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Design Research on Intelligent Assisted Bath Chair for the Elderly

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Abstract: To address key challenges faced by the elderly during bathing—high risk of slipping, physical frailty, and the limited functionality of existing products—this study develops an elderly-oriented intelligent multifunctional assisted shower chair with safety assurance as its core design principle, incorporating anti-slip chair feet and seat surfaces made of specialized materials and integrating a lead-screw lifting armrest with an electric push-rod base plate to form a dual auxiliary standing system; for bathing functionality, the shower arm's elevation and rotation are achieved through the combination of synchronous belt transmission and bevel gears, while an automatic foaming device installed under the armrest enhances cleaning efficiency. The intelligent control system employs a serial port screen for human-machine interaction, enabling automatic adjustment of water temperature and flow rate, and furthermore constructs a three-tier alarm mechanism linked with a buzzer, a guardian APP, and a property management system, thereby forming a closed-loop safety network. This "mechanical assistance-intelligent control-safety early warning" integrated design bridges the functional gap between passive support and active care, provides a technical paradigm for the development of aging-adaptable products, and is expected to be applied in domestic and nursing home settings, contributing to improved quality of life and independent dignity for the elderly.

Keywords: The Elderly, Bathing Aids, Intelligence, Safety Monitoring

1. Design Background

According to statistics, the proportion of the elderly population aged 65 and above in China has reached 11.7%, formally entering a deeply aging society [1]. It is estimated that this proportion will exceed 20% by 2040, entering a super - aging stage. With the expansion of the elderly population scale, the phenomena of empty - nesting and disability have become increasingly prominent, and the issues of daily bathing safety and care for the elderly have become the focus of social attention. Bathing is related to the physical and mental health and comfort of the elderly. However, due to the decline in physical functions and balance ability of the elderly, bathing injuries caused by slipping occur frequently, and the bathing care of disabled elderly has also become a heavy burden on families. Against this background, combining ergonomics[2] and the development trend of the silver economy, it is of great significance to carry out the design research of bathing assistance devices for the elderly[3,4]. Such devices aim to help the elderly maintain a comfortable and stable posture during bathing, effectively reduce risks, reduce the intensity of care, improve the quality of life and dignity of the elderly, and provide practical product solutions for building an elderly - friendly society.

2. Structural Analysis and Composition of the Bath Chair

2.1 Design Ideas

The design focuses on the pain points of the elderly, such as easy slipping, difficulty in getting up, and complicated operation during bathing, with safety and convenience as the core. Mechanically, the bathing module uses a motor, a conveyor belt, and a bevel gear to realize the lifting and rotation of the shower arm, which saves space and covers all areas. The auxiliary standing module relies on the dual support of the lead screw armrest and the electric push rod seat plate to provide stable support for getting up. The cleaning agent module is equipped with an inductive foaming structure. On the electronic control side, the operation is simplified by using an intelligent touch screen and serial communication, combined with a safety alarm, and linked with the guardian APP and property management, so as to adapt to the physiological needs of the elderly. At the same time, it is suitable for scenarios such as families and nursing homes to reduce the care pressure.[5]

2.2 Mechanical Design

The design focuses on the pain points of the elderly, such as easy slipping, difficulty in getting up, and complicated operation during bathing, with safety and convenience as the core. Mechanically, the bathing module uses a motor, a conveyor belt, and a bevel gear to realize the lifting and rotation of the shower arm, which saves space and covers all areas. The auxiliary standing module relies on the dual support of the lead screw armrest and the electric push rod seat plate to provide stable support for getting up. The cleaning agent

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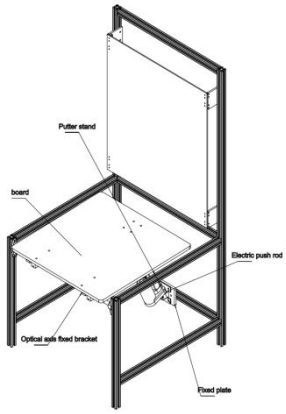

Fig. 1: Seat Plate Lifting Mechanism Figure

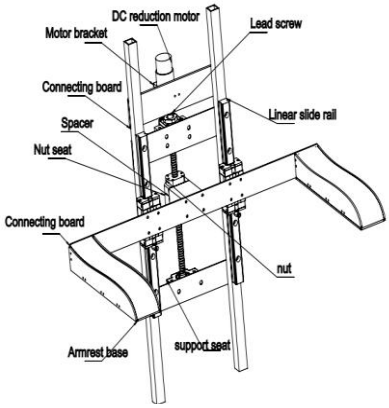

Fig.2: Armrest Lifting Mechanism

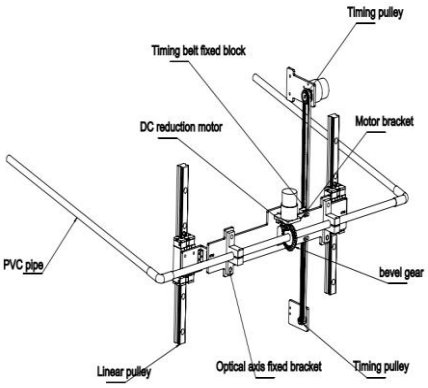

Fig.3: Seat Plate Lifting Mechanism

2.2.1 Seat Plate Lifting Mechanism

As shown in Fig. 1, the seat plate lifting mechanism adopts a four - link structure driven by an electric push rod. It transmits movement and force by connecting multiple movable rods to realize the rotation of the seat plate around the axis for lifting. Thus, during the standing process of the elderly, the seat plate continuously lifts to provide stable support for the elderly's buttocks.

2.2.2 Armrest Lifting Mechanism

As shown in Fig.2, the armrest lifting mechanism adopts a lead screw sliding table structure. The motor drives the spiral lead screw to rotate, which makes the thread interact with the nut on the lifting platform to generate a vertical thrust, thereby pushing the lifting armrest up or down. Therefore, during the standing process of the elderly, the armrest continuously rises, allowing the elderly to support their bodies with the strength of their arms. Combined with the coordinated work of the seat plate lifting mechanism, the elderly can stand up easily.

2.2.3 Shower Arm Lifting and Rotating Mechanism

The shower arm lifting and rotating mechanism is shown in Fig. 3.

The lifting mechanism of the shower arm adopts a synchronous belt drive structure. The motor is fixed on the back of the chair. By driving the synchronous pulley to rotate, the synchronous belt drives the slider to slide vertically on the slide rail through the connecting plate. Since the shower arm is fixedly connected with the slider, the lifting of the shower arm is realized.

The rotating mechanism of the shower arm adopts a bevel gear drive structure. The motor is fixed on the synchronous belt connecting plate, and its output shaft is connected with the shower arm shaft through a keyway to form a bevel gear, realizing coaxial transmission. When the motor is driven, the bevel gear transmits power to the shower arm shaft, driving the structure to make the shower arm rotate around the axis.

The combination of these two mechanisms brings a more convenient and comfortable bathing experience to the elderly and meets the needs of multi - angle spraying.

2.2.4 3D Simulation

The above ideas and design concepts are modeled through 3D simulation using Solidworks software, and the model is shown in Fig.4. The physical design of the device is completed based on this model.

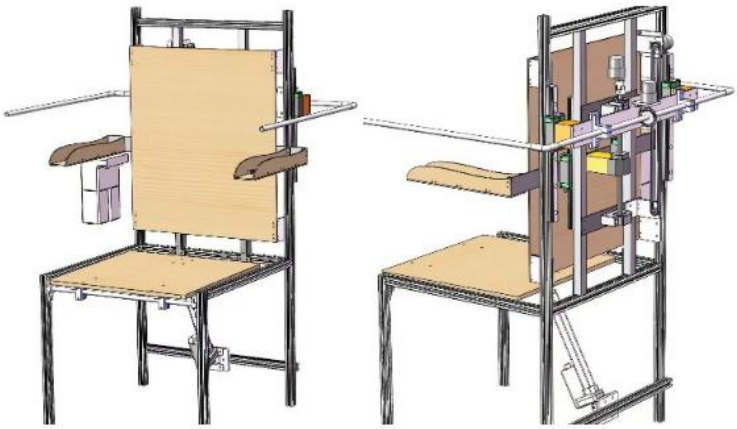

fig.4: 3D Simulation Model Diagram

3. Intelligent Control System of the Bath Chair

The bath chair realizes intelligent interconnection with the cloud network through a single - chip microcomputer and an ESP8266 WiFi module, connecting the traditional chair hardware to the cloud and constructing a data transmission link between the user end and the monitoring end. The hardware is composed of a single - chip microcomputer, a serial port screen, a functional motor, etc. Cloud technology has greatly expanded the functional boundary and use value of the hardware.

3.1 Intelligent Touch Screen Control

An ergonomic intelligent touch screen is built on the right armrest of the chair, through which functions such as chair lifting, armrest lifting, seat cushion lifting and lowering, and water outlet can be controlled by touch. The signal transmission path is as follows: the touch screen collects touch commands → transmits them to the single - chip microcomputer → the single - chip microcomputer program converts them into motor control signals or uploads them to the cloud. At the same time, a red emergency stop button is set on the left armrest. In case of an accident, the user can press the button to stop the equipment and send an alarm to the monitoring end. In addition, an infrared distance meter is used to realize non - contact access to bathing products, adapting to the usage habits of the elderly.

3.2 Remote Monitoring APP

The monitoring end is equipped with a supporting monitoring APP, which allows the guardian to remotely observe the status of the elderly, including the real - time bathing progress and the operation status of the equipment. At the same time, basic settings can be made, such as flexibly setting the bathing duration and the alarm response time. After the bathing time is over, if no feedback is received from the user end within the alarm response time, the APP will issue an alarm in the form of a pop - up window + ringtone to remind that the elderly may be in an accident; if feedback is received in a timely manner, it will automatically enter the next cycle, forming an active equipment alarm mechanism and effectively realizing remote safety monitoring.

4. Working Process of the Bath Chair

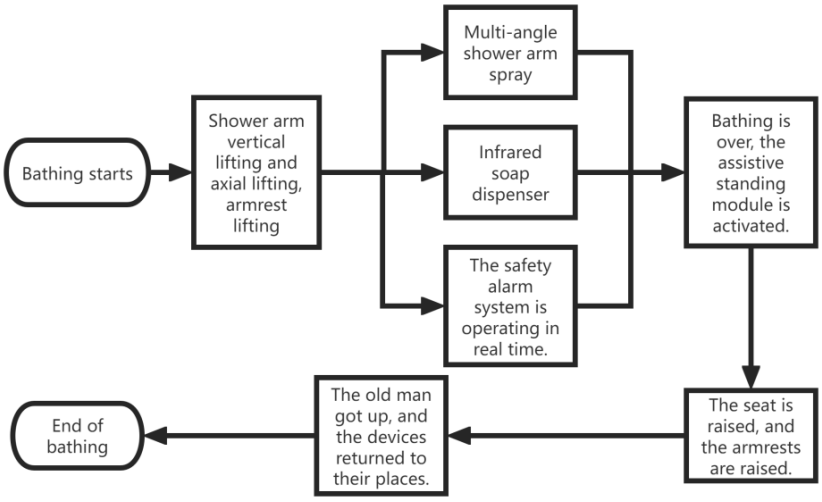

Fig.5: Working Process of the Bath Chair

Bathing Preparation Stage: When the elderly approach the shower chair, the auxiliary standing module starts in advance. The armrest slowly lowers via the lead screw structure to a graspable height, with the seat staying horizontal for stable seating. Meanwhile, the safety alarm module's timer syncs with the intelligent control system for real - time monitoring, and the cleaning agent module's inductive switch stands by.

Bathing Stage: After the elderly sit down, the bathing module is activated. The long rod - type shower arms on both sides can be adjusted as needed: the motor drives the bevel gear transmission to realize rotation around the axis to adjust the spraying angle, covering different parts of the body; with the cooperation of the synchronous belt and the slide rail, vertical lifting is completed to adapt to the height and sitting posture of the elderly. If cleaning agent is needed, when the elderly put their hands close to the inductive switch at the bottom of the shell, the micro - motor is powered on immediately, and the eccentric driven wheel is driven by the gear, so that the connecting rod drives the extrusion plate to squeeze the soft nozzle repeatedly, and the cleaning agent flows out automatically without bending down. During this process, the safety alarm module operates continuously, and the timer monitors with a 20 - minute cycle without triggering an alarm temporarily.

Bathing Completion and Standing Assistance Stage: After bathing, the elderly can issue a command, the bathing module stops spraying water, and the shower arm resets. The auxiliary standing module is then activated. The armrest is gradually lifted through the lead screw lifting structure to provide support for the elderly's upper limbs; the seat plate is slowly lifted upward by the electric push rod link mechanism to push the elderly's buttocks to stand up, maintaining stable support throughout the process and reducing the risk of falling.

Reset and Safety Assurance Stage: After the elderly stand up and leave, each module resets automatically - the shower arm returns to the initial position, the armrest and seat plate are lowered to the standby height, and the inductive function of the cleaning agent module is turned off. If the elderly encounter an emergency during bathing, they can actively press the response button, or if no feedback is given within the 20 - minute cycle of the safety alarm module (no feedback button is pressed within 1 minute and 30 seconds), the system will immediately stop bathing, send emergency information to the guardian's mobile phone, and connect to the property management system to notify the staff, ensuring timely rescue.

5. Design Innovation Points

5.1 Collaborative Auxiliary Standing Design

This design breaks the limitation of traditional bath chairs that “only support sitting but not standing”. It innovatively combines armrest lifting and seat tilting to assist standing. A hidden lead screw mechanism raises the armrest along a slide rail, offering a stable handhold. Simultaneously, an electric push rod lifts the seat to support the buttocks. Together, they create a “hand-pull and hip-lift” force, enabling users with limited mobility to stand up stably without assistance, effectively solving difficulties in rising after bathing.

5.2 Multi - angle Intelligent Bathing Module

Traditional bath chairs lack dedicated shower assistance, requiring users to manually adjust the spray nozzle. This poses risks for the elderly with limited mobility, including incomplete cleaning and slipping. This

design introduces an intelligent motor-driven module using a DC gear motor, conveyor belt, and bevel gears to enable automated lifting and rotation of the shower arm, covering full-body angles. Integrated with a touch control system, it allows adjustment without manual intervention. The built-in water temperature and flow control ensures suitable output, eliminating cleaning blind spots and enhancing bathing safety and comfort.

5.3 Multi - level Intelligent Safety Alarm System

To address the lack of safety monitoring in traditional bath chairs, this design creates a multi-level safety system featuring "active warning + multi-party response". A timer prompts the user to press a feedback button at set intervals. If no response is detected, a local buzzer alerts the user or nearby personnel. Simultaneously, the supporting app notifies guardians via vibration and sound, andconnects to the property management system to dispatch staff. This triple support system of "user–guardian–property" ensures rapid on-site assistance and significantly reduces bathing risks for the elderly [6,7].

6. Conclusion

As China's population ages, improving the quality of life and preserving the dignity and autonomy of the elderly have become urgent priorities. This study addresses the high risks associated with bathing by designing an intelligent assistive bathing chair that integrates safety monitoring, postural support, and user-friendly control. The design emphasizes both structural functionality and human-centered values, making advanced technology accessible and beneficial to daily life. However, further work is needed in user-based iteration, cost reduction, and commercial viability. Future directions include integration with smart home systems, health monitoring platforms, and adaptable modular designs for diverse home environments.

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