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Design of smart hospital bed for stroke patient with linear actuator motor

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Abstract

Improving services for patients is a hospital need. Stroke patients have limitations in the movement of body parts that cannot be controlled. It is caused by vascular disease and brain damage. Stroke patients need special services with electronic beds. The need for electric beds in hospitals can be an effective solution to provide complete patient care services. Manual bed in the hospital that is used to change the patient's position by hand using a crank. The electric bed is designed with an electric motor prime mover equipped with a control system. The purpose of this study is to design an electric hospital bed for stroke patients that can be used to improve patient care. The research method begins with a preliminary study which includes field studies and literature studies. The next stage is the design stage, the manufacturing stage, the purchase of standard components such as the electric linear actuator, the assembly stage, and the smart hospital bed performance testing stage. The results of this study are a smart hospital bed unit with dimensions of 2000×900×600 mm, has an electric linear actuator with a constant speed of 20 mm/s. The smart hospital bed movement test was successfully carried out with a remote control. The test parameters used were the patient's weight in 5 movements, back movement, left leg movement, right leg movement, body tilting movement to the left, and body tilting movement to the right. Smart hospital bed innovation can improve medical personnel services for stroke patients in hospitals.

***Keywords**: Hospital bed, Patient care, Automation, Health industry*

1. Pendahuluan

Good hospital services for patients are highly prioritized. The level of patient comfort reflects the quality of a professional hospital. Sophisticated equipment in the medical world is indispensable for the patient's healing process. Suyitno [1] stated the need for complete care services for stroke patients and health industry innovations in the form of smart hospital beds. Stroke is a functional brain disorder caused by impaired blood circulation to the brain. Yuyun Yueniwati [2].

(a)

(b)

Figure 1. (a) Manual hospital bed and (b) automatic hospital bed

Hospital beds are divided into manual hospital beds and electric hospital beds. In the healthcare industry, manual hospital beds are used to change the position of the patient's limbs by hand using a crank. Electric hospital bed is a bed that has a motor and a cable to conduct electricity and has a control as a remote control. Each button on the remote control has an image that explains how the bed moves when pressing the button. In general, this hospital bed is still limited to only a few movements. Therefore, hospital beds with more or more varied movements in this study were carried out.

Previous studies, Radon Dhelika et all [3] conducted research with the topic of development of a motorized hospital bed with swerve drive modules for holonomic mobility. Sudiro et al. [4] shows the design concept of day minus 1 production model using systems modeling language: a case study of hospital beds production. Syamsuddin [5] proposed research on plans to increase the manufacturing readiness level of hospital bed products. Saladin et al. [6] conducted research on the design of a microcontroller-based smart hospital bed. Abbas et al. [7] optimized the design of the kinematic linkage mechanism for adjusting the height of the patient's bed.

This Smart Hospital bed is specially designed for inpatients or people who need multiple models of healthcare. This bed has special features for patient comfort and also for the comfort of health care workers. Common features include adjustable height for the entire bed, headboard, legs, adjustable side rails and electronic buttons for operating the bed. This Smart Hospital bed is not only used in hospitals, but also in other health care facilities, such as nursing homes, outpatient clinics, and health care at home.

The purpose of this study was to design and manufacture a smart hospital bed for stroke patients equipped with an electric linear actuator and control system. The strategic value of the smart hospital bed for stroke patients is to help optimally provide patient care. Patients who have limited mobility can be served by raising the back, raising the left leg, raising the right leg, and tilting the body to the right and tilting the body to the left. Smart is a method in project management that has five elements, namely specific, measurable, achievable, relevant, and time-bound goals.

2. Material and method

2.1 Material

Electric linear actuator or motor linear actuator is a linear actuator that is driven by mechanical power (thread) from the rotation of the motor. Basically, the main function of a linear actuator is to create a straight line motion in a control or automation system. Figure 2 shows the shape of a linear actuator motor with a motor on the side and has a thread that makes rotational motion into linear motion. The specifications for this linear actuator motor consist of power, speed, stroke and maximum load, where the input voltage, stroke, No-load speed and load capacity are 12V DC, 100mm, 5 mm/s and 1500N respectively. The power supply unit (PSU) functions as a provider of electricity and power used to supply electrical power to several electronic devices. The function of the power supply unit is also to convert excess electrical voltage, into backup power, and convert AC voltage into DC voltage.

Figure 2. Electric Linear Actuator

2.2 Method

The research method begins with a preliminary study, namely field studies and literature studies. The next stage is the design stage, the manufacturing stage, the purchase of standard components such as the electric linear actuator, the assembly stage, and the smart hospital bed performance testing stage, see Figure 3.

The working principle of this smart hospital bed is that there are objects (people) or patients who are above the hospital bed, then there are five frames of motion that are driven using an electric linear actuator where the power source is obtained from the power supply unit. The five frames of motion include the upper frame of motion (the head), the right side of the motion frame, the left side of the motion frame, the right foot frame, and the left foot frame. The existence of a remote control makes it easier to adjust the movement as needed on the smart hospital bed.

In general, the basic mechanism of this smart hospital bed is (1) the power supply unit (PSU) receives voltage from a power source which will be forwarded to the electric linear actuator. (2) Electric linear actuator is in active state. (3) Remote control is connected to each electric linear actuator. (4) Setting the smart hospital bed movement, up and down movement by pressing the buttons on the remote control. (5) Remote control buttons number 1 and 2 to adjust the up and down movement of the stroke patient's head and back. Numbers 3 and 4 to adjust the body tilt; etc.

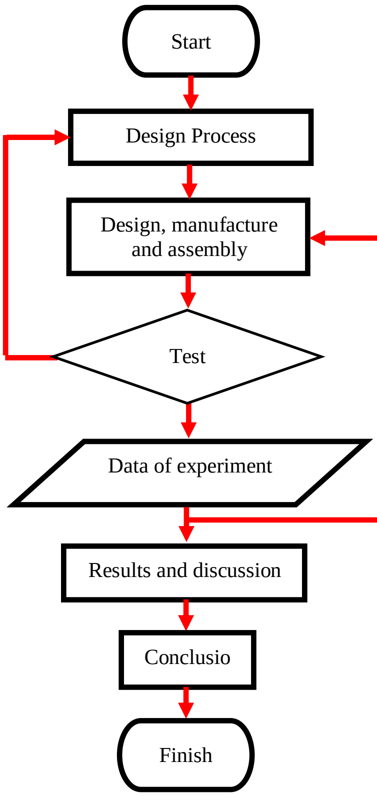


Figure 3. Flow chart of smart hospital bed

The operating mechanism of the smart hospital bed is as follows (1) prepare the object (person) that is above the smart hospital bed to see that the driver can function properly. (2) Inspection of hospital bed completeness components prior to operation. (3) Turn on the drive component by connecting the PSU to a power source. Use the remote control to move parts of the frame by pressing the appropriate button.

2.3 PSU Electric Power Capacity Calculation

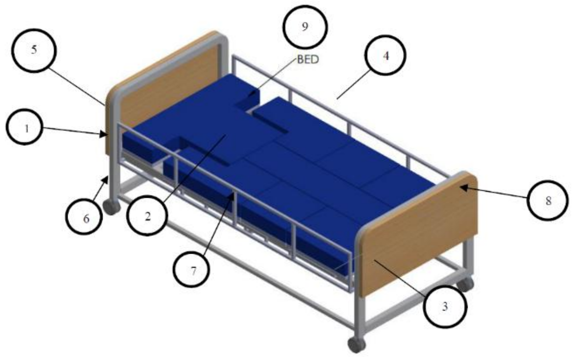
The power value of the PSU used can be known by calculating the five movements on the smart hospital bed to be made, namely head movement, right tilting movement, left tilting movement, right foot movement, and left foot movement. These five movements run alternately, which are then compared with each other to find out which movement requires the most power. This power calculation uses equation 1. Where PSU power is in watts, voltage V is in volts, and current I is in amperes.

$$P = V \times I \quad (1)$$

3. Result and discussion

3.1 Design and Manufacture

The smart hospital bed design and its parts can be seen in Figure 4. This design goes through the design determination stage by making several alternative designs which are then selected the best design.



1. Frame	6. Wheel
2. Hinge	7. Side rail
3. Electric linier actuator 50 mm	8. Hard board
4. Electric linier actuator 100 mm	9. Bed Custom
5. Power Supply Unit	

Figure 4. Design of the smart hospital bed

Figure 5 (a-d) is a prototype of a smart hospital bed that is complete with supporting devices. This prototype is functioning well through testing of five motion functions. Figure 5a shows the position for moving the back, Figure 5b shows the position for moving the legs, Figure 5c-d shows the position for tilting the body to the left and right.


(a)


(b)


(c)


(d)

Figure 5. Smart hospital bed, (a) Posisi gerakan punggung, (b) Posisi gerakan kaki, (c) Posisi miringkan badan kiri, (d) Posisi miringkan badan ke kanan

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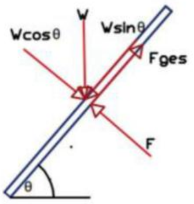
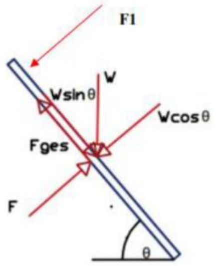
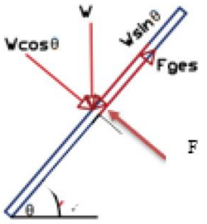
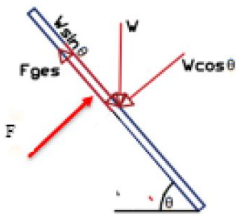
The lift force of this linear actuator motor is found in each part of the movement of the smart hospital bed, see Table 1. This smart hospital bed has five movements with 5 linear actuator motors, where each (a) head movement, (b-c) leg movement right-left, (d-e) right and left side body movements.

Table 1. The free body diagram, data and weight maximum

Free Body Diagram	Data	Weight maximum
 (a) Head movement	$\sum Fy = 0$ $F - W\cos\theta = 0$ W = 120 (kg) Lift force (F)=1500 (N) Lift angle (θ) = 37^o Structure weight = 7 (kg)	Total weight < Lift force actuator 597 < 1500
 (b-c) Leg movement	$\sum Fy = 0$ $F - W\cos\theta - F_1 = 0$ W = 120 (kg) Lift force (F)= 800 (N) Lift angle (θ) = 35^o Structure weight = 7 (kg)	Weight Total < Lift force actuator 422 < 800
 (d) Right side movement	$\sum Fy = 0$ $F - W\cos\theta = 0$ W = 120 (kg) Lift force (F)= 1500 (N) Lift angle (θ) = 37^o Structure weight = 12 (kg)	Weight Total < Lift force actuator 724 < 1500
 (e) Left side movement	$\sum Fy = 0$ $F - W\cos\theta = 0$ W = 120 (kg) Lift force (F)= 1500 (N) Lift angle (θ) = 37^o Structure weight = 12 (kg)	Weight Total < lift force actuator 724 < 1500

3.3 Structural strength analysis

Analysis of the main structural strength using Solidwork 2018 Software. There are three main processes in simulating frame strength, namely selection, fixture advisor, and loading simulation results. The first step that can be taken in conducting frame testing is to determine the material specifications for the hollow square pipe frame.

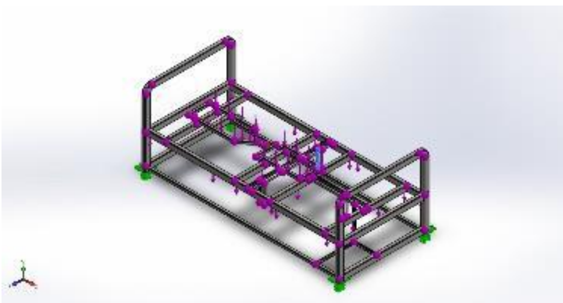


Figure 6. Position of Fixture Advisor

The next step is to determine the fixture advisor, in this frame simulation the selected fixture advisor is all the legs of the frame, visible parts of the frame are marked in green.

3.4 von Mises Stress

The von Mises stress is the magnitude of the force on an object's surface per unit area with units of N/m^2. The von Mises stress indicates a safe category if (von Mises stress yield strength of the material). The highest von Misses stress is 13.5 $N/mm^2 <$ material with a yield strength value of 204 N/mm^2. Figure 7 shows the simulation results of the von Mises stress.

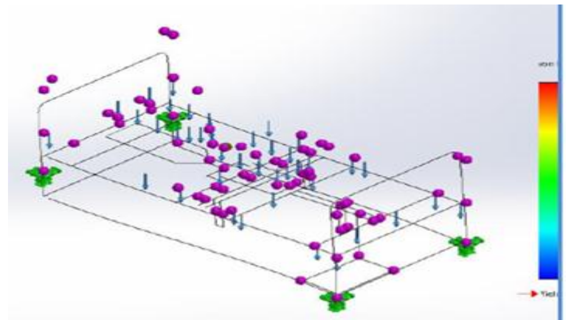


Figure 7. von Mises Stress Simulation Results

3.5 Displacement

Displacement or deflection is a change in the shape of an object that is subjected to a force. When a material is tested for tension with a certain load, the object will experience a change in length. Displacement values are generated according to needs, whether you want a rigid structure or flex as needed. In this design, the desired main frame structure is strong and sturdy so that the planned displacement value is less than one (Displacement < 1). The largest displacement value is 0.1085 mm, this shows the hospital bed structure design has a strong, sturdy and safe construction. Figure 8 shows the results of the displacement simulation.

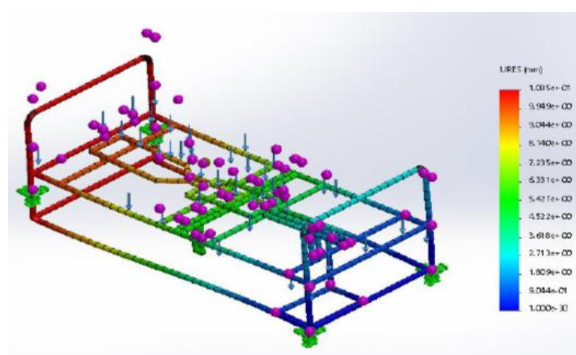


Figure 8. Displacement of structure

3.6 Safety Factor

The ratio of the actual strength to the required strength is called the safety factor. The SF value has a range (1 < SF < 10), if the FOS value > 1), then the hospital bed frame design is safe but if the SOF value <1) then the hospital bed frame design is not safe and needs improvement. Materials with a yield strength value of 204 N/mm² using Solidworks 2018 software obtained a minimum SOF = 1.2. SF value (1 < 1.2 < 10) so that the hospital bed frame design is safe. Figure 8 shows the results of the SOF simulation.

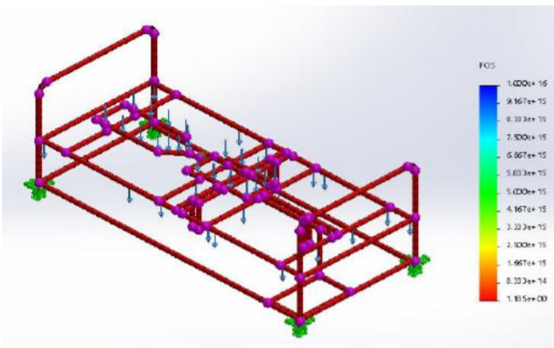


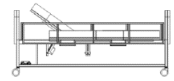
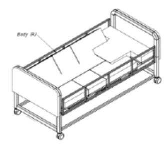
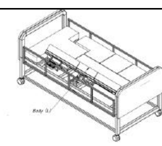
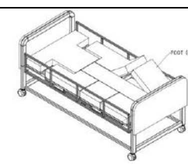
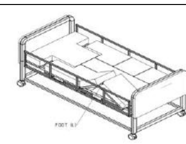
Figure 9. Safety of Factor

3.7 Remote Control Button Guide

The use of remote control requires guidance in the operation of stroke patients' body movements. Figure 10 shows the use of the remote control with various number button options. The movements that occur when the remote control button is used can be seen in Table 2.

Figure 10. Remote control

Table 2. Remote control and body movement

Button	Figure	Note
1		Head up
2		Head down
3		Left body up
4		Left body down
5		Right body up
6		Right body down
7		Right leg up
8		Right leg down
9		Left leg up
10		Left leg down

3.8 Performance testing

Smart hospital bed testing on patient weight and output amperage variables with the position of head movement, left foot, right leg, tilted to the right, and tilted to the left. Figure 11 shows the results of testing the relationship between patient weight and output amperage. Figures 12 and 13 show the relationship between the load weight and the required voltage and power values. The greater the patient's weight value, the greater the output amperage provided by the power source.

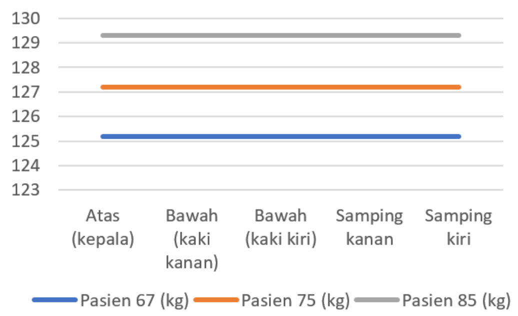


Figure 11. Testing patient weight with ampere output

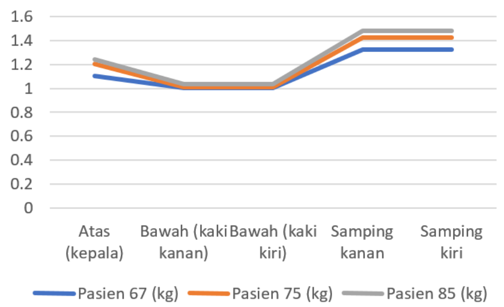


Figure 12. Patient weight testing with voltage output

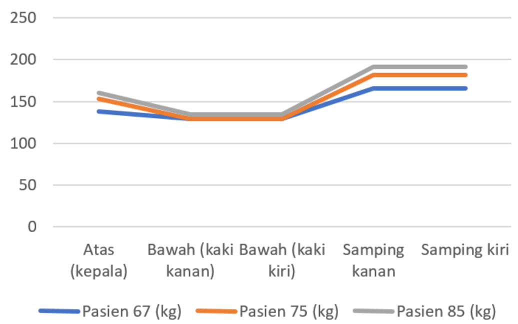


Figure 13. Patient weight testing with power output

The power required for one unit of electric linear actuator without load is 36 watts. The power required is one unit of electric linear actuator with a load of 120 watts.

4. Conclusion

The smart hospital bed design stage produces working drawings, part drawings, assembly drawings, and purchased components such as an electric linear actuator. The smart hospital bed manufacturing stage produces one hospital bed unit for stroke patients with dimensions of 2000 × 900 × 600 mm with a maximum weight of 180 kg. The prime mover is five units of electric linear actuator with input voltage 12 V DC; speed 20 mm/s; strokes 100 mm; hollow square pipe skeleton material. The testing phase of the five smart hospital bed movements set with a remote control produces good movements. Based on the test, the greater the patient's weight, the greater the ampere output, voltage output and linear actuator motor power output on the hospital bed.

References

[1] Suyitno, Yudha. 2019. *Studi Awal Perancangan Tempat Tidur Pasien Berbahan Aluminium dengan Metode Elemen Hingga*. Yogyakarta: Universitas Gadjah Mada.

[2] Yueniwati, Yuyun. (2016). *Pencitraan Pada Stroke.* http://www.fk.ub.ac.id/wp-content/uploads/ repository/dr_yuyun/3-Pencitraan-pada-Stroke.pdf.

[3] Radon Dhelika, Ali Fajar Hadi. 2021. *Development of a Motorized Hospital Bed with Swerve Drive Modules for Holonomic Mobility*. Department of Mechanical Engineering, Faculty of Engineering, Universitas Indonesia.

[4] Susanto Sudiro, Sha'ri Mohd Yusof. 2017. *Design Concept of Day Minus 1 Production Model Using Systems Modeling Language: a Case Study of Hospital Beds Production* Proceedings of the International Conference on Industrial Engineering and Operations Management Rabat, Morocco.

[5] Fadli Syamsuddin. 2019. *Rencana peningkatan manufacturing readiness level di PT. ABC (Studi kasus: teknologi pada produk hospital bed)*. UNS-F. Teknik Jur. Teknik Industri.

[6] Shalahuddin A.S., Luthfi Parinduri, Yusmartato Yusmartato. 2022. *Rancang Bangun Smart Hospital Bed Berbasis Mikrokontroler*. ISBN: 978-623-7297-51-2. SEMNASTEK-UISU 2022.

[7] Abbas, Aries, Sudiro, Susanto.2018. *Optimasi Desain Kinematik Linkage Mekanisme Pengatur Ketinggian Tempat Tidur Pasien.* Jakarta. Magister Teknik Mesin Universitas Pancasila.

[8] Adella. 2019. *Digitalisasi Pelayanan Kesehatan dengan Penerapan Revolusi Industri 4.0*. Diunduh dari https://aptika.kominfo.go.id/2019/04/digitalisasi-pelayanan-kesehatan-dengan-penerapan-revolusi-industri-4-0/ pada tanggal 29 Januari 2022.

[9] Martini, Dede Karyono. 2010. *Hospital Bed 2010*. Diakses dari https://www.esaunggul.ac.id/hospital-bed-2010/ pada tanggal 29 Januari 2022.

[10] Moch Denny Rosyid dan Ayu Cetiya Mahayekti, 2021, *Pengembangan Teknologi Smart Hospital Bed dalam Mengatasi Stres Akibat Covid-19*. Jurnal Ilmu Keperawatan JiwaVolume 4 Nomor 3,Agustus2021 e-ISSN 2621-2978. https://journal.ppnijateng.org/index.php/jikj.

[11] Kifrun, Aszul.2020. *Perancangan Mekanisme Berdiri pada Kursi Roda Elektrik*. Yogyakarta: Universitas Islam Indonesia.

[12] Sonawan, Henry. 2014. *Perancangan Elemen Mesin Cetakan Kedua Revisi*. Bandung: Alfabeta