A Multi-Function Walker for Assisting Elderly Mobility

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2016

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Abstract

The walker is regarded as a promising solution to provide additional support to maintain balance or stability while walking for elderly people. Significant assistance in improving mobility technology have been observed from literature review. However, the walkers available in the market is possible to optimize in design and include additional functionality, including getting out of the seat at home with caregiver aid, emergency care aided system. Considering falling down is a public healthcare problem, we designed the emergency aided system to rescue them [1].

In this paper, we proposed a multiple function elderly mobility and emergency aid system, was developed and modelled by Inventor 2015, and finite element analysis. Simulation was then created to get the value of safety factor, and make comparison base on the results from structural calculation. Finally, the application of few features of the improved walker was illustrated.

Key words: Computer aided design; Elderly mobility device; Finite Element Simulation; Healthcare system; Walker
Acknowledgements

We would like to express our gratitude to our advisor Md. Shafiqul Islam for his support, patience, and encouragement throughout our graduate studies. It is not often that one finds an advisor that always finds the time for listening to the little problems and roadblocks that unavoidably crop up in the thesis. Especially we are not good at academic writing, his technical and editorial advice was essential to the completion of this dissertation and has taught us innumerable lessons and insights on the workings of academic research in general.

Then, our thanks also go to the Dr. Mats Walter and Dr. Sharon Kao-Walter who help us develop much information on the healthcare area. At the same time, we appreciate that Professor Wlodek Kuleza who taught us how to write an appropriate academic paper. Providing many valuable comments that can improve the presentation and contents of this dissertation.

Finally, we would like to thank our family members that support us all the time, we cannot get these achievements without them.

Jindou Shi
Mengfei Zhao
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<th>Unit</th>
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<tr>
<td>( m )</td>
<td>Mass</td>
<td>Kg</td>
</tr>
<tr>
<td>( v )</td>
<td>Speed</td>
<td>m/s</td>
</tr>
<tr>
<td>( u )</td>
<td>Friction factor</td>
<td>N</td>
</tr>
<tr>
<td>( f )</td>
<td>Friction force</td>
<td>N</td>
</tr>
<tr>
<td>( w )</td>
<td>Angular velocity</td>
<td>rad/s</td>
</tr>
<tr>
<td>( n )</td>
<td>Rotate speed</td>
<td>rpm</td>
</tr>
<tr>
<td>( \eta )</td>
<td>Transmission efficiency</td>
<td></td>
</tr>
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<td>( i )</td>
<td>Transmission ratio</td>
<td></td>
</tr>
<tr>
<td>( L )</td>
<td>Length</td>
<td>cm</td>
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<tr>
<td>( r )</td>
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<td>cm</td>
</tr>
<tr>
<td>( \theta )</td>
<td>Angle</td>
<td>°</td>
</tr>
<tr>
<td>( T )</td>
<td>Torque</td>
<td>N.m</td>
</tr>
<tr>
<td>( \varphi_d )</td>
<td>Tooth width factor</td>
<td></td>
</tr>
<tr>
<td>( \delta_{\text{Hlim}} )</td>
<td>The contact fatigue limit</td>
<td>MPa</td>
</tr>
<tr>
<td>([\delta_H])</td>
<td>Allowable contact stress</td>
<td>MPa</td>
</tr>
<tr>
<td>( b )</td>
<td>Tooth width</td>
<td>mm</td>
</tr>
<tr>
<td>( Z )</td>
<td>Number of teeth</td>
<td></td>
</tr>
<tr>
<td>( K_A )</td>
<td>Coefficient of performance</td>
<td></td>
</tr>
<tr>
<td>( K_V )</td>
<td>Dynamic load coefficient</td>
<td></td>
</tr>
<tr>
<td>( K_{Hlo} )</td>
<td>Load distributing factor</td>
<td>Between teeth</td>
</tr>
<tr>
<td>( K_{H\beta} )</td>
<td>Tooth load distribution</td>
<td>Coefficient</td>
</tr>
<tr>
<td>( K )</td>
<td>Load factor</td>
<td></td>
</tr>
<tr>
<td>( Z_E )</td>
<td>Elastic coefficient</td>
<td></td>
</tr>
<tr>
<td>( Z_H )</td>
<td>Coefficient of node area</td>
<td></td>
</tr>
<tr>
<td>( Z_\beta )</td>
<td>Coincidence coefficient</td>
<td></td>
</tr>
<tr>
<td>( S_{1\text{min}} )</td>
<td>Contact stress of the minimum</td>
<td>Safety factor</td>
</tr>
<tr>
<td>( N_L )</td>
<td>Stress-number of cycles</td>
<td></td>
</tr>
<tr>
<td>( Z_N )</td>
<td>Contact life factor</td>
<td></td>
</tr>
<tr>
<td>( a )</td>
<td>Center distance</td>
<td>mm</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
<td>Unit</td>
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<tr>
<td>--------</td>
<td>----------------------</td>
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</tr>
<tr>
<td>$Y_{Fa}$</td>
<td>Tooth form factor</td>
<td></td>
</tr>
<tr>
<td>$Y_{sa}$</td>
<td>Load interaction factor</td>
<td></td>
</tr>
<tr>
<td>$[\delta_{f}]$</td>
<td>Permissible bending stress</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Pitch diameter</td>
<td>mm</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Shear stress force</td>
<td>N</td>
</tr>
<tr>
<td>G</td>
<td>Shear modulus</td>
<td>MPa</td>
</tr>
<tr>
<td>C</td>
<td>Spring index</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>Circles of spring</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Height of spring</td>
<td>mm</td>
</tr>
<tr>
<td>t</td>
<td>Pitch</td>
<td>mm</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Helical angle</td>
<td>°</td>
</tr>
<tr>
<td>$F'$</td>
<td>Stiffness</td>
<td>N/mm</td>
</tr>
<tr>
<td>P</td>
<td>Pressure</td>
<td>Pa</td>
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## List of acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Unfolding</th>
</tr>
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<tbody>
<tr>
<td>FEM</td>
<td>Finite Element Method</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
</tr>
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</table>
Chapter: Introduction

There are 1.63 million elderly people aged 65 and over in Sweden which is about 17 percent of total population according to Figure 1-1. Most elderly people become dependent on supporting from relatives and the community due to various reduced functional abilities, many health problems can arise as people age, which can affect their quality of life. Increased knowledge of the significance and benefits of keeping an active life has led to the older generation being encouraged to remain active. Mobility is a crucial factor which can obviously reduce the risks accompanied with inactivity. At the same time, remaining mobile independently can be one of the greatest challenges for the elderly people.

According to a research by Hjalpmedelsinstitutet (2000) [3], there are 300,000 people in Sweden use a 4-wheeled walkers in their daily environment. The number of users more than any other countries in the world. In Sweden, the 4-wheeled walker has been proven that can maintain good mobility and walk forward independently for elderly people. Although there are several current health-care walkers that can significantly improve their quality of life, other additional issues accompanied with their daily activities was addressed in this study.

Figure 1-1: The proportion of population aged 65 and over [2]
Falling down is a serious public health problem among elderly people because of its frequency [4]. Approximately 30 percent of people aged 65 and over fall each year while walking on the way to public places. The nonfatal results of falls involved physical injury, fear, functional deterioration. Hip fracture becomes one public health problem due to the age, older people are at a higher risk of hip fracture (Figure 1-2) because bones tend to weaken with age. The number of hip fractures in Sweden is estimated to be 18,000 per year, which amounts to a significant public health cost.

A thorough literature review has found that there is a lack of other considerations for current walkers while using in the inside and outside activities. Therefore, in this study, the purpose of the thesis is to investigate the issues occur in the daily life environment and put up with a new design base on the current walker for elderly people. The models are designed in Auto-desk Inventor Professional 2015, and also simulate daily conditions in Inventor, calculating the safety factor.
2 Chapter: Background

The demographic shift towards an aging population making the demand for aged increase, placing more considerations on the health-care walkers. Aging can lead to a steady decline in an individual’s cognitive, physical and sensory functions [6]. These reduced functional abilities can result in omit problems on looking after themselves.

Previous studies have shown mobility can be a crucial factor in reducing risks accompanied with age. Nowadays, there are a lot of walkers in the field of providing a mobility for the elderly and disabled, as Figure 2-1 shows, walker is popular device to assist in this area which to has some advantages in providing an effective and safe approach to respond an increasing demand health-care for elderly people.

![Figure 2-1: General walker for the elderly][7]

Walker is a kind of mobility aid used to assist people who are still able to walk, which allows a person to lean on it for support, balance, and rest, enable the users to have more freedom in movement to perform daily activities. Walkers are usually made up of aluminum so that can pick up and move easily. The wheels are often covered with rubber caps that can prevent slipping and improving stability and suspension. There are different types of walkers.

![Figure 2-2: 4-wheels walker for elderly][8]
For example, as shown in Figure 2-2, the front wheels can be rotated freely to help users overcome difficulties in hard terrain, at the same time, when they are tired on the way to outside, they can seat with a comfortable position. There are many current designs considering the health-care development involved in maintaining good stability and mobility, but less has been done to considerate functionality both in the inside and outside. In that situation, they will face the problems such as: have difficulties standing up after meal at home, separating different items in the supermarket, falling down on the way to outside.

It is important to investigate users’ different needs in several types of conditions. Falling down while standing or walking is a serious public health problem for elderly people. Currently, the emergency trolley stretcher provides an excellent transport with an easy operation. The bed is connected with backrest through ratchet. The structure is made of stainless steel which can support the patient safely and move forward easily because of the light weight [9].

![Existing stretcher in the hospital](image)

Figure 2-3: Existing stretcher in the hospital [10]

There are several kinds of current walkers referring to our problems separately. On the one hand, they have advantages we can learn, but some limitations need to solve. Thus, we will design a new walker base on the current problems that we had mentioned. Because our design is for the old people, we will more focus on considering their daily life environment as well.
Chapter: Problem statement, objectives and main contribution

3.1 Problem Statement

A walker that could help navigate and avoid collisions with barriers could help reduce health cost and increase independence of elderly people. [11] Currently, several different assisted walkers for elderly people had been developed. The purpose of these devices are to provide a support function to increase their mobility. However, based on our research in daily life environments for elderly people, we find there are also several issues as following:

- No support to assist the upper body when getting out of the seat at home.
- Although they bring their own shopping cart, they still use store’s basket in order to separate different items in the supermarket.
- Not enough storage space for elderly people to keep some extra stuff on the 4-wheels aluminum walker.
- They need caregiver to help them when walking on the steep surface.
- No emergency care device to help them when they fall.
- No adjustable and comfortable nor other support for resting on the walker.

3.2 Objectives and Contribution

According to the previous section, there are few health-care issues produced in the daily life of elderly people. We find that health-care emergency is a neglected issue in the literature of mobility device [12]. Since the absence of humanistic concern and emergency device has a direct effect on health-care facilities. Therefore, the main objective of our thesis is to develop a multi-function mobility aid device by integrating walking aid and emergency device. This paper contributes to the existing literature and based on this thesis project have four categories which as follows:

- In order to decrease the risks accompanied with age and improve the mobility in daily life environment, we propose a multi-objective walking aid device which can provide different important functions for the elderly people.
• Due to falling down had been a frequent health public problem, we provide a new approach for emergency case, so that they can be transferred to nearby hospital easily.

• Modeling and simulating in Auto-desk Inventor 2015, and comprised between structural calculation with theatrical parameters.

• Design PLC on the Micro-computer on Keil and Proteus 7.8.
Chapter: Solution

4.1 Specific concepts and design with different solutions

4.1.1 Stair climbing wheels

Stairs provide a method of ascent and descent. Normally powered assisted mechanisms such as elevators or lifts is a best choice. However, when elderly people are needed to be transferred from upstairs to the ground floor without any lift equipment; stairs have come to be virtually representative of ‘barriers’ [13]. The common way to pick up unconscious or disabled person is to use stretcher by two people. As Figure 4-1 shown: this traditional way not only can occupy too much space if there is no elevator, but also spend too much energy to carry.

Figure 4-1: Stretcher carried by two people [14]
The wheeled mobility has been one of the most important technical discoveries, the step function of a stair versus the sinusoidal is illustrated as shown in Figure 4-2.

![Figure 4-2: Variation of wheel diameter in regard to stair negotiation [13]](image)

The second approach is to increase effectively the forward-rear footprint of the wheel, so that it bridges the stairs. Scalevo is a completely automated stair-climbing wheelchair that can getting from A to B a bit easier for disabled people. As shown in Figure 4-3, using rubber belt to climb the stairs, this prototype is called “Scalevo”.

![Figure 4-3: Stair Climbing Wheelchair [15]](image)

This kind of device has flexible automatic control system, by comparison, climbing the stairs backwards to give the person in the chair more legroom and to stop them from having to be tipped backwards, which can be nervous.
Traveling up the stairs backwards also allows the user to see what is below him [16] and the angle of the rubber tracks can be adjusted to not depend on outside force.

The relative advantages and disadvantages of these two solutions to climb stairs are that putting weight on the stair’s tread gradually, at the same time, considering the increased risk of slip is more than that on a flat pathway. However, the existing biggest problem is too heavy in case 2, our design purpose is that can assist the elderly to walk easily, which means have a light weight. So they are not ideal solution to adopt.

Stair climbing wheels as shown in Figure 4-4 are commonly used in market carts and appliance trucks. Using three wheels to climb the stairs. The angle between each wheel is 120 degrees. This way can save space, connected with the gear system. Using this method, it can not only reduce the cost, but also improve the reliability while walking.

Figure 4-4: Climbing wheel structure [17]
We started off with some basic requirements of being safe when climbing stairs and better design, high stability. For the scoring we made a list of few basic criteria to compare with each different solution, see Table 1.

<table>
<thead>
<tr>
<th>Method</th>
<th>Economy</th>
<th>Design</th>
<th>Quality</th>
<th>Safety</th>
<th>Popularity</th>
<th>Total</th>
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<tr>
<td>1</td>
<td>4</td>
<td>2</td>
<td>3</td>
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<td>19</td>
</tr>
</tbody>
</table>

(1-bad 2-poor 3-fair 4-good 5-excellent)

Based on our scoring, the third idea was chosen as an ideal approach. In order to make the walker better, we did some research base on the related existing climbing walkers to gather ideas. These approaches in the market are quite good. If using a single wheel method to upstairs, the balancing mechanism is required in any different situations. The mechanism provides articulated front and backward sliders to keep balance when climbing stair so that enable autonomous stair-climbing operation.

However, after discussing with our supervisors, we find two main shortcomings we need to considerate. Firstly, looking up relevant literature about the three-wheels climbing stairs system, we find that it can produce a big shake while downstairs. Increase the amount of wheels can solve this kind of problem, 3-wheels and 4-wheels structure can be regarded as rectangle frame, which can carry elderly people upstairs, but cannot maintain good stability; increasing the amount of wheels to make the track way almost like a circle, but the control system consisted of motors and other components. The heavy structure can be a tough task to assist them. In addition, according to our survey, we find the elderly prefer to living on the first floor. So we reject this approach.

4.1.2 Handle part

In our daily life, we usually find some old people pushing a small carriage, and can put fruits and vegetable in when go to the supermarket. Handle is still
an important part, which not only can provide a support while walking, but also contains the break that can be used to control the speed.

At first, we design the handle frame shown like Figure 4-5, but this selection the elderly people need to bend down, spend extra force to deal with. So we choose method two.

Figure 4-5: L-Shape handle structure

Figure 4-6: Common handle structure

4.2 Specific concepts and design with final solution

The final version of the design of this walker can be seen in the Figure 4-7 and Figure 4-8. All the disadvantages in the previous designs were considered and optimization was performed in this final design. In this design, the usage should be more convenient, more practical. In addition, some new functions were also considered to make the walker much multifunctional.
This walker has two forms. One is walker, which can help the elderly people to walk and when they want to go to the supermarket, they can put some fruits, vegetables, biscuits and so on into the box in this walker. It is very convenient and useful. The old people do not need to hire another carriage outside the supermarkets. And if old people like backrest when they are sitting in the seat. The walker we design can rotate two telescopic rods to make a backrest, shown like the Figure 4-7. And the backrest is made up of cotton. This part is introduced by us later. And the seat is between both sides of handrail. If the old people want to put something into this box, they can rotate the seat.

Figure 4-7: The walker model (no backrest)
Another form of the proposed walker is stretcher for injured people. When the old people fall down suddenly and they can lie down in the stretcher and other people push this stretcher into ambulances or the closest hospital.
4.2.1 Design of the main structure

The main structure consists of two poles and two couples of connected parts. Two poles look like character “X” when people see it in the rear. There are two couples of connected parts in this structure. Figure 4-11 and Figure 4-12 show them. And this structure is connected with four rods, two of them are telescopic rods and the others are normal rods. They are introduced detailed information by us later in this report.

Due to the old we aim at when we designed this walker, the simple way to fold it is wonderful and suitable for them.

Figure 4-10: Pole in folded structure

Figure 4-11: Connected parts and character "X"
4.2.2 Design of the structure which is on both sides of the walker

This structure which is on both sides of the walker contains handles, rear wheels, front wheels and the main structure is mentioned before. The structure on both sides has triangle framework, which consists of three tubes. And this frame makes the whole structure stable.

And in this structure, there is a stand bar and spring to help the old people stand up according to the habit on the old people. When people want to stand up, this stand bar can descend some directions to the ground and give them some force. This stand bar’s height is suitable for the old according to the normal seat’s height in daily life.

![Figure 4-12: Structure on both sides](image)

In general, when people go outside, they always take a bag which can put a key, some paper and so on in it. And if people have their own pets, they often go outside together with their lovely pet. On the basis of its facts, shown in Figure 4-13 our group design a structure as like a hook which can hang some bags and ropes. People do not worry about losing their pets.
4.2.3 Design of wheels

Through many brainstorms together with group member, we decide to cancel the function that can climb the stairs. A caster is an single, double, or compound wheel that is designed to be mounted to the bottom of a larger object so that enable that object to be easily moved [17].

According to this information above, we decide to use mechanism wheel as the front wheel and we regard the fixed castor as the rear wheel.

On the front wheels, there is a shockproof installation which consists of a bumper cylinder and a shockproof spring. It can reduce shock due to the uneven ground when the walker is in motion.
The rear wheel is installed with breaking systems, and the reason is that they need the breaking system to help stop the walker when they want. As shown in Figure 4-14, the working principle is tread the top beam, which make the friction plate joint with the wheel.

4.2.4 Design of the stretched configuration of the walker

This walker can be changed from the walker to the stretcher is our new and original design. The system of stretcher consists of two telescopic rods, two
normal poles and two stand bars. Telescopic rods can be stretched and shortened. Different people have different height; the rods can be adjusted to a reasonable length when the old people’s height is greater.

Two telescopic rods and two normal poles can rotate from -90 degree to +90 degree. So they are regarded as a backrest as well and users can adjust the height of the backrest so as to feel the most comfortable when they sit down.

PLC can control the rotation of two telescopic rods and two normal poles. Our group introduce it in detail later.

Two stand bars and the body structure make a big triangle shape. The function of two stand bars is that adding stability and catching force.

Figure 4-15: The stretcher model

Figure 4-16: Parts of the stretcher
4.2.5 Design of the seat

Due to the function that this walker can be folded, this seat must have this function as well. So our group designed the seat shown in Figure 4-17. This type of seat, shown in Figure 4-17. And this seat can rotate some angles through an axis because under the seat, there is a box which can be put some things into it when the old people go to the supermarkets or go to the gardens. It is very convenient, useful and use redundant space to reach commendable result.

![Figure 4-17: Foldable walker seat model](image)

4.3 Material choice

As a part of design, getting to know the information about different materials’ price and condition is also important. The wheel’s material as shown in Figure 4-18.

![Figure 4-18: The front wheel's information](image)

- Material: Polyurethane (PU)
- Specification: 8-inch
- Diameter: 200mm
- Maximum load: 450Kg
- Price: around 30kr/Kg
The two wheels’ material is different, because the rear wheel has no bumper and rubber can reduce some shock. This enables the walker keep better stability.

4.3.1 Seat’s material

To select the best material and estimate the possible price of whole walker, some similar items are found in Figure 4-20 and Figure 4-21.

A)
So we have a conclusion: choose polyurethane and sponge.

### 4.3.2 Cotton’s material

This cotton must bear the weight of one person, so it is durable.

Weight: 380 $\text{g/m}^2$  
Price: 8.5kr/m
We choose the Medical fabrics: Oxford cloth (100% Polyester). Oxford cloth is a versatile, new fabrics which is useful extensively. It has good ventilation and it is washable and dries easily.

4.3.3 Total cost of the walker components

After finishing the walker components, i.e. The components have been compared in the market, in order to find the best and the proper components which can not only meet the design requirement but also have the proper price.

The total cost of the walker is shown in Table 3:

Table 3: Price list

<table>
<thead>
<tr>
<th>Name</th>
<th>Weight</th>
<th>Unit-price</th>
<th>Quantity</th>
<th>Total-price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handle</td>
<td></td>
<td>25kr</td>
<td>2</td>
<td>50kr</td>
</tr>
<tr>
<td>Seat</td>
<td>0.6kg</td>
<td>30kr</td>
<td>1</td>
<td>30kr</td>
</tr>
<tr>
<td>Rear wheel</td>
<td></td>
<td>45kr</td>
<td>2</td>
<td>90kr</td>
</tr>
<tr>
<td>Front wheel</td>
<td></td>
<td>30kr</td>
<td>2</td>
<td>60kr</td>
</tr>
<tr>
<td>Oxford cotton</td>
<td>380 (g/m^3)</td>
<td>6kr</td>
<td>1</td>
<td>6kr</td>
</tr>
<tr>
<td>Frame</td>
<td>10kg</td>
<td>38kr/kg</td>
<td>1</td>
<td>380kr</td>
</tr>
<tr>
<td>Motor</td>
<td>1.5kg</td>
<td>503kr</td>
<td>2</td>
<td>1006kr</td>
</tr>
<tr>
<td>Gear</td>
<td>1kg</td>
<td>50kr</td>
<td>4</td>
<td>200kr</td>
</tr>
<tr>
<td>Whole walker</td>
<td>15kg</td>
<td>1622kr</td>
<td>1</td>
<td>1822kr</td>
</tr>
</tbody>
</table>
Compare the similar walker in China, although we have designed several new functions, the price is more expensive. We need to modify this method in the future work.
5 Chapter: Structural Analysis

5.1 Driving System Design

The elderly walk on a steep road after shopping, it will increase more effort to uphill. Designing an automatic speed control on the walker can be a good choice to solve this problem. We will design two kinds of mode: normal and uphill. Driving system is the core part of electric walker, consisted of electric motor, speed controller connected with motor, reducer and other transmission components. DC motor by the controller can be adjusted to reach two speed modes while up hillng. Due to the general higher rated speed of DC motor, rated output torque of the DC motor is low, not enough to drive the rear wheels turn to overcome the friction resistance, therefore, must fix a reducer between motor and rear wheel that can not only reduce the output speed, but also increase the output torque.

5.1.1 Driving Mechanism Design

On both sides of the rear wheel driven by two DC motors respectively, motor power needed about half of a single DC motor, at the same time, motor size can be smaller.

![Diagram of Rear Wheel Driving Structure](image.png)

Figure 5-1: Rear wheel driving structure
5.1.2 Driving Motor Selection

Selecting the right motor and drive combination can save energy and improve performance. Currently, the most commonly used motors are: DC motor, induction motor, permanent-magnet synchronous motor (PMSM) and Switched Reluctance Drive (SRD). Their performance comparison is as follows:

<table>
<thead>
<tr>
<th>Motor Type</th>
<th>DC motor</th>
<th>Induction motor</th>
<th>PMSM</th>
<th>SRD</th>
</tr>
</thead>
<tbody>
<tr>
<td>power density</td>
<td>bad</td>
<td>general</td>
<td>good</td>
<td>general</td>
</tr>
<tr>
<td>torque performance</td>
<td>general</td>
<td>good</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>range of speed</td>
<td>small</td>
<td>general</td>
<td>large</td>
<td>large</td>
</tr>
<tr>
<td>power</td>
<td>bad</td>
<td>general</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>easy to operate</td>
<td>best</td>
<td>good</td>
<td>general</td>
<td>general</td>
</tr>
<tr>
<td>reliability</td>
<td>bad</td>
<td>general</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>price</td>
<td>high</td>
<td>low</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>size</td>
<td>large</td>
<td>general</td>
<td>small</td>
<td>small</td>
</tr>
<tr>
<td>weight</td>
<td>heavy</td>
<td>general</td>
<td>light</td>
<td>light</td>
</tr>
<tr>
<td>overall performance</td>
<td>bad</td>
<td>general</td>
<td>best</td>
<td>good</td>
</tr>
</tbody>
</table>

There are several factors we need to consider when designing a walker in our case, combined performance, price, weight and power. We decide to choose PMSM motor.

Based on our survey, we found the normal people usually walk on the road at the speed of 1.48~1.51m/s, the elderly who need assistance at the speed of 0.7m/s. At the same time, the angle of steep road is in the range of 0.5~20 degrees. We need to calculate how much torque and how many revolutions at least, then choose the motor we need.

5.1.3 Parameters of Motor

As shown in Figure 5-2, we make force analysis under the sloping road,
In this case, we assume $\theta = 15^\circ$, $m=7.8\text{kg}$, $u=0.6$. Hence, the friction force:

$$f = umg \cos \theta = 50.42 \text{N}$$

$$F = f + mg \sin \theta = 72.93 \text{N}$$

In theory, the single stage spur gear reducer gear ratio is not allowed exceed 4, preliminary set reducer gear ratio is 3, transfer efficiency with 90%, then calculate torque:

$$T = \frac{F \cdot r}{2 \eta} = 1.35 \text{N.m}$$

$$w = \frac{v}{r} = 21 \text{rad/s}$$

$$n = \frac{w}{2\pi} = 200.4 \text{r/min}$$

Searching for a matched motor relate to our case, using internet can be an ideal tool base on parameters we calculated (as shown in Figure 5-3)

We get a range of motors, considerate weight and cost, we finally choose ST6018M3008, whose weight is 0.77kg, power is 2.1A.
5.2 Gear Reduction Design

5.2.1 Gear Material

Materials and process selection are key issues in optimal design of industrial walkers. Optimal design of gears requires the consideration of the two kinds of parameters: material and geometrical parameters.

Table 5: Parameters of different materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Rigidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinion 45# steel</td>
<td>240HBS</td>
</tr>
<tr>
<td>Gearwheel 45# steel</td>
<td>240HBS</td>
</tr>
</tbody>
</table>

5.2.2 Initial Calculation

Calculate diameter of pinion base on parameters from Table 6:

$$d_i \geq A_d \sqrt[2]{\frac{T_i}{\varphi_d [\delta_p]}} \times \frac{i+1}{i} = 17.82\text{mm}$$

Choose 18mm

Tooth width:

$$b = \varphi_d \cdot d_i = 18\text{mm}$$
Table 6: Properties of gears

<table>
<thead>
<tr>
<th></th>
<th>Pinion</th>
<th>Gearwheel</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \varphi_d )</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>( i )</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>( \delta_{h_{\text{lim}}}(\text{MPa}) )</td>
<td>590</td>
<td>590</td>
</tr>
<tr>
<td>( <a href="%5Ctext%7BMPa%7D">\delta_{H}</a> )</td>
<td>531</td>
<td>531</td>
</tr>
<tr>
<td>( A_d )</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>

5.2.3 Teeth surface contact fatigue strength check

Calculate circular velocity:

\[
v = \frac{\pi dn}{60 \times 1000} = 0.94 \text{ m/s}
\]

Choosing 8 grades precision,

\[
Z_2 = i \cdot Z_1 = 54
\]
\[
m = \frac{d_1}{Z_1} = 1
\]

Load distributing factor between teeth:

\[
K_{lha} = \varepsilon_a = [1.88 - 3.2 \left( \frac{1}{Z_1} + \frac{1}{Z_2} \right)] \cos \beta = 1.64
\]

Tooth load distribution coefficient:

\[
K_{H\beta} = A + B \left( \frac{b}{d_1} \right)^2 + C \times 10^{-3} b = 1.34
\]

Loading coefficient:

\[
K = K_A K_i K_{lha} K_{H\beta} = 3.62
\]

Contact ratio factor:

\[
Z_e = \sqrt{\frac{4 - \varepsilon_a (1 - \varepsilon_\beta)}{3} + \varepsilon_\beta \varepsilon_a} = 0.86
\]

Contact stress of the minimum safety factor: \( S_{h_{\text{min}}} = 1.05 \)
Assuming the walker at the speed of 0.7 m/s for 3 hours each day in 5 years, stress-cyclic number (S-N):

\[ N_{L1} = 60 \cdot njlh = 6.49 \times 10^8 \]
\[ N_{L2} = \frac{N_{L1}}{1} = 2.16 \times 10^8 \]

Allowable contact stress:

\[ [\delta_{H1}] = \frac{\delta_{H1} \cdot Z_{N1}}{S_{H1} \lim} = 641 \text{MPa} \]
\[ [\delta_{H2}] = \frac{\delta_{H2} \cdot Z_{N2}}{S_{H2} \lim} = 652 \text{MPa} \]

Check calculation of allowable contact stress:

\[ [\delta_H] = Z_e Z_H Z_e \sqrt{\frac{2KT}{bd_1^2 \times \frac{i+1}{i}}} = 383.58 \text{MPa} \]

\[ \therefore [\delta_H] < [\delta_{H1}] \]

Hence, the structure is safe enough.

5.2.4 The tooth root bending fatigue strength check

<table>
<thead>
<tr>
<th>Table 7: Different parameters of gear calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinion</td>
</tr>
<tr>
<td>( Y_{Fa} )</td>
</tr>
<tr>
<td>( Y_{Sa} )</td>
</tr>
<tr>
<td>( K_{Fa} )</td>
</tr>
<tr>
<td>( K_{Ha} )</td>
</tr>
<tr>
<td>( K_{F_{\beta}} )</td>
</tr>
<tr>
<td>( \delta_{F_{lim}} \text{ (MPa)} )</td>
</tr>
<tr>
<td>( S_{F_{min}} )</td>
</tr>
<tr>
<td>( Y_X )</td>
</tr>
<tr>
<td>( Y_N )</td>
</tr>
</tbody>
</table>
From Table 7, calculate spur gear contact ratio factor:

\[ \varepsilon_{av} = [1.88 - 3.2\left(\frac{1}{Z_{v1}} + \frac{1}{Z_{v2}}\right)]\cos 0^\circ = 1.64 \]

\[ Y_c = 0.25 + \frac{0.75}{\varepsilon_{av}} = 0.71 \]

Loading factor:

\[ K = K_A K_f K_{Fa} K_{f\beta} = 3.79 \]

Allowable bending stress:

\[ [\delta_{F1}] = \frac{\delta_{F1\text{lim1}} Y_{N1} Y_X}{S_{F\text{min}}} = 456MPa \]

\[ [\delta_{F2}] = \frac{\delta_{F1\text{lim2}} Y_{N2} Y_X}{S_{F\text{min}}} = 465.6MPa \]

Check bending strength:

\[ \delta_{F1} = \frac{2KT_1}{bd'm} Y_{Fa1} Y_{sa1} Y_s = 116.55MPa \]

\[ \delta_{F2} = \frac{Y_{Fa2} Y_{sa2}}{Y_{Fa1} Y_{sa1}} = 102.95MPa \]

\[ \delta_{F1} < [\delta_{F1}], \delta_{F2} < [\delta_{F2}] \]

Hence, it’s safe enough.

### 5.3 Shock absorbing spring design

Shock absorber is a mechanical device designed to smoothly absorbing shock. Shock absorber is an important part of automobile equipment, and used in the motorcycle suspensions, aircraft landing gear, and the supports for many industrial machine. When designing the spiral compression spring, generally the maximum load, corresponding to the deformation. So we need to select material from the basic mechanical conditions, and then get the allowable shear stress from table, figure out diameter, spring index.

1. Select material

The first thing as

Figure 5-5 that you notice on the average weight chart, showing that men are gradually gaining weight until their early 50’s. After that, the average
weight for men gradually declines. This is nature – natural and healthy. [22] In our case, select mass weight equals 120kg, the walker is approximately 10kg, so the maximum load equals 1300N.

<table>
<thead>
<tr>
<th>Age</th>
<th>20 to 29 years</th>
<th>30 to 39 years</th>
<th>40 to 49 years</th>
<th>50 to 59 years</th>
<th>60 to 69 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilograms</td>
<td>76</td>
<td>81.3</td>
<td>82.6</td>
<td>84</td>
<td>83.5</td>
</tr>
<tr>
<td>Pounds</td>
<td>168</td>
<td>179</td>
<td>182</td>
<td>185</td>
<td>184</td>
</tr>
</tbody>
</table>

These are the ‘median’ (50th percentile) weights, which are very close to, but not exactly ‘average’.

Figure 5-5: Average weight for different ages [26]

![Figure 5-5: Average weight for different ages](image)

1300N

Figure 5-6: Force of spring

We use four springs to absorbing shock accompanied by force, the front wheel system is symmetrical, so each spring will under the 170N load. Considering some important factors, like maximum tensile force, temperature, we choose stainless wire.

<table>
<thead>
<tr>
<th>Material Type</th>
<th>ASTM Grade</th>
<th>250°F</th>
<th>Good Surface Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Tempered</td>
<td>A229</td>
<td>250°F</td>
<td>General purpose spring wire can be heat treated.</td>
</tr>
<tr>
<td>Chrome Silicon</td>
<td>A491</td>
<td>475°F</td>
<td>Shock loads and moderately elevated temperatures.</td>
</tr>
<tr>
<td>Phosphor Bronze</td>
<td>B139</td>
<td>200°F</td>
<td>Cold drawn. Good corrosion resistance and electrical conductivity.</td>
</tr>
<tr>
<td>Stainless Steel 304/304</td>
<td>A316</td>
<td>550°F</td>
<td>Cold drawn general purpose corrosion and heat resistant.</td>
</tr>
<tr>
<td>Stainless Steel 316</td>
<td>A316</td>
<td>550°F</td>
<td>Heat resistant and better corrosion resistance than 304.</td>
</tr>
<tr>
<td>Stainless Steel 17-7 PH</td>
<td>5078</td>
<td>950°F</td>
<td>High strength and general purpose corrosion resistance.</td>
</tr>
</tbody>
</table>

Figure 5-7: Part of the materials of spring [27]
② Calculate diameter
Assume spring wire diameter $d=3\text{mm}$, from table we choose strength of extension $\delta_p=1471\text{MPa}$, shear modulus $G=7.15\times10^4\text{MPa}$, the allowable shear stress $[\tau]=0.45\delta_p=661.95\text{MPa}$, curvature correction factor $K=1$. From Figure 5-8 choose spring index is 6.

<table>
<thead>
<tr>
<th>弹簧直径 $d$ (mm)</th>
<th>0.2~0.4</th>
<th>0.5~1</th>
<th>1.1~2.2</th>
<th>2.3~6</th>
<th>7~16</th>
<th>18~42</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c$</td>
<td>7~14</td>
<td>5~12</td>
<td>5~10</td>
<td>4~10</td>
<td>4~8</td>
<td>4~6</td>
</tr>
</tbody>
</table>

Then,
$$d \geq 1.6 \sqrt[6]{\frac{KFC}{[\tau]}} = 1.98\text{mm}, \text{choose } d=2\text{mm}$$

③ Calculate other corresponding parameters
Mean diameter of coil:
$$D=Cd=12\text{mm}$$
Circles of spring:
$$n = \frac{Gd^4}{8FD^2} = 9.7, \text{choose } n=10$$
There is one circle at the both of side be the support ring, hence:
$$N=n+2=12$$
Experimental load:
$$F = \frac{\pi d^3}{8D}[\tau] = 173.8N$$
Height:
$$t = d + \frac{F}{n} + \delta_1 = 3.86\text{mm}$$
$$H_0 = nt + 1.5d = 49.32\text{mm}$$
Helical angle;
$$\alpha = \arctan \frac{t}{\pi d} = 6^\circ$$
Stability checking calculation:
$$b = \frac{H_0}{D} = 4.11 < 5.3$$
Spring stiffness:
$$F' = \frac{Gd^4}{8D^3n} = 68.96N/\text{mm}$$
When $f=20\text{mm}$, the load can be:
\[ F = F'f = 1379.2N \]

This load is largely more than real value, so it’s safe enough.

5.4 Simulation in software

5.4.1 FEM deformation simulation

When the elderly people falling down on the way to going shopping, the walker can be changed as a stretcher device, they will be transferred to lie down the stretcher under the support of other people. As we have mentioned before, their mass weight is 85kg on the average, in order to check if it is safe, we decide to assume the maximum mass weight is 120kg and then simulate in Inventor.

![Figure 5-9: View of final assembly](image)

We can use FEM to estimate the safety value, INVENTOR has a special procedure for obtaining solutions to engineering problems, the accuracy of the model was verified with hand calculations or response data acquired from laboratory testing. Validate the results predicted by the INVENTOR models by comparing them with relevant experimental data and accepted design calculations. Steps in the solution procedure usually could be like this: as
Figure 5-10 shows, define materials first. In our design, the main structure we consider using Aluminum 6061 due to high strength and light weight. Based on our survey, we find currently using Nylon as the material for stretcher, an ideal material for the emergency stretcher rescue. We choose the maximum height to be 185cm and shoulder width to be 40cm, so the pressure acting on the stretcher:

\[ P = \frac{F}{S} = 0.0018 \text{MPa} \]

Then, fixed constraints on the structure,
Define the element shape we use is rectangle, seed size is 0.1mm^2, and mesh it as shown in Figure 5-12.

Figure 5-12: Mesh view of design

The Von Mises stress distribution in Figure 5-13 illustrate the effect of stress under the load deflection response. The maximum values of safety factor in the figure equals 15ul, minimum value equals 1.85ul, because here the rod is hollow so that can make it lighter. The minimum value is larger than 1, so the walker can carry elderly people safely.

Figure 5-13: Simulation result of final assembly
5.5 PLC System (Programmable Logic Controller)

The PLC in the PLC draft standards issued by the International Electro technical Commission in 1987 made the following definition: "The PLC is a specially designed for applications in industrial environments digital computing operation of electronic devices which can be programmed memory, with to implementation of the logical, sequential operation, timing, counting and arithmetic operations, such as operating instructions in its internal storage and can be digital or analogy inputs and outputs to control various types of machinery or walker processes. PLC and its related peripherals should be easy and industrial control systems to form a whole, easy to extend the principle of functional design. "[29]

Currently PLC has basically replaced the traditional relay control and it is widely used in industrial control. PLC has leapt to the top of the three pillars of industrial automation.

5.5.1 Features and application of PLC

a) Easy to use and program

PLC as a general-purpose industrial control computer, industrial control equipment for industrial and mining enterprises. It is easy to interface, programming language which is accepted for engineering and technical personnel. The ladder language graphic symbol and expression and relay circuit is very close, only a small number of switch PLC logic control instructions can easily relay circuit.

b) Ratio

There are many elements which are programmed within PLC for hundreds of thousands of users. It has a strong logic, data processing, PID conditioning and data communication functions. And it can achieve very complex control functions. If the element is not enough, adding an expansion unit that is needed to expand is very convenient. Compared with the relay system which has the same functions, it has higher cost performance.

c) High reliability, strong anti-jamming capability

High reliability is the key to performance of the electrical control equipment. PLC is due to the introduction of modern LSI technology, strict
walker ion process, the internal circuit to take the advanced anti-jamming technology, with high reliability.

d) Small size, light weight, low energy consumption

5.5.2 The basic structure of the PLC

PLC is actually an industrial control computer; its hardware configuration is similar to the general computer control system. PLC consists of the CPU module, input module, output module and programmers, like Figure 5-14.

![PLC system diagram](image)

Figure 5-14: PLC system

5.5.3 Positive and reverse rotation by using PLC

Stretcher consists of two couples of rods and PLC can control Electric Motor to achieve rods positive and reverse rotation. This function can make walker become stretcher and if people want to have a backrest, this function can make it. So Three-phase asynchronous motor control design is important.

5.3.3.1 Motor reversing control circuit

In order to positive and reverse rotation for motor, we can use two contacts KM1, KM2 to connect to power, but two contacts can no pull at the same time. If they pull at the same time, it can cause a Short-circuit accident. In order to prevent this accident, we should use adopt reliable interlock. And the Figure 5-15 shows using buttons and contacts’ double interlocking in the control circuit which makes motor positive and negative direction.
Figure 5-15: Motor control circuit which has positive and negative direction

Circuit analysis is shown:

(1) Starting for positive direction:
   a. Turn off the air switch QF and turn on the power

   Press the button SB3 which can start for positive direction, then coil KM1 is energized and KM1, which are normally open contacts in the main circuit and control circuit, are all closed and it can make Self-locking link. Finally, the motor is turned on and it can run for positive direction.

(2) Starting for negative direction
   a. Turn off the air switch QF and turn on the power, it is the same as the first one.

   b. Press the button SB2 which can start for negative direction, then coil KM2 is energized and KM2, which are normally open contacts in the main circuit and control circuit, are all closed and it can make Self-locking link. Finally, the motor is turned on and it can run for negative direction.

(3) Interlock link: it has a disable function and it can play a security role in the line.
   a. Contact’s Interlock
We can string KM2’s normally closed auxiliary contact into the KM1 coil loop and string KkM1’s normally closed auxiliary contact into KM2 coil loop. When the forward contact KM1 coil is energized, KM1’s normally closed auxiliary contacts disconnect the KM2 coil circuit. If we want to KM1 is energized and pull, we must make KM2 disconnect first and then its auxiliary normally closed contacts reset, like that can prevent KM1, KM2 pull at the same time to cause short circuit. The line segment is called interlocking link.

b. Button’s interlock

We use control buttons to operate reversing control circuit. The buttons SB2, SB3 have a pair of normally open contacts and a pair of normally closed contacts. And two contacts are connected respectively to KM1, KM2 coil loop, such as chaining together the button SB2’s normally open contact and the contact KM2 coil and cascading the button SB2’s normally closed contact and the contact KM1 coil. On the other hand, we chain the button SB3’s normally open contact together with the contact KM1 coil and cascade the button SB3’s normally closed contact and the contact KM2 coil.

So when we press SB2, only the contact KM2 coil can be energized and KM1 has no power. When we press SB3, only the contact KM1 coil can be energized and KM2 has no power. If we press SB2 and SB3 at the same time, two contact coils are not energized. It can play an interlock role.

(4) Motor overload protection is done by thermal relay FR.
### 5.5.4 I/O ports on PLC for motor

<table>
<thead>
<tr>
<th>Electric input</th>
<th>Point input</th>
<th>Electric output</th>
<th>Point Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop button SB1</td>
<td>X1</td>
<td>Forward contacts KM1</td>
<td>Y1</td>
</tr>
<tr>
<td>Forward button SB3</td>
<td>X3</td>
<td>Reversing contact KM2</td>
<td>Y2</td>
</tr>
<tr>
<td>Reversing button SB2</td>
<td>X2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal relay contact FR1</td>
<td>X0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal relay contact FR2</td>
<td>X4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5-17: I/O wiring Diagram
5.5.5 PLC Ladder Diagram and instruction

![Ladder Diagram](image)

Instruction:

<table>
<thead>
<tr>
<th>LD</th>
<th>X2</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR</td>
<td>Y2</td>
</tr>
<tr>
<td>ANI</td>
<td>X1</td>
</tr>
<tr>
<td>AN1</td>
<td>Y2</td>
</tr>
<tr>
<td>OUT</td>
<td>Y2</td>
</tr>
<tr>
<td>LD</td>
<td>X3</td>
</tr>
<tr>
<td>OR</td>
<td>Y1</td>
</tr>
<tr>
<td>ANI</td>
<td>X1</td>
</tr>
<tr>
<td>AN1</td>
<td>Y2</td>
</tr>
<tr>
<td>OUT</td>
<td>Y1</td>
</tr>
</tbody>
</table>

5.5.6 PLC working principle

According to I/O wiring diagram and ladder diagram, analysis as follows:

Forward start-up process

Press SB3→X3 is closed→C region has power→Y1 coil has power→The motor is forward→Y1’s auxiliary normally open contact is closed in D region(Self-locking)→Y1 is disconnected in A region(Interlock)

(1)Reversion start-up process

Press SB2→X2 is closed→A region has power→Y2 coil has power→The motor is reversed→Y2’s auxiliary normally open contact is closed in B region(Self-locking)→Y2 is disconnected in C region(Interlock)
(2) Stop process

Press SB1 → X1 are disconnected in A and C regions → A and C regions have no power → Y1 and Y2 coils have no power → Each device can reset → The motor stops

5.5.7 Two-speed motor by using PLC

Two-speed motor have two speed called high speed and low speed. When the old people buy many things and put them into box in the walker, they can press the button which can make walker low speed automatically. According to the speed of the old people, choosing a suitable low speed is a good way to reduce their burden. And if the old want to walk downhill, the low speed can make the walker slowly in motion on a slope. And if the elderly people want to walk downhill, can switch the button to change low speed method that make the walker slowly on the slope road. Considering it is very strenuous when the old people walk uphill, we design the system which can make walker at a high speed automatically. At the same time, the speed is not fast for the old people, it is safe for them.

Two-speed asynchronous motor control circuit

(1) Connection of Two-speed asynchronous motor’s stator windings

We use the connection called Δ/YY. The connection Δ represents the low speed and the connection YY represents the high speed.

![Diagram of Δ connection](image)

Figure 5-18: Low speed- Δ connection
Three connected points is connected to three outlet sides U1, V1, W1 and the midpoint of each phase winding is connected to another three outlet sides U2, V2, W2. Then stator winding has six outlet sides. Though changing the connection between six outlet sides and power, we can get two different speeds.

To make the motor work at low speed, the three-phase power is connected to three outlet sides of the stator windings U1, V1, W1, as the three top of Δ. And the other three outlet sides U2, V2, W2 is empty and not connected to anything, like the Figure 5-6.

To make the motor work at high speed, we make the three outlet sides U1, V1, W1 together and the other outlet sides U2, V2, W2 are connected to the three-phase power, like the Figure 5-19.
Press KM1, it is connection Δ at low speed
Press KM2 and KM3, it is connection YY at high speed.

(2) Two-speed motor control circuit by using contacts and buttons
SB2 and KM1 can control the low speed. SB3, KM2 and KM3 can control the high speed, like the Figure 5-9

And the motor is two-speed motor. FR is a motor overload protection, when it is overload, power control circuit and contacts are energized, then the motor stops working.
Figure 5-21: Two-speed motor control circuit

Circuit analysis is shown:

(1) Low speed
   a. Turn off the air switch QF and turn on the power
   b. Press the button SB2, then coil KM1 is energized and KM1, which are normally open contacts in the main circuit and control circuit, are all closed and it can make Self-locking link. Finally, the motor is turned on and it can run at low speed.

(2) High speed
   a. Turn off the air switch QF and turn on the power

   Press the button SB3, then Intermediate relay KA and Time Relay KT is energized. Normally open contact KT and KA is closed. Then coil KM1 is energized and KM1, which are normally open contacts in the main circuit and control circuit, are all closed and it means it has Self-locking link. So just started, the motor runs at low speed. When the 5-second countdown finishes, all the KT is disconnected, two KT can disconnect and only one KT is closed. After that, coil KM2 and KM3 are energized and KM2 and KM3 which are
normally open contacts in the main circuit and control circuit, are all closed. It also has self-locking link. Finally, the motor becomes running at high speed.

Why we need this 5-second time is due to consider to the reaction of the old people. The reaction of the old people is not very fast and we need to give them some second to adapt this speed then improve the speed.

(3) Interlock link: it has a disable function and it can play a security role in the line.

We can string KM2 and KM3’s normally closed auxiliary contacts into the KM1 coil loop and string KM1’s normally closed auxiliary contact into KM3 coil loop. When the forward contact KM1 coil is energized, KM1’s normally closed auxiliary contacts disconnect the KM3 coil circuit. If we want to KM1 is energized and pull, we must make KM2 and KM3 disconnect first and then its auxiliary normally closed contacts reset, like that can prevent KM1, KM2 and KM3 pull at the same time to cause short circuit. The line segment is called interlocking link.

### 5.5.8 I/O ports on PLC for motor

**Table 9: I/O port allocation table**

<table>
<thead>
<tr>
<th>Number</th>
<th>Element Code</th>
<th>Element Name</th>
<th>Signal feature purpose</th>
<th>Line Side Code</th>
<th>Num</th>
<th>Element Code</th>
<th>Element Name</th>
<th>Signal feature purpose</th>
<th>Line Side Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FR</td>
<td>Thermal Relay</td>
<td>Thermal Protection</td>
<td>X000</td>
<td>1</td>
<td>KM1</td>
<td>Contact</td>
<td>Low Speed</td>
<td>Y001</td>
</tr>
<tr>
<td>2</td>
<td>SB1</td>
<td>Button</td>
<td>Stop</td>
<td>X001</td>
<td>2</td>
<td>KM2</td>
<td>Contact</td>
<td>High Speed</td>
<td>Y002</td>
</tr>
<tr>
<td>3</td>
<td>SB2</td>
<td>Button</td>
<td>Low Speed</td>
<td>X002</td>
<td>3</td>
<td>KM3</td>
<td>Contact</td>
<td>High Speed</td>
<td>Y003</td>
</tr>
<tr>
<td>4</td>
<td>SB3</td>
<td>Button</td>
<td>High Speed</td>
<td>X003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.5.9 PLC Ladder Diagram and instruction

Figure 5-23: Ladder Diagram
Instruction:
A LD X002   B LD X003   C LD T0
OR Y001     OR M1      OR Y002
OR M1       AND X000   AND X000
AND X000    AND X001   AND X001
AND X001    ANI Y002  ANI Y001
ANI Y002    ANI T0    OUT Y002
ANI T0      OUT M1    OUT Y003
OUT Y001    OUT T0 K50

5.5.10 PLC working principle

According to I/O wiring diagram and ladder diagram, analysis as follows:

(1) Running at low speed

Press SB2 → X002 is closed → A region has power → Y001 coil has power →
The motor runs at low speed → Y001’s auxiliary normally open contact is closed in A region (Self-locking) → Y1 is disconnected in C region (Interlock)

(2) Running at high speed

Press SB3 → X003 is closed → B region has power → M1 has power and T0 can begin counting down → M1’s auxiliary normally open contact is closed in B region (Self-locking) → When the countdown finishes, T0 is closed in C region → C region has power → Y002 and Y003 has power as well → The motor runs at high speed → Y002’s auxiliary normally open contact is closed in C region (Self-locking) → Y002 is disconnected in A and B region (Interlock)

(3) Stop process

Press SB1 → X001 are disconnected in A, B and C regions → A, B and C regions have no power → Y001, Y002 and Y003 coils have no power → Each device can reset → The motor stops
6 Chapter: Lesson Learned

In our thesis, we combined different kinds of knowledge are taught on class with the real problems exist in daily life. Our thesis is designed to provide an assisted mobility device for elderly people. In the process of preparing our thesis proposal and the dissertation itself, we learned many valuable lessons.

The first lesson we learned is to read extensively and then read some more relevant paper. After all, one needs to know what research exists and how others have treated a particular topic so one can determine what additional research is needed.

Secondly, using some valuable tools and method to help figure out the design solution is important. Brainstorming and sketching are two valuable tools while in the process of figuring out design details. It is not enough to determine the final design solution purely rely on us. In this thesis, we learned consult the expert, especially our dissertation advisors. They can provide the necessary insight for our thesis. As a matter of fact, our design topic in not competitive and innovative this time, because we didn’t realize some problems hidden at first. Our supervisor provides critical comments in our draft, particularly on the design process and FEM simulation.

The last lesson we learned from thesis, don’t pay too much attention on the something necessary. Each design and study obviously have limitations in terms of literature review, method, simulation. In our thesis, to make the walk operate automatically, we use PLC control system to achieve it. We forget it also can be problems from the perspective of weight and cost. It is important to combine different subjects, but we need to think and use it wisely.
7 Conclusion and Future Work

If time and resources were infinite, it would have been improved in many directions, some of these directions may instead suggesting future work. As the start point of doing thesis, choosing an interesting and competitive topic can be even more important. In this study, we indeed select a topic connected with real healthcare area. However, in reality, the topic may be improved by a lot of designers, it’s hard to create something new for users.

Secondly, in multi-function walker design process, obviously, we had considered several problem details accompanied with daily life for the elderly. One key factor is to combine these issues led to an interesting result, definitely better looking than the current walker.

The design we made is to assist elderly people walk and provide additional emergency rescue device. Falling down is a public health problem, the walker can transform into stretcher when needed. If they feel uncomfortable suddenly, they can lie down the stretcher and then other people can pull the stretcher into the hospital. By using PLC system and motors to make the walker automatically to achieve our aim that the walker has two speeds to walk and the rod can rotate some angels to make a stretcher or a backrest. Due to stretcher’s length, we choose a telescopic rod specially. It can be stretched and shorten to satisfied people’s needs.

Then we analysis the model in Inventor. In a welding place, we can get number in simulation, compared with the number by hand calculation, we come to a decision that the two number are similar and the welding place on this automatic equipment is safe. And using the same way to test the safety factor about the whole walker. It is also safe in Inventor.

In the future, due to motors, the weight of walker is larger than similar current walkers. Although we indeed add some new functions base on the current walker, we need to modify the design method in the future work.
8 Case of Study

In our thesis, we designed three main creative functions to help elderly people. In order to let the users easy to understand, we will put the user with our walker in daily life. When they finish shopping, walking on a steep road with much effort. Our design considered this kind of problem, put up with the speed control method as mentioned before. When they feel tired, they can adjust the speed by pressing button.

![Figure 24: Graph of steep road](image)

Another situation is many elderly people struggle to transfer from a chair, in our design we designed the function to support them when they need to stand up from the chair.

![Figure 25: Elderly people struggle to transform from chair](image)
As shown in Figure 26, the user sits between the frame with their hands on the rear handles. Remaining in the seated position, the user pushes the handles down until the feet hit the floor. And then user pushes upright from the seat using the handles as leverage. Support is provided at the initial stage of the standing process. releases the handles once the upright standing position is reached. At this stage the user is able to release the rear handles and switch to the walking handles.

Figure 26: Using the walk to stand up
9 Reference


Appendix 1: PLC Drawing and Simulation Result
Appendix 2: The Drawings of Main Components