AUTOMATIC DYNAMIC MOTION CONTROL OF HOSPITAL BED SYSTEM

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Abstract: Hospital beds are widely used around the world for its various unique qualities. Hospital beds can be categorized into two main types: medical and surgical bed along with intensive care bed. An adjustable backrest is one of the main traits of a hospital bed. Various mechanisms have been found and applied for lifting the backrest. Normally hospital beds are operated manually with the help of both patient and healthcare workers. The present study of the various alternative models of hospital beds, has been decided to modify to automated bed that possess various adjustable for the comfort of the patient. Present fabrication model of automated bed system uses different actuation systems like D.C motor, screw jack and link mechanism. Effective control over the dynamic motions of the bed is acquired through installation of a control panel that is easily accessible by the patient.

Key words: Fabrication, Dynamic Motion Control, Automated Bed Control System.

I. INTRODUCTION

Hospital beds and other similar types of beds are used not only in hospitals, but in other health care facilities and settings, such as nursing homes, assisted living facilities, outpatient clinics, and in home healthcare. Common features include adjustable height for the entire bed, the head, and the feet, adjustable side rails, and electronic buttons to operate both the bed and other nearby electronic devices. Any treatment facility depends on its competent staff as well as quality medical facilities and equipments to create professional and secure medical environment. The quality and working condition of medical equipments are of key concern. Hospital beds are one of the most important medical equipment. Most countries have adjusted their safety regulations and added modifications to avoid patient entrapment. Developing countries in particular are in need of improving and modernized hospital bed.

We have studied various literatures and developed our own design that uses mechanical system coupled with electric circuit for automation. This product is aimed to be used in developing countries and as such we design this bed to be cost effective and use simpler mechanism that requires no use of special machining operation. One of the primary concerns regarding this bed is that it should be feasible in domestic production. So, the bed must adhere to the quality standards while sporting basic methods of fabrication. This paper is being organized as such; after discussing the introductory section a detailed review of different literature are reviewed then the various materials and methods used to fabricate the product and the characteristics of the final product is depicted.

A. Design Outline

Our design has to be an original that overcomes the shortcomings of the previous or existing designs while retaining the quality standards. Also this design should consist of fairly easy fabrication processes which are effective as well as cost efficient.
II. OBJECTIVE

- To study existing bed products and device a design that improves mobility as well as automated control of the bed.
- To successfully install a D.C battery powered system for conducting various motions of the bed.
- To incorporate a screw jack to enable vertical motion of the bed rest.
- To design and implement an automated electric control system that allows the patient easy access.
- To the various motions present in the bed and avail accurate control over the range of motion.
- To improve the quality of the automated dynamic motion control system while simplifying the control panel for user ease.
- To improve the relation between quality and cost.
- To reduce slippage during the operation of the system.
- To reduce use of complicated mechanisms or fluids as seen in hydraulic systems.

III. EXPERIMENTAL SETUP

Below are the components used in the assembly of automated bed according to the design specifications. These components are readily available in current market and does not require special machinery or skilled workers.

A. Screw Jack

Definition

Screw jack is essentially a worm gear that displaces the two ends rotating on the screw winding. This allows high torque as well as considerable decrease in speed. Here the screw jack is operated by using a series D.C motor driven by D.C battery.
B. Wheel

Definition

It is a circular component used to convert rotational motion to linear motion. The wheels are connected by means of an axel which ensures even distribution of the load on to the wheels. The wheels are used to transport the bed system from one point to another.

C. Structural Wheel

Definition

Structural wheel can rotate full 360° while carrying load on its wheels made of composite material. The top end of this structure is actuated by means of ball assembly so that it can move freely within the system.

D. L Angle Frame

Definition

L Angle frame is used to make the outline of the frame. The frame structure was assembled by welding together L angle bars of proper length that were cut according to the design spec. It is made of mild steel.
This component is designed to bear the body weight of the system including the gear assembly, battery, motor and screw jack. Most of the components are attached to the frame set by screw and nut through drilled holes.

**F. Slotter and Roller**

![Slotter and Roller](image)
Definition

They are connected to the link such that the movement of links cause them to actuate vertical movement of backrest while balancing the weight of the frame. Thus they promote underground swiping motion.

G. Link Actuation

Definition

Linkages are a collection of interconnected components and based on specification they are used for actuating the system. 4R links are used for performing the actuation such as compression and rarefaction which is connected to rac

![Fig.7: Link Actuation](image1)

H. Motor

Definition

Motor converts electrical energy into mechanical energy in the form of rotational motion. Motor mainly consists of starting winding and field winding; it generally acts as prime mover for performing certain operations.

![Fig.8: D.C Motor](image2)
I. Metal Bush
Definition
When connecting a gear to a motor there will usually be a clearance between the outer diameter of motor shaft and the inner diameter of the gear. To connect the motor and gear a metal bush is used with a cotter exerted on the holes so that the gears will not possess any wobbling action. The metal bush was machined using a lathe to the desired inner diameter. Then the surface was drilled to accommodate a screw used to tighten.

Fig.9: Metal Bush

J. D.C Battery
Definition
Direct current battery is used to store electric energy while charging and then discharge it to drive the motors. The battery used here are non acid spill proof type to prevent leakage of hazardous material.

Fig.10: D.C Battery

IV. DESIGN CALCULATION
A. Selection of Material for Frame Set
- Material used: MS Steel
- Young’s modulus: 1.35e+011 N/m^2
- Density: 7200 kg/m^3
- Yield strength: 3.4 e+008 N/m^2
• L type steel bar,
  Length = 630 mm
  Breadth = 25 mm
  Thickness = 5 mm

Considering the final member of a rectangular section where maximum loading takes place.
Load applied on this member is uniformly distributed load (UDL).
Average weight of the patient = 320 Kg
Average weight of additional devices = 50 Kg
Maximum load = (100+50) = 150 Kg

Apply this on a single member
Considering this member as a cantilever beam
Maximum bending moment, for a UDL cantilever beam is = (WI/2)
= (150*630)/2 = 46500 Kg-mm

Moment of inertia for a rectangular box,
I = (BH^3)/12
= (25*5^3)/12 = 162760.40 mm^4

from the equation
(M/I) = (f/y)
M = Bending moment
I = Moment of inertia
f = Stress
f = (M*y)/I
f = (46500*40)/162760.40 = 11.42 Kg-mm^2
Yield strength for MS steel = 564 N/mm^2
Considering factor of safety = 2
Maximum allowable stress = 564/2 = 282 N/mm^2
Stress formed on the beam = 19 Kg mm^2
= 11.42*9.81 = 112.107 N-mm^2
As 112.107 N-mm^2 is lower than 282 N-mm^2.....
Therefore the designed structure is safe.

B. Calculation of gear train

![Fig.11: Gear Train](image)

No of teeth used in motor shaft gear (A)T_1 = 22
Speed exerted from the motor is N_1 = 1447 rpm
No of the teeth next to the motor shaft gear (B) T_2 = 26
No of gear teeth followed by rack and pinion is (C) $T_3 = 127$

Power of the motor is $= 0.5$ HP

To find
- Speed achieved to the gear B $= ?$
- Speed achieved to gear C $= ?$
- Determine the torque exerted to gear A B C $= ?$

Formula used

**Gear ratio** $i = \frac{N_1}{N_2} = \frac{T_2}{T_1}$

**Power** $P = \frac{2\pi NT}{60}$

Solution

We know that the gear ratio formula between the teeth $T_1$ & $T_2$ is

$$i = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

$i_1 = \frac{N_1}{N_2} = \frac{22}{26} = 0.846$

$i_1 = 0.846$

Gear ratio between the teeth $T_2$ & $T_3$ are

$$i_2 = \frac{N_2}{N_3} = \frac{26}{127} = 0.204$$

$i_2 = 0.204$

From this $i_1$ & $i_2$ we can determine $N_2$ & $N_3$

$$i_1 = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

$$i_1 = \frac{1447}{N_2} = \frac{26}{22}$$

$N_2 = 1224.38$ rpm

To determine $N_3$

$$i_2 = \frac{N_2}{N_3} = \frac{T_3}{T_2}$$

$$i_2 = \frac{1224.38}{N_3} = \frac{127}{26}$$

$N_3 = 250.66$ rpm

To find the torque

We know that general power formula is

$$P = \frac{2\pi NT}{60}$$

$P = 0.5$ HP $= 0.37285$ KW $= 0.37285 \times 1000 = 372.85$W

From this we can determine torques $T_1$ & $T_2$ & $T_3$

$$T_1 = \frac{60P}{2\pi N}$$

$$T_1 = \frac{60 \times 372.85}{2 \times 1447}$$

$T_1 = 2.461$ N-m

To find $T_2$

$T_2 = \frac{60P}{2\pi N}$

$T_2$
\[ T_2 = \frac{60 \times 372.85}{2 \times 1224.38} \times \pi \]

\[ T_2 = 2.907 \text{ N-m} \]

To find \( T_3 \):

\[ T_3 = \frac{60P}{2\pi N} \]
\[ T_3 = 60 \times 372.85/2 \times \pi \times 250.66 \]

\[ T_3 = 14.204 \text{ N-m} \]

V. FABRICATION PROCESS

A. Body

Procedure

The frame or body of the bed is the component that supports the patient as well as the actuators, motors, power system, transmission system and the chain drive. So ms steel is used as the frame material. According to the design specification, lengths of the frame are cut and weld together.

B. Screw Jack System

Procedure

This system utilises the high torque generated by worm gear to move the back rest of the hospital bed. The prime mover is a series D.C motor which rotates the screw. The screw jack is connected to the link mechanism which will move the slot and roller to balance the weight of the back rest and thus cause vertical motion of the backrest. The motor is powered by a 12V, 5A D.C motor.
C. Chain Drive System

This system utilises a simple chain drive using spur gears that is connected to the wheel axel to impart motion. The pinion spur gear is a fixed part on a shaft along with driven ideal gear. A 12V, 9A D.C motor is used to rotate the ideal gear which when coupled with the driven ideal gear cause rotation of the shaft. This in turn rotates the pinion spur gear of the chain drive. The final rotation of wheel axel and thus the wheel impart horizontal motion to the system.

D. Electrical Circuit

The automated hospital bed runs on electrical energy sorted in D.C battery. Separate batteries are provided for each of the two motors. The motors are connected to their batteries through DPDT-two way switch. This allows the user to switch power as well as the polarity of the motor. Thus controlling the direction of the motor rotation, the user can choose the direction of motion of the bed.
VI. CONCLUSION

The automated bed is designed such that they are can be easily fabricated domestically. This means the availability of various components of the bed is good and the services required can also be easily acquired. The product also has low maintenance issues regarding the need for skilled worker or availability of spare parts. Our product does not need any hazardous working fluids or require special containers for the storage and compression of fluids. This eliminates the need for skilled worker as well as eliminates risk of leakage or compressor failure. The use of link mechanism also results in decrease in weight of the overall system. Additionally the cost of the product is also found to be decreased to about 1/5th of its competitor. Automated bed with simple link mechanism has been designed. Use of DC battery and motor allows free movement without depending on wall sockets for power. Complete control on the movement of the bed can be achieved by the patient by means of the control panel. This eliminated the need to transfer patient to various platforms (eg. Stretcher) for transporting patient. Assists the caretaker while moving the bed using the horizontal motion function of the bed. Since the price of this product is only 1/5th of the existing products, it can be effectively marketed in developing countries. The absence of complex mechanism allows it to be manufactured domestically.

REFERENCES

[15] JL Peterson in (2001) have invented automated bed control by using hydraulic system