# DESIGN OF A WORKING MODEL HOVERCRAFT

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A thesis submitted in fulfillment of the requirements

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# ABSTRACT

This thesis is the design of a small-scale working model hovercraft which providing fully hovercraft basic functions. This final year project carry out by the author to fulfillment the requirement for award the degree of Bachelor Manufacturing Engineering. This designed hovercraft which has two stages of development and included two models. The first model is for PSM 1 and the second and fully functional model is for PSM 2. Basically, the hovercraft design and fabrication process is quite similar to boat, ship, or aircraft design. In this report, I had made the entire analysis requirement, formulas for thrust and lift, drag components calculation and other important parameters to realization the design of the working model hovercraft. On the other hand, this report is aim to provided objective and scope of the research, the literature review study, research methodology, and fabrication process with result analysis and conclusion as part of requirement in submitted the report to PSM supervisor. Although hovercraft research and development is still new technology in Malaysia and no domestic consumption in this technology, but through this project it can help the industry a step further. It is because this project can categorized as successful and working as expected. Finally, I wish this project can carry on research and design development by interest manufacturing students.

# ABSTRAK

Thesis ini mengisarkan tentang pembangunan reka bentuk hoverkraft yang bersaiz kecil dengan menampikan fungsi-fungsi asas sebuah hoverkraft yang mempunyai. Projek tahun akhir ini dijalankan untuk memenuhi syarat penganugerahan Sarjana Muda Kejuruteraan Pembuatan. Proses merekabentuk dan pembangunan model hoverkraft ini terbahagi kepada dua tahap dan melibatkan pembinaan dua model. Model yang pertama adalah untuk PSM 1 dan model yang kedua untuk PSM 2. Secara asasnya, proses merekabentuk dan pembinaan hoverkraft adalah lebih kurang sama dengan bot, kapal, atau pesawat. Di dalam laporan ini, saya telah membuat semua analisis yang diperlukan dan menggunakan beberapa formula bagi pengiraan daya tujah, daya angkat, komponen seretan dan beberapa parameter penting yang lain bagi merealisasikan rekabentuk model kenderaan kusyen udara ini. Dengan ini, matlamat laporan ini adalah untuk menyediakan objectif dan projek skop, kajian literature, cara-cara yang diperlukan, pembinaan dan analisa-analisa dengan kesimpulan sebagai sebahagian daripada keperluan untuk laporan yang perlu dihantar kepada penyelia PSM. Walaupun, penyelidikan dan rekabentuk pembangunan hoverkraft adalah sesuatu yang masih baru di Malaysia dan tiada lagi kegunaan secara domestic di sini, tetapi melalui pembangunan projek ini, ianya akan membantu industry in selangkah kehadapan kerana projek ini adalah boleh dikategorikan sebagai berjaya dan berfungsi seperti yang dijangkakan. Akhirnya, saya berharap projek ini boleh terus dikajikan oleh pelajar yang berminat dalam bidang kejuruteraan pembuatan.

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# LIST OF SYMBOLS

| | |
|---|---|
| F | Force |
| h | Clearance between the ground to the bottom of skirt |
| A | Area of skirt |
| $\rho_{air}$ | Density of air |
| $\dot{m}$ | Mass flow rate |
| $\pi$ | pi |
| $\rho_{water}$ | Density of water |
| Q | The volumetric flow rate |
| D | Diameter of propeller |
| L | Length of hovercraft |
| W | Width of hovercraft |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| $P_L$ | Lifting Pressure |
| $v_e$ | Escape air velocity |
| $R_1$ | Circumference of the skirt front |
| $R_2$ | Circumference of the skirt back |
| $R_t$ | Circumference total of the skirt |
| $S_A$ | Skirt Area |
| BVR | Buoyancy Volume Required |
| $V_{skirt}$ | Volume of skirt |
| $A_{propeller}$ | Area of propeller |
| $V_d$ | Discharge velocity |
| $P_{craft}$ | Perimeter of craft |

# CHAPTER 1

# INTRODUCTION

## 1.1 INTRODUCTION

This chapter described the background of hovercraft, problem statement of this project, the objectives of research, scope of the research, significant of research and expected result for this project.

## 1.2 BACKGROUND OF STUDY

The concept of the hovercraft was born when engineers came up with an experimental design to reduce drag on ships. The revolutionary idea was to use a cushion of air between boats and the water that they plowed through in order to reduce friction. This idea eventually led to what is known today as the hovercraft, basically a vehicle that uses 1 or more fans to float on a cushion of air. These fans serve a dual purpose, to push air below the craft and forcing it off ground, and to create forward thrust by pushing air out the back of the craft.

The first recorded design for an air cushion vehicle was by Swedish designer and philosopher, Emmanual Swedenborg, in 1716. The project was rather short lived however. In the mid 1870s, Sir John Thornycroft built a number of model craft to check the 'air cushion' effects and even filed patents involving air lubricated hulls. Both American and European engineers continued to work on the problems of designing practical craft. Not until early 20$^{th}$ century was a hovercraft possible because only the internal combustion engine had the very high power to weight ratio suitable for hover flight.

The commercially viable model of a hovercraft was designed in 1955 by the English inventor Christopher Cockerell. Cockerell continued work on hovercrafts through the 1960's, was knighted for his services to engineering in 1969 and is credited with coining the word hovercraft to describe his invention. Since then, many types of land, marine and amphibious air cushion vehicle have developed. Hovercraft has paved its way for new opportunity on Malaysia manufacturing sector. Its major introduction is to assist fire and rescue department and was produced by AFE manufacturing company with Japanese technology collaboration.

Hovercraft was also called as Air Cushion Vehicle (AVC). It was supported by a cushion of pressurized air for movement in between the land and sea. The hovercraft was differs from other vehicles which no need surface contract for traction. The main components used to build up the Hovercraft included propeller, fan, flexible skirt, engine, and gear box. The air propeller, or sometimes called as water propeller, functional for provide forward propulsion. While the fans usually functional for forcing the air down under the vehicle to create lift. The skirt was a long strip of material that was mounted onto the underside of the hovercraft. When the skirt was inflated by forcing air from the fans, it lifts the hovercraft. The engine was used to supply power to the fans functioning which mounted on Hovercraft body. Gear box responsible for exchange the gear speeds.

## 1.3 PROBLEM STATEMENT

The aim of this project was to design the fans so that it can supply enough pressure to lift the skirt. Moreover, an experiment is carrying out to test the lifting air pressure of the skirt. On the other hand, it needs to develop a control system for control the movement of small working model hovercraft. The control system included design the rudder system, electronic components system to form a foundation of applications.

## 1.4 OBJECTIVES OF THE RESEARCH

To design of a working model Hovercraft on following:

i. Can be powered by one or two brushless motor

ii. Small crafts have a single brushless motor with drive through the speed

iii. One brushless motor use to drives the fan responsible for lifting the vehicle

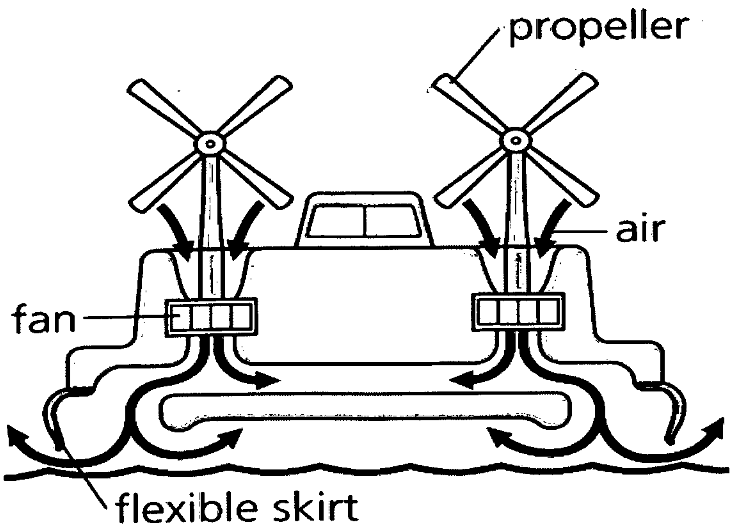


**Figure 1.1:** Working Model Hovercraft

## 1.5 SCOPE OF RESEARCH

i. To study background of the hovercraft

ii. To study the theory use for designing the hovercraft

iii. To study the design factors consideration in designing of small working model hovercraft

iv. To choose the suitable electronic items for build up the small working model hovercraft

v. To study the experiment for lifting the hovercraft

vi. To study the control mechanism for hovercraft

## 1.6 SIGNIFICANT OF THE RESEARCH

I. Momentum Curtain theory

II. Bernoulli theory

## 1.7 DEFINITION OF TERMS

*Hovercraft* is a self-propelled vehicle, dynamically supported by a self generated cushion of slow moving, high-pressure air which is ejected against the surface below and contained within a flexible "skirt" such that it is totally amphibious and has some ability to travel over less than perfect surfaces.

## 1.8 EXPECTED RESULTS

The expected result for the design of a working model hovercraft is that the hovercraft will be able to move in two dimensional axis with desire orientation angle by using remove control or RC transmitter. Moreover, the motor of the hovercraft will be able to drives the fan and propellers. The fans design in the hovercraft will be able to generate enough air for lifting and support movement. The propeller design is able to carry out movement for the hovercraft. The flexible skirt at the bottom of the hovercraft will be able to push the craft off the ground.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter is to describe the literature review research for final year project on journal, book, and internet sources.

## 2.2 WHAT IS HOVERCRAFT?

A hovercraft is a vehicle that is hovering just above the ground, or over snow or water by a cushion of air (Razak, 2000). In a hovercraft a similar cushion of air is maintained by pumping in a steady supply air, to keep pace with the linkage round the sides. There is always some leakage because the craft has to be free to move, but the designers use various methods to keep leakage as small as possible so that only minimum power is required to keep up the air supply (James M. Pruett, 2001). There are various ways of creating the air cushion and reducing leakage. When the fan is rotated, the air preesure is push inside the skirt to create lifting. A hovercraft has been a public transportation in Europe since 1960's. (Malcolm W. Cagle, 1970). A well designed hovercraft is superior to a boat over water because it has less drag and requires less horsepower to push it. This results in higher speeds and better fuel consumption. The hovercraft gets about twice the fuel mileage of a boat with similar size or capacity (Liang Yun & Alan Bliault, 2000). The hovercraft also works very well in rapids or water where standing waves up to a meter high have been encountered for a medium scaled hovercraft (Mujtaba Hussain 2002). Using Bernouli's equation, it can calculate the volumetric flow rate of a hovercraft fan necessary for the vehicle to hover based on its dimension and its mass. The hovercraft diagram is shown below figure 2.1.

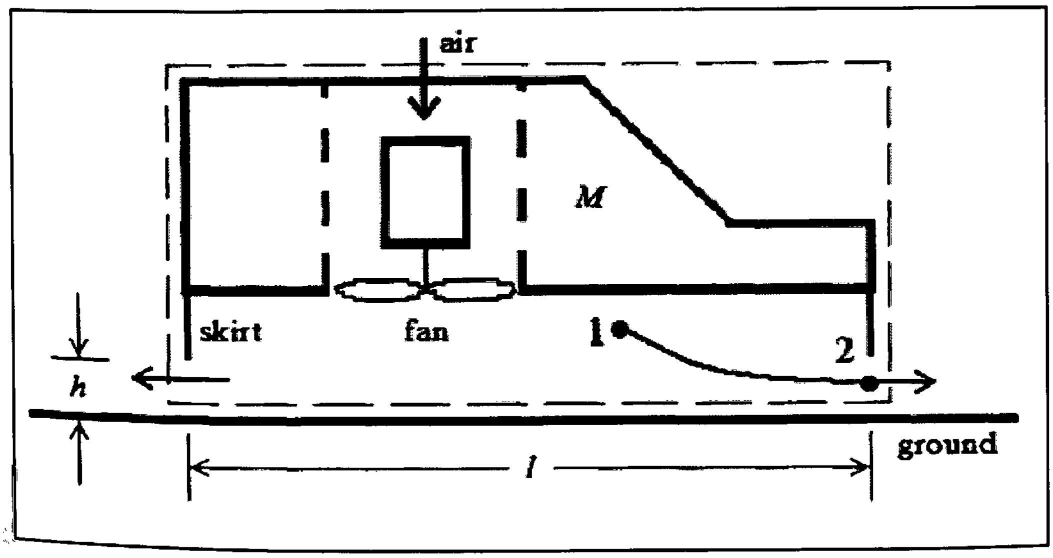


**Figure 2.1:** Labeled Schematic of a Floating Hovercraft

## 2.3 PRESENT HOVERCRAFT

Basically, present hovercrafts consist of hull which is normally made of two large fiberglass and resin moldings. The edge of the top and bottom hull moldings are joined together and an aluminum angled beam is riveted around the hull to give added strength and provide the upper attachment point for the skirt segments. About 30% of airflow from the fan is directed through the hull opening behind the fan into the space between the inner and outer hull molding, called the plenum. The hovercraft is steered by a combination of the air rudder behind the fan and body weight. Steering characteristics vary according to the surface traversed. The air rudders are moved by turning the handlebars left or right.

## 2.4 TYPES OF HOVERCRAFT

In the presence day, hovercrafts exist in variety of sizes, shapes and types according to its purposes and characteristics. There are three basic types, which is amphibious hovercraft, non-amphibious hovercraft, and semi-amphibious hovercraft.

### 2.4.1 AMPHIBIOUS HOVERCRAFT

Amphibious hovercraft are confined to off-the road or over-water surface operation because of their size and relatively poor maneuverability characteristics, which make them unsuitable to be mixed with conventional land vehicles (M. A. Chughtai, 2002).

### 2.4.2 NON-AMPHIBIOUS HOVERCRAFT

The non-amphibious hovercraft is limited to over-water operation only. This type of hovercraft constructed whereby the air cushion or captured air bubble is contained beneath the craft by rigid side walls and flexible skirting at the front and rear of the craft that known sidewall hovercraft.

### 2.4.3 SEMI-AMPHIBIOUS HOVERCRAFT

Semi-amphibious hovercraft is also limited to travelling over water. It lies somewhere between the fully amphibious and the non-amphibious sidewall types in principle of operating and use.

## 2.5 MATERIAL

Material uses for hovercraft hulls are high strength marine aluminium alloys, fabric-covered structures and fiberglass. High strength steels may be more attractive for larger craft (Winkler, P.J. 2000).

Skirt material for hovercraft based on nylon fabrics coated with Neoprene or natural rubber. The following was the consideration required during select of skirt materials (Liang Yun & Alan Bliault, 2000):

a) Tension strength of material
b) Tearing strength of material
c) Flexibility and anti-ageing capability of skirt cloth (nylon fabric coating)

## 2.6 DESIGN CONSIDERATION

The weight of the hovercraft is one of the considerations in design. Light weight materials used for construction have the good strength for design. Moreover, the pressure design must in plenum chamber in order to create the sufficient lift force to the hovercraft (H. Emdad, 2007). Lift force is calculated by pressure time area of the craft. The lift force must more than the weight of the craft. On the other hand, moments are the consideration for stability of the hovercraft. As rotating parts involved, the unbalance moments particularly due to the lift fan must be balanced to avoid spinning of the craft (Dr.J.M.Chuang, 2001). To generate the thrust force, a good power system must be design. The power supply to thrust motor and lift motor must be design in standard ratio. The skirt design is also one of the considerations. A bag skirt is generally preferred as it is easy to build and gives good performance to hovercraft. Duct system is also one of the mini designs (R. Rathore, 2005). The duct although do not have much effect on thrust due to propellers. But, it must be design used for safety of propeller blades in design a duct should have a decreasing area towards exit, such that velocity of air, leaving the duct increases and hence thrust increases.

### 2.6.1 PLENUM CHAMBER PRINCIPLE

A plenum chamber is the main part of all hovercraft. This is a pressurized housing containing a gas or fluid at pressure higher than surroundings (Liang Yun & Alan Bliault, 2000). The function of the plenum is to equalize pressure by the air supplied by a lift fan which helps for thrust of the craft. The plenum chamber diagram is show below figure 2.2.

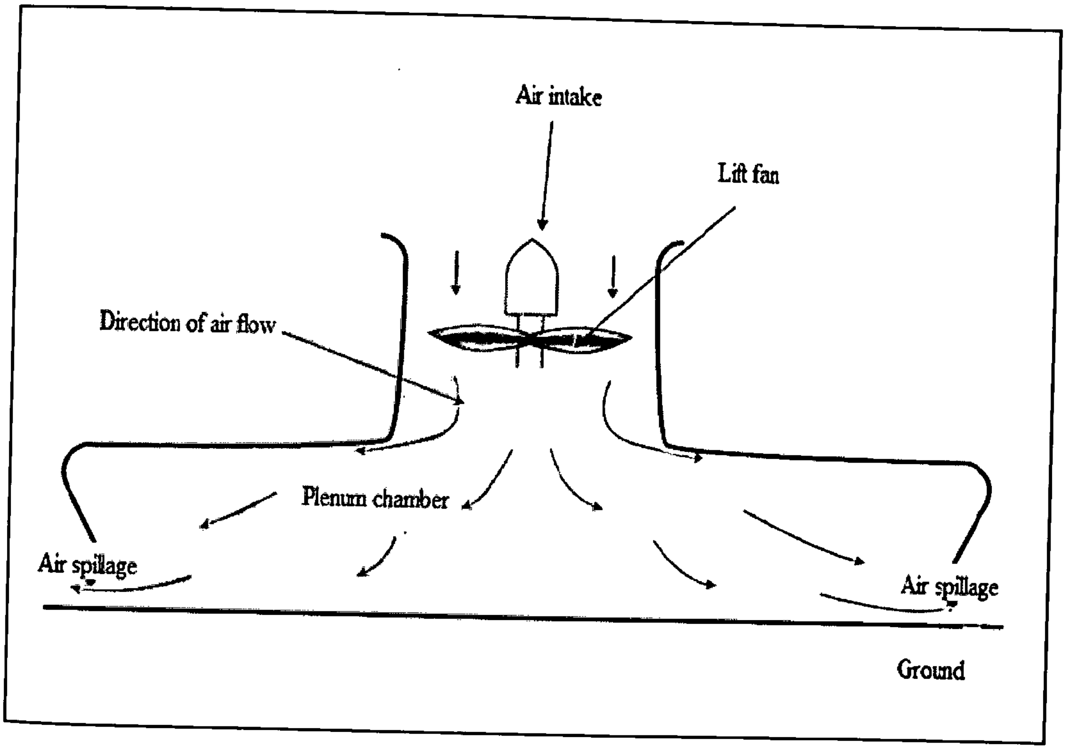


**Figure 2.2**: Plenum Chamber Principle

### 2.6.2 MOMENTUM CURTAIN

Momentum curtain is the air supplied by the lift fan is flowed through the gape in between the surfaces. This air while passing through a small area, its velocity becomes high (K.T. Anwar Sadath, 2007). It creates a high velocity curtain of air, reducing the amount of escaping air and thus increasing the pressure of air trapped beneath the craft. The downward thrust generated by the air jets levitates the hovercraft. The figure 2.3 below shows that momentum curtain principle.

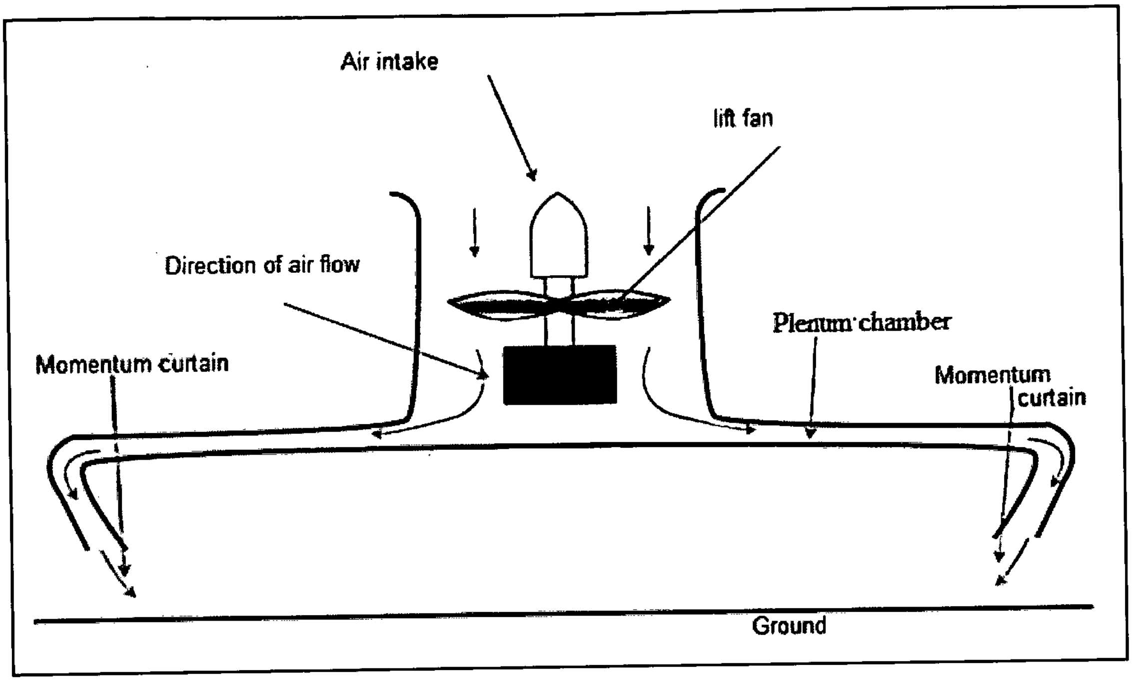


**Figure 2.3:** Momentum Curtain Principle

## 2.7 NONLINEAR RECEDING HORIZON CONTROL OF AN RC HOVERCRAFT

The main objective of this paper is to demonstrate a real-time algorithm of nonlinear receding horizon control for an under actuated vehicle in a hardware experiment. In nonlinear receding horizon control, control performance is optimized at each time over a finite future. Closed-loop stability of nonlinear receding horizon control has been studied extensively in recent years. However, existing stability conditions are still conservative, and a closed-loop system is often stable without satisfyiug them. Real-time algorithm is also a major issue in nonlinear receding horizon control. An algorithm called C/GMRES is employed to solve the optimal control problem at each time. Nonlinear receding horizon control drives the state sufficiently close to the objective state, which shows practical effectiveness of the control method. (Hiroaki Seguchi and Toshiyuki Ohtsuka)

## 2.8 WORKING RADIO FREQUENCY REMOTE CONTROL TO HOVERCRAFT

A standard RC transmitter has 2 joystick A1 and B1. Each joystick can be moved manually from fingers by 0 to 180 degrees. The output of joystick is analogue. An analogue output is converted to digital format from A/D converter. This digital output is sent to Pulse generator IC to produce pulses. Joystick AI controls the pulse width of A and joystick BI controls pulse width of D. This receiver has two outputs RI and R2. The block diagram is shown below figure 2.4.

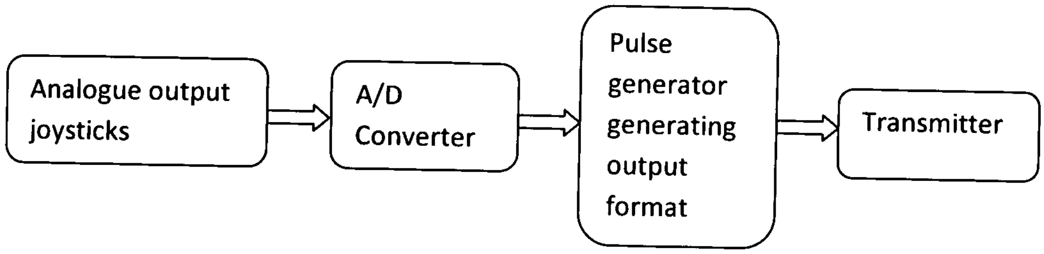


**Figure 2.4:** Block Diagram

## 2.9 ADVANTAGES AND LIMITATION

The hovercraft is a vehicle supported on air. Hovercraft will be well support by it cushion of air whether there is solid land below, water or snow. It will not sink in and get stuck like wheel vehicle.

Secondly, a hovercraft can travel easily over rough ground because air cushion is strong enough to hold it at a height where it will clear rocks and other lumpy obstacles.

Thirdly, a hovercraft has almost no friction and can be moved extremely easily. The air cushion ensures there is no rubbing of one solid part against another to cause friction. Moreover, the air cushion provides automatic springing over rough ground or rough sea waves.

Fourth, the air cushion will support the hovercraft safely and comfortably at speeds. The table below shown another advantages and disadvantages of hovercraft:

**Table 2.1**: Advantages and Description of Hovercraft

| No | Advantages | Description |
|---|---|---|
| 1 | Fully amphibious | Operate over water, land, ice and others |
| 2 | Negligible noise level | About the same as a truck at high speed boat |
| 3 | Low operating cost | Similar to conventional boats of the same speed and payload. |
| 4 | Highly maneuverable | More maneuverable than boats |
| 5 | Simple | Simple in design, manufacture, operation and maintenance. |
| 6 | Easy to operate | Same level as for learning to drive a car or truck. |
| 7 | Reliable | Proven over ten thousands of operating hours. |