From: The Hope Team#14

To: Dr. Oman

Date: 08/01/2018

Re: Testing proof summary

Introduction

Paralysis is one of the major issues in the world that specific category in the society suffer from. In paralysis, a part of the body stops working and in this project the team is trying to solve the leg paralysis issue. A paralyzed person finds himself unable to walk normally. Worldwide research is taking place on how to improve and aid a paralyzed person in movement. The Project is a device that should help specific foot paralyzed individuals to walk normally again. The project contains three main supports that will allow targeted individuals to walk easily. Two supports will be used in along both legs and the third support will be used for balancing purpose. The device is named as "Hope" which is given to it because this device is a hope of walking for a paralyzed person to walk.

Aim and Objective

Following are the aims and objectives of the project:

- The aim of the project is to design a device that helps a specific foot paralyzed person in walking and maintaining his balance.
- A device should be able to hold a person with 225 lbs. weight.
- A device should be easy to carry i.e. light weight and easy to use.

Initial Design

The design problem is the device should be able to hold a 225lbs. weight and should be designed with lightweight and easy to use. The device was designed so that the weight of the body could act only on one leg, when moving while the other leg will balance the body. Following tools are used for the initial design of the device.

- Solid works
- Ansys

In initial design, device is divided into three components which are:

- Long Crutch
- Short Crutch
- Chest support

Figure 1: Final design

Long Crutch

The leg support is designed such that it controls the underarm. There are belts on the harness connected along with the stick so it can provide the flexibility for the user and safety. One cuff holds the leg from thigh, one from knee, one from lower leg and the bottom strip grips the ankle. There is footrest so, the foot can be aligned with the ground and it can also balance the leg of the person. The pads provide comfortability to the user and decrease the pain of the underarm. The model of the underarm leg support is given below with its schematics:

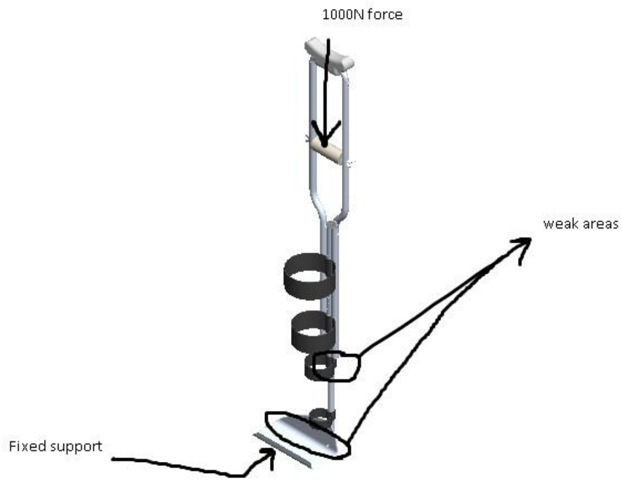

Figure 2: Long Crutch

Analysis was carried out on this design of short crutch with the help of Ansys to check whether it would work or it needs a redesign. Force of 1000N was applied on it and the minimum factor of safety was 1.6 and the maximum factor of safety was 15. As a result, engineering requirements such as safety, lifting capability of user and weight were successfully met by this testing. The force applied vertically.

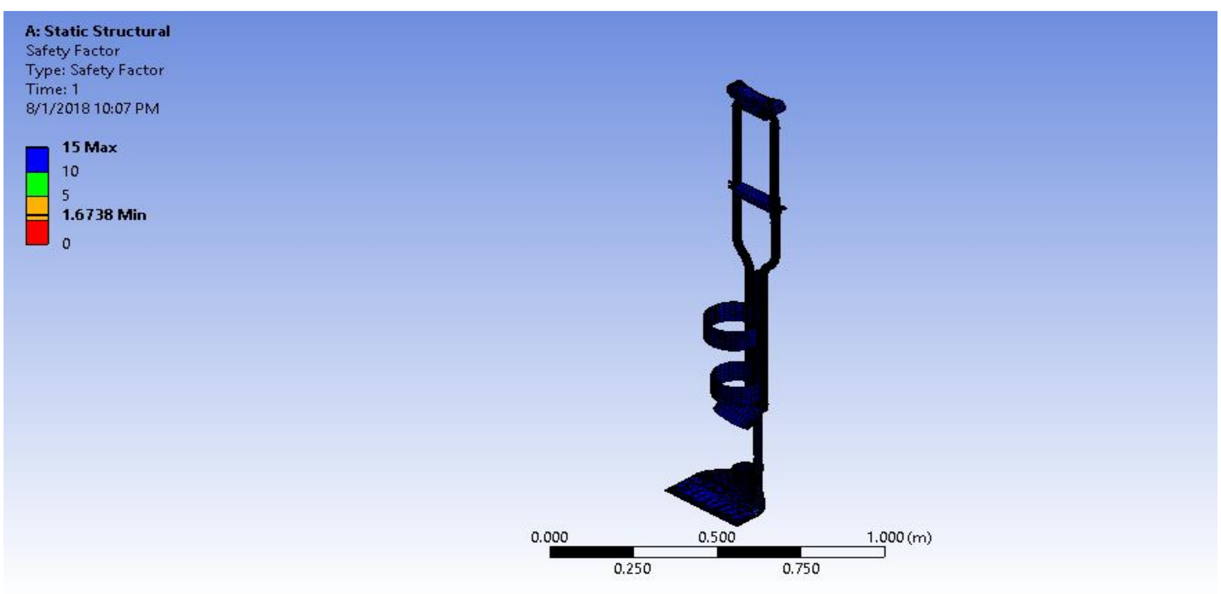

Figure 3: FEA calculation

Short Crutch

The short crutch is designed on the same pattern on which long crutch designed. The only difference between them is that the short crutch is controlled by hand rather than by the long crutch. The length is smaller with fewer numbers of cuffs however, height is adjustable so the user can choose which crutch to be long and short to use depending on his flexibility of choosing. The short crutch holds the leg from knee and lower leg. The footrest is there to provide balance and extra support that will help in walking. The model of the short crutch is given below with its schematics:

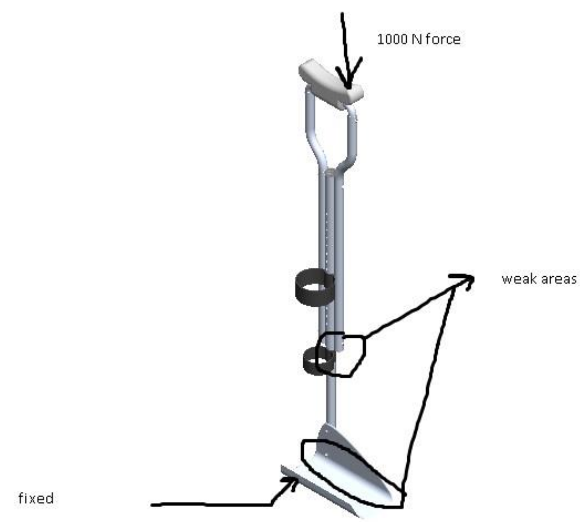

Figure 4: Short crutch

Same type of analysis was carried out on the short crutch as on first and minimum factor of safety was 5.5 and maximum factor of safety is 15, which is more than enough in terms of safety. Therefore, one of the most important categories in the engineering requirements which is the safety has been successfully met.

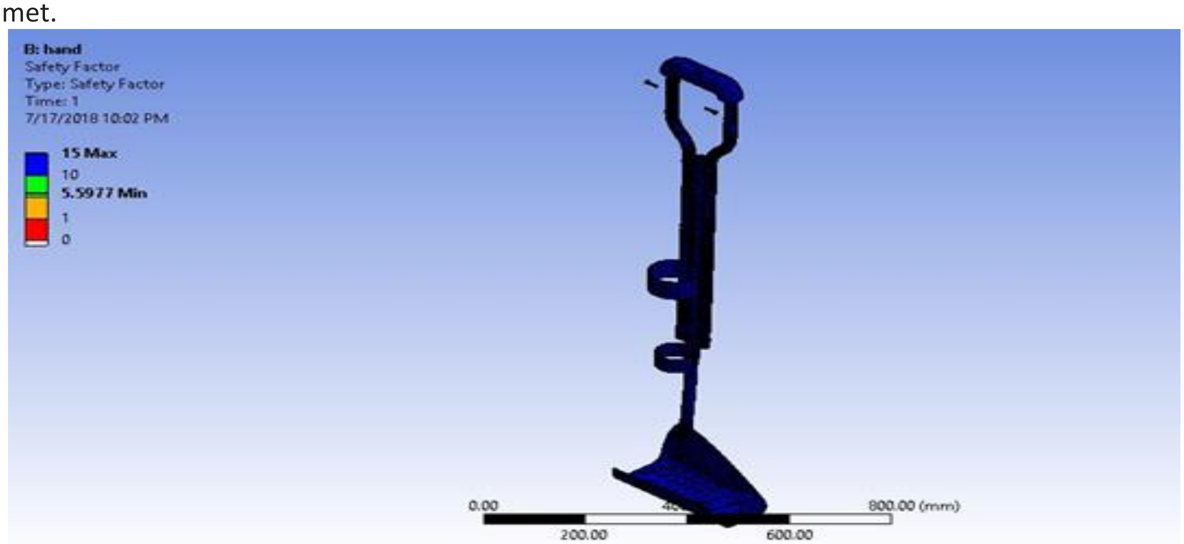

Figure 5: FEA calculation

Chest Supporter

Along with the two crutches, third supporter was added in the device that will help more in balancing and safety of the user. This part designed like a harness, which can be easily wearable. There are belts at the side of this harness, which make it easier to wear and adjust the size according to different chest sizes. There is a rod pinned at the front of the chest, with the roller at its other end. The rod will keep the body balance while walking. There is a breaking pad attached with the rod near roller. The breaking pad works at a certain angle. In case person loses its balance, the roller will move and at a certain angle roller gets in touch with the ground and stops the roller. This will prevent the person from falling. The roller also aids in the walking.

Redesign

Some changes were made to improve our device further; changes were made to make the device capable of carrying a person of 225 lbs. with considerable factor of safety. Changes made in the device are

- Improving the design of brackets used in the chest support to provide two rods to provide more balance.

  As previously the bracket used in chest assembly was rectangular type with three holes, since rectangular type of body was more susceptible to failures due to stress concentration.

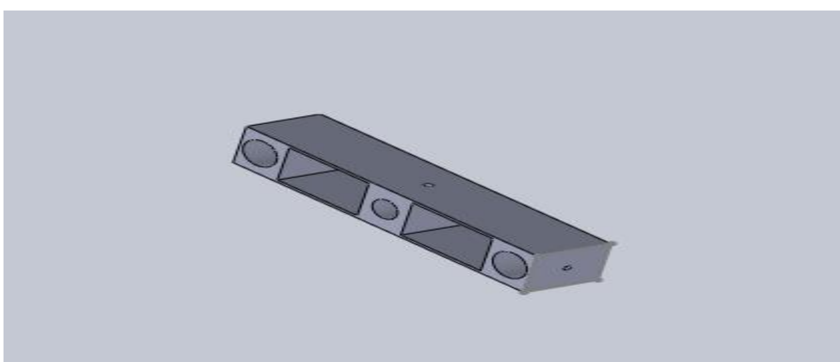

Figure 6: Old design

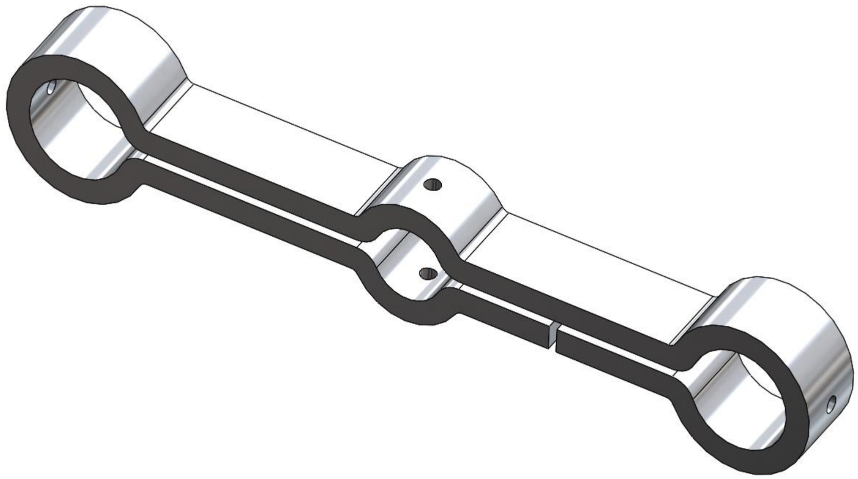

Figure 7: New design

These changes were proposed to give more balance and improve the safety.

Figure 8: Chest support redesigned

Below is the FEA calculation on the chest support before the redesign.

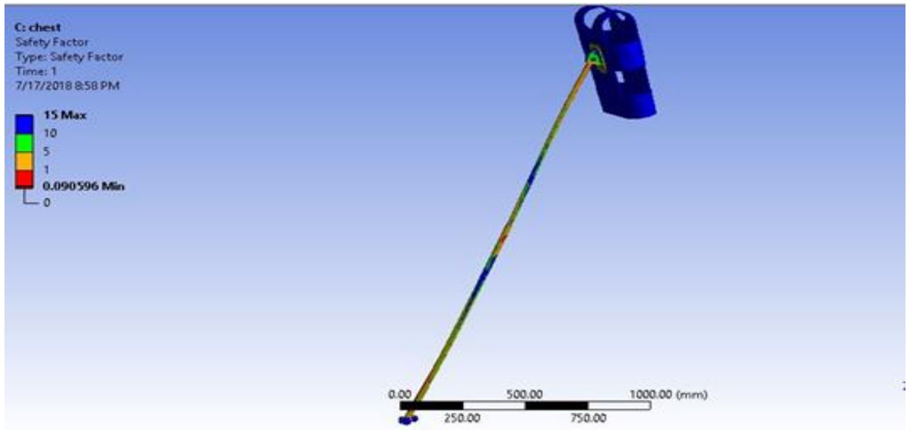

Figure 9: Chest supporter old design

After redesign the chest support by increasing the thickness of the rod and adding two more rods to keep the balance which improved the factor of safety of support assembly attached with chest support. Furthermore, the team attached the brocket to the harness directly to get rid of the brocket base which was weak. Analysis was performed on the chest support also to look into its performance worst case scenario. We applied 743N to the rods based on the angle where the brake system stops the body from falling. And the minimum of the factor of safety is 2.5 since the chest supporter rods will not get the load as much as the other two crutches.

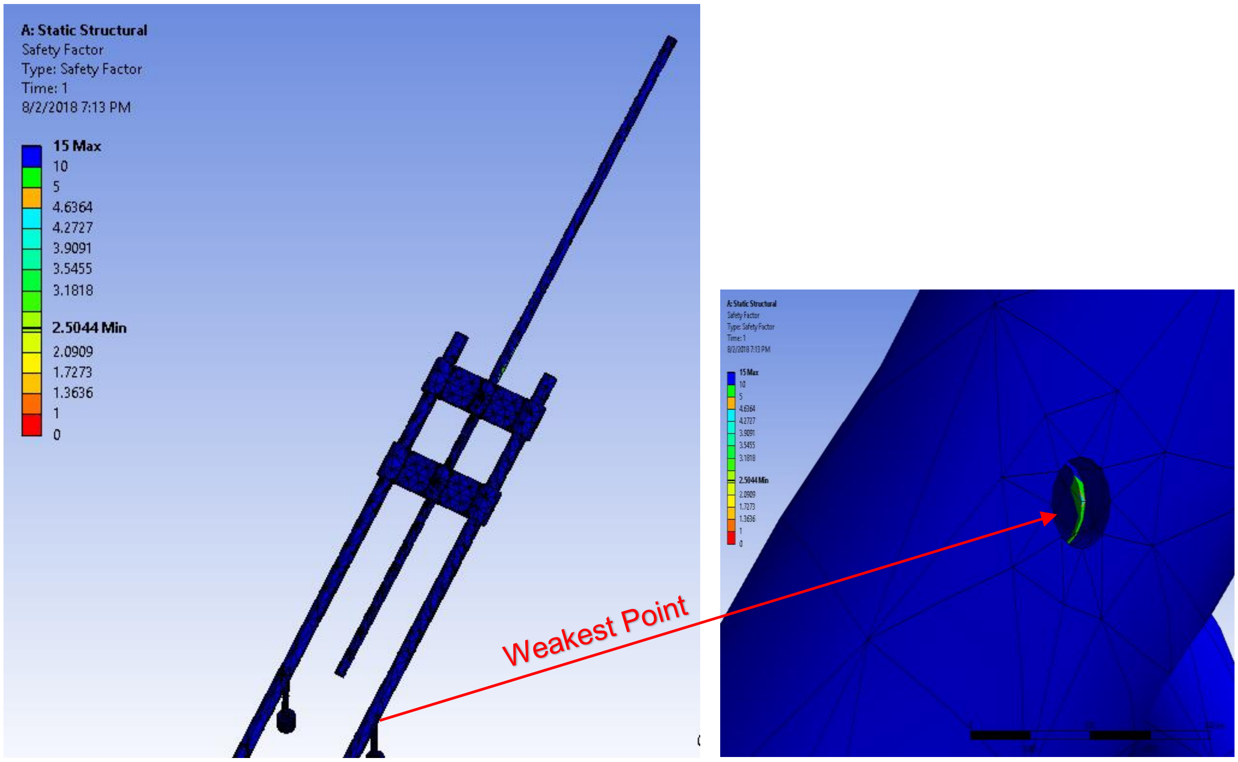

Figure 10: FEA chest support new design

That important parts do not break under extreme conditions like accidents, so the breaking assembly was analyzed for 980N force to check how will perform during extreme loads. Minimum factor of safety was found to be 3.4548 which are more than enough for our product to be safe.

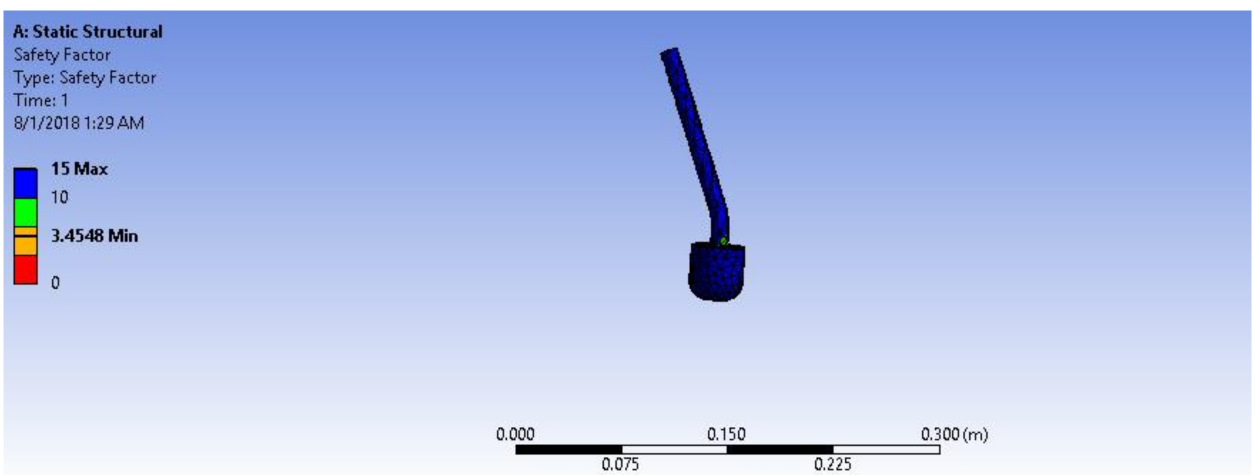

Figure 11: FEA of break system

More analysis were performed on the bracket attached to the harness as it is also one of those components which are more susceptible to extreme loads under accidents. When force of 980 N is applied to the bracket the minimum Factor of safety was found to be 12.14.

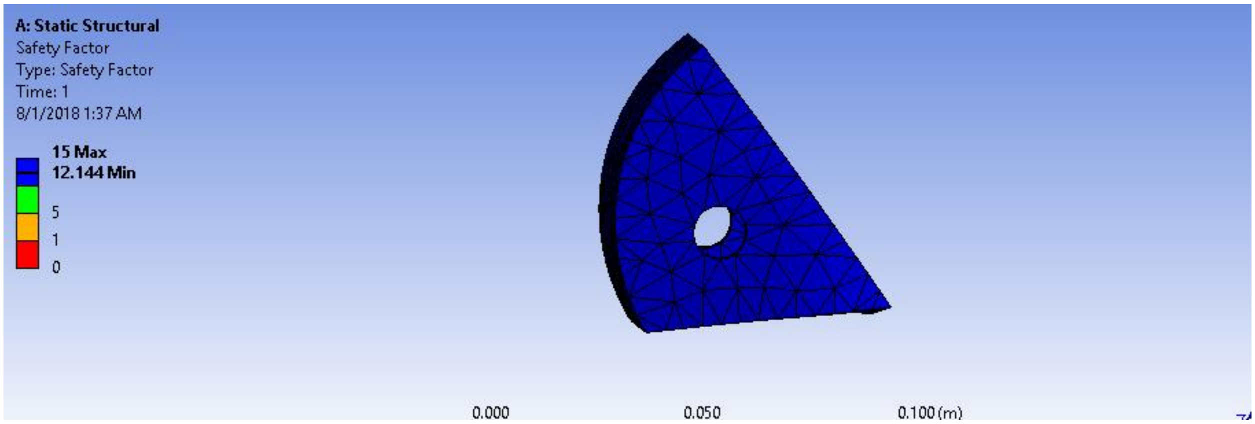

Figure 12: FEA of bracket

Static Analysis

The team has done hand calculations for the coefficient friction and frictional force according to the discussion below. The team calculated the frictional based on the angle gotten from the Finite Element Analysis when the body falls the roller will be stopped due to friction happened at 42 degrees between the wheel and the dry road surface. Also the team used a weight of 225 lbs. to get the F_f. First we need the free body diagram of the image, which is displayed in the figure 13. When the body rest on the front support, the weight will have two components as shown in figure 5.

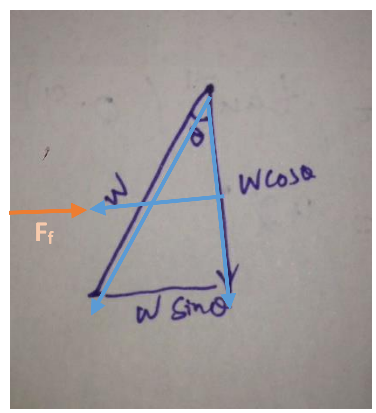

Figure 13: Free Body Diagram

As we know that, $F_f = N\,\mu_k$ F_f is the frictional force

For dry road $\mu = 0.9$

For Braking System,

$F_f = N\,\mu_k$

Where N will be the cosine component of Force,

$N = W\ Cos\theta$

To stop the person from falling the frictional force will be equal to the forward weight

So,

$F_f = W\ Sin\ \theta$

Where

$N = W\ Cos\theta$

So, the equation becomes

$W\ Sin\ \theta = W\ Cos\theta\ \mu_k$

$Tan\ \theta = \mu_k$

$Tan\ \theta = 0.9$

$\theta = 42°$

So, the angle of brocket is $42°$**.**

Now, Calculate the Frictional Force in this direction.

$F_f = N\ \mu_k$

$N = W\ Cos\ \theta$

$N = 225\ Cos\ 42°$

$N = 167.2\ lbs$

So,

$F_f = N\ \mu_k$

$F_f = 150\ lbs$

This is the frictional force. Material for braking body: For stopping it from the sudden imbalance occurred in it we are using rubber shoed pad. The diameter of the pas is 1 inch to make it soft and wear resistant. Both soft rubber and hard rubber can be used to stop it. But hard rubber (similar to Tire) mixed with metal is more efficient and resistant to wear.

Results are listed below

- $\theta = 42°$
  This is the angle at which the brakes will be available to stop the brocket and stop the person from falling
- $F_f = 150\ lb$

This is the force available at the brake, it is also the frictional force available at that point.

Engineering Requirements

Table 1: Engineering Requirements

Engineering Requirements	Target Values
1. Costs ≤$800	$775
2. Weight ≤35 lb.	28 lb.
3. Lifting capability of user ≤15 lb.	10 lb.
4. Height of Device	5 – 6.5 ft.
5. safety (not falling)	Factor of safety ≥1
6. comfortability for the user	Attach point has comfy material (foam)
7. Appropriate price for spare parts ≤$40	$25≤$40

Cost

Material	Part Name	Quantity	Cost
Almunium	Lower stick	2	$30
Almunium	Stick	4	$40
Almunium	Bended Underarm Stick	2	$50

Almunium	Bended Arm stick	2	$40
Almunium	Underarm	2	$30
Almunium	Leg Base	2	$20
Almunium	Supporter Base	1	$5
Almunium	Bracket	1	$15
Almunium	Wheel	4	$40
Almunium	Break	2	$20
Foam	Hand Grip	2	$10
Foam	Underarm Foam	1	$5
Foam	Hand Grip	2	$10
Rubber	Cuff	6	$60
Rubber	Tire	4	$80
Rubber	Break	2	$20
Total	16	39	$475

Total price for the material= $475 [1]

Labor price $30 per hour

The estimation time to manufacture the device 7-12 hour by showing the CAD to one of the machine shop in Phoenix. So, the labor price will cost the team around $300

Total budget = $775

Appropriate price for spare parts

According to the above table the highest value for a spare part is bended underarm stick which is $25. Therefore, the engineering requirement for spare parts has been satisfied.

Safety

The minimum factor of safety is ≥1 has successfully met. Minimum factor of safety was found on the long crutch by 1.6 while the minimum factor of safety was found in the brocket by 12.144. Therefore, All the device parts have meet the safety requirement.

Weight

As shown on the figure 14 below the weight of the whole device is almost 35 lbs. which meets the weight requirement on the table provided for engineering requirements.

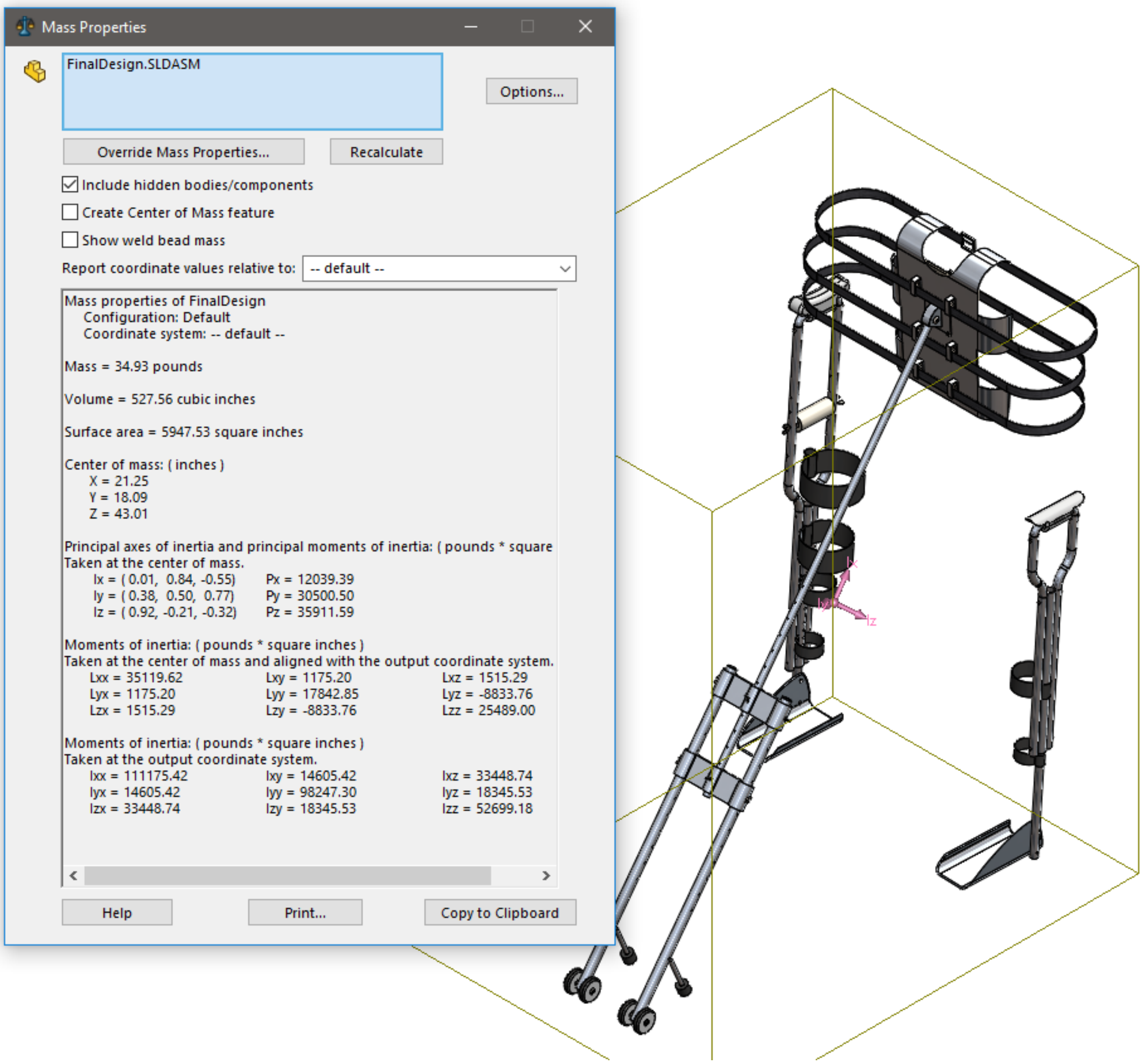

Figure 14: Mass properties of the device

Lifting capability of user

The whole device weight 35 lbs. The long crutch weigh 5 lb. As the team designed it on the CAD we recommend the lifting capability to be 10 lbs. As the user may use two long crutches instead of one long and one short, which met our engineering requirements.

Height

The average from the underarm to the top of the head is between 0.7ft to 1ft. Based on this information, the team got the highlighted dimensions as shown on the CAD figure below for the long crutch.

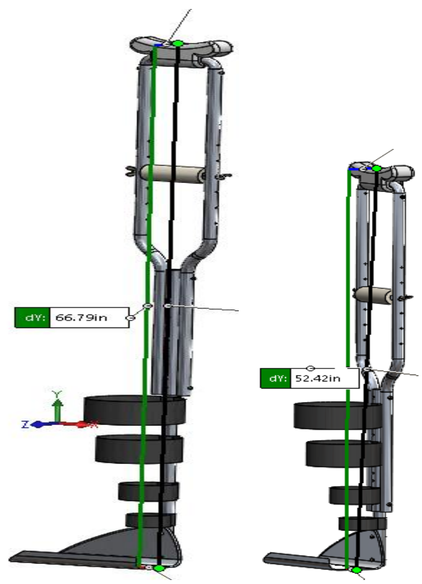

Figure 15: Long Crutch Height

The short crutch has dimensions of 40.73in when the user wants to make it taller and 31.91in when the user wants to make it shorter as its height flexible.

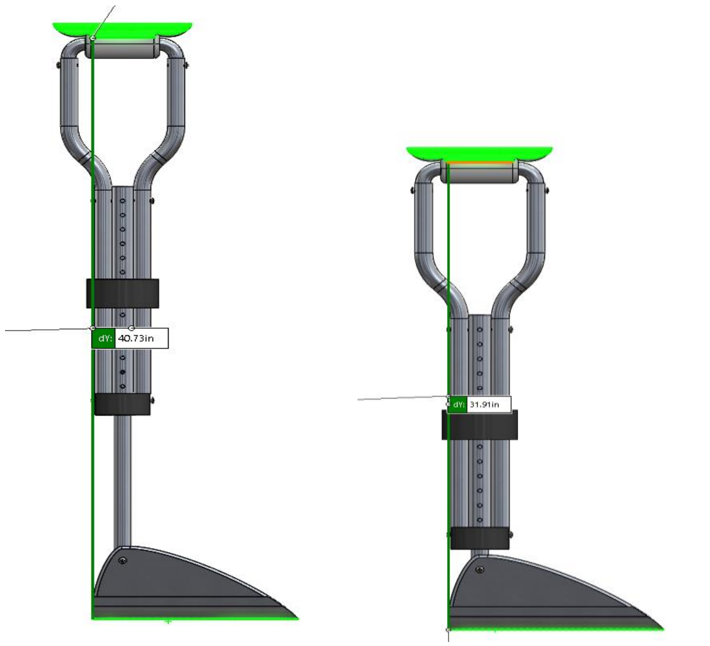

Figure 16: Short Crutch Height

The Supporter rods have flexible angle and flexible length. The approximate maximum length = Middle rod length + side rod length - 2*Brocket length.
So, the approximate maximum length of the supporter = 39.25 + 40 - 2*3= 73.25in = 6ft
The approximate minimum length of the supporter = Side rod length + Middle rod length - 2* # of holes of middle rod = 39.25 + 40 - 2* 13 = 53.25in = 4.4ft

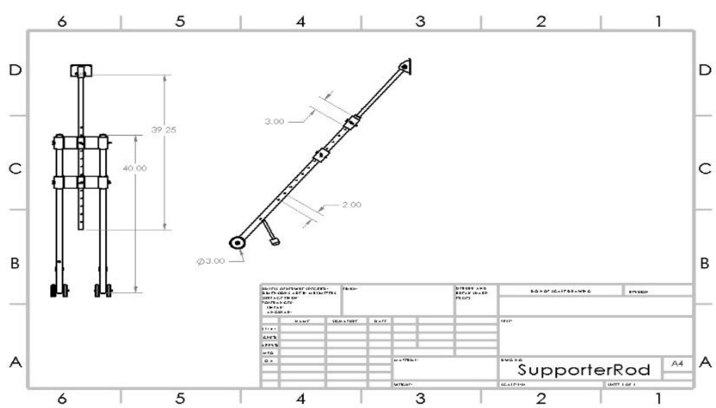

Figure 17: Supporter Rod

Comfortability for the user

The team decided to attach some comfort materials like the foam to the user body. Furthermore, some important areas that the user needs to have comfort are handgrip, underarm and chest. The foam material will help the user in this case to feel comfortably when using the device. Therefore, the engineering requirement of comfortability has been met successfully.

Conclusion

The device is designed to aid paralyzed person of weight 225 lbs. in walking. The device was designed by taking weight consideration into account. The Aluminum is selected for manufacturing because of its light weight. The FEA of device carried out on Ansys. The results depict some weak areas on some parts of the device. The chest support initially shows a very low factor of safety but then it is redesigned to achieve a safe value of factor of safety. The footrest of the underarm and hand stick shows some weak points in the analysis along with the cuff joints. The redesigning of it will improve the device overall for practical use. Finally, the testing for device parts that has been done by the Ansys of Finite Element Analysis software showed that engineering requirements were successfully met. The FEA analysis showed that the crutches have a good factor of safety, which is enough to ensure safety when using of device. On the other hand, the hand calculations shows that the friction when happened on the dry road normal force gotten is 167.2 lbs. and results show the frictional force equal 150 lbs. which ensures the safety in falling situations at angle of 42 degrees. So, the team did both ways of hand calculations and Finite Element Analysis efficiently to ensure that the device is meeting the engineering requirements and that was occurred apparently.

References

[1] Grainger.com. (2018). *Grainger Industrial Supply - MRO Products, Equipment & Tools*. [online] Available at: https://www.grainger.com [Accessed 7 Jul. 2018].