International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 3 Issue 9 ǁ September. 2015 ǁ PP. 01-05

The Turning over Mechanism Designed for Rehabilitation Nursing Bed

Wang Yu-Zhao, Hang Lu-Bin, Cheng Wu-Shan, Lu Jiu-Ru, Ding Hong-Han
(College of Mechanical Engineering, Shanghai University of Engineering Science, Shanghai, 201620, China)

Abstract: According to the requirements of turning over function of the nursing bed in this paper, the actual situation of body turning over was analyzed and a new turning over mode was introduced based on the principle of normal pressure driving. And the segmentation model of turning over bed frame is given, the design of nested bed frame and the transmission mechanisms have the capability of force adaption and driving switch were completed based on the requirements of auxiliary nursing. The relationship between the displacement of driving block and turning angle is analyzed. The turning over function with fixed angle was realized by using the middle frames and side frames. The results show that this turning over mechanism has practical significance for enhancing comfort when turning over and improving the efficiency of rehabilitation.
Keywords: Principle of positive pressure driving; Nested middle frame; Turning with constant angle

I. Introduction

Turning over is a basic function of rehabilitation nursing bed which can help patients to adjust sleeping posture and change the contact state between patient's skin and the rehabilitation nursing bed. It will improve blood circulation of human body and facilitate medical staff to take care of patients. Turning over function can reduce bedsore incidence and relieve work intensity of nursing staffs， as well as greatly improve nursing efficiency [1-3].

The existing turning over rehabilitation nursing bed can realize the turning over function, but it still has some drawbacks which need to be improved. Such as, large friction force exist between human body and bed, lack of comfort and efficiency, and also patient is prone to slide from bed frames when turn over. The patient body parts which need to be nursed is often disturbed because human body keep contact with turning over frames, etc. .[4-10]

Based on the functional requirements of turning over and research of the turning over function deficiency on existing rehabilitation nursing beds, this paper analyzes the actual force when the patient turn over. Furthermore a new turning over mode is put forward according to normal pressure driving principle. Then, the new bed frame with several linked segments and their corresponding actuators are designed, and turnover principle is presented according to the needs of auxiliary nursing.

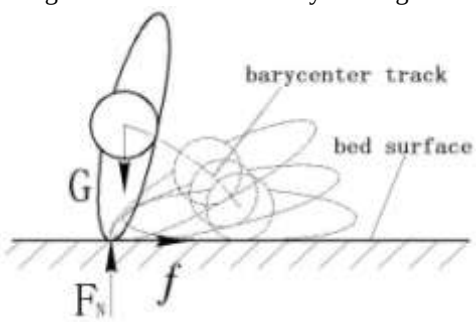
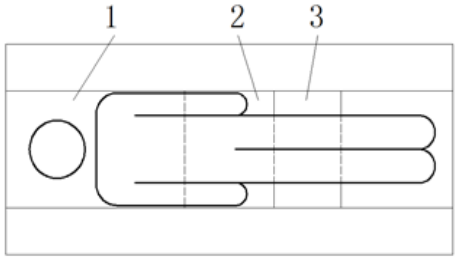


Fig.1 the pure rolling with variable curvature mode of human turn over



1—upper body turning over frames; 2—buttock turning over frames; 3—thigh turning over frames

Fig.2 Schematic diagram of the Segmentation of middle turning over frames

II. Analysis of turning over function requirements

Two aspects should be considered during the design process of turning over mechanism, one is to realize the turning over function of human body. The other one is the turning over mechanism should comply with the principle of ergonomics. It should be safe and reliable which can operate steadily during the process of turning over and consist with the actual situation of human body turn over. Therefore, the actual turning over movement should be analyzed [11].

In this paper, we simplified turning over movement of the patient's shoulders as a variable curvature pure rolling movement on the bed, as shown Fig.1. As gravity center of human body is always over the bed, patient's shoulders bear the normal pressure in vertical direction and the friction in horizontal direction. It achieve turning over movement that the overturning torque which formed by gravity and normal pressure was conquered by

friction.

In this case, wounds can be protected and the turning over comfort was improved because the turning over mechanism which designed according to the fixed axis rotation mode eliminate the relative motion caused by pure rolling movement; the patient depends on normal pressure to achieve turning over and the trajectory of human gravity center is similar to the actual turning over trajectory. This greatly improved the turning over comfort.

III. The configuration of turning over frames based on efficient nursing demands

The turning over function should not only meet the needs both changing human sleeping posture and alternatively support the contact parts between the patient's skin and bed, but also should fully consider whether it can help nursing staffs to improve nursing efficiency. Auxiliary turning over function is convenient to nurse patient's back and buttock, but the middle frame may shield patient's body parts where need to nurse. If remove these turning over frames the patient can hardly keep balance when nursing, the patient need to be supported by the nursing staff what is inconvenient for nursing. Hence, the configuration of the bed frames should be designed reasonably. Because the force mainly exert on buttock, thigh and upper part of human body when turning over, the middle frame should be placed under these parts accordingly. In order to nurse the patient more convenient for nursing staffs, we divide the middle frame into three parts, as is shown in Fig.2.

When patient want to turn over to one side, the turning over frames 1,2,3 rotate synchronously and keep coplanar. The turning over frames under the parts where need to be nursed rotate to the original position when nursing, the other two frames support the patient. The auxiliary nursing process was finished by three parts of turning over frames rotate to the original position alternately.

IV. The design and analysis of the turning over mechanism

4.1 The design of turning over frames

In this part, we determined the connection mode of bed frames and designed the transmission mechanism of the turning over frames according to the actual situation of human body turn over.

According to the analysis of the turning over movement, the middle frames should turn over to both left and right side. On this basis, we designed a nested middle frames which are composed by inside frame and outside frame, as is shown in Fig. 3.

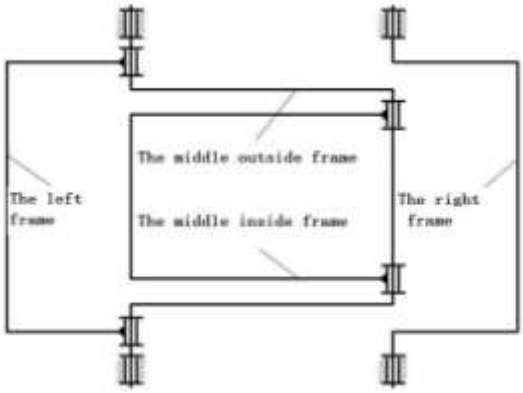


Fig.3 Schematic diagram of the connection of middle frames

Fig.4 the photo of the rehabilitation nursing bed frames

When turn over to left side, the middle outside frame together with the middle inside frame turn over to the left; when turn over to the right side, the middle outside frame remain stationary the middle inside frame turn over to the right. Fig.4 gives the photo of the rehabilitation nursing bed frames.

4.2 The principle of turning over transmission mechanism

Only one of the left frame or the right frame rotates its axis when turning, as same as the nested middle frames, just one of the nested frames rotate actively. Because the side frame and the middle frame move independently, each of them needs a drive mechanism. According to the movement demands what analyzed mentioned above. A type of turning over transmission mechanism was designed which kinematic diagram is shown in Fig. 5.

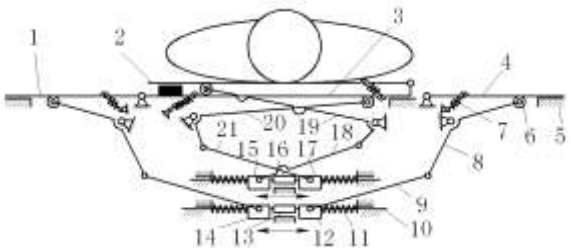


Fig.5 Kinematic diagram of the turning over transmission mechanism

1—the left frame; 2—the middle frames; 3—the middle outside frame; 4—the right frame; 5—baffle plate; 6—roller; 7—extension spring; 8—the push rod of left frame; 9—the connecting rod of left frame; 10—lead rail; 11—compression spring; 12—passive sliding block of right frame; 13—drive block of side frame; 14—passive sliding block of right frame left frame; 15—passive sliding block of middle inside frame; 16—driven block of middle frames; 17—passive sliding block of middle outside frame; 18—connecting rod of middle inside frame;19—push rod of middle inside frame ; 20—push rod of middle outside frame; 21—connecting rod of middle inside frame

This mechanism is driven by two motors, the turning over movement is realized by controlling the driven block (13,16) move along the lead rail (10). When turning to the right side, the drive block of side frame (13) push the passive sliding block of right frame (14), the movement was transmitted to the right frame (4) through the connecting rod of left frame (9), the lead rail (10) and the roller (6). Realized the right frame turn to the right. When the turning over mechanism needs to turn to a specific angle, the drive block of side frame (13) move to the original position, at the same time, the passive sliding block of middle inside frame (15) drive the middle frames (2) and the right frame (4) rotate to the right with a constant angle, then it was pushed to the right by the driven block of middle frames. The turning over movement with fixed axis rotation of constant angle was completed during the process. The driven block (16) and (13) move inversely when the nursing work was finished, the patient turn to horizontal position with constant angle; the drive block of side frame (13) move to the middle and the right frame (4) rotate to the original position.

The passive block always contact with the corresponding driven block due to the action of the compression spring during the process of the middle frames (2,3) and the side frames(1,4) rotate to their original position, at the same time, the driven rods return to the original position too. The force offered by the extension spring keep the rollers which fixed on the rods contact with the corresponding middle frames and the side frames. The idle stroke of the passive block was eliminated by using the springs which can ensure the middle frames and the side frames return to their original position continuously and reliably. All of these make the mechanism acquire the capability of force adaption. At the same time, owing to the driven block located in the middle of the two passive blocks, one motor can drive the two passive blocks respectively through changing the rotating direction of the motor.

4.3 The improved mechanism by considering safety

Safety should be considered when designing the turning over mechanism of rehabilitation nursing bed. Because the bed is composed by several parts, a gap was generated between the frames when turning over where the patient's arms may drop in. In that case the patient's arms will be clipped. Based on the safety requirements, a new type of connection mode of turning over frames was proposed.

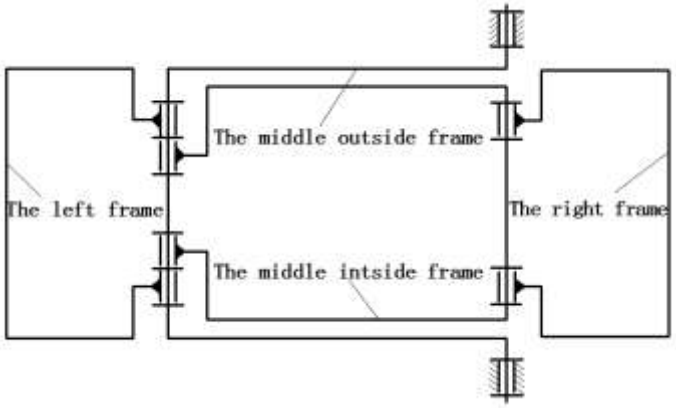


Fig.6 the connection of turning over frames based on safety considerations

The middle inside frame and the right side frame are connected by revolute joints. The middle inside frame

and the middle outside frame connect to the side frame through compound hinges.

4.4 kinematic analysis of the transmission mechanism

The transmission kinematic diagram is shown in Fig.7. This is a combined mechanism which composed by slider-crank mechanism and crank-rocker mechanism. Each mechanism was analyzed respectively. The two mechanisms are connected by the push rod of middle outside frame (20).

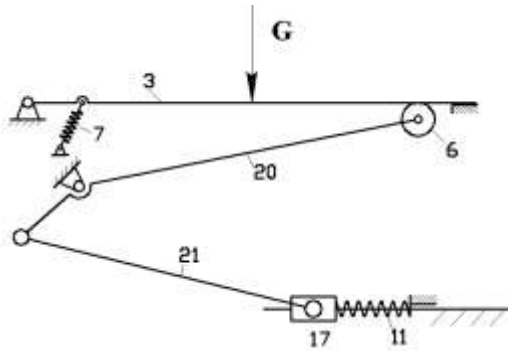


Fig. 7 The transmission kinematic diagram of the middle outside frame

4.4.1 The kinematic analysis of transmission mechanism of the middle outside frame

The rectangular coordinate system shown in Fig.8 was built according to the transmission kinematic diagram of the middle outside frame.

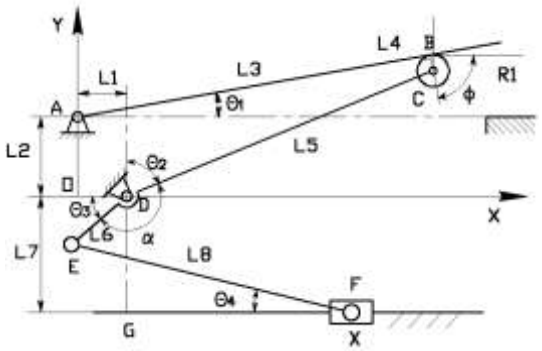


Fig.8 Coordinate system of transmission mechanism

θ_1 is the angle between the middle outside frame and horizontal line, θ_2 is the angle between the push rod and plumb line. α is the fixed angle of the push rod. X is the position of the driven block on the lead rail.

$L_4 = \overline{AB}$, $\theta_1 + \varphi = \frac{\pi}{2}$, $\theta_2 + \theta_3 + \alpha = \frac{3\pi}{2}$;

We divide the above combined mechanism into two loops, the loop ABCDA and the loop DEFGD respectively.

According to the follow vector equation (1) we can obtain the equations (2):

$$\overrightarrow{AB} + \overrightarrow{BC} + \overrightarrow{CD} = \overrightarrow{AD} \tag{1}$$

$$\begin{cases} L_4 \cos\theta_1 + R_1 \cos\phi - L_5 \sin\theta_2 = L_1 \\ L_4 \sin\theta_1 - R_1 \sin\phi - L_5 \cos\theta_2 = -L_2 \end{cases} \tag{2}$$

According to the follow vector equation (3) we can obtain the equations (4)

$$\overrightarrow{DE} + \overrightarrow{EF} = \overrightarrow{DG} + \overrightarrow{GF} \tag{3}$$

$$\begin{cases} -L_6 \cos\theta_3 + L_8 \cos\theta_4 = x \\ L_6 \sin\theta_3 + L_8 \sin\theta_4 = L_7 \end{cases} \tag{4}$$

The relationship between the position of the driven block x and the angle θ_1 was obtained according to the equations (2) and (4).

$$x = \sqrt{L_8^{\,2} - \left[L_7 + L_6 \cos(\alpha + \arctan\frac{1}{\tan\theta_1} - k) \right]^2} + L_6 \sin(\alpha + \arctan\frac{1}{\tan\theta_1} - k) \tag{5}$$

$$k = \arcsin \frac{\tan\theta_1(L_1 - R_1\sin\theta_1) + L_2 - R_1\cos\theta_1}{L_5\sqrt{1+\tan^2\theta_1}} \tag{6}$$

4.4.2 The analysis of the turning over motion with constant angle between the middle frames and the side frame

The transmission kinematic diagram of the left side frame is shown in Fig.9. Fig.10 is the schematic diagram of left turning over. The angle γ should keep constant during the constant angle turning over process.

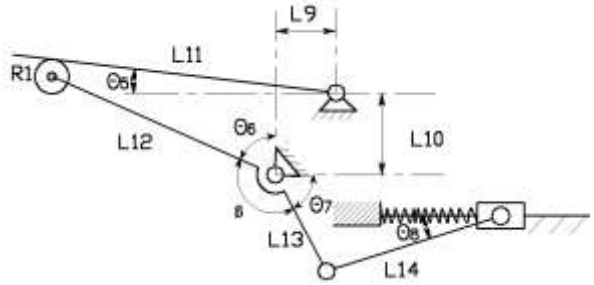


Fig.9. the transmission kinematic diagram of the left side frame

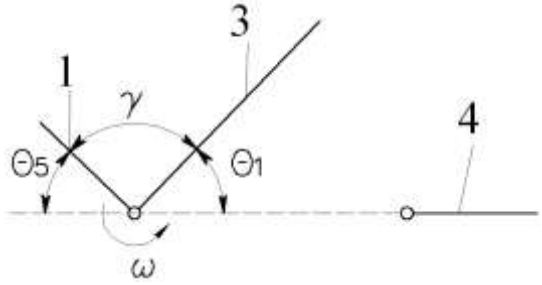


Fig.10 the schematic diagram of turn over to left with constant angle.

The angle θ_1, θ_5, γ satisfy:

$$\theta_1 + \theta_5 + \gamma = \pi \tag{7}$$

The relationship between the position of the driven block and the angle θ_5 was obtained according to the equations (5) and (7).

V. Conclusion

(1) A new turning over model was proposed according to pure rolling with variable curvature model, this new turning over model can let the users feel more natural and comfortable.
(2) The slide of human body and relative motion between human body and bed can be reduced effectively when using the turning over model which with constant angle between the nested middle frame and side frame when turning.
(3) A new turning over mechanism was proposed according to the new turning over model, and the relationship between the middle frame and side frame was given through kinematic analysis.
(4) The segmentation of bed frames designed in this paper have practical significance to improve nursing efficiency and reduce nursing intensity.

VI. Acknowlgement

This work is supported by the Shanghai Committee of Science and Technology Key Support Project (1251 0501100)

References

[1] Cheng Bo. Turn-over bed design for medical use[J]. Machine Design and Research, 2007, 34(9): 20-22
[2] Luo Lishan. A study on effect of automatic alternative support turnover bed on prevention of bedsore [J].Journal of Qingdao University CHINESE NURSING RESEARCH, 2005, 19(8):1450-1451
[3] Zhang Chunbin. Study on modeling design of intelligent turn over nursing bed[J]. JOURNAL OF MACHINE DESIGN, 2011, 31(4): 120-122
[4] Liu Qianqian. Structure Design and Mechanical Analysis of Multifunctional nursing Bed[D]. Biejing:China University of Geosciences, 2011. 137-139.
[5] Liu, Yu. M achine Design and Research[J]. Design of A MultifunctionalNursing Bed, 2008, 24(5): 125-129
[6] Li Guokang. Design of a Multifunctional Nursing Bed[J]. Journal of Shenyang Ligong University, 2013, 32(3): 91-94
[7] Gen, Hongzhu.The Development of the Multifunctional Automatic Rotating Bed with Process-monitoring [J]. Journal of Biomedical Engineering, 2013, 30(2): 301-305
[8] Hu Shaozhong. Mechanism Design and Dynamics Analysis of Multifunctional Nursing Bed[J]. Science Technology and Engineering, 2013, 13(3): 730-734
[9] Shih-Wei Peng.Mechanism Design and Mechatronic Control of a Multifunctional Test Bed for Bedridden Healthcare.IEEE/ASME TRANSACTIONS ON MECHATRONICS, VOL. 15, NO. 2, APRIL 2010
[10] Wei Ching Hua.Hospital Bed with Auxiliary Functions of Lateral Positioning and Transferring for Immobilized Patients,The 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON)Nov. 5-8, 2007, Taipei, Taiwan
[11] Zhang Jianguo. The development of a multifunctional nursing bed based on humanized design [J]. MANUFACTURING AUTOMATION.2010.