

Medical Assistance Device

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Abstract

As the frequency of lower extremity injuries increase in the United States from more active individuals, medical assistance devices to help people with daily tasks are of a growing importance. Initially, the need for an assistance device was recognized to help recent surgery patients get in and out of a car. The objective was to research, design, and build a prototype of a seat that would help assist recent surgery patients in and out of a car. These patients may not be able to lift themselves under their own power. After considering several design alternatives for the lifting mechanism, an electric scissor jack was chosen for sustainability and cost saving measures. The seat would be portable and its useful life would last until the person had full mobility back in his/her lower body extremities (~500 cycles). The seat does not just help lift the person, but it also swivels to allow the person to position their legs outside of the car before the lifting begins. Since there are similar devices on the market, the main purpose was to design an affordable and portable device for these individuals.

The major criteria that were considered when designing the seat were: cost, weight, and thickness. In all three criteria, the main focus was to keep these measures as low as possible. The need to keep cost and weight of the device low are intuitive. The reason to keep the thickness of the seat as thin as possible is so that it does not interfere with the individual's head touching the ceiling or knees touching the steering wheel.

Introduction

According to an online source, 5.3 million people annually visit a doctor about a foot or ankle problem (bunions, bone spurs, ankle sprains, fractures, Achilles tendon, shin splints, etc.)[1,3]. Also, osteoporosis affects 75 million people in Europe, USA, and Japan. Osteoporosis may lead to: injuries requiring hip/knee replacements, lower back injuries, herniated discs, and ankle injuries. These may cause people to require assistance with daily tasks such as standing up out of a car. As the number of injuries continue to increase, a growing market for medical assistance devices is created to help those who have difficulty entering and exiting a car. People who may benefit from this kind of medical device are patients that have had lower body surgery within a few months. A recent surgery patient may not have the strength in their legs to support themselves to get out of a car. Many different types of assistance devices are on the market for this purpose. However, the existing devices either do not combine the lifting and swiveling mechanism, or are too heavy to be portable. Therefore, the current existing designs do not address all the needs for assisting this target market of people out of a car.

Device Design

The device in current work emphasizes two attributes, swivel and lifting mechanism. The lifting mechanism is an electric scissor jack that can lift 2000lbs and the swivel mechanism implemented is a “Lazy Susan” rotating disc to rotate the seat to position the person’s legs out of the car. The device is portable and can be used in other scenarios other than in a car. In addition, if a person sustains an injury that temporarily immobilizes them, this device could be used until their healing/rehabilitation is complete.

The device had some strict requirements/constraints that needed to be adhered to in order to be successful. These constraints are as follows:

- Size – less than 20” long x 20” wide x 6” thick
- Controlled height levels from 0” to +10”
- Controlled rate of lifting motion must be between 0.1in./sec and 1.0in./sec
- Device must rotate
- Weight - Less than 50lbs
- Must last for 500 cycles of rotation and lift
- Must be able to lift up to 270lbs
- No sliding/ rotating while driving

An average car seat’s dimensions were the basis for the size constraint. The weight of 95% of the target population influenced the lifting strength constraint [2]. This weight limit was found by researching the heaviest gender and ethnic group which, based on online studies, is male African Americans. In order for the proposed device to lift 95% of this group, the device would need to be able to lift 270 pounds [2]. Additional information obtained through research showed that this device has uses for all people with lower body injuries/surgeries. Elderly individuals that cannot physically lift themselves, individuals with back problems, and mothers-to-be may benefit from this device. The main challenge is to keep the cost of the product affordable to the middle class. This could open other viable avenues to promote this device, while meeting a vital need in society.

Analysis

In order to ensure that the scissor jack would be strong enough to lift 95% of the target population, some calculations were necessary. Summing moments about the front hinge on the seat would prove that the scissor jack is strong enough to provide the lifting force. Calculations for the seat were done at two critical positions, the closed position and a completely open position. A free body diagram of the seat in its both positions is shown on the following page in Figure 1.

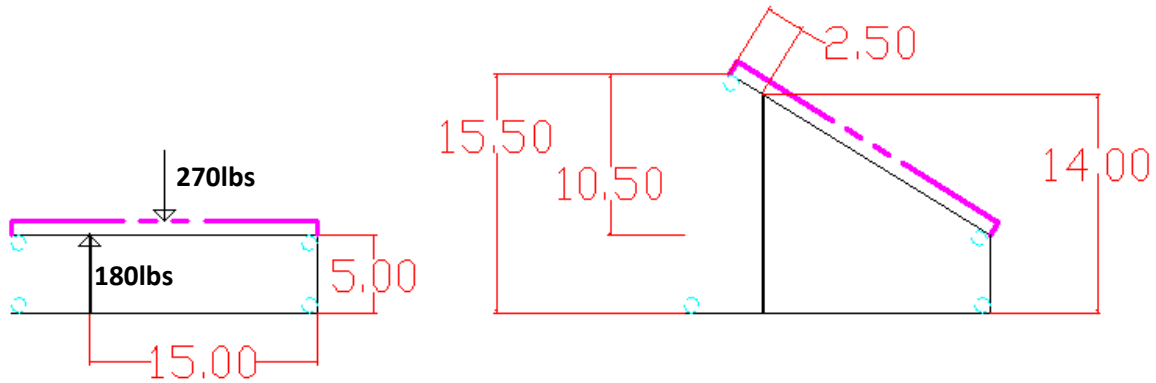


Figure 1: Device in closed position (left) and in open position (right).

As seen in Figure 1 (left) the scissor jack is acting in the direction of motion, giving the maximum mechanical advantage. The force of the person sitting is the 270lbs acting down on the center of the seat and the scissor jack is acting upward on the far back end of the seat. The distance of the scissor jack from the front hinge is larger than that of the person sitting and therefore creates more of a mechanical advantage as well. The 270lb person sitting 10 inches from the hinge would create a moment of 2700 in-lbs. For the scissor jack to lift this person, it must overcome this moment. If the scissor jack is placed 15 inches from the front hinge, it would require 180lbs of force. The scissor jack can provide 1 ton of force (2000lbs) and will lift the person with ease. The nearly open position is critical because the scissor jack is no longer acting in the same direction as the motion. Therefore, only the force normal to the surface is causing the moment. When the device is nearly open, it is at an angle of 32 degrees. The force acting in the direction of motion is 1060lbs ($\text{force} = 2000\sin(32)$), which is still enough to overcome the weight of the person.

Doing finite element analysis on the 3-D model also tested the durability of the seat. A model, created using SolidWorks, can be seen below in Figure 2 (left), and was then uploaded into ANSYS (an FEA workbench program). The forces from the scissor jack and the person's weight were applied to the model, and are shown in Figure 2 (middle) below. There is an upward force representing the scissor jack pushing against the slider and a downward force of 270 lbs representing the person sitting on the cushion. These forces were used to determine the amount of stress that would be present on the device, shown in Figure 2 (right). The forces were determined to be much less than the 33,000 psi yield strength of the materials used for the device, with the stresses varying between 22.6 and 0.00976 psi.

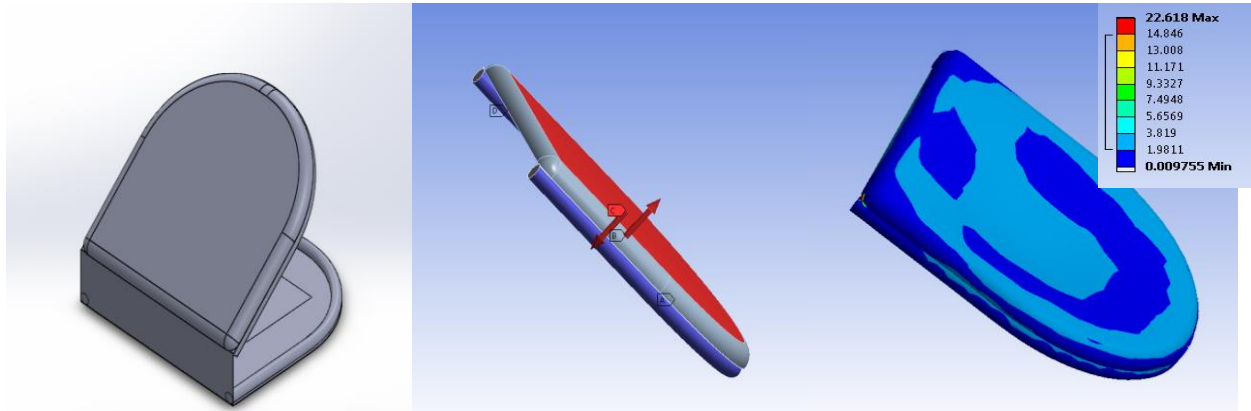


Figure 2: A Solidworks model of the device (left), Diagram of forces from ANSYS analysis (middle), and Diagram of resulting stresses from ANSYS analysis with the minimum and maximum scale

Since the forces are so much less than the yield strengths, this device is over designed and is to be used only as a prototype. If the device were to be used for mass production, more inexpensive materials could be implemented and the device would still be successful.

Building the prototype

The device has many different parts that are needed to make it function as desired. The most important part is the electric scissor jack because it is the component that supplies the force for the lifting motion. The “Lazy Susan” turntable is also important because it provides the swivel motion. The rechargeable battery is useful in case a car does not have power supplied to the cigarette lighter when the car is turned off. All of the parts that were ordered and used can be seen in Table 1 below.

Table 1: Parts and Descriptions

Budget Estimation	
Item	Description
Electric Scissor Jack	4" closed - 8" open (2000lbs)
Foam Sofa Seat Cushion	1"x24"x108" Medium density
12" Lazy Susan turntable bearing	12" x 12" x 5/16" thick
Rechargeable Battery	Auto/Car Self-Charge Jump Starter 12 Volt DC Cigarette Lighter Rechargeable+AC
Sheet metal	Weldable Steel Sheet, 24" x 24"
Cushion Fabric	Per yard. Waterproof Nylon Fabric (Black)
Seatbelt	60" Adjustable lap belt
Steel Pipe tubing	3/4" SCH 40 (1.05 OD X .113 wall) A-500 ERW Structural Carbon Steel Pipe
Bolts/Nuts	10x32x2- 6, 10x32x0.5-10
Press fittings	1" push press fittings
Hinges	Piano Hinges
Sliders and Tracks	IGUS Drylon Linear Frictionless Sliders and Rails

The seat was built to be 5 inches thick in order to fit the lifting mechanism inside and still be thin enough to prevent the individual's knees from interfering with the steering wheel in some cars. The device was designed in SolidWorks and assembled to ensure that the components fit in the allotted space. The sheet metal was cut by using the plasma cutter provided by Ohio Northern University. The 1 inch steel tubing was bent into shape by using a custom method created by the team. This involved heating the tubing with an acetylene torch and bending it around a mold of the desired radius. The tubing was bolted to the sheet metal using the press fittings and the "Lazy Susan" was also bolted to the sheet metal. A foam cushion was added to the top of the seat and the leveling foam was attached to the bottom to ensure that it will rotate in most vehicles.

Testing

After building the device, different tests were conducted to make sure the device was safe and reliable. The first test conducted was to ensure that the lifting mechanism could withstand 270lbs. A 278 lb. person was used to test the strength of the mechanism. The scissor jack was cycled multiple times and the height of the seat at its extended height was measured to verify it did extend to 10 inches. This procedure was done with and without a person sitting on the seat to exemplify that the scissor jack would work in both loaded and unloaded conditions. The swivel mechanism was also tested in multiple vehicle to verify that it will work in most cars.

Conclusion

A problem was identified in society with people requiring assistance entering and exiting a vehicle. The lifting device was researched, designed, and a prototype was produced. The seat was analyzed and tested to make sure that the device met all the criteria and constraints. The device was successful and lifted a 278 lb. person which surpassed the 95th percentile for the population. Many different types of lifting mechanisms were analyzed. A key feature in the design was providing mechanical advantage and supplying force strong enough to lift a 270lb person out of a seat. The merits of a number of lifting mechanisms were discussed, many of which fell short on this constraint. A hydro-electric actuator was too large and when placed at an angle, would not provide enough force in the direction of intended motion. Inflatable seat cushions are not durable enough and could not be as easily controlled for an acceptable inflation rate. The scissor jack provided enough force and a reasonable lift rate for its intended use. This device could be implemented in society and used by a large population since such a large number of lower body injuries occur.

Bibliography

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