TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 64, Issue Special IV, December, 2021

NEW CONCEPT AND DESIGN OF A SMART HOSPITAL BED

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Abstract: *The present study highlights a new concept and design of a smart hospital bed. The process of designing and manufacturing of affordable medical assistive devices in developing countries, where resources are much more limited, represents a major challenge and research in this field is critical in the actual context of the recent global pandemic and of global ageing. The main goal of this research was to design a new advanced concept of smart hospital bed, which subsequently will be produced and developed in order to be used in hospitals, homes, recovery centers and nursing homes. The designed smart bed can provide eight medical positions depending on specific requirements, and has also the option to develop three more, if needed.*
Key words: *Smart products, Mechatronic design, healthcare, CAD.*

1. INTRODUCTION

Over the last twenty years, the evolution of the hospital bed can be described as a transformation from a simple extensor hospital bed into a multifunctional bed, designed with many features like flexible frames, that allows to adjust different body parts in accordance with the patient's needs, access controls and voice-controlled application [1], detection of incontinence and occupation sensors [2], multimodal interfaces [8] and other features that can assists the hospital staff in different patient-care procedures.

The recent global pandemic has shown us how fragile we are in terms of medical equipment, resources, but also many of the difficulties that medical staff go through in such a crisis, as well as their needs. More than that, it is estimated that the aging rate of the world population is increasing and the number of people over the age of 60 will reach 2 billion by the year 2050 [5]. Therefore, the growing demand for medical equipment and the lack of experienced medical personnel represents a major problem in patient care and in the next years, the challenge will be to support the medical staff by decreasing the amount of physical interaction with patients.

Into the era of "smart" paradigm that we are living through right now, designers and engineers can develop highly sophisticated functionality by integrating electrical and mechanical systems that tends to improve the functions and operation of the hospital beds [7]. On the other hand, this growing range of the medical applications leads to higher costs of productions, with a severe impact from the point of view of affordability, especially in the developing countries [3].

Satisfying the hospital needs through assistance and monitoring, as well as improving the patient comfort by patient-centered solutions is always a priority in designing a smart hospital bed which fulfill a successful healthcare system [4, 6].

2. OBJECTIVES AND METHODOLOGY

The main objective of this research was to design a new, advanced, and interactive concept of smart hospital bed, which subsequently will be produced and developed so that it can be used in hospitals, homes, recovery centers and nursing homes.

The dimensions of the structural elements were taken in order to comply with the FDA recommendations regarding the dimensional limitations for hospital beds and also, ISO-IEC 60601–2-52:2009 standard was taken into account in the design process (basic safety and essential performance of medical beds intended for adults). According to this, the length of the designed bed is 2000 mm, the bed width is 1000 mm and a minimum weight capacity of the patient of 230 kg was considered.

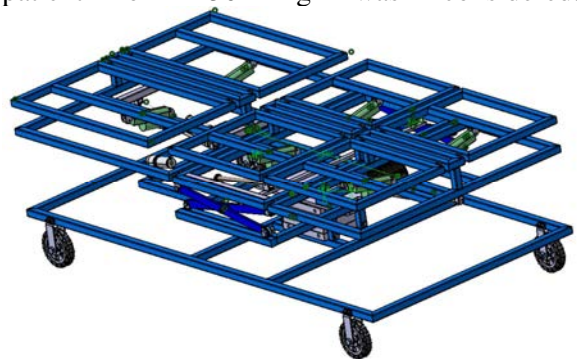

Fig. 1 The structure of the new Smart hospital bed

The bed designed and presented in Figure 1, has a unique modular structure made of aluminum profiles, being the only intelligent hospital bed of this kind, which facilitates its construction and allows, at the same time, performing several necessary positions either during hospitalization of the patient, to increase his comfort, either to facilitate various medical therapy procedures.

The software package used for designing this bed and to simulate different scenarios and positions is Catia V5, together with SolidWorks.

3. DEVELOPMENT OF THE BED

3.1 Positions of the smart bed

Many smart hospital bed manufacturers provide a long range of models that are suitable either for hospitalization or for intensive therapy. Some positions are provided by each bed model, depending on requirements, but the most common positions are orthopedic, Fowler and also foot elevation, tilting and sit.

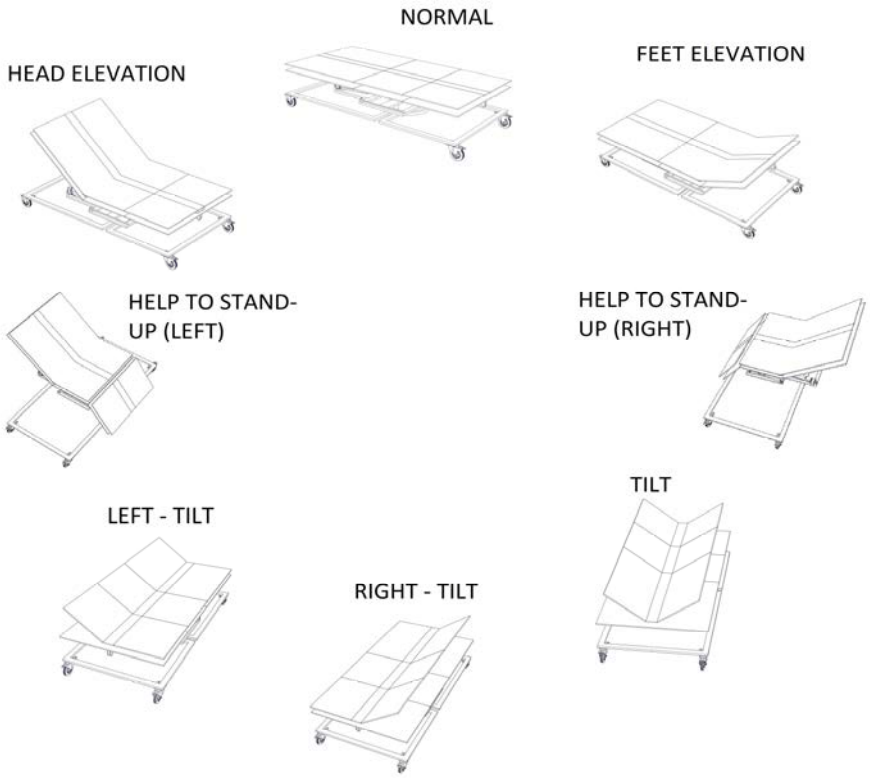

Fig. 2 The positions of the hospital bed

The proposed design of the bed has the current possibility of eight required positions, presented in Figure 2, and also the option to develop three more, if needed: Cardiac, Orthopedic and Semi-fowler.

3.2 Designing of the bed

To achieve a good mechatronic design, a lot of information from several areas must be processed and a high degree of coordination must be achieved, in order to fulfill all criteria for the design. In the following sections, the tasks and requirements for the mechanical design, electrical and industrial design are described; medical experts from the Regional Institute of Gastroenterology and Hepatology „Prof. Dr. Octavian Fodor" were asked to define these requirements.

The base frame of the bed is placed on four omnidirectional wheels, which offers the structure the possibility to move both classically and transversely (Figure 3). These wheels are provided with cylinders that can rotate freely and thus offer the possibility of movement in a unique way.

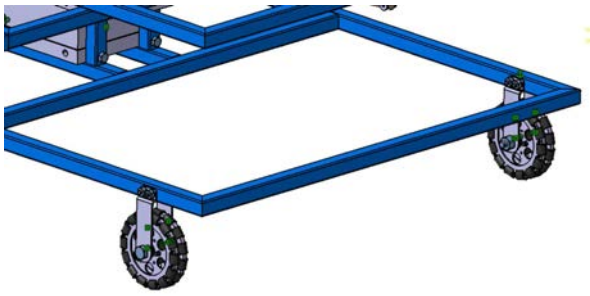

Fig. 3 Base frame and omnidirectional wheels used

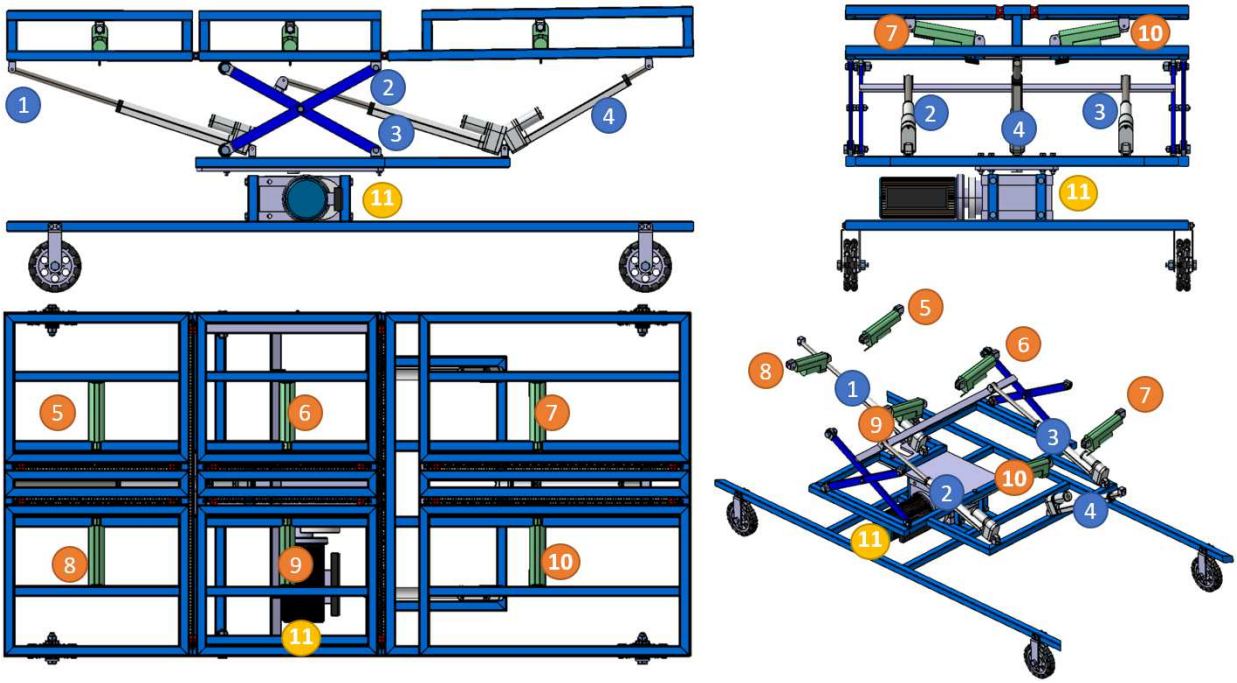

Fig. 4 The frame of the bed and the positioning of the motors used to operate the bed

The bed frame must ensure high stability to prevent falls or any other dangerous situation to the patient's health. Another set of two wheels will be attached to the base, which will also have the function of assisted movement of the bed, and of ensuring directional brake or total brake, in order to ensure the safety of the patient when the bed is at rest.

To apply the appropriate motion to each mechanism, a number of ten linear actuators of two specific trademarks were selected, together with the electric motor no. 11, which is responsible for the rotational movement as it can be seen in Figure 4:

- linear actuators with number 1 to 4 are Glideforce MD 122012 and they are responsible for the following positions of the bed: Head elevation, Feet elevation, Normal and Help to stand-up Left and Right (together with motor nr. 11);
- linear actuators with number 5 to 10 are Glideforce MD 122010-P and they are responsible for the following positions of the bed: Tilt, Left-Tilt and Right-Tilt;
- the motor with no. 11 is a single phase motor, type GMYL-71M2-4B5 which performs the rotational movement of the

frame, towards the position Help to stand-up Left and Right, presented in Figure 2.

The bed frame of the bed is a set of open chain mechanisms with a unique modular structure, composed of three main parts, where the body of the patient sits.

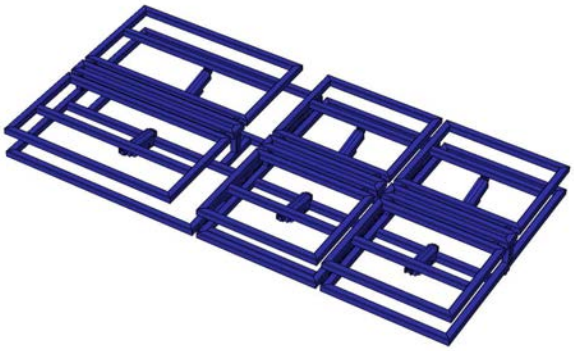

Fig. 5 The bed frame mechanism

The designing of this component had to take into account all the positions and angles of the three main elements (head area section, middle component and foot section – Figure 5), so that there is no risk to the patient when switching from one position to another.

Table 1

Head Elevation position of the linear actuators

HEAD ELEVATION	Initial position (cm)	Final position (cm)
Motor 1	0	0
Motor 2&3	0	0
Motor 4	0	300
Motor 5	0	0
Motor 6	0	0
Motor 7	0	0
Motor 8	0	0
Motor 9	0	0
Motor 10	0	0
Motor 11	0	0

Table 2

Help to stand-up (Right and Left) positions of the linear actuators

	Help to stand-up right (cm)	Help to stand-up left (cm)
Motor 1	-80	-80
Motor 2&3	5	5
Motor 4	300	300
Motor 5	0	0
Motor 6	0	0
Motor 7	0	0
Motor 8	0	0
Motor 9	0	0
Motor 10	0	0
Motor 11	90	-90

Following the next section, some of the usual positions of the bed will be exposed together with each linear actuator course within DMU Kinematics module from Catia, which allow us to control the presented positions of the bed (Table 1,2 and 3).

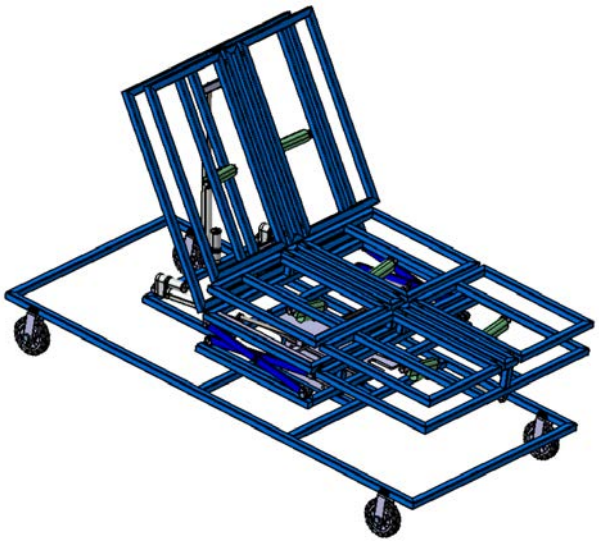

Fig. 6 "Head Elevation" position

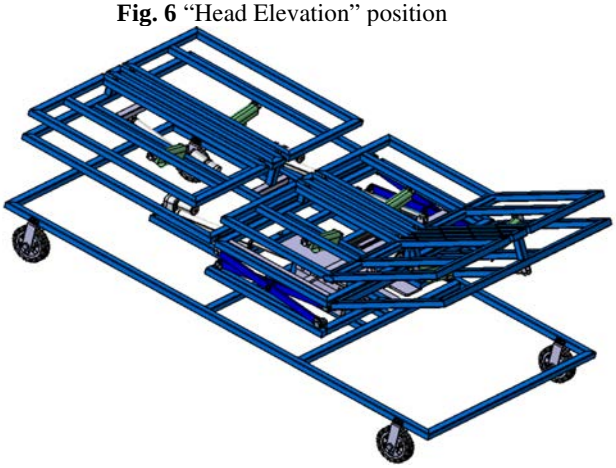

Fig. 7 "Feet Elevation" position

Fig. 8 "Help to Stand-up (Right)" position

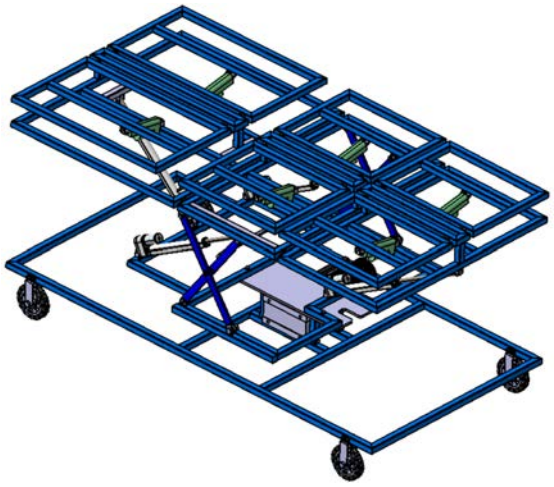

Fig. 9 Maxim elevation in "Normal" position

Also, the bed has the possibility to adjust the height in Normal position with approximately 350 mm, in order to facilitate certain medical procedures within the hospitals.

Table 3

Left Tilt and Right Tilt position of the linear actuators

Left Tilt	Left Tilt (cm)	Right Tilt (cm)
Motor 1	0	0
Motor 2&3	0	0
Motor 4	0	0
Motor 5	-50	0
Motor 6	50	0
Motor 7	50	0
Motor 8	0	-50
Motor 9	0	-50
Motor 10	0	50
Motor 11	0	0

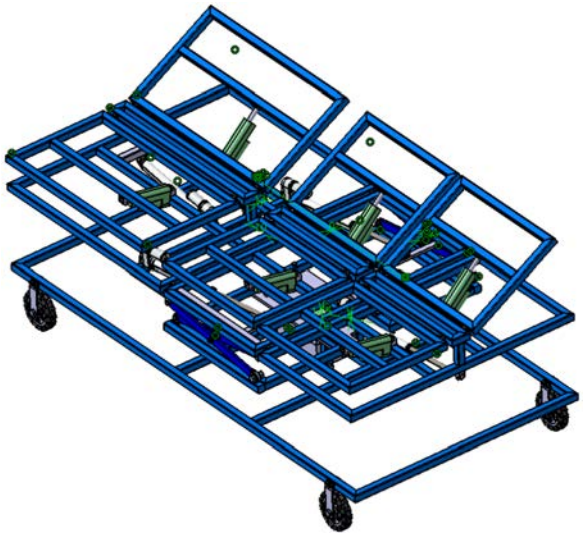

Fig. 10 "Left Tilt" position

4. CONCLUSION

The aim of this research was to design a new, advanced concept of smart hospital bed, with a unique modular structure, which will be produced and developed so that it can be used in hospitals, homes recovery centers and nursing homes.

The hospital bed is an innovative one in terms of the fact that it is a modular construction, and from a commercial point of view it can be sold as a combination: a simple bed that turns into an armchair, a bed that helps to turn the patient from one side to the other and a combination between the two.

To the three variants can be added a module with a mattress that helps to distribute drugs against bedsores and skin diseases that occur in the case of long convalescence. The hospital bed can be interfaced with a control system that allows local adjustments by the patient or centralized from a surveillance room.

The hospital bed will be driven exclusively with electric actuators (linear and rotary), the linear ones operating at 12 VDC thus opening the way for the use of a short-term battery if the patient is moved from the hospital ward or from the normal operating area (Figure 11).

Fig. 11 The bed drive system

5. ACKNOWLEDGEMENT

This paper has benefited from the support of Romanian Ministry of Research and Innovation grant, the project intitled "Pat de spital intelligent - HOPE", contract no. 345PED/2020.

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DEZVOLTAREA SI PROIECTAREA UNUI NOU CONCEPT DE PAT DE SPITAL INTELIGENT

Abstract: Lucrarea evidențiază un nou concept și un nou design al unui pat de spital modular inteligent. Scopul principal al acestei cercetări a fost proiectarea unui nou concept avansat de pat de spital inteligent, care ulterior va fi produs și dezvoltat pentru a fi utilizat în spitale, case, centre de recuperare și aziluri de bătrâni. Patul inteligent dezvoltat poate efectua momentan opt poziții medicale în funcție de cerințele specifice și există, de asemenea, opțiunea de a dezvolta încă trei poziții, în cazul în care nevoile de natură medicală o să impună acest lucru. Patul de spital este unul inovativ prin prisma faptului că este modular și din punct de vedere comercial poate fi vândut ca și o combinație: pat simplu care se transformă în fotoliu, pat care ajută la întoarcerea pacientului și o combinație între cele două. La cele trei variante se poate adăuga un modul cu o saltea care ajută la distribuirea de medicamente împotriva escarei și a bolilor de piele care apar în cazul convalescenței îndelungate.

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