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Mechanism Design and Debugging of an Intelligent Rehabilitation Nursing Bed

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Abstract: With the improvement of medical standards and the increase of the people's requirements for medical devices, it is a certain necessity to design and develop an intelligent rehabilitation nursing bed with high intelligence and integrated functions for the elderly, the paralyzed and the disabled. Taking into account the actual needs of patients, we design the mechanisms of supporting back, curving legs and side turning-over. With six dofs screw-slider-link mechanisms, we achieve the 90° side turning-over district nursing function. And we analyze the problems of the debugging process. Practical application shows that the bed runs smoothly, and the parameters of design is reasonable. With the state of side turning-over, we can scrub and massage the patient's back, buttock and legs.

Key words: intelligent rehabilitation nursing bed; side turning-over district nursing; debugging

I. Introduction

Recently, the number of over sixty-five years old people has reached about 118.83 million,and the aging rate is about 11.9% in China. It is predicted that ,in 2020,the number of the elderly people will be about 248 million, and the aging rate will be 17.17%.China is in a stage of rapid aging: 1) from 2021 to 2050,it will be a accelerated aging stage; 2)from 2051 to 2100,it will be a stable severe aging stage, and Chinese elderly population will reach a peak about 437 million in 2051.China is the largest elderly population, the fastest aging country. The elderly, the paralyzed and the disabled should be widespread concerned in the community.

Nursing care is a very important job for helping person to regain health or achieve the quality of life. This intelligent rehabilitation nursing bed is from the humane point of view, based on the concept of ergonomics[1], designed by the Solidworks. It is a kind of nursing bed with the functions of lying, raising back, curving legs and side turning-over, etc. On the position of side turning-over, we can do some nursing work, such as scrubbing, massage, for the patient's back ,buttock and legs. The design of this intelligent rehabilitation nursing bed will meet the needs of families, patients, and medical institutions. This nursing bed is not only to meet the basic physical needs of patients, but also more attention to comfort patient in each position and to facilitate the rehabilitation nursing care for patients. The intelligence of this nursing bed can help patients autonomously perform rehabilitation exercises, and the patient's body gradually recovered.

II. Overall program design

According to the functional requirements and the design specifications, we do overall layout to the bed. We determine the size of each bed panel based on commonly used anthropometric data. We each functional module structure and the corresponding control mode selection, and the overall design of the bed---mechanical system design and control system design.

The design of mechanical system is mainly including determining the overall size and each module layout, mechanism selection and optimization of each module. During the design of the mechanical system, we considered the following points: 1) Achieving the functional simulation of various postural poses; 2） Rotation angle of each activity bed panel should consistent care request and take into account the human's comfort; 3) Reliability, stability and security of bed movements; 4) Compatibility and consistency among mechanism of the process in motion; 5) Bed plane design with the entire space bed restrictions and functional requirements. Used Solidworks modeling design to ensure supporting back, curving legs and side turning-over and other ergonomic needs of different positions in the structure.

The control system includes a controller, image processing and expert system. In order to control the nursing bed intelligently and abreast the current operating status of the bed, we choose to use a dual-CPU ARM embedded system. The ARM embedded system has the advantages of low-power low-cost, high performance, high speed of instruction execution, simple and flexible addressing, high efficiency, etc. The image processing part adopts the structure design of Pan - monitoring system - the Internet - the user terminal, system wide coverage and signal transmission is clear and stable. Feature extraction using patients with facial expressions, and the characteristic values stored in the rule base expert system. Real-time acquisition of patients picture of

reasoning machine, and compares the recognition and decision according to certain mechanism, its decision value as the triggering signal controller, to meet the patients physiological demands and needs of rehabilitation.

III. Mechanism system design

A The overall structural design

Schematic structure of the intelligent rehabilitation nursing bed as shown in figure 1.It realizes the pose of 6 basic postures on nursing bed of the requirements, that is flat, the back support, curved legs, left / right turn over, sit, seat toilet, etc..As the 10 bed panels shown in Figure 1 are independent of each other. Through the coordination of movement. Between each of the bed panel, pose of all position uses the single acting or linkage approach to achieve the required nursing bed.

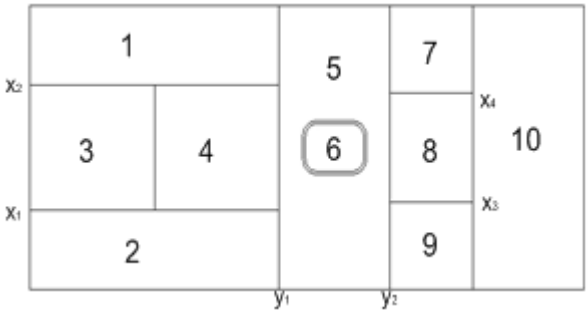
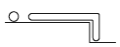
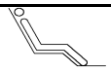
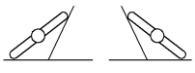


Figure 1 Schematic diagram of the bed panel 1 ,2 ,3 ,4-The supporting back (including the left / right turn) bed panel；5-Sitting bed panel；6-Seat toilet bed panel；7 ，8 ，9-Thigh (including the left / right turn) bed panel；10-Leg bed panel

The intelligent rehabilitation nursing bed with double plane multi-position design, achieves the bed surface multi-module and flexible movement, mainly including: the relative motion - translational bed surface and ground mechanism and rotation; with moving bed surface in different parts of the relative motion - series and parallel superposition of movement. The intelligent rehabilitation nursing bed pose and corresponding bed panel action is shown in table 1. The realization of each functional bed panel rotation angle is required: supporting back,0°~ 90°;curving legs,0°~ -90°； side turning-over，0°~ 90°。

Table 1 The pose and the corresponding bed panel action of the intelligent rehabilitation nursing bed

Pose	The Corresponding Bed Panel Action
	The bed panel is shown in Figure 1 of the 1-10 were in the initial state.
	The bed panel 1-4 cooperate with each other in and around motion, as shown in Figure 1 Y1 longitudinal axis
	The bed panel 7-9 rotating around the Y2 panel 10, bed pan down, realizing the leg bending motion
	1-4 around the bed panel is shown in Figure 1 of the Y1 rotation, 7-8 rotation around the Y2 bed panel, at the same time drives the bed surface 10 decline
	The bed panel 3, 4 around the X1 axial rotation, the bed panel 8 rotating around the X3, realize the right turn; a bed panel 3, 4 rotating around the X2 bed panel, 8 rotating around the x4, the realization of left turn
	When implementing a left / right turn, a bed panel 3, 4, 8 in which a single axis rotation around its corresponding to the initial position, can realize the nursing on the corresponding parts
	The bed panel 6 moves down, the toilet hole opening

B Mechanism Design

a The back support mechanism

The movement process of the back supporting movement achieve relatively simple, but the back supporting angle reach 90 degrees, and can stay at any angle between 0 degrees ~ 90 degrees. The back supporting process can stop at any angle, you can proceed to the back support movement, also can return to the initial flat state. To determine the use of screw transmission characteristics, using screw travel range is larger and can realize self-locking anti stroke. The servo motor is transferred to drive screw rotation, screw nut in screw motion, the connecting rod mechanism driving the hinged with the back supporting bed panel to make up, so as to realize the back supporting activities. When the servo motor reversal, the back supporting bed panel is slowly down to the initial flat state. If the cycle of the back supporting is in action, it can promote blood flow in patients with head, make the patient's back and waist rehabilitation training. The back support mechanism is shown in Figure 2.

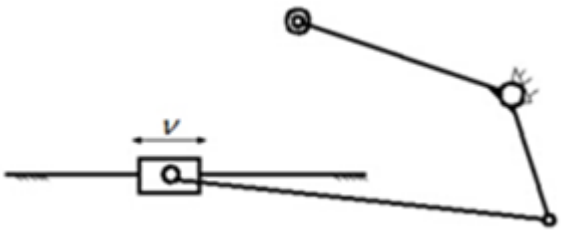


Figure 2 The back support mechanism

b The leg bending mechanism

Leg bending mechanism and the back supporting mechanism are similar to that of the leg bending mechanism three dimensional model and its mechanism in figure 3. It is composed of a screw rod and a connecting rod mechanism. The screw is driven by servo motor, rotates to drive the lead screw nut movement, the motor shaft and the screw is connected with the coupling between. Screw nut drives the thigh and leg motion bed panel bed panel movement through the connecting rod mechanism. The initial state, thigh and calf bed panel bed panel in a horizontal position. The next song leg, thigh bed panel activity at 0 degrees -90 degrees . In Figure 3, the connecting rod a and calf bed plate are fixed together, the bed surface to always maintain a level of leg.

In order to enable patients to comfort in the curved legs, in the process of curved legs, the back supporting activities can give patients a certain angle, the angle can be set between 45 degrees ~ 60 degrees, can improve the leg blood flow and comfort.

Figure 3 Leg bending mechanism

c Rollover the rotating mechanism

In order to achieve the purpose of nursing rollover partition function, using the rollover rotating mechanism of three parallel, each rollover rotating mechanism with two degrees of freedom, is a symmetrical mechanism can achieve about flip, rollover rotating mechanism is composed of screw, screw, a sliding block and a connecting rod mechanism and rolling etc., the the agency called the six freedom of screw - slide - linkage combined mechanism. Its mechanism of the rollover of the rotating mechanism is shown in Figure 4, the dotted line represents the initial position of the part of the screw nut, namely the middle position of screw. When the left turn, servo motor is transferred, the right moving screw nut, slide block is driven on the right side of the right move, drives a connecting rod to move, so that the bed panel rotate left. When the right turn, the motor reverse, mobile screw nut to the left, right side slide block is driven to move to the left, to drive the connecting rod movement, so that the rotating bed panel to the right. Patients can through the left / right turn to change your body by extrusion parts.

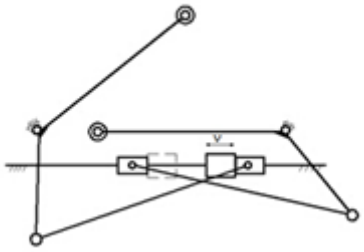


Fig. 4 Rollover rotating mechanism

The rollover activity, structural design of mechanism is simple, save a space, the bed panel base design nested type, single bed panel can rotate around on both sides of the axis of rotation, through the connecting rod mechanism transformation in different directions to realize left / right turn, achieve the two-way 90 degree turn, broke through the traditional sense of the 45 degree ~ 50 degree turn to enable patients to turn over, achieves the best comfortable state. The traditional nursing bed can only achieve about turn, nursing of patients can not be back, buttocks and legs and other body parts. In the nursing bed, rollover bed panel using three independent bed panel, based on both sides of the roll over in the implementation, can be a piece of bed panel which separate action, which can achieve the nursing back, buttocks and legs and other body parts, such as cleaning, massage, rehabilitation training and treatment, namely the rollover partition nursing care of patients with functional, so that all parts of the body to get exercise or treatment.

d Kinematic analysis of rollover rotating mechanism

The rollover rotating mechanism is a symmetrical mechanism, can achieve so up. To the left turn as an example, analyses the kinematics. Due to the slow speed of turning in his patients, assuming that its are in static state at each moment of the movement, the intensity of the connecting rod can meet the requirement, the mathematical relationship between the solution of rollover rotation angle and the displacement. Figure 5 is a graph analysis of rollover rotating mechanism.

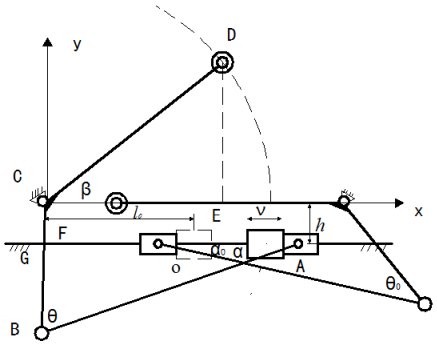


Figure5 Graph analysis rollover rotating mechanism

The connecting rod CD level state set as the initial state, with the C point was set up right angle coordinate system xCy. The initial state, an angle between the AB and X axis to the α_0, an angle between the AB and CD for theta 0, an angle between the BC and CD is set to the value of γ, connecting rod AB and BC length are respectively fixed value of l_{AB} and l_{BC}, C to block the center distance of H, C to screw center point O distance of l_0. In the movement of the slider in the process, the A slider displacement relative to remember screw center point O of S, an angle between the AB and X axis is denoted as α, an angle between the AB and CD are written as θ.

After calculation, the rotation angle of the bed panel for rollover is β:

$$\beta = \gamma - 180° + \theta + \alpha ,$$

To establishment the relationship between the rotation of the slide displacement S, turnover bed panel of β:

$$\begin{cases} l_{BC}\cos(\theta+\alpha) + l_0 + S = l_{AB}\cos\alpha \\ l_{BC}\sin(\theta+\alpha) = h + l_{AB}\sin\alpha \\ \beta = \gamma - 180° + \theta + \alpha \end{cases}$$

According to the design requirements, the maximum displacement of the slider is 300mm, rollover maximum angle of 90 degrees, we use MATLAB to simulate the obtained curve, as shown in figure 6.

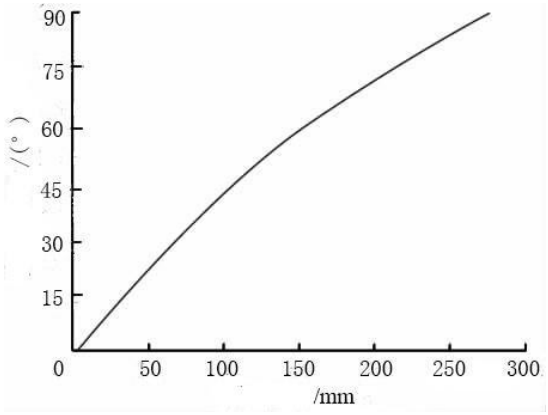


Figure 6 Rollover rotation changes with the slider displacement diagram

IV. Debugging and running fault treatment

The main problems found in the debugging process are: there is noise generated in running process mechanism, screw unstable operation, the bearing temperature is too high or vibration, motor temperature is too high, the coupling cracking.

Treatment methods are: (1) the main source of noise of reducer, coupling and motor, slide block and the screw friction, examine whether these components are damaged, if damaged, replace the new parts, ensure the slide block and the screw axiality; (2) check the motor, reducer, coupling and a screw is installed coaxially. If not coaxial or the existence of radial run-out, different thickness of the copper increased in the installation base, looking for the coaxial degree and the base installation surface degrees, so that in the allowable error range; (3) selecting appropriate size and reducer reducer ratio, the installation speed reducer, must ensure that the mounting base with fixed plane and motor, and the coupling of coaxial; (4) check each of the base seat is provided with a bearing is in the same plane, the bearing is coaxial; (5) screw nut, a pin shaft to add a small amount of lubricating oil.

V. Conclusion

Design of intelligent rehabilitation nursing bed above the dorsal branch, curved legs and turnover mechanism, and the rollover rotating mechanism kinematic analysis was performed with the MATLAB simulation of the prototype, and the repeated testing and debugging process, verify the rollover stability of process, the realization of the 90 degree rollover, the rollover partition nursing, can well ensure the coordination of the back, buttocks and legs of care. The experimental prototype of multiple operation shows that, no interference exists between design and operation done in this paper is stable and reliable, the agencies, can be very good to achieve the desired functionality.

Each module mechanism and embedded control system will be designed in this paper, image feature extraction and pattern recognition expert system for intelligent integrated rehabilitation nursing bed, humanization and the advanced intelligent nursing bed can be achieved, using the rehabilitation nursing bed reasonably intelligent, realization of nursing and rehabilitation training combined, patients will be conducive to the rehabilitation exercise, the patient's physical and mental health. The rehabilitation nursing bed in intelligent and reasonable structural design, convenient operation and safety, is mainly for the use of object -- chronic patient, paralysis patients and the disabled and other long-term bedridden patients, especially applicable to individual families and medical rehabilitation places etc.

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