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TRI WHEELCHAIR

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***Abstract* - With sharply increasing of elderly and disabled people at present, the work which focuses on making life easier for those people have beenpaid more attention. So a new stair-climbing wheelchair was designed in this paper which can work in three modes: stair-climbing mode, powered wheelchair mode and manual mode. It helps physically disabled and elderly people to move more flexibly and comfortably. The walking mechanism was first designed in this paper, as well as the theoretical design and calculation which was used to decide the structure and dimension; then transmission system design was followed. An optimization design for the planetary wheels mechanism is carried out based on the model which was modelled in software Autodesk Inventor A seat backrest adjustment system was designed to adjust the center of gravity before climbing up and down stairs. At the same time, a locking system was installed to make the wheelchair working more safety. Computer simulations were performed to evaluate this design. Stress analysis for different materials of the frame was carried out in inventor, in order to realize optimal selection for the material. Finally animation was made to show how the wheelchair works in different situations.**

Keywords:
Stair-climbing Wheelchair, Autodesk Inventor modelling, Optimization Design, Simulations

I. INTRODUCTION

The number of patients with disabilities is on the rise according to the first official report "the global disabled persons report", there are 650 million people which are about 10% of the global population are disabled in the 1970s, and now the number has increased to 15%. Aging population who have chronic diseases is rising which makes the proportion of disabled persons expand.

The following picture (Figure 2.1) is about the proportion change of elderly people and younger people from 1950 to 2050, the percent of the young children is decreasing from 13% to 6%, in contrast to the percent of elder population which keep increasing sharply.

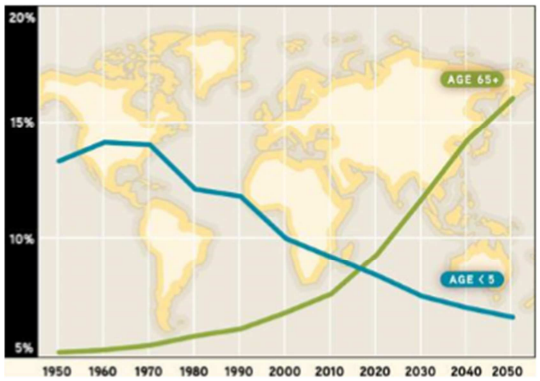


Figure 2.1 Young children and older people as a percentage of global population.

And figure 2.2 shows that the sick or disabled people among working age of 15 to 64 are 13.2% of the population in EU, and Sweden have the highest number which is 36.5%. Therefore the situation in Sweden is very serious and nursing care for the elderly and disabled people will become a big burden in the near future.

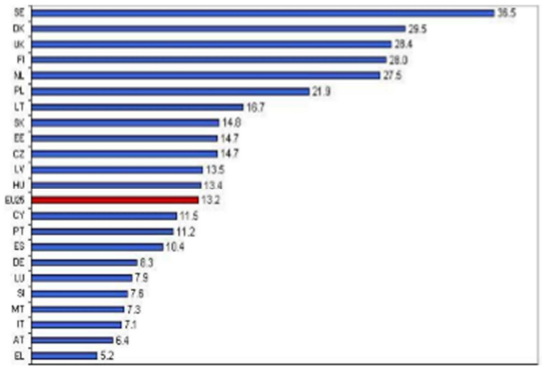


Figure 2.2 Inactivity due to illness or disability among working agepopulation (15-64).

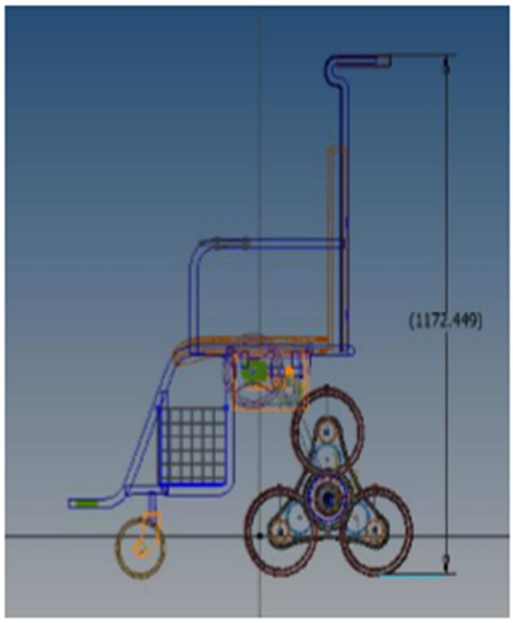
The people with physical disability not only have less living space, but alsothe quality of life is seriously affected and it also brings big burden to their family. Wheelchair as a means of transport tool plays an important role in the life of those people who are old and disabled. With the society paying more attention to the benefits of elderly and disabled people, barrier free facilities as well as the elevator has been widely popularized,

common wheelchairs can easily access many places, but when the user face stairs which often poses as obstacles, people can only step back, even though with the assistance from others, it is still very difficult to overcome these obstacles, which is inconvenient for those people who use wheelchairs. So most of the time these disabled or elderly people can only stay at home, and lack of activities outside may influence on their physiology and psychology. BTH had a collaboration agreement with the government and the projects of recent years had been focused on making life easier for the disabled and elderly people. The previous students in BTH had already designed some wheelchairs like "Electric wheelchair for easy access to toilet[4]"、"Optimization design for the standard manual wheelchair etc.but the device for helping people to go up and down stairs can be much improved, therefore considering above factors this topic is chosen by our group.

This thesis is based on the existed stair-climbing wheelchair; the advantages and disadvantages between different types of wheelchairs are compared and summarized, in order to make our design overcome those disadvantages. The planetary wheels mechanism is optimized to extend the life of the gear for the transmission system and improve the security of the wheelchair; the seat backrest adjustment system is added which is used to adjust the center of gravity of the wheelchair and keep the seat always in level with the ground while climbing up and down stairs. This device can also prevent the wheelchair from overturning backward, and improve the security and comfort of the wheelchair. Locking system is added which is used to lock the wheelchair while climbing up and down stairs, making sure it can only move in one direction, and protect the wheelchair from slipping down. And combining the principle of ergonomics: a desk, shopping basket is added, and a curved seat is designed which makes the seat more comfortable and convenient. Then all parts of the wheelchair are modeled in Autodesk Inventor, and the strength of the important components of the wheelchair will be simulation analyzed

II. THEORETICAL DESIGN AND CALCULATION

The structure dimensions will be first determined in order to modelling the wheelchair. Then stress analysis will be carried out in different motion modes. At last the pulling force will be estimated.



2.1 Structure design and calculation

Determination of the basic parameters of the planetary wheels system

The range of the structure size of the planetary wheels system is determined by the staircase, and the wheels of the wheelchair needs a stable support on the stairs during the process of climbing stairs, if the diameter of the wheelsare too large, the wheelchair is unable to support itself on the stairs, and it isalso not good for reducing the volume of the wheelchair; if the diameter istoo small, the wheelchair will have a low efficiency when it moves on the flat ground, and it has a poor ability to adapt to the terrain. The step-wide G and the step-height R are determined by the stair design rules, which is shown in the table 4.1

Table 4.1 Different types of stairs. [15]

RISER (R)		GOING (G)		SLOPE RELATIONSHIP = 2R+G	
MAXIMUM	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
190	115	355	240	700	550

Apparently, the width of the staircases should be less than 240mm; the height should not be more than 190mm. The design of stair-climbing wheelchair should have stable support in the minimum width of 240mm, and can also roll in a certain distance. So here the width of the stairs b=240mm, and the height h=140mm are chosen, as the calculation reference of our design (The structure diagram of the planetary wheel is shown in figure 4.5).

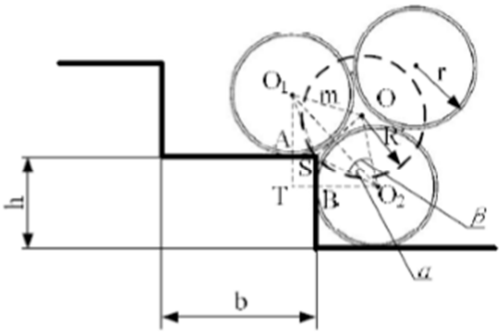


Figure 4.5 Structure diagrams of the planetary wheels.

Based on the geometrical relationship in the picture above, the following calculation is carried out,

$SO_2 = \sqrt{(BO_2^2 + BS^2)} = \sqrt{(r^2 + (h - r)^2)}$

$O_2O_2 = 2m\cos 60° = \sqrt{3}m$

$SO_1 = \sqrt{(O_1A^2 + AS^2)} = \sqrt{((3m^2 - h^2 - r)^2 + r^2)}$

Therefore：

$\cos a = (SO_1^2 + O_1O_2^2 - SO_1^2) \div (2SO_2 \times O_1O_2)$

$= (h(h-r) + r\sqrt{(3m^2 - h^2)}) \div (m\sqrt{(3r^2 + 3(h-r)^2)})$

Considering the structure limits and non-interference between the planetary wheels, the rotation arm m=104mm is selected, based on the geometrical relationship r＝90mm is calculated, then substituting the value of m,r, h into the equation (4.4), α = 22° is calculated.

Therefore：$\beta = \alpha + 30° = 52°$

$R\ max = OS = \sqrt{(OO_2^2 + SO_2^2 - 2OO_2 \times SO_2 \cos\beta)} = 90.7mm$

The maximum dimensions of the drive shaft center should not exceed the radius R max , in order to ensure that there is no interference between the wheelchair and the edge of the stair when the wheelchair climbs the stairs.

III MATERIAL SELECTION

There are two principles that should be followed, when selecting materials, and analyzing if the selected materials will meet the strength requirements. The two principles are: choosing materials based on strength theory and choosing materials based on stiffness theory, which will be introduced in the “Appendix 4 principles for choosing material”. And other factors such as comfort, environmental friendliness and so on should also be considered. Considering the situation of our design, the primary stress act on the frame is tension so principle one based on strength theory is applied to choose our material.

$\sigma = FN \div A \leq [\sigma]$

$\sigma = FN \div A = 93.1 \div (\pi \times 0.01^2) = 0.296MPa \leq [\sigma]$

Where FN = FP , FP is the pulling force which has been calculated in section 4.2.3. At present manufacturers usually choose aluminium alloy or alloy steel as wheelchair materials and both of these two materials can meet the above strength requirements, so simulation analysis in the chapter ofsimulation and analysis will analyze which material has better properties

IV. CONCLUSIONS

In this project we designed a new kind of stair-climbing wheelchair, which has compact structure, can cope with flat or inclined terrain, stairs and obstacles. All parts of the wheelchair were modelled in software Inventor and Rhino, then simulation analysis to make sure the strength of the framework, gear shaft as well as the folding desk, the results are:

- Design the walking mechanism and transmission system for our stair-climbing wheelchair, according to the calculations which decide the structure of the wheelchair, then model all parts of the wheelchair.
- The optimization for the planetary wheel system changes the torsion acting on the box of the gear train instead of acing on the gear, which protect the security and service life of the gear.
- The seat backrest adjusting mechanism adopts manual operation, which is not only energy-saving, environmentally friendly, but also reduces the weight of the wheelchair by not installing a motor.
- Users can adjust the seat backrest system to make sure the seat of the wheelchair is parallel to the level ground when it climbs up and down stairs.
- The optimization of ergonomics has been added in our design to make the wheelchair more convenient and comfortable.
- Lock system is added to avoid the wheelchair slip down while climbing up and down stairs.
- Two different kinds of materials have been chosen to analyse in Autodesk Inventor, in order to realize optimization selection.
- Strength checking on locking system and the desk in Autodesk Inventor to make sure the safety of the wheelchair is good.
- Assembling simulation is carried out in Autodesk Inventor in order to avoid interference between different parts of the wheelchair
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