A Study about HOVERCRAFT

Rohit Jaiswal[1] Ravi Bhardwaj[2] Rajesh Anant[3] Prakash Kumar Sen[4] Shailendra Kumar Bohidar[5]
[1,2,3]Student [4,5]Faculty
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]Kirodimal Institute Of Technology, Raigarh, Chhattisgarh, India

Abstract— A hovercraft, also known as an air-cushion-vehicle or ACV, is a craft capable of travelling over land, water, mud or ice and other surfaces. Hovercraft are hybrid vessels operated by a pilot as an aircraft rather than a captain as a marine vessel. It is popularly known is the newest vehicle in today's transport scene. As well as being new, this vehicle is different from other more conventional terrestrial vehicle in that is requires no surface contact for traction and it is able to move freely over a variety of surface while supported continuously on a self-generated cushion of air. We use standard calculation to determine the lift forces required. The thrust force required are greatly reduced due to reduction in frictional forces, both static and dynamic. The total study process is concluded with mention of details for the constituent parts. This paper brings out the details of the theoretical study carried out for the successful propulsion of the hovercraft.

Keywords: Lift force, Air gap, Integrated propulsion, Thrust, Static friction, Dynamic friction, Hover height

I. INTRODUCTION

Merriam Webster defines a hovercraft as a vehicle that is supported above the of land or water by a cushion of air produced by downwardly directed fans.

The concept was first proposed by **John Thornycroft** in the 1870s, but a working model was not produced until 1955, when **Christopher Cockerell** solved problem of keeping the air cushion from escaping from under the vehicle, and formed Hovercraft Ltd. to manufacture prototypes. Problems with skirt design and engine maintenance have restricted the vehicle's commercial application. Today hovercraft are used mainly as ferries.

Hovercraft are a new technology and they have been in mainstream use. Practical hovercraft designs have only been around since the 1950's and some people don't even believe in their existence.This have been for various reasons. Its inability for precise manoeuvring control and its relatively high maintenance and noise levels compared to the automobile have been sufficiently difficult to overcome to keep the air cushion vehicle at the fringe of modern transport.

Typically this cushion is contained within a flexible 'skirt'. They typically hover at heights between 200 mm and 600 mm above any surface and operate above 20 knots and can clear gradients up to 20 degrees.

Hovercraft work on the two main principles of lift and propulsion. 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. The process of attaining lift begins by directing airflow under the craft. The force for thrust is responsible for the movement of hovercraft in the horizontal direction, and is achieved with the help of propeller fan.

When the hovercraft is finally able to move it will most definitely require steering capabilities. This is achieved through the use of rudders. 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. [1]

II. PRICIPLE OF OPERATION

The hovercraft floats above the ground surface on a cushion of air supplied by the lift fan. The air cushion makes the hovercraft essentially frictionless. Air is blown into the skirt through a hole by the blower as shown in (**fig 1).** The skirt inflates and the increasing air pressure acts on the base of the hull thereby pushing up(lifting) the unit. Small holes made undemeath the skirt prevent if from bursting and provide the cushion of air needed. A little effort on the hovercraft propels it in the direction of the push. (**Fig 1)** shows how pressure is developed in the skirt.

As soon as the assembly floats, a blower incorporated in the thrust engine blows air backwards which provides an equal reaction that causes the vehicle to move forward. Little power is needed as the air cushion has drastically reduced friction. Steering effect is achieved by mounting rudders in the airflow from the blower or propeller. A change in direction of the rudders changes the direction of air flow thereby resulting in a change in direction of the vehicle. This is achieved by connecting wire cables and pulleys to a handle. When the handle is pushed it change the direction of the rudders. [2]

III. CONSTRUCTION

A. Lifting Fan

Firstly the volume of air needed is very large and a propeller is designed to be most efficient in open air like on an aircraft. Also the fan needs to force air into the chamber below the craft so creating a specific pressure under the craft. When the assembly is rotated at high speed air is sucked into the center hole in the fan and the slats force it out at the edges. The advantages of the fan are two fold. They operate efficiently in an environment when backpressure is high and they will move larger volumes of air for a given rotation speed than a propeller with the same speed and power input. The engine also drives the propeller on the craft, which provides thrust for forward motion of the Hovercraft. [3]

B. Thrust Propellers

The propeller used to drive the hovercraft along is usually an aircraft type with variable pitch blades. Its speed of rotation must remain fixed to that of the engine and the lift fan. This is because the amount of lift air required dictates the engine speed to drives the lift fan.
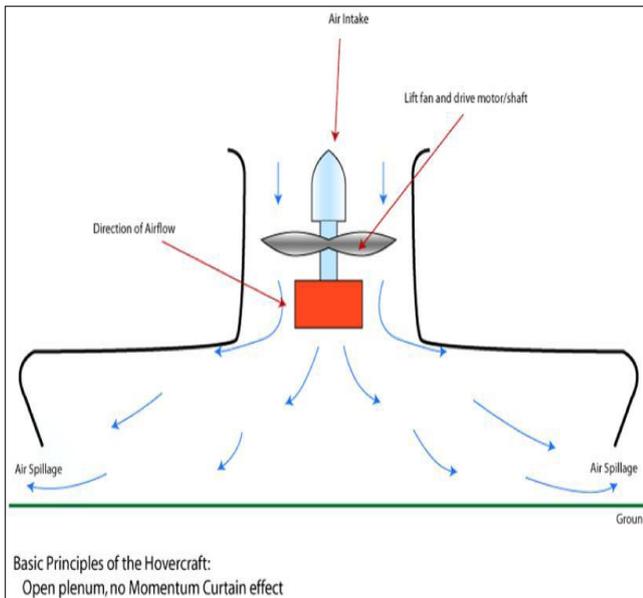
Fig. 1: Pressure Development in Skirt

In turn the amount of propulsion, which the propellers provide, must be obtained by varying the propeller pitch and not its rate of rotation. This system is termed integrate lift/propulsion.

C. Momentum curtain

The craft would require enormous power to maintain a reasonable hover height. To solve these problems, a plenum chamber with a momentum curtain was developed.

D. Hovercraft skirt

All modern hovercraft- large and small, use a skirt of one sort or another for their suspension system so that the power required to lift the craft can be minimized.

A hovercraft skirt is required to fulfill the following function:-

- Contain the cushion of air beneath the craft at the required hover height.
- Have the ability to conform of contour efficiently over obstacles so as keep the loss of cushion air to a minimum.
- Return to its original shape after having been deformed.
- Give adequate stability.
- Offer little resistance to the passage of obstacles beneath it.
- Have the ability to absorb a large proportion of the energy which is produced on impacts or collisions with obstacles greater than hover height or cushion depth.

Despite the momentum curtain being very effective the hover height was still too low unless great, and uneconomical, power was used. The skirt is a shaped, flexible strip fitted below the bottom edges of the plenum chamber slot. As the hovercraft lifts, the skirt extends below it to retain a much deeper cushion of air. The skirt of a hovercraft is one of its most design sensitive parts. The skirt material has to be light flexible and durable all at the same time. [3]

E. Air box

The air box takes about 10% of the air being pushed backward by the propeller and forces it downward, underneath the hovercraft. There are three small ducts cuts into the base of the hovercraft, underneath the air box. Two of these ducts lead into the skirt, which is basically a bag that goes all the way around the perimeter of the craft, while the third duct leads directly underneath the hovercraft.

F. Lift system

The hovercraft relies on a stable cushion of air to maintain sufficient lift. The weight distribution on top of the deck is arranged so that the air is distributed the air from the rear of the deck throughout the cushion volume in an approximately even fashion to provide the necessary support. The skirt extending below the deck provides containment, improves balance, and allows the craft to traverse more varied terrain.

G. Thrust system

The air not directed to the cushion and skirt Is propelled backwards, providing forward thrust to the craft. The size of the propeller, rpm output of the engine, and height of the lift/thrust divider are the determining parameters for the thrust force.

H. Steering system

Rudders are a main source of steering and are attached to the rear of the duct to direct the flow of air and the direction of the subsequent momentum transfer from the air to the craft. Because of the air cushion effect, the driver may influence the steering by shifting his weight nearer to any of the four sides of the deck.

We being our consideration by determining the necessary power for static lift. If we assume that all of the air through the propeller goes into the air cushion and model the flow of air with Bernoulli equation ignoring frictional losses.

Note that the velocity associated to the minor losses through the propeller and duct are since this is the only relevant velocity available from calculation. From these equation, we can determine the energy gain needed from the propeller. The total expected weight of the craft is obtained by summing the individual weight of all components such that, in pounds. [3]

Total Weight= 200 passenger +50 engine + 25 round + 10 skirt + 40 deck/supports = 325 lb

Assuming incompressible flow, we can multiply the mass flow rate of the escaping air by the air's kinetic energy to obtain the power needed to pressurize the cushion at a certain clearance height for a given weight load on a deck of specific area. This is the power needed to maintain the pressure in the cushion.

I. The engine

The engine has a main shaft on which is mounted a compressor and a turbine. A starter motor is connected to one end of the shaft and the other end is connected to the lift fan and propeller gear box. When the engine is started, the compressor compresses air from the engine intakes and pushes it into combustion chambers mounted around the engine. Fuel is squirted into the combustion chamber and ignited. The compressed air then rapidly expands as it is heated and forces its way out through the turbine to the

exhaust. As the gas pressure rises, the turbine speeds up, thereby driving the compressor faster. The engine speed increase until it reaches the engine's normal operating speed.

A power of 2.2 horsepower at a rotational speed of 2000 revolutions per minute was required to achieve the desired fan characteristics. This motor was capable of outputting 3.5 horsepower at 2000 rpm, with a torque of 12.9 Nm. A table of this engines data is shown below. [4]

Engine Displacement	28.2 cc
Max Engine Power	Hp @ 8500 rpm
Average Air Volume	15.20 CBM/sec
Net Weight	6.2 kg

Table 1: Engine Specification

This engine was capable of producing sufficient power and torque for the lift system, however there were several drawbacks.

Approximate lift perimeter	(m)	4.875	(ft)	15.995
Total hover gap area	(m^2)	0.097	(sq. ft.)	1.04
Total cushion area	(m^2)	1.392	(sq. ft.)	14.99
Cushion pressure	(N/m^2 = Pa)	563.14	(lbs/sq. ft, PSF)	11.76
Cushion pressure	(mm of water @ 4degC)	57.12	(inches of water @ 60degF)	2.66
Expected actual air velocity	(m/sec)	17.55	(ft/sec)	57.59
Lift air volume	(m^3/sec)	1.711	(CFS)	60.45
Estimated lift engine power	(kW)	1.806	(HP)	2.154
Estimated fan diameter	(m)	0.470	(inches)	18.33/64

Table 2: Value of Necessary Parameters

J. Lift power

The lift system must produce a steady state cushion pressure that will provide enough force to counteract the weight of the craft, shown by the equation below,

$$Pc = f(M,g)$$

The sensitivity of lift requirement to weight were derived by differentiating the governing equation. This resultant graph is approximately linear, giving a sensitivity of 32 W/kg for the lift system. [3]

K. Lift calculation

In response to modifying the hull and skirt size it was decided to re-examine the fluid dynamics of the lift system. This involved calculating the cushion pressure, volumetric flow rate and the pressure inside of the hull.

L. Calculation

Hull Length = 1.52 meters = 4.99 feet
Hull Width = 0.91 meters = 2.99 feet
Amount of Air Gap Required = 19.99 mm = 0.788 inches
Maximum Gross Weight of Craft = 79.98 Kg = 176.33 Lbs. [4]

The obtained values of various parameters are specified in the following Table 2.

M. Thrust

The lift forces generated by the engine i.e. leaf blower are used to create an air gap between the skirt and the ground surface. As indicated in the above lift calculations, the air gap generated is approximately 20 mm. As a result of air gap generation, the static and dynamic frictional forces are reduced immensely, because the co-efficient of friction of air is very low when compared to the ground surface. Thus, the thrust force required for propelling the hovercraft in the horizontal direction, is greatly reduced.

The drag forces associated with aerodynamics, the slope of the ground, and momentum of the cushion air can be calculated using the standard equations. The preliminary calculation are done respective to the design weight of 100 kg. DA can be estimated using given equation, giving a value of 3.5 N. Although the total design weight is 100 kg, the design weight for thrust is far lower. [6]

IV. RESULTS

The hovercraft has shown capabilities of static hovering with over a 300 lb payload on the smooth garage floor.

The skirt fills well when inflated from the propeller indicating that the splitter functions properly and the contours of the skirt were cut and attached well. The clearance gap between the propeller and the duct was significantly reduced since the air that previously escaped the wrong way now follows the correct path. The rudders divert the thrust air as can be felt when driving and steering along a downwards slope. Better maneuverability can be deck to redistribute the air in the pressurized cushion. The cantilevered design for the splitter is held rigidly with fiberglass within the duct and resists the forces from the propeller air well with small vibration.

V. CONCLUSION

Hovercraft are generally simple mechanisms in theory. Yet the process from theory to manifestation is not as easy as if may seem. A plethora of problems exist and must be faced in other to attain a well functioning hovercraft. The plans and designs must be flawless. One must take under consideration the weight and the shape of each component in order to avoid problems such as instability and dysfunction. This is a marvelous machine which greatly cuts down the friction which in turn helps it to attain greater speed and more stability.

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