Design of Bed for Bedridden Patients: Analysis and Synthesis of Mechanisms

Atul Andhare , Anil Onkar, Pramod Padole

Abstract

Managing bedridden patients is an important issue as many people are involved in it and patients need round the clock assistance. An attempt is being made by the authors, to reduce the amount of assistance required in managing these patients by designing a new bed. This paper presents analysis and synthesis of mechanisms for realizing such bed.

Keywords: Design of bed, Mechanism synthesis, Bedridden patient, Bed with commode

1 Introduction

There are many people who are permanently or temporarily bedridden. They have to use bedpan for normal physiological functions such as defecation and urination. Using bedpan on the bed is cumbersome and uncomfortable and there is a need to reduce the inconvenience and assistance required for such patients.

Few attempts have been made earlier to address the problem. These can be broadly classified in following three approaches. The first is that of a robotic or automated bed cum wheel chair, operated by the patients themselves [1-3]. The second is focused on the positioning of patients within the bed for transportation or preventing bed sores [4-5]. The third approach focuses mainly on the transportation of patients from bed to wheel chair and vice versa [6]. All the previous work is focused on the use of automated devices/systems, which costs quite high and patient or caretaker has to be familiar to the sophisticated controls for using such systems. There is a need to develop a simple, low cost alternative for the Indian population. Therefore, it was thought of designing such bed for bedridden patients.

A survey was carried out to find the requirements of such a system and the following requirements were listed- providing commode, easy operation, minimum patient movement, elimination of bad odour, minimum assistance and low cost [7].

2 Analysis and Synthesis of Bed Mechanism

Based on the requirements listed above, tentative arrangement of the bed was proposed and is shown in Fig. (1). It shows a commode (1) attachable to bed (2) which shall come up through a hole (3) in bed when required. Sitting position is achieved by moving the backrest (4) up. Chair position is achieved by moving leg part (5) downwards for easy urination and defecation. The commode can be raised to the top level of mattress (6) through a hole in it. Hole in mattress is covered by a

Atul Andhare, (Corresponding Author),
Mechanical Engineering Dept., V. N. I. T., Nagpur- 440010, India. Email: abandhare@gmail.com

Anil Onkar
Mechanical Engineering Dept., V. N. I. T., Nagpur- 440010, India, Email: ceo.onkar@gmail.com

Pramod Padole
Mechanical Engineering Dept., V. N. I. T., Nagpur- 440010, India, Email: pmpadole@rediffmail.com

matching piece (7) of mattress mounted on a mechanism which closes the hole when not in use and moves out when commode is needed.

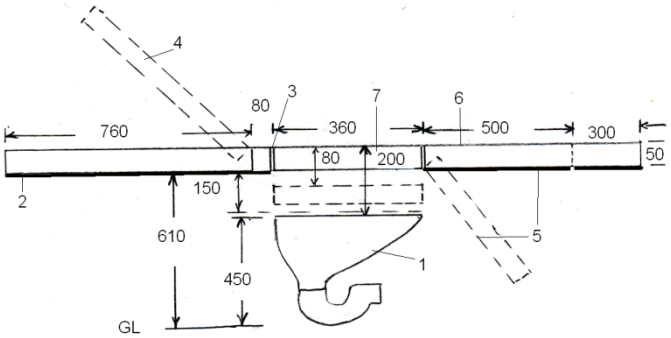

Figure 1: Arrangement of bed showing various features and dimensions in cm

Various drives for the motions of backrest (4), leg-rest (5), commode (1) and platform (7) were evaluated for their suitability. Drives considered were - handle driven screw and nut mechanism, hydraulic cylinder with hand operated or motorized power pack, air cylinder with air compressor and electrical actuators. Handle driven screw and nut arrangement appears to be suitable to drive the mechanisms for leg-rest, back-rest, commode and platform, for its low cost, easy manufacture, easy maintenance, no power requirement and long trouble free life. Following paragraphs presents a discussion on synthesis of mechanisms for the commode (1) and platform (7) motions.

2.1 Synthesis of mechanism for raising and lowering commode

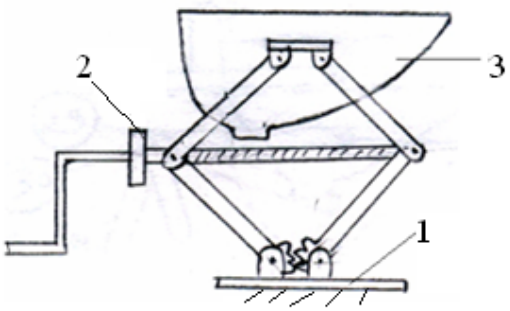

Figure 2: Two toggle jack arrangement to move commode up and down

Fig. (2) shows two toggle jacks (1) connected to each other by chain and sprocket (2). It can raise the toilet seat (3) to the required height. It can be seen that the handle does not have fixed position and it moves upwards when commode is raised. The commode needs vertical guides to match the hole in bed (part 3 of Fig. 1). Also, the operator has to sit on ground or be in bent position to operate the handle. This arrangement is not convenient for operation. Therefore, to maintain a suitable, fixed height of handle, arrangement as shown in Fig. (3) is considered.

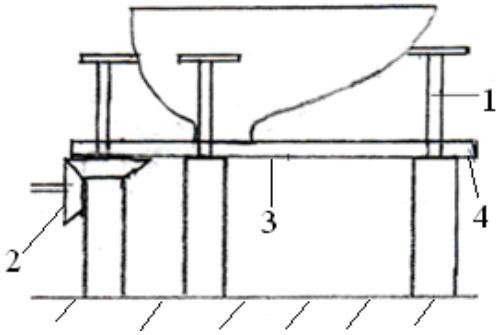

Figure 3: Three lead screw arrangement to move commode up and down

Fig. (3) shows arrangement of three lead screws (1) driven by a bevel gear (2) chain (3) on sprockets (4). Over a period of time there may be play in chain drive due to sprocket wear and chain elongation which can result in lag in motion of the screw and the commode top may not remain horizontal. The system is complicated and costly as compared to toggle jack. Hence, one more arrangement, shown in Fig. (4), is considered for evaluation.

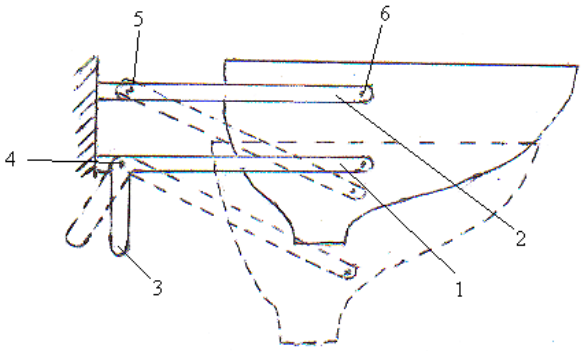

Figure 4: Parallel link arrangement to move commode up and down

Fig.(4) shows two parallel links (1and 2). One of which (1) is a 'L' type lever which is activated by a horizontal screw. When horizontal force is applied at lower end (3) of link (1), the horizontal link rotates around pin (4) resulting in up down motion of commode. The upward motion of commode is guided by link (2) moving on pins (5 and 6). This mechanism is simple and needs negligible maintenance. It also keeps the commode in level as well as it guides the motion vertically. Hence this mechanism can be used if it does not obstruct the mechanism needed for operation of moving platform (part 7 of Fig. 1).

2.2 Synthesis of mechanism for platform

Fig. (5) shows a platform (1) on hinge (2) below bed, pulled by a drive (3) through link (4) which will open the hole in bed. This mechanism is simple and has low initial cost. However, it needs space below it for its movement.

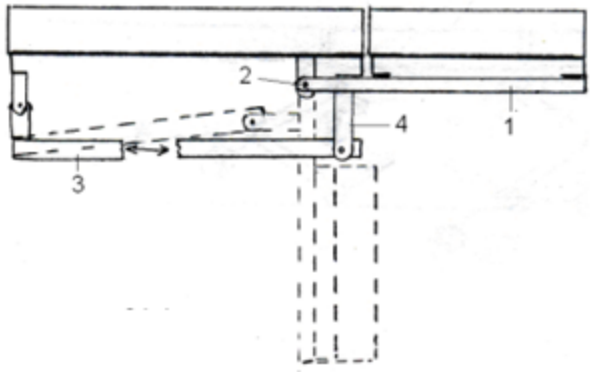

Figure 5: Hinged platform arrangement to open and close hole in bed.

The approx. length of cover is 450 mm. The normal height of hospital bed is 610 mm. The remaining height needed for commode is 150 mm. It is not possible to accommodate any commode seat in this height. If at all this mechanism is to be used then the mechanism earlier selected for commode (Fig. 4) cannot be used. Then the commode has to be fitted on the other side of mechanism. The commode will have to be shifted horizontally towards left first and then vertically upward. Considering the weight and volume of commode and pipes attached to it, it shall need heavy mechanism and more power. Therefore, this arrangement of Fig. 5 is not suitable.

Hence, to use the mechanism of Fig. (4) for commode motion, the platform should have mechanism which shall move the cover first vertically down and then horizontally to clear the hole as shown in Fig. (6).

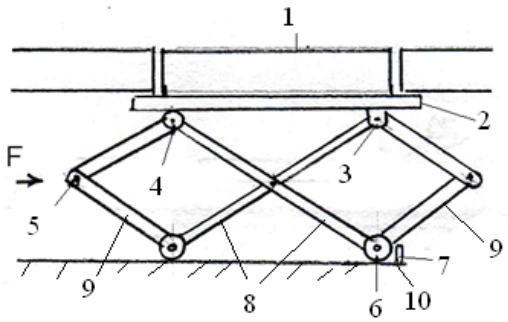

Figure 6: Platform with parallelogram links to open and close hole in bed.

Fig. (6) shows cover (1) fixed on platform (2) with parallel links crossed to form two parallelograms. One joint (3) is a pin joint whereas other joint (4) is a roller contact joint. The links (8 and 9) are with 4 wheels (6) resting on fixed channel (10). When force is applied at joint 5, the total parallelogram structure moves below the hole in bed till wheels (6) stop at stopper 10. Further application of force will raise the platform to close the hole in bed. To lower the platform, force in opposite direction has to be applied. Till the cover (1) is in contact with mattress, the platform will move down and as soon as the cover (1) moves below the mattress the mechanism will start moving horizontally away from hole. This shall lead to high wear and tear of mattress. To avoid this, it is required to have a guide for vertical motion of platform which shall disengage after mattress comes below the bed level.

This system of Fig. (6) shall consume minimum vertical space below the hole and allows space for selected commode mechanism. This mechanism may be used after considering other option as shown in Fig. (7)

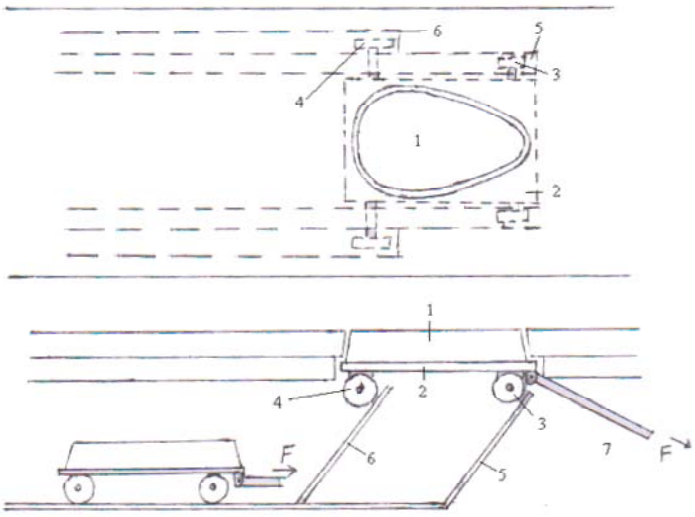

Figure 7: Platform with wheels and sloping guides to open and close hole in bed.

Fig. (7) shows cover (1) fixed on platform (2) having two front wheels (3) and two rear wheels (4). The front wheels (3) move on upward turning guides (5) which are close to platform. The rear wheels (4) move on upward turning guides (6) which are away from platform by distance more than width of wheel or equal to width of guide (5). When Force (F) is applied to link (7) the platform moves first on horizontal part of guides and then on sloping part to close the hole. The above mechanism also consumes minimum vertical space below hole and allows space for mechanism for commode. However, the force required to raise the platform on slope is considerably high as compared to that required in mechanism of Fig. (6). This mechanism may also be used after considering other option of a four bar mechanism for three positions of the platform.

Fig. (8) shows a four bar mechanism for three positions- closed, lowered and extreme side position of the platform. The mechanism was synthesized by using analytical (matrix) method. The location of fixed pivots has to be below the bed level and below the backrest as backrest does not come below bed level. Initially, the fixed pivots are assumed at $M_0(5, 15)$ and $N_0(15, 55)$. All positions of platform were considered to be horizontal. Positions of moving pivots were obtained and are $M_1(48, 40)$ and $N_1(58,40)$. For getting other positions, the X coordinate of No was incremented to increase the distance between Mo and No. The results are tabulated at Sr. No 1 to 5 in Table 1. For next five positions, the Y coordinates of Mo and No were lowered by 5 cm and the X coordinate of No was incremented to increase the distance between Mo and No. The results are tabulated at Sr. No 6 to 10 in Table 1. For further points, platform was considered to be tilted by 5^0 and 10^0 with respect to its closed position. Keeping all the other data same as in 1-10, positions 11-20 of Table 1 were obtained.

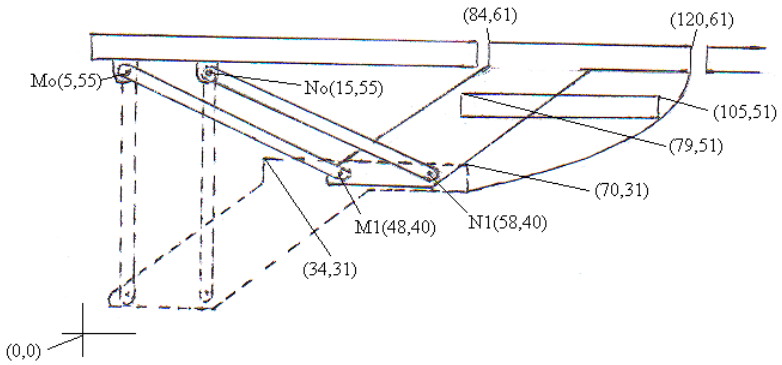

Figure 8: Platform on four bar mechanism (Mo, No, M1, Ni) to open and close the hole in bed.

Table 1: Results of three position synthesis for four bar mechanism

S. N.	M ox	M oy	N ox	N oy	X. Travel betn 1- 3 mm	Y Travel betn 1-3 mm	Tilt at 3 wrt 1 mm	Tilt at 2 wrt 1 mm	Y Travel betn 2- 3 mm	M 1x	M 1y	N 1x	N 1y
1	5	55	15	55	50	30	0.00	0.00	10	48	40	58	40
2	5	55	20	55	50	30	0.00	0.00	10	48	40	63	40
3	5	55	25	55	50	30	0.00	0.00	10	48	40	68	40
4	5	55	30	55	50	30	0.00	0.00	10	48	40	73	40
5	5	55	35	55	50	30	0.00	0.00	10	48	40	78	40
6	5	50	15	50	50	30	0.00	0.00	10	48	35	58	35
7	5	50	20	50	50	30	0.00	0.00	10	48	35	63	35
8	5	50	25	50	50	30	0.00	0.00	10	48	35	68	35
9	5	50	30	50	50	30	0.00	0.00	10	48	35	73	35
10	5	50	35	50	50	30	0.00	0.00	10	48	35	78	35
11	5	55	15	55	50	30	6.25	3.14	10	24	95	38	85
12	5	55	20	55	50	30	6.25	3.14	10	24	95	45	80
13	5	55	25	55	50	30	6.25	3.14	10	24	95	52	75
14	5	55	30	55	50	30	6.25	3.14	10	24	95	59	70
15	5	55	35	55	50	30	6.25	3.14	10	24	95	66	66
16	5	50	15	50	50	30	6.25	3.14	10	27	82	40	74
17	5	50	20	50	50	30	6.25	3.14	10	27	82	47	70
18	5	50	25	50	50	30	6.25	3.14	10	27	82	53	66
19	5	50	30	50	50	30	6.25	3.14	10	27	82	60	62
20	5	50	35	50	50	30	6.25	3.14	10	27	82	66	58

From Table 1 it is found that the four bar mechanism of Fig. (8) is not useful due to following reasons.-

1. From the comparison of readings (1-10) with (11-20) it is observed that by tilting the platform in positions 2 and 3, the positions of moving pivots go above the bed level. This is totally unacceptable.
2. Comparison of readings (1-5) with (6-10) shows that lowering of fixed pivots lowers the position of moving pivots. There is no change in x coordinate.
3. Assuming all the positions of platform in horizontal plane, while using the four bar mechanism, location of fixed pivots needs to be on the body of the bed and below the backrest. The moving pivots are far away from the platform. The load due to platform is like a cantilever on the moving and fixed pivots. This demands accurate pins without any play. Moreover, little clearance in pins will not allow platform to reach closing position.
4. The force required to keep platform in closed position will be continuous and high as weight of patient body will be continuously acting on it.
5. If the four bar mechanism is used, separate mechanisms for commode and platform with two separate drives are needed.
6. The path of extreme point of platform is interfering with the commode at lowered position

Thus, the alternatives available for platform mechanism are mechanism from Fig. (6) or Fig. (7). The mechanism in Fig. (7) needs high force to raise platform on the slope. Moreover, there is tendency of platform to roll down on slope and some force is required to keep it at its position. Hence mechanism in Fig. (6) is selected as a single drive can operate commode and platform both. CAD models of the proposed bed with selected mechanisms discussed above are shown in Fig. (9) and (10).

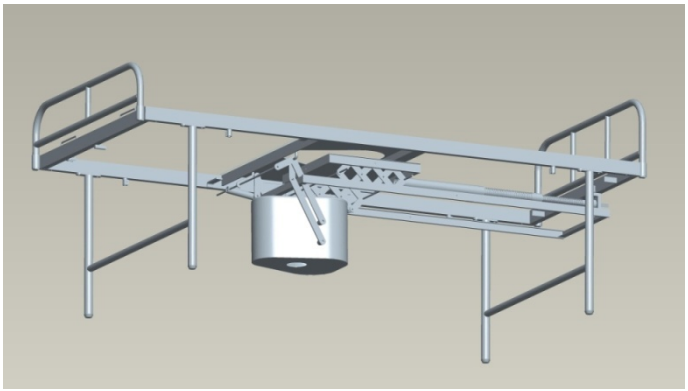

Figure 9: Model of bed showing selected mechanisms for commode and platform

3 Conclusions

The paper has discussed the various alternatives for obtaining the required motions in proposed bed for bedridden patients. Out of the three alternatives for commode motion, one with parallel links is selected and out of the four alternatives for platform motion, one with parallelogram linkages is selected. After preparation of CAD models and simulation of motions, the mechanisms have shown correct motions and positions. Hence, the bed fabrication can now be taken up.

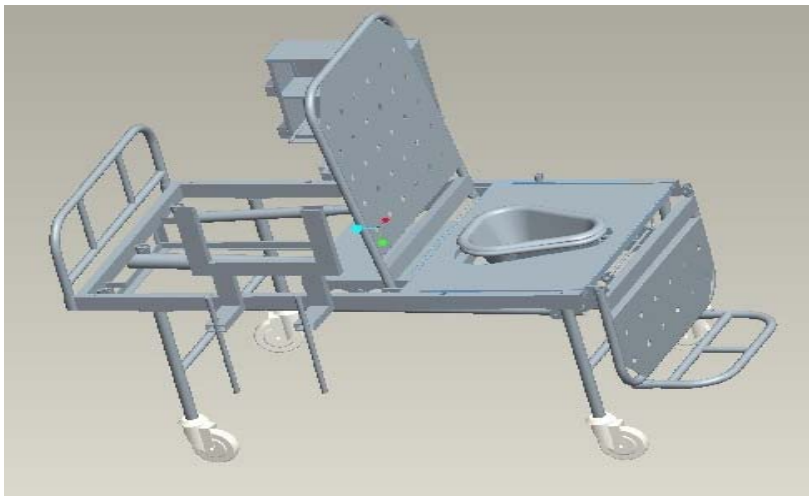

Figure 10: Model of bed showing backrest in raised position, leg-rest in lowered position and commode in up position.

References

[1] S. Mascaro, J. Spano, and H. Asada, "A reconfigurable holonomic omni-directional mobile bed with unified seating (RHOMBUS) for bedridden patients," in *IEEE International Conference on Robotics and Automation*, pp.1277-1282, 1997.

[2] L. Tan, S. Lu, W. Zhang, "A robotic nursing bed design and its control system", in *Proceedings of the 2009 IEEE International Conference on Robotics and Biomimetics*, December 19 -23, 2009.

[3] S. Peng, and F. Lian, "Mechanism design and mechatronic control of a multifunctional test bed for bedridden healthcare", in *IEEE/ASME Transactions on Mechatronics*, pp. 234-241, Vol. 15, No. 2, April 2010.

[4] W. Ching-Hua, T. Ting-Chun, H. Shin-Chieh, C. Wan-Chun, C. Yen-Ming, T. Kun-Tse , Y. Chun-Went and C. Kuo-Yi, "Hospital bed with auxiliary functions of lateral positioning and transferring for immobilized patients", in *The 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON)*, pp. 2991-2995, 2007.

[5] A. Basmajian, E. Blanco, and H. Asada, "The marionette bed: automated rolling and repositioning of bedridden patients", in *Proceedings of the 2002 IEEE International Conference on Robotics & Automation*, pp. 1422-1427, May 2002.

[6] H. Wang and F. Kasagami, "Careful-patient mover used for patient transfer in hospital", in *IEEE/ICME International Conference on Complex Medical Engineering*, pp. 20-26, 2007.

[7] A. Andhare and A. Onkar, "Design of bed for bedridden patients: determination of design criteria", in *4th International Conference on Advances in Mechanical Engineering (ICAME), R. V. Rao (Ed.)*, Sept 2010.