Structural design and motion simulation of walking aid

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Abstract. The advantages and disadvantages of existing walking aids on the market are analyzed and improved. The overall structure is designed and analyzed, and the length of each segment is considered comprehensively from the perspective of adapting to human body. The 3D model was established in SOLIDWORKS, and the motion simulation analysis was conducted in ADAMS to obtain the speed, step distance and other parameters during the movement. The results were compared and analyzed with the applicable human motion parameters to verify its feasibility.

1. Introduction

The walking frame is a very important walking mechanism for the elderly or disabled who have poor mobility of lower limbs and perfect function of upper limbs [1]. The common walking frame on the market has frame type walking frame and wheel type walking frame. The frame-type walking frame needs to be lifted in the walking process, which is more difficult for the elderly and prone to danger in the lifting process [2]. In the process of walking, the stability of the wheeled walking frame is relatively poor, and it is easy to slide when it meets the ramp, and the road surface will also be bumpy. The common front wheel and rear leg walkers are better, but they can't solve the contradiction between stability and labor saving. Traditional wheelchairs do not work as rehabilitation exercises [3]. Through the existing technical search, it is found that the walking robots designed at present are wheeled, and wheeled walking robots are prone to sliding problems [4]. In this paper, a kind of robot with built-in speed regulating device, only one power source, and can work normally on uneven road surface is proposed.

2. Structural design of walking aid

The walking aid proposed in this paper is to help the poor mobility of lower limbs, but the elderly or the disabled with sound function of upper limbs can stand up with the strength of upper limbs and exercise their walking ability effectively with the power of the walking aid. Therefore, the design has high requirements on the safety and reliability of the device, and the coordination between the walker and the user cannot be ignored. Taking the above factors into consideration, the walking aid designed mainly includes frame, support frame, universal wheel, telescopic rod, support pad, crank, rocker, connecting rod, walking parts, turning plate and so on. The mechanical mechanism is simple and easy to manufacture. To allow for easier control, there is only one degree of freedom on one side of the structure, so only one motor drive is required. The motor is selected for driving mode to drive the synchronous belt, and the torque is transferred to the spindle, and then the torque is transferred to the walking parts on both sides by the spindle. During installation, pay attention to the position relationship of the walking parts on both sides, and make use of the accurate transmission ratio to keep
the position relationship between the two sides constant. Its overall structural design is shown in figure 1, and the driving part is shown in figure 2. The moving members are connected by pin shaft and split pin to reduce surface wear and facilitate disassembly. The shaft and frame of the driving system are connected by rolling bearings to reduce friction. The two axes are connected with the synchronous belt through the synchronous wheel, so that the movement process is smooth and the noise is small.

1 framework; 2 support frame; 3 wheel; 4 telescopic rod; 5. Support pad; 6 the fence; 7 speed adjusting grip; 8 the crank; 9. Upper rocker; 10 down joystick; 11 side connecting rod; 12 walking parts; 13 floor mats; 14 battery box; 15 baseboard

Figure 1. General structure of walking aid.

16 spindle; 17 Screw locking ring; 18 sleeve; 19 motor; 20 speed reducer; 21 driving gear; 22 driving gear; 23 step shaft; 24 deep groove ball bearing; 25 screw fastening shaft end stop ring; 26 deep groove ball bearing; 27 synchronous pulley

Figure 2. Walker drive system.

The schematic diagram of the structure of the design scheme is shown in Figure 3. The degree of freedom of its moving parts is:

\[ F = 3n - l - 2h = 3 \times 2 \times 5 - 7 - 0 = 1 \]

Where:

n - number of active components
l - number of lower pair
h - number of higher pair
Figure 3. Schematic diagram of the structure.

Its working principle is as follows: by adjusting speed wrap different angle for motor rotation speed, driving the spindle rotation, spindle by synchronous cog belt on both sides of the crank rotates, so the moving parts on both sides of the present law of periodic motion, the friction with the ground drive walk a caster forward movement, in order to realize the help line device integral action to move forward.

3. Walker parameter design

In order to make the walker coordinate with the human body in the process of use, it is necessary to carry out reasonable design of each component size under the premise of its normal movement. According to the national standard of "normal adult body size in China", the data of body sizes of men aged 18-60 in the study were collected in the sitting position. The data at the 50th percentile was taken as a reference, with the upper limit to the 90th percentile and the lower limit to the 10th percentile. The dimensional data of each percentile are shown in table 1.

According to the data in the table, the height range from the top of the whole motion mechanism to the ground of the walking aid except the handrail part is 389-439mm, so as to achieve the best state of sitting and standing for rest. After the overall height is determined, the length of each member is determined according to the movement characteristics of the instrument. The results are shown in table 2.

Table 1. Sitting size data of Chinese normal adult male (mm).

| Percentile | 1  | 5  | 10 | 50 | 90 | 95 | 99 |
|------------|----|----|----|----|----|----|----|
| Thigh clearance height, sitting | 103 | 112 | 116 | 130 | 146 | 151 | 160 |
| Knee height, sitting | 441 | 456 | 464 | 493 | 523 | 532 | 549 |
| Lower leg-foot length | 372 | 383 | 389 | 413 | 439 | 448 | 463 |

Table 2. Dimension data of each member.

| Segment | L12 | L23 | L34 | L45 | L46 | L38 | L57 | L17 | L18 | L78 |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Length/mm | 83  | 300 | 225 | 247 | 289 | 120 | 127 | 328 | 313 | 225 |

4. Design and simulation of walker prototype model

Based on the above analysis, a 3d model is built in SOLIDWORKS. Considering the cost of materials and machinability, prototype subject adopt aluminum alloy material, in order to reduce the overall weight of each shaft parts to can bear larger torque and only small deformation, steel material,
installed at the bottom of the motor in the framework of beams, in order to be able to withstand the motor weight and prevent bending during movement, the aluminum alloy material must be in which material, using overall connection bolt with the framework. The speed adjusting device adopts the hall speed adjusting grip. The output voltage depends on the magnetic field strength around the hall element. Turning the handle changes the strength of the magnetic field around the hall element, which changes the output voltage of the hall handle. And input the voltage to the controller, the controller according to the size of the signal PWM pulse width modulation. Thus, the ratio of power tube on and off is controlled to control the motor speed.

According to the 3D leg model established in SOLIDWORKS, the motion simulation analysis of walking aid leg was carried out in ADAMS. Firstly, add simple constraints and moving pairs of each connection part, and then add a driving system at the connection of the active member of leg member. Since the movement mode of leg active member can be simplified to circular motion, the driving system function can be simplified to a simple periodic function.

Walking components of walker schemes are two cycle simulation, the simulation after the reprocessing, parts contact with the ground to walk in the leg to establish the Measure for the measurement of displacement on the X direction and Z direction, resulting in two cycles samyama line machine parts contact with the ground of the legs to walk on the X direction and Z direction measurement data, as shown in figure 4.

According to the data obtained from the simulation test, it can be seen that the displacement of the legs in contact with the ground in a single cycle along the X direction is about 0.3m, while the displacement in a single cycle along the Z direction is about 0.1m.

Therefore, the optimal walking speed range of the elderly is 1.06m/s-1.28m/s, so the design adopts the speed control knob to realize the different needs of the elderly for walking speed in daily life, so the design of the walking parts meets the design requirements. Therefore, it is determined that the output speed of the motor through the reducer should be between 180-240 RPM in the load state.

5. Conclusion
This paper designs a kind of walking aid, which is simple in structure, makes use of the precise transmission ratio of gear and synchronous gear belt to save the tedious driving of multiple motors, which is convenient to drive, and solves the problem that the common old walking aid is time-consuming and laborious by manpower, which is a feasible scheme. After determining the relevant dimensions, modeling was conducted in SOLIDWORKS and motion simulation analysis was carried out in ADAMS. The obtained results verified the stability of its gait, providing a reference for the further design and optimization of the walker in the future.

The walking aid can provide support and forward power for the elderly or disabled people with leg disorders. The speed can be controlled by the user, which is safe and reliable. It can provide users with
confidence to recover their walking ability, contribute to the serious aging situation in China, and promote social harmony.

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