Remotely Propelled Water Lifeguard Robot

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Abstract

Remotely propelled water lifeguard robot also known as Marine Lifeguard Robot (MLR) is designed for rescuing distressed people in water. The preeminent aim behind the construction of this robot is to make it cost effective, easily operable by remote control to navigate the distressed person at the safe place. as it will work on the principle of jet propulsion, better efficiency, sturdiness and speed can be achieved. The MLR is specifically made for organizations, having direct relation to sea or water bodies, such as rescue teams, life squad, Merchant navy, cargo ship owners, etc. for their unpredictable circumstances. The risk for both victims as well as saviours can be lowered significantly, with the help of this remotely controlled robot. Besides this, MLR will be cost-effective, light weighted, along with having capability to carry an average person who is in danger, to the safe place. The hull of the robot is made in such a way that it can sustain load up to 120kg in static condition and the range of operation can be varied by using high-tech transmitter and receiver.

Keywords **–** Marine lifeguard robot, Unmanned Surface Vehicle (USV), Jet propulsion, Disaster relief, Solidworks, Humanitarian aid

Nomenclature

F	buoyancy force (N)
ρ	water density (kg/cm^3)
V	volume of water displaced (cm^3)
g	gravitational acceleration (m/s^2)
CAD	computer aided design
MLR	Marine Lifeguard Robot

1. Introduction

It is a very challenging task for lifeguards to retrieve flood victims out while risking their own lives. Uneven shifting of weather and temperature, downpour occurs which becomes common problem across the world. The deadliest incident was happened in 2019, where 1900 people were dead in India which could have been saved if evacuated. To rescue these distressed people, we need whole rescue team for instance, NDRF (Natural Disaster Response force) with their boat, weather there is one person or more in danger. Inversely, in many cases, it can be seen that the NDRF team itself is put in critical conditions because of some obstacles. For instance, open drainage holes, high waves, heavy water logging. In addition, even whole NDRF boat which rescues drowning victims got drowned. Therefore, we can't afford this kind of causalities [2]. To overcome this type of constraints we are trying to make radio control (RC) vehicle called marine life guard robot which would be working based on the principle of "jet propulsion". Main objective of this project is no skilled person is required to operate the robot is also light in weight & compact in design. There are some problem specifications such as in India that people accidently fall in dams or canals while they are roaming at surrounding or doing such activities like taking selfies and having fun. Open drainage tunnels, fallen tree on the roads and choked roads, this kind of problems been usual in India so in this kind of situation NDRF team faces lots of problem and get difficulties to rescue the drowning victims. To handle and perform duties in this kind of situations we have tried to make MLR (marine life guard robot) which would be unmanned [3].

The key point of making the hull of the robot is the selection of material. There are lot of different types of material regarding this project. We have opted between two types of materials on the basis of their properties, cost, and processibility. The materials are HDPE, and foam sheet (with coating of composite fibre, resin and hardener). Here we have described properties of HDPE and foam sheet cover laying with the use of composite fibre, resin & hardener (in suitable proportion) – flexible, good chemical resistance, easy to process, tensile strength, thermal co-efficient expansion, density, good toughness even at lower temperature and also at low cost.

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1.1. Selection of material

Now here we have discussed properties of the foam sheet, composite fibre with hardener and resin which is going to be used as the parent material of this robot. Fibres used in composite manufacturing are made of glass. Such as, glass fibres. Fibre with hardener, usually replace heavy metal parts because it gives almost similar properties as heavy metals gives. Polyester is most commonly used resin bond with composites because of its balanced properties in dimensional stability, cost and ease of handling and processing. Also cost of foam sheet is very cheap and its weight is extremely low. When we apply coating of composite fibre, resin and hardener on foam sheet having specific ration of resin and hardener (2:1) then it will give good properties like hardness, floatability, bouncy, corrosive resistance and doesn't give porous effect which will be the best properties for working environment in water. After seeing all the properties of these two materials we have to analyse their processibility and its cost. As we make by our self and there is no need any type of manufacturing process. So this robot will be made by using foam sheet with composite fibre, resin and hardener as it gives required properties which is suitable for required working environment.

1.2. Working principle and Components

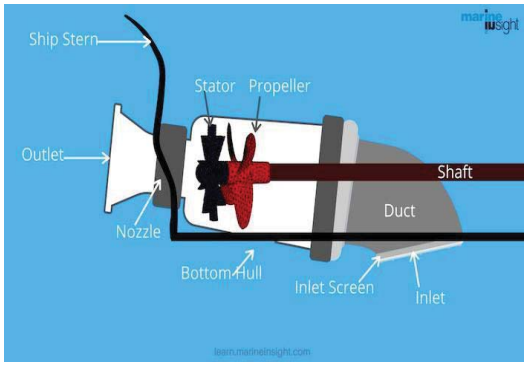
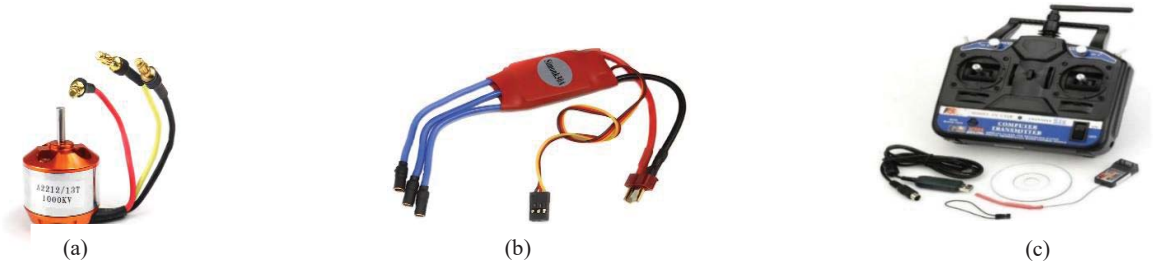


Fig.1. Illustrates the name of components and working principle of jet propulsion unit. [4]

Fig (1) shows that the what are the components uses in jet propulsion unit and placement & connection of each one. By this unit we would induce force which led to momentum of a boat by means of pressure difference. Feed water would directly inject into the main system through inlet duct which has placed at the underside of the unit. Normally single duct uses in vessels but in such cases if we need to require high power for the sake of large size vessel operations, here we can use multiple inlet duct instead of single using. Water passes to the main machinery which consist blades and stator assembly, nozzle. Blades (propeller) are powered by the impeller and the impeller is powered by the outside placed DC motor. This propeller and stator assembly connected to the motor by shaft as per shown in the figure. Shaft is rotated by the main drive shaft, connected to the motor and coupled using reinforced bearings and connectors. Injected water does not acquire high velocity energy therefore, we have to convert it into high energetic fluid. This can be achieved by producing turbulence using hydro dynamically shaped blades (propeller). When the propeller and stator assembly powered by the motor induce huge pressure difference would be generated between inlet and outlet by the means of this pressure difference and turbulence induced by the blades high energy fluid exert a force though the nozzle placed at outlet. Due to this exerted force by high energy fluid, boat would move forward by means of its reaction force. On the basis of that we can say that jet propulsion unit works on the principle of newton's third law which states that "every action has an equal and opposite reaction."
Other components from electronic side are also there, which are responsible for autonomous capabilities of robot which includes BLDC (brushless DC) motor, ESC (electronic speed controller), li-po battery, transmitter and receiver, servo, and propellers.



(a) (b) (c)

Fig.2. (a) BLDC motor (b) ESC (c) Transmitter and receiver [5]

Here we have used brushless DC motor (BLDC motor) which used as an engine of the jet propulsion unit because shaft is connected to the DC motor through shaft coupler. Brushless DC motor also known as an electronically commutated motor (EC motor). DC motor powered by DC electric power source via integrated inverter which is produce AC electronic signals to drive the motor.

Specifications of BLDC motor:

- Operating range: 3-9V, R.P.M.: 9200, No load current: 0.006A, stall torque: 35.19 gm-cm

Here we have used ESC (electronic speed controller) to get motor speed as per our requirement and to spin that shaft as per our need. ECS is directly connected to the power source or battery by using power distribution board because here we need two electronic speed controllers. ECS use to control speed of motor with frequency but not voltage. Here we can also use ECS which consist in-built battery eliminator circuit

Specifications of ESC:

- Peak current: 80A, type: brushless, battery: 2-6s, li-po, Ni-MH

Transmitters and receiver are used for make communication wirelessly over a distance. Transmitter generate radio frequency AC current antenna which is exert radio waves by radiates & navigate it. Combination of transmitter and receiver called transceiver. Which use to take place communication over a particular distance by means of radio waves generating and locating it.

Receiver which is use to catch transmitted signals by antenna as a input signal, use electronic filter to make separate wanted radio signals among all other signals which was picked up by antenna. For further processing signals must have to be at suitable level which can be accomplish by amplifies all of them. Finally, to make it readable by operator, decoding all the signals by demodulation. It is the end of communication channel

Specifications of transmitter and receiver:

- Power input: 12V DC, antenna length: 26 mm, channel: 2CH, frequency range: 2.405-2.47 Ghz

(a) (b) (c)

Fig.3. (a) Li-Po (Lithium-Polymer) battery (b) Marine propeller
(c) Servo [8]

In As power source of robot, battery is used, which is called as lithium-ion polymer (Li-po) battery. Also, it is rechargeable battery of lithium-ion technology which make out like pouch format. This sort of batteries comes out in package or pouch sue to this it is usually be in lighter as compare to cylindrical and plasmatic cell but it is also less rigid.

Specifications of Li-po battery:

- Voltage: 14.8V, constant discharge: 40C, maximum discharge: 50C (10sec), dimension: 127 x 44 x 40 (L x W x H) (mm)

Propeller which is kind of hydrodynamically shaped blades three or more than that which is placed at the end of the shaft. Propeller produce thrust from powered rotational motion by creating a pressure difference between the forward and rear surfaces of the air foil-shaped blade.

To get automatically movements with parts of machine with precision of particular velocity and acceleration we can be use servos, servo motors. Servos are mainly act as linear or rotary actuators. It is also called as electronic actuators.

Specifications of servo:

- Operating range: 4.8~6c (VDC), stall torque: 10 kg-cm, speed: 0.22 sec/60 degree, rotation: 180 degree

1.3. Water cooling system

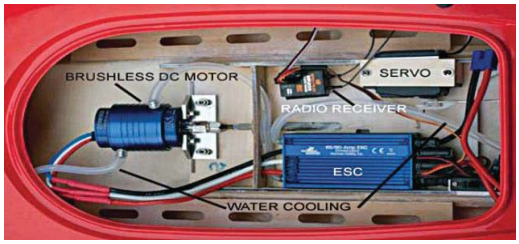


Fig.4. Water cooling system [11]

Heat used to be generated due to physically connected movement between two mechanical components, need to dissipate this unwanted generated heat, we can be accomplished this by using colling system. Here we are using water cooling system which is use widely to keep ECS and other components comparatively cool. The components are wrapped with aluminum tubing coils which is connected to the flexible tubing by means of water pick up from bottom of the hull. Water suck by that flexible tubing and provide conductive cooling to components. First of all, we have lubricated main propeller which would keep cool by dissipate heat which is produce due to friction between shaft and blades.

2. Design and analysis

For the analysis purpose we have made the CAD design of the robot in the 3d cad modelling software called solidworks and for analysis we have used Ansys software. Solidworks is the 3d modelling CAD software, used by many industries such as automobile, product designing, etc., owned by company named Dassault System. Ansys is the software which is used to analysis the designed product. Many MNC's are used this software at industrial level for their analysis purpose.

(a) (b) (c)

Fig.5. (a) 2d design of hull (b) 3d cad design of hull (c) Simulation of hull

Fig.6. 3d design of motor stand

Fig.5 (a) and (b) shows the design and dimensions of hull which is designed using solidworks software. Which consists of slots which are used for connection of all electronic parts and two provisions for jet propulsion unit. Fig.5 (c) shows the simulation analysis of hull which shows the maximum pressurized area in water. Key point of design is the stability and flexibility of hull. Design should be such that hull can withstand the sudden impact of waves.

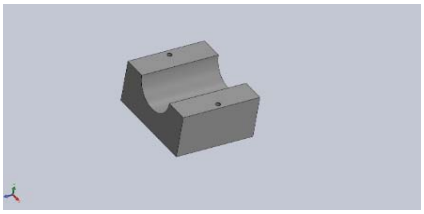


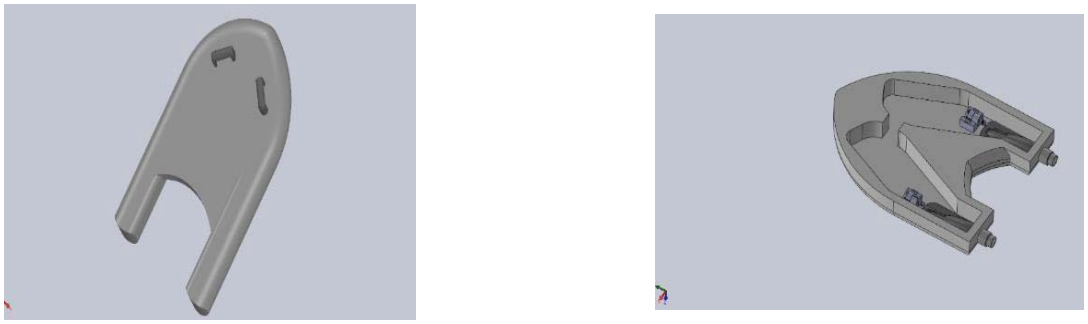
Fig.6 stand of motor

Fig.6 shows the stand for motor. Purpose of making this stand is that the shaft which is connected to the motor shaft by using coupler must be straight with the propeller off the jet propulsion unit and it will rigidly be coupled with clamp to avoid deflection while in action.

(a) (b)

Fig.7. (a) 3d design of jet propulsion unit (b) Simulation of jet propulsion unit

Fig.7 (a) and (b) shows the design and analysis of jet propulsion unit which is going to be 3d printed. It consists of a base which is going to mounted on the base of the hull, one manifold having inlet at base and outlet at upside where nozzle and propellers are going to mounted at the outside of the hull. Fig.14 shows the flow simulation of manifold of jet unit for experimental purpose.



(a) (b)

Fig.8. (a) Cover of hull (b) Assembly of hull and jet propulsion unit

Fig.8 (a) and (b) shows the upper cover of hull which consists of two stand which are mounted on the top side of the cover for holding purpose for drowning victim as they can hold it easily and they could be saved. fig.16 shows the assembly of hull, motor and jet propulsion unit. To reduce pressure energy at the outlet and reversely to increase velocity at out let two nozzles is connected with the two jet propulsion units respectively. Motor is mounted on the stand rigidly to avoid deflection of shaft which is connected to the motor shaft using coupler through jet propulsion unit having propeller mounted on the other side. When motor rotates, shaft is also rotate and therefore propellers rotate and start sucking water from the inlet of the propulsion unit and throw it with high velocity to the outlet of jet and because of this, propulsive force is generated and vehicle goes in forward direction.

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2.1. Block diagram

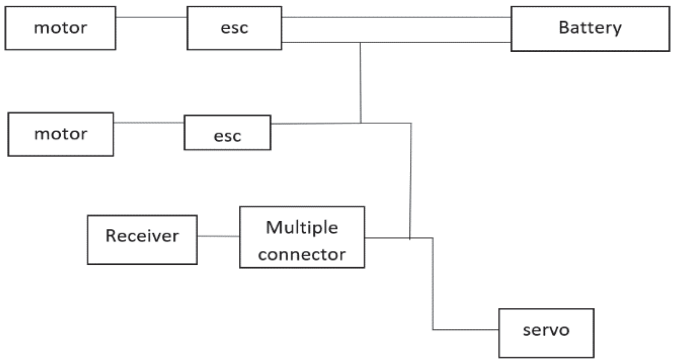

Fig.9. Illustrates the Block Diagram of connection of the electronic parts [12]

Fig.9 shows the working block diagram of the connection of all the electronics. Two jet propulsion unit therefore two BLDC motors are used for propulsion system. Two ESC (electronic speed controller) are used for each motor to control the speed. Servo is connected to the battery through multiple connector receiver is also connected to receive signals form transmitter and one rechargeable li-po battery is connected to the system as power supply.

3. Calculation of load carrying capacity

3.1. Principle of calculation

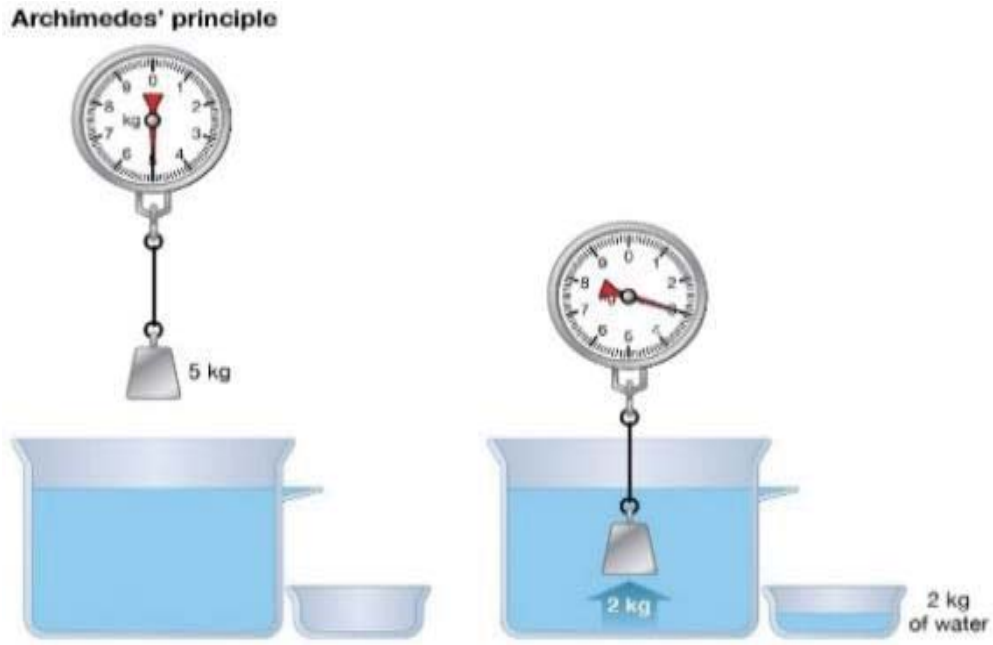

Fig.10. Illustrates the Archimedes principle. [13]

Here calculation of buoyancy and capacity of boat to hold people on it play important role. Capacity of boat can be determined by using the principle of Archimedes' which states that Archimedes' principle states that the upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially, is equal to the weight of the fluid that the body displaces.

3.2. Mathematical calculation

$\boldsymbol{F = \rho v g}$ **…… (1)** [14]

- F = Buoyancy force, N,
- ρ = water density, kg/cm^3,
- V = volume of water displaced, cm^3,
- g = gravitational acceleration (m/s^2)

Considering static position of hull,

(a=g) **…… (2)**

From equation (1),

$F = \rho v g$

Ma = $\frac{m}{v}$ vg

M = $\frac{m}{v}$ v (from equation (2)

M = ρ v where, **($\rho = \frac{m}{v}$)**

V = $\boldsymbol{M/\rho}$ …… (3)

M = total weight (kg)

Now, from dimensions of hull,

Length (L) = 90 cm, Width (W) = 70 cm,

Height (H) = 20 cm

w = 5 kg (weight of hull)

Area of hull, (A) = W*L (cm^2)

Now, considering full loaded condition

$\frac{volume\ of\ water\ displaced}{area\ of\ hull}$, $\frac{cm^3}{cm^2}$ = buoyancy, (cm)

$\frac{x}{6300}$ = 20, (cm)

X = 126000 cm^3 (volume of water displaced)

Now,

ρ = 0.001, kg/cm^3

From equation (2)

M = v * ρ

M = 0.001 * 126000 = 126, (kg) **…… (4)**

Now, subtracting weight of hull (w) from equation (3) we get max. load carrying capacity of robot,

M – w = 126 – 5 = 120 (kg)

here 120 kgs will be the max. load can be sustained by boat. Now considering 80 kgs is the average person weight than factor of safety can be determined as

FOS (Factor of safety) = max. stress / working stress

= 120/80

= 1.5

4. Results and discussion

Implementation of coating of composite fibre with appropriate mixture of resin and hardener having ratio of (2:1) respectively.

(a)

(b)

Fig.11. (a) and (b) coating of composite fibre with resin and hardener on foam sheet

(a)

(b)

Fig.12. (a) final product (b) hull is floating on water

Fig.12 (a) shows the final product after coating. Fig (b) shows that final product can easily float on the water surface.

4.1. Costing estimation

Following is the cost estimation which includes cost of various components and other necessary details.

Table of cost estimation

Sr. No.	Description	Cost (Rs.)
1	Composite fibre (Rs. 150 per kg)	1000
2	Resin (Rs. 150 per kg)	300
3	Hardener (Rs. 130 per kg)	250
4	Foam sheet (60 Rs. Per sheet)	580
5	BLDC Motor (Rs.400 per motor)	800
6	ESC (Rs.448 per piece)	896
7	Li-po battery	2000
8	Transmitter	600
9	Receiver	150
10	Servo	431
11	Propeller (Rs. 1100 per piece)	2200
12	**Total**	**9207/-**

Table shows the cost estimation of robot which is approximately 9000 to 10,000/- Rs. where existing water rescue product price is nearly $10,000 (cost of E.M.I.L.Y.) which is around 7 lakhs. in INR.

4.2. Conclusion

- It is very economical and fairly simple to operate.
- Performance and handling of the robot is much batter by using jet propulsion principle.
- It can be used by any organization for emergency rescue operation as it is light in weight, easy to operate having low cost.

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