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Development of Electric Motion Wheel Chair Driving System using Planetary Gear Device

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Abstract

A wheelchair is an essential rehabilitation assistant device for the movement of paraplegia patients and generally paralyzed patients who cannot walk normally. In particular, the applicability of the manual/motorized wheelchair is gradually increasing. Until now, decelerators using belt, chain and worm gears, etc have been widely used. However, a decelerator takes a large space although it is a simple device and thus is not ideal for the driving part of manual/motorized wheelchair. For these reasons, in this study we developed a driving part producing a large driving force through a decelerator using planetary gears rather than conventional worm gear-based decelerator. We designed the tooth profile of the planetary gears for decelerator using Kisssoft program, In addition, we designed the driving part so as to apply it to the wheels of conventional wheelchairs, and then optimized the mechanism for the principles of manual/motorized transposition of the driving part and the operational principles. Based on the results of this study, we finally designed and manufactured a driving part for wheelchair decelerator in the form of planetary gears with 1 sun gear, 2 planetary gears and 1 ring gear.

Keywords: *Electric motion wheel chair, Disadhesion, Planetary gear, Driving system.*

1. Introduction

Wheelchair is a rehabilitation assistive device which is essential for patients with paraplegia or general paralysis who cannot walk properly. The research and development of wheelchair is being proceeded in two large ways. The first one is a special wheelchair which can assist the patients with general paralysis working. It enables users to actually stand up in random position and work. This type of special wheelchair is designed in a way that the users can move their body into certain position that they want and they can control all the

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movements with buttons[1-3]. The second one is a wheelchair which is suitable for patients with paraplegia or disorders with lower body whose lower body is not functional but can still use their upper body. This type of wheelchair is manufactured with composite fibrous material or ultralight material, enabling to adapt not only in vehicle-related long distance movement, but also in many sports such as basketball, ski and marathon[4]. And recently, electric motion wheelchair, which contains both manual and automatic function, is being developed centering around Germany and Japan. It modulizes the parts such as frame, drive system, battery, and control so that the users can assemble and dismantle the product and can have variety of activity scope such as driving on steep incline. As we can see on Figure 1, electric motion wheelchair has the structure of functioning by control operator, equipping drive system, battery and control part.

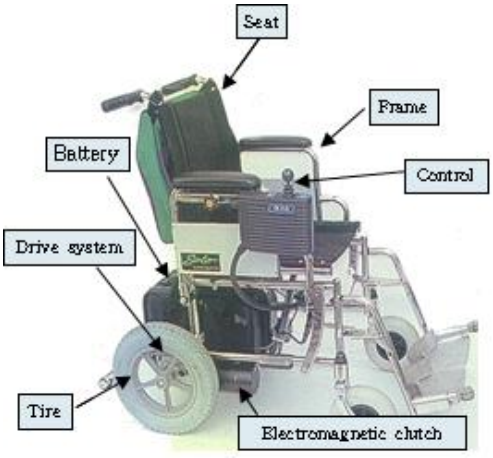


Figure 1. Electric wheelchair

The key point to design an efficient driving system is to choose adequate motor and reduction gear. And the role of reduction gear is to increase the low torque to higher torque and reduce the high velocity to lower velocity to run the wheelchair and then deliver them to the wheel. Therefore, reduction gear has to be efficient in power delivery and be downsized to lighten the weight of whole wheelchair even it is on load[5]. Until now, reduction gear using belt, chain, worm gear was generally used. Reduction gear using belt or chain is simple but takes too many spaces which is not suitable for electric motion wheelchair that has the space restraints. Reduction gear using worm gear make relatively less noise and can reduce the velocity dramatically. But due to its vertical structure of input and output axis, power loss by moment of inertia is huge, and it also has limitation of installation space. As a result, it is not suitable driving system of electric motion wheelchair, which needs lightened and downsized[6,7]. On the other hand, reduction gear using planetary gear is possible to be lightened/ downsized, and is effective in power delivery which makes us to get the reduction ratio we want. Also, planetary gear system is suitable for every type of driving condition since it can maximize both reliability and durability by alleviating damages, and does not have moment of inertia by positioning input and output axis at the same axis[8-10]. So on this research, we designed electric motion wheelchair by designing gear teeth of planetary-gear-formed reducer and adapting the reducer to hub area. Also, we chose DC motor which is suitable for lightening/ downsizing the driving system of electric motion wheelchair, then integrated motor and planetary gear.

2. Motor Drive Structure Design

We designed reducer to maximize lack of torque when running the motor. This reducer is a planetary form and designed as a form of existing warm gear. With planetary gear, the whole volume can be minimized, and

driving system is able to be downsized by installing sun gear, planetary gear and ring gear at the same position[11-13]. Planetary gear device designed on this research has the form of combining two planetary gear and one ring gear to one sun gear, which is described in Figure 2. The final reduction ratio 24:1 was embodied with using normal wheelchair and setting up 12 units of sun gear, 48 units of first planetary gear, 9 units of second ring gear, 51 units of ring gear.

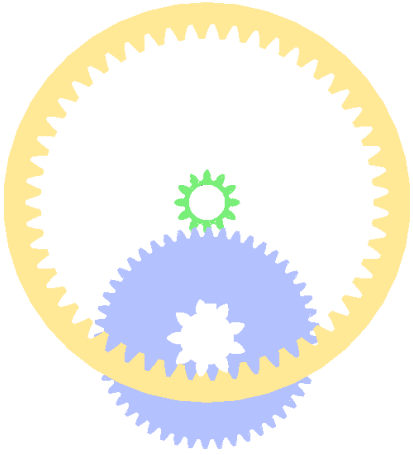


Figure 2. Design of planetary gear speed reducer

Based on basic structure of reducer, we have designed gear teeth with gear-designing program Kisssoft as Table 1 and Table 2.

Table 1. Design of sun gear and planet gear1.

Article	Sun gear	planet gear1
Module	1.000	
Pressure angle	20.000	
Number of teeth	12	48
coefficient of potential	0.300	0.000
Backlash	0.158	
Minimum Backlash	0.072	
Maximum Backlash	0.201	
Center distance	29.500	29.500
Pitch diameter [do]	12.000	46.000
Basic diameter [dg]	11.276	43.226
Addendum circle diameter [dk]	14.579	47.979
Dedendum circle diameter [dr]	10.100	43.500
Torque [N·m]	1.000	3.833
RPM [rpm]	1800.000	469.565
Peripheral velocity [m/s]	1.150	

Face width [mm]	5.000
circumference force [N]	163.842
Teeth stress[N]	177.363
Axial stress [N]	67.923

Table 2. Design of planet gear2 and ring gear

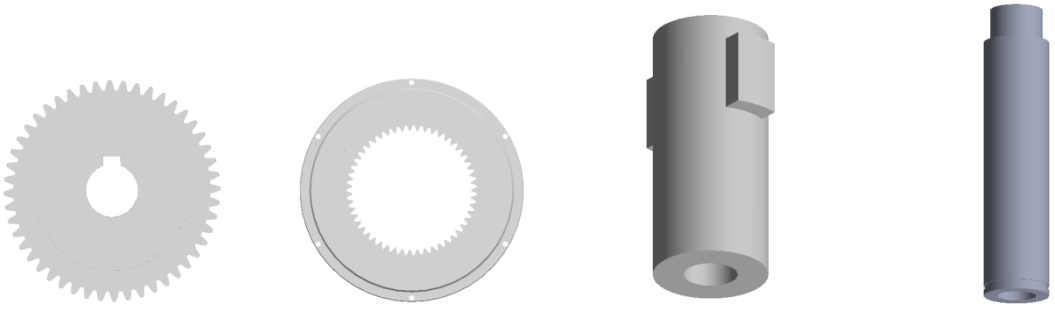
Article	Planet gear2	Ring gear
Module	1.500	
Pressure angle	20.000	
Number of teeth	9	51
coefficient of potential	0.400	0.000
Backlash	0.162	
Minimum Backlash	0.082	
Maximum Backlash	0.307	
center distance	32.724	32.800
Pitch diameter [do]	13.500	81.000
Basic diameter [dg]	12.686	76.115
Addendum circle diameter [dk]	17.700	78.000
Dedendum circle diameter [dr]	10.950	84.750
Torque [N · m]	5.000	30.000
RPM [rpm]	350.000	58.333
Peripheral velocity [m/s]	2.404	
Face width [mm]	10.000	
circumference force [N]	762.195	
Teeth stress[N]	788.280	
Axial stress [N]	201.106	
Article	Sun gear	planet gear1
Module	1.000	
Pressure angle	20.000	
Number of teeth	12	48
coefficient of potential	0.300	0.000
Backlash	0.158	
Minimum Backlash	0.072	
Maximum Backlash	0.201	
Center distance	29.500	29.500
Pitch diameter [do]	12.000	46.000

Basic diameter [dg]	11.276	43.226
Addendum circle diameter [dk]	14.579	47.979
Dedendum circle diameter [dr]	10.100	43.500
Torque [N·m]	1.000	3.833
RPM [rpm]	1800.000	469.565
Peripheral velocity [m/s]	1.150	
Face width [mm]	5.000	
circumference force [N]	163.842	
Teeth stress[N]	177.363	
Axial stress [N]	67.923	

3. Development of wheelchair reducer

3.1 Part design

We have set up the mechanism of reducer using planetary gear from. Based on designed gear teeth, shown as Figure 3. made 3D model using the program "Pro-engineering" and all the parts assembled is shown as Figure 4.



(a) Planet gear1 **(b) Ring gear** **(c) Clutch pin** **(d) Clutch pin shaft**

Figure 3. 3- D Modeling of driving system parts

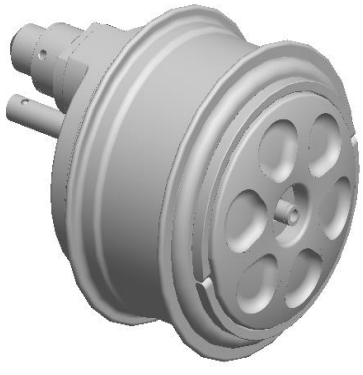


Figure 4. Assembly of driving system

Having the detachable structure to the wheel that is already being used, by pushing the button placed on the middle of housing, wheel can easily separate reducer, removing the ball part which is fixed in the hub of wheel. As a result, it has the advantage of detachability. Also, when losing all the battery and the function of electric wheelchair running with this reducer, input gear can replace the function of clutch, so that the electric wheelchair can convert into manual. As Figure 5, its fundamental is when pushing the hand ring, it becomes electric wheelchair since the input gear is adjusted to the serrated wheel inside the inner gear of clutch pin by the pressure of the spring. Then once the hand ring part is activated once again, input gear is dismantled from clutch pin by the pressure of the wheelchair and becomes manual.

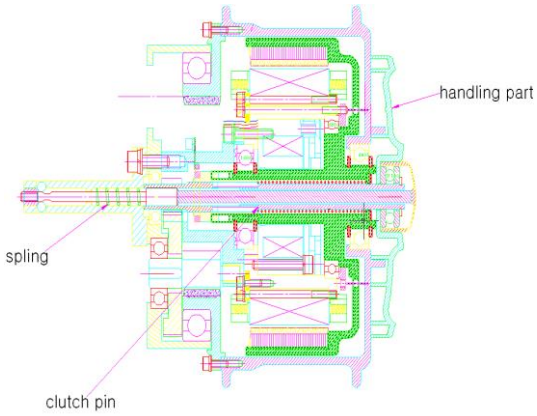
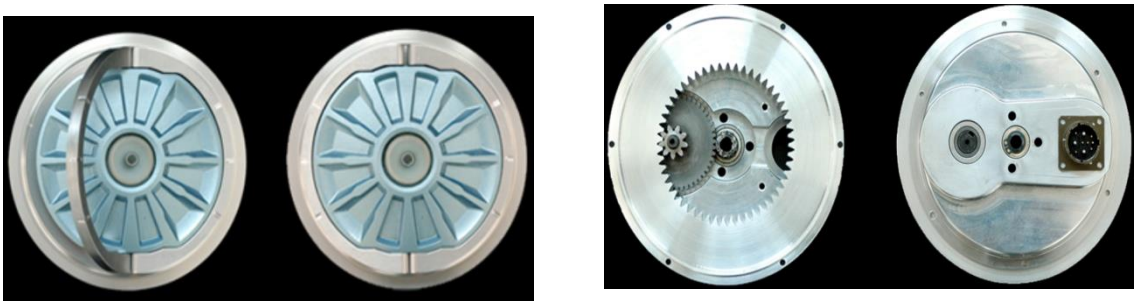


Figure 5. Performance property of speed reducer

3.2 Manufacture of drive part

The performance property of planetary-gear-formed reducer is as follows. Once the rotating cylinder is activated by the external power, it generates driving torque on motor axis, then by first and second planetary gear on input shaft, each first and second speed reduction is made. So, through operating wheels of wheelchair which is connected to ring gear, wheelchair can finally be functioning. Driving part designed on this research, can be converted into automatic and manual, and we preceded minimized designing of driving part by using planetary gear. Using designed model, produced parts of wheelchair as Figure 6, and structure of reducer is shown on Figure 7.

Figure 6. Analysis of plate



(a) Front view **(b) Rear view**

Figure 7. Manufacture of driving system

4. Conclusion

On this research, study on driving part, without changing the original from of wheelchair, that can be converted into automatic and manual using the wheel attached on wheelchair was made. Choosing number of gears and designing detail of gear teeth was based on JIS standard. Also, by designing planetary-gear-formed reducer, we were able to maximize the effectiveness of driving part, lighten through minimization of its volume, and reach to the conclusion as below.

1) By using existing wheelchair, we increased the driving torque of electric wheelchair's detachable driving part setting up the reduction ratio as 24:1.

2) Minimization on the whole part of driving part was made through substituting worm gear form of reducer, which delivers the power in vertical direction, to planetary gear form of reducer, which delivers the power in straight direction.

3) Optimization on gear teeth of reducer was proceeded by designing planetary-gear-formed gear teeth of reducer.

4) By designing the reducer of wheelchair as automatic/ manual convertible, we were increased the comfort of users so that they can convert it easily to manual even when the battery is all used.

5) Produced electric motion wheelchair based on designed data.

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