PRINCE MOHAMMAD BIN FAHD UNIVERSITY

جامعة الأمير محمد بن فهد

College of Engineering

Department of Mechanical Engineering

Spring - 2019

Senior Design Project Report

Fabrication of a scuba diving wheelchair

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

Team Members

	Student Name	Student ID
1	Osama AlGarni	201501499
2	Abdulrhman Tarzan	201401385
3	Mussad AlBattah	201400771
4	Ahmad AlAlwan	201502550

Project Advisor:

Dr. Nader Nader

Abstract

Just like able-bodied individuals, people with physical disabilities have the desire to experience and partake in exciting and recreational activities, but their physical disability makes doing so difficult for them. Everyone has dreams and ambitions, and it is our objective to find ways to allow everyone to live their lives to the fullest. Moreover, we will be discussing how we have designed a system that allows individuals with physical disabilities to easily and effectively partake in underwater oceanic activities, such as scuba diving. Also, we will discuss all the requirement parts that will be used to make our project safe and efficient for a human been.

Acknowledgement

The success and final outcome of this project required a lot of guidance and assistance from many people and we are extremely privileged to have got this all along the completion of our project. All that we have done is only due to such supervision and assistance and we would not forget to thank our advisor Dr.Nader Nader.

We respect and thank Dr.Nader Nader, for providing us an opportunity to do the project work in time and giving us all support and guidance which made us complete the project duly. We are extremely thankful to him for providing such a nice support and guidance, although he had busy schedule managing the corporate affairs. We owe our deep gratitude to our project guide Dr. Panos, who took keen interest on our project work and guided us all along, till the completion of our project work by providing all the necessary information for developing a good system.

We heartily thank our internal project guide, Dr. Fdjavanroodi, the chairman of engineering department, for his guidance and suggestions during this project work. We are thankful to and fortunate enough to get constant encouragement, support and guidance from all Teaching staffs of our engineering department which helped us in successfully completing our project work. Also, we would like to extend our sincere esteems to all staff in laboratory for their timely support.

List of Acronyms

V	**Velocity**
V_o	**Initial Velocity**
ρ	**Density**
C_d	**Drag Coefficient**
F_d	**Drag Force**
A	**Area**
V	**Electric Potential**

Table of Contents

Chapter # 1: Introduction

1.1 Project Definition

This project is wheelchair that is customized with certain features to allow disabled people to enjoy various underwater recreational activities. This scuba diving wheelchair is equipped with the right material to allow disabled people to dive smoothly and without any effort. Moreover, the ability to rotate in a 360-degree angle. grant disable people the overwhelming experience of deep-sea diving while providing them with the comfort needed along the ride.

1.2 Project Objectives

- To design an underwater wheelchair which is efficient and helpful.
- To allow disabled people to do underwater recreational activities.
- To ensure safety for disabled people who will participate in scuba diving

1.3 Project Specifications

The idea of our project is to get disabled to join normal people in there activates. By installing electromechanically machines and parts such as mostly unbreakable glass fins and torpedoes in a light wheelchair that fits with the human body weight and the parts we will install. As the torpedoes are actually for scuba diving purposes it's been tested under water. Also, the glass fins that we will use been tested under a high pressure and tested its hardness.

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1.4 Project Applications

The main application behind this project is to grant disabled people the breathtaking experience of discovering the depths of the seas and enjoy the various recreational activities underwater. To grant disable people the overwhelming experience of deep-sea diving while providing them with the comfort needed along the ride.

Chapter # 2: Literature Review

2.1 Project Background

In our senior project, we are getting the most modern and efficient parts to be used in our design. We have tested and studied the parts to be safe and helpful for our purpose that getting disabled to enjoy this nature. As there are no previous work to develop this project will be as the first scuba wheelchair for disabled.

2.3 Comparative Work

The idea behind out project was inspired by a researcher called Sue Austin. She believed that being in a wheel chair does not limit one's potential of acquiring total freedom. Hence, she developed the idea of an underwater wheelchair so that disabled people can roam the depths of the sea and feel the extraordinary feeling of exploring a new world. Thinking of another idea like this can be testing; however it additionally makes the most surprising, personality extending encounters. The major components used in her design were the following:

1. Wheelchair

2. Underwater propulsion vehicles
3. Two sheets of acrylic glass
4. Oxygen cylinder
5. Regulator

While submerged underwater the wheel chair is equipped with self-inflating life supports to supply the chair with the needed amount of buoyancy so that the chair doesn't completely sink. The acrylic glass is mounted on top of the foot pedestals to facilitate the movement under water. The acrylic glass was used because it has the same affects as regular glass excluding the shattering affect. While underwater the propulsion vehicles supply the diver with the sufficient amount of thrust. And the oxygen cylinder attached to the regulator is used for the diver's supply of oxygen.

Figure # 1: Diving WheelChair Idea

Chapter # 3: System Design

3.1 Design Constraints and Design Methodology

3.1.1 - Geometrical Constraints:

Since the minute we chose to take on this venture and alter it to our structure we acknowledged rapidly that the parts were substantial. It would make it difficult to move from one spot to another without two individuals being there to help one another. Along these lines genuine weight decrease was done to make it less demanding to transport around, Therefore, we are creating most of the parts as opposed to structuring another one, we had constrained space on the base plate. Because of our arrangement to join two torpedos on the sides and on the back of the seat. Additionally, we needed to build up an elective method to append the torpedos vertically to finish everything, to make it less demanding for transportation and lessen Wight.

3.1.2 - Sustainability:

Our model is expected to be utilized at open-air conditions, it is anything but difficult to deal with and can be utilized by debilitation individuals. Appropriate and occasional support will continue it for a noteworthy measure of time. Additionally, heading and moving parts may require a few upkeep after task as it is presented to the air, sand particles and ocean water could ensnare between the greased-up surfaces So we used an aluminum wheelchair and acrylic glass we have also used an automatic torpedo that runs underwater by itself. We put in mind that the level of PH in sea water will let us be limited to some conditions.

3.1.3 - Social Impact:

The end goal for our project is to help those handicap people to start practicing their hopes freely and don’t feel that they are limited to some type of activities. Also, to show them the beauty of life. We believe that we as engineers should create and design based on what humanity and people need. So, we are basically creating this chair to serve this part of our society.

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3.1.4 - Economic:

Our wheelchair submarine is one of the best ideas that was ever made as a concept as far for our prototype it may not be the perfect design to go with but up to our weight and materialistic limitation, this is the best prototype to come out with. And there will be some major maintenance programs that we will apply to this prototype. Wi might start doing some modifications to the prototype itself one we are done with the final presentation, but for now, we believe that it is the best design to come out with. If it comes to economics, we believe that its cost is expensive so far is cost us around 4000 SR so if we want to convert it into a product to sell it would cost too much because we will sell it for at least 4400 SR per chair which means we will benefit 10% only out of the product.

3.1.5 - Assembly:

We had the wheel chair made out of aluminum to sustain the Wight and under sea water condition limitations. We were looking for materials that are corrosion resistance, because we considered that sea water is really bad for materials that are easy to corrode. We have also used turbidus that are made of plastic the blades are also made out of plastic, so we took these two turbidus and wield it next to the wheel chair one on the right and one on the left. We have also used acrylic glass because it is light in weight and hard to corrode.

3.1.6 - Safety:

Since we are dealing with handicap people in our project, we have to take a safety in a really important matter. So, the first thing that we will but into consideration was the blades of the turbidu so make sure that the turbidus blades are covered and isolated perfectly in order to save the passenger. We have also put into consideration that a handicapped person won't is able to stay at the chair by himself so we wielded a seat belt to the chair

3.1 Engineering Design Standards

3.1.1 Introduction

The motivation behind these details for configuration is to make clients mindful of different principles which might be considered amid the plan procedure.

The American Society for Testing and Materials (ASTM) models will be utilized for ordering what kind of material has been chosen, just as giving the measurements and expressing which material has been assigned for every segment.

The scuba diving wheelchair will be powered by a sealed lead acid battery with speed up to 3.2KM/H.

Below is a list of all the materials used, along with the engineering standard for each component.

Components	***Engineering Standards***
Wheelchair	ASTM-B211: Aluminum 6061-T6
RDS200 Seascooter	B075FN5VD1
Diving Life Vest/ Buoyancy	STP1237: B01LWBGYQS
Acrylic Glass	ASTM D4802 – 16: B000FPC3F0
Diving Air Tank	MNL36-2ND: B018WMPSJK

Table # 3.2: Engineering Standards

3.1.2 Wheelchair

Material: Aluminum 6061-T6

Engineering Standard: ASTM-B211

Wheelchair	Hight	Width	Length	Weight
Aluminum 6061-T6	0.9347 m	0.8255 m	0.2794m	20.04878KG

Table 3.2.2 (a): Dimension of the wheelchair

3.1.3 RDS Seascooter

This component is not classified by the ASTM, but a brief description is given for the component

Seascooter is the perfect vehicle for cruising through the water. Rated to a depth of 65ft (20m) and a cruising speed of 2.0mph (3.2km/h) the RDS200 is designed for both recreational divers and snorkeling enthusiast.

Quantity: 2

Table 3.2.3 below lists the RDS seascooters used in the prototype, along with their dimensions.

RDS Seascooter	Hight	Width	Length	Weight
B075FN5VD1	0.612m	0.385m	0.312m	6KG

Table 3.2.3: Dimension of the RDS Seascooter

3.1.4 Diving Life Vest/ Buoyancy

Material: B01LWBGYQS

Engineering Standard: STP1237

Table 3.2.4 shows the dimension of the diving life vest/ buoyancy

Hight, Width, Thickness	Weight
(0.4572 x 0.3048 x 0.0508) m	0.680388555 KG

Table 3.2.4: Dimension of the Diving Life Vest/ Buoyancy

3.1.5 Acrylic Glass

Material: B000FPC3F0

Engineering

Standard:ASTMD4802

Table 3.2.5 shows the measurements of the acrylic glass.

Width	Thickness	Length
0.3048m	0.009525m	0.3048m

Table 3.2.5: Dimension of the acrylic glass

3.1.6 Diving Air Tank

Material1: B018WMPSJK

Engineering Standard:MNL36-

2ND

Table 3.2.6 shows the dimensions of the diving air tank.

Working Pressure	Weight
3000PSI (200) Bar	14.333KG

Table 3.2.6: Dimension of the diving air tank

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3.3 Theory and Theoretical Calculations

3.3.1: Scuba Diving Wheelchair Design Calculations

Design and calculations of scuba diving wheelchair is all about physics, specifically fluid mechanics and thermodynamics, we will need drag force equation, RPM conversation of brushless motor, horsepower equivalence and thrust equation.

Mechanical Calculations:

- **Sea scooters reactive force underwater**

Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value	Progress	Use In Convergence	Delta	Criteria
GG Max Velocity (X) 1	[m/s]	3.184	3.129	3.029	3.184	24 %	Yes	0.125	0.030
GG Max Velocity (Y) 1	[m/s]	2.806	2.801	2.788	2.806	100 %	Yes	0.019	0.030
GG Max Velocity (Z) 1	[m/s]	4.703	4.697	4.678	4.743	68 %	Yes	0.065	0.044
GG Normal Force (X) 1	[N]	-0.228	-0.333	-0.740	-0.104	42 %	Yes	0.178	0.074
GG Normal Force (Y) 1	[N]	84.543	82.514	78.298	84.603	51 %	Yes	6.304	3.206
GG Normal Force (Z) 1	[N]	129.928	129.032	127.472	129.928	100 %	Yes	2.455	6.987
GG Force (X) 1	[N]	-0.223	-0.320	-0.725	-0.089	44 %	Yes	0.170	0.074
GG Force (Y) 1	[N]	84.088	82.042	77.822	84.142	51 %	Yes	6.320	3.206
GG Force (Z) 1	[N]	134.379	133.359	131.700	134.379	100 %	Yes	2.679	7.120

Table 3.3: Forward Drag Simulation

To validate the results the following drag calculation was performed.

$$F_d = \frac{1}{2}(\rho * C_d * A * V^2)$$

Equation 1: Drag Force Equation

With the projected frontal area equal to approximately 0.0735m, a desired velocity of 0.888 $\frac{m}{s^2}$ and water density of 998kg/m^3 and applying a drag coefficient of 1 the required force is 133.83N. This study is not including the sloping edge or curved face of the cylinder that generates friction and utilizes a worst-case scenario for drag on a basic rigid body. This value due to symmetry within the model is essentially double for vertical thrust required. In addition to the current analysis to determine required power to sustain a given speed more analysis must be conducted. Primarily the pressure vessels for the components must be tested to make sure they will meet depth requirements for the competition. This will be done by simulations in either ANSYS or SolidWorks. Computations must also be performed for the ROV drivetrain. These tests are thrust calculations on the propellers in addition to a conversion of brushless motor specifications to a more standardized value of RPM's and Horse Power.

RPM = Volt * Kv(rating of motor)

Equation 2: RPM Conversion of brushless motor

$$\text{Horse Power} = \frac{Amps * Volts}{745.7\left(\frac{Watt}{HP}\right)}$$

Equation 3: Horse Power Equivalence

$$F_{Thrust} = Density * Area(stream) * Velocity * (Velocity - Initial\ Velocity)$$

Equation 4: Thrust Equation

Once these computations are completed a structural analysis on the design can be performed to validate the structure is capable of the loads applied from the motors

3.3.1 : Discussion

However, since we are also aiming to provide a scuba diving wheelchair that can be used in pools and sea underwater, this would be achieved in the testing and observations section of Chapter # 4.

This project does not have a lot of calculations or manufacturing because it is all about the material selection and the imagination of creating and applying the parts all together on the wheelchair.

3.4 Product Subsystems and selection of Components

The underwater wheelchair serves as an underwater recreational vehicle for people who are disabled. The wheel chair is the base of witch different components are attached to, to facilitate the movement and to allow people with disabilities to flow smoothly under water. The aluminum wheelchair has two major advantages regarding its manufacturability. One, its less in weight. Two, it is less prone to corrosion that a stainless-steel wheelchair. The two sheets of acrylic glass are mounted to the two-foot pedestals to grant the wheelchair with buoyance and to facilitate the movement of the diver under water. the reason behind the selection of acrylic glass is that it has the same components as regular glass excluding the shattering affect which will become useful when diving under water.

Wheelchair

The Drive Medical Viper GT is the most flexible wheelchair directly out of the case and is simpler to move and transport than a normal weight seat. The Viper GT comes standard with movable cushioned arms, numerous seats to floor stature positions, flexible enemies of tippers with flip-up wheels which never must be evacuated and push to bolt wheel locks. The back is both point movable and stature movable to give included patient solace. The 16", 18" and 20" form of the Viper GT arise standard with a seat rail augmentation component. The all-aluminum outline is high quality while staying lightweight. The wheelchair upholstery is made of sturdy nylon which is fire resistant and opposes buildup and microscopic organisms. Exactness fixed wheel heading in front and back guarantee durable execution and dependability. The fast discharge, 24" composite Mag-style wheels are lightweight and upkeep free. Instrument free movable swing ceaselessly hassocks additionally include simple to get to discharge handles. Urethane back tires and casters offer prevalent execution, smoother ride and are lightweight. Moreover, it fitted with a seat belt to ensure the safety of the passenger.

Chair Specifications:

- Weight Capacity: 300 Lbs.
- Weight: 31 Lbs.
- Standard Color: Black
- Seat Width: 18"
- Seat Depth: 16" - 18"
- Back Height: 18""
- Frame Material: Aluminum
- Standard Seat: 16" - 20"
- Caster: 6" Solid Rubber
- Rear Wheel: 24" Rubber
- Seat to Floor Heights: 17.5" - 19.5"
- Wheel Lock: Push to Lock
- Warranty: Lifetime on All Durable Parts, Excusions: Tires, Upholstery.

<u>Figure # 2: Wheel Chair</u>

Oxygen cylinder

Faber steel chambers give you the quality and execution you expect and acknowledge in a steel scuba barrel. With one of the most stretched out scopes of sizes in the market today Faber barrels offer you the required volume and adaptability to expand your base time. The Scuba Doctor has accessible the full scope of Italian made 232 bar Faber Steel Cylinders. We ordinarily have Faber 3, 10.5, 12.2 standard and 15-liter steel tanks in stock on the shop floor and request in whatever else. Every one of the 232 bar Faber Steel Cylinders are provided oxygen clean direct from the industrial facility, making them appropriate for O2 administration.

Figure # 3: Oxygen Cylinder

Cylinder Specification:

- Fill pressure: 232 bar (3365 psi)
- Test pressure: 348 bar (5047 psi)
- Standard: BS 5045 Pt 1
- Material: 34CRMO4 Chromium Molybdenum Alloy Steel
- Manufacturing Process: Cold deep drawing from steel plate
- Primary Finish: Hot Zinc sprayed, layer thickness 60/70 microns
- Final Finish: 2 part polyurethane white paint sprayed and air dried
- Internal Finish: Chemically treated with Ferrous Phosphate
- Neck Thread: 3/4 inch NPSM

Faber 232 Bar Cylinder Specifications						
Water Cap.	Volume Cu Ft	Tare Weight	Len.	Dia.	Buoyancy	
					Empty	Full
2 liter	16 cf	3.0 kg 6.6 lb	360 mm 14.17 in	100 mm 3.9 in	-1.1 kg -2.42 lb	-0.5 kg -1.21 lb
3 liter	25 cf	3.4 kg 7.5 lb	500 mm 19.7 in	100 mm 3.9 in	-0.5 kg -1.1 lb	-1.25 kg -2.8 lb
5 liter	40 cf	5.8 kg 12.8 lb	460 mm 18.1 in	140 mm 5.5 in	-0.5 kg -1.1 lb	-2.0 kg -4.4 lb
7 liter	55 cf	7.6 kg 16.8 lb	605 mm 23.8 in	140 mm 5.5 in	-1.0 kg -2.2 lb	-3.0 kg -6.6 lb
9 liter	75 cf	10.4 kg 22.9 lb	495 mm 19.5 in	178 mm 7 in	-1.5 kg -3.3 lb	-4.0 kg -8.8 lb
10.5 liter	85 cf	11.3 kg 24.9 lb	560 mm 22 in	178 mm 7 in	-1.0 kg -2.2 lb	-4.0 kg -8.8 lb
12.2 liter **standard**	100 cf standard	12.9 kg 28.4 lb	625 mm 24.6 in	178 mm 7 in	-0.75 kg -1.7 lb	-4.25 kg -9.4 lb
12.2 liter **compact**	100 cf compact	14.2 kg 31.3 lb	515 mm 20.3 in	204 mm 8 in	-1.5 kg -3.3 lb	-5.0 kg -11 lb
15 litre	125 cf	16.5 kg 36.4 lb	610 mm 24 in	204 mm 8 in	-1.0 kg -2.2 lb	-5.25 kg -11.6 lb
18 litre	150 cf	22.4 kg 49.4 lb	715 mm 28.1 in	204 mm 8 in	-0.75 kg -1.7 lb	-5.75 kg -12.7 lb

Table # 3.4 : Oxygen Cylinder Specifications

Acrylic glass (PMMA)

Poly (methyl methacrylate) (PMMA), also known as acrylic, acrylic glass, or Plexiglas, is a tough, intense, and lightweight material. It has a thickness of 1.17– 1.20 g/cm3, which is not exactly a large portion of that of glass. It additionally has great impact quality, higher than both glass and polystyrene; notwithstanding, PMMA's effect quality is still fundamentally lower than polycarbonate and some built polymers. PMMA touches off at 460 °C (860 °F) and consumes, framing carbon dioxide, water, carbon monoxide and low-sub-atomic weight mixes, including formaldehyde. PMMA transmits up to 92% of unmistakable light (3 mm thickness), and gives an impression of about 4% from every one of its surfaces because of its refractive record (1.4905 at 589.3 nm). It channels bright (UV) light at wavelengths beneath around 300 nm (like common window glass). Some manufacturers add coatings or added substances to PMMA to improve retention in the 300– 400 nm go. PMMA leaves infrared light of behind to 2,800 nm and squares

IR of longer wavelengths up to 25,000 nm. Shaded PMMA assortments enable explicit IR wavelengths to pass while blocking noticeable light (for remote control or warmth sensor applications, for instance). PMMA swells and breaks up in numerous natural solvents; it likewise has poor protection from numerous different synthetic substances because of its effectively hydrolyzed ester gatherings. All things considered, its natural strength is better than most different plastics, for example, polystyrene and polyethylene, and PMMA is in this manner frequently the material of decision for outside applications. PMMA has a most extreme water ingestion proportion of 0.3– 0.4% by weight. Tensile quality declines with expanded water absorption. Its coefficient of warm extension is generally high at (5– 10) ×10−5 °C−1.).

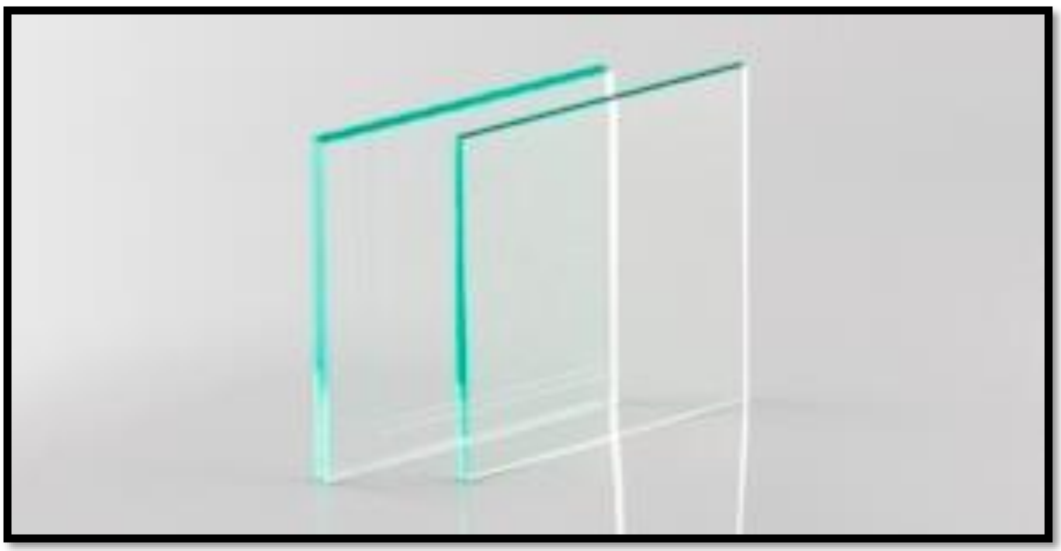

Figure # 4: Acrylic Glass

Applications:

The acrylic glass will be formed into the shape of a fin. Furthermore, the fin shaped sheets will be mounted individually on each of the foot pedestals attached to the wheelchair. This will serve the wheel chair which will serve the diver with extra mobility under water and the needed buoyancy to keep the chair floating in the water.

Figure # 5: Acrylic Glass Application

The sea scooter (propelling system)

The Yamaha RDS200 Sea scooter is the impeccable vehicle for voyaging through the water. Rated to a depth of 65ft (20m) and a sailing speed of 2.0mph (3.2km/h) the RDS200 is calculated for both entertaining divers and swimming aficionados.

Scooter Specification:

- Run up to 1 hour with normal use.
- Rated to 65 ft / 20 m.
- Speed up to 2 mph / 3.2 km/h.
- Removable buoyancy control chamber (The RDS200 is designed for use in salt water. It will have less buoyancy in fresh water, and may slowly sink in fresh bodies of water.).
- Powered by a Sealed Lead Acid Battery (Occasional battery maintenance required).
- Product size: 24” x 15.2” x 12.3” / 612 x 385 x 312 (mm).
- Weight just 13 lbs / 6 kg including battery.
- Item # YME23200.

Figure # 6: Yamaha Sea-Scooter

24” x 15.2” x 12.3” / 612 x 385 x 312 (mm) sea scooter.

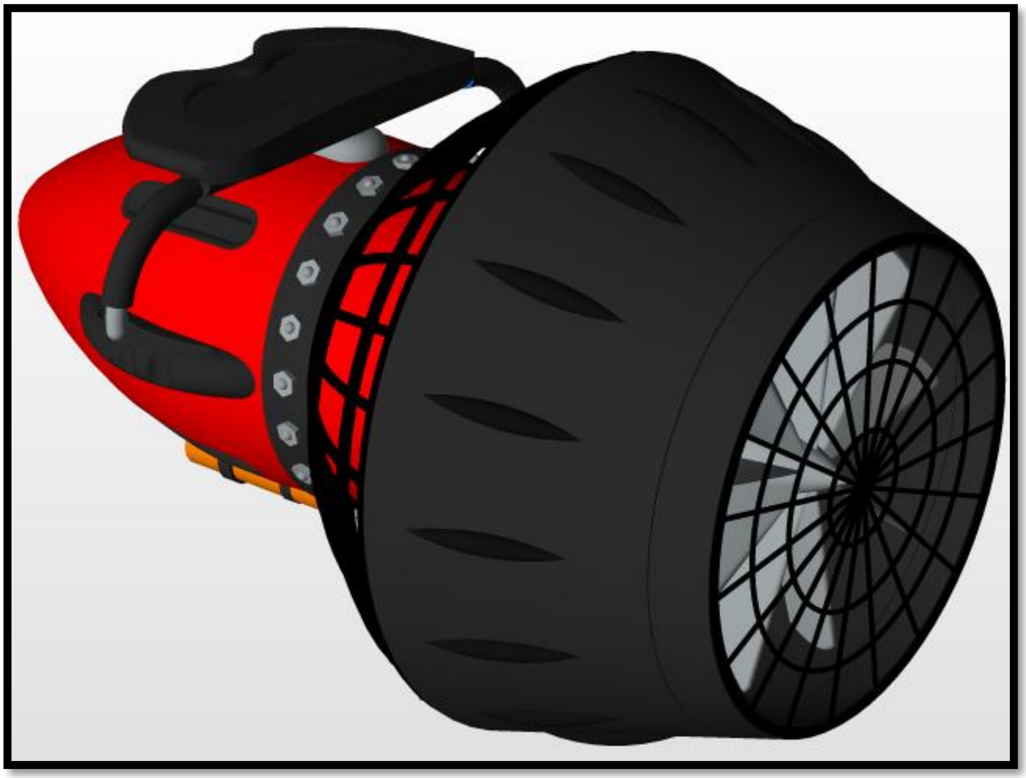

Figure # 7: Sea Scooter CAD Model

Figure # 8: Prototype CAD Model

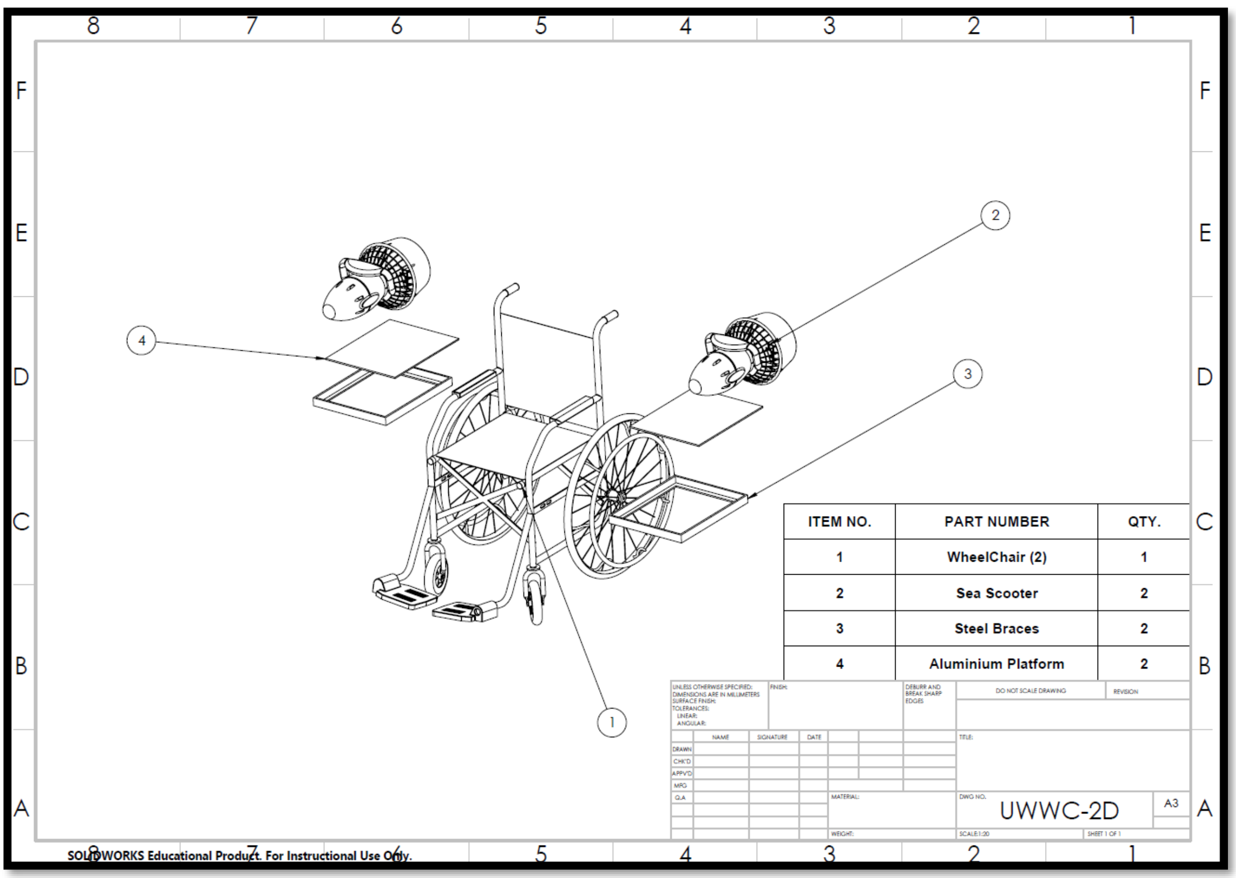

Figure # 10: Exploded View of Prototype

3.5 Manufacturing and Assembling (Implementation)

The wheelchair acts as the base of the whole project and with its aluminum body it acts as a tough yet lite base for that matter. Hence, the wheelchair will flow smoothly and still withstand the pressures and the obstacles that awaits under the deep blue sea. Furthermore, attached to the wheelchair from bot side will be the sea scooters to supply the wheelchair along with its passenger with the needed thrust. Moreover, to ensure the passenger’s safety, the wheelchair is equipped with self-inflated life reservoirs. Hence, supplying him with the needed amount of buoyancy to ascend to the surface. Also, to supply the diver with the amount of oxygen needed to enjoy a long and adventurous trip under water, we attached an oxygen tank along with its regulator to the back of the wheelchair. Regarding the facilitation of movement under water, the two fin shaped sheets of acrylic glass will be mounted on each of the self-adjusted foot pedestals on the wheelchair. Also, the two sheets of acrylic glass grant the wheelchair with extra buoyancy to make the overall project less in weight under water which will allow the thrusters to supply more power. Hence, less weight and more power will allow the passenger to experience an adventure of a lifetime.

Chapter 4: System Testing and Analysis

4.1 Experimental Setup, Sensors and data acquisition system

4.1.1: Humidity Meter

4.1.2: Digital Thermostat

Testing Parameters	
Humidity Meter	**To obtain the output moisture content**
Digital Thermostat	**To control temperature**

Table # 5: Testing Parameters

4.2 Results, Analysis and Discussion

Data obtained from performing the setups in order to get our system performance figures, following tables have been compiled

Chapter 5: Project Management

5.1 Project Plan

The project comprises of various tasks that are assigned to each group member in an equal manner, to ensure fairness between the members. Each member was given a specific task that needed to be completed within a certain amount of time.

The times and dates listed in the Gantt Chart were followed to ensure consistency and quality of the work done by the group members.

Table 5.0 displays the number of tasks done alongside with the number of days it took for that specific task to be completed.

S. No.	**Tasks**		**Start**	**End**	**Duration**
1	Ch. 1: Introduction		23.01.2019	27.01.2019	4 days
2	Ch. 2: Literature Review	Project Background	30.01.209	03.02.2019	4 days
		Previous Work			
		Comparative Study			
3	Ch. 3: System Design	Design Constraints & Methodology	08.02.2019	19.02.2019	9 days
		Engineering Design Standards			
		Theory & Theoretical Calculations			
		Product Subsystems & Component Selection			

		Manufacturing & Assembly			
4	Ch. 4: System Testing & Analysis	Experimental Setup, Sensors & Data	10.03.2019	29.03.2019	19 days
		Results, Analysis & Discussion			
5	Ch. 5: Project Management	Contribution of Team Members	06.04.2019	09.04.2019	3 days
		Project Execution Monitoring			
		Challenges & Decision Making			
		Project Bill of Materials & Budget			
6	Ch. 6: Project Analysis	Impact of Engineering Solution	05.04.2019	08.04.2019	3 days
		Contemporary Issues Addressed			
7	Ch. 7: Conclusion & Recommendation	Conclusion	07.04.2019	09.04.2014	2 days
		Future Recommendation			
8	Design of Prototype		08.02.2019	11.02.2019	3 days
9	Parts Purchased		11.02.2019	27.03.2019	46 days
10	Manufacturing		20.03.2019	27.03.2019	7 days

11	Testing	28.03.2019	04.04.2019	7 days

Table 7: Tasks and their Duration

Table 7 identifies the team members responsible for their respected tasks.

S. No.	Task	Assigned Members
1	Introduction	Osama, Tarzan & Mussad
2	Literature Review	Mussaad & Osama
3	System Design	Osama & Tarzan
4	Testing and Analysis	Tarzan, Osama & Mussad
5	Project Management	Osama & Tarzan
6	Project Analysis	Mussad
7	Conclusion and Recommendation	Osama
8	Design	Tarzan
9	Parts Purchased	Osama, Tarzan & Mussad
10	Manufacturing	Tarzan & Osama
11	Testing	Osama, Tarzan & Mussad

Table 8: Assigned Members for Each Task

5.2 Contribution of Team Members

Each member's contribution and their willingness to work was discussed in our first meeting as a team, and the tasks were divided and agreed upon by each member.

Table 9 shows how much work each group member contributed, as a rough percentage.

S. No.	Tasks	Assigned Member	Contribution
1	Ch. 1: Introduction	Osama, Tarzan & Mussad	100%

2	Ch. 2: Literature Review	Project Background	Osama	33%
		Previous Work	Mussad	33%
		Comparative Study	Tarzan & Mussad	34%
3	Ch. 3: System Design	Design Constraints & Methodology	Mussad	20%
		Engineering Design Standards	Tarzan	20%
		Theory & Theoretical Calculations	Osama	20%
		Product Subsystems & Component Selection	Tarzan	20%
		Manufacturing & Assembly	Osama & Mussad	20%
4	Ch. 4: System Testing & Analysis	Experimental Setup, Sensors & Data	Tarzan & Mussad	40%
		Results, Analysis & Discussion	Osama	60%
5	Ch. 5: Project Management	Contribution of Team Members	Tarzan, Osama & Mussad	100%
		Project Execution Monitoring		
		Challenges & Decision Making		

		Project Bill of Materials & Budget		
6	Ch. 6: Project Analysis	Impact of Engineering Solution	Mussad & Osama	100%
		Contemporary Issues Addressed		
7	Ch. 7: Conclusion & Recommendation	Conclusion	Tarzan & Osama	100%
		Future Recommendation		
8	Design of Prototype		Osama	50%
			Tarzan	50%
9	Parts Purchased		Tarzan	20%
			Osama	30%
			Mussad	30%
			Tarzan	20%
10	Manufacturing		Mussad	60%
			Tarzan & Osama	40%
11	Testing		Tarzan, Mussad, Osama	100%

Table 9: Contribution of Tasks

5.3 Project Execution Monitoring

To ensure the continuous progress of the project, regular meetings between the group members, to discuss the next step, and between the group members and the advisor, to take approval for said step, needed to be done on a regular basis. In addition to these meeting, we were asked to hand in progress reports and perform a presentation to explain what we have done in the project till the date of the presentation. All the dates are listed in table 10 below

Activities and/or Events	Time and Date
Assessment Class	Once a week
Meeting with the group members	Weekly
Meeting with the Advisor	Bi-Weekly
First Finished Prototype	16 February 2019
Midterm Presentation	21 March 2019
First Test of System	24 March 2019
Finishing Final Prototype	30 March 2019
Test of the System	06 April 2019
Final Submission of Report	18 April 2019
Final Presentation	18 April 2019

Table 10: Dates of Activities and Events

5.4 Challenges and Decision Making

First and foremost, our project as a prototype concluded out to be a bit expensive that the budget PMU provided to us. Moreover, if we consider the parts and the components, we have used in our project prototype to ensure safety of the occupant, environment and spectators, there has been no compromise made on such stuff since it can get life-threatening if any of the component fails in our prototype and is not able to function properly. In addition, there were a lot of moments where we had to make quick and thoughtful decisions which included mainly of the materials we were using because we needed it to be safe and secure by all means.

5.4.1: Equipment and Device Problems

- **Sea-Scooter Platform**

  In order to provide our system a part that acts like oars, we had to figure out a proper, safe and non-deteriorating material which is environmentally friendly and extremely lightweight along with being strong enough to be not deformed by the currents or water pressure.

- **Sea-Scooter**

  Since we were to use Sea-Scooters for our underwater propulsion, we were having difficulties managing to figure out a proper mounting position where we needed to consider a 4-axis degree of freedom to provide complete control maneuvering capability. Moreover, since the sea-scooter works on a battery and contains a shell to provide buoyancy, we had to secure the buoyancy shell and also specify the maximum working time on full-charged battery to avoid getting in trouble underwater.

5.4.2: <u>Testing & Safety Issues</u>

The system stages of our prototype really concerned almost the whole group including our project advisors since we had to do numerous modifications to give it buoyant properties and floating properties altogether. So, to test it underwater, we had to make use of a private swimming pool with the authorities giving us a greenlight to perform all future testing and experiments. Also, as far as safety was concerned, our prototype was lacking a proper five-point harness to keep the occupant in position so we had to improvise on using a three-point simple harness that was easily attachable and detachable but when it comes to safety, it was not very dependable.

5.4.3: <u>Design Problems</u>

Our project being very unique and complicated when considered that it will be used underwater, we had several design problems especially in material selections where we needed to ensure the buoyant forces and its effect underwater with the occupant in place. Secondly, in order to propel the wheel chair there was a huge concern of an immense drag force acting on the system due to lack of streamlining dynamics. So, to compensate for that, our propulsion system was strong enough to produce ample thrust to easily move underwater without any unnecessary and extreme stresses.

5.5 Project Bill of Materials & Budget

The table below illustrates the parts we purchased and the amount given to the third party for manufacturing some of the intricate parts for us. It includes the total amount spent in our project in Saudi Riyals (SAR).

Table 11 shows the amount of money paid for each part in Saudi Riyals (SAR).

Material	**Cost /SAR**
Yamaha RDS-200 Sea Scooter (QTY: 2)	3526.5
Wheel Chair	1450
Manufacturing and Fabrications Costs	140
Strap for Sea-Scooters	50
Total Sum	5166.5

Table 11: Bill of Materials

Chapter 6: Project Analysis

6.1 Life-Long Learning

We had a soul purpose that was completely firm in our minds while occupied on our project, and that was to accomplish all the targets we had set in the beginning of the semester. Of course, in order to complete that, we were inclined to utilize software and hardware by consuming our time in a very competent manner. Furthermore, to achieve all of these things, we had to arrange and impose a preordained schedule which really provided us an enhancement in every aspect we worked on and we would like to share some of that experience.

6.1.1: Software Skills:

As mechanical engineers, the most basic platform to begin our designing starts from designing on computer-based software especially SolidWorks. Over the semesters we have earned the necessary skills to successfully design any prototype and simulate the conditions we would be planning to work in. Moreover, we also made use of MS excel to record data and illustrate them in a comprehensive graph which speaks better than words.

6.1.2: Hardware Skills:

There is not any complicated or sophisticated hardware we have used in order to test and run our prototype, apart from sea scooter which just needs a little bit of an attention and practice to master its operation. Moreover, welding and cutting skills were in extensive usage in order to make and mount a platform for the sea scooter.

6.1.3: Time Management:

Considering a total time span of three months in which had to design, build, test and produce software data for our project, it seemed quite distant and hectic to achieve but to make things happen as soon as possible with enough time gap to considering in failures and setup. We had to plan tasks in such a manner that we outdo ourselves. And due to such strategies and tactics, we made sure to finish every task assigned to us with enough gap to figure out the mishaps, mistakes and even setbacks which we were expecting.

6.1.4: Project Management:

This project itself is and was not entirely easy and we were bound to consider many things to go wrong. However, due to proper management and division of tasks between each member of the group which made a lot things easier and streamlined since the responsibilities were handed over to each individual with a sense of determination and motivation to eventually help the people with special care and needs.

6.2 Impact of Engineering Solutions

6.2.1: Society:

Socially, it would create a very positive impact towards the society where people are deprived and are in a special needs class of their own, for their morale boost and a sense of motivation, we as a group are very determinant to pose a great reputation in the social environment since there are many people in need recreational activities especially when it comes to diving and exploring the marine life.

6.2.2: Economy:

In order to properly make our prototype possibly functional, we had to breach the university budget just a little five thousand Saudi riyals since the parts such a sea scooters were not available locally and we had to get it delivered from amazon which considers in the shipping charges along with the hefty price tag of the sea scooter itself. Moreover, the wheel chair itself was a bit pricy considering it as a component which comes under medical field as they have to engineer to keep a very high factor of safety. Conclusively, the project was not very friendly to the pockets but to work things out we had to break the bank just a little bit especially ensuring the safety of the occupant.

6.2.3: Environment:

Our project is very environmentally friendly and there are no safety hazards towards the atmospheric conditions in any way when considering its operation underwater. We have made sure the choice of materials to use are noble enough that they do not deteriorate underwater which could harm the marine life.

6.3 Contemporary Issues Addressed

Since our project was much more focused and aimed towards the majority with disabilities or special needs, we have to address that there are some major and minor problems our prototype contains at the moment. Firstly, it has platforms which act as an immovable rigid body holding the sea scooter in place and maneuvering the wheel chair might not be as comforting as should be. Secondly, we have observed that in order to emerge up towards the surface of water, we did not make measures to improve it since one can encounter any kind of emergency underwater and quick actions are much needed in such a consideration as the occupant will be already disabled from his/her lower limb functions.

Chapter 7: Conclusion & Future Recommendations

7.1 Conclusion

To sum up, our project has been devoted towards the disabilities people face which poses a huge hurdle towards their recreational activities especially in case of scuba diving to explore the world underwater. Since, they have been deprived naturally from the lower limb's functionality. Our group successfully managed to design and build a prototype which will actually support and compensate for the disabilities a diver suffers from in the form of an underwater wheel chair. In order to maneuver with ease underwater, two sea-scooters were used on either side of the wheelchair which will help with movement and propulsion in underwater conditions.

As graduating seniors, we as a group really felt committed and satisfied to achieve and contribute towards the world where people with special needs can also enjoy the wonders of life by developing this project.

7.2 Future Recommendations

Considering the fact that such a prototype was achieved by students at an institution with sufficient knowledge and background data in order to make it happen, there are some minor places where attention is required since our prototype can gladly be looked after if any modifications are intended to be added in it. First of all, it includes the addition of a five-point harness in order to keep the occupant securely in place. Moreover, the platforms which we have designed for the sea-scooters could be fabricated to move about an axis for a more efficient maneuvering capabilities. And finally, a addition of an emergency inflatable cushion which can be deployed in case of an emergency so the whole mechanism briskly emerges towards the surface of water.

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