Senior Project – Mechanical Engineering – 2014

Design of a Medical Walker with an Integrated Crutch Mechanism

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Introduction / Background

Many people around the world are limited by their lack of mobility due to physical complications caused by age or injury. Companies have designed an array of options to aid people who strive to remain independent despite their lack of mobility. In general, there are four options that stand out in the current market: standard medical walkers [1], basic standing-assist bars/poles [2], costly standing-assist furniture [3], and medical standing-assist machines [4] that require the help of an assistant to operate. An example for each of these four options is presented in Figure 1 below.

Figure 1: (1) Medical Walker, (2) Standing-Assist Pole, (3) Standing-Assist Chair, (4) Standing-Assist Machine

After considering the available options for the elderly population and people affected by limited mobility, it was concluded that a simple, automated, and portable aid that can provide essential stability features at a reasonable price is needed. The overall objective for this study is to develop an altered walker frame that can be easily integrated with a light weight crutch mechanism. Ultimately, this design will be able to support regular weight transitions from the seated to standing positions and vice versa.

Final Design

The walker/crutch mechanism was designed to minimize its overall size and total weight, as well as ensure its stability, ergonomic factors, low key profile, and ease of use. In general, the basic design of the machine consists of attaching two crutches to either side of an altered walker frame that is powered by two linear actuators and a 12V battery. It will be able to achieve duel functionality since it is intended to be used as a standing aid as well as a medical walker. A SolidWorks model can be viewed in Figures 2, 3, and 4:

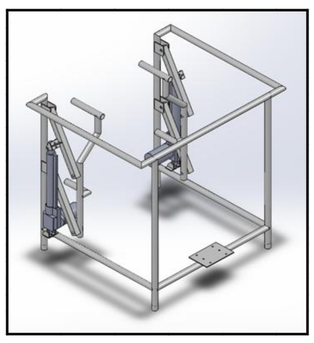

Figure 2: Isometric View of the Assembly

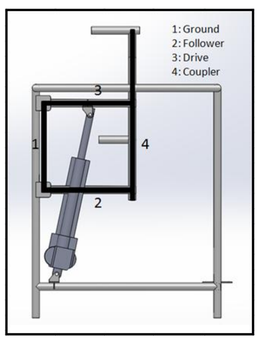

Figure 3: Linkage Design

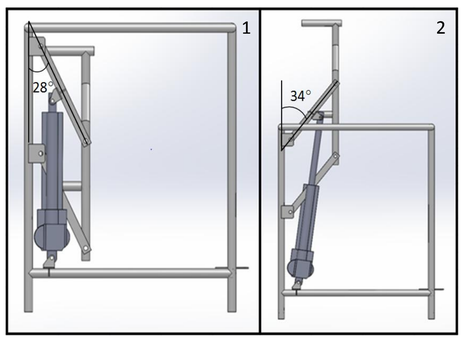

Figure 4: (1) Actuators in retracted position, (2) Actuators in extended position

The prototype was constructed from 1026 steel tubing and incorporated double locking casters for stability as well as crutch pads for comfort. Two linear actuators with a 10 in. stroke and a 200 lb maximum load rating were used in conjunction with a 12V battery and a control box to raise the four-bar linkages simultaneously. Figures 5 shows the fully constructed prototype, and Figure 6 shows the machine being operated:

Figure 5: View of Prototype

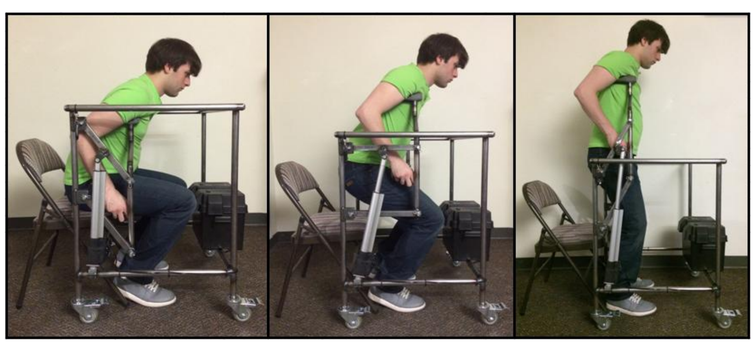

Figure 6: An average subject using the walker/crutch machine

One of the most crucial features of the machine is its control box, which allowed the linear actuators to extend and retract simultaneously. As shown in Figure 7, the 12V battery and the actuators were wired directly to the terminals of the control box. Moreover, both of the output terminals were wired to a potentiometer that allowed a user to change the voltage going to the actuators, thereby allowing speed control. The control box came complete with two wireless remotes.

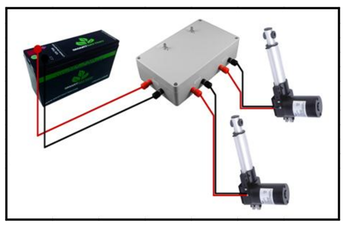

Figure 7: Schematic of the various electrical components

Physical Motion Analysis

To ensure that the walker/crutch mechanism is comfortable to use, a study was performed to determine the natural sitting and standing motions of healthy people. In the early stages of the design process, it was determined that the crutch mechanism would engage a person at two main points to provide support, stability, and safety. These two contact points were identified to be the point underneath the armpit and the center point of the hand, much like traditional crutches. In particular, focus was directed on determining the path of the armpit contact point since it dictated the motion of the upper body. Therefore, it was concluded that data needed to be acquired at the armpit in order to design a functional crutch mechanism. Figure 8 displays the acquired data, and Figure 9 shows a test subject in the seated and standing positions:

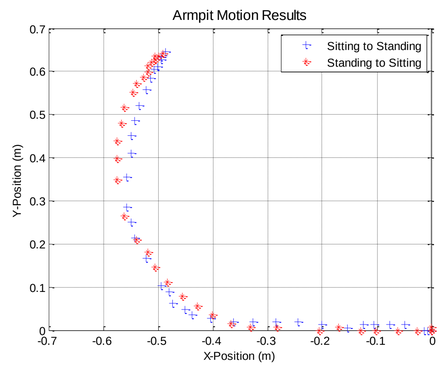

Figure 8: Acquired standing and sitting data for a test subject

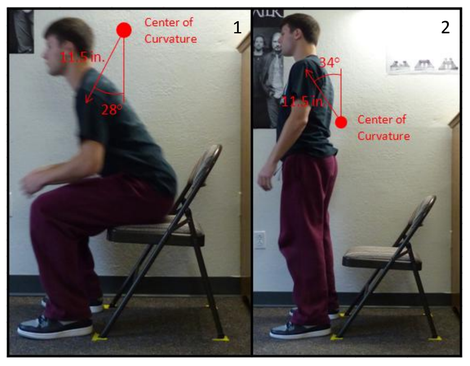

Figure 9: (1) Initial angle in bent over seated position, (2) Final angle in standing position

The results indicated that: (1) the standing and sitting motions were the same, (2) the crutch mechanism will follow a circular/arcing path to mimic the curve of the armpit contact point, (3) the radius of curvature for various people differs according to their height, and (4) a person should begin slightly bent over to eliminate translation of the crutch mechanism.

Structural Analysis

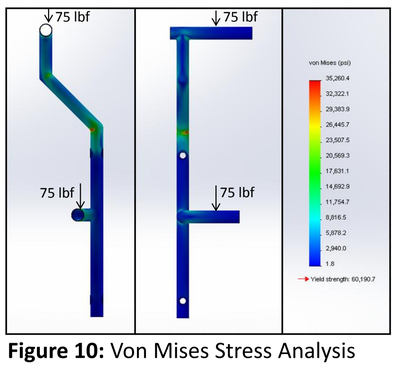

Figure 10: Von Mises Stress Analysis

To ensure that the crutch mechanism could withstand a 300 lb maximum load, an FE analysis was performed in SolidWorks. Each crutch was loaded with 150 lbf split evenly between the armpit support bar and the handle. It was determined that a stress maximum occurs at the 45° joint.

Using von Mises failure criterion:

$\sigma_y = 60200 \text{ psi} > \sigma_{mises} = 35260 \text{ psi} \therefore \text{F.S.} = 1.71$

It was concluded that the crutch link will not yield assuming the maximum load condition of 300 lbs.

In addition to the crutches, the steel tubing used for the drive and follower links had a 1 in. X 1 in. cross-section and a 0.060 in. wall thickness. This size tubing yielded a F.S. = 4.46.

Conclusions and Recommendations

Performance metrics were measured for the first generation prototype during the physical testing process and were compared to the design requirements. This allowed the overall function of the detailed design to be assessed. The key performance metrics included the time to raise a patient, weight, stability, and total cost of the machine. Table 1 shows the results:

Table 1: The measured performance metrics as compared to the design requirements

	Design Requirement	Performance Metric
Lift Time	14.3 sec	15.0 sec
Weight	< 35 lbs	45.1 lbs
Stability	Must support 300 lbs	Tested Range: 100 lbs to 225 lbs
Cost	< $1000	Total = $650

The first generation prototype functioned as expected in that it met the design requirements and successfully raised/lowered various test subjects. It was recognized, however, that improvements could be made for a second generation prototype to increase its adjustability features and ease of portability. Some improvements include incorporating adjustable telescoping tubing in the frame and lift-arms as well as a LED light to indicate low battery. Although the machine was designed for in-home use, it can also be used in nursing homes and hospitals where patients need assistance to stand up and walk around.

Acknowledgments / References

Professor William D. Keat Ph.D., Rhonda Becker, the Union College Machine Shop

[1] <http://www.wayfair.com/Briggs-Healthcare-Sit-to-Stand-Walker-MAB1543>
[2] <http://www.homehealthmedical.com/p/Standers-Security-Pole/>
[3] <http://www.usmedicalsupplies.com/cache/1320876667000/resources/product/22476/picture.jpg>
[4] <http://www.medicaleshop.com/arjohuntleigh-sara-lite-powerstanding-and-raising-aid.html>