

DESIGN OF A WORKING MODEL HOVERCRAFT

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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 menampilkan 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 ke hadapan 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
ρ_{air}	Density of air
m	Mass flow rate
π	pi
ρ_{water}	Density of water
Q	The volumetric flow rate
D	Diameter of propeller
L	Length of hovercraft
W	Width of hovercraft

LIST OF ABBREVIATIONS

C_T	Thrust Coefficient
C_D	Drag Coefficient
S_A	Skirt Area
A_p	Area of propeller
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
BVR	Buoyancy Volume Required
V_{skirt}	Volume of skirt
V_d	Discharge velocity
P_{craft}	Perimeter of craft

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Over the centuries there have been many efforts to reduce the element of friction between moving parts. A hovercraft is a relatively a new means of transportation. 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 n the problems of designing practical craft. Not until early 20th 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. It's different from traditional vehicles because it has no surface contact when it's in motion. 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.

1.2 PROBLEM STATEMENT

The aim of this project was to design the shape of the small working model hovercraft with dimension included. The model must be well designed and powered. The working model hovercraft must perform basic function of hovercraft and able to travel on water surface. This model must able to produce enough air cushion to hover its body and also can lift some loads. The hovercraft must able to produce enough thrust to move along the ground by itself and with some loads.

1.3 RESEARCH OBJECTIVES

The research objectives of this project are to design of a small scale working model hovercraft under the following condition:

- Can be powered by one or more engines.
- Small crafts have a single engine with the drive through the speed.
- One engine used to drives the fan responsible for lifting the vehicle.
- The other forces air from.

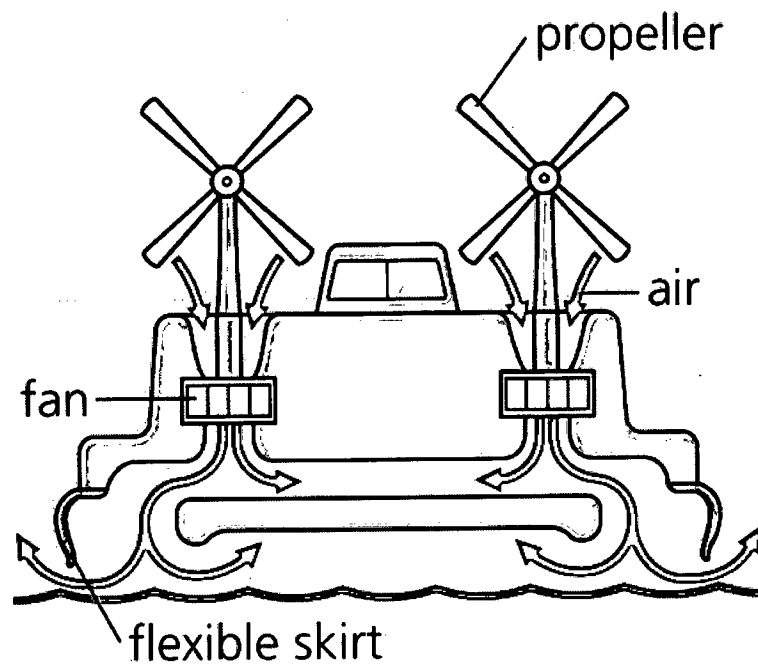


Figure 1.1: Working Model of Hovercraft

1.4 RESEARCH QUESTIONS

- a) How to design a small scale working model hovercraft?
- b) What are design factors need to consider for designing a small scale working model hovercraft?
 - How much load can this small scale working model hovercraft carry?
 - What is the material used to built the hull of this hovercraft?
 - The working model hovercraft is powered by how many engines?

1.5 SCOPE OF RESEARCH

- a) To find the design fundamental for small working model hovercraft.
- b) Make the research for small hovercraft background and construction.
- c) Find principles dimension for hovercraft that will design and make comparison with other hovercraft.
- d) To find drag component and lift force that stride to hovercraft.
- e) To find the best material used to build this small hovercraft.
- f) To recognize all hovercraft applications and limitations and also to define a small hovercraft in their classification.

1.6 DEFINITION OF TERM

- *Hovercraft*- A 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 is totally amphibious and has some ability to travel over less than perfect surfaces. Propulsion is not derived from contact with the water or the ground.
- *Skirt*- Skirt is the device that grants air cushion to be maintained. Skirt is fixed in the craft perimeter, holds and keep enough air mass and pressure beneath the hull granting it to be away from surface, it must be flexible and contour surface irregularities and waves and be water and air proof.
- *Lift*- Lift is the air cushion beneath the hull surrounded by the skirt.
- *Thrust*- Thrust is the force that will fight and win Drag, inducing movement to the hovercraft.
- *Drag*- Drag is the force that hinders forward motion.

1.7 EXPECTED RESULT

During the testing of all criteria put forward, the project was deemed a success as it met virtually all of the listed criteria. The primary goal is to prepare a full drawing of preliminary design of small hovercraft. The principal dimension of hovercraft is depending on their ability to support the determined payloads. This hovercraft model is for study and research purposes while still perform its basic functions. Thus, it must have all the required characteristics of the hovercraft even this is a small scale model. The hovercraft will be fabricated with polystyrene or Styrofoam This hovercraft will use dual power plant (engines or electric motors) for thrust and lift systems. Because of their consumption for this craft to lift some loads, high speed engine or motor is applied to the lift power. Lift power should be controllable to get sufficient pressure in the cushion and suited with the applied loads. Skirts materials must flexible and has sufficient stiffness so that it can operate on water surface.

1.8 LAYOUT OF THESIS

The overall content of the thesis will consist of five chapters. The first chapter is discussing about the introduction of the topic followed by the theory and literature review will be in chapter two. Discussion and explanation of the research methodology for all the methods and the components that require for mechanical design will be in chapter three. In chapter four, the contents are about the results and discussion for the project. Last but not least, the conclusion and recommendation for the project will be in the chapter five.

CHAPTER 2

LITERATURE REVIEW

2.1 WHAT IS HOVERCRAFT?

Nowadays there are several types of hovercrafts, but a definition of a hovercraft can still be given: A 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. Propulsion is not derived from contact with the water or the ground [1].

A hovercraft is one of the children of the air cushion vehicle (ACV) family that flies above the earth's surface on a cushion of air. It is powered by an engine that provides both the lift cushion and the thrust for forward or reverse movement. The hovercraft child is a true multi-terrain, year-round vehicle that can easily make the transition from land to water because it slides on a cushion of air with the hovercraft skirt and only slightly brushes the surface. In its simplest form, a hovercraft is composed of a hull that can float in water and is carried on a cushion of air retained by a flexible 'skirt'. The air cushion (or bubble),

trapped between the hull and the surface of the earth by the skirt, acts as a lubricant and provides the ability to fly or slide over a variety of surfaces. Hovercraft are boat-like vehicles, but they are much more than just a boat, because they can travel over not only water, but grass, ice, mud, sand, snow and swamp as well.

A hovercraft is a craft that has little to no friction, and does not touch the ground. There are two methods of lift which are ground effect and seeping pressure. The ground effect is caused by blowing air at the ground, creating a higher pressure below the fan than above the fan, forcing the craft upwards. This is inefficient in comparison to a pressure based craft, since the pressure between the fan and the ground is easily dissipated to the sides. The more efficient way to have a craft hover is to create a higher pressure under the skirt in comparison to the ambient pressure. This would create a force on the air to move from the high pressure, under the craft, to the lower pressure, outside the craft. This force causes the air under the craft to seep out. With a design where the fans have a direct path to the ground below them, the ground effect will add more lift power. A side effect of the lift fans is a lower pressure above the fans.

2.2 HOVERCRAFT PRINCIPLES

In fact there are different types of hovercraft one of them is an amphibious hovercraft. The model hovercraft is also supposed to be an amphibious hovercraft, this means it can operate over land and over water. Hovercrafts work on the two main principles of lift and propulsion [1]. When dealing with a hovercraft, the existence of lift is imperative for the proper function of the vehicle. Lift is an essential factor because it is that which allows the craft to ride on a cushion of air several inches off the ground. This process, the process of attaining lift begins by directing airflow under the craft. In order to quarantine the air under the air cushion, a skirt is required. This is done in order to create pressure under the hovercraft which forces the vehicle off the ground. Attaining the proper amount of airflow is imperative for the maintenance of the craft's stability. If too much airflow is directed under the craft, it will then hover too high above the ground, resulting in the

hovercraft to tip. Not enough lift will cause the craft to remain on the ground which defeats the very purpose of the hovercraft altogether.

The source of the airflow which propels the craft off the ground is a fan. The fan can be used for lift and thrust. It can be dedicated to lift or thrust or even both simultaneously. In either case the passage where the air flows through to reach the air cushion affects the stability of the hovercraft. This passage is a hole located on the base of the craft. Another vital component is the motor. The motor is usually located in the rear of the vehicle and is the heaviest of the components. Due to the weight of the motor, extra pressure is required under the area where the motor is positioned in order to attain hovering capabilities. Which makes hovercrafts so efficient and different from other vehicles of its category is that very little force is required for it to move. Propulsion is that which makes the craft move. The source of this effect is the fan, which is used to move the air for propulsion.

Hovercrafts have no contact with the ground; therefore any resistance the ground may produce under other circumstances is now non-existent for the craft. As explained above, the propulsion of the craft requires a fan but a normal fan is not sufficient. This is because a normal fan does not blow air straight back. Instead it spins the air in a spiral shape. Therefore engineers decided to use turbines or stationary blades, that un-spin the air. When air does not spin more of its kinetic energy can be used for translation and less is required for rotation. The shape of the body also affects the stability of the hovercraft. The larger the area of the base, the more stable it will be. Wider base implies greater stability. Longer and narrower shapes increase speed but decrease stability. Most hovercrafts have rounded ends, and offer both stability and speed.

The skirt is another vital component. The common skirt is known as a bag skirt. It is comprised of a bag that covers the bottom of the base and has holes in it to allow air to escape and push the craft off the ground. Each part of the skirt inflates independently which makes repairs much easier and improves stability. Unfortunately, the more stable a skirt, the slower it will go.

When the hovercraft is finally able to move it will most definitely require steering capabilities. This is achieved through the use of rudders. These rudders can be controlled by a variety of devices including computers. Rudders cannot be too heavy otherwise they will weigh down the craft because they are located very close to the motor. The shape of the rudder dictates how well it will be able to move air. When riding a hovercraft the natural state of motion is easily seen to be constant vector velocity with a constant rate of rotation. A sloping floor will definitely change velocity vector without changing your rate of rotation. In addition to Newton's three laws of motion it will become obvious that to avoid spinning or tilting the hovercraft you must apply the forces in line with the center of mass of the combination of the craft and your body.

2.3 DESIGN CONSIDERATION

Before the designing process of hovercraft began, we developed a list of criteria which would guide us. Four important criteria that we must consider in designing a working model hovercraft including the performance, serviceability, manufacturability, economic concerns [2].

Table 2.1: Design Consideration

No.	Consideration	Priority	Comments
1	Performance	Essential	Must transport over land
2	Serviceability	Essential	Must be easy to maintain be designer
3	Manufacturability	Essential	Must be constructed with limited resources
4	Economic	High	Must minimize cost

Performance for the hovercraft was a high priority. The main criteria governing performance was that the device must lift and transport the weight of the craft included. Serviceability was a concern for this project as it was assumed that, in time, the device would encounter unforeseen problems and need maintenance. Materials and parts were selected based on their availability and ease of use in repair. Economics played a large factor in the design of the device. So simplicity of design and ease of manufacture ruled. The hull must be light weight, rigid, float in water, and resist light abrasion, as well as support mounting hardware for various system components. The skirt must also be easily tailored from a light weight water resistant fabric and be fully detachable from the hull without damage to the rest of the craft. Environmental and sustainability criteria did not significantly impact the design of the device as there are no serious environmental concerns which arise from the production and use of the craft. Health and safety of the user were taken into consideration, though this did not significantly impact design. There are also no real ethical, social, or political concerns which were taken into consideration as hovercraft have been built by many societies in many nations for many different reasons.

2.4 DESIGN CRITERIA

Using the design considerations, we developed a set of criteria to guide the design and fabrication of the hovercraft over the 2 semester. Criteria were developed based on the perceived feasibility of the project after work completed in the end. The criteria can be divided into four categories, shown in table below which are pertain to lift, thrust, control, and materials [2].

Table 2.2: Design Criteria

Criteria	Priority	Description
Lift		
lift skirt	Essential	Skirt to generate air cushion
Performance	High	Must lift entire craft, higher is better
Thrust		
Propeller speed control	Essential	Must have speed control for craft, use E.S.C.
Performance	High	Must move entire craft, higher is better
Control		
Remote Control	Essential	Must be able to control craft remotely
Stopping	High	Must be able to stop to avoid collisions
Materials		
Low weight	High	Lighter is better to achieve sufficient lift
Durability	High	Must be able to withstand impact and abrasion
Workability	High	Must be easy to work with using basic tools
Low cost	High	Lower is better

2.5 HOVERCRAFT DYNAMICS

Since the hovercrafts are moving in air we have to consider its aerodynamics also. Aerodynamics is defined as the branch of fluid physics that studies the forces exerted by air or other gases in motion. The three critical dynamic parameters are pitch (the angles of rotation in three dimensions about the vehicle's center of mass, known as), roll and yaw. Roll, pitch and yaw refer to rotations about the respective axes starting from a defined equilibrium state. The equilibrium roll angle is known zero bank angles; equivalent to a level heeling angle on a ship. Yaw is known as "heading". The equilibrium in aircraft, this usually refers to angle of attack but in submarine is known as "trim". The roll acting about the longitudinal axis, positive with the starboard (right) down. The yaw is about the vertical