Design of Advanced Multi Desire Wheel-Chair

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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 been paid more attention, so a new stair-climbing wheelchair has been designed in this paper which can work in two modes: Stair-climbing made powered wheelchair mode and manual mode it helps physically disabled and elderly people to move more flexibly and comfortably. The walking mechanism and the theoretical calculation based design had been designed in this paper, the transmission system design and the hydraulic mechanism design for carrying person to a height was further followed. An optimization design for the planetary wheels mechanism was carried out based on the model which was modelled in software Solid works. A seat backrest adjustment system had been designed to adjust the centre of gravity before climbing up and downstairs. At the same time, a locking system had been installed to make the wheelchair working more safety. Computer simulations were performed to evaluate this design. Stress analysis for different materials of the frame is carried out in inventor, in order to realize optimal selection for the material of imperceptibility.

Keywords – Stair-climbing, wheelchair, solid works modelling, optimisation Design.

I. INTRODUCTION

It is rightly said that "Necessity is a mother of Invention" and thus the main focus of technology is on providing comfort to the people. Many countries are currently experiencing what is referred to as an "Aging population". The average human age is increased and accordingly the Number of old people is also increased. A common problem the selderly people are facing is impaired mobility. In this regard, traditional wheelchairs and powered wheelchairs continue to play a vital role. However wheelchairs to date provide a high level of mobility in "barrier free" environments. There remains a significant gap between the obstacle negotiating ability of a wheelchair and that of the average able bodied person. This aspect is perhaps most apparent when considering stair-climbing. While modern architecture and new policies continue to make newly built areas as "accessible" as possible, to persons with a wide variety of disabilities, "Steps" will always be a reality in the "real world". Many old buildings are without elevators and "non-availability of lifts" cannot be a reason for redevelopment of these buildings, in densely populated areas of society.

Extensive research is being carried out in the field of "Development of Staircase Climbing Wheelchair". Many designs are put forth and some designs are already converted in the actual products. Main problem that lies with all these designs is the "Cost" factor. After giving due consideration to all the constraints, which are coming on the design process of these chairs, the final manufacturing cost of these chairs, goes so high that the product no longer remains affordable. This paper proposes a new design of a stair-climbing capable mechanism for the wheelchairs for elderly or disabled.

II. DRAWBACKS OF EXISTING DESIGN

Many designs are proposed till date and some of them are accepted finally and are converted into reality. But the main problem with all these designs is the cost factor. Too many considerations are involved in the design process of these chairs. Right from motion on flat surface with specific speed, the most critical consideration is "Balancing of chair and maintaining Centre of Gravity within the base" during climbing the stairs. To accommodate all these requirements in the design, very much sophisticated mechanisms are incorporated in the designs. Due to the complex mechanisms and accessories, these products are so expensive that a common man cannot afford it. A stair climbing wheelchair "VARDAAN" developed by four students of IIT Kanpur is a low cost solution to the problem, but operation of that wheelchair is purely manual. So, substantial driving force is needed to operate the chair. Considering the health and weakness of the elderly people, it may not be useful all the time. This Design is shown below:

Figure 1. VARDAAN stair-climbing wheelchair

The designs proposed by Murray Lawn are better acceptable but yet to be converted in actual products.

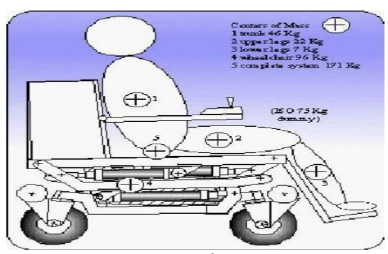

Figure 2. Design of Murray Lawn

III.PROPOSED DESIGN

In view of reducing the cost, we plan to modify the regular chair into staircase climbing chair. The driving mechanism is basically an epicyclic drive.

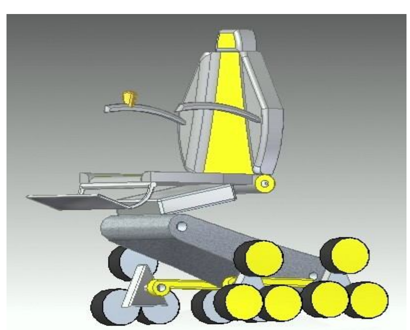

Figure 3. Position 1 of proposed design

The drive system can be called as selective drive system. The drive shaft will be a compound concentric shaft with inner solid shaft and outer partial hollow developing shaft. When the chair is travelling on horizontal surface, power will be supplied to inner solid shaft and in turn to the sun gear of the epicyclic gear train. The sun gear transmits motion to the planets, which are finally driving the wheels. The arm of the gear train remains stationary in this period. Top gear of the epicyclic gear train and hence the corresponding top wheel rotates freely. Four such epicyclic units are mounted at the base of the four supporting legs of the chair. But the main difference is: The two frontal epicyclic units are directly connected to the frontal legs, without any height controlling rack and pinion arrangement. The rear leg supports of the chair are telescopic, using either hydraulic cylinder or the rack and pinion arrangement. The epicyclic unit to the rear leg supports is fitted to the extendable leg.

A. POSITION I

When the front most wheels touch the first step of the staircase, the person seating on chair needs to operate the selector clutch, thereby the power is supplied to the outer hollow shaft which is directly connected to the arm of the epicyclic gear train. So the arm starts rotating and the front portion starts climbing the step. Simultaneously the rack driving pinion rotates and pushes the rack down, thereby increasing the height of the rear leg supports. This extension of rack continues till the height of one step is reached. The power is still supplied to the inner solid rear shaft so that the rear epicyclic units are still operating in the “Fixed Arm” mode or “Flat Travel” mode and the planet gears along with the planet wheels rotate taking the chair forward. This continues till the free wheels touch the next step.

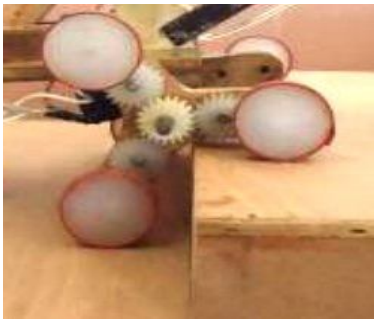

Figure 4. Planetary wheels mechanism

Then after the rack extends further till the height of two steps is reached. Simultaneously the front epicyclic units work in “Moving Arm Mode” or “Climb Mode” and lift the frontal part of chair, maintaining the level of the seat horizontal. In short, while climbing the staircase, there is a level difference that is deliberately created between the two front legs and two rear legs.

B. POSITION 2

The further problem that a disabled person faces is to reach up the surface or to pick any substance which is at height , for this we proposed a design on this wheel- chair by providing a mechanism so that the person can reach at a certain height from this figure 5 we can get the design.

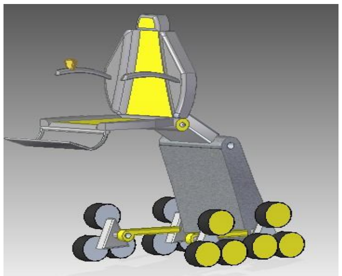

Figure 5: Position 2 of proposed design

C. POSITION 3

We made the survey and find out that the disabled person can’t reach the downward surface or ground level , so in our proposed design we have also made some adjustments so that the person the wheel chair can reach the ground level, below figure 6 shows the position 3.

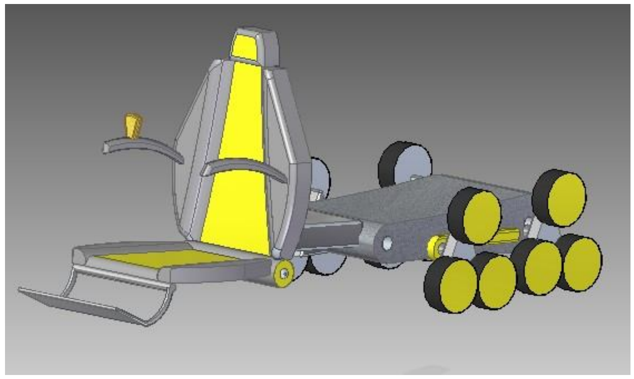

Figure 6: Position 3 of proposed design

IV. WALKING MECHANISM

The walking mechanism is a very important part of the stair-climbing wheel chair it directly impacts on the stability, safety and comfort of the wheelchair, so all kinds of factors must be considered to choose the walking mechanism.

According to the analysis about the advantages and disadvantages between different types of climbing wheelchairs in the last chapter, the following concepts were observed.

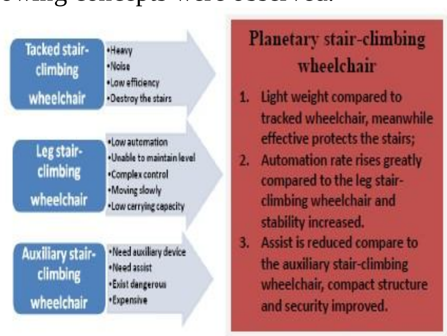

Figure 7: Comparing different kinds of mechanism

Planetary wheel mechanism has a great of advantages among the stair-climbing wheelchairs, which not only has a simple and compact structure, flexible movement, good stability, small fluctuation range of gravity centre, but also combines the advantages of moving on the ground and climbing stairs. Therefore planetary wheel mechanism is chosen as the walking in our design.

The number of planetary wheels can be two, three or more than three, in order to realize the requirements of small volume, light weight, consideration of overturning moment and wheel cluster centre fluctuation.

V. THEORETICAL DESIGN AND CALCULATION

V.1 STRUCTURE DESIGN AND CALCULATION

A. DETERMINATION OF 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 staircase, and the wheels of the wheelchair needs a stable support on the stairs during the process of climbing stairs, and it is also not good for reducing the of the wheelchair, if the diameter is too 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.

Apparently the width of the staircases should be less than 240 mm, the height should not be more than 190 mm. The design of stair climbing wheelchair should have stable support in the minimum width of 240 mm, and can also roll in a certain distance. So here the width of the stairs b=140mm and the height h=140 mm are chosen, as the calculation reference of our design.

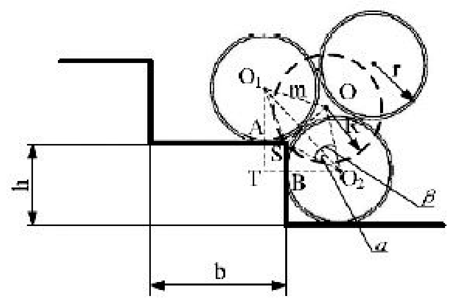

Figure 9. Structure diagram of the planetary wheels

Based on the geometrical relationship in the picture above, the following calculation ,

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

$$O_1O_2 = 2m\cos 60^0 = \sqrt{3}m$$

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

$$Therefore:$$

$$\cos\alpha = \frac{SO_2^2 + O_1O_2^2 - SO_1^2}{2SO_2 \times O_1O_2} = \frac{h(h-r) + r\sqrt{3m^2 - h^2}}{m\sqrt{3r^2 + 3(h-r)^2}}$$

Considering the structure limits and non-interference between the planetary wheels, the rotation arm=104mm is selected, based on the geometrical relationship r=90mm is calculated, then substituting the value of m,r,h in the equation we get $\alpha = 22^0$.

Therefore: $\beta = \alpha + 30^0 = 52^0$ $R_{\max} = OS = \sqrt{OO_2^2 + SO_2^2 - 2OO_2 \times SO_2 \cos\beta} = 90.7mm$

The maximum dimensions of the drive shaft centre 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 and the edge of the stair when the wheelchair climbs the stairs.

B. THE CONDITION OF CLIMBING STAIRS WITHOUT SLIPPING-

The situation shown is the easiest position to slip down the stairs. The distance between the front and the backwheel is supposed to be 1m and the distance between the gravity centre and backwheel is supposed to be x.

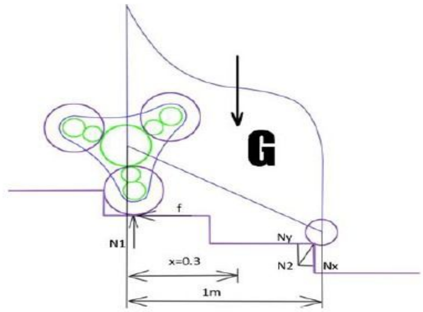

Figure 10. Condition of slip

According to the force and moment equilibrium principle the following equations are obtained.

$$N_y = xG$$
$$N_1 = (1 - x)G$$
$$N_x = N_y tg 30^0$$

To make the wheelchair climb up stairs without slipping have to meet the requirement of the following condition:

$$\mu N_1 \geq N_x$$
$$\mu (1 - x)G \geq xGtg30$$

Friction coefficient $\mu = 0.3$ is chosen here,

$$0.3(1 - x)G \geq 0.58x \;\; x \leq 0.34$$

In order to make sure the wheelchair is safe enough, the centre of the gravity should be close to the back of the wheelchair, because of the driving wheels as the main weight of the wheelchair and the wheelchair leans forward when it is climbing upstairs. So the location of gravity centre is set at x = 0.3 m from the rear wheel, which can realize the condition of climbing stairs without slipping.

V.2 STRESS ANALYSIS

There are three motion modes for the stair-climbing wheelchair, they are: moving on a level ground, moving on a sloping ground and climbing stairs. Each of the motion modes will be stress analyzed to find out which case has the best stress condition and which case has the maximum torque.

A. STRESS ANALYSIS FOR THE WHEELCHAIR MOVING ON A LEVEL GROUND

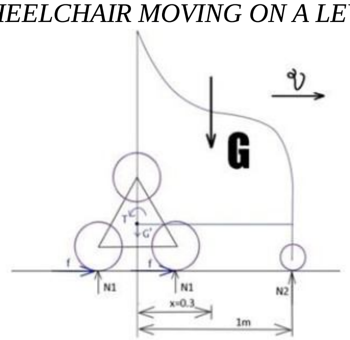

Figure 11. Moving on level ground

When the wheelchair is moving at constant speed the following equation is obtained,

$$f_{friction} = F_{resistance}$$
$$T = f \times r$$

Where r is the radius of the wheel, F is the moving resistance, which is small enough and can be neglected. Therefore the force which acted on the transmission gears is very small, so the wheelchair moving on good stress situation.

B. STRESS ANALYSIS FOR THE WHEELCHAIR MOVING ON A SLOPE GROUND

The degree of the slope is supposed to be 8 degree as shown, the positive pressure can be calculated in following equations,

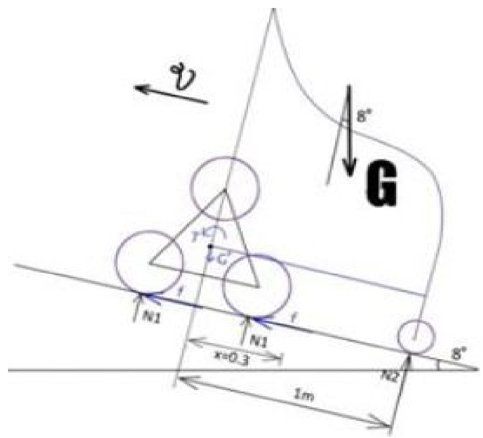

Figure 12. Moving on a sloping ground

$$f = \mu N_1$$
$$2N_1 = (1-x)G \times \cos 8^0 = 519.89N$$
$$N_1 = 259.95N$$
$$f = \mu N_1 = 0.3 \times 259.95 = 77.98N$$
$$T = f \times r = 7.02Nm$$

C. *STRESS ANALYSIS FOR CLIMBING STAIRS*

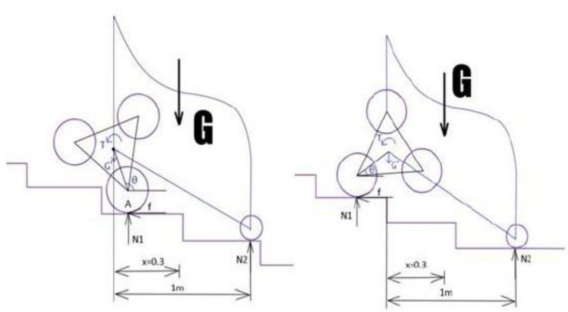

Figure 13. Wheelchair climbing stairs

The gravity can be transferred to the planetary wheel system and marked as G, which plays two important roles when the wheelchair climbs stairs, one helps the planetary wheel turning

And the calculation obtained is as follows,

$$G^{'} = (1 - x)G = 0.7 \times 750 = 525N$$

The balance equation for point A:

$$T = G^{'} m \cos\theta = 54.6 \cos\theta$$

Where T is the torque, G' is the total gravity of the wheelchair act on the planetary system. The design weight of the wheelchair is supposed to be 50Kg and the weight of user is 100 Kg, so the total weight is M = 150 Kg. And the single side gravity G = 75X10 = 750N, m is the length of the turning arm is m = 104 mm. It is easy to see that when the rotating arm of the planetary wheel in the horizontal state, i.e θ = 0, the distance between the barycentre of the wheelchair and the supporting point of the planetary wheels train is farthest where it also needs the largest motor torque, $T_{\max} = 54.6Nm$.

The results of different move modes

i. Moving on ground $T_1 = 0Nm$
ii. Moving on slope $T_2 = 7.02Nm$
iii. Climbing stairs $T_3 = 54.6Nm$

VI. TRANSMISSION SYSTEM DESIGN

In this section the transmission system will be designed and the principle of the transmission mechanism will be considered first, then the gears inside of the planetary wheel system will be selected and assembled.

VI.1. TRANSMISSION DESIGN SYSTEM FOR PLANTARY WHEEELS

Wheelchair is designed to cope with flat, inclined ground, stairs and obstacles. An epicyclic gearing is chosen as the transmission system for each locomotion unit, where the two degrees are wheels and planet carrier rotations. If we want the wheelchair to have determined locomotion, we must give two determined inputs to every locomotion unit.

And the work principle for our stair-climbing wheelchair is: one input comes from two motors driver solar gears of the planetary wheels system and the other degree of freedom is constrained by the situation of the ground. When the surface of the ground has low friction planet carrier can make the real-time adaptive adjustment according to road conditions, when the wheelchair climbing stairs, one of the degrees of the freedom is restricted by the stairs, the wheels cluster can revolve into a planetary wheel system, the planet carrier drives the other two wheels around the wheel which degree of freedom is constrained to achieve the function of climbing stairs.

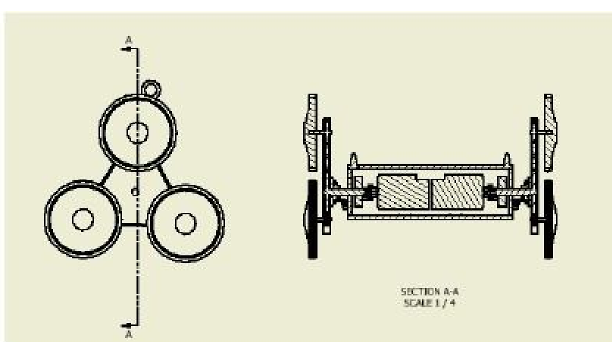

Figure 14. Section views of planetary wheels.

VI.2.GEAR SELECTION

The gears inside of the planetary wheels cluster is shown, and now the teeth and modulus for each gear will be selected.

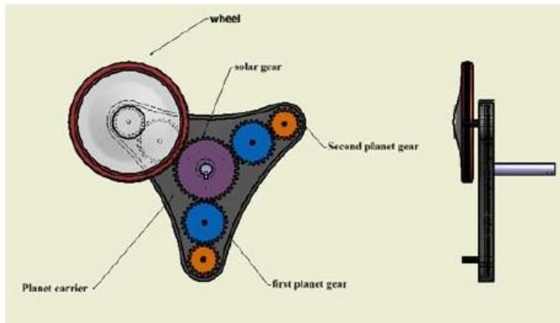

Figure 15. Structure of wheels cluster

In the section of stress analysis, three different motion modes have already compared, and the maximum torque happened when the wheelchair climbs up and down stairs, according to the size requirements of the triangle star wheel and in order to decrease the installation accuracy, the modulus of gears is selected as m=3 and the number of every gear teeth is supposed as: $z_1 = 38, z_2 = 26, z_3 = 18, and, z_4 = 45$ steel quenched and tempered gears are chosen, the strength checking on the centre gear z1 as follows,

$$T_{\max} = 54.6Nm = 54600Nmm$$

$$Where, Y_N = 2, Y_{st} = 2, S_{Film} = 1.5, \sigma_{Film} = 270Mpa$$

$$\sigma_{FP} = \frac{\sigma_{Film} Y_{st}}{S_{Film}} Y_N = \frac{270 \times 4}{1.5} = 720Mpa$$

$$\sigma_F = \frac{2KT_1}{\varphi_d m^3 Z^2} Y_{Fa} Y_{Sa} = \frac{21.554.6}{0.08338} 2.8 \times 1.52 = 2.2351 \prec \sigma$$

$$Where, Y_{Fa} = 2.8, Y_{Sa} = 1.52, \varphi_d = 0.08, K = 1.5$$

VI.3. MOTOR SELECTION

The rolling friction coefficient between tire and normal road surface is 0.02,which is decided by checking the mechanical design manual and we take factor of safety Ks=1.5, the total weight of a person and the wheelchair is 150kg. And the power required when the wheelchair works is,

$$P = K_S \times fmgv$$

$$P = 1.5 \times 0.02 \times 150 \times 9.81 \times 2 = 90W$$

The motor is primarily used as the engine when the wheelchair moving the ground or climbing up and downstairs, so rated power should be much bigger than 90W.

VI.4. STORAGE BATTERY

The battery selected has following features:-

a. Lead acid battery has the advantage of long service life, low price, and can store a large current discharge.
b. It has a small volume and light weight.
c. The selected motor needs 24V storage battery.

Table 1. Specification of selected battery

Item	Rated Voltage (V)	Rated Capacitance (AH)	Outline size Length	Width	Height	Weight (KG)
FM24V 1.3AH	24	1.3	193	42	52	1.1

VII. OPTIMISATION DESIGN

In order to improve our wheelchair, the following optimisations are designed:- Planetary wheels mechanism optimisation, seat backrest adjustment mechanism, locking system and improvement the comfort.

VII.1. PLANETARY WHEELS SYSTEM OPTIMISATION

Ordinary planetary wheel structure is when the central shaft drives the central gear, the central gear will drive the planetary gear and the planetary wheels to make the wheelchair go forward. When the wheelchair climbs stairs, the planet wheel is locked by the resistance, the whole planetary structure is derived by the central shaft rolling and completes the process of climbing.

One idea is got from the car clutch, which is used to control the engine and the wheels transmission separation and combination. Depress the clutch, driving device of the engine ids disconnected from the wheels, the power of the engine cannot pass to the wheels, the power of the engine cannot pass to the wheels, release the clutch, the engine driving device is connected with the wheels, the power of the engine can then pass to the wheels. The principle diagram of the clutch, the engine driving device is connected with the wheels, the power of the engine can then pass to the wheels.

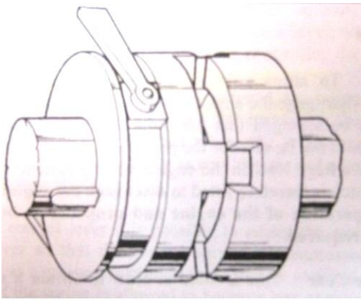

Figure 16. Dog Clutch plate

So kind of mechanism is chosen which can make the central gear and the box lock together when the wheelchair goes up and downstairs , and the driving force will act on the rotating arm, instead of the planetary wheels. It will avoid the gear bearing torque and impact during climbing up and down stairs and protect the structure of the planetary gear. Except that, for the ordinary planetary wheel structure there is relative rotation when planetary wheel contacts with the ground during the process of climbing stairs, the wheelchair can slip easily and the tire will wear and tear more easily, this is a hidden security danger. This problem is solved by the improved planetary wheel structure, because after optimisation the central gear and the box has been locked together, all the gears cannot rotate by its own axis, they can roll together with the box, the whole planetary wheel system changes into a rigid body, then the centre shaft will drive the whole body rolling-over. This design ensures it relatively static between the planetary wheels and the ground and prevents the wheelchair from slipping when it goes up and downstairs. The man advantage of the optimisation are:

a. The same drive system through simple transformation has two driving modes-move on the ground and climbing stairs which have compact structure and convenient operation.
b. Improved security and service life of gears

VII.2. LOCKING SYSTEM DESIGN

When the stair climbing wheelchair climbs stairs, there is danger of falling down the stairs, in order to protect the user and avoid this kind of situation to happen we installed a rachet mechanism locking system on the central axis as shown in fig. When the wheelchair goes up and down stairs, people can screw the handle to lock the wheelchair and thus prevent the wheelchair from slipping downstairs.

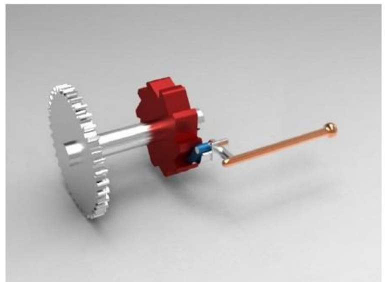

Figure 17. Ratchet locking device

VII.3. SEAT BACKREST MECHANISM

Most wheelchairs are oblique during the process of climbing up and down stairs, the user will feel uncomfortable, it can easily turnover, which poses a big safety risk. In order to overcome this problem, a seat backrest adjusting device is designed for our wheelchair, so before the wheelchair climbs up and downstairs, this device will adjust an angle for the seat and backrest to make sure the seat of the wheelchair keeps level with the ground all the time.

It consists of a handle, helical gear shaft, helical gear shaft and the worm and gear mechanism. The working principle for the seat and backrest system is: the user through the handle controls the helical gear shaft rotation, helical gear shaft will transfer torque to helical gear and drives the worm rotation, finally the worm transfer torque to the main shaft, and makes the seat backrest system adjust to any angle.

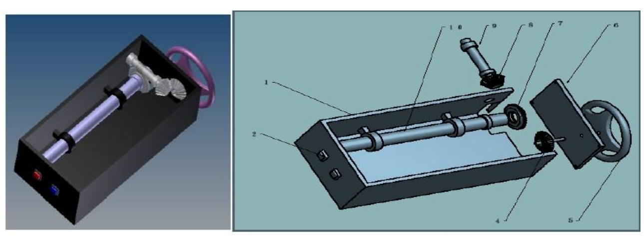

Figure 18. Seat backrest mechanism

The advantages of the design are:

1. The seat and backrest adjusting mechanism adopts manual operation which is not only energy saving environmentally friendly, but also reduces the weight from installing the motor.
2. User can adjust the seat backrest system to make the seat of the wheelchair parallel to the level ground when climbing stairs, which makes the user more comfortable.

VIII. CONCLUSION

a) The optimisation 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.

b) 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
c) Users can adjust the seat backrest system to make sure the seat of the wheel chair is parallel to level ground when it climbs up and downstairs.
d) The optimisation of ergonomics has been added in our design to make the wheelchair more convenient and comfortable.

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