ROWBOATICS ABSTRACT

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Team Code : RB-225844

CATAMARAN WITH DIFFERENTIAL DRIVE

ABSTRACT

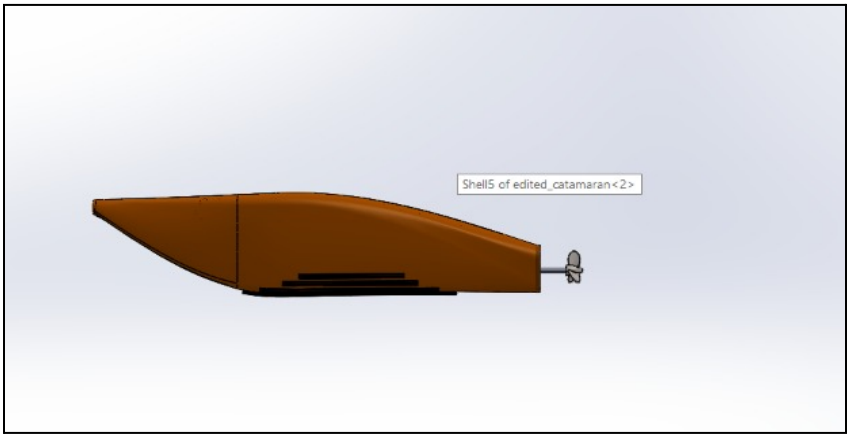
We are designing a multi-hull catamaran with differential drive using twin motor(12V).For efficient propulsion we are using ducted propellers and to control the twin motor we are using an electronic speed controller(ESC) which is powered by Lipo battery and operated wirelessly using a transmitter and receiver.

HULL DESIGN

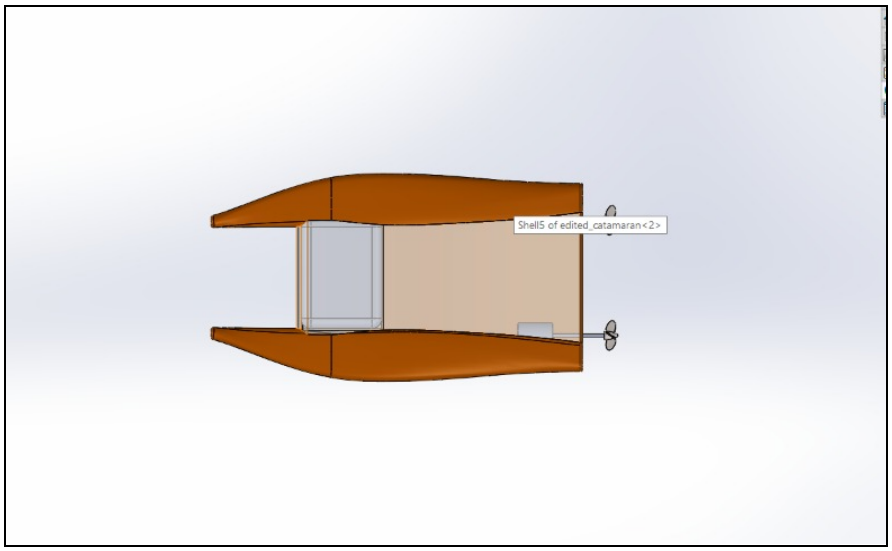
Catamaran

A catamaran is a multi-hulled watercraft featuring two parallel hulls of equal size, The catamaran design is a cross between a hydroplane and a monohull, With the centre tunnel, the hull has less drag then a deep vee, while also creating lift. The twin hull design makes it relatively faster than a deep vee. The only drawback to the design is that a blow over in windy conditions is possible. They are somewhat harder to set up than a monohull. At very high speeds the catamaran will be more stable than the mono because of the twin hulls.

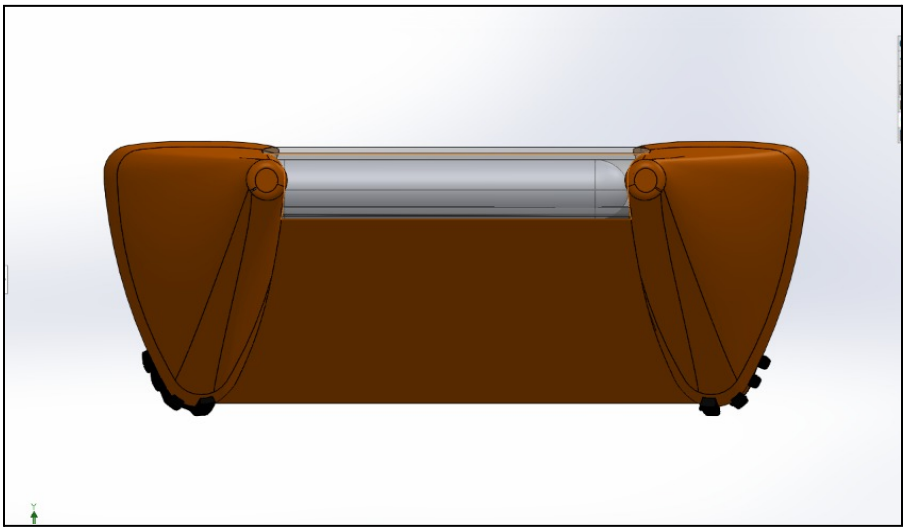
CAD DESIGNS



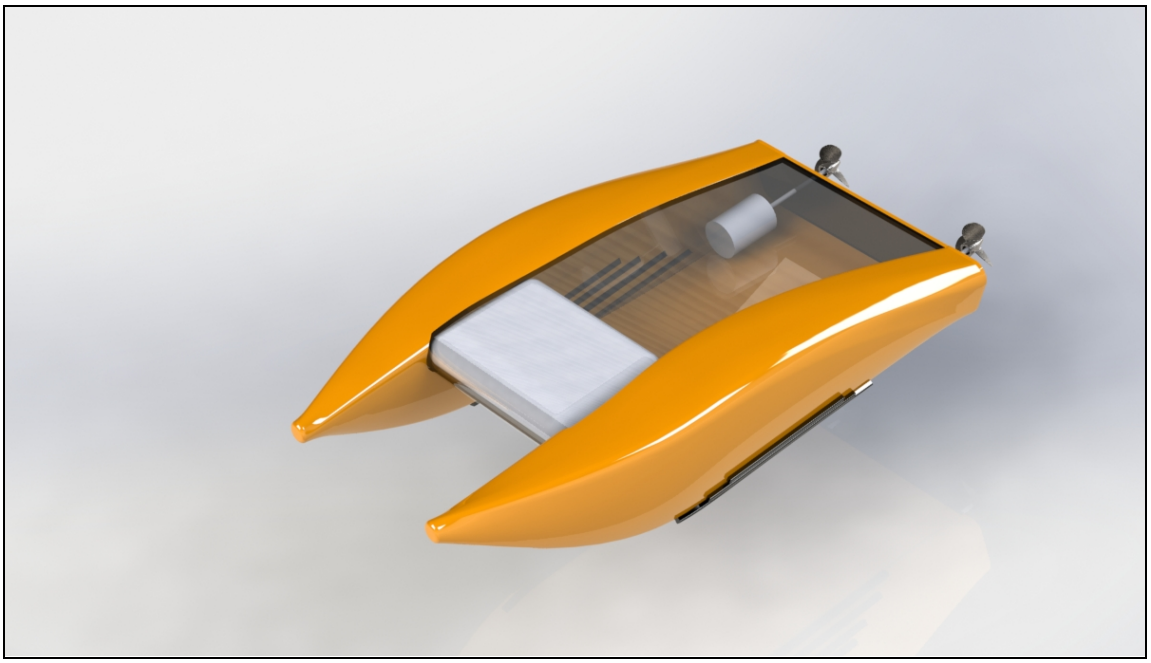
Side view



Top view



Front view



Full render

AERODYNAMIC AND HYDRODYNAMIC DESIGN

Hydrofoils

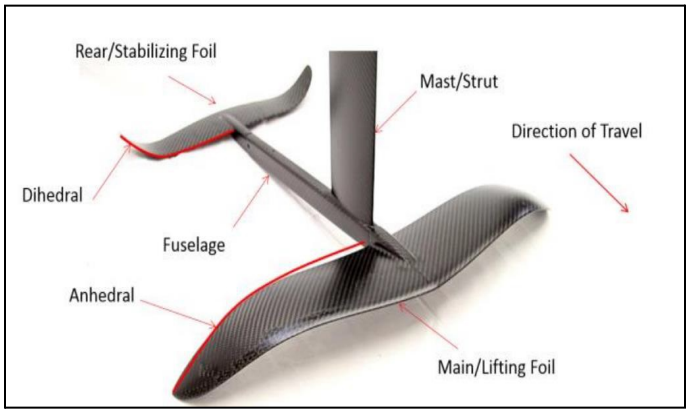
Hydrofoil (It is a foil or wing under water used to lift the boat's hull until it is totally outside the water.).Hydrofoils can increase the speed of our vessel drastically. With the lift that occurs once your hydrofoils are operating, you're dealt with less drag and resistance that's caused by the water. It is not only more fuel-efficient, but it brings a whole new level of eco-consciousness.

EXPLANATION OF HOW IT WORKS/ IS USED:

1. At low speeds the hull (body of the ship) sits in the water and the hydrofoils are totally submerged in the water.
2. As the boat's speed increases, the hydrofoils create lift.
3. At a certain speed, the lift produced by the hydrofoils equals the sum of the boat and cargo weights. Therefore the hull comes out of the water.
4. Instead of having an increase in drag with increasing speed because the hull is lifted out of the water (contrary to what happens in traditional boats due to pressure drag), the hydrofoils provide a more efficient way of cruising. Decreasing the drag contributes to the better use of the power needed for the movement of the boat.

Since the boat should be designed in order to cross obstacles and take steep turns and the focus on

speed is secondary, this as a part could be optional or could be added on the sides which could be activated and deactivated using a servo motor.



Hydrodynamic Resistance

The essential goal in modelling hydrodynamic resistance is determination of the function $F_{wr}(V_b,\lambda)$, or alternatively $F_{wr}(V_b,F_{wh})$, for any prescribed hull form in prescribed sea conditions. A useful approach is to use an additive resistance model of the following form:

$F_{wr} = D_{hf} + D_r + D_{af} + D_{hi} + D_w - T_u$

Where:

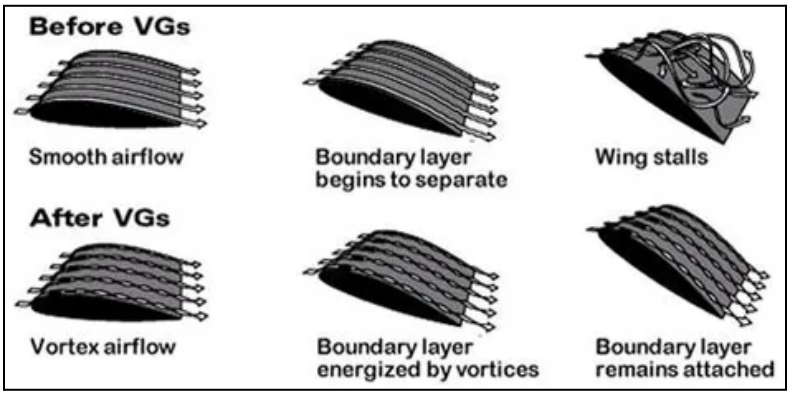
F_{wr} is the total hydrodynamic resistance (drag),
D_{hf} is the frictional drag of the hull,
D_r is upright residuary resistance of the entire vessel,
D_{af} is the friction and interference drag of the appendages,
D_{hi} is the drag due to heel and yaw (leeway), or equivalently, due to heel and heel force production,
D_w is the resistance due to sea waves (added resistance), and
T_u is the mean dynamic thrust due interactions of appendages with the unsteady flow resulting from vessel seakeeping motions and sea wave orbital velocities.

Guides

Guides can be used under the hull, to provide directional stability.
They must be precisely aligned to be parallel, otherwise the boat may lose control and move in a chaotic manner, losing speed and efficiency as well.

Vortex generators

A vortex generator (VG) is a small aerodynamic device, attached to a lifting surface (or airfoil, in our case the hull of the hydrofoil)or a rotor blade of a wind turbine. VGs may also be attached to some part of an aerodynamic vehicle such as an aircraft fuselage or a car. When the airfoil or the body is in motion relative to the air, the VG creates a vortex, which, by removing some part of the slow-moving boundary layer in contact with the airfoil surface, delays local flow separation and aerodynamic stalling, thereby improving the effectiveness of wings and control surfaces, such as flaps, elevators, ailerons, and rudders.



1. Drag Force for Rectangular Vortex generator at 0° (D= 21288.9 N).
2. Drag Force for gothic Vortex generator at 0° (D= 16916.1 N) .
3. Drag Force for delta wing Vortex generator at 0° (D= 16783.7 N).

WORKING OF BOAT

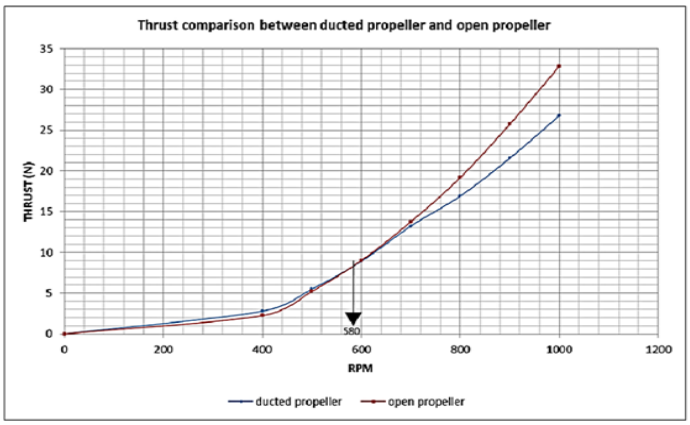
Propeller Design

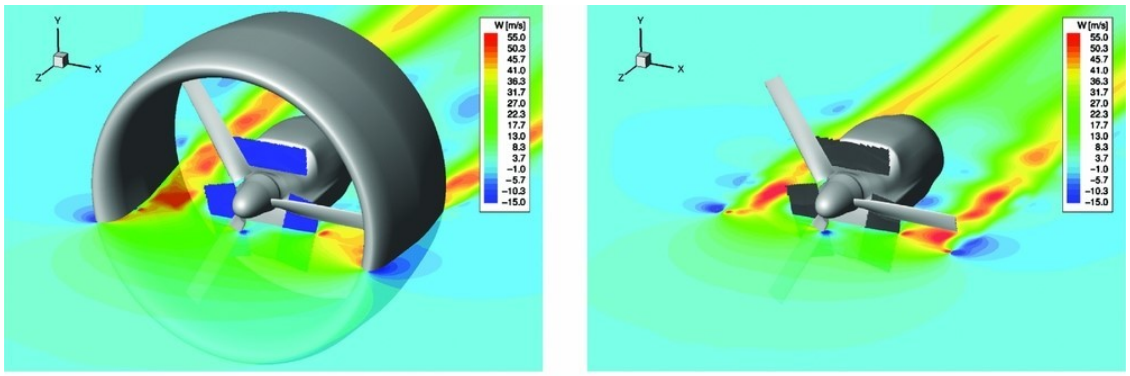
Ducts in propeller

In our research, we have found that duct showed two-fold effects on the propeller:

1. Inducing an increment of velocity through the propeller in forward motion, and

2. Negating tip effects if the gap between the inner wall and the propeller tip is very small(i.e,0.03 in.)





Axial velocity in a slice of the flow field- ducted propeller (left) and free propeller (right).

Hence, using a ducted propeller increases speed and energy efficiency drastically.

Blade Size, Pitch and Rake Angle

Propeller diameter calculation (considering 100% engine horsepower and RPMs):

- 3-bladed Propeller Diameter(in inches)= [632.7*(Propeller Shaft Horsepower)$^{0.2}$]/(RPM)$^{0.6}$
- 2-bladed Propeller Diameter = (3-bladed Propeller Diameter)*(2-bladed Propeller Diameter Conversion Factor)

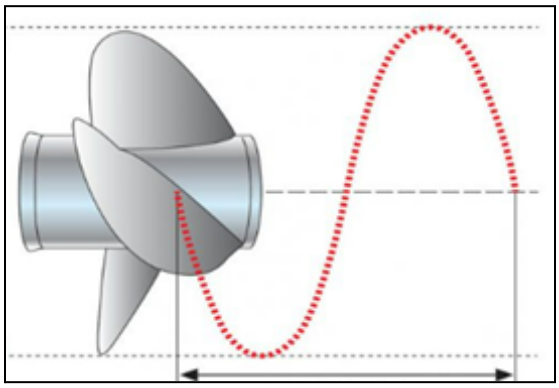
Two-Bladed Propeller Diameter Conversion Factor is 1.05
Four-Bladed Propeller Diameter Conversion Factor is 0.94

The higher the pitch, the higher the speed of the boat and greater the efficiency of the propeller.

- 90% Engine Horsepower = 0.90*(Fuel Stop Power Brake Horsepower – Total Horsepower Losses)
- 90% Maximum Propeller Drive Shaft RPM = 0.90*(Maximum Propeller Drive Shaft RPM)
- Knots @90% = [10.665 / {Displacement in Pounds / (90% Engine Horsepower)}$^{1/3}$] x (Loaded Waterline Length in Feet)$^{0.5}$
- Propeller Slip = 1.4 / (Knots @90%)$^{0.57}$
- Three Bladed Propeller Pitch in Inches = [(12 in/ft)*(Knots @90%)*(101.3 kts/ft/min)] / [(90% Maximum Propeller Drive Shaft RPM)*(1.0 + Propeller Slip)]

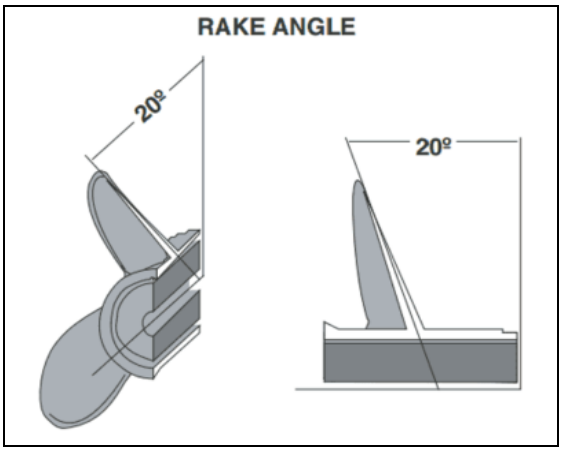
Pitch values should be rounded down unless the decimal is 0.7 or greater.

Two-Bladed Propeller Pitch Conversion Factor is 1.01
Four-Bladed Propeller Pitch Conversion Factor is 0.98



Pitch

RAKE: Rake is the angle between the blade and the hub. Propellers can have between 0- and 20-degrees rake. It determines how much the bow lifts out of the water. **High rake** propellers are **ideal** for **light-weight** and high speed boats.



Optimization of the number of blades

- Theoretically, a single-blade propeller would be the most efficient - if the vibration could be tolerated. To achieve an acceptable level of balance with much less vibration, a two-bladed propeller is the most efficient, practically speaking.

- With more blades, efficiency decreases, but so does the vibration level. Most propellers are made with three blades as a compromise for vibration, convenient size, efficiency, and cost.
- The efficiency difference between a two- and a three-bladed propeller is considered less significant than the vibrational difference. Nearly all racing propellers are presently either three- or four-bladed.

- With the growing frequency of propellers being run at an increased height (surfaced), four- and five- bladed props have become more popular. They suppress the higher level of vibration and improve acceleration by putting more blade area into the water. They can also help to make the rake more effective in lifting the bow of the boat for added speed.

Mechanism of Differential Drive

Differential drive works using a twin motor setup.Boat moves forward when both the propellers are rotating in opposite directions(clockwise and counter-clockwise) and when we want to move the boat to left or right there are two ways by which we can do that:
1)Rotating only one propeller

2)Rotating both the propellers in the same direction(preferable for steep turns).

Braking System

During the motion of the boat, if we want to slow down the boat or stop the boat,we have to reverse the direction of propellers in which they are rotating.
Example:If the boat is moving when the left propeller is rotating in clockwise direction and right propeller is rotating in counter-clockwise direction and if we want to stop the boat(apply a break) simply we have to reverse the directions of the propellers.

MATERIALS

Depron sheets

Depron is a brand name for Extruded Polystyrene (XPS) closed cell foam in sheet form, it is a fantastic medium for building model aircraft, and also a popular medium for architectural model building, as well as model boats and prototype design, XPS foam is stronger than traditional EPS Thermocol and can be further strengthened with carbon fibre or wood strips.

- Strength to weight ratio and rigidity is perfect for RC boats, cars and aeroplanes.
- Easy to cut with precision by knife
- Easily sandable
- Sheets are flat and have a smooth finish.
- Density: 300GSM 50-60 kg/m³

- **Mechanical Properties**

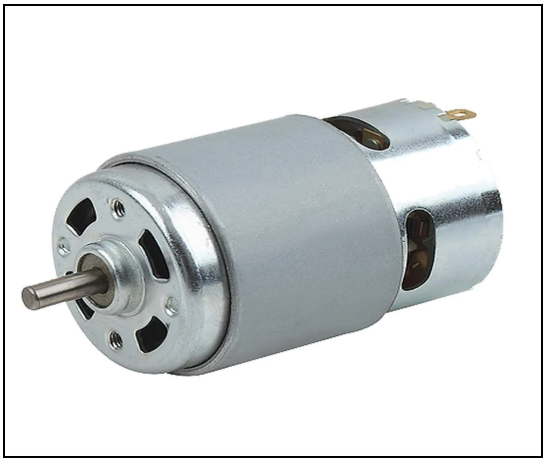
Compressive Stress (@ 10% foam deformation): 0.10MPa - 0.15MPa
Tensile Stress (@ break, length direction): 0.90MPa - 1.30MPa
Tensile Stress (@ break, transverse direction): 0.70MPa- 0.90MPa
Elongation (@ break, length direction): 9% -10%
Elongation (@ break, transverse direction): 12%
We will use depron sheet as material. Based on the materials availability in our locality, our boat model may have a different material in the final design.
Cost: INR 3.66/sq. in.

Alternative to Depron Sheets

3-D printed models can also be put to work using either PLA or ABS or PETG depending upon which of them best fits in rigidity, water resistance, light weight, cost efficiency and availability.

ELECTRONICS

Configurations of Motor



12V Brushed DC Motor RS 775 for DIY

- Operating Voltage: 12V
- No-load Current: 0.6A
- Maximum Current: 2A
- No Load Speed: 10000 RPM
- Mounting Screw Hole Diameter: 4.5 mm
- Distance between Screw Holes: 35 mm
- Diameter of the Motor: 41mm
- Length of the Motor (Body): 67mm
- Length of shaft: 16 mm
- Motor Shaft Diameter: 5mm
- Main Color: Silver Tone
- Material: Metal Net Weight: 286gm

Configuration of Battery

Orange 2200mAh 3S 30C/60C (11.1V)Lithium Polymer Battery Pack

- Model No: ORANGE 2200/3S-30C
- Weight : 175.0g
- Voltage : 11.1V
- Dimensions : 23x34x106(mm)
- Max Continuous Discharge : 30C(66.0A)
- Balance Plug : JST-XH
- Max Burst Discharge : 60C(132.0A)
- Discharge Plug : XT-60
- Charge Rate : 1-3C Recommended, 5C Max

Configurations of Transmitter and Receiver

Flysky FS-GT2 Transmitter with FS-GR3E Receiver

- Operating Voltage (VDC):12
- No. of Channels:2

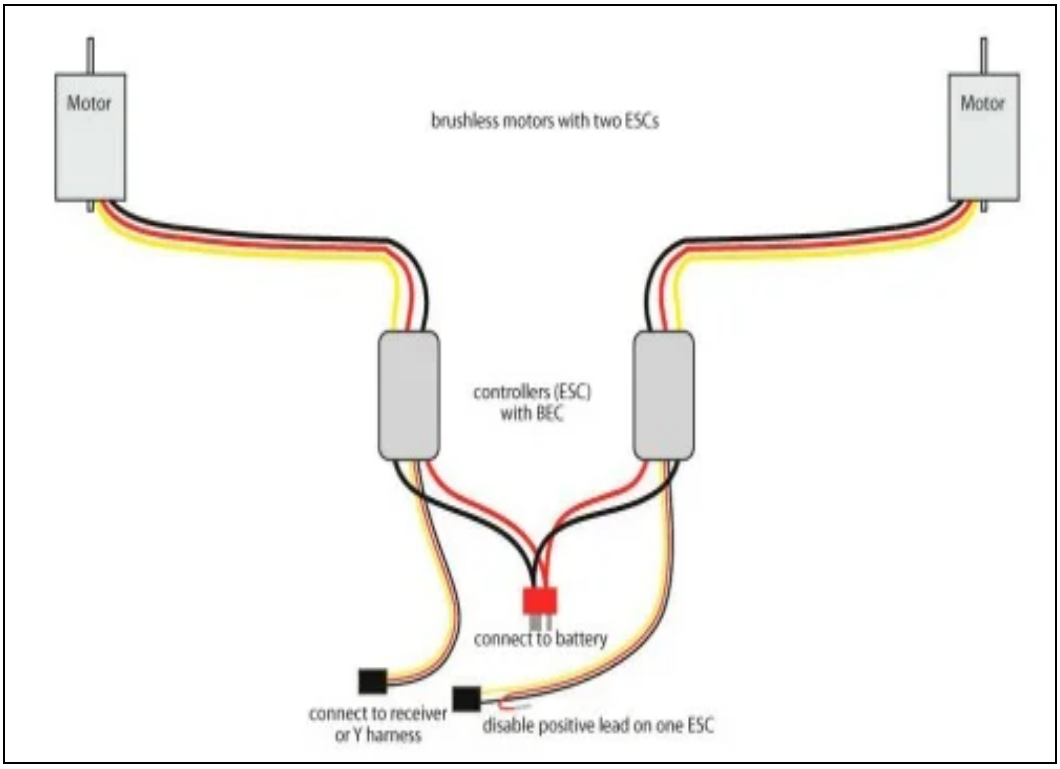
- Antenna Length (mm):26
- Certificate: CE
- Charging Port: Yes
- Code Type: Digital
- DSC Port: Yes(3.5mm)
- Modulation Type:GFSK
- RF Power:Less Than 20 dBm
- Sensitivity (dBm):1024

Configuration of Electronic speed controller(ESC)

Hobbywing Skywaller-40A- UBEC

- Continuous Current: 40A
- Burst Current: 55A (10 Sec.)
- BEC Mode: Linear Mode, 5V@3A
- Programmable: Yes
- Battery cell : Li-PO / NiMH

Working of Electronic parts



- **For Emergency purposes we are adding a small button which is used to instantly break the circuit by disconnecting the motor and battery.**

WEIGHT DISTRIBUTION

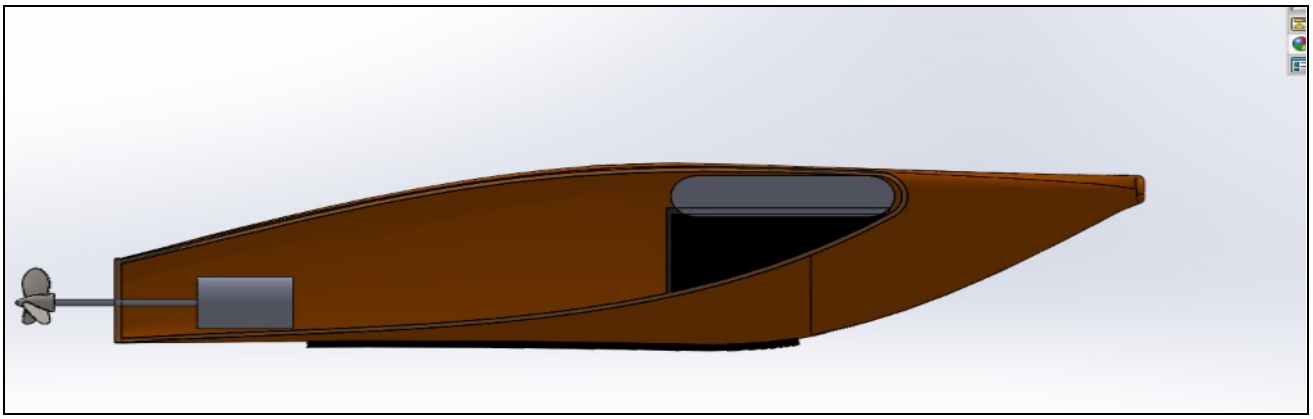
Weight distribution is very important in a boat because we need to balance the boat on the water(i.e.,a bit of the front part should be slightly lifted from the surface so that we can reduce the drag force due to water) .There are many chances of flipping and jumping of boats,so we have to take into account the following.

Mainly we are concentrating on four following factors:

(1).Position of Motor.

(2).Balancing the torque produced due to the propeller.

(3).Position of Battery.



Cross-sectional view

1)Position of Motor

We have to adjust the motor at the back of the boat so as to reduce the distance between propeller and motor thus avoiding the need for long transmission systems , thus avoiding losses.

2)Balancing the Torque produced due to the Propeller.

In case of our boat since we are using differential drive(in dual motor system one motor rotates in clockwise direction and other in anticlockwise direction) so net torque on the boat due to propellor is zero , irrespective of the direction of the motion of motors , since the torque about the centre of buoyancy would be zero.

3)Position of Battery

Position of battery entirely depends on the weight of motors we are using and the position where we are placing them.In our case since we are using **RS-775 High RPM Torque 12V DC motor,**they are about 250-300 grams and since we are placing two of them the total weight is around 500-600 grams is placed at the back of the boat.To balance them we have only battery and electronic speed controller(ESC),whose weights are approximately 175 grams and 35 grams respectively.So we can't place the battery at centre of gravity(CG). Therefore we have to place both battery and ESC a bit ahead of CG so that we can reduce the torque produced due to the motors and also we can avoid jumping and flipping of boats.

Conclusion:

Before getting into conclusion we want to introduce a small concept called **THRUST LINE**.

Thrust line: Thrust line is a theoretical line that through the structure represents the path of the resultants of the compressive forces.And also for a structure to be stable, the line of thrust must lie entirely inside the structure.
We should arrange the parts in the boat in such a way that the thrust line is always ahead of the centre of gravity(CG),so that the front part of the boat will be raised a little bit which helps to reduce the drag force on the boat due to water.

BUDGET

ITEM	NO. OF ITEMS	PRODUCT LINK	PRICE
motors(12v)	2	https://robu.in/product/orange-rs775-12v-6000rpm-high-speed-dc-motor/	449/pc
Paper Cutter	1	https://www.amazon.in/STANLEY-10-143-S-Basic-Snap-off-Blade/dp/B0999CV888/ref=sr_1_18?keywords=Paper+Cutter&qid=1667150681&qu=eyJxc2MiOiI1Ljg5IiwicXNhIjoiNS40MyIsInFzcCI6IjUuMDcifQ%3D%3D&sr=8-18	68/pc
Transmitter and Receiver	1	https://robu.in/product/flysky-fs-gt2-transmitter-with-fs-gr3e-receiver-for-rc-car-boat/?gclid=Cj0KCQjw--2aBhD5ARIsALiRlwA9qKtYIJDIpGf1pQwDSIEk9dJRn8CBHYrSinsT6MEWUrBGrlVhOI8aAo39EALw_wcB	2190/pc
Propellers	2	https://www.flyrobo.in/40mm-nylon-three-blade-propeller-for-rc-boat-model-parts	49/pc
Depron sheets	19" * 39"	https://www.havochobby.in/products/depron-sheet-5mm-19x39-pack-of-5pc?variant=43555648241914&currency=INR&utm_medium=product_sync&utm_source=google&utm_content=sag_organic&utm_campaign=sag_organic	1180/5pcs
ESC	1	https://robu.in/product/hobbywing-skywaller-40a-ubec/?gclid=Cj0KCQjw--2aBhD5ARIsALiRlwD2dNKSrP_Vx_hkco5z4XMWa8d6Cd_TU2o5Zwn_htNX5nXl0qTwzY8aArxiEALw_wcB	1409/pc
Battery	1	https://robu.in/product/orange-2200mah-3s-30c60c-lithium-polymer-battery-pack-lipo/?gclid=Cj0KCQjw--2aBhD5ARIsALiRlwBRqbDyyJZ5N6xbBgIEExh5QnJT2Cy86F4VesID6eOHEiFSKDUl7p0aAjBOEALw_wcB	1699/pc

The approximate cost of the boat would be somewhere around INR 7,500-8,000.

Thank You for reading!