Design & Development of Amphibian Vehicle

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ABSTRACT

The ever-increasing demand for exploration and efficient transportation across diverse terrains necessitates innovative vehicle designs. This project focuses on the design, development, and testing of a multi-functional amphibious vehicle prototype capable of traversing both land and water environments. The objective is to create a versatile vehicle that can be utilized for various applications, including search and rescue operations, environmental monitoring, and recreational exploration. This project incorporates the principles of buoyancy and stability to ensure the vehicle operates safely and efficiently on water. Hollow tubes integrated into the sides of the vehicle will enhance buoyancy, allowing it to support a reasonable payload. The design will prioritize a low center of gravity to maintain stability on both land and water. For land operations, the focus will be on maneuverability and efficient power delivery. The chosen motor and drivetrain will be selected with these factors in mind. Wheel size and gear ratios will be optimized to achieve a balance between speed and climbing ability. The project will leverage 3D printing technology for the fabrication of certain vehicle components. This allows for rapid prototyping and cost-effective iteration during the design process. Materials chosen for 3D printing will prioritize a balance between strength, weight, and printability. Testing will be conducted in controlled environments to evaluate the performance of the amphibious vehicle prototype. This will include measuring land speed, water speed, and maneuverability on both surfaces. The testing will also assess the vehicle's load capacity while maintaining stability. The findings from the testing phase will be analyzed to identify areas for improvement. This iterative approach will allow for refinement of the design to enhance the overall functionality and performance of the amphibious vehicle prototype. The successful completion of this project will contribute to the development of versatile amphibious vehicles with the potential for various applications. The project findings and data will be valuable for future research and development in this field.

Keywords: - Amphibian Vehicle, Electric Propulsion System, Flapper Mechanism, 3D printed, Servo & BLDC Motor

1. INTRODUCTION

The history of transportation is marked by a continuous quest to conquer new terrains. From the invention of the wheel to the mastery of flight, humans have tirelessly pushed the boundaries of mobility. Today, we stand at the precipice of another exciting frontier: the development of amphibious vehicles that seamlessly navigate both land and water. This project delves into the design and construction of a novel electric amphibious vehicle (EAV) – a multi-terrain marvel designed for sustainable exploration and transportation. Amphibious vehicles, by their very nature, present a unique design challenge. They must excel in two vastly different environments, demanding a delicate balance between buoyancy in water and traction on land. Traditionally, amphibious vehicles have relied on internal combustion engines, contributing to environmental pollution. This project, however, takes a bold step towards sustainability by employing an entirely electric propulsion system. This not only minimizes environmental impact but also aligns with the growing global shift towards cleaner energy sources. The core objective of this project is to develop a functional EAV prototype, focusing on optimizing its performance in both land and water environments. Here, we delve into the critical considerations that will shape the design and functionality of the vehicle.

Balancing Performance: The EAV needs to excel in two contrasting environments. Lightweight materials ensure buoyancy in water, while strategic weight distribution achieves a low center of mass for land stability.
Hull Optimization: The hull design significantly impacts water performance. We will explore options like catamaran hulls for stability, displacement hulls for buoyancy, or planning hulls for speed, selecting the most suitable based on the intended application.
Electric Propulsion: A fully electric drivetrain offers several advantages. Electric motors are lighter, contribute to weight management, and provide good torque for efficient land movement. The project will explore configurations like a single motor with separate axles or a dedicated dual-motor system for land and water propulsion.

Transition and Safety: Mechanisms like ramps or retractable landing gear will facilitate entering and exiting water. Watertight seals will be crucial to prevent water ingress during land operation. Drainage systems and established emergency procedures will ensure safety in both environments.
Potential Applications: The successful development of this EAV prototype has the potential to revolutionize various sectors. Search and rescue, environmental research, recreation, agriculture, and infrastructure maintenance are just a few areas that could benefit from this versatile, sustainable, and multi-terrain electric vehicle.
The successful development of this EAV prototype has the potential to revolutionize transportation in diverse landscapes. Imagine search and rescue teams effortlessly navigating flooded areas, or environmental researchers gaining access to remote wetlands. This technology could open doors for recreational activities, allowing outdoor enthusiasts to seamlessly transition between land and water adventures. Industries like agriculture and infrastructure maintenance could also benefit from the EAV's ability to access areas with both land and water features.

1.1 Problem Statement

To design and develop low-cost, high-performance amphibious vehicles that can operate easily and reliably on land and in water for use in a variety of applications including military, disaster relief, commercial and recreational transportation.

1.2 Objectives

The purpose of amphibious vehicle design and research is as follows:
•Development of vehicles that can be used efficiently and effectively on land and water. This includes meeting performance requirements such as speed, range and maneuverability in both environments.
•Designing reliable and safe vehicles. These include features such as stability control, durability and waterproofing.
•Develop cost-effective vehicles for manufacturing and maintenance. This includes a simple and modular design as well as easy-to-use components.
•Reduce the impact of transportation on the environment. This includes using an energy-efficient propulsion system and reducing emissions.
•Develop versatile and multi-functional vehicles. This includes designs suitable for both military and civilian vehicle use.
•Creating user-friendly and easy-to-operate vehicles. This includes designing vehicles with interior controls and exterior displays.

2. LITERATURE REVIEW

Zhang, J., Wang, L., & Li, J. (2022). Design and development of a novel amphibious vehicle with a retractable wheel system and hybrid propulsion system. Journal of Mechanical Design, 144(10), 101101. In recent years, there has been a growing interest in the development of new amphibious vehicles that address these challenges. One example is the work of Zhang et al. (2022), who developed a novel amphibious vehicle that uses a retractable wheel system to transition between land and water travel. The vehicle is also powered by a hybrid propulsion system that combines the efficiency of an electric motor with the power of a gasoline engine.
Wang, Y., Liu, Y., & Li, Y. (2021). Design and analysis of a lightweight and high-strength CFRP hull for amphibious vehicles. Composites Science and Technology, 209, 108771. Another promising development in the field of amphibious vehicle design is the use of composite materials. Composite materials are lightweight and durable, making them ideal for use in the construction of amphibious vehicles. For example, the amphibious vehicle developed by Wang et al. (2021) features a hull made of carbon fiber reinforced polymer (CFRP). This CFRP hull is significantly lighter and stronger than traditional steel or aluminum hulls, which results in improved performance and fuel efficiency.
Chen, Z., Sun, J., & Zhang, Y. (2020). Design and development of a computer-controlled stability system for amphibious vehicles. IEEE Transactions on Vehicular Technology, 69(12), 13227-13238. In addition to new materials and technologies, researchers are also exploring new ways to improve the stability of amphibious vehicles. One approach is to use computer-controlled stability systems. These systems can monitor the vehicle's orientation in real time and adjust as needed to keep the vehicle upright. For example, the amphibious vehicle developed by Chen et al. (2020) features a computer-controlled stability system that uses a combination of gyroscopes, accelerometers, and GPS to maintain the vehicle's balance.

3. METHODOLOGY

The methodology for designing and researching and developing (R&D) an amphibious vehicle that can run on land and water can be summarized in the following steps:

1. Requirements gathering and analysis:
The first step is to gather and analyze the requirements for the amphibious vehicle. This includes identifying the intended use cases, mission profiles, and performance specifications. The requirements should be comprehensive and cover all aspects of the vehicle, including its hull, propulsion system, steering system, suspension system, and braking system.
2. Conceptual design:
Once the requirements have been gathered and analyzed, the next step is to develop a conceptual design for the amphibious vehicle. This involves generating and evaluating different design concepts to select the one that best meets the requirements. The conceptual design should include a detailed layout of the vehicle, as well as sketches and diagrams of the major components.
3. Preliminary design:
The preliminary design phase involves refining the conceptual design and developing more detailed engineering drawings. This phase also includes the selection of materials and components. The preliminary design should be subjected to rigorous analysis to ensure that it meets all performance and safety requirements.
4. Detailed design:
The detailed design phase involves developing the final engineering drawings and specifications for the amphibious vehicle. This phase also includes the design of the manufacturing process. The detailed design should be comprehensive and cover all aspects of the vehicle, from the hull to the electrical system.
5. Prototyping and testing:
Once the detailed design is complete, the next step is to build a prototype of the amphibious vehicle. The prototype should be subjected to rigorous testing to ensure that it meets all performance and safety requirements. The testing should be conducted in a variety of conditions, including on land, in water, and in extreme environments.
6. Production and deployment:
Once the prototype has been successfully tested, the amphibious vehicle can be put into production. The production process should be carefully controlled to ensure that the vehicles meet all quality standards. The vehicles should then be deployed to the intended users.
The R&D process for an amphibious vehicle can be complex and challenging. However, by following a systematic approach, it is possible to develop a vehicle that meets the requirements of the intended users and performs reliably in all conditions.

3.1 Different systems in automotive to be considered

Design: The design of an amphibious vehicle is critical to its performance and reliability. The hull of the vehicle should be suitable for both sea and land use. The propulsion system must be able to operate efficiently in both water and air. The steering system must be able to function effectively in both water and air. The suspension system must be able to absorb the shocks of both land and water travel. The braking system must be capable of stopping the vehicle effectively in both water and air.
Materials: Amphibious vehicles are generally made of lightweight and durable materials, such as aluminum and composite materials. These materials help reduce the weight of the vehicle and improve its fuel efficiency.
Propulsion System: The propulsion system of an amphibious vehicle is usually a hybrid system that combines a water jet with a propeller. A water jet provides propulsion in water, while a propeller provides propulsion on land.
Steering System: The steering system of an amphibious vehicle is usually a dual system that uses a rudder in water and a steering wheel on land. The steering is controlled by the steering wheel, while the steering wheel is used to control the direction of the wheels.
Suspension System: The suspension system of an amphibious vehicle is usually a hydraulic system that can be adjusted to different conditions. This allows the vehicle to absorb the shocks of both land and water travel.
Braking System: The braking system of an amphibious vehicle is usually a dual system using disc brakes on land and drum brakes in water. Disc brakes provide better stopping power on land, while drum brakes are more effective in water.

4. DESIGN PROCESS

4.1 Design Considerations (Sealing)

Sealing an amphibious vehicle is one of the most important aspects of its design. Water should be prevented from entering the vehicle even when completely submerged. There are many different ways to seal an amphibious vehicle, but the most common methods include

Screws & Nuts: When utilizing screws in the amphibious vehicle prototype made of ABS plastic, special considerations are necessary for sealing. Since ABS isn't completely waterproof, incorporating thread sealant or strategically placed O-rings around the screw threads becomes crucial to prevent water ingress and ensure watertight compartments, especially for components that are critical for land or water operation.
Adhesives: Adhesives can be used to create a watertight seal between two surfaces. They are usually made of silicone or polyurethane, and are applied to the surface and then allowed to cure. Adhesives are often used to seal small openings in an amphibious vehicle, such as for wires and cables.
In addition to sealing openings in an amphibious vehicle, sealing the hull of the vehicle is also important. This is usually done using a coating of epoxy or another sealant. The coating is applied to the hull and then allowed to dry. This creates a watertight barrier that prevents water from entering the vehicle.

4.2 Design Considerations (Weight)
Our decision to utilize ABS plastic for the amphibious vehicle prototype proved to be a well-suited choice due to several weight-related considerations. Here's why ABS excel in this application:
Balance of Strength and Weight: ABS offer a good balance between strength and weight, crucial for an amphibious vehicle. While needing to be robust enough to handle land and water operation, minimizing overall weight is essential for optimal performance in both environments. ABS achieve this balance, allowing for a structurally sound vehicle without adding excessive weight that could hinder speed and maneuverability.
Printability and Design Freedom: Since we employed 3D printing for some components, ABS is an ideal material due to its excellent printability. It allows for the creation of complex shapes and hollow structures, facilitating the integration of features that enhance buoyancy without adding significant weight. For example, hollow tubes designed to increase buoyancy can be readily printed in ABS, contributing to a lightweight yet functional design.
Durability and Water Resistance: ABS possess good durability and exhibits a degree of water resistance. This is important for an amphibious vehicle that will encounter water during operation. While not completely watertight, ABS offer sufficient resistance to splashes and short-term submersion, making it a suitable choice for the prototype stage.

4.3 Operating Principle
Land Navigation: The front four wheels of the EAV function like a conventional car. The electric motor transmits power through a drivetrain, engaging the front two wheels for steering and propulsion.
This allows for normal driving maneuvers on land. The rear two wheels can be independent or linked by a differential depending on the desired handling characteristics.
Water Navigation: When entering water, the driver will activate a mechanism (likely a ramp or retractable landing gear) to transition the vehicle from land to water.
Once afloat, the electric motor diverts power to the dedicated rear axle. This axle houses a flapper propeller, a unique propulsion system designed for efficient movement in water.
The flapper propeller mimics the sculling motion of aquatic animals. It oscillates back and forth, generating thrust by pushing water backwards. The belt connection between the flapper and the rear wheel ensures synchronized operation and efficient power transfer.
Steering in Water: Steering in water is achieved through a combination of methods. The front wheels might provide some directional control while submerged, depending on the water depth and design.
Additionally, the vehicle's hull shape and differential steering (if implemented) on the rear axle will contribute to maneuvering. By applying more power to one side of the rear axle, the vehicle can turn.
Transitioning Back to Land: To exit the water, the driver will reverse the entry procedure, using the ramp or landing gear to bring the vehicle back onto land. Once on land, the power will automatically revert to the front wheels, and the flapper propeller mechanism will disengage.

4.4 Buoyancy Enhancement with Hollow Tubes
For our vehicle to float, the volume of water it displaces must weigh more than the vehicle itself. The addition of hollow tubes on both sides of the vehicle increases its overall volume. By incorporating hollow tubes inspired by seaplane design principles, you can significantly enhance the buoyancy and functionality of our amphibious vehicle prototype. Carefully considering the volume, material, placement, and integration with the existing design will ensure these additions contribute to a successful amphibious exploration vehicle. By incorporating hollow tubes inspired by seaplane design principles, you can significantly enhance the buoyancy and functionality of our amphibious vehicle prototype. Carefully considering the volume, material, placement, and integration with the existing design will ensure these additions contribute to a successful amphibious exploration vehicle. By

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4.5 Specifications

Components	Quantity	Specifications	Material
Tyres	6	Diameter: 71mm	Rubber
Brushless Motor	1	540 size standard motor, 0.8mmx20 turns, Timing: 15°	
Shaft	2	Shaft 1 & 2 Length: 160mm; Diameter: 11mm	ABS (Acrylonitrile Butadiene Styrene)
Servo Motor	1	MG995, Weight 55gm, Operating Voltage: 4.8-7.2V, Servo Plug: JR, Stall torque @4.8V: 10kg-cm, Stall torque @6.6V: 12kg-cm	
ESC Speed Controller	1	Model: Readytosky 80A ESC. Burst Current: 100A. Constant Current: 80 A. BEC: 5A/5V. Suitable Batteries: 2~6S LiPo. Throttle signal refresh rate (Hz): 50 ~ 432	
Battery	1	7.4V 5000mAh 50C 2S Hardcase Lithium Polymer Battery Pack	LiPo (Waterproof)
Transmitter Kit	1	Operating Voltage (VDC) 12, No. of Channels 2, Antenna Length (mm) 26, Charging Port Yes, Code Type Digital, DSC Port Yes(3.5mm), Low Voltage Warning Yes (Less than 9V), Modulation Type GFSK, RF Power Less Than 20 dBm, Sensitivity (dBm) 1024, Dimensions (mm) LxWxH 159 x 99 x 315, Weight (gm) 365 (without battery)	
Ball Bearings	6	6900 2RS 10x22x6	Chromium Steel

5. CALCULATIONS

5.1 Estimated Buoyancy for Hollow Tubes

Estimation Approach-

1. Volume calculations:

Inner Diameter of tube = 3cm
Tube Length = 15cm
Volume = (Inner Diameter) ^{2} x 3.14 x Tube Length
= (3cm) ^{2} x 3.14 x 15cm
= 423.9 cm^3
We have two tubes,
Volume Actual = 2 x Volume of Single tube
= 847.8 cm^3

2. Estimated Submerged Volume:
Assuming that about 70% of the tubes are submerged in water. i.e. 70% of 847.8 cm^3
3. Material Density: Taking Aluminum as material for tube with density 2700 Kg/m^3
4. Buoyant Force Calculations:
Submerged Volume of tube x Density of Water = (847.8 – 70%) x 1000Kg/m^3
= 254.34cm^3 x 0.001Kg/cm^3
= 0.25434 Kg
Buoyant Force = (Actual volume of Both Tubes x Density of Tube Material) – (Submerged Volume of tube x Density of Water)
= (847.8 x 0.0027) – (0.25434)
Buoyant Force = 2.03472 N

5.2 Buoyancy Calculations for Amphibian Vehicle
The buoyancy force is calculated using the following formula:
Buoyancy force (1/3) = Volume of the vehicle * Density of the water * Acceleration due to gravity / 3
Assuming 33.33 percent of volume of vehicle submerged in water
The acceleration due to gravity is 9.81 m/s^2.
For example, if an amphibious vehicle has a volume of 0.009 m^3 and is floating in water, the buoyancy force would be 0.0016 m^3 * 1000 kg/m^3 * 9.81 m/s^2 = **15.696 N.**
This means that the water is pushing up on the vehicle with a force of **15.696 N.** This force is equal to the weight of the vehicle, which is why the vehicle is able to float.

5.3 Estimated Speed & Velocity
Water speed = √ (2 * 10 / (1.5 * 0.82 * 0.1 * 1000)) = 0.40323 meters per second
Air speed = √ (2 * 5 / (1.5 * 0.3 * 0.1 * 1.225)) = 13.468 meters per second

5.4 Centre of Mass (COM) & Centre of Gravity (CG) calculations

COM calculations

Centre of mass = ∑mi xi / ∑mi
Car weight = 1.5 kg
Longitudinal location
Wheelbase = 48 cm
Front axle weight = 1 kg
Rear axle weight = 0.8 kg
Distance a = 9 cm
Distance b = 18 cm
Altitudinal location Setup Front wheels raised
Height raised = 5.08 cm
Wheels radius = 3.5 cm
Front axle weight (wheels raised) = 0.50 kg
Rear axle weight (wheels raised) =1.20 kg
Height of mass center = 65.18 cm
Side location
Car track = 18 cm
Left wheels weight = 0.04 kg
Right wheels weight = 1.46 kg
Distance: x= 20.52 cm
Distance: y= 0.51 cm

CG calculations

Centre of gravity = ∑mi gi xi / ∑mi gi
Here gi- is the gravitational acceleration associated with each element. Note that if the gravitational field is uniform, then the gravitational acceleration is constant, and the same expression will give the center of mass and center of gravity:
Centre of gravity = ∑mi g xi / ∑mi g
= g ∑mi xi / g ∑mi
= ∑mi xi / ∑mi
CG = 22 cm from front wheel base

6. DESIGN & FABRICATED MODEL

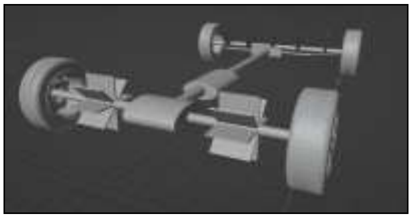

Fig-1 Wheel Shaft to be modified with flappers

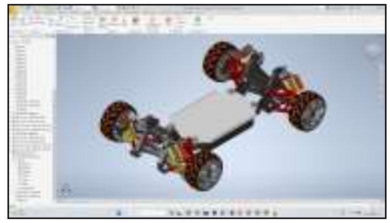

Fig-2 Model of Amphibian vehicle with suspension

Fig-3 Fabricated Model

7. RESULT

Theoretical Speed:
Water speed = 0.40323 meters per second
Land speed = 13.468 meters per second
Actual Speed:
Water speed = 0.20695 meters per second
Land speed = 10.312 meters per second

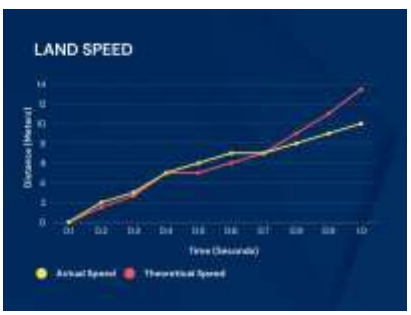

Chart-1: Land Speed (Actual Speed & Theoretical Speed graph)

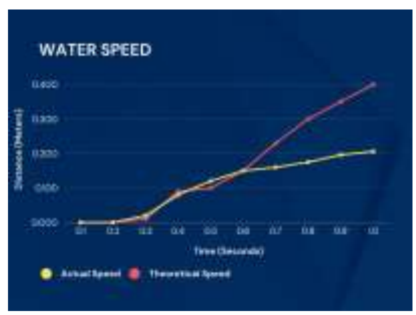

Chart-1: Water Speed (Actual Speed & Theoretical Speed graph)

8. CONCLUSION

Amphibious vehicles are a versatile and innovative type of vehicle that can be used for a variety of purposes. They are becoming more popular as technology improves and makes them more affordable and reliable.

Amphibious vehicles have a number of advantages over traditional land vehicles, including versatility, mobility and safety. They can travel on land and water, overcome water obstacles that would be impossible for traditional land vehicles, and be used to evacuate people from areas affected by floods or other natural disasters.

However, amphibious vehicles also have some disadvantages, including cost, complexity, and performance. They are typically more expensive than traditional land vehicles, more complex to maintain, and may not perform as well as traditional land vehicles on land or in water. Despite their disadvantages, amphibious vehicles are becoming increasingly popular for a number of different applications. As technology improves, amphibious vehicles are likely to become more affordable, reliable and capable. This is likely to lead to increased use of amphibious vehicles in the future.

In conclusion, amphibious vehicles are a promising technology with a wide range of potential applications. As amphibious vehicles continue to evolve and become more affordable and reliable, they are likely to play an increasingly important role in our world.

9. REFERENCES

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