



**NORTHERN
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Design for disability simulation

Preliminary Report

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1 BACKGROUND

1.1 Introduction

Disability is a problem which is affecting most people since they lack the awareness of how to tackle it so as to enable them to lead better lives just like normal people. The major aim of this project is to create a disability simulation display which will be used by normal people so as to make them feel like they are disabled. In this simulation new designs will be focused on making people learn what it feels to be disabled as a result of ailments or accidents. Some of the disabilities the project seeks to focus on include arthritis, loss of fingers or hands, or lack of DOF in an arm and lower body disabilities such as inability to walk and use of prosthetic.

The team seeks to apply a variety of skills and information in developing the new system. There are various requirements and targets the team seeks to attain, including determining the kind of disabilities the display will simulate to enable the users to understand certain disabilities in a clear and appropriate manner. The team will ensure that they create a perfect disability simulation which can be used as many times as possible and thus satisfy the needs of the clients. In addition, the team will ensure that they apply the knowledge they have acquired during the course so as to make sure that the design function appropriately. When those targets are attained, the team will have met all the needs that have been indicated by the client.

1.2 Project Description

The team's design will meet all the clients' standards to ensure that the project address its intended purpose in an effective manner. For instance, the client requires that the display be used numerous times every day for weeks. However, the design will be able to simulate to the users in the most appropriate way possible by focusing on relevant disabilities entailing the upper body and the lower body. However, the design which will be adopted by the team should be easy to operate, efficient and durable. The team will work together to brainstorm on the ideas to incorporate in the design in order to make it better. Different aspects of the design will be considered based on the customer needs and the engineering requirements. The project will take around 10 weeks to be completed.

People who have lower and upper limb muscles inabilities normally require assistive devices so that they can be able to carry out their tasks in a simple way. These designs which the team intends to come up with are supposed to act as simulations that help a person to understand what it means to be disabled. However, the designs will also be of great significance in teaching and exposing the users to a variety of disabilities associated with the upper and the lower limbs. The designs selected should ensure that the clients are able to use them in a comfortable manner and also enable them to utilize them efficiently. In this regard the design should be simple to operate so that the clients spend limited time when they are using it.

1.3 Original System

For a long period of time, engineers have always been interested in coming up with various simulation designs that are able to provide users with the real feeling of a person who has a disability in certain parts of the body. In respect to this engineers have ventured into a variety of fields, to come up with devices that are able to teach the interested stakeholders such as students and people who assist the disabled to have a firsthand experience [1]. Due to such interests, engineers have developed different kinds of simulation designs for lower limb, upper limb, middle limb and even full body assistance. These designs have been in existence for quite a long period of time but are constantly changing as time goes by due to noteworthy changes in the worldly activities, including changes in technological inventions and innovations.

Currently, there are a wide variety of disability simulation devices for disabilities such as broken legs, fractured legs, short legs, paralysis of hands, and stiffness of joints among others. However, the most common type of simulation device is the legged robot bag.

1.3.1 Original System Structure

For a relatively long period of time, legged robot bag have been used by the disabled people to providing assistance during various activities such as movement and also performing various operations. The bags are very crucial since they help in supporting people with neuromuscular disorders. However, the original designs have different sizes so that they can suit people of different ages. Normally strong metallic elements are used to build them and this ensures that they are strong enough and also last for a long period of time [2]. However, materials which are readily and locally available are used so as to save on cost. In order to ensure that the devices are comfortable appropriate materials are used. During their invention such devices were very crucial in meeting the current demands. Even though the devices fulfill their needs, they still need to be improved so that they meet the client's needs.

1.3.2 Original System Operation

The original system was easy to operate since it was operated manually and it did not require third party manipulation. Its intended purpose was only for facilitating movement and exercise for the user. However, their use was tedious since the materials used to make them are heavy thus overburdening the user as they are required to use a lot of energy. In this regard, the original system was not user friendly even though there have been improvements which are being made so as to facilitate its operation.

1.3.3 Original System Performance

Currently, it can be said that the original system is serving its intended purpose since there is no other alternative. However, even though the simulation device helped the clients to learn about disabilities they had to bear with numerous challenges which were associated with the device such as heavy weight. In other instances, the device lacked the comfort required and often resulted to bruising the users. As a result, the device needs to be improved so as to increase the user's satisfaction.

1.3.4 Original System Deficiencies

Despite the original system performing its intended purposes it still have some deficiencies that need to be addressed so as to ensure that it meets the customer requirements fully. For instance, some of the challenges that the users are facing is that the materials used in the construction of the simulation device are very heavy hence making them to use a lot of energy. Also, the system lacked comfort ability thus making the users to be unable to work for long hours. In other case the systems posed a health hazard to the users since it led to injuries in form of bruises. In addition the system lacks adjustment features and hence this limits it to only one user which is very expensive since this means a lot of devices need to be bought for a number of clients which is expensive. This is a reflection of a technology which is outdated and is not serving its intended purpose [5].

2 REQUIREMENTS

There are a variety of requirements that the team seeks to meet by the end of the project. These include the customer requirements, which will be taken into consideration while formulating the engineering requirements. The requirements will be included in the final design system to facilitate effectiveness in functioning in addition to meeting the customer requirements.

2.1 *Customer Requirements (CRs)*

Customer requirements are the different forms of requests in which the clients and the users have on how a design can be improved so as to suit their needs. Since they are the major users of the device, they have a lot of experience on how the device operates including its strengths and weaknesses [3]. The experience is of great significance since the clients and users may have views on how the device can be improved, which are then translated into customer requirements. Some of the customer requirements are as shown in the table below.

Customer requirements

- Safe
- Durable
- Reliable
- Transportable
- At least three disabilities simulated
- Easy to Use/ understand by children and adults
- Requires users to perform certain tasks while simulating disability

Discussion

In the Table 1 above the customer requirements have been indicated by the client. These requirements are very crucial in the design process since they provide the guidelines which will be followed by the team when they are designing the system.

2.2 *Engineering Requirements (ERs)*

From the customer requirements the team was able to come up with engineering requirements which were to be used in improving the original design into a more appropriate and effective one. The engineering requirements are specific and measurable and this is very crucial as it make work easy during later analysis and interpretation. The engineering requirements are as shown in Table 2 below.

Engineering requirements:

This is what we got for engineering requirements :

- Use light Wight material and cover it with fabric
- Use good quality plastic
- Use environmental friendly materials
- Use basic simulator for angles
- Use less parts and add information

Discussion

Customer requirement above indicates the engineering requirements which were obtained from the customer requirements. These requirements will help the team to remain in track when they are proceeding with their design.

2.3 House of Quality (HoQ)

House of Quality helps will be used since it will help to analyze gadgets given various parameters. It will be used to investigate the plan that will be selected by the team to help them in settling on the most appropriate plan to use. In this regard, the team members will be required to remember all the prerequisites which have been investigated above [3]. The requirements include a device that is light in weight, simple to use, strong, flexible, durable and comfortable. By using the house of quality the team was able to make tremendous effort by improving the original design so as to meet the engineering requirements.

House of Quality (HoQ)							
Customer Requirement	Weight	Engineering Requirement	use light wight material and cover it with fabric	use good quality plastic	use envorment friendly materials	use basic simulator for angles	use less parts and add information
1. Safe	5		9	3		9	
2. Durable	4		3	9	3	3	3
3. Reliable	3			3	3	9	3
Treansportable	3		3	1	1	1	
5. Easy to use/ understand	5					9	9
6. simulating disability	5		1			3	3
Absolute Technical Importance (ATI)			71	63	24	147	81
Relative Technical Importance (RTI)			3	4	5	1	2
Target ER values			lb	mpa	mpa		
Tolerances of Ers			-3	6Mpa ± 1 Mpa			
Testing Procedure (TP#)			1	2	3	4	5
Approval (Zaid Almutairi, ZA, 10/6/2017):							
Team member 1: Zaid Almutairi							
Team member 2: Dhari Alshammari							
Team member 3: Eisa Almutairi							
Team member 4: Yousef Alazmi							
Client Approval:							

Figure 1: House of quality

3 EXISTING DESIGNS

Over the years engineers have come up with various forms of simulation technologies aimed at teaching medical practitioners, students, people who assist the disabled and other interested stakeholders to understand what it feels to be disabled. The team has inquired about various gadgets that are intended to simulate in an appropriate way. While conducting their research on various sources, the team focused on designs which met the various customer requirements. They also focus on designs which had the ease of improving so as to satisfy the user's needs. In order to get the most appropriate designs the team carried a lot of research from the internet, interviewed the clients and the sponsors. Some of the already existing designs that the team embarked on focusing are as discussed below.

3.1 *Design Research*

Since the first design of assistive devices was invented, improvements have been made over the years so as to meet the upcoming customer requirements. This has been facilitated by the growth and development of technological innovations and inventions. Therefore the team was burdened with the task of analyzing the merits and demerits of each design so that they can use the shortest time possible and fewer resources in improving it [7]. The analysis was very crucial since it helped the team to have efficient ways of coming with a design which meets the customer requirements.

3.2 *System Level*

Over the years the simulation devices for the disabled have evolved so as to suit the needs of the user. The changes have been facilitated by technological advancements which have occurred over the years. In order to make their work effective the team members made an analysis of the merits and demerits of the various existing designs.

3.2.1 **Existing Design #1: Artificial Hand Prosthetics**

This design is an artificial hand which is manufactured using high grade materials hence it is durable. It also has advanced components and has a variety of sizes so as to fit people in various age brackets. It is also assembled from the finest quality components to enhance the amputee's needs. The hand is also light weight, easy to wear and remove, has convenient design, has reliable performance and low maintenance.



Figure 2: Artificial Hand Prosthetics [7]

3.2.2 **Existing Design #2: Reciprocating Gait Orthosis**

This design is light in weight and has enhanced durability since it is made up of high quality materials. The device is mostly used to assist people who have a spina chord injury.

The device also has a long working life, high performance and excellent finish.



Figure 3: Artificial Hand Prosthetics [8]

3.2.3 Existing Design #3: Functional knee brace

The design is intended to assist those people who have knee defects due to anterior and/or posterior cruciate ligament deficiency. It has streamlined frame design has ROM hinges with plug-in flex, hypoallergenic silicone-grip strap pads for anti-migration, breathable padding liner for shock-absorption and optimal heat exchange and tibial strap padding to improve suspension and customized fit.



Figure 4: Artificial Hand Prosthetics [9]

3.3 *Functional Decomposition*

In this project, the major aim is to design a device which will assist the client in carrying out simulations of people with upper and lower limb disabilities and hence enable them have an experience of a disabled person. The functional decomposition of the team will be a device which is easy to operate, durable, and light in weight. The functional decomposition is of great significance to this project since it will enable the team members to focus on the specific customer and engineering requirements.

3.3.1 Black Box Model

After analyzing the original design, the team realized that there were problems with the general operations due to limited functionality. In this regard, the team made a decision of including a black box so as to improve on its performance. The black box will be used to store data. It will also help in coordinating other functions such as movement with minimal efforts. The major setback of the black box is that it is expensive and needs regular maintenance.

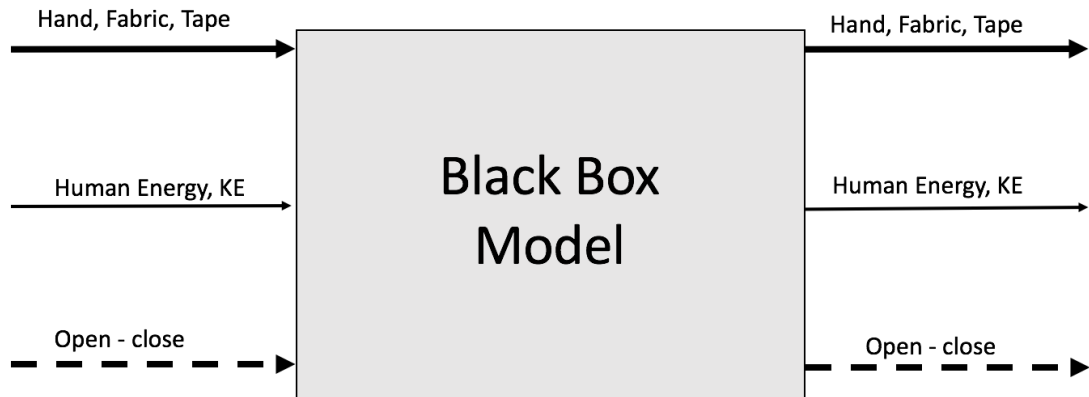


Figure 5: black box

3.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

In order to ensure that the team does not deviate from the objectives of the project, we will make use of a functional model which will act as a guide. The model will have the engineering and customer requirements which will be fulfilled.

3.4 Subsystem Level

After carrying out a thorough research it is evident that when devices are designed in a better way they are able to meet customer requirements. This is accomplished by using proper gadgets [6].

3.4.1 Subsystem 1: Efficiency

The design has a variety of specifications which make it efficient when it is being used by the client.

3.4.1.1 Existing Design #1: Weight

It is light in weight hence ease enable the user to carry out their simulation for a long period of time.

3.4.1.2 Existing Design #2: Convenient

It has a convenient design thus making the user to wear and remove it with ease.

3.4.1.3 Existing Design #3: Maintenance

It is made from high quality materials which are easy to clean and maintain.

3.4.2 Subsystem #2: Durability

Since the device will be used for long periods of time I should be strong and be made

from long lasting materials.

3.4.2.1 Existing Design #1: Frame

The frame is made from carbon fiber polymer to ensure it is strong and rust free.

3.4.2.2 Existing Design #2: Casing

The frame is covered with a leather casing and hence it is durable.

3.4.2.3 Existing Design #3: Steel bearings

The movable parts have steel bearings hence making it strong.

3.4.3 Subsystem #3: Flexibility

The device should ensure that the user is safe all the time.

3.4.3.1 Existing Design #1: Locks

They ensure that the device is stable by avoiding unnecessary movement.

3.4.3.2 Existing Design #2: Strap padding

This helps to improve suspension and customized fit.

3.4.3.3 Existing Design #3: Breathable padding

They enhance shock-absorption and optimal heat exchange

4 DESIGNS CONSIDERED

During various meetings the team members came up with a variety of designs during the g which were in line with both the customer and engineering requirements. Some of the designs selected are as discussed below.

4.1 Design #1: Neck support

The device comprises of a head support which enabled persons who have deformed neck muscles to support their head and also enable the larynx and the voice box to operate appropriately. The idea is shown in the figure below

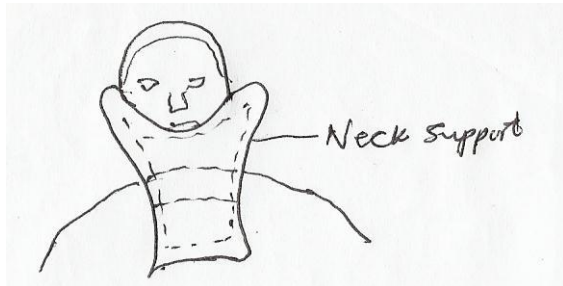


Figure 5: neck support

4.2 Design #2: Hand glove

The device mimics a normal glove and it is made up of plastic polymer. It has flexible joints so as to enable the user to move their wrists and fingers freely. It is also perforated to allow free flow of air. Also the lining has a lining made of soft cloth thus making the user to be comfortable while performing various tasks. The idea is shown in the figure below

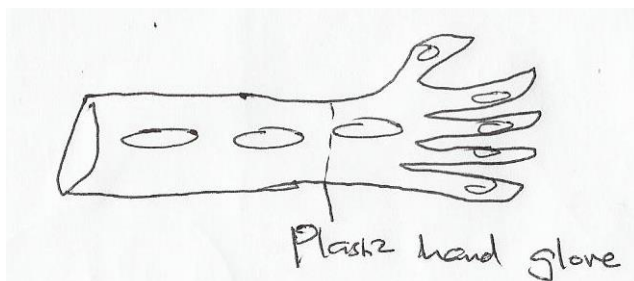


Figure 6: hand glove

4.3 Design #3: head belt

This design is showing in the figure in which a forehead belt connected with the shoulder bag to make the neck straight and if any healthy person will wear such a belt, he will not able to rotate his neck properly and will understand the feelings of disabled persons who cannot move their neck.

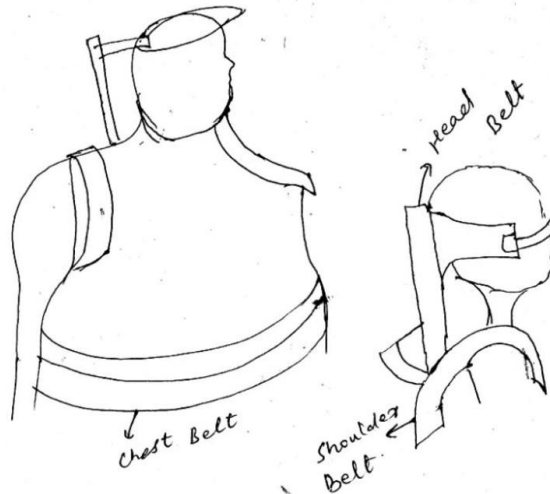


Figure 7: Head Belt

4.4 Design #4: Chest Belt

The design showing in the following figure is a support for neck, chest and shoulders. If a healthy person wear this belt he will realize that it's really difficult to survive with straight neck and chest pain. And the design idea is showing in the following figure.

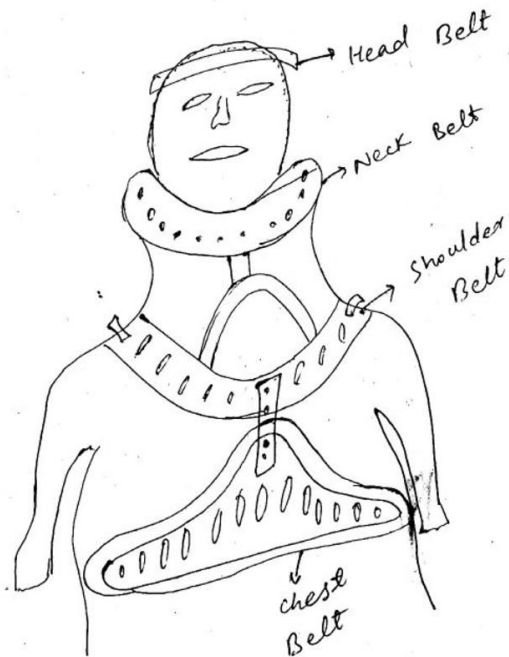


Figure 8: chest belt

4.5 Design #5: Arm belt

A moveable arm is useful for disabled persons but if any healthy person wear such a product and he will not able to move his hand properly then he will understand the miseries of disabled person who has to wear such a belt as the figure is showing below.

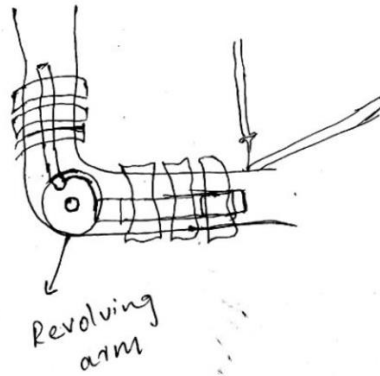


Figure 9: Arm Belt

4.6 Design #6: Leg skeleton

A leg skeleton is useful thing for disabled persons, it gives the capability to those persons whose legs are weak and don't have enough capability to walk. If a normal person use this skeleton he will understand the difficulties of disabled person and will feel the misery for not having the leg working properly. Design is showing below in the figure.

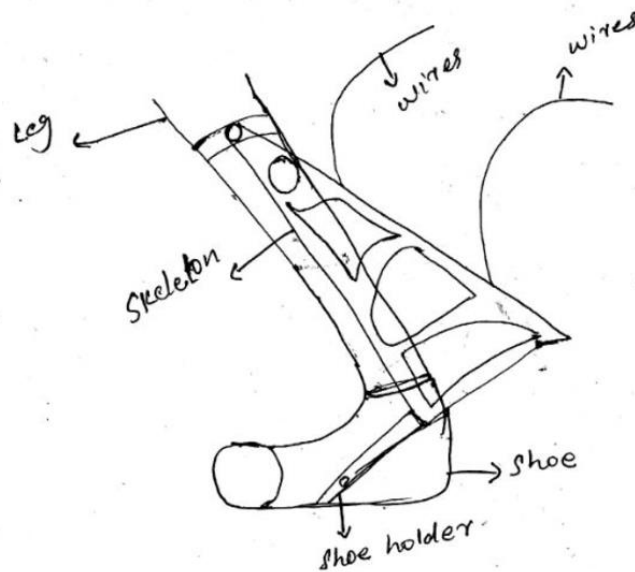


Figure 10: leg skeleton

4.7 Design #7: Legged robot bag

This design is basically a legged robot bag and if the normal person wear this belt he will feel that legs are important part of human body and it's really difficult for disabled persons with legs to survive. This idea is showing below in the figure.

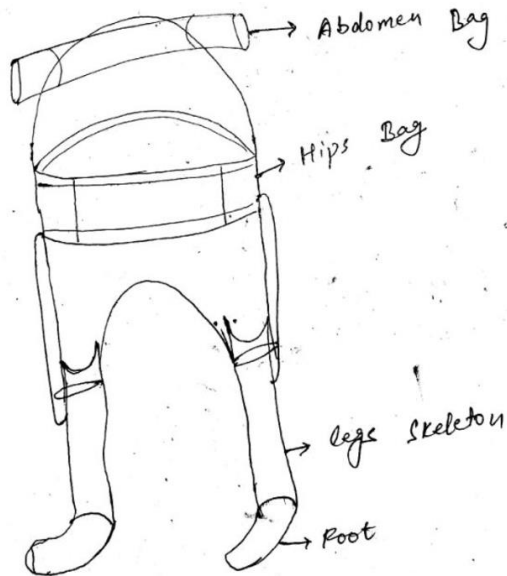


Figure 11: legged robot bag

4.8 Design #8: Knee leg Cover

This design is only a knee cover which provide the support to the leg for moving. If a healthy person wear this knee cover he will realize the feelings of disabled person when they don't have the ability to move around. This idea is showing below as

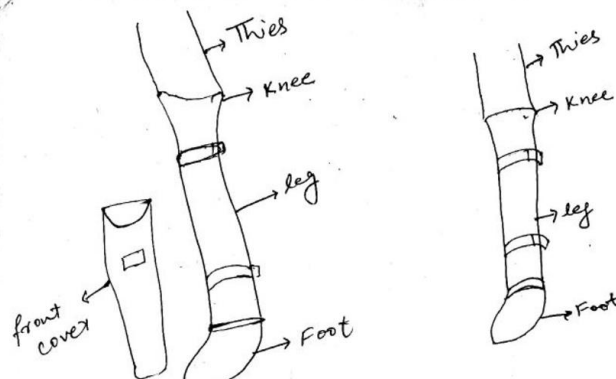


Figure 12: knee leg cover

4.9 Design #9: Chest Bag

A bag for chest and back is a good idea to support for backbone but when such bag wear by a healthy person it will give him the feel of disabled persons as it will hold the complete backbone and chest so the person will realize the pain of backbone. As the figure is showing below

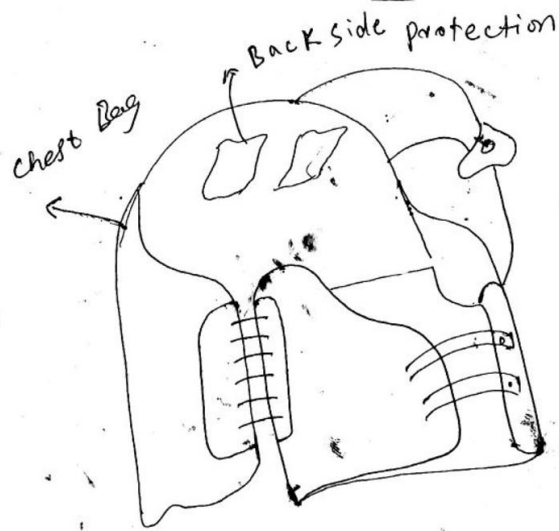


Figure 13: chest bag

4.10 Design #10: Arm cover

Some disabled persons cannot fold their hand and rotate, but if a healthy person wear such a belt he will realize the missing of folding hands for disabled persons. As showing below in the figure.

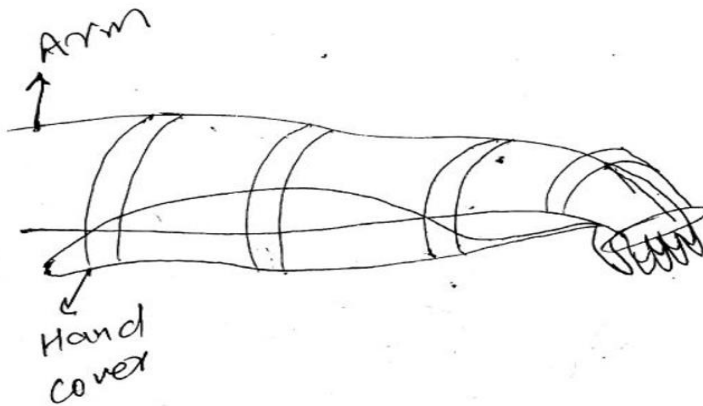


Figure 14: Arm cover

5 DESIGN SELECTED

In this chapter the rationale which was use by the team to come up with a final design has been discussed. Also a description of the design has been given.

5.1 Rationale for Design Selection

After carrying out their analysis the team came up with an appropriate design that met both the engineering and customer requirements. In order to come up with the best design the various components constituting various designs were looked into. This was very crucial since it ensured that the final product was efficient and will meet the client’s tastes and preferences. In this regard, the team agreed with the eighth design since it had the highest score as presented in the decision matrix below.

(The score of 1-10 is use, where 1 is the least effective and 10 is the most effective)

Designs:	Meets client’s needs	Meets users’ needs	Improves the existing designs	Total score
Design#1	8	7	8	23
Design#2	5	5	5	15
Design#3	4	5	5	14
Design#4	5	4	4	13
Design#5	6	4	5	15
Design#6	7	5	6	18
Design#7	7	6	6	19
Design#8	9	9	8	26
Design#9	7	8	5	20
Design#10	7	6	6	19
Design with highest score	Design #8			

Figure 15 : Decision Matrix

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