جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

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Senior Design Project Report

Design of a Hovercraft

In partial fulfillment of the requirements for the

Degree of Bachelor of Science in Mechanical Engineering

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Abstract

The hovercraft is an important used for many purposes. It can float above any type of terrain. Hovercraft sometimes called Air Cushion Vehicle due to its ability to move by cushion or skirt filled with air and causes the board to hover above the ground, and it moves by a thrust engine forward and fills up the cushion by the lift engine.

In this project, the aim is to design and manufacture one-man hovercraft. It can carry around 70 kg with a rated speed between 5 to 10 kilo meter per hour. Two fans are used for this hovercraft; one of the fans is used for thrust while the other is used for lift. Each fan has a separate engine to perform the required task. The thrust engine produces up to 5.5 horsepower at a rated revolution per minute of 3300, and the list engine is rated at 6.7 horsepower at rated revolution per minute of 3600. The dimensions of the hovercraft is 1.75 meters long and 0.875 meters, and reason behind these dimensions is to have performance and equilibrium a hovercraft must a have 2:1 ratio for length and width for the optimum stability. Furthermore, the thrust duct diameter used in this hovercraft is 90 cm, while the thrust propeller is approximately 80 cm (32 inches) with a pitch of 10. The engines shaft is connected to a hub, which is linked to the propeller. However, the design of the hovercraft applies a horizontal shaft engine and a vertical shaft engine that is used for the list mechanism. The hovercraft is provided with rudders to control the direction of airflow, consequently controls the direction of movement of the hovercraft. The whole engine base of the hovercraft is semi rectangular in shape, while the edges are semi circle in shape (fillet) in order to decrease unneeded friction and increase aerodynamics. While the base itself is made out of natural wood that is from Indonesia, while the skirt of the hovercraft 1680 D. Traveler Nylon which is a plastic material that has rigid properties and used in all sorts of hovercrafts. Moreover, the propeller are made of wood that CNC cut and pre-balanced to decrease vibration during engine rotation. Finally, our objective is to approach a hovercraft that is able to float and move while carrying a person with a weight of 80 kg.

Acknowledgments

At this stage of graduation, we would to extended our hearts to thank Prince Mohammad Bin Fahd University (PMU) and the distinguished doctors Dr. Faramarz Djavanroodi and Dr. Esam Jassim for their guidance and unparalleled support, efforts, and most importantly their time in our project to make the hovercraft from an idea to a reality. Our senior project design, and development of hovercraft is extremely unique and requires an enormous amount of time and effort from the concept to design and to construction. It needed continuous support, cooperation and collaboration from team members and our advisers. Finally we would like to extend our thanks to Mr. Abdullah Alhalawi for providing us with a workshop to work on the hovercraft senior project.

List of Acronyms (Symbols) used in the report:

Air Cushion Vehicle	A Vehicle that floats on any terrain such as ice, sand, grass, and water
CAD	Computer Aided Design
Skirt	Filled with air and is surrounded around the body
Engine Mount	Brackets that holds the engine with the body
Steering	Controls the direction
Rudders	Changes the direction of the airflow via steering
Thrust Duct	Designed as a nozzle to increase air flow
Thrust Propeller	Produces air flow
BHC	British Hovercraft Cooperation
Aerodynamics	Motion of air and gases acting on a body
Plywood	Sheet of layers made out of wood
Horsepower (HP)	A unit of Foot Pound second (fps) to express mechanical energy

MDF	Median Density Fiberboard
RPM	Revolution per Minute
LPR	Low Pressure Rubber
HPR	High Pressure Rubber

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Chapter 1: Introduction

1.1 Project Definition

Figure 1 (Example of Hovercraft)

A Hovercraft is a vehicle that floats above any lands such as ice, sand, grass, and water. Hovercraft sometimes called Air Cushion Vehicle due to its ability to move by cushion or skirt filled with air and cause the board to hover above the ground, and by the thrust engine it runs forward and fills up the cushion as shown in figure 1.1. In this project, we intended to build and design our hovercraft, which could work in many circumstances as much as the car regarding any land. The concept of the hovercraft is simple, starts with a particular kind of wood that has the property in carrying loads and has some gaps to help wood floats above any land. Underneath the wood, the skirt or cushion takes place, and it functions to create a change in pressure by catch the air in one area to create the required difference in pressure between inside and outside of the skirt. The mechanical part of our project is the engine and control system which help in maneuvering and monitoring the direction ofthe hovercraft. The project is helpful and necessary many cases such as military and security in which hovercraft are excellent for off beach protection and rescue. For commercial operation also hovercraft can play a distinct role in guiding the ships to the shore safely and efficiently rather than using small boats, which can cost a lot in maintenance. The best application of the hovercraft comes in situations such as flooded areas same as happened in Khobar back in 2016. The figure 1.2 explains the basic mechanisms of a hovercraft.

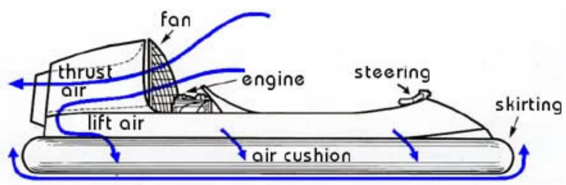


Figure 2 [Simple Explanation of Hovercraft]

1.2 Project Objectives

The hovercraft project went into several phases, and challenges to approach the following objectives.

1. Prototype the hovercraft with a simple design that can do the required functions of movements.
2. The approach design of hovercraft is to move with a rated speed of 10 to 15 kilometers per hours.
3. Hovercraft can tolerate with more weight up to 200 kilograms and operates under intensive conditions smoothly.
4. Improve the factor of safety for all materials during all operation processes.
5. Propagate new vision for a vehicle that can operate in different terrains and conditions.

1.3 Project Specifications

Our project specifications are mainly the following:

I. Design ans assemble the parts of the vehicle using CAD.
II. Construct a vehicle with a dimension of 1.75 m in length and 0.875 m in width.
III. Implementing two engines one for thrust with a rated power of 5.5 Hp and another engine with a rated power of 6.7 Hp for lift.
IV. Construct the manual mechanism system to monitor the hovercraft.
V. Minimize the weight of the hovercraft by selecting material such as: plywood, foam, MDF, and Fiberglass.

1.4 Applications

Hovercraft fly over any flat surface so can be used for many different applications, to include commercial, military, leisure, for rescue for during and after flooding emergencies, for rental, as a Super Yacht tender, and for survey applications. Hovercraft are the most versatile vehicle available, they float like a boat but has no propeller to get damaged on rocks or coral, and can work at anytime regardless of tidal conditions. The Hov Pod hull is very buoyant so will float when ice is thin, so far less risk from drowning and hypothermia than drivers of snow mobiles suffer.

Chapter 2: Literature Review

2.1 Project background

The first hovercraft was conducted and protected by English innovator Christopher Cockerell, in 1952 and figure 2.1 shows the first prototype. A few innovators preceding that date had fabricated or endeavored to manufacture vehicles given the “ground effect” rule (the possibility that catching air between a fast moving vehicle and the ground can give addition lift and decrease drag). These endeavors were of restricted achievements and did not utilize the annular air pad that is known today. The initial design for a hovercraft was obtained from a British development in the 1950’s to 1960’s.

Figure 3 (First Hovercraft Prototype by Christopher Cockerell)

They are presently utilized all through the world as accurate mean of transport in misfortune alleviation, cost guard, military, study applications, and also for leisure and travel. Large forms have been utilized to transport individuals and vehicles over the English channel, while others have military application used to carry tanks, fighter, and expensive hardware in antagonistic situations and landscape. Although, now a non-exclusive term for the kind of specialty, the name hovercraft itself was a trademark possessed by Saunders-Roe (later British hovercraft cooperation (BHC), then Westland). Subsequently, other producers'' utilization of option names to portray the vehicles. [1,2]

Some hovercraft has two motors with two arrangements of controls for lifting and thrust as figure 2.3 and some hovercrafts do (lift and thrust) by one engine as figure 2.2 , the only engine outline parts air lessening the requirement for two motors, to spare weight and disentangle operation. Left and right bearing is overseen by steering to control rudders into the back of the fan channel get together. Some hovercraft has a high focus of gravity and can be hard to guide around corners; like a car like which lowers center of gravity that helps cornering. [3]

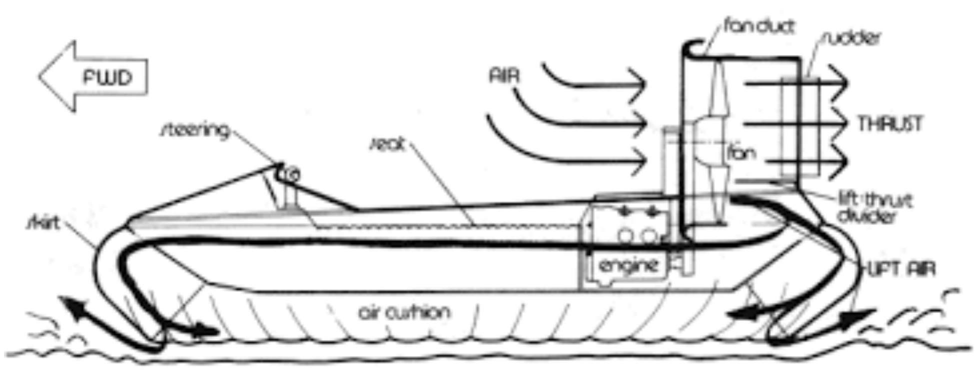


Figure 4 (One-Engine Hovercraft)

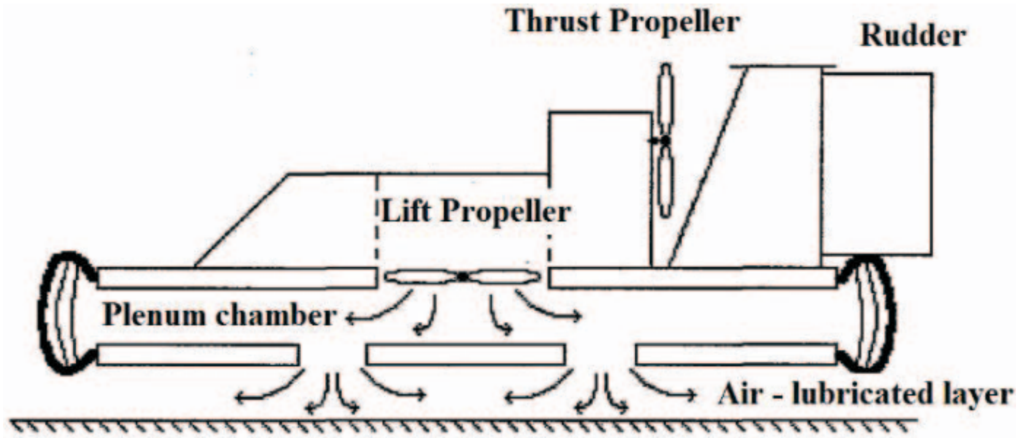


Figure 5 (Two-Engine Hovercraft)

2.2 Previous Work

A hovercraft, otherwise called an air-cushion vehicle or ACV, is a specialty equipped for going over land, water, mud, ice, and different surfaces. Hovercrafts are half vessels worked by a pilot as a flying machine as opposed to a chief as a marine vessel. A hovercraft is a land and water capable vehicle that is bolstered by a pad of marginally pressurized air. Although regularly observed as a secretive, even unusual method of transportation, it is reasonably straightforward. To see how hovercraft functions, it is important to understand that the progression is more firmly identified with airship than to boats and automobiles. As an individual from a group of air pad vehicles (ACVs) or Ground Effect Machines, which incorporates wing-in-ground-impact or ram wings, surface impact ships, sidewall hovercraft ship and surface skimmers, hovercraft are the land and water capable individuals from the air pad vehicle family. They are the most novel among vehicles that are bolstered by pressurized air. Allude to the delineation underneath as presented that how precisely hovercraft functions.

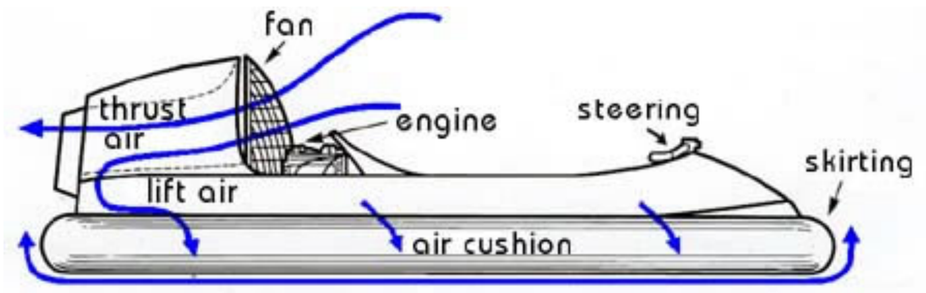


Figure 6 (Distribution of Air Along the Hovercraft)

As in (figure 2.4): Hovercraft glides on a pad of air that has been constrained under the specialty by a fan. This causes the hovercraft to rise or lift. The measure of lift can run from 6" to 108" (152mm to 2,743mm) contingent upon the extent of hovercraft. The measure of aggregate weight that a hovercraft can raise is equivalent to pad weight duplicated by the zone of the hovercraft. To make the specialty work all the more effectively, it is important to restrict the pad air from getting away, so the air is contained by the utilization of what is known as a hovercraft skirt. Formed from texture, which allows a thick cushion or clearance of obstacles, hovercraft skirts shift in style extending from packs to cells to isolate fingered areas called fragments. Once "lifted" or "on the cushion," push must be made to propel the hovercraft. With many specialties, this is produced by a different motor from the one used to make the lift, yet with a few, a similar motor is utilized for both. The fan-produced air stream is the part, so that piece of the air is coordinated under the body for lift, while a significant portion of it is utilized for thrust. Since the hovercraft has lift and thrust, it must be controlled securely. This is accomplished using an arrangement of rudders behind the fan, controlled by handlebars in advance. Directing can likewise be controlled by the utilization of body weight dislodging, an aptitude which is accomplished after practice. Hovercraft utilizes blowers to deliver a large volume of air underneath the frame that is somewhat above air weight. The weight distinction between the higher pressure air underneath the frame and lower weight encompassing air above it produces lift, which causes the body to skim over the running surface. For dependability reasons, the air is commonly blown through openings or gaps around the outside of a slots or holes giving most hovercraft a trademark adjusted rectangle shape. Often this pad is contained inside an adaptable "skirt," which permits the vehicle to go over little checks without harm. Small hovercraft has a developing part to play in pursuit and protect businesses and military operations around the globe. Hovercraft can be a down to earth recommendation for operations in zones out of reach to different vehicles including solidified water (ice), mud pads, intertidal regions, shallow streams and overflowed inland regions. Hovercraft has at least one separate motor (some hovercraft, for example, the SR-N6, have one motor with a drive split through a gearbox). One motor drives the fan (the impeller), which is in charge of lifting the vehicle by compelling air under the hovercraft.

The air in manner must exit all through the skirt, lifting the arc over the territory on which the craft resides. At least one extra motor is utilized to give a thrust, keeping in mind that the goal is to drive the hovercraft over the desired course. Some hovercraft use ducting to permit one engine to perform both tasks (lift and thrust), by guiding a specific portion of the air to the skirt which is usually a third of the airflow, whichever remains of the going out of the back is used to act as thrust to push the hovercraft forward. [4]

Hover work, of Parry Sound planned to improve the situation of the hovercraft rudder, which utilizes a hybrid and skirt outline that consolidates the best of routine hovercraft innovations.

The Air Rider Hovercraft is proposed to defeat a portion of the shortcoming of the two most basic hovercraft plans. An adaptable elastic or plastic skirt that hangs down from the structure delivers the air pad of a hovercraft. The skirt should be sufficiently flexible to hold the chassis all around, yet sufficiently to permit the arc to arrange rugged landscape, waves, and low impediments. This settles on the selection of skirts somewhat of a bargain, of the two primary options showing unmistakable qualities and shortcomings. The first is loop skirt, which as the name suggests, encloses the hull of the craft . The compressor lift fan blows air the body where the circle catches it, shaping a cushion and lifting the craft. It's an effective plan. The loop skirt is great at making and keeping up the air pad, yet on water, it makes for all incredibly rough ride with heaps of shower and drag. As per hover work. Air-Rider hovercraft split the contrast between the two skirts by method for a loop/segment hybrid design. The sides and stem are secured by a loop skirt, and the bow has a fragmented skirt. This eliminates the splash and slamming as the fragmented bow respects approaching waves, while the circuit gives greater security and to a lesser degree all inclination to catch. Hover-works says that the plan likewise improves the Air-Rider much then either customary outline at arranging stony stream beds or waterway rapids. [5]

Sir John Thomycroft was a British architect who in the 1870s started to test his hypothesis that delay a ship's structure could be diminished if a ship had a plenum chamber, basically an empty box, open at the base. He imagined that if the chamber could be pumped brimming with air, the ship would skim over the water and move quicker because there would be less resistance. He wasn't able to prove that how to keep the "air pad" from getting away from under the craft. Cockerell throws away the plenum load guideline, guessing rather that if he could pump air under the vessel through a limited space that circled it, the air would stream toward the vessel's middle, in this manner shaping an outer blind that would trap the rise of air under the hull. Cockerell trusted this framework, which got to be distinctly known as a peripheral jet, would permit the boat to hover. He petitioned for a patent in late 1955, and the following year shaped Hovercraft Ltd. In 1959, he propelled the principal down to earth air pad vehicle, the SR-Nl. It had an elastic skirt that contained the air pad over harsh terrains or water. This model crossed the English Channel in June 1959. It had a top speed of 10 mph and couldn't arrange rushes of more than 18 inches or land hindrances higher than a foot. [6]

2.3 Comparative Study

1) The Indiana State University 's Society of Manufacturing Engineers (SME) and Society Automotive Engineer (SAE) have teamed up to build a hovercraft. The students hope to enter a few races in the fall of 2004. [7] With encouragement from Chris Fitzgerald, founder of the World Hovercraft Organization and president of Neoteric Hovercraft, Inc., in Terre Haute, the ISU team has spent long hours planning, designing and building their hovercraft from a material kit purchased from Universal Hovercraft in Harvard, III. The materials package the ISU team is using consists of plywood, foam, fiberglass, epoxy, contact cement, PVC-coated nylon, a propeller, an alumilum hub, a ten horsepower Tecumseh engine, and screws and pulleys.

The purchase of the kit was made possible by a donation of $1,060 from the local parent chapter of SME 275. The local chapter 275 has been a big supporter of the ISU student chapter 089.

A team of 15 ISU students began working on the Hovercraft project in January 2004. ''A lot of SME guys are graduating, and we wanted to do something before we were gone." Dave Oelschlager, a senior from Columbia City, Ind ., said.

The students downloaded a set of hovercraft blueprints from www .DiscoverHover.org, the website of the World Hovercraft Organization's International School Hovercraft Program, which provides hovercraft plans and instructions at no charge to students, schools and youth organizations. The ISU team then began a redesign of the original blueprints. According to Oelschlager, who is heavily involved in the project, the redesigning of the blueprints took well over 70 hours of volunteer work. Through the use of AutoCAD and ProE, junior high and high school students can easily understand the new blueprints.

Rob Wilson, Neotcric Hovercraft's Technical Director in Australia, is currently reviewing the new plans for accuracy.

“ISU playing a key role in taking the Discover-I-lover Build-a-Hovercraft School Project to schools and students throughout the world by creating a prototype project for the program and improving the original plans,” said the marketing director for Neoteric Hovercraft and the World Hovercraft Organization.

James Smallwood, chairperson and professor of manufacturing/construction technology and Mike Hayden, professor of industrial/mechanical technology, serve as advisers to the students.

“When an organization does a project like this, it gives students additional real -life, problem-solving skills;” Smallwood said. “They are not only doing the work; they are managing a project. We've learned that all else being equal, a manager who has experience in the technology behind a project is a better manager than one who does not have that experience, we're preparing managers.”

Hovercraft operates by floating on a cushion of air over land, water, ice, and mud. “They're very environmentally friendly, with little impact,” Herring continued. “A Hovercraft can be flown over a nest of bird 's eggs without harming them.”

Figure 7 (Hovercraft of another student's project) [8]

The photo was taken at the end of spring semester, 2004. Students were able to get the craft running around Campus, but it still needs to be painted and fine-tuned. [8]

2/ A hovercraft, as known by the world today, is a type of an air-cushion vehicle (ACV) with the capability of traveling on both lands and water. It had been in use for over half a century and gone through various modifications since then, to apply its unique features to modern day transportation needs.

We, a team of 2nd year engineering undergraduates of the University of Moratuwa, Department of Mechanical Engineering, would like to inaugurate this transportation technology to Sri Lanka by proposing a project to design and build a single passenger hovercraft.

The designing and adding modifications to the hovercraft will be carried out in such a way that it will best suit the transportation needs and topography of Sri Lanka.

The project will be conducted under the supervision of:

● Dr. Palitha Dasanayake (Head of Department – Mechanical Engineering)

● Dr. Nirosh Jayaweera (Senior lecturer)

● Mr. Sasiranga De Silva (Lecturer)

As engineering undergraduates of DOME UoM, Our goal is to conduct a study on Hovercraft technology and ultimately design and manufacture a cost effective working model, using the knowledge and skills of the finest undergraduate talent in the island and the facilities of our very own country.

Objectives:

● To design and build a hovercraft to be presented to the exhibitions.

● To analyze the potential capabilities of designing and building hovercrafts locally and to assess the advantages of such a conveyance to Sri Lanka.

● To identify potential research areas related to hovercraft technology and implement upon completion of the project.

● To introduce an energy-efficient way of travelling and search for other utilities of implementing this technology.

● To understand the applications of basic engineering principles learnt as a mechanical engineering student and to improve professional and teamwork skills.

● To get hands on experience with various manufacturing methods and engineering tools.

Chapter 3

System Design

3.1 Design Constraints

3.2 Design Methodology

3.3 Product Subsystems and Components

3.4 Implementation

3.5 Engineering Standards

3.1 Design Constraints:

The hovercraft is a vehicle that can be used on all types of land and water. In order to achieve a successful result of the hovercraft, you will need a good quality design. Using a CAD such as SOLIDWORKS will definitely assist in achieving the target. Therefore, there are multiple parameters need to be considered during designing as follow:

- The engine, horse power, torque, and rpm.
- The full size and weight of hovercraft body.
- Thrust duct design.
- The material for the hovercraft.
- The air channel to the skirt.
- The maximum load for hovercraft.

These are some of the important factors which one needs to be considered for designing a hovercraft. Material selection is very important, it needs to be as mush strong and light as possible to assure that lifting process is guaranteed. The sizing and measuring for (height, weight, length) are crucial to run-up your assembly in SOLIDWORKS program. In the university lab, material properties can be tested for quality purposes. In addition, the design should be balanced by measuring the dimensions of the hovercraft with respect to the engines that will be assembled on it. Both left and thrust engines will be important in balancing the hovercraft, apart from their main objectives. Our hovercraft project recommended design specification shown in (Table3.1)

Capacity	1 person
Payload	up to 168 kg
Speed	10-15 km/h
Length	2.00 m
Width	1.00 m
Wet Weight	88 kg
Dry Weight	85 kg
Thrust Engine: **Wet Weight** **Dry Weight**	5.5 HP horizontal shaft 16 kg 14 kg
Lift Engine: **Wet Weight** **Dry Weight**	5.5 HP vertical shaft 9.5kg 8.5kg
Construction Method	Wood and plastic polythene

Construction Time	3 months

The payload is the total weight of the hovercraft including a 80 kg person on it. Payload involves the weight of base (wood material, approximately 25 kg), left and thrust engines, skirt, propellers (1.5kg) and other small parts (expected 20kg in total).

The hovercraft is expected to reach a minimum speed of 10-15 km/hr due to the size of the thrust engine. On the one hand, the team decided to minimize the dimensions of the design as much possible as they could without effecting the strength of the chassis nor the balance, therefore, it would be length of 2m by with of 1m.

In terms of its wet weight without considering the person weight would be 88kg. That's including the fluids inside the engines. However, it would be approximated to be 85 kg in a complete dry weight. Roughly 1 litter for every 1 kg. The team have decided to select wood for most of their design project in order to reduce the total weight, ensure a lifting process by increasing the pressure inside the cushion skirt. We will use the full time of the deadline of the project, which is 3 months, to maximize our results efficiencies.

Choosing the size of thrust and lift engines will be explained in details in the calculations part in this chapter.

3.2 Design Methodology:

Before the designing process of hovercraft began, we determined the most important principles to structure our hovercraft. We consider the following points as criteria guidance:

- Availability of materials

- Good performance

- Economical

The performance of hovercraft is depend on the material selection and function for each part. Materials and parts were selected based on their availability and easy to use in repair and maintenance when facing problem. The main principle governing process was the guide line to achieve our aim for successful project. The most important factor is minimizing the friction between the hovercraft structure and the ground. On other hand, material cost played a large factor on hovercraft designing. After that, we determined the type and specifications of the hovercraft designing based on factors below (Table 3.2). Most of our selections are locals, except the propellers.

The team would be required to order it from overseas, as no factory in the Eastern Province is willing to make these kinds of parts. On the other hand, lifting the chassis is more critical than having a high speed from the thrust engine, that is why limit speed is considered optional.

(Table 3.2 Specifications based on Factors)

Factors	**Factor Priority**	**Description**
Skirt	High	Minimize friction between hovercraft and floor
Lift Engine	High	Generate air cushion in the skirt
Speed control	Low	

Limit speed	Optional	
Low weight	High	Can't exceed person weight (80kg)
Low cost	medium	3000 – 4000 SAR
Durability	High	Both Engines

By applying the previous principles and factors, we expecting to have a successful project has been designed to perform the required functions.

Starting with the engine, we checked the previous researches and studies in addition to home hovercraft manufacturer. We reached to the fact that all hovercraft of the same size can be designed with one or two engines for both functions (thrust and lift), use a horizontal shaft engine with 5.5HP gasoline engine with 3000 rpm for thrust and a vertical shaft engine with 5.5 HP gasoline engine with 3000-4000 rpm for lift. By using SolidWorks program, we were able to apply our design using real dimensions. That afforded valuable information of how the hovercraft will be. Also, it enabled manufacture team to correctly create all necessary pieces so that we were able to avoid unnecessary engine vibrations that result from wrong measurements of the pushing that connects shafts to the engine. On the hand, we used rubber sheet between the engine and engine base to minimize the vibration.

Moreover, through the team's efforts in looking for most suitable building materials, we found that one manufacturer was able to contract wood thickness, supporting it with a high-density foam board, which provided a lighter weight. The team was able to find that type of waterproof foam boards that effectively was used for isolation purposes. On the other hand, the martial used for the skirt was the hardest challenge of the project, we selected 250 China type from the market. The martial originally used for skirt building which is also used for tent manufacture.

It was easy to find horizontal thrust engine from the market, but it was the opposite for a suitable vertical engine. Moreover, the team came up with an excellent solution by buying a second hand mowing machine, dissemble it, and use its engine.

Thrust duct is the most critical part of a hovercraft. It was important to learn about past experiments of thrust duct designs. Thus, the strategy used for designing thrust duct is to use nozzle shaped like wooden boards. The design was completed through SolidWorks program. It depended on using foam spray with a wooden object then it is arranged in the figure attached.

3.2 Theoretical Calculations:

$D_{in} = 0.92\ m$, $D_{out} = 0.92\ m$, $R_{out} = \frac{1}{2} D_{in} = \frac{1}{2}(0.92) = 0.46$ m

Where:

D_{in} : Duct entrance diameter.

D_{out} : Duct outer diameter.

- **Thrust Calculation:**

$$F\ \Delta t = \Delta \vec{p} \quad , \quad \vec{p} = m\vec{V}$$

$$F = \left(\frac{m}{\Delta t}\right)(V_f - V_i) \quad , \quad \text{where,} \quad V_f = 0 \ \ and \ \ V_f = V_{avg}$$

$$F = \dot{m}\ (V_{avg})$$

$$F = \rho \dot{V}\ (V_{avg}) \text{ .... Equation (3.1)}$$

Where:

$\vec{p}$: Linear Momentum

V_{avg} : Average Measurement Velocity

ρ : Density of Air = 1.03

V : Volume flow Rate

Furthermore, the volume rate is required to be calculated to get the Thrust force and the equation is per the follow:

$$\text{Volume rate } (\dot{V}) = V_{avg} * A \text{ .... Equation (3.2)}$$

***Where*:**

V_{avg} : Measured velocity by an air velocity measurement instrument tool.

A : Area of the exit for thrust

However, the volume rate result will be calculated in table 3.3 when the calculation of the exit area that is suggested for the duct design is done.

- **Area for the exit air calculation:**

$$A \ = \ \pi \ R_{out}^2 \ \ldots\ldots\ldots\ldots\ldots \text{Equation (3.3)}$$

$$A \ = \ \pi \ (0.46^2) = 0.6647 \ m^2$$

Where:

A : Area of the exit for thrust

R_{out} : The exit radius of thrust duct

(***Table 3.3:*** Comparison between measured and theoretical Volume Rate and Percent of Error)

RPM	Measured V_{avg}	Theoretical calculated $\dot{V}$			Measured $\dot{V}$	Error %
		$V_{avg} * A$	m^3/s	cfm		
1000	23	23*0.6647	15.2881	32393.6494	31476.50	2.91
2000	30	30*0.6647	19.9410	42252.5861	39445.55	7.11
3000	36	36*0.6647	23.9292	50703.1034	42943.10	15.30

Table (3.3) is showing the calculating of the volume rate by multiply the measurement velocity to the area of the exit duct as mentioned in equation (3.3). Furthermore, the error included in the table is to determine the percentage differences between the measured volume rate and the theoretical volume rate calculation.

Nonetheless, the force that is required to help out with design and the materials to be chosen most be applied by using the equation (3.1) and the calculations are shown below.

(***Table 3.4:*** Thrust force Calculation)

RPM	$\dot{V}$	V_{avg}	Thrust force N
1000	15.2881	23	362.175
2000	19.9410	30	616.177
3000	23.9292	36	887.295

- ❖ **The needed power for the Hovercraft to be lifted is depending on the following:**

Work (kw) = Cushion Pressure $(\boldsymbol{pa})$ $*$ Volume rate of cushion $(\frac{\boldsymbol{m^3}}{\boldsymbol{s}})$ ……..…Equation(3.4)

After researching for the right cushion to help out with.

#First needed is the Cushion Pressure in (pa):

Length = 2.00 m, Width = 1.00 m, Gross Mass = 180 kg

- ➢ **Cushion Pressure $(\boldsymbol{pa})$** = Gross weight (N) \ Cushion Area m^2………..…Equation (3.5)
  - **Gross weight (N)** = m*g ……………………………………......…..…Equation (3.6)

    → **Gross weight (N) = 180 $*$ 9.81= 1765.8 N**
  - **Cushion Area** = Length $*$ Width ………………………….……………...Equation (3.7)

    → **Cushion Area = 2* 1 = 2 $\boldsymbol{m^2}$**

Cushion pressure: the amount of the pressure produced by the lift engine to the skirt.

Gross weight: overall wright.

Cushion area: the total area of hovercraft's skirt.

Equation (3.5) will be helpful to determine the cushion pressure calculation:

- ❖ **Cushion Pressure (pa)** = $\frac{\mathbf{1765.8}}{\mathbf{2}}$ **= 882.9 pa**

Volume rate of cushion in ($\frac{m^3}{s}$) calculation:

 Volume rate of cushion ($\frac{m^3}{s}$) = Total Hover Gap Area (m^2) $*$Velocity of Air($\frac{m}{s}$). Equation (3.8)

- **Total Hover Gap Area =** Lift Parameter $*$ Air-gap………………. Equation (3.9)

-Where total hover gap area: is the total area that the air released out beneath the hovercraft.

- **Lift Parameter =** (2 $*$ Length) + (2 $*$ Width) ……………………Equation (3.10)

  → **Lift Parameter = 5.3125**

-Where lift parameter indicates the overall parameter of the hovercraft

- **Air-gap:** the lift gap between the hovercraft and the ground that will accrues after the theoretical calculation which is = $\mathbf{0.072}\ \boldsymbol{m^2}$

Using the equation (3.8) we can determine the hover gap area

- **Total Hover Gap Area** = 5.3125 m * 0.072 m = 0.3825 m^2

❖ **Volume rate of cushion** ($\frac{m^3}{s}$) = Total Hover Gap Area $*$Velocity of Air($\frac{m}{s}$)

= 0.072 $*$ 13.055= 0.94 ($\frac{m^3}{s}$)

Since the majority of companies are using an imperial standards for their equipment we had to convert the (Volume rate of Cashion) from ($\frac{m^3}{s}$) to (cfm) we shall use the following equation:

[Volume rate of cushion(cfm) = Volume rate of cushion ($\frac{m^3}{s}$) $*$ 2118.88]

Work = [Cushion Pressure (pa) $*$ Volume rate of Cushion] ………..…..…. Equation (3.12)

To convert the work into (kw), we shall multiply the result by (10^{-3})

the, it should be dived by the fan's Coefficient friction **= (0.0038)**

➢ **Work (kw)** = [882.9(pa) $*$ 0.94 ($\frac{m^3}{s}$)] x 0.0038 = 3.206 kw

Since the engine are all in horse power we shall convert the work result as per below equation, with multiplying 1.341:

Work (HP) = Work (kw) $*$ = 3.206 * 1.341 = 4.3 HP

3.3 Product Subsystems and Components:

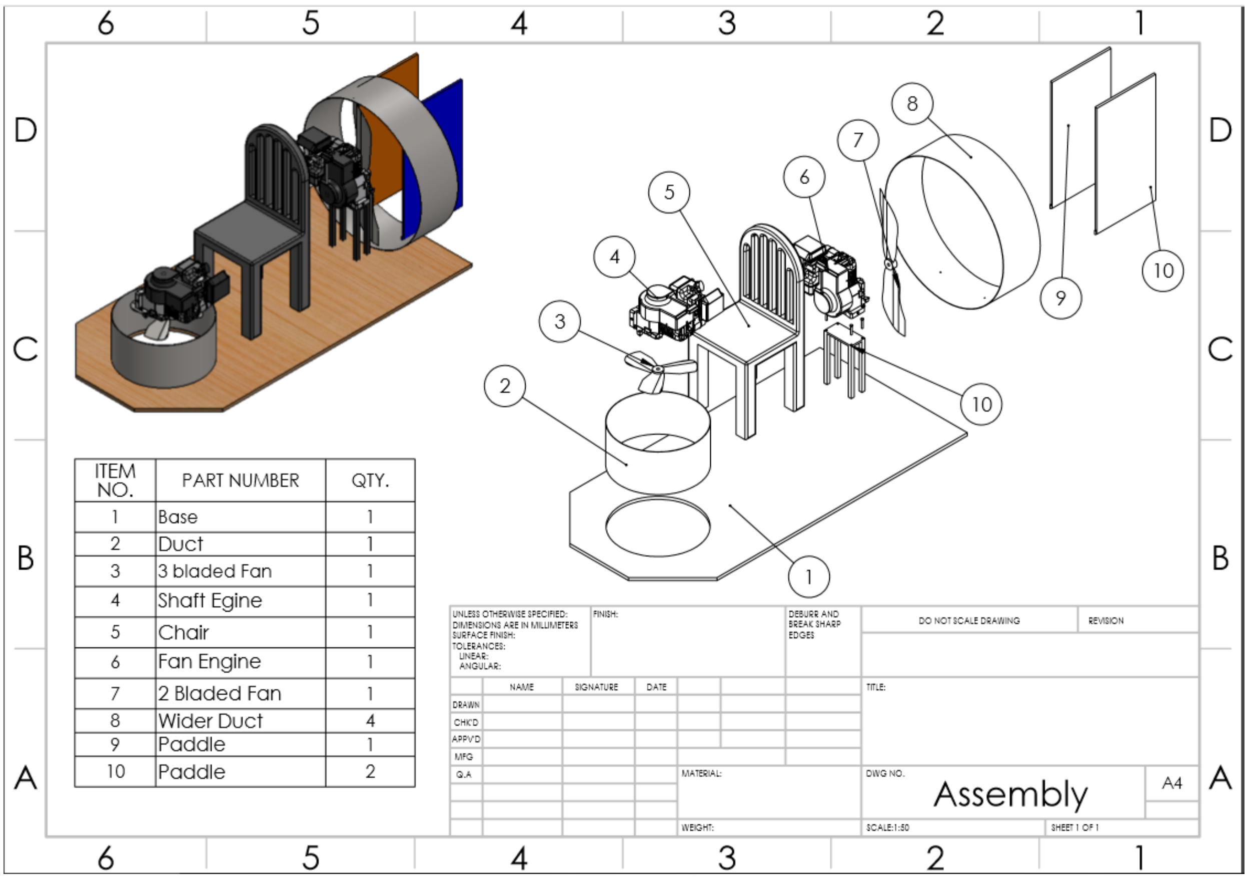


Figure 3.3 (Components of Hovercraft)

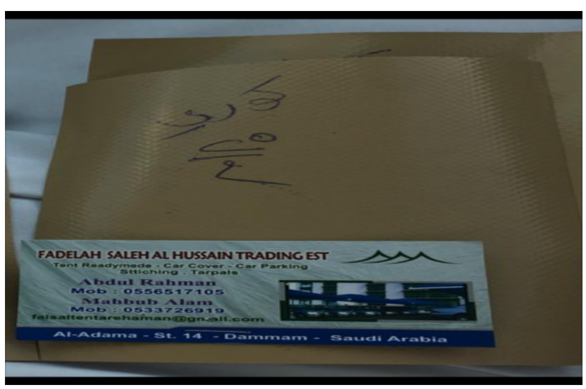
Table 3.6: Type pf Material of each component

ITEM NO	PARTS	MATERIAL
1	Base (chassis)	Plywood Indonesia
2	Lift Duct	

		Galvanized sheet
3	Propeller, 16 in	wood
4	Lift engine	steel
5	Hover seat	wood
6	Thrust Engine	steel
7	Propeller, 32 in	plastic
8	Thrust duct	steel
9, 10	rudder	Wood

There are other components, which are not indicated in the CAD, as it is difficult to illustrate them, however, all the components are mentioned in details below:

- Skirt is the clothing cover that grants air cushion to be maintained.



A sample of skirt that was chosen for the project

The skirt is fixed at the edges of chassis' perimeter holds and allow enough air mass and pressure beneath the chassis granting it to be away from the surface, with the help of supports beneath the chassis, it must be flexible, contour surface irregularities, waves and be water and air proof, and have high resistance to tearing.

Figure 3.4 Hovercrafts supports in the bottom of chassis

- Propeller 32 in: Most hovercraft use an engine with an airplane-type propeller or multi-blade axial fan to push air behind the hovercraft, creating forward thrust. Often, a circular enclosure called a thrust duct is built around the propeller, for safety reasons and protect the propeller from any objects that could hit it.

- Lift Propeller – 16 in: Similarly here, a propeller is connected with the lift engine to push air vertically into the cushion skirt and create a volume.

- Rudder – as we see in figure (3.5) the rudder works as a steering wheel of a any vehicle. The direction of rudder I the primary control of the hovercraft direction by moving opposite direction of the deflecting the air hitting the rudders. Rudders are fitted with the duct in the back of the hovercraft. This will allow control over the normal direction of movement with a maximum degree of 30-45 degrees. It is made of wood in our project same as chassis material.

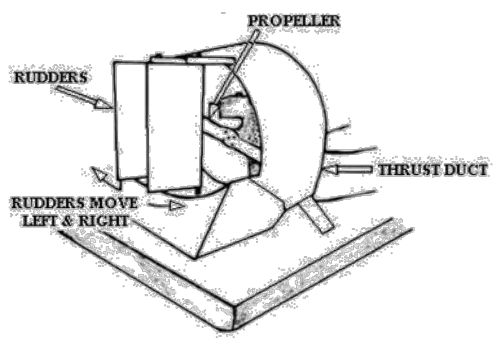


Figure 3.5 (Propeller, Rudders and Thrust duct)

- A Thrust duct – is a propulsion arrangement whereby a mechanical fan, which is a type of propeller, is mounted within a cylindrical shroud or duct. The duct reduces losses in thrust from the tips of the props, and varying the cross-section of the duct allows the designer to advantageously affect the velocity and pressure of the airflow according to Bernoulli's Principle. The thrust duct made from the wood type.
- Hover seat – Its for the convenience of the hovercraft driver and be able to control the mechanism properly.
- Thrust engine – it has a main shaft which is mounted a compressor and a turbine. It's

connected to the thrust system. The engine was selected due to less weight comparing other engine and more power as provide 5.5 HP at 3100 RPM.

- Lift engine – it is a vertical shaft engine with 5.5 HP

3.4: Implementation:

After defining the specification of each part on the hovercraft, we then move the assembly and implementation part in order to get to the final shape as shown in the CAD figure. First of all, we will discuss the base part (chassis) the part used for this is called Indonesian plywood with a thickness of 16mm. The plywood is strong enough and thick enough to hold the person with the rest of the material, such as both engines and propeller, and the person himself. The below figure shows and exploded view of the hovercraft assembled before the implementation. At the same time, after fully preparing the wood base, we then move to a new part which is the engine brackets. The engine brackets will be connected to the wood base where between them there will be a rubber bracket to decrease the vibration of the engines. After creating the engine brackets, we then install the bracket to the wood base, and then install the engines on them. After installing the engines, we then install the fans to the engines. After checking the engines and fans, we then move to the installation of the skirt, the skirt was pinned to the wooden where it is drilled to it by a screw and nut, and then sealed with a type of silicon that is water proof and has a high point of adhesiveness.

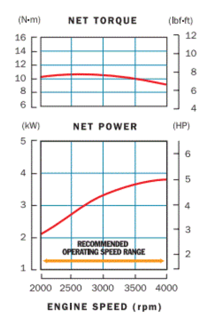
3.5 Engineering Standards:

Lift Engine: It follows the Honda Engineering Standards. Currently not Available in KSA as a resource, but will be provided within the project duration.

Model	Shipping Weight	Crankshaft	Cranckshaft Extension			
1018	29	691455	Tapped 3/8-24, WK & Keyway, 7/8" dia			
Dimension	Starter Position	Heavy Flywheel	Governor	Control	Fuel tank size	Speed (RPM)
1-13/16(b)	6	X	M	R/MF	1.6	3100

Thrust engine: It follows the Honda Engineering Standards. Currently not Available in KSA as a resource, but will be provided within the project duration.

Engine Type	Air-cooled, 4-Stroke, OHV, single cylinder
Bore x Stroke	2.7" x 1.8" (68 x 45 mm)
Displacement	9.9 cu in (163 cm3)
Compression Ratio	9.0 : 1
Net Power (kW/rpm)*	4.8 hp (3.6 kW) at 3,600 rpm
Net Torque*	7.6 lbs ft (10.3 Nm) at 2,500 rpm
PTO Shaft Rotation	Counterclockwise (from PTO shaft side)
Ignition System	Transistor Magneto
Starting System	Recoil & Electric Starter
Carburetor	Butterfly
Lubrication System	Splash
Governor System	Mechanical
Air Cleaner	Dual Element
Oil Capacity	0.61 US qt (0.58 L)
Fuel Tank Capacity (liter)	3.3 US qt (3.1 L)
Evaporative Emissions	Low permeation hose and purge joint provided
Exhaust Emissions	Certified for use in all 50 states
Dimensions (L x W x H) Q-Shaft	12.2" (312 mm) x 14.3" (362 mm) x 13.6" (346 mm)
Dry Weight	33 lbs (15.1 kg)



Propeller:

- Propellers: PREMIUM MATERIAL: Made of Premium Top Grade German Pollmeier Beechwood Lumber. It is excellent for minimal elongation, breakpoint and distortion; therefore, it is the best for making Wooden Model Airplane Propellers.
- CNC DIGITAL IMAGING: CNC digital imaging process ensures consistent quality in diameter, propeller blade profile and pitch which are all crucial for RC aircraft performance.

- PRE-BALANCED*: Each Xoar prop is manually finished to reach perfect surface smoothness. It is balanced both horizontally and vertically for minimal vibration caused by airplane propeller.
- SPEC: Diameter: 32 in | Pitch: 10 | Weight: 325g | Shaft Diameter: 10mm | Type: Tractor

Skirt:

Property and usual symbol	*Brief definition*	*Common units*	*Some standards relevant to determination in plastics*	*Typical values or value ranges for PVC*[a]	
				Rigid PVC	*Flexible PVC*
Density ρ	Mass of a unit volume. For practical purposes numerically equal to relative density (also sometimes called specific gravity), which is the ratio of the density of a material to that of water at the same temperature.	kg m^{-3} g cm^{-3} lb in^{-3} lb ft^{-3}	ISO/R 1183-1970; BS 2782: Part 6: Methods 620A–D: 1980; BS 4618: Section 5.1: 1970; ASTM D 792-66 (1979) (Displacement method); ASTM D 1505-68 (1979) (Density gradient tube); DIN 53 479-1976	M; S: 1·30–1·45 g cm^{-3} M(G): approx 1·5 g cm^{-3} F: approx 1·4 g cm^{-3} PVC homopolymer: 1·4 g cm^{-3}	M: 1·10–1·35 g cm^{-3}
Tensile strength $\sigma_T{}^b$	Maximum stress which the material will withstand before failure (yield or break) NB Comments on common types of failure in strength tests are given in BS 4618: Section 1.3: 1975	N m^{-2} (= Pa); lbf in^{-2} (psi); kgf cm^{-2}; *For fibres:* g per denier, *or* g per tex	ISO/R 527-1966; ISO/R 1184-1970 (for films); BS 2782: Part 3: Methods 320 A to F: 1976 Methods 326 A to C: 1977 (for films); ASTM D 638–82; ASTM D 759-66 (1976) (at low and elevated temperatures); ASTM D 882-81 (for thin sheet and films); ASTM D 1708-79 (microtensile specimens);	M: 31–60 MPa (BS 2782 *or* ASTM D 638)[c] M(G): approx 110 MPa (ASTM D 638) S: 38–45 MPa F: 2·7–3·0 g per denier (= 330–370 MPa approx)	M (and other compounds): 10–25 MPa (BS 2782) S: 15–21 MPa (ASTM D 882)

Chapter 4:
System Testing and Analysis

4.1 Experimental Setup, Sensors and data acquisition system

4.2 Results, Analysis and Discussion

4.1 Experimental Setup, Sensors and data acquisition system

After assembly, the team started to collect data through various equipment. First of all the use of tachometer is used where the revolution of each engine was collected in different settings, such as idle, and full throttle, afterwards, the use of the anemometer to collect the values of flowrate for both the lift and thrust engine. As for sensors, and gauges we were not able to find gauges suitable for our set up to obtain the experimental value of the pressure within the skirt. In addition, weights were used to determine the best suitable weight for the hover craft to a carry a single person.

Although many problems surfaced when working on the lift mechanism, as the weight distribution of the hovercraft was not completely balanced, therefore, it created a degree of floatation where the skirt was not able to float the area surrounding the thrust engine. As a result, the skirt was changed numerous times based on trial and error to increase the height of floatation around the thrust engine. In addition, another problem surfaced is the leakage of air from the skirt through areas were leakage was not intended to happen, where the previous set up of the skirt was having the wooden columns stapled to the skirt and hovercraft chassis. As a result, wooden columns are disregarded and then changed with a strong adhesive tape that showed to be effective in eliminating air leakage, therefore, all air are flowing through the custom air gap made.

4.2 Results, Analysis and Discussion:

The aim of the test is to show how effect our design for the thrust and how we can run smoothly. To achieve a good result, we started conduct some meetings at the workshop nearby Dammam, Eastern Province, Kingdom of Saudi Arabia. We used some tools we purchase from outside of the Kingdom:

Devices that uses in the project:

Tachometer: measuring the RPM.

Digital Anemometer: to measure the velocity of the air and the air flow.

Table 4.2 (Actual testing result using the proper equipment at 1000 RPM)

RPM	1000
Outside temperature C	22
Humidity (%)	15
Wind speed (Km/h)	29
Air flow (cfm)	31476.50
Area of flow (m^2)	0.6647
Air velocity (m/s)	23

Table 4.3 (Actual testing result using the proper equipment at 2000 RPM)

RPM	2000
Outside temperature C	22
Humidity (%)	15
Wind speed (Km/h)	29
Air flow (cfm)	39445.55
Area of flow (m^2)	0.6647
Air velocity (m/s)	30

Table 4.4 (Actual testing result using the proper equipment at 3000 RPM)

RPM	**3000**
Outside temperature C□	**22**
Humidity (%)	**15**
Wind speed (Km/h)	**29**
Air flow (cfm)	**42943.10**
Area of flow (m^2)	**0.6647**
Air velocity (m/s)	**36**

Discussion

The above table's shows significant increase on the main parameters of the hovercraft. By increasing the RPM speed of the engine the values of the vibration showing increase, in order to avoid that we go into the process of finding High Pressure Rubber (HPR) it will do the job of reducing the vibration and stable the Engine.

Chapter 5:
System Testing and Analysis

5.1 Project Plan

5.2 Contribution of Team Member

5.3 Project Execution Monitoring

5.4 Challenges and Decision Making

5.5 Bill of Material

5.1 Project Plan:

The team consisted of four members and were waiting for an opportunity to work together in a remarkable project. The members known each other since 2015 from the start of university journey, and worked together in variable projects with different disciplines. Thus, every member was willing to apply of their skills and mechanical knowledge into the senior project. As a result, we were all aware of each other's capabilities, strengths, skills and knowledge. Based on it, we held a thoughtful meeting before the start of the semester to vote and select a leader among us and that was Saad Al-Ajmi.

After several seminars and meetings with our advisor Dr. Javanroodi, the team decided to choose the Hovercraft project. We choose this particular project as the previous senior project team failed to assemble the hovercraft within the given period, so we saw the opportunity to work on this challenging project from the scratch all the way up.

By contacting the previous project team, we noted down the obstacles they had faced during their projects the reasons behind failures. Their two main difficulties were choosing the suitable and availability of the project materials from the market, which some of them were delivered to us internationally that meets engineering standards. The other concern was choosing a strategic location that goes with the project inquiries. Luckily, we found a carpentry workshop in Thoqbah, only 20 minutes drive from PMU. The table below (Table 5.1) shows a detailed process of the hovercraft project along with the tasks:

	ACTIVITY	Tasks	Responsible	Start date	Due date	Days to Complete
Chapter 1: Introduction	Project allocation + introduction	Project Definition	Saad, Omar, Faris & Hassan	13-Sep-18	30-Sep-18	17
		Project Objectives				
		Project Specifications				
		Applications				
Chapter 2: Literature Review	Literature Review	Project background	Saad, Omar, Faris & Hassan	13-Sep-18	30-Sep-18	17
		Previous Work				
		Comparative Study				
Chapter 3: System Design	Design	Design Constraints and Design Methodology	Omar + Saad	16-Sep-18	30-Sep-18	14
	Equipment and material selection (3.4)	select the appropriate items	Faris & Hassan	16-Sep-18	30-Sep-18	14
	Theoretical Calculations	Main calculations required detailed calculations to our design.	Saad, Omar, Faris & Hassan	16-Sep-18	7-Oct-18	21

	Prototype initial parts	Find main suitable parts from the market (engines & skirt)	Faris & Hassan	13-Sep-18	23-Sep-18	10
	Design specifications & CAD	Material selections, fabrications of chassis	Saad, Omar, Faris & Hassan	23-Sep-18	20-Oct-18	27
	Order international parts	Purchase suitable Propeller (10 pitch)	Faris	20-Sep-18	20-Oct-18	30
	Visit workshop	Assemble Parts	Saad, Omar, Faris & Hassan	20-Oct-18	11-Nov-18	21
Chapter 4: System Testing and Analysis	Testing and analysis	Experimental Setup and data acquisition system	All Team	11-Nov-18	29-Nov-18	18
		Results, Analysis and Discussion				
Chapter 5 & 6: Project Management and Project Analysis	Chapter 5: Project Management	Project Plan	Saad & Faris	11-Nov-18	29-Nov-18	18
		Contribution of Team Members				
		Project Execution Monitoring				
		Challenges and Decision Making				
		Project Bill of Materials and Budget				
	Chapter 6: Project Analysis	Life-long Learning	Omar & Hassan	11-Nov-18	29-Nov-18	18
		Impact of Engineering Solutions				

		Contemporary Issues Addressed				
Report submission	Final Report	Completion of report	All Team	20-Nov-18	2-Dec-18	12
	Presentation preparation	Making Slides, practice & present	All Team	20-Nov-18	2-Dec-18	12
	Booklet	Print the report	Omar	20-Nov-18	2-Dec-18	12
	Banner	Follow rubric	Saad	20-Nov-18	2-Dec-18	12
	Brochure	Follow rubric	Hassan	20-Nov-18	2-Dec-18	12
	Final Presentation	Making the slides	All Team	20-Nov-18	2-Dec-18	12
Monthly progress report		1st progress report	Saad & Faris	Monthly, 1 Day	End of: Sep, Oct, Dec	

5.2 Contribution of Team Member:

Each member was excited to be as much professional as possible and show dedication to the work. However, due to some difficulties with the short time given to deliver each task, the team faced minor lateness that did not impact the progress of the project and tried contain the situation by delegating other members from time to time. All in all, we overcome the complications without reaching the failure edge due to the professionalism and contribution of all members. The leader was keeping a record of the all the tasks that were accomplished and advising them to the team regularly, along with the next agenda to be delivered and assigned to specific members with a deadline. Saad and Faris spent more efforts in the field with the manufacturing and technical side while Omar and Hassan put their hands more into the theoretical and reporting side. However, all team members were aware of each other's process, in order to, avoid lake of understandings and conflicts.

(Table 5.3 Task Distribution)

#	Task	Team member assigned
1	Researching and Writing the project report	Faris Almahamidh Saad Alajmi Hassan Alabbas Omar Alghamdi
2	Group project allocation	Faris Saad Hassan Omar
3	Gantt Chart	Saad Omar
4	Introduction & project objective (report)	Faris Saad
5	Literature review (report)	Omar Hassan
6	System Design (report)	Faris Omar Saad Hassan
7	Project Management	Saad

8	Project analysis	Saad
9	Meet Dr.ROODI regularly	All members
10	CAD-drawing	All members
11	Design and build engine base	All members
12	Design and build lift thrust divider system	All members
13	Choosing material	All members
14	Applying and choosing fan system	Hassan
15	Manufacturing Hovercraft Base	Saad Faris
16	Manufacturing Thrust Duct	Saad Omar
17	Choosing and applying the engine	Saad
18	Measurement and Testing	Omar Hassan
19	Manufacturing Adapters	Faris Saad
20	Manufacturing Rudder	Omar Saad

21	Applying the skirt around the hovercraft	All members
22	Control System	Hassan

The above table 5.3 explains all the tasks and every member that work on the task.

5.3 Project Execution Monitoring:

The members of the team meets at least once a week during the first 2 months, then meets almost every day during the last month. Everything was tracked, updated and communicated through the social App, WhatsApp or through teleconference, as the leader is living in Jubail and is brave enough to risk his life driving every day to meet at university. We had different timetables and was hard to meet up between the classes times. On the other hand, every member was supportive, enthusiastic and eager to give a hand whoever is in need. We have known each other since 2015 and there is a strong chemistry between us in understanding and executing the tasks with fewer complications. Whenever there is a situation that needs an advice, the team would directly have a contact with the advisor to clear things out and move on.

5.4 Challenges and Decision Making:

The team suffered during the project in many aspects. One of the issues we had was finding the right material that is efficient and could fit into our expectations, particularly in the design in a time manner. The whole period was a 4 month in total, including other subjects, assignments and projects that we take during the semester. Moreover, the team managed to be positive and consistent in managing their duties and private responsibilities for the sake of making this project successful.

Another difficulty was that the leader used to live in Jubail Industrial city, which was 120 km away from PMU. It required him extra efforts to make sure that this senior project is on the right track, so it made him under a severe pressure driving almost everyday forwards and backward.

The size of the project was considered the biggest prototype among other senior projects from PMU this semester and required a lot of attentions and concentrations especially in choosing the materials. Initially, our main target was to make sure that the lifting system works. However, it was costly to purchase a list engine, and we bought a second hand engine and required a 6.7 hp, but it turned out to be a 5.5 hp and it was too late and expensive to purchase another engine. As a result, we changed our assumptions and calculations just to make sure it lift the chassis with less weight on the system (less that 80 kg of the rider's weight).

Another obstacle we had was following the engineering standards precisely. Fans and skirt were difficult to chase their engineering standards as we gouht them locally from shops that do not had any intentions in keeping a record of their standards. Their main goal was selling the product, not informing their clients with the products' details. We carried on using the lift fan and skirt in the assemble because the project was working. In addition, the team tied previously with 4 different types of skirts and fans that accommodate the engineering standards, but they were either broken or teared during testing.

As we are students, paying from our pockets, it was costly to some extent, especially in purchasing the product internationally or several times like the fans and skirts. Fortunately, the members expected a 5000 SR at the beginning of the project and it was close by at the end.

Even though there was a carpentry workshop, there were several manufactures who were biased to their regular customers by giving them a faster service than us. It took longer time than expected from the manufacturer to accommodate our needs, thus, delaying our tasks.

Lastly, it was not a safe place for both keeping our prototype in Thogbah and working there. It is considered a low income neighborhood, where stolen parts occur normally. Working their next to an electric saw with a confined area is against safeness. However, the team had limited options and had to work there with precautions.

The group were suffering with the time of the meeting. One of the members is an employee and he faced many problems to manage his time between his work, classes, and project meetings. The leader tried hard to manage the meeting to be at noon to be flexible for all members. On the other hand, there is another member living outside of our meetings. Also, this member faced a hard situations. We solve this problem to make some of the meetings by an application that is meet all of us together online. Our group did not faced any cooperating problems. The members were divided the work and made the plan early which is in the beginning of the semester. Every member was supporting the other in any needs that happened for the project.

5.5 Bill of Materials:

Table 5.5: Bill of Material

Type	Cost (SAR)
Thrust Engine	766
Lift Engine	1700
Skirts	300
Lift Engine Base	100
Thrust Engine Base	100
Lift Duct	40
Wood Chassis	120
Wood Labor Cost	500
Wood Propellers	720
Lift Propeller Plastic 30 cm	50
Lift Propeller Plastic 39 cm	30
Lift Propeller Plastic	50

39 cm	
Pilot Seat	60
Thread Lock	50
Engine Adapter (x3)	650
Wire Mesh	90
Tachometer	120
Sum	5446

Chapter 6:
Project Analysis

6.1 Life-Long Learning

6.2 Impact of Engineering Solutions

6.3 Contemporary Issues Addressed

6.1 Life-long Learning:

This project assisted us in enlarging the scoop of learning and improves our skills in team management and relates the work to our undergrad studies. We have been working together for many years, but building a hovercraft from scratch is by far the best experience we had as a team. The team went through major challenges that could have affected the process of manufacturing negatively with the limited time given, but we managed to innovative, initiative and cooperative throughout the whole journey. Yes, we had debates and strong arguments on some points, but they were part of the learning spirit and acknowledged each other's opinion. This project by far the longest most dedicated and challenged task during our undergrad studies and the team were rewarded with the completion of the prototype. This could have not been done without the commitment from each member, leadership skills from every member and not waiting for an order from our leader, as if every one of us would have the initiative to deliver the task smoothly. The team kept supporting each other and be positive at the difficult situations.

Also, we set a budget for this project with the limited time given, and strictly speaking, it was crucial to improvise, adapt and overcome for any uncertainties and flows. For instance, had to replace lift fans 5 times and every time tried to minimise the expenses by selecting a suitable fan that can withstand the high RPM without breaking the pedals.

As a result, the team carried out the project and achieved the target by completing the prototype and finish it before the deadline, not exceeding the proposed budget and dividing the loads among us fairly and equally. In addition, the team relied on external resources from journals and websites that are related to hovercraft. During the process of making, we visited various manufacturing workshops and learnt a lot from them, particularly in mechanical engineering concepts.

One example of a major learning is that there are many different types of engines whether they are vertical or horizontal, in addition to, knowing the importance of horsepower and how to relate it to RPM. We managed to order a 6.75 HP lift engine, but it turned out to be a 5.5 HP, so we managed adjusting its racer and increase the RPM manually, in order to achieve a cushion skirt and stabilize the pressure inside the skirt. With every step we made, we would look back to similar projects that were done internationally, understand the differences and build the hovercraft based on the availability of materials from the surrounding market.

6.2 Impact of Engineering Solutions:

When it comes to the impacts that our project achieves, we can divide this achievement into three categories: society, environment, and economy:

6.2.1 Society:

Hovercraft is a very efficient method of transportation at any type of surface, whether it is water and sand surface. Hovercraft is a very simple mechanism that does not require a lot of maintenance nor too much work to be fixed, additionally, easy to control and handle. Hovercraft can be used at harsh situation when it comes to rescuing citizens during a flood. It can used to pick up people who are drowning and safe their lives. Another benefit of hovercraft is transporting equipments quickly at war level. Other uses of the hovercraft is that it can be utilized in a swamp or difficult places for a boat, because the hovercraft is considered smaller that a regular boat, plus, the only thing that touches the water is the skirt, otherwise the engine of a boat could be stuck in the swamp.

6.2.2 Environment:

Hovercraft is considered an environmentally friendly vehicle. This is true when we compare its functionality and efficiency with other types of transportations that uses and burn a lot of fusel fuel like cars and airplanes. This is due to the amount of friction that is produced between the skirt and the land. With minimum friction, it would require less fusel fuel to be burned and pushes the hovercraft forward with the thrust engine, additionally, the size of both lift and thrust engines do not exceed 1.5 litters of petrol. Moreover, with less friction, the amount of noises from the hovercraft is very low, thus, less disturbance to the environment.

6.2.3 Economy:

Following vision 2030’s of Saudi Arabia, the government is focusing on searching other resources to rely on, in order to reduce the excessive use of oil and gas. Thus, with the spread of hovercrafts among the citizens, people will less and less use their cars and reduce filling their tanks regularly. If this project was successful, its cost to manufacture it is very cheap comparing to V8 cars, as a result, the price of purchasing a hovercraft would be much less than buying a new car

6.3 Contemporary Issues Addressed:

There was a huge gap between the students and outside of the university campus. What they learn is not enough to be a real mechanical engineer. Students need these kind of project to clear the gap with their expectations and look for other resources related to their major. In addition, most of the workshops do not support the idea of co-operating with the university standards, all they do is selling their products, there should be a strong link between the university learnings and applications in the field from workshops. Also, Saudi Arabia is missing tool shops that provide all sort of manufacturing equipment’s that can be purchased and utilised at home. The team had to deal with several manufacturers at different locations, in order to make the hovercraft. We could have saved a lot of money, effort and time if we had had our own manufacturing devices. To be honest, we were lucky to find a carpenter, who would keep our prototype for nearly 2 months in his workshop. Another problem we faced is finding the right parts. Some parts had to be shipped from overseas, thus, Saudi Arabia lacks specialised manufactories here to accommodate our needs. However, with Vision 2030, there are hope flags from the government for a better future by taking care of the youth citizens and build more manufactories that fit the development curriculum.

Chapter 7:
Conclusions and Final Recommendations

7.1 Conclusions

7.2 Final Recommendations

7.1 Conclusions

In consolation, we as a team went into the process of designing and manufacturing of one-person hovercraft. Hovercraft is a vehicle which can float in any lands also it is known by Air Cushion Vehicle due to its ability to move by cushion or skirt filled with air. The concept of the hovercraft is simple, starts with a particular kind of wood that has the property in carrying loads attached to a skirt in order to surround the air, which leads to developing pressure under the hovercraft. When it comes to the power system, it runs with a two separate engines connected with one propeller each made of wood and the other is plastic, which generates the power for both thrust and lifts to enable movement. Also, we went into the process of designing the rudder system, which used in steer and directs the thrust air generated by the motor in the required direction.

During this period we spend on this project, we get to know a lot of things that are essential and required to accomplish a successful project. It starts with time management; time plays a big role in this project. Due to the lack of places that supply the required materials for duct and the base, we manage the time between team members to avoid any losing of time and finish the work within the time. Also we get to know how to assemble multiple parts together. It was very difficult process but we did it and preformed the required checks to insure that fit within the standards of the hovercraft. Besides that, we get to know the importance of minimizing the weight and achieve a balanced hovercraft, which is a major part in any design of vehicles.

7.2 Future Recommendations

As a team, we come up with recommendations that lead to have a faster and more durable hovercraft, which give better results:

1- Try to reduce vibration generated by the motor by using some materials to absorb the vibration impacts such as rubber mounts between the engine and the engine mounts. Material is available in the Saudi market however, most stores sell rubber dampers in bulk and bulk price is out of reach with our budget.

2- For fast hovercraft, we recommend to use two engines, one horizontal shaft for thrust and one vertical shaft for the lift to increase the power which leads to more powerful hovercraft which can handle more weight and sliding easily on surfaces.

3- Use an engine with a higher power rating, more than 5.5 HP, to produce a higher amount of air flow with a change of the lift propeller to increase the amount of air flow and reduce the stress of the propeller by a bigger engine. And most importantly, achieve a rate of 80 kg to a carry a person, as our hovercraft has a rating of 40 kg.

4- Change the location of engines, as the current hovercraft has the lift engine at the front end. This has caused a huge imbalance in the hovercraft, as the persons weight and the thrust engine, which is, located the rear end made hovercraft slightly slanted at the rear end. In addition, another point can be stated that it is a safety factor, as it much safer to have both engines behind the pilot rather than having the pilot sit between both engines.

5- Decrease the contact point between the lift propeller and the skirt. During our testing and experimenting procedure is that the nearer the lift propeller to the skirt the better the flow is, as the back pressure is decreased when it becomes nearer to the skirt.

6- Minimize the contact area between the skirt and the ground, as less contact means less friction, numerous ways was tested to decrease friction between the hovercraft and the ground, such as increasing the area of the open skirt where air flows. However, this technique has a limit, if increasing the area could lead to failure of inflation of the hovercraft.

7- Increase the diameter of the lift propeller to have a better airflow in the system. And minimize the excess area between the duct and the lift propeller to decrease the amount of backpressure and more importantly to cancel out any air turbulences in the system.

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Appendix A:
Monthly Progress

Appendix B: Engineering Standards

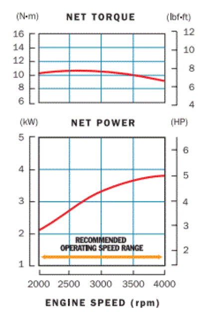
Lift Engine:

Model	Shipping Weight	Crankshaft	Cranckshaft Extension			
1018	29	691455	Tapped 3/8-24, WK & Keyway, 7/8” dia			
Dimension	Starter Position	Heavy Flywheel	Governor	Control	Fuel tank size	Speed (RPM)
1-13/16(b)	6	X	M	R/MF	1.6	3100

Thrust Engine:

GX160

Engine Type	Air-cooled, 4-Stroke, OHV, single cylinder
Bore x Stroke	2.7" x 1.8" (68 x 45 mm)
Displacement	9.9 cu in (163 cm3)
Compression Ratio	9.0 : 1
Net Power (kW/rpm)*	4.8 hp (3.6 kW) at 3,600 rpm
Net Torque*	7.6 lbs ft (10.3 Nm) at 2,500 rpm
PTO Shaft Rotation	Counterclockwise (from PTO shaft side)
Ignition System	Transistor Magneto
Starting System	Recoil & Electric Starter
Carburetor	Butterfly
Lubrication System	Splash
Governor System	Mechanical
Air Cleaner	Dual Element
Oil Capacity	0.61 US qt (0.58 L)
Fuel Tank Capacity (liter)	3.3 US qt (3.1 L)
Evaporative Emissions	Low permeation hose and purge joint provided
Exhaust Emissions	Certified for use in all 50 states
Dimensions (L x W x H) Q-Shaft	12.2" (312 mm) x 14.3" (362 mm) x 13.6" (346 mm)
Dry Weight	33 lbs (15.1 kg)



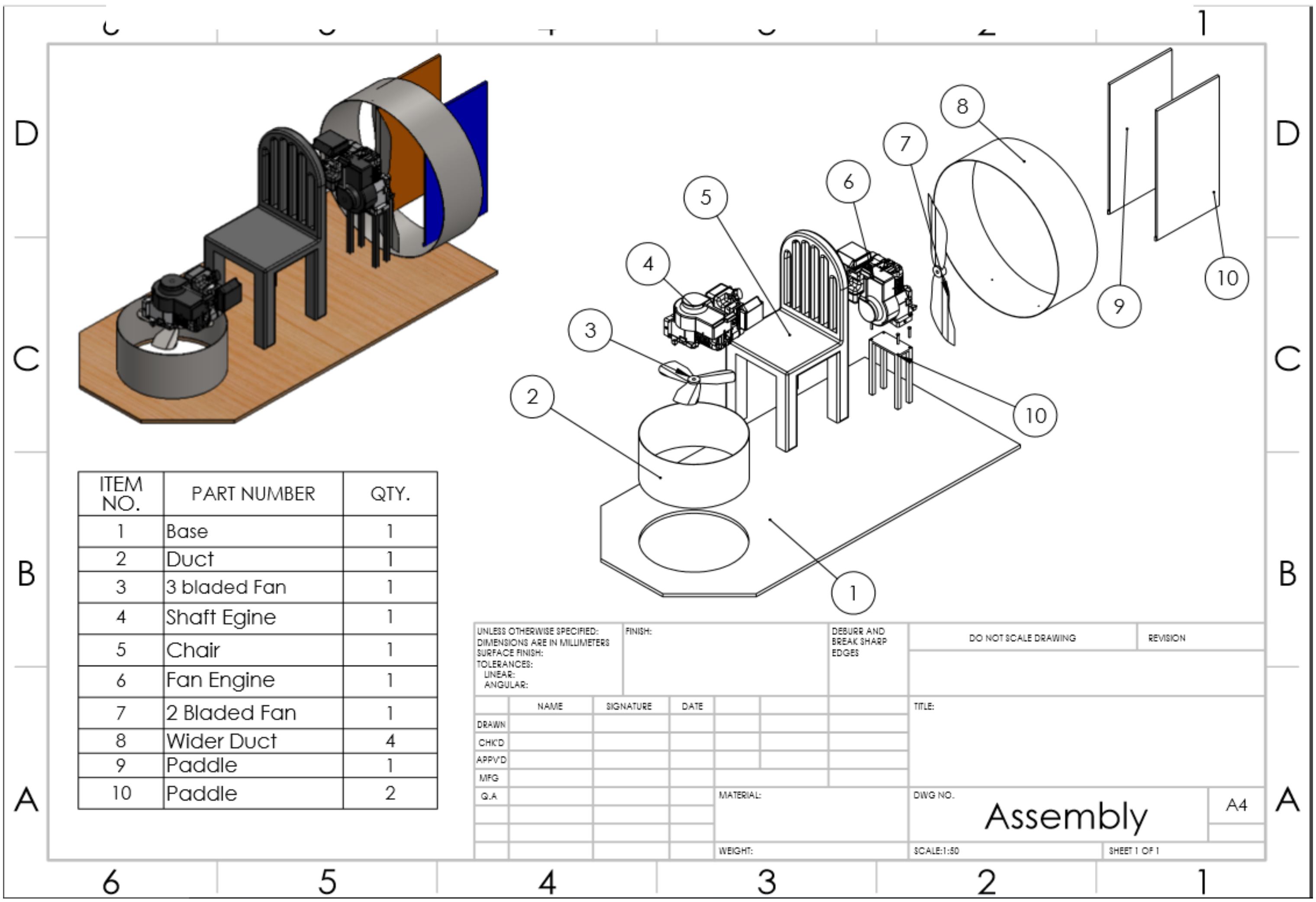
Propeller:

- Propellers: PREMIUM MATERIAL: Made of Premium Top Grade German Pollmeier Beechwood Lumber. It is excellent for minimal elongation, breakpoint and distortion; therefore, it is the best for making Wooden Model Airplane Propellers.
- CNC DIGITAL IMAGING: CNC digital imaging process ensures consistent quality in diameter, propeller blade profile and pitch which are all crucial for RC aircraft performance.
- PRE-BALANCED*: Each Xoar prop is manually finished to reach perfect surface smoothness. It is balanced both horizontally and vertically for minimal vibration caused by airplane propeller.
- SPEC: Diameter: 32 in | Pitch: 10 | Weight: 325g | Shaft Diameter: 10mm | Type: Tractor

Skirt:

Property and usual symbol	*Brief definition*	*Common units*	*Some standards relevant to determination in plastics*	*Typical values or value ranges for PVC*[a]	
				Rigid PVC	*Flexible PVC*
Density ρ	Mass of a unit volume. For practical purposes numerically equal to relative density (also sometimes called specific gravity), which is the ratio of the density of a material to that of water at the same temperature.	kg m^{-3} g cm^{-3} lb in^{-3} lb ft^{-3}	ISO/R 1183-1970; BS 2782: Part 6: Methods 620A–D: 1980; BS 4618: Section 5.1: 1970; ASTM D 792-66 (1979) (Displacement method); ASTM D 1505-68 (1979) (Density gradient tube); DIN 53 479-1976	M; S: 1·30–1·45 g cm^{-3} M(G): approx 1·5 g cm^{-3} F: approx 1·4 g cm^{-3} PVC homopolymer: 1·4 g cm^{-3}	M: 1·10–1·35 g cm^{-3}
Tensile strength σ_T[b]	Maximum stress which the material will withstand before failure (yield or break) NB Comments on common types of failure in strength tests are given in BS 4618: Section 1.3: 1975	N m^{-2} (= Pa); lbf in^{-2} (psi); kgf cm^{-2}; *For fibres:* g per denier, *or* g per tex	ISO/R 527-1966; ISO/R 1184-1970 (for films); BS 2782: Part 3: Methods 320 A to F: 1976 Methods 326 A to C: 1977 (for films); ASTM D 638–82; ASTM D 759-66 (1976) (at low and elevated temperatures); ASTM D 882-81 (for thin sheet and films); ASTM D 1708-79 (microtensile specimens);	M: 31–60 MPa (BS 2782 *or* ASTM D 638)[c] M(G): approx 110 MPa (ASTM D 638) S: 38–45 MPa F: 2·7–3·0 g per denier (= 330–370 MPa approx)	M (and other compounds): 10–25 MPa (BS 2782) S: 15–21 MPa (ASTM D 882)

Appendix C:CAD & Bill of Material



ITEM NO.	PART NUMBER	QTY.
1	Base	1
2	Duct	1
3	3 bladed Fan	1
4	Shaft Egine	1
5	Chair	1
6	Fan Engine	1
7	2 Bladed Fan	1
8	Wider Duct	4
9	Paddle	1
10	Paddle	2

Type	Cost (SAR)
Thrust Engine	766
Lift Engine	1700
Skirts	300
Lift Engine Base	100
Thrust Engine Base	100
Lift Duct	40
Wood Chassis	120
Wood Labor Cost	500
Wood Propellers	720
Lift Propeller Plastic 30 cm	50
Lift Propeller Plastic 39 cm	30
Lift Propeller Plastic 39 cm	50
Pilot Seat	60

Thread Lock	50
Engine Adapter (x3)	650
Wire Mesh	90
Tachometer	120
Sum	5446

Appendix D: Operation Manual

Start up the Hovercraft:

1. Before starting the vehicle, check out the surroundings and run it in places that are clear.
2. Check the general condition of the hovercraft (skirt and rudder)
3. Use the safety googles and earbuds for protection.
4. Check the oil levels in both engines before start's them.
5. Check the rudder system and joint lubrication,
6. Run the thrust engine. Don't increase the RPM Suddenly.
7. Run the lift engine. Don't increase the RPM Suddenly.
8. Drive Safe!

Shut down the Hovercraft:

1- First turn off the lift engine and then wait until the hovercraft landed on ground.

2- Turn off the thrust engine.