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Design and Research of Aging Device based on Ergonomics

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Abstract

At present, the elderly over 65 years old occupy a high proportion of the population in China, and the aging trend is still increasing. The products used in the market to help the elderly stand and squat are developing rapidly and widely used, but they are uneven, which can not solve the problem of getting up at home for the elderly living alone. In this paper, a seat is designed for the elderly in China, and the structural module and control module of the seat are optimized. The main research contents are as follows: 1) The basic physiological characteristics of the elderly are analyzed based on ergonomics, and the related factors affecting the seat design of the elderly are analyzed in combination with physiology. According to the physiological conditions of human spine, intervertebral disc and hip compression, the basic parameters of seat basic form design are determined. The basic size of the seat for the elderly is constructed by using the parameters of the human body size model, and then combined with the literature, the correction value with higher comfort of the seat is selected to correct the size, and finally the basic shape size of the seat is determined; 2) Using proe software to carry out three-dimensional modeling. With reference to China's adult human body data standards, optimize the structure and parameter design of the elderly seat, determine the size and load-bearing of each component, and select the motor, ball screw and other components. The research shows that the elderly seat can help the elderly to complete the actions of getting up, sitting down and squatting, and the split gear design can be applied to the elderly of different heights.

Keywords

Ergonomics; Auxiliary Standing; Optimization Modeling; Gear Design.

1. The introduction

1.1. Research Background and Significance

As we enter the 21st century, the number of elderly people in our country has increased dramatically and has gradually evolved into an ageing society. At the end of 2017, the population aged 60 and over accounted for 17.3 per cent of the total population to 240.9 million, while the population aged 65 and over accounted for 11.4 per cent of the total population to 158.31 million [1,2], according to the survey. And by 2022, China's over-65s are expected to make up 14% of the population, transforming the country into an ageing society.

"As we age, cell division slows or even stops, muscle mass shrinks, the transverse area shrinks, and fast muscle fibers shrink," the study found. "As we age, the force on the lower extremities decreases [3], ultimately making it difficult for older people to stand and squat, causing great inconvenience to their daily lives and distress to their families." As our country enters the aging society, the problem of sitting up for the elderly has been paid more and more attention to by the society. A lot of assisted-sitting designs have come into being. These assisted-sitting designs range from the most traditional support poles and crutches to various kinds of hydraulic or electric cushions. However, at present, most of the assistive devices are only in the theoretical

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research stage, and can not be used in practice. Some of the devices that can be used in practice have the problems of high price and difficulty in use.

1.2. Current Situation at Home and Abroad

Back in 2000, Tomita and Ogiso Toshio, among others, developed a robotic arm to help older people stand and sit [4]. The project developed a program to analyze the motion loads of lower limb joints by experimentally measuring joint positions and floor reversals, enabling it to calculate joint positions in different paths using the Newton-Ola formula, and to assess the support performance of the robotic arm's path. Used to help an old person sit or stand.

Case Western Reserve University in the United States has designed a device to assist the elderly to stand [5]. The agency uses air springs as power originals and uses the spring's extension to aid standing and sitting motion in older adults. It is a purely mechanical structure with a simple structure, easy to use and no need to rely on power other than the elderly's weight. However, man's standing and sitting motion is not a plumb line motion, but a curvature of horizontal velocity that is higher than that of plumb line velocity [6]. Therefore, the linear rise and fall trajectory of the agency is contrary to human physiological habits and does not meet the needs of the elderly well. Moreover, the size of the facility is fixed and does not fit well with older persons with different physical characteristics.

In 2018, a foreign company invented UP N'GO Cushion Booster Seat, which is a typical hydraulic booster seat. The cushions can support up to 270 pounds, making it easy for older people to get started. This rising cushion uses the principle of hydraulic support rods to lift or support up to 80 per cent of the body weight of an elderly person when standing up. Thus, it can help the elderly with inconvenient legs to get up or sit down from furniture such as chairs or sofas [7].

Developed by Wang Yan Lung, Yang Yung-kan and others, Smart Home Standing Device is designed to assist the elderly to stand in a variety of settings within the family (as shown in Figure 1.3) [8]. The wire rod and the electric putter can cooperate to fit the displacement curve of the center of gravity of the elderly in the process of standing, and by controlling the speed of the wire rod motor and the speed ratio of two putters can fit various curves to suit the elderly of different body types and different rising heights.

In 2018, Zhang Weikang, Mou Du and others at Yanshan University designed a smart wheelchair for the elderly and disabled [9]. The control core of the device consists of motion control, movement navigation and obstacle avoidance, human-machine interaction and so on. can help the user stand; Helps the user recline.

2. Design of Arise Device based on Ergonomics

Senior-assisted standing chairs are specially designed to help older people with awkward legs get up from their seats. First of all, this chapter is based on the theoretical basis of ergonomics to analyze the basic physiological characteristics of the elderly model; Secondly, based on physiological study, the physical characteristics of spine and buttocks were analyzed to determine the basic morphological characteristics of the seats. Finally, the basic external dimensions of the auxiliary standing chair are established by the parameters of human template dimensions.

In order to simplify the structure and help the elderly to achieve the purpose of standing, sitting and squatting, the device uses multi-motor as the power source, divided into rotating plate structure and lifting frame structure. The rotating plate structure depends on an electric motor to drive a pair of meshing gears. The lifting frame structure depends on a motor driven ball screw structure. This part combines national human data with 3D modeling of the model in ProE to determine the final data and component model.

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2.1. Ergonomics Theory

Ergonomics in seat design mainly involves human physical characteristics and psychological responses. By means of measurement, experimental calculation, subjective evaluation and other analytical and research methods, to provide effective data support for seat design. This paper introduces the principle of ergonomics into the study of the design of seats for the elderly. The purpose of this study is to optimize the physical characteristics of the seats for the elderly, so as to achieve the optimal combination of human-machine-environment system and design the assistive rising device suitable for the elderly.

2.2. Age Booster Sitting Device Structure

2.2.1. Parameter Design

Human size is an important basic data of ergonomics, and the model of human size of the elderly is the foundation of chair design. Metabolism slows down as we get older, and every part of our body shrinks to varying degrees, especially in height. The available ergonomics data provide little statistical information on body size in older adults. Therefore, before carrying on the senior citizen chair design, must carry on the analysis summary to our country senior citizen human size.

According to the Chinese Body Size Standard GB 100,000-88, most adult men do not sit more than 486 mm deep, 460 mm wide in shoulders and 439 mm high in calves. Adult female not to exceed 461 mm in depth, 430 mm in maximum shoulder width and 399 mm in calf height; Therefore, it is determined that the maximum trip length of the chairlift mechanism is 925mm and the width of the seat is 480mm, which can be adapted to most elderly people [10].

Access to data shows that older people need about 2.41S [11] from sitting to standing, which is less time than standing to sitting, so the same amount of time is used in calculations. Seat depth generally does not exceed 486 mm. It can therefore be determined that the average speed at which older persons sit does not exceed 201.6 mm / s, or 0.2 m / s.

2.2.2. Buying a Type

Motor Selection: According to the weight table of Chinese adults aged 65 and above, Chinese men usually weigh no more than 70Kg and women weigh no more than 62Kg [12,13]. Therefore, the load of the auxiliary chair is determined to be 70Kg, or 700N / M, and the motor is selected according to the required power and torque.

One of the important principles of motor selection is to meet the requirements of power, torque and other practical applications. Under the condition of satisfying these practical application data, choose a motor with low price, simple structure, stable performance and easy to maintain later. Servo motor and stepper motor are commonly used. The servo motor has closed loop control, which produces high torque and accurate control, but it is expensive. Stepper motor is open-loop control, using the input signal pulse frequency and pulse number to control, when the input end to a signal pulse, step motor, usually step number, maximum angular speed, angular acceleration and other parameters to control. Stepper motor is suitable for short trip and frequent action. It has the characteristics of cheap price, simple structure and precise control. Due to the short trip and frequent change of direction of the seat plate and chairlift, stepper motor is used for control.

(1) Calculation of dangerous speed of ball screw

Based on general design criteria， the speed of the ball screw structure lift is 0.2 m / s. With a maximum lift of 925mm, support gravity of 700n / m, and a ball screw structure of fixed -free link. Smaller speed ball screw guide is often selected 1mm, 2mm, 4mm, 6mm, 8mm, 10mm, 20mm, considering that the speed of the older seat lift frame here is smaller, the trip is larger, so the ball screw structure guide is determined to be 20mm. According to the speed and load

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bearing diagram of the ball screw structure, select the ball screw structure with a diameter of 18 mm.

Relationship between speed and load bearing of ball screw structure.

By Formula:

$$N = \frac{V}{M} \tag{1}$$

N is the dangerous speed in the formula; V = 0.2 m / s is linear velocity; M = 20mm as guide

Substitution calculated:

$$N=(0.2m/s)/10mm$$
$$=(0.2*103mm/s)/20mm$$
$$=100r/min$$

By Formula:

$$\sqrt{(EIg/\gamma A)} \tag{2}$$

$$A=(\pi/4)*d2 \tag{3}$$

$$\gamma=7800*10\text{-}9kg/mm3*9.8N/k \tag{4}$$

$$I=(\pi/64)*d4 \tag{5}$$

In the equation, ß = 0.8 is the safety factor; A is cross-sectional product (mm2); L is for installation spacing; Gamma is density; I is the minimum cross sectional secondary moment of the screw shaft. (b) the coefficient of the epsilon in relation to the manner of installation.

For data access, the following types of values are available for epsilon depending on the method of installation, as shown in Table 1.

Table 1. epsilon extraction table

Installation method	ε values
Fix -Free	ε≈1.875
Fix-Brace	ε≈3.927
Fix – Fix	ε≈4.703
Brace – Brace	ε≈Π

The formula has been simplified:

$$N= ß *(60*\varepsilon 2)/2\pi L2*\sqrt{(EIg/\gamma A)}=(60*a/8\pi)*(\sqrt{(1000*E)}/\sqrt{p})*(\varepsilon 2/L2)*d$$
$$\approx 107*\varepsilon 2*d/L2$$

Just get:

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$$N \approx 107*\varepsilon 2*d2/L2 \approx 107*1.8752*18/9002=781\ r/min$$

Since the limit speed of the device is less than the dangerous speed of the ball screw structure at 100r / min < 781r / min, it is feasible to select the ball screw structure with a diameter of 18mm and a guide length of 20mm.

(2) Motor at Seat Board

The force received by the rotating plate structure during operation is a process of change. When the plate is vertical, the plate has no force. As the old person sits down, the force on the plate increases gradually until the final plate is horizontal, the weight of the user is all on top of the plate.

It takes about 2.41s for the old person to sit and stand, and the seat only needs to rotate in that time, with a gearing ratio of 1: 1, making the rotation angle theta. t = 2.41s for the elderly to sit and stand; omega is the angular velocity of the plate; n is rpm; By Formula:

$$\omega=\theta/t \tag{6}$$

$$n=\omega/360 \tag{7}$$

Availability of proxy data:

$$\omega=\theta/t=/2.41=\pi/(4*2.41)=0.33rad/s$$
$$n=\omega/2\pi=0.33/6.28=0.053r/s=3.18r/\ min$$

The mechanical transfer efficiency of the motor and its apparatus is @ 70kg, the base plate is aluminium and the supporting rod is low carbon steel. The friction coefficient is μu = 0.47. The force distance between the gears is measured at S = 44mm and the maximum power of the motor is:

$$P=\mu mg*\omega*S1/0.8=0.47*700*0.33*0.044/0.8=6W=0.006KW$$

Then by formula:

$$T=9550*P/n \tag{8}$$

Substitution data calculated as T = 9550 * 0.006 / 3.18 = 18N.M.

The maximum power required for each motor is P = 18 / 2 = 9N.M as the drive plate rotates into two motors

Therefore, model number 86HS12660A4J is an option, with parameters corresponding to those shown in Table 2 below.

Table 2. Motor I Parameters

Model	Static torque	Current	Step angle	Number of leads
86HS12660A4J	9.5N.M	6A	1.8°	4

(3) Elevator

Motor II with ball screw structure can be calculated using the following formula:

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$$Ta=(Fa*I)/(2*3.14*n1) \tag{9}$$

$$Fa=mg+\mu mg \tag{10}$$

Ta is the driving torque; I = 20mm is the guide length of the wire bar; n1 = 0.8 is the positive efficiency of the feed screw; Fa is radial force; m = 70Kg as bearing weight; g = 10 for gravitational acceleration; Friction coefficient mu = 0.6.

Availability of proxy data:

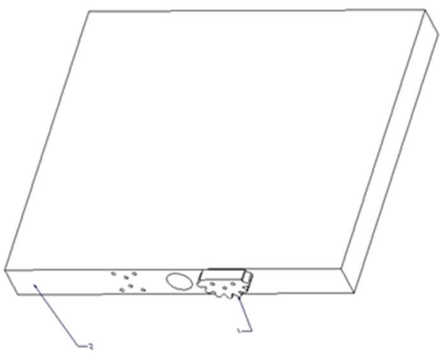
$$Fa= mg+\mu mg =70*10+0.6*70*10=1120N$$
$$Ta=(Fa*I)/(2*3.14* n1)$$
$$=(1120*0.02)/(2*3.14*0.8)$$
$$=4.48N.M$$

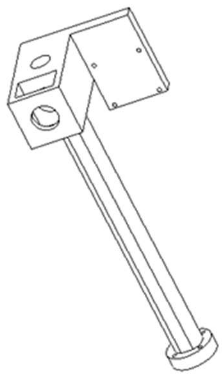
Since there are two motors, each motor torque is T = 4.48 / 2 = 2.24 N.M.

Therefore, J-8618HB1401 can be selected.

2.2.3. Design of Age-Booster Device

Helper seats are mainly composed of a rotating structure of seat plate and a lifting frame. The rotary structure of the seat plate is composed of the seat plate, support rod, motor I, gear I and lifting rod. Gear I is fixed to the seat plate, the upper end of the lifting rod is used to secure the motor I, the support rod, and the lower end is equipped with ball screw, ball screw is driven by motor II, as shown in figures 1 and 2.





1 -Gear I 2 -Seat

Figure 1. Seat Plan **Figure 2.** Lift Bar Design

The upper end of the lifting rod is fixed to the motor I, the motor I links to the gear II, the gear II engages with the gear I, and the gear I is fixed to the seat plate. Gear II rotates clockwise when the motor I rotates, Gear I rotates counterclockwise, and the seat plate rotates counterclockwise from a vertical position to a horizontal position to assist the elderly in sitting. When motor I inverts, gear II rotates counterclockwise, gear I rotates clockwise, and the seat plate rotates clockwise from vertical to horizontal to assist the elderly in standing and squatting.

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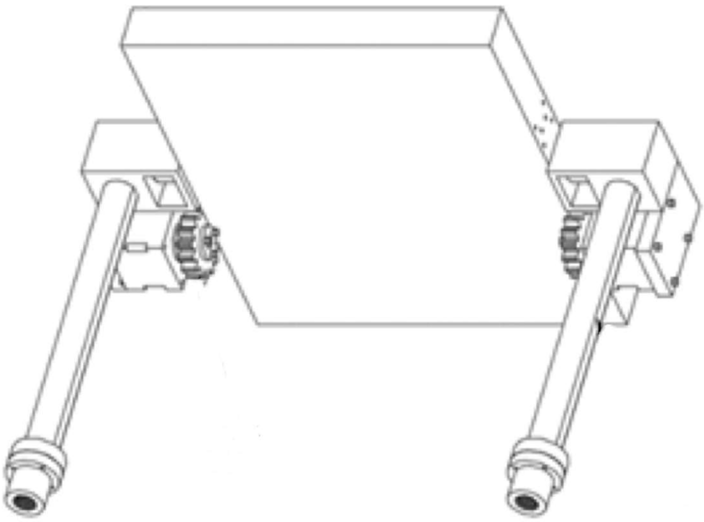

Figure 3. Rotational Seat Chart

The lifting frame is composed of motor II, ball screw, lifting rod and so on. The motor II is connected to the ball screw structure, which is connected to the ball screw structure. As shown in Figure 4, when the motor is turning, the ball screw moves up to assist the elderly in the standing process, and when the motor is reversing, the ball screw moves down to assist the elderly in sitting or squatting.

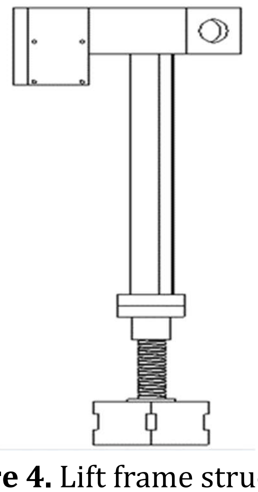

Figure 4. Lift frame structure

Before the device is used, the seat plate is in a lead-weight position and remains in the center of the device, i.e., the longitudinal stroke origin position. When the older person's buttocks are near the seat, start the switch and motor I is turning, driving the seat counter clockwise to a horizontal position, while motor II is turning, driving the lift frame down to assist the older person to sit. When motor I inverts, the drive seat rotates clockwise to a vertical position, motor II continues to rotate forwards and the riser descends to assist the elderly in performing squats. When motor I inverts and the seat plate rotates clockwise from the horizontal position to the vertical position, motor II reverses and the riser rises to assist the older person in the standing motion. The device has different gears. After the elderly choose a gear suitable for their own height, the lift trip of the device is adjusted according to the selection to suit the needs of the elderly of different heights.

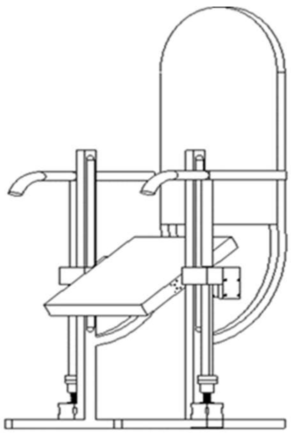

Figure 5. Sitting Board Rotation Master Chart

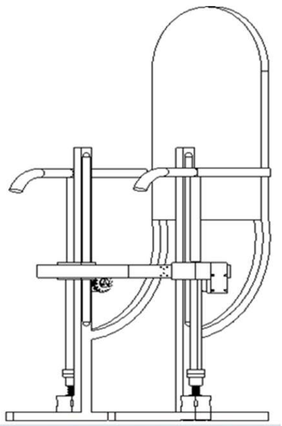

Figure 6. Horizontal Chart of Seat Plate

3. Conclusion

Wen designed an assisted-rising device for the study of elderly people who have difficulty getting up from their seats after sitting for a long time. Based on ergonomics, the physiological characteristics of the elderly were analyzed. The basic form of the assisted standing mechanism is designed, and the basic model of the assisted standing chair for the elderly is finally constructed by the combination of interactive design and emotional analysis.

Before the design of assisted-aging seats, research relevant literature, do market research, found that the products on the market can be roughly divided into crutches, assisted-aging cushions, robotic arms, assisted-aging mechanical design and so on. Crutches are the most commonly used, but also the most strenuous. Age-assist cushions are small in design, but limited to use on sofas, seats and the like, and do not help the elderly squat. Robotic arms and some assistive devices are complex and cumbersome to use. The seat can assist elderly people living alone to complete the movements such as sitting, standing and squatting, very convenient. The purpose of the structural design is simple and small. Finally, the structure of the seat is composed of two parts: rotating board structure and lifting frame structure. Two motors control the operation of both parts. The rotating base plate structure is driven by gears, and the generating and lowering frame structure is driven by ball screw. According to its mechanical structure and the actual conditions of bearing gravity, the structure of motor and ball screw is selected and designed by calculation.

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