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Structural Analysis of Portable Repositioning Equipment for Bedridden Patients

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Graphical abstract

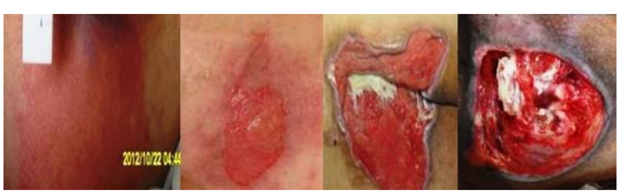
Abstract

A new approach of preventing bedsore risk for bedridden patients is presented. The design is proposed by transferring the conventional method into a portable mechanism that was derived from popular nurses' practice using bed sheet to relieve patient skin pressure by repositioning or rolling them every 2 hours. The portable equipment is installed in between the bed to reposition the patient. In this paper, the development of prototype design is addressed, followed by the simulation of structure stress analysis and software development. This study will match the proposed design with the behavior of its user.

Keywords: Bedridden patient; bedsore; decubitus; pressure ulcer; prevention; repositioning method

1.0 INTRODUCTION

Bedsore is one of the critical problems faced by paraplegics and stroke patients. Paraplegic patients are those who are completely paralyzed at the lower half of the body including both legs, usually caused by damage to the spinal cord. Due to this, paraplegic and stroke patients normally will lay on their bed for a very long period of time. Hence, this will introduce them to prolonged skin contact with the bed, which causes them to have higher tendency to suffer from bedsore problem. Figure 1 shows the severity of bedsore reflects to various stage of infection. According to previous reports, the infection would end up with serious complication and the risk of death is increased [1-3]. To overcome the problem, early prevention of bedsore is required and must be part in all hospitality and clinical services [4].



(a) (b) (c) (d)

Figure 1 The bedsore ulcer at (a) stage 1, (b) stage 2, (c) stage 3 and (d) stage 4

Current researchers are actively looking for an effective method to encounter bedsore problem. The goal is to reduce the time contact and exposure of pressure on patient's back body from their bed. There are several repositioning attempts to prevent or treat bedsore patients in daily regular basis. Each repositioning might be including mattresses, beds, overlays, cushions, or chairs in order to provide additional support and pressure distribution. As bedsore would happen at many parts of patient's back body, a robust method integrated with reliable equipment is urgency. Figure 2 shows the tendency parts of patient's back body, which expose to bedsore problem.

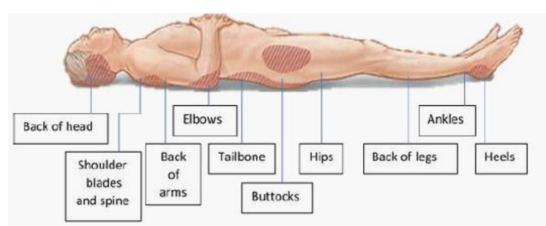


Figure 2 Contact skin pressure that expose to bedsore problem

Based on clinical study in Netherland, Van Leen *et al*. [5] reported that there is slightly difference on medium and high-risk patients when it comes to utilize static air mattress after additional repositioning protocol. However, the additional repositioning protocol would effect on nurse daily management and hospitality or clinical cost. In addition, the air is easily decreased with respect to time. Compared to static air mattress, alternating air pressure mattress provides different method to encounter bedsore problem. The inflates and deflates cell induce different elevation and vary in interface pressure, based on the size of the patient's body. According to Nixon *et al*. [6] it is observed that bedsores are still developing when using this type of mattress. Sanada *et al*. [7] suggested that it happened due to skin contact over the bony prominence to the bottom of the support surface, which leads to the unacceptable elevation of interface pressure. The situation might be happened during alternating phase of inflates and deflates cells. Furthermore, inflation and deflation cells still have limitation in operation since it not user-friendly with different types of body postures of the patients.

As bedsore problem always reflects to secondary disease, there is a strong argument for hospital and clinical administration to provide better services. Nurse management is always part to ponder as they served the patients closely. Defloor *et al* [8] reported that manual turning by the skillful nurse is still considered to be an effective way of preventing bedsore without pressure-reducing mattress. Based on previous research, manual turning with 2 hours in frequency could drastically decrease the incidence of bedsore [9]. Hagisawa *et al*. [10] also share similar findings in his review report, but it only covered for certain body parts[10]. Degree of tilting and its mechanism also part of discussion among current researchers in order to obtain optimal effect of bedsore prevention. Tilting at 30° elevated repositioning is a familiar method for both primary and secondary prevention of bedsore as a result of reductions in localized pressures over bony prominences[11].

■2.0 SYSTEM DEVELOPMENT

2.1 Product Design and Development

This study is conducted to address crucial elements needed in the development of the prototype to satisfy the user and market needs. Several designs drafted using raw sketches and Computer Aided Design are compared and improved. The aim is to get the basic concept of how the device will work and to meet the requirements for the bedridden patients (bed dimension, average patient weight, normal shoulder length for Asian, ergonomics, etc.).

2.2 Structure Design

An equipment comprises of two sets of structures with the size of 600 x 1980 x 1000 mm (width x length x height) each is shown in Figure 3. It is approximately the same length of the bed available in most hospitals. This design enables the operator (nurse in-charge) to attach and detach the equipment in between the bed. Hence, the equipment can operate to multiple beds in 24 hours as compared to conventional methods.

Figure 3 Proposed prototype design

2.3 Electrical and Electronic System

Figure 4 shows the proposed mechanism comprises of a pair of electrical actuators (lifting the bed sheet), DC geared motor (rolling the bed sheet), PLC hardware (controller) and, HMI panel (user interface). The linear actuator is controlled using a driver which requires 4-bit inputs from the controller to notify the elevation required. The motor rotation is directly controlled by injecting 12V supply and changing polarity to control the rotation of direction.

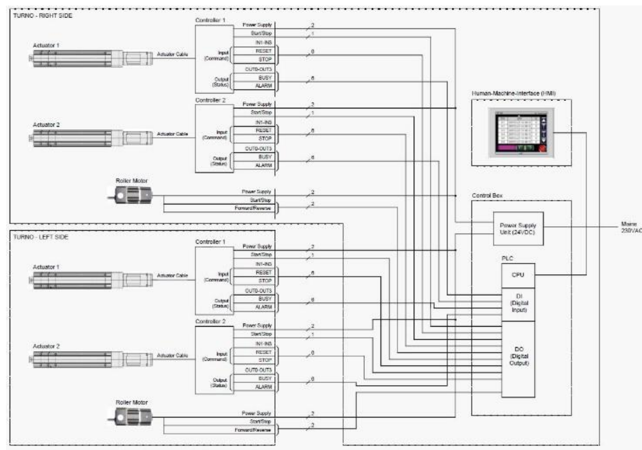


Figure 4 Electrical and electronic configuration system

2.4 Software Development

The software developed is responsible for taking the input by user and controlling the mechanism movement by actuators. Auto mode is designed for the equipment to run the therapy in continuous interval sets as shown in Figure 5. Different bedridden patients may need different setup such as time interval, tilting degree, left or right side option, and others. Operator can also overwrite the system by using manual mode on the interface. It gives the authority for the operator (nurse) to ensure or avoid any dangerous movement attempts on the patient based on their expert judgment.

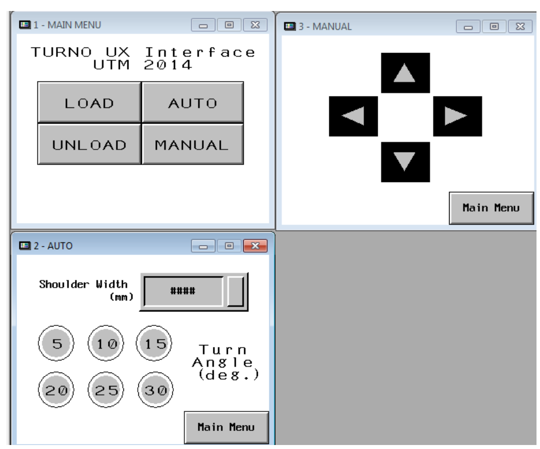
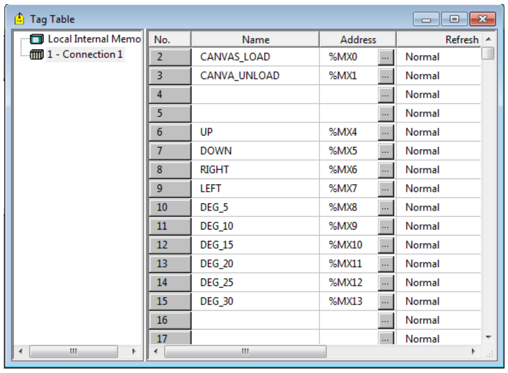


Figure 5 HMI interface design

The software used for PLC and HMI are LGIS GMWIN 4.17 and Beijer ADP v6.5.1. Both input interface and ladder diagram control are integrated using bit control with address prefix

%MX<bit number> as shown in Figure 6. The address mode used is in the PLC ladder diagram shown in Figure 7.



No.	Name	Address	Refresh
2	CANVAS_LOAD	%MX0	Normal
3	CANVA_UNLOAD	%MX1	Normal
4			Normal
5			Normal
6	UP	%MX4	Normal
7	DOWN	%MX5	Normal
8	RIGHT	%MX6	Normal
9	LEFT	%MX7	Normal
10	DEG_5	%MX8	Normal
11	DEG_10	%MX9	Normal
12	DEG_15	%MX10	Normal
13	DEG_20	%MX11	Normal
14	DEG_25	%MX12	Normal
15	DEG_30	%MX13	Normal
16			Normal
17			Normal

Figure 6 HMI tag table showing the address of each input

Figure 7 PLC ladder diagram example

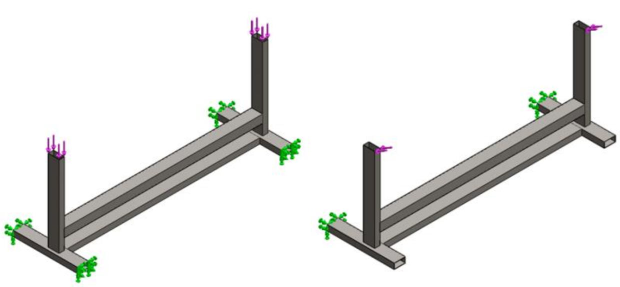
All the actuators are control with timer delay function where the switching of bit address will turn on the respected timers. Once the timer finished counting it will shut off the switching based on the configuration below. The DC geared motor is control by enable the polarity of the direction. The electrical linear actuator is control by enable the binary input and SET pin of the driver.

The timer count is set from the actuators initialization till final displacement. The timer setup also depends on the speed of the actuators and current reading of displacement. These factors have the potential to occur in the actual testing with the patient due to body weight and others.

■3.0 RESULTS AND DISCUSSION

3.1 Structure Stress Analysis

3D SolidWorks Simulation Express is used to run the stress analysis. 200 kg load (pink arrows) resembles the patient weight is tested onto the structure vertically and horizontally as shown in Figure 8. The green arrows show the fixtures setup for the static experiment.



(a) (b)

Figure 8 Stress analysis (a) vertical (b) horizontal load configuration

The simulation is done to determine the reliability of the design material, dimension, yield strength, and etc.

3.2 Structure Stress Analysis Result

Structure stress analysis is conducted for vertical and horizontal load test as shown in Figure 9 using SolidWorks software.

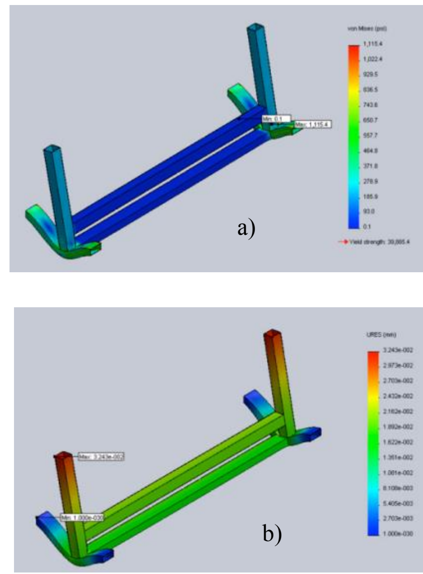


Figure 9 (a) Vertical Load Test (b) Horizontal Load Test

As shown in Figure 10, the beam structure bending deformed with minimal value of 0.0324 mm (vertical) and 3.6473 mm (horizontal) with the designated 200 Kg load. Von misses analysis shows the stress area at the main joint can endure the heavy load. These results prove that the proposed structure is safe and durable for human patients' usage.

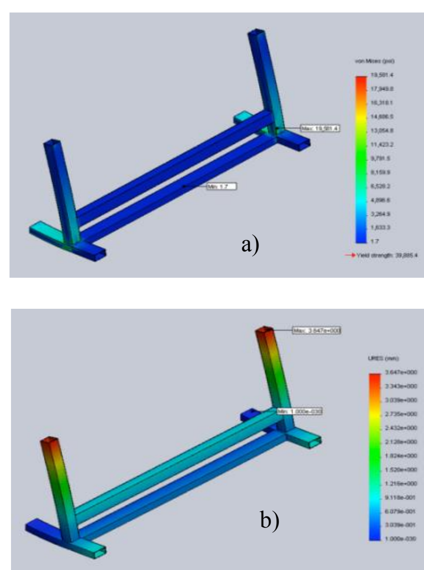


Figure 10 (a) Von misses (b) displacement analysis

The proposed structure is designed with mild steel material, square hollow beam size of 3 x 3 inch and wall thickness of 2.3 mm. The sample variation in terms of material, size and wall thickness of the beam are picked from the available off the shelf steels. It is due to the consideration of the simplicity in fabrication process afterwards and manufacturing cost.

3.3 Repositioning (Elevation)

In translating the mechanism movement to actuator programming in PLC, the linear actuators' stroke and motors' rotation are determined. Given in the Figure 11 is the ideal patient repositioning of 30° tilting.

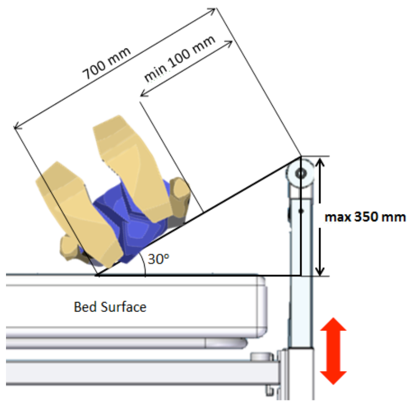


Figure 11 An ideal repositioning tilting

By applying Pythagoras theorem, the stroke displacement needed by linear actuator is 350 mm maximum. This is achieved with the maximum Asian's shoulder width of 600 mm and clearance of 100 mm.

In non-ideal cases, the utilization of the motor comes forth. The weight of the bedridden patient during elevation tends to bend the bed sheet downwards as shown in Figure 12 due to the nature of the bed sheet fabric. The curvature liked shape fabric will result the current repositioning tilting achieved to be below than the optimum level of 30°. Hence, the tension of the bed sheet is considered by stretching the bed sheet outwards using motor rotation.

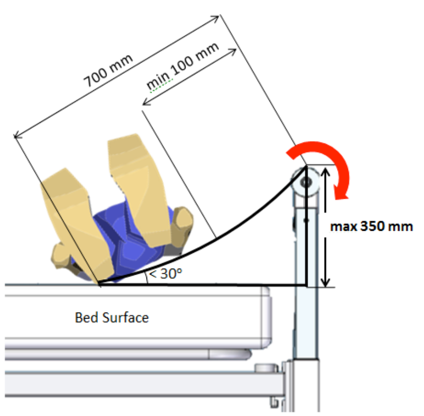


Figure 12 A non-ideal 30° repositioning tilting

4.0 CONCLUSION

A new approach of preventing bedsore risk for bedridden patients is presented using a robotic approach to reduce constant between skin and bed surfaces. The proposed structure design with the material of mild steel, wall thickness of 2.3 mm, and 3 x 3 inch hollow square beam can endure the human or bedridden patient weight up to 2000 N (200 kg) load. The actuators were optimally selected according to the required specifications to ensure the safety of user. The integration between PLC and HMI worked accordingly by using addressing mode. The proof of concept with simulation results have successfully demonstrated and analyzed. The fabrication phase can be executed for prototype beta testing at designated hospitals.

Acknowledgement

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Reference

[1] Olivier, C., Nicolas, V., Marek, B., Bruno, D., Francis, C. and Yohan, P. 2013. An Innovative Embedded Device for Pressure Ulcer Prevention. Preliminary Results with a Paraplegic Volunteer. *Journal of Tissue Viability*. 22: 83–90.

[2] Daphne, S. 2012. Support Surfaces for Pressure Ulcer Prevention. *Journal of PeriAnesthesia Nursing*. 27(5): 341–342.

[3] Ba' Pham, Laura Teague, James Mahoney, Laurie Goodman, Mike Paulden, Jeff Poss, Jianli Li, Nancy Joan Sikich, Rosemarie Lourenco, Luciano Ieraci, Steven Carcone and Murray Krahn. Support Surfaces for Intraoperative Prevention of Pressure Ulcers in Patients Undergoing Surgery: A Cost-Effectiveness Analysis. *Surgery*. 150(1): 122–132.

[4] Jan, Y. K. and Brienza, D. M. 2006. Technology for Pressure Ulcer Prevention. *Top Spinal Cord Inj Rehabil.* 11(4): 30–41

[5] Martin van Leen, Steven Hovius, Jacques Neyens, Ruud Halfens, Jos Schols. 2011. Pressure Relief, Cold Foam or Static Air. A Single Center, Prospective, Controlled Randomized Clinical Trial in a Dutch Nursing Home. *Journal of Tissue Viability*. 20: 30–34.

[6] Nixon, J., Cranny, G., Iglesias, C., Nelson, E. A., Hawkins, K. and Phillips, A. 2006. Randomised, Controlled Trial of Alternating Pressure Mattresses Compared with Alternating Pressure Overlays for the Prevention of Pressure Ulcers: PRESSURE (Pressure Relieving Support Surfaces) trial. BMJ. 332: 1413.

[7] Natsu, S., Gojiro, N., Kozue, S., Yuko, Y., Hirofumi, K., Yuko, N. and Hiromi, S. 2012. Determining the Optimal Inner Air Cell Pressure for the Effective Reduction of Interface Pressure. *Journal of Tissue Viability*. 21: 47–53.

[8] TomDefloor, Dirk De Bacquer, Maria, H. F. Grypdonck. 2005. The Effect of Various Combinations of Turning and Pressure Reducing Devices on the Incidence of Pressure Ulcers. *International Journal of Nursing Studies*. 42: 37–46.

[9] Mary, D. S., Linda, C. C., Martha, D., Rugenia, R., Elizabeth, R. L., David, L. C., Timothy, G. B. and Craig, M. C. 2013. The Turn Team: A Novel Strategy for Reducing Pressure Ulcers in the Surgical Intensive Care Unit. *J Am Coll Surg*. 216(3): 373–379.

[10] Satsue, H. and Martin, F. P. 2008 Evidence Supporting the Use of Two-hourly Turning for Pressure Ulcer Prevention. *Journal of Tissue Viability*. 17: 76–81.

[11] Mayumi, O., Junko, S., Hiromi, S., Chizuko, K. and Atsuko, K. 2005. Measuring the Pressure Applied to the Skin Surrounding Pressure Ulcers While Patients Are Nursed in the 30° Position. *Journal of Tissue Viability*. 15: 3–8.