Journal of Mechanical Design and Testing 4(1), (2022), 25-31
DOI: http://dx.doi.org/10.22146/jmdt.63146
e-ISSN: 2685-8029, ISSN: 2716-1293

Preliminary Design of Electric Linear Actuator for Hospital Bed Domestic Product

S. Hermawan[1,*] and H.S.B. Rochardjo[2]

[1]Universitas Muhammadiyah Pekajangan Pekalongan. Jl. Pahlawan No. 10 Gejlig Kajen Pekalongan Jawa Tengah Indonesia 51161
[2]Departemen Teknik Mesin dan Industri, Fakultas Teknik, Universitas Gadjah Mada, Jl. Grafika 2, Yogyakarta Indonesia 55281
E-mail: setiyohermawan0306@gmail.com

Abstract
Nowadays, the need for linear actuator as a component of a hospital bed is increasing due to the growing needs of electric bed. The function of this component is to adjust the form of the bed for the patient's comfort. However, the producers of the local hospital bed mostly rely on foreign products. To reduce the production cost, an effort was made to design a low cost yet functional electric linear actuator. The actuator using basic components, consists of a DC motor, transmission, and screw mechanism. Stainless steel pipe with outer diameter of 26 mm was used for the body of the actuator. The performance of the actuator was tested by applying gradual loading with variations on the stroke. It was shown that the the actuator works well in varying loads from 0 to 150 kg with varying stroke from 0 to 19 cm.

Keywords : Hospital bed, electric linear actuator, screw mechanism.

Abstrak
Saat ini kebutuhan akan linier aktuator sebagai salah satu komponen tempat tidur rumah sakit semakin meningkat, seiring dengan meningkatnya kebutuhan akan tempat tidur tipe elektrik. Fungsi dari linier aktuator ini adalah untuk mengatur tinggi rendahnya posisi tempat tidur dengan maksud agar pasien merasa nyaman. Namun, produsen tempat tidur rumah sakit skala lokal, sebagian besar komponen linear aktuatornya masih mengandalkan produk luar negeri. Berdasarkan permasalahan tersebut, maka untuk menekan biaya produksi, dilakukanlah perancangan linier aktuator tipe elektrik berbiaya rendah. Aktuator menggunakan komponen yang terdiri dari motor DC, transmisi, dan mekanisme sekrup. Pada komponen pipa, digunakan pipa stainless steel dengan diameter luar 26 mm. Performa aktuator diuji dengan menerapkan pembebanan bertahap dengan variasi panjang langkah selama pembebanan. Telah ditunjukkan bahwa aktuator bekerja dengan baik pada beban yang bervariasi dari 0 hingga 150 kg dengan variasi langkah dari 0 hingga 19 cm.

Kata kunci *: tempat tidur rumah sakit, linier aktuator elektrik, mekanisme skrup.*

1. INTRODUCTION

The need for hospital beds is increasing from year to year (Lolita et al, 2020). The increase occurred more in the non-VIP class. This condition tend also to increase the need of linear actuator. The linear actuator is a part of the hospital bed that changes the shape of the bed to get a comfortable position for the patient. This component still needs to be imported. The production capacity of local industries needs to be increased by using as many local products as possible.

Linear actuator is a component that can extend and retract linearly. For centuries actuators like this use hydraulic power. However, the use of hydraulic power on the hospital bed will make noise, heavy and expensive. On the other hand, the use of an electric actuator will be quiet, light and inexpensive as well as easy to control, and can stop at the desired position.

Today there are many linear actuator design innovations that have been carried out. For example, Khidir (2004) made a linear actuator with Shape Memory Alloy material. This actuator is only for small loads and small strokes. Enrici et al. (2016) made linear actuator design for the aeronautic application. The actuator was designed to replace pneumatic or hydraulic devices that function as cylinder. The weaknesses of this special actuators are complex manufacturing design but with the existing technological advances such as mechanics and microelectronics. The innovation can be upgraded to reach more functional in control system such as increasing the ability to positioning in accurate position (Peng, 2015).

This paper reports the design, manufacture and testing of an electric linear actuators using DC motors, transmissions, and screw mechanisms for use in hospital beds.

2. METHODOLOGY

Collecting data needed for design calculation in the research of data on the DC electric motor which included RPM motors, power needed, materials used on the upper arm pipe and determining calculations for elections diameter upper arm pipe, bearing type used to support the load of screw.

Design based on the load received by the linear actuator primarily on the upper arm pipe section and calculated the torque required by the motor to up and down the power of bearing, buckling on the screw and so on.after the calculation process completed, the next step is to draw a design using notebook installed the autodesk software inventor 2015.

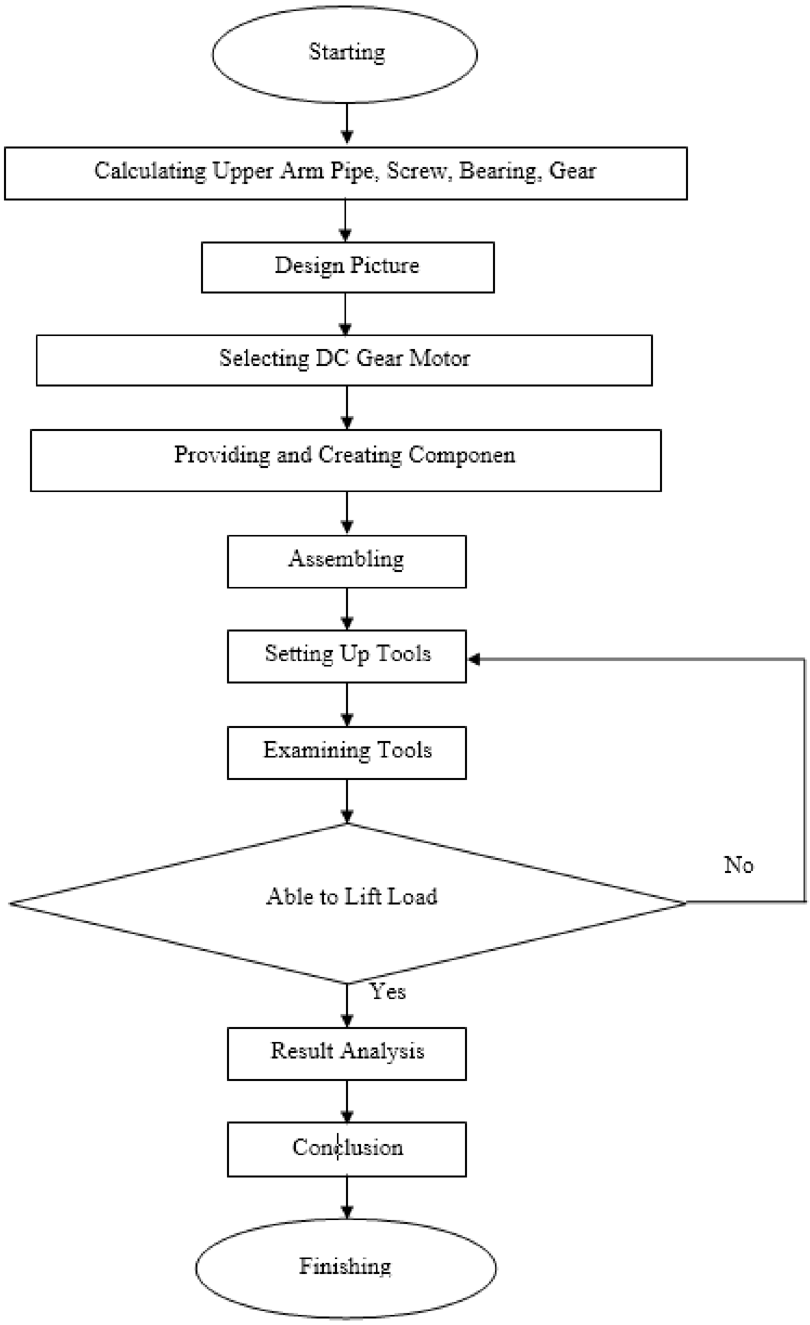

Figure 1. Flowchart

First of all is starting early process research. The next step is calculating the power and the diameter of the upper arm pipe. Counting the length and type of the screw, gears and also counting the power of bearing which support load on the screw. Then selecting the motor used. There are several types of motors, such as AC motor, motor stepper or DC. AC motor is electric motor works as alternating current. While stepper motor is a motor handled by microcontroller. The voltage on microcontroller is usually only 5 volt, therefore it needs other component to supply current on stepper motor. Dc motor is direct current, it is appropriate for this research as motor drive. The raise and fall of the actuator shaft, not as fast as the turn of the motor, therefore it is used DC type gear motor in order to reduce the spin. In selecting motor, RPM and torque are concerned. It refers to the previous calculation which is the torque needed to screw and so on, because the motor function is rolling the transmition which drive the up and down power to lift the load. If the choosen motor doesn't work, we recheck the calculation.

The next step is providing the materials used and then designing work picture by using autodesk inventor 2015 software from electric linear actuator made. After that assembling the support component of electric linear actuator. Then setting up for the tools to prepare object test.

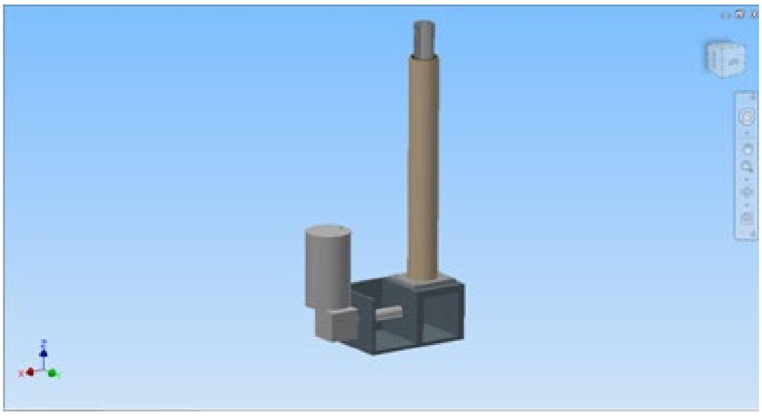

Figure 2. Electric linear actuator design

3. RESULT AND DISCUSSION

In this chapter there are some calculations on electric linear actuator design. Such as calculation on diameter upper arm, bearing power and screw. Power screw used in this design is lead screw type because it has self-locking character. Calculating the diameter upper arm pipe to the certain load (P) = 6500 N, upper arm length (L) = 300 mm, safety factor = 5.

The material used is stainless steel pipe with value of Yield Strength = 170 MPa. A material said yield when the stressed reach a critical value known as Yield Strength. The safe limit for the voltage is the Yield value strength is devided by safety number, so that:

$$\sigma_a = \frac{\sigma_y}{sf} \quad (1)$$

$$= \frac{170\ \text{MPa}}{5} = 34\ \text{Mpa}$$

Pipes used for safe design are pipes that have a stress value below 34 MPa.

$$A = \frac{\pi(d_2^2 - d_1^2)}{4} = 0.785(d_2^2 - d_1^2) \quad (2)$$

$$A = 0.785\ (26.67^2 - 20^2)$$

$$= 0.785\ (311.28)$$

$$= 244.47\ \text{mm}^2$$

The upper arm diameter used is a pipe with an inner diameter of 20 mm and an outer diameter of 26.67 mm. The pressure acting on the bearing (Pb) is calculated using the formula:

$$P_b = \frac{P}{2\pi n_a r_m h} \quad (3)$$

$$P_b = \frac{6500\ \mathrm{N}}{(2)(3.14)(17.5)(1.5\mathrm{mm})(1\mathrm{mm})} = \frac{6500\mathrm{N}}{164.8\mathrm{mm}} = \mathbf{39.42\ Nmm^{-2}}$$

Safe load on the bearing

$$W = P_b d_b l_b \quad (4)$$
$$W = (39.42)(15)(11) = \mathbf{6504\ N}$$

The calculating on the screw can be seen in the caption below. Figure 3 shows a scroll mechanism that has the function of raising and falling load by spinning nut. If one thread we draw, than the result is as shown in figure 4 that shows the section of the scroll and the forces that work on raising and falling load.

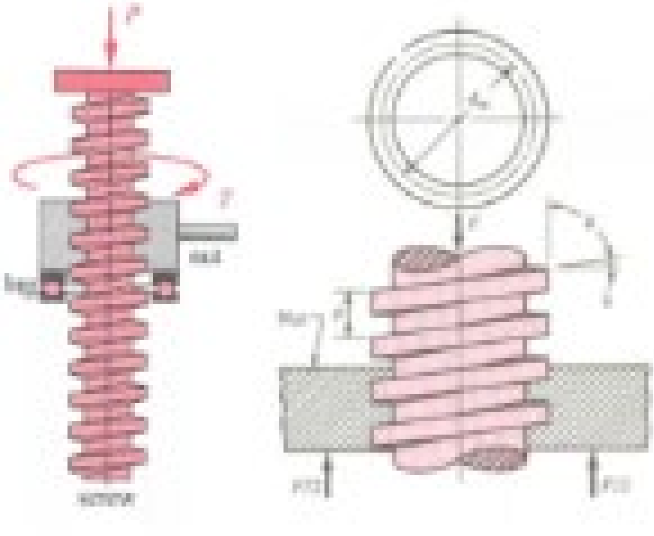

Figure 3. The Power Mechanism

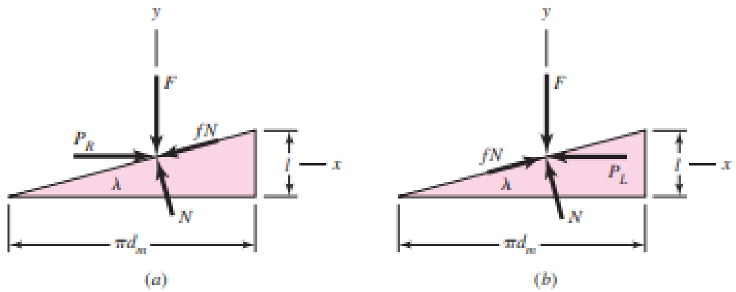

Figure 4. Force diagrams raising and falling load.

$$T_R = \frac{(6.5)(12)}{2}\left(\frac{4 + (3.14)(0.11)(12)}{3.14(12) - 0.11(4)}\right) + \frac{(6.5)(0.11)(12.5)}{2}$$
$$= 39\left(\frac{4 + 4.14}{37.7 - 0.44}\right) + 4.46$$
$$= 39\left(\frac{8.14}{37.26}\right) + 4.46 = \mathbf{12.98\ Nm}$$
$$T_L = \frac{(6.5)(12)}{2}\left(\frac{3.14(0.11)(12) - 4}{3.14(12) + 0.11(4)}\right) + \frac{(6.5)(0.11)(12.5)}{2}$$
$$= 39\left(\frac{4.14 - 4}{37.7 + 0.44}\right) + 4.46$$
$$= 39\left(\frac{0.14}{38.14}\right) + 4.46 = \mathbf{4.60\ Nm}$$

$$P_{screw} = \frac{nT}{9545}(kW) \quad (5)$$

$$\text{Speed rate screw } (V_s) = 2\ {}^{mm}/_{s} \quad (6)$$

$$n = \frac{\text{speed rate}}{\text{pitch}} \qquad n = \frac{2mm/s}{2mm} = \frac{1put}{s} = \frac{60put}{menit} \qquad Z \quad (7)$$

$$P_{screw} = \frac{60(12.98)}{9545} = 0.0081\ kW = \mathbf{81\ Watt}$$

$$i = \frac{\text{Motor rotation (N)}}{\text{Screw rotation (n)}} \quad (8)$$

$$i = \frac{92\ rpm}{60\ rpm} = 1.52 \sim 1.5$$

Input = 1.5 Output = 1

Self locking on power screw concern on the condition where the screw can't spin when no axle style is given on nut. It is very usefull because self locking is keep on the position when support the load. The power screw stays in its place when it holds the load. A screw will lock itself (self locking) when fulfilling the following equation

$$\pi f d_m > l \quad (9)$$

$$3.14\ (0.11)12 > 4$$

$$4.14 > 4$$

The results of the research tests appear to be shown at table 1 and table 2. The given load to the electric linear actuator, is gradually ranging from light loads to heavy ones. At the same power and speed of the motor, it shows the test of the upper stroke arm the linear actuator gets bigger. Then it would take more and more time to travel, according to the formula. The greater the lending, the greater the P would be. It showsThe time of passage is directly proportional to the size of the power.

Table 1. Result at Stroke Length 15 cm

No	Load (kg)	Stroke length (m)	Time (s)	P
1	15	0.15	19.3	4.694×10^{-5}
2	20	0.15	20.7	5.073×10^{-5}
3	40	0.15	25.0	5.076×10^{-5}
4	44	0.15	25.9	5.698×10^{-5}
5	48	0.15	26.6	5.738×10^{-5}
6	50	0.15	26.9	5.779×10^{-5}
7	60	0.15	28.5	5.831×10^{-5}
8	70	0.15	29.8	5.951×10^{-5}
9	76	0.15	30.6	5.968×10^{-5}
10	100	0.15	33.5	5.984×10^{-5}
11	115	0.15	35.0	6.034×10^{-5}
12	131	0.15	36.5	6.061×10^{-5}
13	136	0.15	36.9	6.090×10^{-5}
14	143	0.15	37.5	6.101×10^{-5}
15	150	0.15	38.1	6.102×10^{-5}

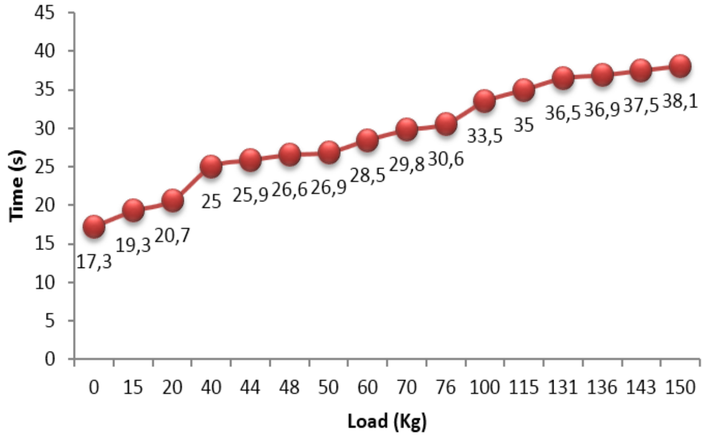

Figure 5. Chart of test results at stroke of 15 cm

Table 2. Results at Stroke Length 19 cm

No	Load (kg)	Stroke length (m)	Time (s)	P
1	15	0.19	24.1	3.054×10^{-5}
2	20	0.19	26.0	3.243×10^{-5}
3	40	0.19	32.1	3.446×10^{-5}
4	44	0.19	33.0	3.489×10^{-5}
5	48	0.19	33.9	3.511×10^{-5}
6	50	0.19	34.3	3.531×10^{-5}
7	60	0.19	36.4	3.545×10^{-5}
8	70	0.19	38.3	3.550×10^{-5}
9	76	0.19	39.3	3.568×10^{-5}
10	100	0.19	43.0	3.584×10^{-5}
11	115	0.19	45.0	3.596×10^{-5}
12	131	0.19	46.9	3.619×10^{-5}
13	136	0.19	60.1	1.783×10^{-5}
14	143	0.19	60.2	1.868×10^{-5}
15	150	0.19	60.4	1.933×10^{-4}

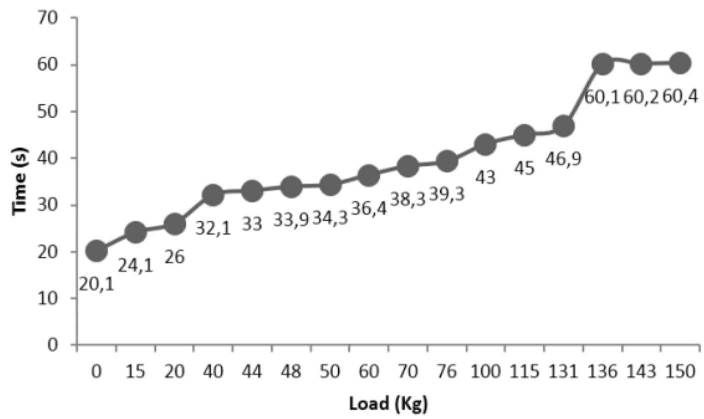

Figure 6. Chart of test results at stroke of 19 cm

4. CONCLUSION

Based on the results of calculations and test tools, it can be concluded that the electric linear actuator design is in accordance with the calculations to be applied to hospital beds.

Testing the tool by giving loading gradually on the electric linear actuator, the results obtained are directly proportional to the load and travel time. The greater the load given, the longer the travel time required to perform the push step.

5. REFERENCES

Budynas, R.G., and Nisbett, J.K., 2011, "Shigley's Mechanical Engineering Design Ninth Edition.", Mc Graw Hill, New York.

Dacapo Stainless, 2018 "Nominal Pipe Sizes,Pipe Dimensions, Imperial/Metric Pipe Chart", Netherland.

Enrici, P., Dumas, F., Ziegler, N., and Matt, D., 2016, "Design of a High – Performance Multi – Air Gap Linear Actuator for Aeronautical Applications", Volume 31 No. 3, IEEE Transactions on Energy Conversion.

Kemenperin, 2009, Peraturan Menteri Perindustrian Republik Indonesia Nomor 49/M-IND/PER/5/2009, tentang "Pedoman Penggunaan Produk Dalam Negeri dalam Pengadaan Barang dan Jasa Pemerintah.", Jakarta.

Kharagpur, 2015, "Module 6 Power Screw – Lesson 1 Power Screw Drives and Their Efficiency", India.

Khidr, EA., Mohamed, NA., Nor, MJM., and Mustafa, MM., 2007, "A New Concept of a Linear Smart Actuator", Sensor and Actuators, A 135, 244 – 249, Elsevier.

Kohara Gear Industry, 2015, "Katalog Steel Bevel Gears Modul 1 – 8", Nakacho Kawaguchi-shi Saitama-ken Japan.

Lolita, Sella, Nurhayati, and Kusworini, Dyah, (2017), Analisis Kebutuhan Tempat Tidur Tiap Kelas di Unit Rawat Inap Rumah Sakit Djatiroto Kabupaten Lumajang, Artikel Ilmiah Hasil Penelitian Mahasiswa, Universitas Jember

Paramount Bed Indonesia, 2018, "Produk Rumah Sakit ICU Bed PA-66250DX", Jakarta.

Peng Y., Cao, Jie, Guo Zhao and Yu Haoyong (2015), A linear actuator for precision positioning of dual objects, Smart Materials and Structures 24(12):125039

Yunus, A.D., 2010, "Diktat Mekanika Kekuatan Material", Program Studi Teknik Mesin, Universitas Darma Persada, Jakarta.