College of Engineering
LAMAR UNIVERSITY
Department of Mechanical Engineering

HPV-Sea

OCI Beaumont · TotalBoat (Exclusively from Jamestown) · Kieschnick Industries · Callahan Machine Works Inc.

HPV-Sea: The Amphibious Human-Powered Vehicle

Background and Purpose

This human powered vehicle efficiently traverses land and water and combines the principles of a bicycle and a paddle boat. Many current amphibious HPVs today have a rough transition from water to land and poor pedaling cadency and efficiency. This project aims to address and resolve those issues while providing an environmentally clean mode of transportation. The final product is an efficient and innovative amphibious vehicle that can be used for activities such as exploration, exercise, and recreational use.

This project emphasizes traversing terrain efficiency, buoyancy, balance, ease of pedaling, and maneuverability of the vehicle. The buoyant and propelling agents for the water terrain were major challenges that were overcome with a pour-and-mix boat foam and a 3-D printed propeller. Components designed for the project included sprockets, paddle wheel styled propellers, a two-in-one steering mechanism that serves as a steering tire on land and a rudder in the water, a tiller arm, and shaft bearings. These components were designed with friction, drag force, buoyant forces, and human force capability in mind.

Concept Generation and Evaluation

Three important categories of the vehicle design process presented themselves that would influence every other minor detail and decision for the duration of the project. These categories include the material of the vehicle frame, the propeller style, and the drive train style. A decision matrix was generated to rank alternatives for each category based on rubric that includes cost, weight, strength, ease of construction, efficiency, stability, comfort, and maneuverability.

The Issue
Pedal boats are not land-compatible and are a hassle to get into the water.

Alternatives
Pedal boats: not land-compatible and are more of a hassle.
Bicycle: eliminates electrical components but not water compatible.
Back wheel as a rudder instead of a drop rudder for the sake of being amphibious.
Aluminum and foam instead of wood and steel to make vehicle lighter.
Hull design: hollow or foam filled.

Criteria
Vehicle must not exceed 250 pounds and must be able to hold up to 250 pounds in both land and water. The vehicle cannot exceed 9 feet in length and 7 feet in width. The vehicle must be able to turn on land and have a ground clearance of 3 inches. The vehicle must be able to brake on land. The vehicle must be able to steer in water using a rudder system. The vehicle must remain afloat the entire time it is in the water and keep the driver dry from splashes. The vehicle must transition from land to water using a boat ramp. The driver should be able to pedal without reaching exhaustion before 5 minutes. The vehicle must accelerate to 2 mph in 2 minutes in water and to 10 mph in 1 minute on land. The vehicle must be safe to use.

Importance
Aligning the pedals and handles with the seat properlly is importance for human ergonomics when operating the vehicle.

Vehicle weight, depth of flotation device, and surface area of floation devices are the most imporant factors in ensuring that the vehicle floats high enough to keep the drivere dry while still providing enough ground clearance for land maneuverability.

Using the back tire for the combined use as both a steering mechanism on land a a steering rudder in the water eliminates the need for two different steering systems and reduces clutter, making it easier to operate, build, and more aesthetic.

Sprocket ratios and pedal length are important in order to ensure that driver can move the total weight of 400 lbs to 450 lbs without becoming physically over-exterted too quickly.

Evaluation
We evaluated the most crucial parts of the vehicle (the frame, propulsion, and drive train) based on nine criterion. Each component had two design concepts that were each rated on a scale of 1 being the worst to 5 being the best in cost, weight, strength, ease of construction, efficiency, stability, comfort, and maneuverability. The scores for each design concept were calculated and the highest scoring design concept ended up being the design that we chose for that particular component.

Results
The final result is an amphibious vehicle with a hollow aluminum frame, a paddle wheel style propeller, a tire-style rudder system, a chain drive, a 4:1 sprocket ratio, a floation device molded and shaped of foam, and a back wheel that is mounted on a vertical axis.

CONCEPT GENERATION

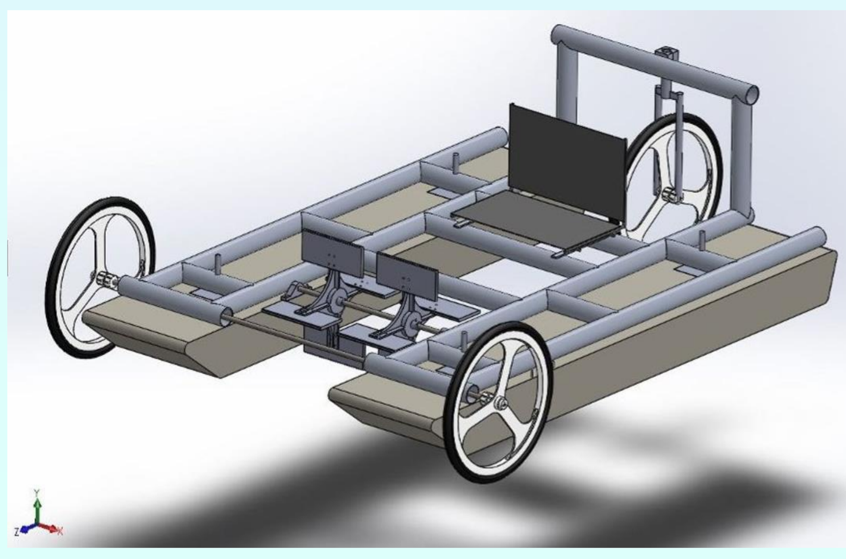
Frame	Material	Cost	Weight	Strength	Ease of Construction	Efficiency	Stability	Comfort	Maneuverability	Total Score
Design A	Aluminum	5	5	3	4	5	4			26
Design B	Steel	3	3	5	4	3	5			23

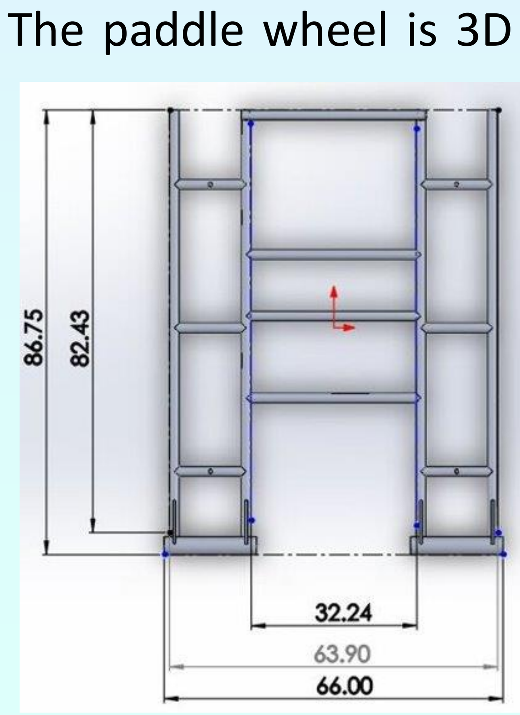
Propulsion	Propeller	Cost	Weight	Strength	Ease of Construction	Efficiency	Stability	Comfort	Maneuverability	Total Score
Design A	Paddle Wheel	5	3	4	5	3	5	4	4	33
Design B	Modern Marine	3	5	5	2	4	3	3	3	28

Driving	Drive	Cost	Weight	Strength	Ease of Installation	Efficiency	Stability	Comfort	Maneuverability	Total Score
Design A	Belt	3	3	5	4	5	5	4	4	33
Design B	Chain	5	5	3	4	4	4	5	5	35

Modeling and Analysis

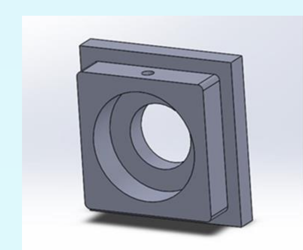
The frame is made 1.5” schedule 40 square aluminum tubing and is 86.75” long, 66” wide, and weighs 54 pounds. The entire vehicle weighs 250 pound and can support a rider’s weight of 290 pounds. This creates a normal force of 134 pounds on each wheel. The propellers has a 4:1 gear ratio with the pedals. The selected teeth for the sprockets will be 0.5 inches. With 25 pounds of force for pedalling, the torque produced on the propeller shaft is 88 lbf-in. The paddle wheel propeller is designed to allow the largest diameter and widest paddle wheel that will fit between the two flotation devices without interfering with the seat. The propeller system has set of two identical paddle wheel assemblies with a diameter of 19 inches. There are 4 paddles on each assembly, each 11.4” by 5”. The paddle wheel is 3D printed using polycarbonate filament.

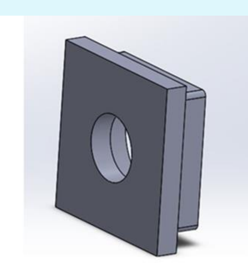


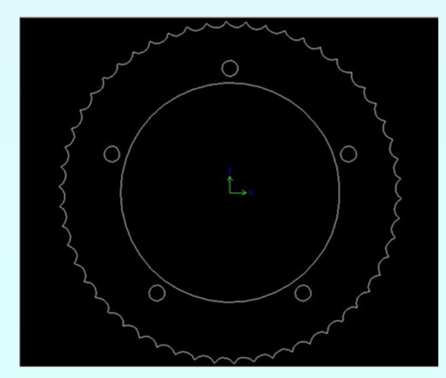


Manufacturing

The aluminum frame was fabricated at the Kieschnick Industries fabrication shop using TIG welding. The propeller hubs and paddles were 3D printed separately and fitted together onto the shaft using nuts and bolts. The flotation devices were built by mixing and pouring a 2-pound-density two-part polyurethane foam solution donated by TotalBoat into a plywood mold. After curing, gaps were filled into the floats and the rough uneven areas were sanded down. Next, two layers of fiberglass sheeting and epoxy resin was applied to the flotation devices, then painted for a finished look. The bearing adapters for the main shaft was manufactured and modified by Callahan Machine Works. The sprockets were machined using a plasma cutter and designed with a ½” pitch and 52 teeth to suit the industrial chain used for the chain drive. The tiller arm was designed to control the turning of the rear wheel for both land and water steering. It fits into a flange bearing and uses a pulling system to control movement.







Performance Testing the Final Product

The expectations for the vehicle was set to be able to support a person up to 180 pounds, meet 2 mph on land and in water, and have a comfortable pedaling cadency for the rider without causing strain or exhaustion. In the water,

WATER
The vehicle comfortably supported two people with a combined weight of 290 pounds. The vehicle balanced well and did not tilt to any side. It remained in the water for 45 minutes and no leaks or damages were observed afterwards. The vehicle maintained a speed of 1.9 mph in the water before the chains slipped off the pedal sprockets.

LAND
Vehicle comfortably supported a 160-pound person on land without bending of the shaft or tires. It maintained a speed of 1.8 mph on land before the chains slipped off the pedal sprockets. Pedaling in reverse produced less chain slippage.

SUGGESTIONS FOR IMROVEMENTS
The pedal sprocket teeth needs to be deeper and thicker in order to better catch the large industrial chain better without slippage. The flange bearing for the tiller arm has omni-directional movement and should be replaced with one that has only horizontal movement to prevent overstraining the pulley system for the steering mechanism. The propellers should be made of a more durable and more flexible material that is not so brittle.

Students
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