Mechanical Analysis and Simulation of Intelligent Nursing Bed

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Abstract. How to take better care of the elderly and disabled people has become an urgent problem. This paper focuses on the development of a set of intelligent toilet collection system for the sanitary problem of excreting on the bed, which can help patients automatically excrete. First of all, we designed the overall structure of the nursing bed, its frame and planar linkages. Then, we used the Adams software to make kinematics and dynamics analysis of the nursing bed’s mechanism. According to the data of the dynamic analysis, we conducted a finite element analysis of the frame of the nursing bed, and tested the strength of its parts. The results showed that the motion of each mechanism was stable, the experimental value was much less than the yield strength of the material. Consequently, it could meet the design requirements.

1. Introduction

According to international standards, a country will be called aging when the number of over-60s accounts for 10% of its total population or its share of over-65s reached 7% of the total population [1]. Nursing beds as a medical AIDS, is widely used in hospitals, nursing homes, individual families and rehabilitation centers [2]. For patients, they would generate huge psychological pressure because they cannot take care of themselves. Not only that, if nursing work is not good enough, it will cause some Disuse Syndrome such as muscle atrophy, pressure ulcers. For the nurses, repeated nursing work is extremely heavy and boing. Accordingly, in order to decrease the workload of the nursing staff and provide them with cleaner, healthier, safer and unembarrassed nursing, society needs a multifunctional nursing bed, which not only has many basic functions such as roll over, curve legs [3-5] but also could deal with the problems of excretory and sanitary problems. These problems are also the most difficult and embarrassing problem to solve in nursing work. Consequently, it is particularly important to design a nursing bed with pedestal pan.

2. Design of nursing bed

The nursing bed is divided into six parts: bed frame, back lifting mechanism, rollover mechanism, leg training mechanism, pedestal pan lifting mechanism and intelligent stool collection system. The nursing bed can be truly intelligent through the collaborative work of 6 institutions. The overall mechanism is shown in Fig.1.
The electric putter has many advantages such as stable transmission, high driving efficiency and small noise. Additionally, it also has excellent variable speed, starting, braking and reversible control conditions. These make electric putter suitable for remote control, it will not affect patients [6] even if its structure is damaged. Therefore, according to the movement mode required by the nursing bed, electric putter is selected as the driving device. And then, the model of electric putter is selected according to the force of each driving point.

2.1. Bed frames
The bed frames are comprised of internal frame and external frame. Internal frame is decorated with other mechanism, hence the design of bed frames needs to reserve space and installation locations for other structures, especially internal space, need to set aside to put space of toilet system. At the same time, also need to guarantee institutions not to interfere in each other [7]. The structure is shown in Fig. 2.

2.2. Back-lifting mechanism
The back-lifting function is mainly used to change position and posture from lying to sitting, assist patients in eating, reading and other activities. Meanwhile, it is also used as the front operation of pedestal pan function, which can help patients aim at the pedestal pan. The main movement is simple and can be driven directly by electric putter, just achieve the angle of the back-lifting and comfortable back-lifting process. At the same time, the back-lifting mechanism could prevent patients from squeezing and dumping. The back-lifting mechanism is shown in figure 3.
2.3. **Rollover mechanism**

The nursing bed can help users to carry out nursing operations such as body cleaning and relieving pressure. It can also effectively reduce the fatigue of long-term bed and effectively reduce the occurrence of bed sores and other bed diseases.

The design requirement of the rollover mechanism is to be able to roll at an Angle of about 30°, which is relatively simple and can be driven directly by electric putter. Figure 4 is a schematic diagram of the rollover mechanism.

2.4. **Leg training mechanism**

Leg training mechanism is also a part of the nursing bed, can effectively help nursing patients to carry out rehabilitation training and prevent muscle atrophy. When mechanism turned upwards or downwards, support plate must be in the level of state to provide adequate support for the patient. The hip support plate and the leg support plate are the origin point of articulation, parallelogram mechanism is connected externally, the concrete structure as shown in figure 5.

![Fig. 3 Back-lifting mechanism](image1)

![Fig. 4 Rollover mechanism](image2)

![Fig. 5 Leg training mechanism](image3)

3. **Pedestal pan lifting mechanism and intelligent stool collection system**

During use, the pedestal pan can be quickly moved to the correct position. During idle, the sealing mechanism should be used to seal the pedestal pan with air leakage prevention [8]. The sealing
mechanism is required to support patient's weight when he sitting up. Due to space inside the bed body is limited, the normal operation cannot also be interfered. Therefore, we adopt lifting plate mechanism to realize the transposition of the pedestal pan, and use a separate electric putter to carry out sealing operation.

To make nursing bed self-cleaning, we use the vacuum suction to collect excreta. Then hip flushing and drying function are realized by faucet and drier, effectively solve the problem of defecation and sanitation. Among them, the overall capacity of the water tank is 10L, and hot water accounts for 1/3. The temperature control system keeps the water temperature at 40°C. The concrete structure is shown in Fig.6.

![Intelligent stool collection system](image)

**Fig. 6** Intelligent stool collection system

4. Kinematic analysis

The three-dimension model of nursing bed is assembled in Adams, and attribute material properties. Then, apply 450N pressure at the center of mass of the leg plate [9] and electric putter drive 8 mm/s, sets the elongation time 5.8 s and shrinkage time 9.6 s, back-lifting plate’s pressure is 675 N. When patient is lying flat, hip support plate has a force of 375 N. The stress condition of each electric putter is obtained to select suitable putter. Taking the back-lifting putter as an example, the simulation result is shown in Fig.7 and Fig.8 below.

When the back-lifting mechanism runs to 31.9 s, its speed reaches maximum value. At this time, its angular speed is 4.06°/s, patience’s body is almost completely right.

![Back-lifting mechanism angular velocity curve](image)

**Fig. 7** Back-lifting mechanism angular velocity curve
5. Finite element analysis

The external frame’s model is input into Ansys, and fixed constraints were added between the casters and the external frame. Then, apply 3000 N at the internal frame, evenly distributed at the front and rear ends of the bed. The weight directly borne by the internal frame is set at 2500N. Standard grid division [10] was adopted to divide 27985 cells and 54166 nodes. Finally, the total deformation, stress and strain of the nursing bed are solved, and the stress cloud Fig.9 and Fig.10 were obtained.

Through the stress cloud diagram, the maximum deformation is 0.46mm, which appears in the middle position of the internal frame of the nursing bed. The maximum stress value on the nursing bed is 77.4Mpa, which appears on the support points of the internal and external frames. Compared with the mechanical properties of the Q235B material, far less than its yield strength, and there is still a large amount of margin, which can be used safely.
6. Summary
This paper designs a nursing bed with toilet function. The core technical point lies in the posture adjustment mechanism and the toilet system, which provides basic service requirements for the aged and the disabled people. It can effectively alleviate the pressure on the family caused by the rehabilitation needs of the elderly or disabled people. At the same time, advanced functions such as vital sign detection, remote monitoring, and voice recognition functions can be added according to actual needs, and the various requirements of the nursing staff can be met as much as possible.

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References
[1] Huilin Liu. Research on the Status Quo of China's Social Economy Based on Population Aging [J]. Farm staff, 2018 (15): 239+161.
[2] Chun Liu, Jingmei Zhai, Xiao Xu and more. Development of embedded intelligent health monitoring equipment [J]. Mechanical design and manufacturing, 2009 (11): 258-260.
[3] Pengfei Zhao. Design and Research of Multifunctional Nursing Bed for Disabled Elderly Based on Interaction Theory [D]. Taiyuan University of Technology, 2016.
[4] Shigang Wang, Wei Shi, Yinghui Liang, Longjun Huang, Zhanqiang Huang. Design and manufacture of multi-function electric nursing bed [J]. Journal of Physics: Conference Series, 2019, 1213 (5).
[5] YoFa Biotechnology Co. LTD.; "Care Bed Combining Wheelchair" in Patent Application Approval Process (USPTO 20190091079) [J]. Biotech Business Week, 2019.
[6] Tie Zhang, Cunxi Xie, Huiqiang Zhou, Wei Xiong. The utility model relates to a robotic multifunctional nursing bed and its control system [J]. Journal of South China University of Technology (Natural science edition), 2006 (02): 47-51.
[7] Zongjie Tao, Qi An. Optimized workspace design of planar 3-RRR parallel mechanism considering interference [J]. Journal of East China University of Science and Technology (Natural science edition), 2013, 39 (02): 239-244.
[8] Changhong Dai, Peijun Wang, Shaochun Li. Design principle and characteristics of double sealed toilet [J]. Chinese pottery, 2010, 46 (01): 29-30.
[9] Ligang Zhao, Tao Ruan, Junzheng Ding, Aisheng Wu. Optimization design of multi-function nursing bed support mechanism based on ADAMS [J]. Journal of Jiangsu University of Science and Technology (Natural science edition), 2019, 33 (01): 45-50.
[10] M. Mahler, J. Aktaa. Eurofer97 Creep-Fatigue assessment tool for ANSYS APDL and workbench [J]. Nuclear Materials and Energy, 2018, 15.