Research on auxiliary bed - lifting device for the elderly

Yuanhang Yang*, Lei Qi, Haonan Jing

School of Mechanical and Electrical Engineering, Wuhan University of Technology, Wuhan 430070, China

*Corresponding author: 283876@whut.edu.cn

Abstract. Although there are devices to assist the elderly to get out of bed in China, most of them are aimed at the disabled elderly or still need artificial assistance. For some old people with certain activity ability, there is no appropriate auxiliary equipment at present. Based on this background, the electric push rod and gear system are used to realize the back lifting, leg bending and auxiliary standing functions of the elderly when they get up and lie down. The matching design of connecting rod mechanism and gear mechanism is adopted to meet all the needs of the elderly when they get up and lie down with a simple mechanism.

1. Introduction

With the continuous improvement of China's economic level, the process of population aging is accelerating. According to China's 2018 population data released by the National Bureau of Statistics, in terms of age structure, the working-age population aged between 16 and 59 is 897.29 million, accounting for 63.3 percent of the total population. The population aged 60 and over reached 249.49 million, an increase of 8.59 million over the previous year, accounting for 17.9 percent of the total population. Among them, the number of people aged 65 and over reached 166.658 million, an increase of 8.27 million over the previous year, accounting for 11.9 percent of the total population.

The related service facilities for the elderly have gradually become a problem that cannot be ignored, and various problems that the elderly living alone encounter in life have also been paid more and more attention. In the Opinions of the General Office of the State Council on The Formulation and Implementation of Elderly Care Service Projects published by the State Council in 2017, it was mentioned that professional service institutions should be strongly supported and other organizations and individuals should be encouraged to provide life care, medical care, spiritual consolation and other services for the elderly at home. The emergence of many service agencies and auxiliary instruments for the elderly living alone also proves that how to solve the problems of the elderly, especially the elderly living alone, is indeed a hot topic in the society.

Nowadays, with the increasing proportion of the elderly living alone, the focus of China's elderly care has shifted from institutional care to community care and home-based care. The development of industries such as family doctor and convenient life service is still in the ascendant. At the same time, the elderly living alone in the daily life of all kinds of small problems have become not to be underestimated. The community has strengthened its support for the elderly living alone. However, due to the limited manpower and time, it cannot take care of and solve the frequent but minor difficulties in the elderly's life, such as difficulty in getting up and lying down, difficulty in getting out of bed and so on.
2. Introduction of the overall model of the device

This device is an auxiliary device for the elderly to get up in bed, as shown in Figure 1. The whole device is mainly composed of three parts: back lifting module, leg bending module and bed lifting module. The back module mainly adopts the four-bar mechanism, which is driven by the steering gear. The upper part of the bed can be rotated to a certain Angle to help the elderly back. The leg bending module is composed of three electric putters, which pushes the thigh board to rotate upward, and the putter drives the calf board to rotate down, thus assisting the old man to bend his legs. The lifting module of the bed body is driven by the electric push rod to push the slide block, which drives the entire bed body to tilt at an appropriate Angle, and coordinates with the handrail at the end of the bed body to assist the elderly to stand.

![Figure 1. Overall installation diagram (four states).](image)

The overall operation process is as follows: when standing up, the old man is initially located in a flat state, the back lifting module drives, and the back bed board rises upward to drive the old man's upper body to lift. At the same time, the bending leg module drives the bed boa

2.1. Adopt scheme of back module

The lifting module is mainly composed of the putter at the bottom, the lever connected by the putter, the slider and the back plate. As shown in Figure 2., ① is the back plate of the bed, ② is the slider stuck on the bottom of the back plate, ③ is the connecting rod connecting the slider and the putter, ④ is the power putter that pushes the back plate to rotate upward.
2.2. Bended leg module
The module consists of thigh board, calf board, slider, putter 1 and putter 2. As shown in Figure 3., ① is the thigh plate with a length of 570mm. ② is a slider. ③ is a crus plate, its length is 510mm. ④ is the putter 1, ⑤ is the putter 2. Among them, the electric push rod 1 is fixed, perpendicular to the ground, 90°, without hinge, and can only be oriented and telescopic. One end of the push rod is connected to the slide block, and a slide track is placed under the thigh plate to limit the slide block, which can only move up and down the slide track in a straight line. One end of the putter 2 is connected to a hinge fixed on the thigh plate so that it can move with the thigh plate and rotate around the hinge in a certain Angle. The other end is connected to the shank plate by connecting rod. The connecting rod and push rod 2 can be moved, but it is fixed to the connecting rod and shank plate, so that the connecting rod and shank plate are always 90°.

2.3. Bed body lift auxiliary standing module
As shown in Figure 4, the device is mainly composed of ① big gear, ② bed board, ③ bedside handrail, ④ pinion and ⑤ electric push rod.
Figure 4. Bed body lift auxiliary standing module

When it is necessary to assist the elderly to stand, the electric putter will turn forward, and the putter can extend to lift the bed board at an angle from $0^\circ$ to $25^\circ$, which can ensure that the elderly can get the help of the bed board when they stand up. The proposed design size of the bed board is 200mm long, 120mm wide and 50mm high. When the bed board is raised, the handrail beside the bed is also raised synchronously, so that the elderly can use the handrail next to them for support when they stand. The length of the bedside armrest is 660mm, which enables people to get maximum assistance when using the bedside armrest. The bed armrest and bed board are connected by a pair of large and small gears. Are connected by a small gear and bed rails, make the rotation of the pinion to control the bed rails, and the bed board is controlled by big gear, the rotation of the wheel to the rotation Angle of the bed board, between normal size gear meshing, the size of the big gear parameters for 113, the size of the small gear parameters for 37, with a certain ratio when moving a circle can be made when the big gear, the pinion rotating three times, made when the bed board turn $25^\circ$, bedside armrest rotate $75^\circ$, makes the old man to stand, not only can the greatest degree of assisted by bed board at the same time, they can stand the best use of bedside armrest.

3. Theoretical basis and mathematical model
This part of the device for the size of the gear and other data calculation check.

3.1. Select gear type, precision grade, material and heat treatment
Spur cylindrical gear transmission is selected according to the transmission scheme, and the accuracy grade is 7. In order to ensure that the gear has sufficient strength and reduce the size as far as possible, the hard tooth surface gear should be selected. Since the transmission ratio of the two gears is 1 and the size is basically the same, 20CrMnTi steel is carburized and hardened, and the hardness is 56-62HRC. The bending fatigue limit stress and contact fatigue limit stress can be obtained by looking up the table. $\sigma_{F,\text{lim}} = 430\text{MPa}$, $\sigma_{H,\text{lim}} = 1500\text{MPa}$.

3.2. Calculation of gear strength
According to the bending fatigue strength design of gear teeth, the calculation formula is

$$m = 12.63 \sqrt{\frac{KT_{Y_{F,\text{lim}}}}{Y_{d}Z_{1}^{3/2}\sigma_{FP}}}$$  \hspace{1cm} (1)

3.3. Determine the allowable bending force $\sigma_{FP}$
according to the formula

$$\sigma_{FP} = \frac{\sigma_{F,\text{lim}}Y_{ST}}{S_{F,\text{lim}}} Y_{N}$$  \hspace{1cm} (2)
The stress correction coefficient of the test gear is calculated $Y_{ST}=2$ according to the national standard $\sigma_{F_{lim}}$. Considering that the speed of gear is not high, the life coefficient of fatigue bending strength is $Y_{N}=1$. Minimum safety factor for bending strength is $S_{F_{lim}}=1.6$. The

$$\sigma_{FP} = \frac{\sigma_{F_{lim}} Y_{ST} Y_{N}}{S_{F_{lim}}} = \frac{430 \times 2 \times 1}{1.6} = 537.5 \text{MPa} \tag{3}$$

3.4. Calculate the nominal torque of the gear $T_1$

According to the above calculation, the pair of gears transfers the power to the central axis, and the torque of the central axis is the torque of the pair of gears, $T_1=24340 \text{Nm}$.

3.5. Select the load coefficient

As the prime mover is a motor, the rotation speed of the device is small, the movement is relatively stable, and the accuracy class is 7. Therefore, the load coefficient can be selected to be smaller. So, $K=1.3$.

3.6. Gear parameters are selected preliminarily

Considering that the torque transferred to the gear is large, the number of teeth also needs to take a larger value, $Z_1=80$, $Z_2=Z_1=32$, coefficient of facewidth $\psi_d=0.6$.

3.7. Determine the composite tooth profile coefficient $Y_{FS}$

Because the two rounds of the selected materials and heat treatment is the same, the same $\sigma_{FP}$, can be seen from the table $Y_{FS}=3.93$.

The above parameters can be substituted into the calculation formula

$$m = \frac{12.6 \sqrt{\frac{KT Y_{FS} Y_{N}}{\psi_d z_i^2 \sigma_{FP}}} = 12.6 \sqrt{\frac{1.3 \times 24340 \times 3.93 \times 1}{0.6 \times 80^2 \times 537.5 \times 10^6}} = 4.94 \text{mm} \tag{4}$$

Look up the table and take the standard module $m=50 \text{mm}$, The center distance

$$a_1 = \frac{m(Z_1 + Z_2)}{2} = 400 \text{mm} \tag{5}$$

3.8. Computational geometry

$$d_1 = d_2 = mz_i = 400 \text{mm} \tag{6}$$

$$b_1 = \psi_d d_1 = 240 \text{mm} \tag{7}$$

$$b_2 = b_1 + (5 \sim 10) \text{mm} = 250 \text{mm} \tag{8}$$

3.9. The formula for calculating the contact strength of the checked tooth surface is
The pair of gears are steel gears with desirable elasticity coefficient $Z_E = 189.8 \sqrt{MPa}$. So

$$\sigma_H = 112 Z_E \sqrt{\frac{KT_i (u+1)}{bd_i u}} \leq \sigma_{HP}$$

(9)

The allowable contact stress calculation formula of the tooth surface is

$$\sigma_{HB} = \frac{\sigma_{Hlim}}{S_{Hylim}} Z_N Z_w$$

(11)

The minimum safety factor is $S_{Hylim} = 1.5$, the life coefficient calculated by contact fatigue strength is $Z_N = 1$, and the working hardening coefficient is $Z_w = 1$, then

$$\sigma_{HB} = \frac{\sigma_{Hlim}}{S_{Hylim}} Z_N Z_w = \frac{1500}{1.5} \times 1 \times 1 = 1000 \text{MPa}$$

(12)

As a result $\sigma_H \leq \sigma_{HB}$, the contact fatigue strength is also sufficient.

4. Conclusions

Compared with the existing devices to assist the elderly to get up in bed, this work has the following two advantages: The electric push rod and gear system can realize the back lifting, leg bending and auxiliary standing functions of the elderly when they are getting up and lying down, and realize the integration of functions, which can effectively reduce the pressure on the back and back of the elderly, and provide assistance when the elderly need to get up and lying down, which greatly helps the elderly.

The device adopts the matching design of connecting rod mechanism and gear mechanism, and meets all the needs of the elderly when they get up to bed with a simple mechanism. Compared with some professional and tedious bed-raising machinery at present, the device employs fewer workers, has a higher efficiency, and has a broad development prospect.

The machine in the process of meeting the needs of the elderly sleeping up, to solve the problems faced by the elderly sleeping up at the same time, but also simplify the mechanism, connecting rod residual gear matching design, simplify the operation, improve efficiency, reduce the cost. It makes the machine product more widely applicable, more popular, has a broad prospect and research significance.

References

[1] Jiang Hao, Wang Wei, Liu Yongping. Research and development of multifunctional nursing bed [J]. Computer information, 2006, 22(7-2): 117-119.
[2] Wang Xianfang, Wang Shuyang, Wang Xiaodong. Older products humanized design [J]. Journal of forestry labor safety, 2006, 12 (4): 37-38
[3] Jiang Shengyuan, Hu Yanjuan, Li Jianyong, etc. Development of intelligent multi-functional electric rehabilitation bed [J]. Mechanical design, 2008, 25(5): 61-62.
[4] Ren Yi, Zhang Junxia, Xue Qiang, etc. Mechanical Design, 2009, 26(3): 43-45. (in Chinese)
[5] Zhang Shaoru, Chen Wanqiang, Zhang Yi, etc. Research on multifunctional hospital beds [J]. China rehabilitation, 2010, 25(5): 392-393.
[6] Zhang Jianguo, Tan Yunli, Xue Qiang. Multifunctional nursing bed Design based on Ergonomics [J]. Manufacturing Automation, 2010, 32(6): 88-90.

[7] Liu Guotian, Zhu Yajun, Sun Shoubing. Design of Intelligent Wheelchair Bed with Adjustable Posture [J]. Mechanical and Electrical Engineering Technology, 2011, 40(12): 57-60.

[8] Liao Yi. Development status and trend of intelligent nursing bed, medical equipment, 2013, 26(10): 5-7.

[9] Lu Changzheng. Product innovation design factor analysis based on user experience [J]. Science and technology bulletin, 2015, 31(01): 151-154.