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DESIGN OF AN UNMANNED HOVERCRAFT

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Abstract:-This paper deals with the design of hovercraft where the hovercraft can travel on land as well as on water which is an unmanned aerial vehicle with a maximum take-off weight are 0.8 kg. The design of this hovercraft which is capable of hovering and forward motion. The hovercraft design criteria involve the stability and power to weight ratio. The air intake in a hovercraft plays a major role in the flow of air into the skirt. This design involves a multi-propeller hovercraft. There are holes designed for optimizing the design. The hover height is 15 cm. An open plenum type of hovercraft with a bag skirt configuration opts. The design of hovercraft is done via CATIA.

Keywords: Hovercraft, hover, Open Plenum, Multipropeller hovercraft

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1. Introduction

Hovercraft is a type of Vehicle that can travel on land as well as on water. The hovercraft is classified into two categories based on the kind of application as manned hovercraft and unmanned hovercraft. In this paper, the unmanned aerial vehicle is designed. There are a lift fan and a thrust fan for generation of lift and thrust. There is a splitter used in some hovercraft such that there is only one thrust fan and a splitter is placed so that some percentage of air flows below for generation of lift. For steering purpose or directional movement is done in hovercraft using rudder which is put on the rear side of the hovercraft. The hovercraft relies on a constant cushion of air to sustain adequate lift. The air evicted from the propeller was alienated by a horizontal divider into pressurized air exploited for the air cushion and momentum taken for thrust. The weight distribution on top of the deck was given so that the air was disseminated from the rear of the deck to throughout the cushion volume in an approximately even fashion to provide the necessary support. The skirt is extending under the deck given containment, better balance, and permits the craft to traverse more assorted terrain [5]. The hovercraft is subdivided into two categories where manned hovercraft with powerful engines is designed, and unmanned type of hovercraft with simple design is also developed.

Figure 1. Design of manned hovercraft

Figure 2. Design of unmanned hovercraft

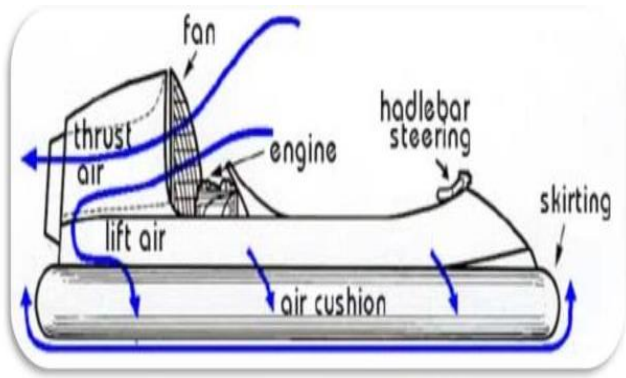

Figure 3. Various parts of hovercraft with airflow direction

A hovercraft is a self-propelled vehicle which is dynamically supported by a self-generated cushion of slow moving high-pressure air which is ejected against the surface below and collects the air within a flexible "skirt."
This hovercraft should have the ability to travel over less than perfect surfaces.

- Propulsion is not derived either from contact with water or ground.
- A hovercraft is composed of a hull that can float in water. It is carried on a cushion of air retained by a flexible "skirt." The air cushion is trapped between hull and surface of Earth by "skirt."

A hovercraft comprises of three main components such as the hull, skirt, Thrust propellers or duct fan. The fan blows the air underneath the platform where it is trapped between the hull and bottom layer of the skirt. The region of trapped air underneath the hull is said to flow over and form the plenum chamber. The air flowing past the chamber forms a ring of circulating air around the base of the skirt that aid to collect the air from escaping. Since a large volume of air is forced to move into the plenum chamber, there is high pressure at the bottom of the hovercraft. There is more pressure in the hovercraft when compared to the extreme condition. This high pressure pushes the hovercraft upwards, and the hovercraft starts hovering at some height from the ground. This height is referred to as "hover height." During the hover condition, there is an important parameter to be noted that is the lift generated must be equal to the weight of the hovercraft.

2. Design of the hovercraft model

The design of the hovercraft is with the following criteria.
Width of the hull = Assumed value
Length of the hull = Twice the width of hull
Hovercraft configuration:

- Multipropeller hovercraft where there are two propellers namely for thrust and lift purpose.
- The hovercraft with open plenum configuration opts where the air from the top layer of the hull is directed downward from which a high pressure is generated in the chamber below the hull and the ground.
- Hovercraft with bag skirt is opted due to the operation of hovercraft on water; the frontal area will cause buffeting in waves and turbulent river rapids. This skirt is also referred as loop skirt.
- There are two rudders placed for the directional control and yaw movement on the rear side of the hovercraft.

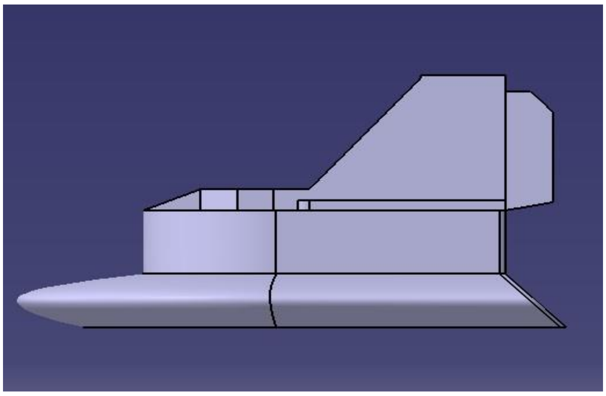

Figure 4. Side view of hovercraft

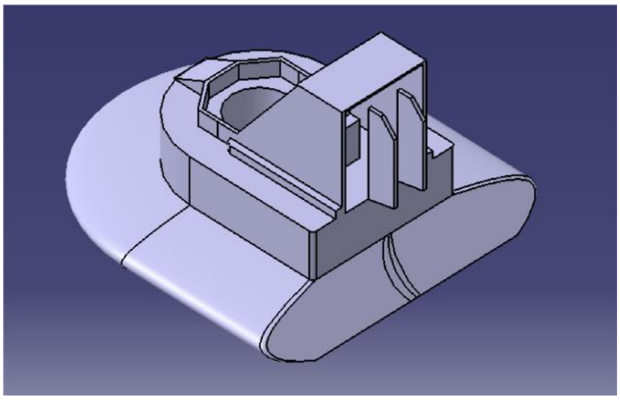

Figure 5. Isometric view of hovercraft

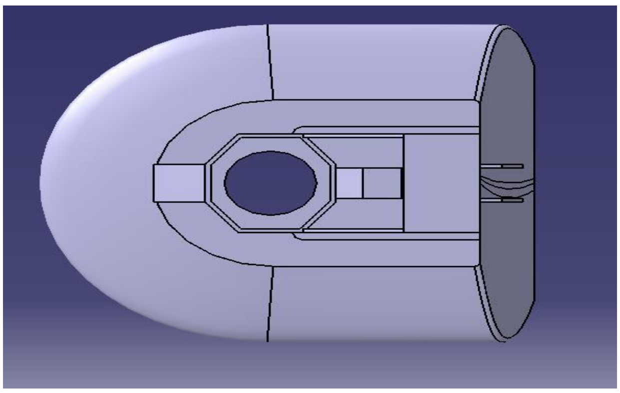

Figure 6. Top view of hovercraft

3. Design Calculation of Hovercraft

The design calculations of the hovercraft with the various conditions are as follows.

Area of Hull:

The area of the hull is determined by the length and width of the hovercraft.

Length of hull = 88cm = 0.88 m
Width of hull = 44 cm = 0.44 m
Area of hull = (0.88) *(0.44)
= 0.3872 m^2

Hence the area of the hull is 0.3872 m^2

Skirt Design:

The skirt is designed with the following dimension
Length of skirt = 1 m
Width of skirt = 0.68 m

Hence of area of skirt = 0.68m^2

Cushion Pressure:

The cushion pressure is calculated on the area of the skirt. On the assumption of the hover condition where lift generated is equal to the weight of the hovercraft.

$P_c = F/A_s$ ……….. (1)

Where,

F = *Lift generated*

A_s = *Area of the skirt*

P_c = *Cushion Pressure*

$P_c = 0.8/0.68$
= 1.1765 kg/ m^2
= 1.1765 * 9.81
= 11.5415 N/m^2

Hence the cushion pressure generated is 11.5415 N/m^2

Total area in which air escapes:

Hover height = 0.15 m

L' = 2 (L+B) …………… (2)

Where,

H = Hover height

A_h = Area in which air escapes

L' =Perimeter of skirt
L' = 2(L+B)
= 2(1+0.68)
= 3.36 m

A_h = L' * H ……………. (3)

= 3.36* 0.15
= 0.5040 m^2

Hence the Total Area in which air escapes is 0.5040 m^2

Exit velocity:

$V_e = \sqrt{2P_C/\rho}$ …………….. (4)

Where,
ρ = *Density*

$V_e = \sqrt{(2 * 11.54)/(1.225)}$

$= \sqrt{(23.08)/(1.225)}$

= 4.3406 m/s

Hence the exit velocity is 4.34 m/s

The flow rate of air escaping through hovercraft:

$Q = A_h \times V_e$ …………… (5)

Where,

Q = Flow rate of air

Q = 0.504 * 4.34

= 2.1874 m^3/s

Hence the flow rate of air escaping through the hovercraft is 2.1874 m^3/s.

Lift duct calculation:

The total area of the duct, hovercraft holes are all based on the lift duct calculation.

Diameter of duct(d) = 19 cm = 0.19 m
Radius of duct(r) = 0.095 m
The area of duct = πr^2 …...………… (6)
= 0.0284 m^2
Hence the area of lift duct is 0.0284 m^2

Hovercraft holes:

Area required per hole $= \frac{Area\ of\ duct}{Number\ of\ holes}$ ……….……… (7)

Case-1:

Number of holes = 1

Area required per hole = $\frac{0.0284}{1}$

= 0.0284 $m2$

Case-2:

Number of holes = 11

Area required per hole = $\frac{0.0284}{11}$

= 0.0026 m^2

Hence one big hole is opted with respect to case-1 and the area of hole is 0.0284 m^2

Area required per hole and radius per hole:

Area required per hole = $\pi r2$
0.0284 = $\pi r2$
$r2$ = 0.0090
r = 0.0951 m
r = 9.5 cm

Hence the radius required per hole is 9.5 cm that is 0.09 m.

The design of Rudder:

The rudder is placed on the rear side of the entire layout. There are two rudders which are attached to the top aspect of the hull. The calculations are as follows.

The percentage of force that hits the rudder = 80 %

Number of rudders per thrust motor = 2

Rudder height = 0.25 m

Rudder width = 0.08 m

Rudder Area = 0.0200 m^2

Rudder angle of attack = 45 degree

= 0.785 radian

Actual force per rudder for directional control is the product of thrust pressure and rudder area.

Selection of Propeller:

The propeller is selected mainly with different configurations such that the diameter and pitch are varied across different propellers. The calculation of thrust is based on the pitch and diameter of the propeller, the specification of the propeller is as follows

L ift propeller = 7 * 4
Thrust propeller = 7 * 7.5

Thrust calculation:

The thrust to weight ratio is obtained from the literature survey on various configurations of hovercraft.

$\frac{T}{W}$ = 0.5 (Forward motion as thrust)

$\frac{T}{W}$ = 1.2 (Forward motion as thrust)

Thrust required for Forward motion = (O.8) * (0.5) = 0.40 Kg = 3.924 N

Thrust required for Hovering = (O.8) * (1.2) = 0.960 Kg = 9.417 N

Hence the thrust of forwarding motion is 0.4 Kg and for hover is 0.96 Kg. Based on the thrust required, the brushless DC motor must be opted along with required battery specification.

Calculation of drag:

The drag is calculated for the lift duct with various shapes. The coefficient of drag varies for each design. A long cylinder is opted for the design of lift duct with Coefficient of drag as 0.82 for the area of duct as 0.0284 m^2.The drag is calculated below.

$$F_D = [1/2] * [\rho] * [V^2] * [C_D] * [A] \quad -- \quad (7)$$

= 0.2637 N.

Table 3.1

S.NO	SHAPE OF DUCT	COEFFICIENT OF DRAG	DRAG FORCE (N)	PROBABILITY
1	SPHERE	0.47	0.153	1
2	SHORT CYLINDER	1.15	0.37	4
3	LONG CYLINDER	0.82	0.26	2
4	CUBE	1.05	0.34	3

4. Conclusion

This paper proposed a hovercraft model with two propellers placed for multi-propeller configuration of hovercraft with open plenum type. The thrust generated creates a hover height of about 15 cm. The hovercraft is stable. The thrust required for forwarding motion is 3.9 N and for hover is 9.4 N. The maximum take-off weight of hovercraft is 0.8 Kg with a bag skirt. The drag force generated is 0.26 N.

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