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Development of a Hovercraft Prototype

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ABSTRACT

The design and development of a hovercraft prototype with full hovercraft basic functions is reported. The design process is quite similar to that of boat and aircraft. In-depth research was carried out to determine the components of a hovercraft system and their basic functions; and in particular its principle of operation. Detailed design analysis was done to determine the size of component parts, quite in accordance with relevant standard requirements as applicable in the air cushion model. Test performance was carried out and the prototype was found to meet design expectations giving an air cushion of 0.5 inch. The test performance result gave an efficiency of 69% for the design. Further research is recommended to improve on the efficiency of the craft.

Keywords: *Hovercraft, Design, Performance, Functions, Parts.*

1. INTRODUCTION

A hovercraft is a vehicle that hovers just above the ground, or over snow or water, by a 'cushion of air' (Spedding, 2001). Also known as air cushion vehicle, it is a craft capable of travelling over land, water or ice and other surfaces both at speed, and when stationary. It operates by creating a cushion of high pressure air between the hull of the vessel and the surface below. Typically this cushion is contained between a flexible skirt. Hovercrafts are hybrid vessels operated by a pilot as an aircraft rather than a captain as a marine vessel. They typically hover at heights between 200mm and 600mm above any surface and can operate at speeds above 37km per hour. They can clean gradient up to 20 degree. Locations which are not easily accessible by landed vehicles due to natural phenomena are best suited for hovercrafts. Today they are commonly used as specialized transport in disaster relief, coast ground military and survey applications as well as for sports and passenger services. Very large versions have been used to transport tanks, soldiers and large equipment in hostile environment and terrain. In riverine areas, there is great need for a transport system that would be fast, efficient, safe and low in cost. Time is spent in transferring load from landed vehicle to a boat. With hovercraft there is no need for transfer of goods since it operates both on land and water. It is said to be faster than a boat of same specifications which makes it deliver service on time.

2. LEGAL ISSUES

To understand the principle of the air cushion effect, assuming of dropping a 'cark' tablemat on to the table cloth, so that it falls completely silent. If the mat is dropped perfectly horizontal, it is bought to a stop guide gently by the air trapped underneath it. Of course the air escapes, but it makes temporary 'cushion'. In a hovercraft a similar cushion of air is maintained by pumping in a steady supply of air. There is always some leakage because the craft has to be free to more, but the designers use various methods to keep leakages as small as possible so that only minimum power is required to keep up the air supply (McPeak, 2004).

The simplest arrangement for creating air cushion and reducing leakages is like a bowl turned upside down and fitted with engine and a propeller which sucks in air through a hole at the top and forces it into the hollow part beneath. Increasing air pressure pushes on the sides of the bowl (Fig.2.1). But the bowl is not elastic, and so instead of forcing the rubber to stretch, the air pressure forces the bowl up off the ground.

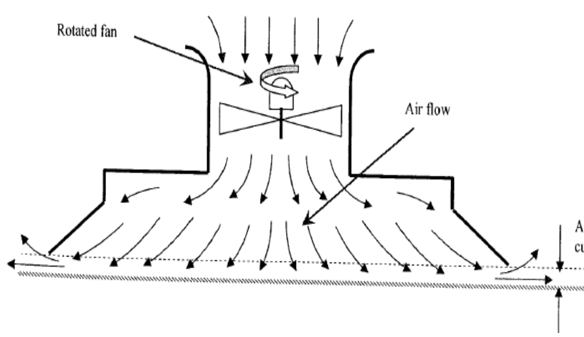


Fig.2.1 Simple Hovercraft Air Cushion Supply

As soon as the bowl rises, the air has a way of escape all round the bottom edge, but as long as the fan keeps on pumping in air fast enough to keep with the pace of leakage, the bowl will remain supported and the faster the air is pumped in the higher the bowl will rise (Amyot , 1989). Hovercraft has been a public means of transportation in Europe since 1960's. Every load of the vehicle is supported by volume air underneath. All movement and motion is generated by either aerostatic or aerodynamic force or both. A well designed hovercraft is superior to 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 and capacity (Nakamura et al, 1997). It gives a smoother ride than a boat because it maneuvers above the water, not on it. It travels over water with no concern for depth or hidden obstacles. It will go against the current of river at the same ground speed as going along the current. 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 (Kerrington, 2011).

3. DESIGN CONCEPT

Figures 3.1 and 3.2 show the assembly and orthographic views of the hovercraft respectively. Table 3.1 shows the parts list.

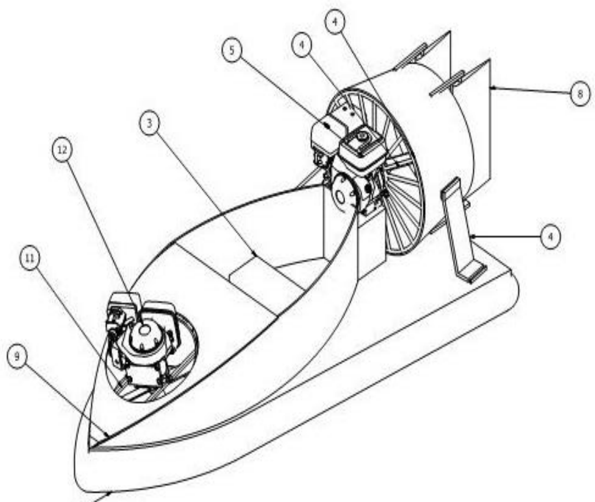


figure 3.1: Assembly view of the hovercraft

Table3.1 Component Parts of the Hovercraft

Item	Description	Qty
1	The hull base	1
2	Lift duct	1
3	Seat assembly	1
4	Thrust duct assembly	1
5	Thrust engine and fan assembly	1
6	The skirt	1
7	Stand	1
8	Rudder	2
9	Body cover front	1
10	Seat assembly main	1
11	Lift engine mount	1
12	Lift system	1

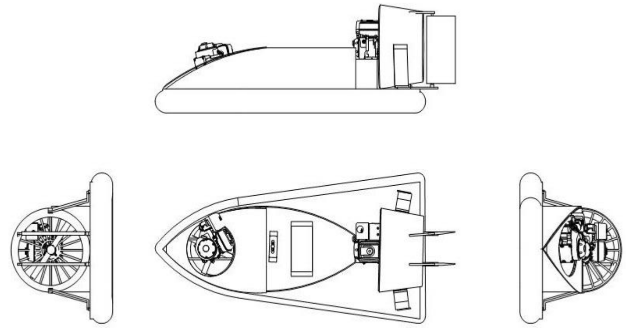


figure 3.2:orthographic view of the hovercraft

3.1 Principle 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.3.3.The skirt inflates and the increasing air pressure acts on the base of the hull thereby pushing up (lifting) the unit. Small holes made underneath the skirt prevent it from bursting and provide the cushion of air needed. A little effort on the hovercraft propels it in the direction of the push. Fig.3.4 shows how pressure is developed in the skirt.

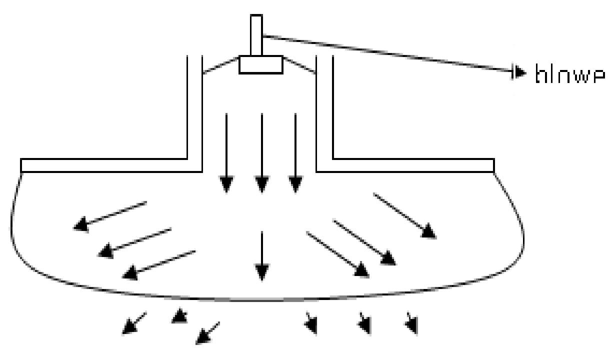


Fig.3.3 Blower/Skirt Arrangement

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 (Fig.3.5). This is achieved by connecting wire cables and pulleys to a handle. When the handle is pushed it changes the direction of the rudders.

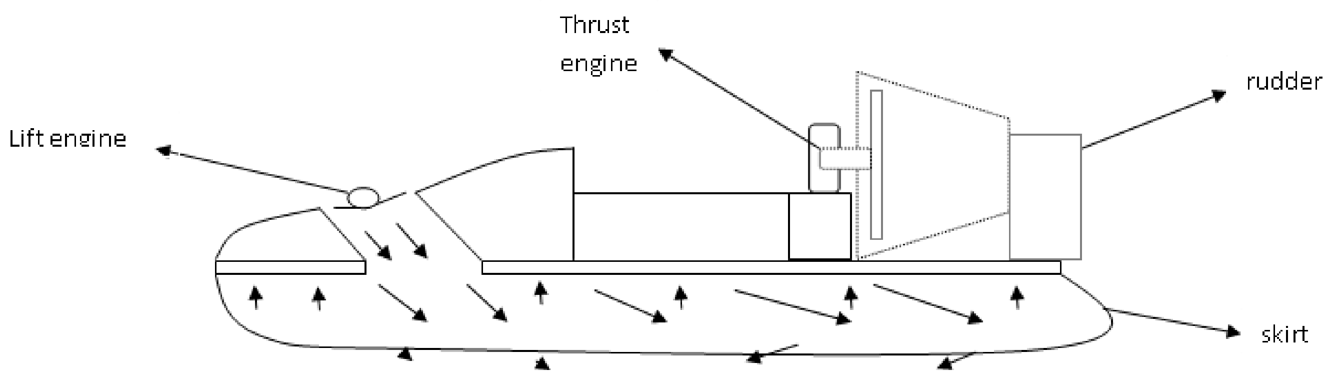


Fig.3.4 Pressure Distribution in the Skirt

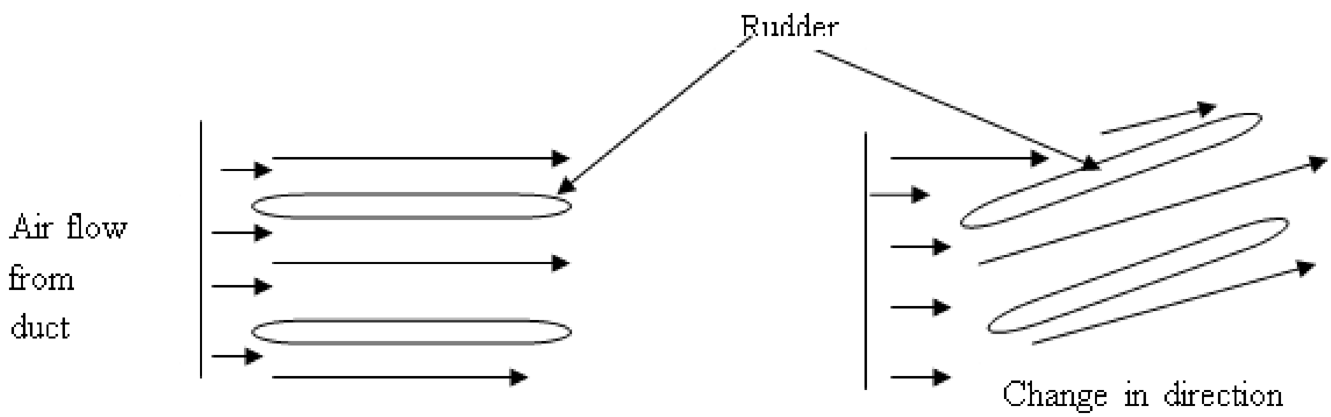


Fig.3.5 Change in Direction of Rudders

3.2 Description

The hovercraft works on air cushion. Air cushion is provided through a blower which pumps air into the skirt thereby inflating the skirt. The air pressure thus raises the craft up above the ground. The vehicle has two engines; the rear and the front. A stator fan is attached to the front or lift engine which directs air into the skirt to provide air pressure needed to lift the craft. The propeller attached to the rear or thrust engine develops the thrust needed to propel the craft. The propeller is enclosed by the thrust duct which makes it possible to direct the air. The duct is bell-shaped such that it increases the velocity of air escaping the duct. The polyester skirt is PVC coated which gives it more strength to sustain the air pressure. It is made air tight. The hull is a platform which sustains the entire weight of the craft. A hole is made on the hull through which air enters the skirt.

4. DESIGN OF MAJOR COMPONENTS

4.1 The Hull

For demonstration purposes, let the craft be designed to carry one person of weight 70kg + 15% of 70kg = 80.5kg

Let length of hull = twice the width

If width =1.22m; length =2W= 2.44m; Surface Area = 1.22 X 2.44 = 2.98m^2

Width = 1.22m = 4 feet; length = 2.44m = 8feet
Material of construction is plywood

4.1.1 Centre of Gravity

Dead weights of components resting on the hull are as follows.

Key	Description	Weight (kg)
A	Lift Engine 8.98kg and fan 1kg	9.98
B	Pilot	80.5
C	15.5kg 5hp, 3800rpm thrust engine, 3kg	18.5
D	Propeller cover	3
E	**Weight of Hull** ¼ Inch plywood density= 3.47kg/m^2 **(www.rfcafe.com)** Area of plywood =2.98m^2; Mass = 3.47 x 2.98 =10.34kg	10.34
Total		122.32 kg

The location of the weights relative to the centre of gravity is very important for stability of the hull.

Key	Weight, (N)	X(m)	Y(m)	XW(Nm)	YW(Nm)
A	97.90	0.61	0.61	59.72	59.72
B	789.71	o.61	1.80	481.72	1421.48
C	181.49	0.61	2.06	110.71	373.87
D	29.43	0.61	2.31	17.95	67.98
E	101.44	0.61	1.22	61.89	123.76
Total	**1199.97**			**731.98**	**2046.81**

$XW = \sum XW$, $X = \sum \frac{XW}{W}$,_ $x = \frac{731.98}{1199.97} = 0.61m$

$YW = \sum YW$, $Y = \sum \frac{YW}{W}$, $Y = \frac{2046.81}{1199.97} = 1.71m$

4.2 The Lift System

In general, air cushion vehicles use two design configurations namely the plenum chamber and the peripheral jet (Paik et al, 2005). Using the peripheral jet design configuration (Fig.4.1) and under equilibrium conditions;

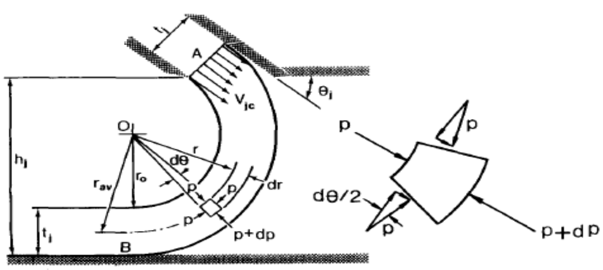


Fig.4.1 Geometry of peripheral jet system

Weight of craft, w = Lift force, F_{cu}

$F_{cu} = w = P_{cu}A_c + J_j L_j \sin\theta_j$ (Paik et al, 2005)

Where

J^j = the momentum flux of the air jet per unit length of the nozzle

Lj = the nozzle perimeter; T_j = the thickness of the jet/nozzle width

H_j = the lift height; R_{ar}= the average radius of the curvature of the length

P_{cu} = the cushion pressure ; A_{cu} = Cushion area

Q_j =total volume flow; P_{aj}=the power required (lift power)

P_{ajmin}= min. lift power;

θ_j = the angle of the nozzle from the horizontal

Let max. weight of pilot = 80.5kg;

also weight of craft = 150kg (total weight on the hull excluding the pilot)

Let the nozzle angle to the horizontal = 71.2^0 ; Let the lift height = 0.2m = h_j

Thickness of jet = 24 inch = 0.6096 = t_j = orifice diameter

Weight force of craft and pilot, W = mg = (150+80.5) kg x 9.81/s^2 =2261.2N = F_{cu}

Cushion Area, A_{cu} = L x W = 2.44 x 1.22 = 2.98m^2

$F_{cu} = W = P_{cu} A_{cu} + J_j L_j \sin\theta j$ **Eqn. (1)**

$J_j = P_{cu} \times r_{av}$

$r_{av} = \frac{h_j}{1+\cos\theta_j} = \frac{0.2}{1+\cos 0.2} = 0.1513$;

Where hj = 0.2m; $J_j = 0.1513\ P_{cu}$

$L_j = \pi \times t_j = \pi \times 0.6096 = 1.9151$

Substituting in equation (1); 2158.2= P_{cu} 2.98 + (0.1513 P_{cu} x 1.9151 x sin 71.2
= 2.98 P_{cu} + 0.2743 P_{cu}= 3.2543 P_{cu}; P_{cu} = 694.8N/m ^{2}

The expression relating the cushion pressure P_{cu} & the total Pressure of the jet P_j is given by;

$\frac{P_{cu}}{P_j} = 1 - e^{-2t_j/r_a}$ **Eqn. (2)** **(**Paik et al, 2005**)**

P_{cu}/P_j = 1- 3.1641 x 10^{-4}; $P_j = P_{cu}/[1-3.1641 \times 10^{-4}]$ = 695N/m^2

Total volume flow Q_j (i.e. air flow rate by volume) is given by;

$$Q_j = \frac{L_j h_j}{1+\cos\theta_j}\sqrt{\frac{2P_j}{p}}\left(1-\sqrt{1-p_{cu}/p_j}\right)$$ **Eqn. (3)**

$$= \frac{1.915 \times 0.2}{1+\cos 71.2}\sqrt{\frac{2(695)}{1.2754}}\left(1-\sqrt{1-694.8/695}\right) =$$
0.2897 x 32.2539 x 0.9822

(i.e. assuming dry air density = 1.2754 kg/m ^{3});

Q_j = 9.1776m ^{3}/s

Power required is given by;

$P_{aj} = P_j \times Q_j$ = 666.410 x 9.1776 = 6,116.044 watts = 6.116 KW

4.3 The Skirt

The skirt must be able to sustain the pressure needed and also push the craft up.

The cushion pressure = 694.8 N/m ^{2}

Area of skirt = Cushion area = 2.98m ^{2}; Height of lift h_j = 0.2m

Thus, Volume of skirt = Area x height of lift = 2.98 x 0.2m = 0.596m ^{3}

4.4 The Thrust System

Less force is needed to thrust the craft and it is normal to assume that thrust equals half of lift force (Paik , 2004).

Lift force, Fcu = 2158.2N

Thrust force =2158.2/2 = 1079.1N = Horizontal force acting on the rudder

But Force = ma; a = 1079.1/1199.97 = 0.9m/s^2

Acceleration, a = Change in Speed/Time

Let time =10secs; Change in speed = 9.0 m/s = 32.4km/hr

5. PERFORMANCE TEST

Classical method was used to establish the speed of the craft.

Distance covered=100m; Speed of craft=100/16.1=6.21 m/s

Designed speed = 9m/s; Efficiency=(6.21/9) x 100 = 69%

5.1 Result

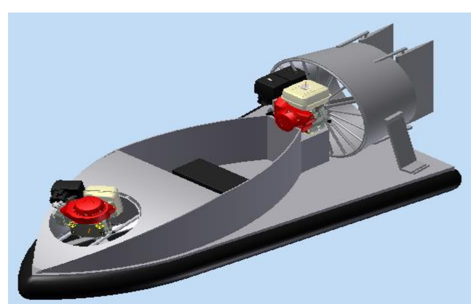
The hovercraft was lifted and was propelled by the thrust system. It was able to carry one person of weight 75kg and hovered with an air cushion of 0.5 inch. Maneuverability was achieved with the steering system.

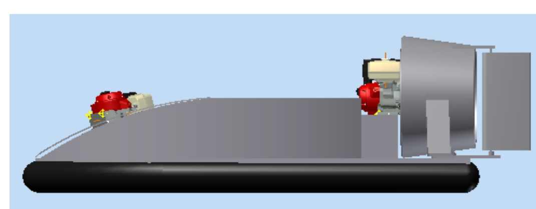
6. CONCLUSION

The craft principle has been demonstrated using low cost material and has proved capable as a viable means of transport both on land and water after series of tests. The propulsion and lifting systems gave excellent performance and with good maneuverability.

7. RECOMMENDATION

More research is recommended to improve on the efficiency of the hovercraft. The skirt has to be air-tight without leakage.





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