

# *Structural Optimization Design of Separable Bed and Chair Based on ANSYS*

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**Abstract:** At present, the aging of population is increasing, more and more people pay attention to the medical care related equipment. As a device used to help the elderly live independently and travel easily, the detachable bed chair combines the electric wheelchair and the nursing bed, and can be switched between the wheelchair and the nursing bed at will when used. The scientific and reasonable structure design also plays an important role while the function is improving. In this paper, aiming at some problems existing in the leg and back lifting mechanism of the device, the finite element software ANSYS Workbench is used to analyze the force of the important parts existing in the structure and improve its structural performance through optimization design. The results show that the stress of the original part is large and uneven after loading, while the stress distribution of the optimized part is uniform and the overall strength is improved under the same load. Through this optimization design, it provides a more substantial theoretical basis for the follow-up improvement of the product, indirectly promotes the development of the medical device industry, and has a certain research value.

## 1. Introduction

Statistics released by the National Bureau of Statistics show that by the end of 2018, 17.9% of the total population in China is 60 years old or above, among which 11.9% are 65 years old or above <sup>[1]</sup>. It can be seen that China has entered the stage of rapid aging, and the aging problem is becoming more and more serious. It is also expected that the population aged 65 will increase from about 180 million to a peak of about 400 million from 2019 to 2059 <sup>[2]</sup>, which will lead to more severe problems of independent living care for the elderly.

In today's rapidly developing society, people have higher and higher requirements for the quality of life, and increasingly upgraded intelligent, convenient and safe pension services are attracting more and more attention. However, the existing nursing beds in China can basically realize the main functions of turning over, sitting up, kneeling and eating <sup>[3]</sup>. Therefore, nursing beds that can live independently and travel conveniently are becoming more and more important. At the same time, the combination of wheelchairs and nursing beds is getting closer and closer.

The nursing bed industry started in developed countries such as Europe and the United States. K.s. Jaichandara et al. from Singapore Institute of Technology designed an intelligent and low-cost

nursing bed based on FPGA to help users turn over <sup>[4]</sup>. Enterprise 9000 nursing bed developed by Arjo Huntleigh In Sweden <sup>[5]</sup>, MIT WHEELSLEY Project in the United States, VAHM project in France, TIDE Project in The European Union, etc., all countries began to attach importance to the nursing bed field. For example, Stylish Hospital Bed developed by Japan Bachiomeng Company can lift and lower the backrest and knees, display and limit the Bed Angle, and nurse control panel, etc. <sup>[6]</sup>. The newly developed Songkang bed and chair robot of Siasong Company in China solves the problem of user turning over through two-page folding <sup>[7]</sup>. A nursing bed developed by Tianjin University of Science and Technology has the functions of supporting the back, lifting the legs, sitting up, and overall lifting of the bed frame <sup>[8]</sup>.

It can be seen that different research directions bring different research results, and their products also have different performance and serve different objects. Whether to seize the opportunity to enter the foreign market, whether to use a more functional medical equipment to meet the market has become the current weather vane.

Through market research, we found that China's current wheelchairs can be divided into general mechanical wheelchairs, special wheelchairs, electric wheelchairs, special sports wheelchairs and scooters.

General mechanical wheelchair: Currently on the market is known by the public products, with the style of the chair, there are a pair of wheels, before and after each rear wheel usually have much bigger than the front wheel diameter, the user can push by hand wheel drive the wheelchair to go forward, backward and the brakes, front wheel usually adopt universal wheel, can have the effect of steering, general mechanical wheelchair has a more portable structure, It is the most common wheelchair on the market for efficient space saving by folding when not in use.

Special wheelchair: As the name implies, a wheelchair with special functions for special users. Through the use of special design, the use of special parts to meet special needs. Since it is a special wheelchair, its price is naturally more expensive than ordinary wheelchairs. It is generally used only for patients with severe illness or very severe deformity of limbs and trunk.

Electric wheelchair: through the electric motor drive, and then complete a series of actions of the wheelchair, the most commonly used is to take a rocker to control the wheelchair's movement, such as moving back, but also useful head or suction system and other switches to achieve control. Electric wheelchairs are a natural choice for long-distance mobility, but there are other factors to consider in advance, such as battery capacity and road suitability. In addition, electric wheelchairs generally require more space for movement and parking.

Sports wheelchair: a wheelchair used in recreational sports or competitions. Wheelchair racing, a special basketball game, has been commonly used in dance. Compared with other wheelchairs, the main advantages of this type of wheelchair are durability and more lightweight, and the combination of increasingly rich new materials enables its structural strength to reach a higher level. The outstanding performance of this special sports wheelchair is known by more people and has gradually increased the utilization rate of this wheelchair.

Nursing beds and wheelchairs are in great demand, showing the great potential of detachable beds and chairs. In order to optimize the structural design of the bed and chair, some important structural parts of the separable bed and chair were optimized based on the finite element analysis, and the structure of the bed and chair was further improved.

## 2. Working Principle of Bed and Chair

A nylon waterproof cloth seat is fixed above the aluminum alloy skeleton. The front of the seat is hinged with a front panel and a rear hinged backplane. The height of the seat is equal to that of the nursing bed. The electric screw drives the lifting mobile pole, which can adjust the front baffle and

the wheelchair backplane in the range of  $0 \sim 90^\circ$  in the vertical plane. When the front baffle and the wheelchair backplane are rotated to the same plane as the nylon waterproof cloth seat, they can butt with the nursing bed and become part of the bed surface. The front end of the wheelchair front baffle and the right arm of the wheelchair form part of the guardrail of the nursing bed, so that the user can rest in the bed smoothly. The general schematic diagram of detachable bed and chair is shown in Figure 1.

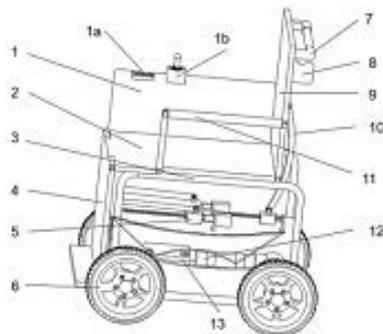


Figure1: Electric wheelchair.

(Figure 1, Figure 2, 1 - wheelchair right armrest bracket, 1 a - wheelchair console, 1 b - wheelchair console marching, 2 - waterproof nylon fabric seats, 3 - aluminum alloy frame, front of 4 - wheelchair, 5 - electric screw, 6 - composite compressive hub, 7 - push armrest, 8 - shopping bag hook, 9 - wheelchair backboard, 10 - lifting movement strut, 10a- strut 1,10b- strut 2,11 - connecting rod, 12- motor, 12a- reducer, 12b- motor connection bracket, 13- battery)

The detachable bed chair is unfolded as shown in Figure 2 before the bed surface is combined.

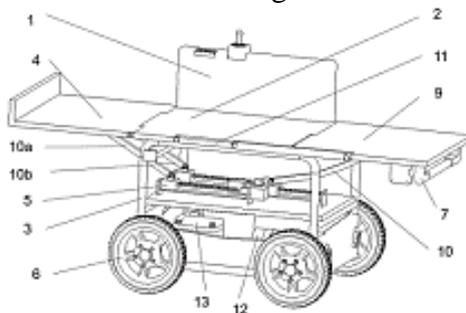


Figure 2: Expansion state of electric wheelchair.

### 3. Analysis of Key Components

#### 3.1. Functional Analysis

Lifting mobile brace :(10,10a,10b, in Figure 2) the lifting mobile brace is driven by an electric lead rod, which enables the front baffle to be adjusted from  $0^\circ$  to  $90^\circ$  in the vertical plane with the back of the wheelchair. Parts of the brace are shown in Figure 3.

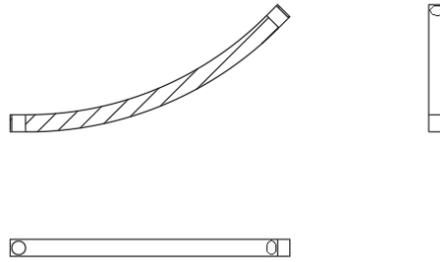


Figure 3: Lift the mobile brace.

### 3.2. Finite Element Analysis

In this paper, ANSYS Workbench finite element analysis software is used to analyze the three-dimensional model of the brace. Using this software can not only facilitate the establishment of complex models, but also simulate various contact problems<sup>[9]</sup>. Various systems necessary for analysis, such as relevant parameter system, response surface system, objective driven optimization system, six Sigma analysis system, etc.<sup>[10]</sup> and the grid division of variable units can make our analysis results more accurate.

Assume that the weight of the user is 80kg, because the bed and chair usually put the longest arm, the maximum force of the pole is 400N. Material selection structural steel, the material compressive strength of 250MPa, tensile strength of 460MPa. The Mises strain diagram obtained by applying the maximum pressure to both ends of the brace is shown in Figure 4.

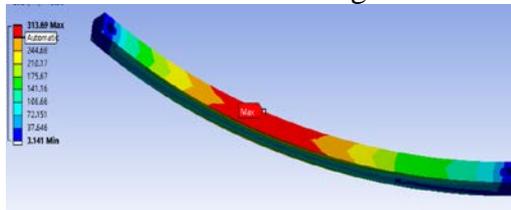


Figure 4: Mises strain diagram.

It can be found from Figure 4 that the stress in the middle of the strut is 313.60Mpa, which far exceeds the compressive strength of the material. In this regard, we optimized the strut structure, and the results are shown in Figure 5:

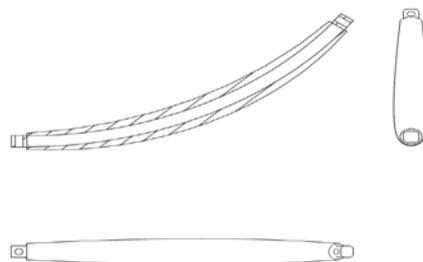


Figure 5: Optimization design results.

Similarly, the Mises strain diagram obtained by finite element analysis of the optimized parts is shown in Figure 6.

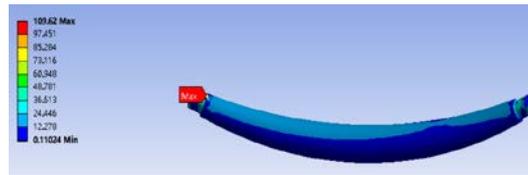


Figure 6: Mises strain diagram of optimized design.

According to the optimization design results in Figure 6, we can see that the stress in the middle of the strut is less than its compressive strength, which means that the structural design is reasonable.

By comparing the before and after Mises stress diagram, we can obviously observe that the position of the central arc of the strut has changed from a dangerous section to a safe section. In our optimization, the diameter of the central arc is enlarged and the edge that is easy to produce stress concentration is changed to a circular edge. In order to make full use of the material, we change it from a solid rod to a hollow part with a certain thickness, which can not only meet the requirements of use but also reduce the quality of parts to a certain extent, and achieve a certain improvement in the overall structural strength of the separable bed and chair.

#### 4. Conclusion

In this paper, through the combination of analysis and optimization design of parts by ANSYS Workbench, we can find deficiencies in the design results and timely modify the model, which not only improves efficiency but also has more accurate results, supplemented by lightweight can also reduce costs, which can be said to be multiple birds with one stone. It can be seen that with the emergence of separable bed and chair, there is no doubt that the nursing bed industry has more evolution direction, in its continuous development at the same time, if the combination of finite element analysis and lightweight design, computer-aided Three-Dimensional modeling, can achieve not only meet the needs of the use but also meet the design requirements. Promote the field of medical devices in China towards the direction of intelligent, multi-functional, diversified development, and gradually improve the elderly service in China.

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