

Working Model of Remote Controlled Hovercraft

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Abstract- In this study, mainly focus on analysis and procedure about designing and making of the working model of Hovercraft. Different criteria vital in designing procedure of the model hovercraft are theoretically calculated here. Subsequently, proper material is elected and working Hovercraft was prepared. Main problem is to create enough pressure of air cushion and that leads to decrease in accuracy and poor operation of model. Main intention of our project is to produce an amphibious vehicle that can also be operated over less perfect surfaces.

Keyword- working model, Hovercraft, Design, Performance, function, component.

I. INTRODUCTION

Hovercraft can be defined as a self drive vehicle, dynamically holed by a self created cushion of slow moving, elevated 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 surface (Fig1). Air propellers, water propellers, or water jets was usually provide forward propulsion whereas air-cushion vehicles may be able to attain higher speeds than the ships or most land vehicles of same size. Owing to lower frictional resistances and exploit a comparatively fewer power than helicopters of the similar weight. (Fig 1)

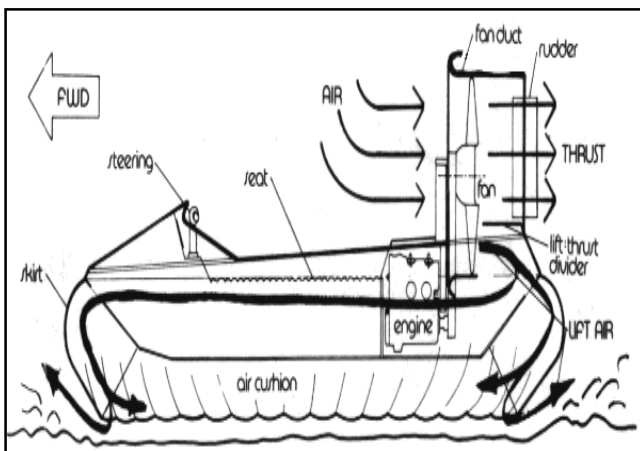


Fig. 1 Basic Components of Hovercraft

Applications of hovercraft: In recent years, the hovercraft has been rehabilitated into versatile vehicle. It is used to save lives in rescue operations, transportation of military troops, ferries traveler, helps in identified land mines and offer a enormous array of recreational prospect such as racing and cruising to people all over the world.

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Advantages of hovercraft: It can be worked over water, land, ice and other smooth surfaces. It generates negligible noise similar to truck or high speed boat. It is more maneuverable than boats. It has equivalent operating cost to the conventional boats of the same speed and payload. It is effortless in design, manufacture and operation.

System of the hovercraft: For understanding the correct running and operation of a hovercraft, it required to know three basic systems that are mainly responsible for lifting and moving of the entire vehicle: Lift System, Thrust System, and Steering System. (Fig 2)

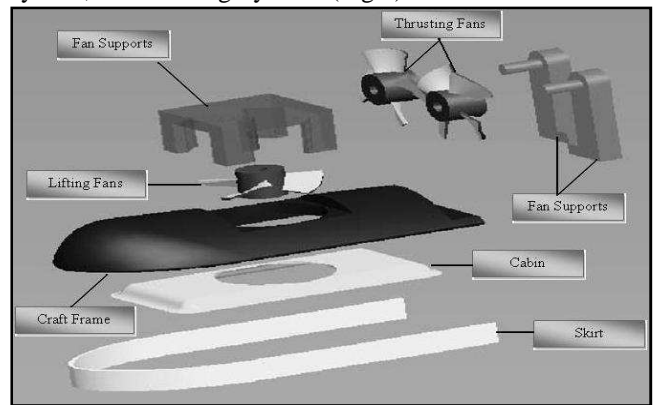


Fig. 2 System of Hovercraft

i) Lift system: 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 extending under the deck given containment, better balance, and permit the craft to traverse more assorted terrain.

ii) Thrust system: The air was 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 was the formative parameters for the thrust force. A thrust duct channeling the air into the propeller can offer up to a 15% boost the efficiency [Universal Hovercraft]. The limiting factor for the thrust was the air flow existing to direct backwards as our prime concern is providing pressurized air for air cushion and lift. Consequently, our forward speed was limited but maintainable.

iii) Steering system: Since a hovercraft required the similar frictional and drag effects as boats or cars, steering must be approached without precise control in mind. This is especially true in our case as the power supply is limited. 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. The driver controls the movement of the rudders through a

joystick located in the front of the craft. A throttle on the engine situated next to the driver allows him to vary the speed of the craft.

II. MECHANICAL CALCULATION

a) Lift calculations: In response to alter the hull and skirt size, it was decided to reexamine the fluid dynamics of the lift system. This involved calculating the cushion pressure, volumetric flow rate and the pressure inside of the hull.

Total Weight, $F = \text{Motor Weight} + \text{Duct Weight} + \text{Skirt Weight} + \text{Propeller Weight} + \text{Battery weight} + \text{Auxiliary Weight}$
 $= [170\text{gm} + 16\text{gm}] + 200\text{gm} + 35\text{gm} + 50\text{gm} + 360\text{gm} + 60\text{gm} = 2000\text{gm}$.

Area of the hovercraft, $A = \text{Length} * \text{width} = 2\text{ft} * 1\text{ft} = 2\text{ft}^2$

The Pressure inside the air cushion (P_{cu}) to regulate the craft, $P_{cu} = \frac{F}{A} = \frac{2}{2} = 1 \frac{\text{kg}}{\text{ft}^2}$

According to Bernoulli's equation, the existing velocity of the air from under the skirt through the gap made from the craft hovering can be calculated by:

$$V_{\text{exit}} = D_c \sqrt{2 * \frac{P_{cu}}{\rho_{\text{air}}}} \quad V_{\text{exit}} = 0.53 \sqrt{2 * \frac{1}{0.00108}} = 22.82 \frac{\text{ft}}{\text{sec}}$$

Where, V_{exit} is the exit velocity of the air in ft/s, D_c is the discharge coefficient and ρ_{air} is the density of air in kg/ft^3 . The velocity is assumed to be zero at an arbitrary distance from the craft, so that the pressure is simply atmospheric pressure and the pressure difference due to height is neglected. The discharge coefficient comes from the flow modeled by that of an orifice leading to an approximated D_c of 0.53. The lift design was based on obtaining a hover gap of "1", which is typical for hovercraft such as this. This gives us the total area through which air would be escaping, as defined by:

$$A_{\text{hovercraft}} = 1 * h = 6 \text{ft} * 0.0834 \text{ft} = 0.4824 \text{ft}^2$$

Where, A_{hovergap} is the area of the space between the ground and the hovering craft in respective unit, L is the perimeter in same unit and h is the hover gap height, as previously given. The proper design pressures for a skirt require at least 20% more pressure inside the skirt than the pressure directly lifting the craft over the area of the underside. If these aforementioned pressures were equal, it is unlikely that the craft would hover since escaping air would not provide any lift. Therefore, to ensure that the bag pressure is higher than the cushion pressure in our design:

$$P_{\text{bag}} = 1.3 P_{cu} = 1.3 * 1 = 1.3 \frac{\text{kg}}{\text{ft}^2}$$

The flow rate of air escaping through the hover gap is calculated using the general formula for flow rate: $Q = A_{\text{hovergap}} * V_{\text{exit}} = 0.4824 * 22.82 = 11.0083 \frac{\text{ft}^3}{\text{sec}}$

Now, flow rate $Q = C * A_{\text{net}} * \sqrt{2 * \frac{P_{\text{bag}} - P_{cu}}{\rho_{\text{air}}}}$

$$\text{so, } A_{\text{net}} = \frac{Q}{C * \sqrt{2 * \frac{P_{\text{bag}} - P_{cu}}{\rho_{\text{air}}}}} = \frac{11.0083}{0.86 \sqrt{2 * \frac{1.3 - 1}{0.00108}}} = 0.7674 \text{ft}^2$$

- The number of holes was arbitrarily chosen, so that the area of a single hole, in in^2 can be calculated as: $A_{\text{hole}} = \frac{A_{\text{net}}}{N} = \frac{0.7674}{35} \text{ft}^2$ so, $\frac{\pi}{4} d^2 = 0.0219$; $d = 0.16 \text{ft}$; $d = 4.12 \text{cm}$

b) Thrust calculations: Thrust calculation was vital to move the model hovercraft properly. At the end of the mathematical calculations, information about the requirement of power and electrical supply required to lift the vehicle properly can be estimated. Thrust calculated in below equation was the theoretical value of the thrust essential to move the hovercraft. And the gross thrust is the practical value of thrust that was existing when motor was running at mentioned rotational speed.

- Thrust is the force applied by the volume of air passed at the discharge of the fan. For propeller which pitch to diameter ratio less than 0.6 the formula for thrust is, $\text{Thrust} = P * D^3 * \text{RPM}^2 * 10^{-10} \text{oz} = 6 * (9)^3 * (13154)^2 * 10^{-10} = 75.68 \text{oz} = 21.0401 \text{N}$
- Velocity of air at sea level, $V_c = 4 \text{m/s}$ approximately.
- Induced velocity, $V_i = \frac{\pi DN}{60} = \frac{\pi * 0.09 * 13154}{60} = 61.98676 \text{m/s}$
- Exit velocity, $V_e = V_i + V_c = 4 + 61.9867 = 65.98676 \text{m/s}$
- Gross Thrust, $T_g = V_i^2 * A * \rho_{\text{air}} = (\frac{\pi DN}{60})^2 * \pi r^2 * \rho_{\text{air}} = (\frac{\pi * 0.09 * 13154}{60})^2 * \frac{\pi}{4} * (0.09)^2 * 1.16 = 28.35507 \text{N}$

c) Propeller calculations: These calculations will give the idea about the selection of the fan or propeller required for the proper operation of the vehicle

- Diameter of the required propeller, $= (632.7 * \text{SHP} \wedge 0.2) / \text{RPM} \wedge 0.6$

Here "RPM" is the propeller shaft turning speed, "SHP" is propeller shaft horsepower, and "D" is propeller diameter in inches.

- For Lift, $D = \frac{632.7 * (\text{SHP})^{0.2}}{(\text{RPM})^{0.6}} = \frac{632.7 * (1544.235)^{0.2}}{(15984)^{0.6}} = 8.25 \text{inch} \approx 9 \text{inch}$
- For Thrust, $D = \frac{632.7 * (\text{SHP})^{0.2}}{(\text{RPM})^{0.6}} = \frac{632.7 * (1270.78)^{0.2}}{(13154)^{0.6}} = 8.92 \text{inch} \approx 9 \text{inch}$

III. SELECTION OF MATERIAL

a) Selection of base and cover: the material used for body and support structure of the vehicle was vital to select in such a way that it should not exceed the weight limits so vehicle can be lifted appropriately. In addition, material should not get broken as force of the air come from the propeller or fan in a continuous manner.

Selection of base: A combination of wooden and thermocol sheet was used as a base of the hovercraft. The supporting structure of the vehicle was also made from the same wooden plate. The wooden plate was containing 6 mm thickness and waterproof. Thermocol sheet was 50 mm thick and wrapped with the thin layer of sticky tape. So, it was protected in case of water contact. A thin cardboard was also attached below the thermocol sheet.

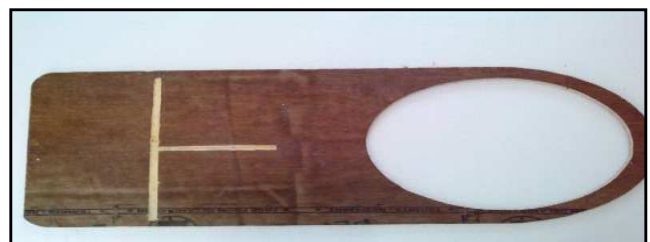


Fig. 3 Base of Hovercraft

Selection of cover: A red colored cardboard sheet was taken as the cover material owing to it's very light in weight and protect the crucial parts of the vehicle like propeller, battery, electronic speed controllers, receiver etc from the dust and other small physical obstacles. It also provides an excellent and decent look to the model hovercraft.

b) Selection of motor and battery: Selection of motor and battery was done in such a way that motor can run with appropriate amount of rotation per minute. So that it can easily provide the required lifting force and thrust for movement of the vehicle. A servo motor was also used for controlling the steering of the hovercraft. The selection of battery was based on two basic necessities. 1) It should be

light in weight. 2) It should deliver adequate voltage and power when connected with both motors at the same time.

Selection of motor: here two different dc motors was taken for lift and thrust operations. Both motors were equivalent in terms of size and weight. Only difference was their rotation speed and operating current in form of the power supplied to them (fig 4). Specifications of motors are as following (Table 1) A servo motor was used to connect the steering mechanism of the hovercraft. A servo motor with 3 kg torque and 40 gram weight is used in steering mechanism. It is having speed of 60° movement per 0.11 seconds. Use of metal gears makes it durable and its rotational range is 180° with 20 ms pulse cycle (fig 5).

Table 1: Specifications of D.C Motor

Specifications	RPM / V (KV)	Battery	Operating Current (Amps)	Peak Amps (15sec)	Propeller
KA36-225	1440	2 Lipo	20	32	10*5
		3 Lipo	16	28	8*4
KA36-10L	1185	3 Lipo	29	40	10*5
		4 Lipo	15	27	

KA36-L ; Shaft Size: Φ 5.0mm \times 20mm; Weight: 152g
Motor Dimensions: Φ 37.4mm \times 42mm



Fig. 4 D.C Motors



Fig. 6: Lithium Polymer Battery



Fig. 5 Servo Motor

Selection of battery: On the basis of motor, 3-lipo battery was enough to run motors at required speed and also it was cost effective then 4- lipo battery.

Table 2: Specification of Battery

SPECIFICATION	DETAIL
Min. Capacity	2200 mAh
Configuration	3S1P / 11.1 V / 3 Cell
Constant Discharge	30C
Peak Discharge (10 sec)	60C
Pack Weight	167 g
Size	(106*34*24) mm
Charge Plug	JST-XH
Discharge Plug	T-Connector with 12AWG Pure Silicon Wire

c) Selection of electronic speed controller: for controlling the speed of the running motors, proper electronic speed controller was selected. It would work as an accelerator and also brakes whenever required. Here two electronic speed controllers was used

d) Selection of propeller: the propulsion device would be driven by the respected motors. Here a propeller was

selected instead of a fan. Because of this required thrust and lift for better operation of the hovercraft was achieved.

e) **Bill of materials:** The model hovercraft was containing wooden sheet as a base construction material and the supporting structure is also created from same material. A detailed list of materials along with their specifications was given in table 4.



Fig. 7 Propeller of Hovercraft

Table 3: Fan v/s Propeller

PROPELLER	FAN
More thrust per HP – generally 5-8 lb/hp.	Less thrust per HP – generally 3-6 lb/hp.
Faster throttle response.	Slower throttle response.
Very loud due to higher tip speed.	Quieter operation.
Higher thrust line due to larger size.	Lower thrust line due to smaller size.
If damaged, entire prop must be replaced.	Individual blades can be replaced if damaged.
High blade erosion.	Less blade erosion.

Table 4: Bill of Materials-I

Material	No. of Parts Used	Dimensions of Material	Specifications of Material
Wooden Ply Sheet	2	2*1 feet	6 mm thickness; Waterproof layer
Thermocol Sheet	1	2*1 feet	40 mm thickness
	1		10 mm thickness
DC motor	1	DC brushless motor 24V, three phase	10,000 rpm
	1		7,000 rpm
Electronic Speed Controller	2	--	Brushless lipo

Table 5: Bill of Materials-II

Material	No. of Parts Used	Dimensions of Material	Specifications of Material
Servo Motor	1	Tower pro MG90 micro	3 kg Torque; Weight:40 gm
LiPo Battery	2	-	2200 mAh capacity; 11.1V/3 Cell; 30C Constant discharge
Remote Controller	1	-	6 channels support; Min. 500 m range; Wireless operation
Receiver	1	-	Spring made; 6 channels support
Propeller	3	9*5 inch	Graupner style - carbon reinforced; 2 blades
Skirt	1	3ft * 2 ft	Nylon Ripstop fabric military material

IV. DESIGN OF HOVERCRAFT

a) **Design of model with AUTOCAD:** a model hovercraft was prepared with the help of AutoCAD software on the basis of collected data from the theoretical calculations and selected materials and electronic components. Images of computer design in AutoCAD were shown in fig 8 & 9.

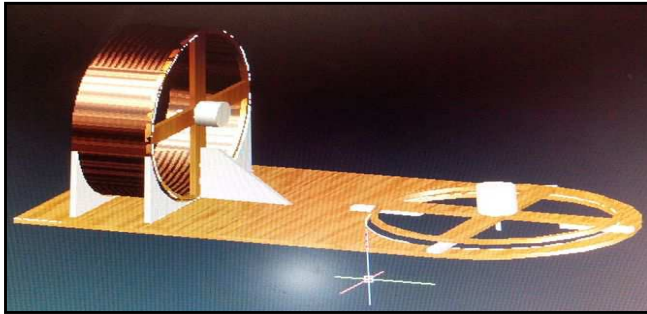


Fig. 8 Design of Hovercraft in AutoCAD-1

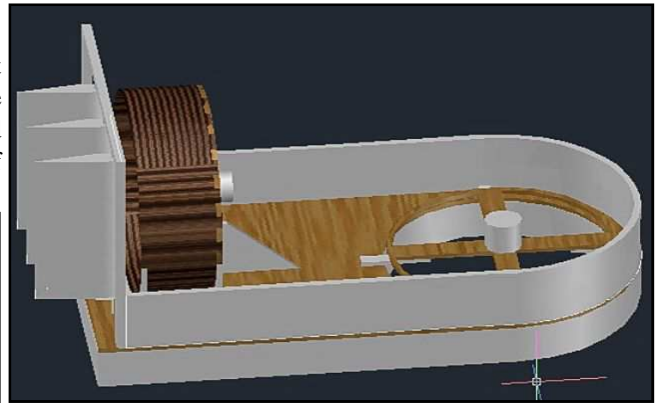


Fig. 9 Design of Hovercraft in AutoCAD-2

b) **Design of model in Creo:** In the last stage, the design of whole model and different assembly was prepared with the help of Creo software. This final design of model along with the design of its different components was shown in fig. 10.

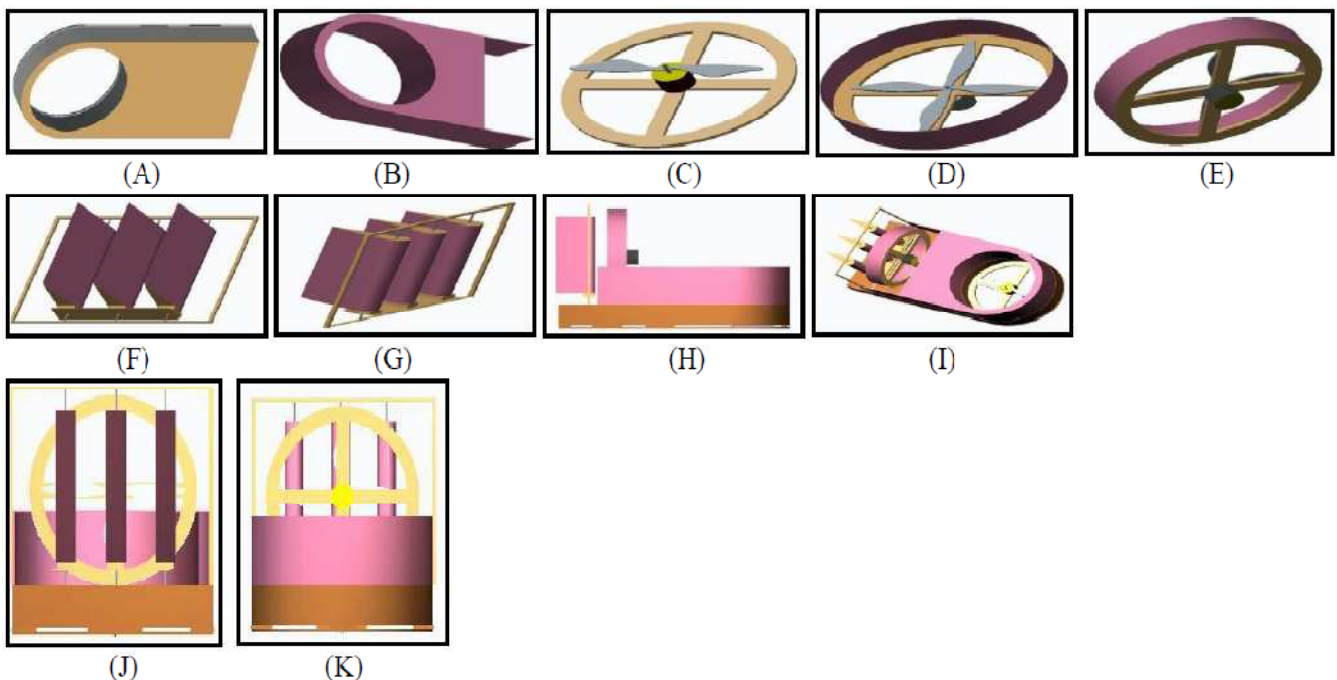


Fig. 10 (A) Design of Base of Hovercraft in Creo; (B) Design of Cover of Hovercraft in Creo; (C) Front View of Propeller in Creo; (D) Front View of Propeller with Cover in Creo; (E) Back View of Propeller with Cover in Creo; (F) Front View of Steering Mechanism in Creo; (G) Side View of Steering Mechanism in Creo; (H) Side View of Model Hovercraft in Creo; (I) Top View of Model Hovercraft in Creo; (J & K) Back and Front View of Model Hovercraft in Creo

a) **Structure of vehicle:** Selected wooden sheet was cut into a rectangular sheet of specific dimensions. It was given a semi circular curve at the front side. So, it has to face less resistance of air while moving. At the front side of the vehicle, a circular hole was cut which having the faintly larger diameter than the propeller diameter. A thermocol sheet was also cut into the same shape and covered with the sticky tape for its protection against the water. Wooden sheet was placed over the thermocol sheet and attached with it. This was the base structure of the hovercraft. A thin cardboard sheet was also attached below the thermocol sheet for safety point and also for proper balancing of the hovercraft while moving fig 11. For supporting structure as well as the setting of thrust motor and propeller, same wooden sheet was used and cut into the small supports. Lift motor was also supported by similar wooden structure. A

red cardboard sheet was provided for the cover of the vehicle body fig 12.



Fig. 11 Base Thermocol Sheet

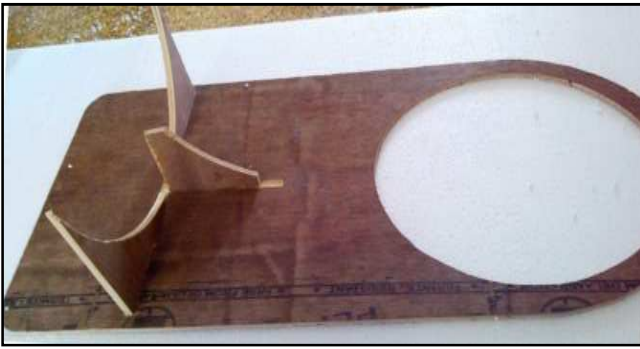


Fig. 12 Wooden Base Structure

b) Steering mechanism: Wooden plate is cut into small wooden chips that are symmetrically tapered and given a small curve at their front and end sides. A small iron rod or scope is passed through their holes and attached with a cover. A rectangular column type of arrangement is created by connecting these wooden chips in a row. Three columns of the same size are connected with each other with help of the string and that string is attached to the servo motor then. A servo motor will control the steering of the hovercraft. At last, the steering mechanism is placed on the body with help of the wooden support.

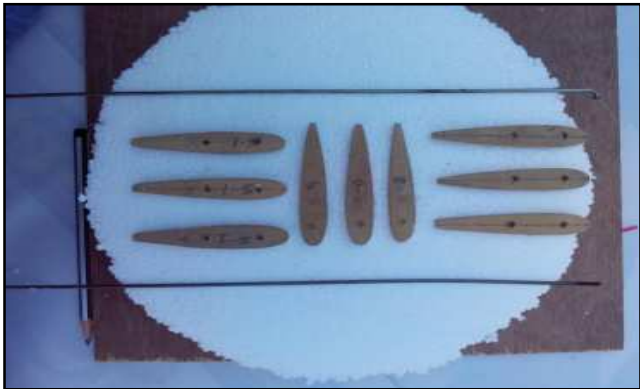


Fig. 13 Wooden Chips for Steering Mechanism

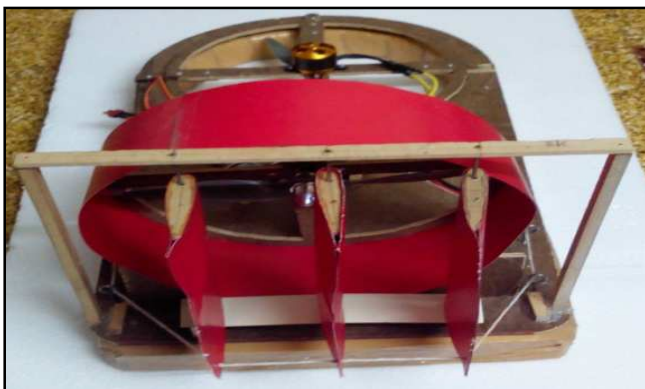


Fig. 14 Steering Mechanism of Hovercraft

c) Skirt: Skirt is made of Nylon Rip stop fabric military material. It is a plastic type of flexible layer that contains the pressured air cushion and is responsible for lifting the body of the vehicle. Numbers of holes are provided for removal of air from the skirt so that it can continuously lift the hovercraft and provide properly balanced cushion of air. Skirt is fitted at the bottom of the hovercraft with the help of the sticky tape. It is having bigger dimensions than the base structure of the vehicle. Because of it is going to be filled with the pressured air moving with the slow velocity.

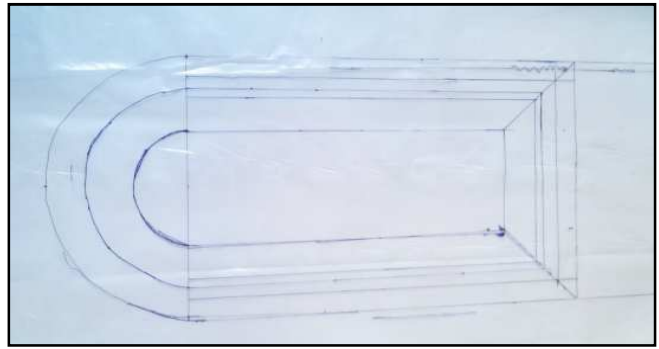


Fig. 15 Skirt for the Hovercraft



Fig. 16 Fitting of Skirt on Hovercraft

d) Mounting process: The wooden parts of the vehicle body are mounted with the help of fevicol and nails are also used wherever they are required. Motor and Propellers are connected on the wooden supports with the help of the screws of the proper size. Steering mechanism is attached with the hovercraft by taking support from wooden strips and it is connected to a servo motor with the help of a string. Electronic members like receiver, electronic speed controller, battery, servo motor etc. are placed into a box made from cardboard sheet and that box is placed on the base structure of the hovercraft.

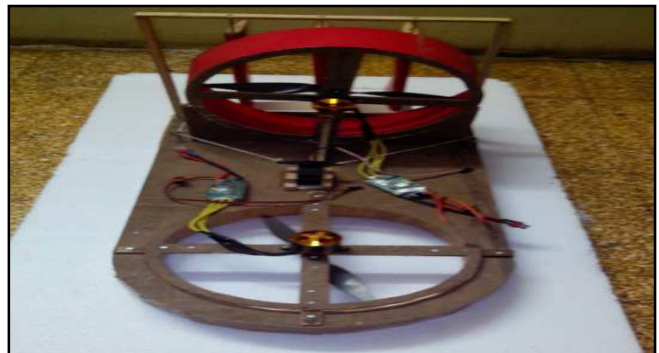


Fig. 17 Components Mounted on Hovercraft



Fig. 18 Covered Body of Hovercraft

e) Working of the hovercraft: Hovercraft is powered by a lithium polymer battery that is connected to the DC Motors and a Servo Motor with the help of a Y-Connector. Two front propellers blow air in such a way that it produces the force in the opposite direction of surface. This pressurized air is converted into the air cushion with the help of the flexible skirt and vehicle body is lifted above the surface. Air is gradually released from this cushion of air and leaves from the holes provided in the skirt. End side propeller supplies the required thrust to move the vehicle in the proper direction. A Servo Motor is used for getting the proper movement of hovercraft by controlling the steering mechanism.



Fig. 19 Model of Hovercraft

Whole movement of the vehicle is operated by a wireless remote controller with the range of 500 meters. Speed of both motors is controlled by two separate electronic speed controllers in case of variation in required amount of thrust or lift. There is no external braking mechanism developed for the reduction of speed of hovercraft. Speed of the vehicle can be reduced easily by reducing the speed of the thrust motor which is controlled by ESC.

V. RESULTS

Model of the hovercraft was picked up and also propelled through the thrust system. It was able to handle 3 Kg weight and hovered with an air cushion of 0.4 inch. Proper operation was achieved with the steering system and successfully completed trial run.

VI. CONCLUSION

The principles of the hovercraft have been demonstrated using suitable material and power sources. The design of the hovercraft has come up to the level of expectations and it has helped a lot in constructing the model. It is proved that it is capable as an amphibious vehicle that can be used on both land and water after series of tests. The thrust and lifting systems gave excellent performance and steering system is very useful to achieve considerable good maneuverability.

VII. FUTURE SCOPE AND RECOMMENDATION

We are planning to add a robotic arm mechanism that can hold different types of props like a small spy camera, land mine detectors etc. so it can be useful in such operations that are related to security issues. We have also planned to attach a small remote operated torch arrangement at front of the hovercraft. So that it can be operated during the night

period and also in the areas where very low light is available. We would like to recommend that if skirt can be attached in such a way that it is totally air tight and leakage free than it will directly affect the performance of the hovercraft during its operation and it will improve the movement control of the hovercraft.

VIII. ACKNOWLEDGEMENT

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