	0.41151
230	0.56354	0.97212	0.91651	0.41151
240	0.55277	0.98511	0.91651	0.41151
250	0.54258	0.99728	0.91651	0.41151
260	0.53293	1.00872	0.91651	0.41151
270	0.52378	1.01951	0.91651	0.41151
280	0.51507	1.02969	0.91651	0.41151
290	0.50679	1.03933	0.91651	0.41151
300	0.49888	1.04848	0.91651	0.41151
310	0.49134	1.05716	0.91651	0.41151
320	0.48412	1.06543	0.91651	0.41151
330	0.47721	1.07331	0.91651	0.41151
340	0.47058	1.08083	0.91651	0.41151
350	0.46423	1.08803	0.91651	0.41151
360	0.45812	1.09491	0.91651	0.41151
370	0.45224	1.10151	0.91651	0.41151
380	0.44659	1.10784	0.91651	0.41151
390	0.44114	1.11392	0.91651	0.41151
400	0.43588	1.11976	0.91651	0.41151

Table 6. When the radius of the auxiliary wheel unit is longer than the radius of the front wheel, impact of vertical component

Vertical component				
r_2	After mounting: $\cos(\theta_1\ {}_2)$	After mounting: $\theta_1\ {}_2$	Before mounting: $\cos(\theta_2\ {}_1)$	Before mounting: $\theta_2\ {}_1$
200	0.8	0.92729	0.4	0.41151
210	0.80952	0.94334	0.4	0.41151
220	0.81818	0.95824	0.4	0.41151
230	0.82608	0.97212	0.4	0.41151
240	0.83333	0.98511	0.4	0.41151
250	0.84	0.99728	0.4	0.41151
260	0.84615	1.00872	0.4	0.41151
270	0.85185	1.01951	0.4	0.41151
280	0.85714	1.02969	0.4	0.41151
290	0.86206	1.03933	0.4	0.41151
300	0.86666	1.04848	0.4	0.41151
310	0.87096	1.05716	0.4	0.41151
320	0.875	1.06543	0.4	0.41151
330	0.87878	1.07331	0.4	0.41151
340	0.88235	1.08083	0.4	0.41151
350	0.88571	1.08803	0.4	0.41151
360	0.88888	1.09491	0.4	0.41151
370	0.89189	1.10151	0.4	0.41151
380	0.89473	1.10784	0.4	0.41151
390	0.89743	1.11392	0.4	0.41151
400	0.9	1.11976	0.4	0.41151

Figures 3 show the horizontal and vertical components of the radius of the auxiliary wheel unit between 100 mm and 200 mm. In the component in the horizontal direction, it can be easily confirmed that the amount of the impact decreases as the radius of the auxiliary wheel unit becomes larger. On the other hand, when there is no auxiliary wheel unit device, it has a constant value and is distributed close to 1. There is a clear difference between the case with and without vertical component. Figures 4 show that the larger the radius of the auxiliary wheel, the greater the difference between the two values than when there is no auxiliary wheel unit.

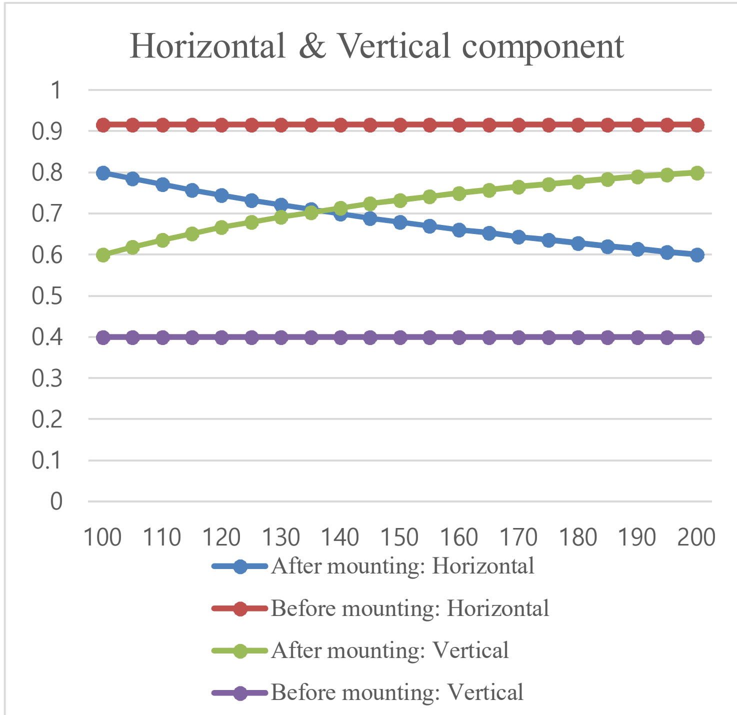

Figure 3. Horizontal and vertical component impulse comparison graph before and after mounting of auxiliary wheel unit longer than front wheel radius

3. 3 D - Modeling

We designed the auxiliary wheel unit using the 3D design program Inventor and made the first prototype using 3D printer. Figure 4 is a model of the second prototype. Functional and structural aspects have been improved over the first prototype by eliminating unnecessary parts in the first modeling and supplementing the design with efficient design. Figure 5 shows a second prototype made with a 3D printer to assemble to the front of the electric kickboard. The test was carried out over the obstacle by attaching it to the actual kickboard, and it was possible to move beyond the obstacle normally.

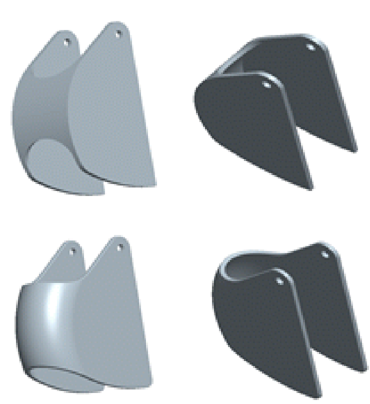

Figure 4. 2nd prototype design through complementation of 1st prototype design

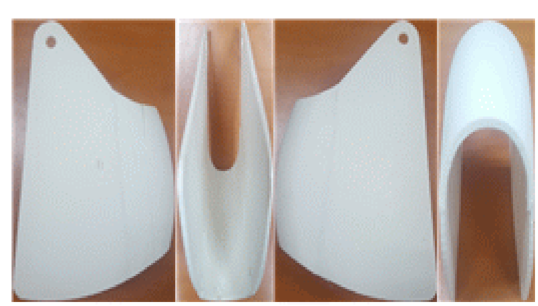

Figure 5. Manufacture of prototype model

4. Conclusion

In this paper, we developed a mechanism for improvement of driving stability and accident prevention of personal mobility using small wheels. Particularly, it was possible to safely pass obstacles by attaching a small fan-shaped auxiliary wheel unit without using an expensive additional device. The auxiliary wheel unit is mounted in front of the front wheel of the moving means to meet the obstacle first, and the auxiliary wheel unit overcomes the obstacle. The front wheel is lifted above the obstacle by the resultant force of the forces in the vertical direction and the horizontal direction. Then, the auxiliary wheel unit is returned to its original position by the spring tension, and the front wheel can pass the obstacle safely. The above facts were confirmed through experiments.

In this study, we thought that it can contribute to coping with accidents that may occur when driving a small wheel, and the optimization study such as the offset distance between the auxiliary wheel unit and the front wheel will be conducted later.

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