AquaScooter2

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Concept Analysis
Document

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ABSTRACT
The objective of this proposal is to present the analysis and calculations performed by the team for the Aqua Scooter capstone project. The Aqua Scooter has a two cycle gas powered engine that, as of January 2010, the EPA's regulations prevent future sales. The capstone team needs to design and engineer a new engine which meets current and immediate future EPA regulations.

This report gives the background information pertaining to the emissions along with the current technology and some possible solutions. The constraints provided by the client to the Aqua Scooter team are given and some particular. The designs that are being analyzed are separated into two sections. One is the engine analysis and the second is the shell analysis. This proposal will address both of these components for a definitive direction for further testing.

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1. INTRODUCTION

1.1.1 Product and Client Information

Aqua Scooter is a portable, submersible, gasoline powered water craft for individual use. Aqua Scooter is family owned and operated out of Sedona, Arizona. The client for this project (R.S.W. /D.I. Inc) is the owner and CEO of Aqua Scooter. The current device design is shown in Figure 1 and Figure 2. The numbered component descriptions are found in the Appendix of this report. The design incorporates a 2-stroke engine which provides approximately 2HP of power to the user. The scooter provides around 5 hours of operating time with a 2 L fuel tank capacity.

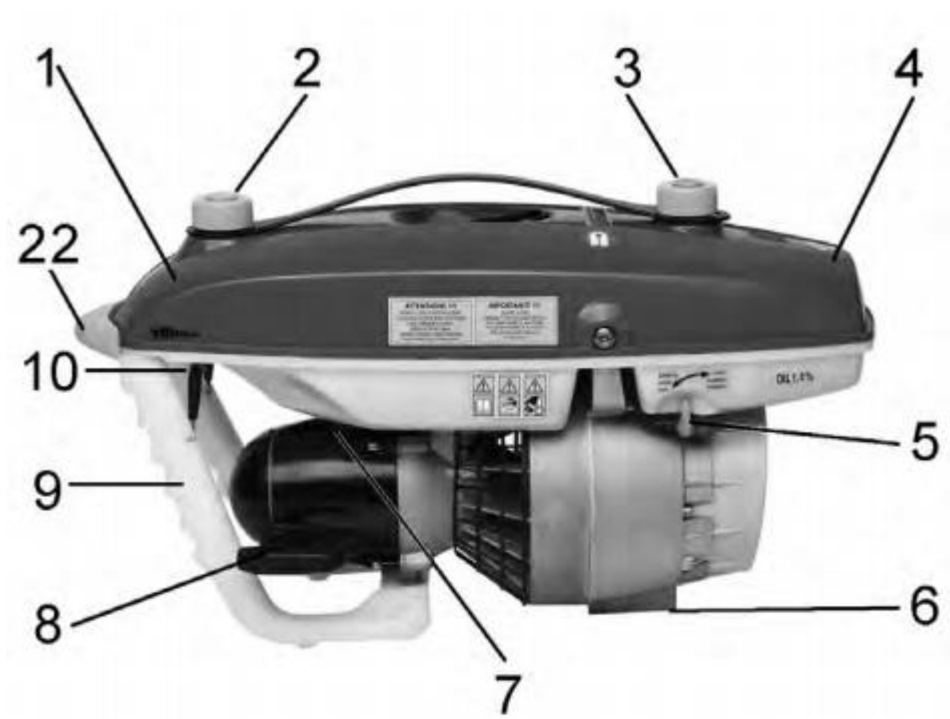


Figure 1: Aqua Scooter side view with designated components

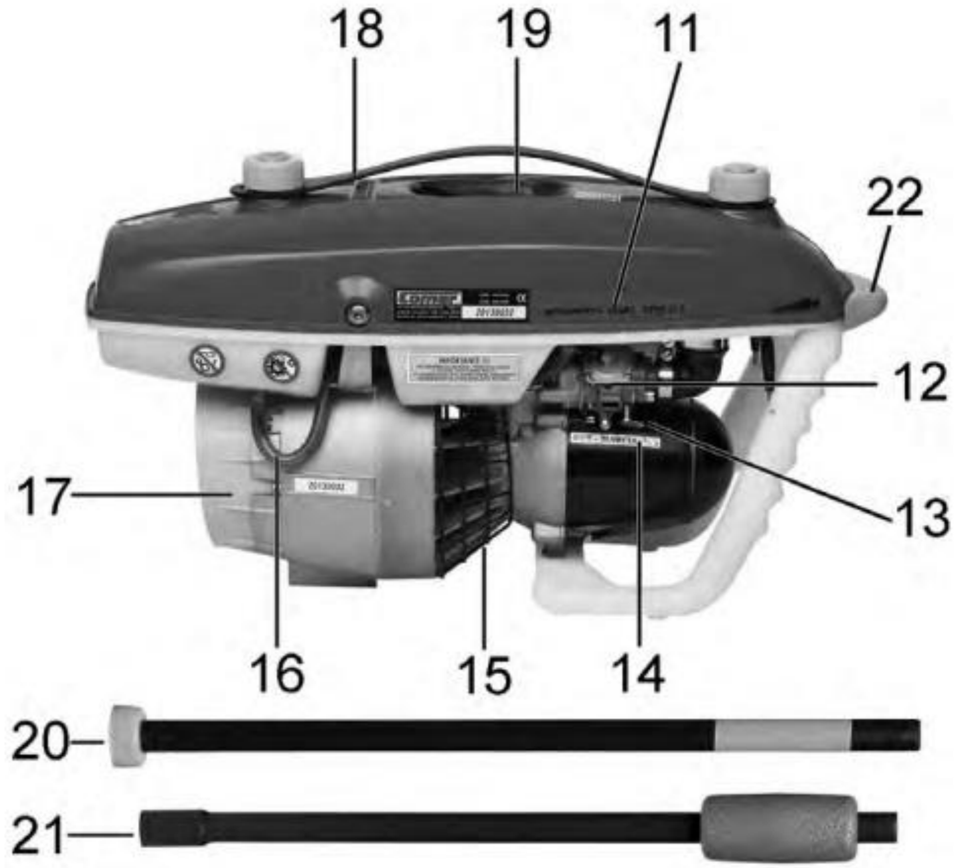


Figure 2: Aqua Scooter with designated components and snorkel extension

1.1.2 Background

A chemical technician by the name of Bernd Boettgers wanted to escape from East Germany, but he knew he would need some type of machine to help pull him through the sea. His first attempt to test his "water-machine" resulted in an arrest and jail time of three months. He was convicted of an illegal attempt at border crossing. After he was released, he decided to work on a second machine, and after a year of building, he entered the sea in September of 1968 for his second attempt. He traveled by water for six hours, two of which were done fully submerged under the sea, until he was finally spotted by the Danish Lightship, named Gedser. His successful escape broke into the European Press, and by the end of January in 1978 the "Aqua Scooter" had been brought to the United States and the first commercial prototype was successfully tested.

1.1.3 Aqua Scooter Emissions

The current 2-stroke, direct drive engine does not comply with EPA regulations. As a result, the client is unable to sell the Aqua Scooter in the United States. The current emission standards that the Aqua Scooter must meet are as follows:

- It must have less than or equal to 30 g of hydrocarbons
- Less than or equal to 490 g of carbon monoxide per kilowatt hour.

Emissions testing will be done by either the Arizona Department of Transportation, or Arizona Game and Fish Department.

1.1.4 Why Test for Emissions

A good questions one might find themselves asking, is why test for emissions? What benefits does it bring to the customer, if any, and why is it important to pass? It turns out that passing an emissions test and just taking the test in general, brings several advantages. Here are three reasons why emissions testing are very important:

1. It identifies necessary repairs to improve vehicles performance and fuel economy
2. It improves air quality by reducing carbon monoxide, hydrocarbons, and nitrogen oxides
3. If emission controls are not working properly, testing ensures that owners make the appropriate repairs to aid in the reduction of ground level ozone

Although testing for emissions improves the air quality for everyone around you, it also turns out that emission testing also brings several benefits to the customers themselves.

1.2 Current Technology

The group researched two and four stroke engines for this project. The current technology on the market is available to implement in a possible solution for our client. Options available in the current market are conventional gas models or alternatives such as propane or compressed natural gas.

1.2.1 Material Properties

The materials for the new design need to be lightweight so that the Aqua Scooter can float. The new scooter should also have materials strong enough to support its own weight and handle the pressure exerted when submerged to maximum operating depth. The manufacturing of the device will also need to be considered when selecting the materials so that the cost of making the new design is still feasible.

1.2.2 Possible Solutions

Current solutions to the problem are either a four stroke internal combustion engine or a fuel injected two stroke internal combustion engine. The issue with the four stroke solution is implementing an engine that is light enough to meet the weight and thrust constraints. Research to resolve this issue has been focused primarily on compressed fuels contained in cylinders. There may be an advantage in losing the weight of a gas tank to lighten the overall weight of the machine. As for the two stroke solution, current technology is available that monitors and controls fuel intake to minimize the unburned amounts of fuel that enter the atmosphere as seen with previous two stroke models. Fuel system modification, along with implementing biodegradable two stroke oils that are also recently available, can be a viable solution in designing a product that meets current EPA requirements.

1.2.3 Summary

The Aqua Scooter is a machine that has been useful for over four decades. The power system that the machine has used since its origin is obsolete based on current environmental regulations. In order for the Aqua Scooter to keep fulfilling the legacy it has created, the team has been tasked with redesigning the device. This will be accomplished through testing and implementation of state of the art technology in the field of materials, as well as internal combustion engines.

2. PROBLEM STATEMENT

The current design for the Aqua Scooter does not comply with the most recent Environmental Protection Agency's regulations on two-stroke engines for recreational use. In order to have a marketable product, this team will design a hydrodynamic, inexpensive, aesthetically pleasing Aqua Scooter, with a marine engine that complies with EPA regulations.

2.1 Constraints

The prototype needs to meet certain constraints the team has determined based off communication with the client. The constraints are the following:

- Gasoline powered
- Engine housing must be metal
- Muffler housing must be metal
- Throttle control
- Exhaust valve
- Starter assembly made of plastic and metal
- Plastic propeller protection
- Control handle
- Plastic fuel tank, with minimum volume of ½ gallon
- Must have a dry weight of 18 lbs. or less
- Must be buoyant enough to float itself
- Must provide at least 50 lbs. thrust
- Must cost no more than $450 per scooter manufactured

2.2 Quality Function Deployment (QFD)

Table 1: Quality function deployment showing the engineering requirements and customer needs.

Aqua Scooter QFD Matrix	Weight	Buoyancy	Fuel Capacity	Thrust	Exhaust emission	Operating Life	Warranty	Cayago Seabob	Seadoo Seascooter
Aesthetically pleasing	X		X					O	O
Child safe	X	X		X	X				O
Lightweight	X	X	X	X					
Floats	X	X	X					O	O
Propels operator through water				X	X			O	O
Runs for extended period			X						
Meets current EPA regulations					X	X	X	O	O
units	lb.	lb.	gal.	lb.	g/kW-h	Hours/Years	Hours/ Months		
	>= 18	>= 18	>= 0.5	>= 50	<=30 of Hydrocarbon, <=490 of Carbon Monoxide	>= 350/5	>= 175/30		

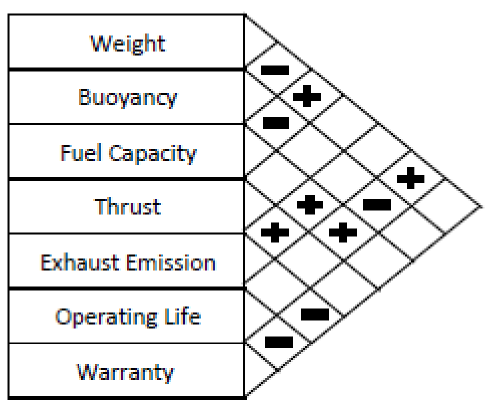
2.3 QFD Summary

The QFD matrix (Table 1) above is useful for correlating the needs of the customer to the requirements that the team can quantify. The requirements that need the most attention based on the matrix are exhaust emissions, fuel capacity, weight, buoyancy, and thrust. The exhaust emissions carry a significant amount of weight due to the fact that without falling below the constraint, the new design will not meet EPA regulations. This is not a desirable outcome because that is the main problem the current Aqua Scooter design is facing. Secondly, the weight of the machine is important because that affects the buoyancy, as well as how much exhaust gas the engine emits. For example, the heavier the device is, the harder the engine will have to work to propel the device and operator through the water. Moving forward, keeping the needs, requirements and constraints in mind will be crucial in developing an effective alternative to the current Aqua Scooter model.

2.4 House of Quality

The house of quality (Table 2) correlates the engineering requirements that are listed for this particular project. If the requirement is positively correlated, indicating that the increase of a particular item produces the same effect on another requirement, a (+) symbol is shown. If the requirements are negatively correlated, a (-) symbol is shown. If there is no correlation the space is left blank.

Table 2: House of quality, which correlates engineering requirements



3. ORIGINAL CONCEPTS

The team selected two main concepts to focus on for analysis. These two concepts are listed below along with their original sketches. The basis for the design of the final concept is based on these two original ideas. Analysis was performed in order to validate or eliminate the feasibility of these concepts.

3.1.1 Boomerang with Propane and 4-Stroke Engine

The first concept selected utilizes the aesthetics of the boomerang design and combines the propane 4-stroke engine with an adjustable jet. The boomerang design allows for both an aesthetically pleasing design that has good opportunity to create a buoyant vessel, which has appropriate area to include necessary fuel tanks and geometry to create an effective steering system. The nozzle coupled with a propane modified 4 stroke will allow the design to have the necessary thrust required while still meeting EPA emission regulations.

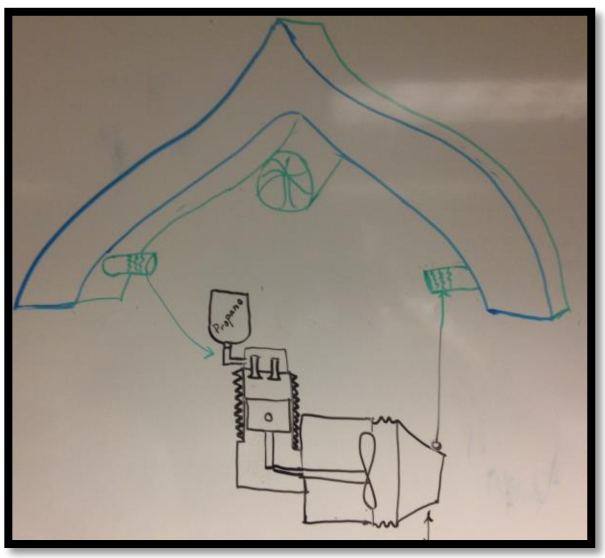


Figure 3: Boomerang with Propane Injected 4-Stroke Engine

3.1.2 2-Propellers with 4-Stroke 4-Mix Engine

The second concept selected utilizes the aesthetics of the two-propeller design and combines the 4 Mix 4 stroke engine and adjustable jet. The two-propeller design is an aesthetically pleasing design, which can house all necessary components for the new

Aqua Scooter while being a more modern design, which should allow the design to be marketable and desired. The use of two propellers that push water through two nozzles will allow the thrust requirement to be obtained by the design. In addition to meeting the thrust requirement the dual nozzles, which are set on either side of the craft, creates thrust on either side of the user rather than pushing water into the user like the current Aqua Scooter. The 4 Mix engine will be able to be housed completely in the two-propeller design and designed such that a single drive shaft from the engine will drive both propellers.

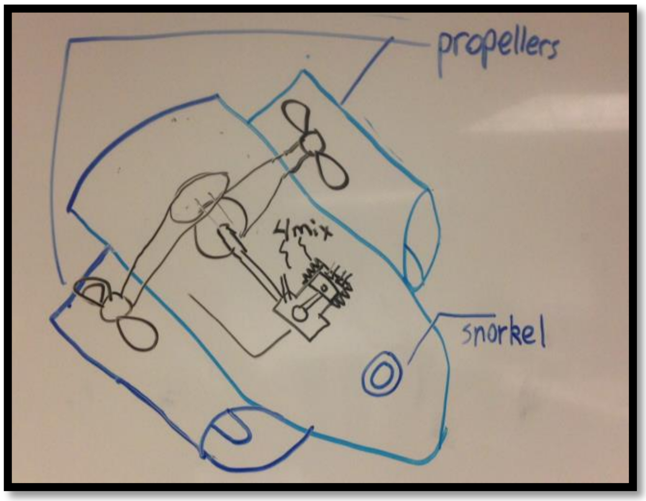


Figure 4: 2-Propeller with Belt and Pulley system Including 4-Stroke 4-Mix Engine

3.2.1 Final Design Conclusions

A duel propeller design was determined to be an invalid design. This determination was based upon examining competing products and marine transportation. Research done on the subject shows that a single engine powering two propellers in an aquatic environment would undergo significant stresses during operation. The stresses would likely wear the engine quickly resulting in a short operating life for the engine. If the engine has a short operating life the entire new design would have an unacceptable operating life. Therefore the design will be powered by an internal combustion engine with a direct drive shaft to a single propeller.

4.0 ENGINE ANALYSIS

The main objective of this report is to analyze and compare the use of propane and butane with gasoline in a 4-stroke engine. Along with alternative fuels, the drag coefficients of the final two shell designs were calculated, as well as the drag force that each of the shells experience at the required velocity. Finally, the propeller was designed to meet the thrust requirement prescribed by the client.

4.1.1 Gasoline Analysis

The main objective for the team is to create prototype that will meet and surpass the current and known future EPA regulations for marine engines. After some initial analysis, the team decided to pursue a design which included a 4-stroke engine. The 4-stroke Honda GXH50 engine shown in Figure 1, engine currently complies with the EPA regulations. This engine will be analyzed as a foundation for all calculations in the report. This 4-stroke engine has an intake stroke, compression stroke, power stroke, and exhaust stroke. The extra 2 strokes in the 4-stroke engine result in fewer emissions and a higher percentage complete combustion of fuel. There are currently many EPA approved 4-stroke engines on the market today, so that is the direction we chose.

Dimensions	Aqua Scooter 2-Stroke Engine (AS 650)	4-Stroke Engine (Honda GXH50)
Length (mm)	530	225
Width (mm)	195	274
Height (mm)	320	353
Weight (lb)	16.53	12.1
Bore (mm)	40	41.8
Stroke (mm)	39	36
Displacement (cc)	49	49.4
Power (HP)	2	2.1 @ 7000rpm
Thrust (kg)	22	22
Fuel	Mixture	Unleaded 86 Octane or Higher
Fuel Tank Capacity (L)	2	1.89271
Price ($)	(+/-) 970	420

Figure 5: Current engine and proposed 4-stroke engine

In the figure shown above, the existing (entire) Aqua Scooter is displayed on the left, and the Honda GXH50 4-stroke engine is shown on the right. This is a potential 4 stroke engine on which we will base our calculations. We found that the Honda engine is both wider and taller than the entire existing Aqua Scooter, so the shell will need to be redesigned in order to accommodate the larger engine size. Also, despite the 7000 rpm capability of the Honda motor, for the desired application it will be running at less than or equal to 80% of maximum rpm. Because of this, for all future calculations we assumed a horsepower of 5600 rpm. The price of the new Aqua Scooter (with a Honda 4-stroke engine) will be considerably higher than $420 because only the engine is measured. However, since the engine is the most costly part, the total cost of manufacturing should not exceed the $970 price of the current Aqua Scooter.

4.2.1 Propane and Butane Analysis

Although moving forward with a design that includes a standard octane fuel for a 4-stroke engine is a viable concept, alternate fuels are being analyzed. The client stated interest in butane and propane engines when presented with the concepts; therefore, the team worked to show that these fuels were feasible. The fuels were put through volume, thrust, combustion, and adiabatic analysis.

4.3.1 Volume Analysis

Volume analysis was conducted in order to verify the fuel would be capable to provide the amount of thrust required by the client. Additionally, the amount of butane and propane required and the weight were both major concerns in the design of the Aqua Scooter. It was necessary to prove that these two gases and the sizes of the correct volume containers needed would be feasible for the client requirements.

- Calculated weight of propane is 12.52 ounces.
- Calculated weight of butane is 12.50 ounces.

4.3.2 Thrust Analysis

The thrust analysis uses the following velocity equations:

$$T = \dot{m}V_e - \dot{m}V_0 \quad (1)$$

$$\dot{m} = \rho V_i A \quad (2)$$

$$T = \rho V_i A(V_e - V_0) \quad (3)$$

$$T = A\Delta p \quad (4)$$

$$T = 2\rho A V_i^2 \quad (5)$$

Equations 1 and 2 can be manipulated to produce thrust based on density of fluid, disk area of the propeller, and velocity of fluid immediately after the propeller (V_i), entering water velocity (V_0), and exiting water velocity (V_e) as shown in equation 3. Using equation 3 and 4 it can be shown that V_i is twice that of the V_e. This relationship allows for thrust to be determined based on area, density and V_i. The mathematical model used assumes the craft moves through relatively still water due to the nature of being a low speed recreation vehicle and therefore V_0 is assumed to be zero. Thrust and V_e are based upon client desires for the final project. The area of the propeller is an estimation for an appropriately sized propeller for a personal water craft, which will move at low speeds.

$V_0 = 0$
$V_e = 2.235\,\frac{m}{s}$
$A = .0324\ m^2$
$T = 222\ N$

$$V_i = \sqrt{\frac{T}{2\rho A}} = 2.593\,\frac{m}{s} \quad (6)$$

This value for V_i reinforces the fact that an appropriately designed engine pair with an appropriately designed propeller should adequately power the redesigned Aqua Scooter.

4.3.3 Dry Combustion Analysis

Dry combustion analysis is the best way to compare different fuel types against conventional octane that fuels majority of 4 stroke engines on the market. For dry combustion analysis stoichiometry must be computed for each theoretical chemical combustion to determine the air to fuel ratio (AF). For convenience the stoichiometric analysis is done to have the fuel's coefficient to be one so the AF number is easier to compare with the AF ratio for octane of 15.1 (11).

Propane stoichiometry:

$$C_3H_8 + 5O_2 + 18.8N_2 \rightarrow 3CO_2 + 4H_2O + 18.8N_2 \quad (7)$$

Butane stoichiometry:

$$C_4H_{10} + 9O_2 + 33.84N_2 \rightarrow 4CO_2 + 10H_2O + 33.84N_2 \quad (8)$$

Air Fuel ratio for ideal combustion equation:

$$AF = \frac{moles\ of\ air}{moles\ of\ fuel} * \frac{M_{air}}{M_{fuel}} \quad (9)$$

AF ratio for propane

$$M_{air} = 28.97 \; ; \; M_{propane} = 44.09$$

$$AF_{propane} = (5 + 18.8) * \frac{28.97}{44.09} = 15.66 \frac{lb\ air}{lb\ propane} \quad (10)$$

AF ratio for butane

$$M_{air} = 28.97 \; ; \; M_{propane} = 58.12$$

$$AF_{butane} = (9 + 33.84) * \frac{28.97}{58.12} = 21.36 \frac{lb\ air}{lb\ butane} \quad (11)$$

As the above math shows the air to fuel ratios for propane and butane do no matter significantly when compared to that of octane. For this reason an adiabatic flame temperature calculation was determined to help determine which of the potential fuels would be the best alternative to octane. Adiabatic flame temperatures are determined using interactive thermodynamics equation solver software shown in Appendix D.

Examination of the adiabatic flame temperatures of products for the dry analysis of propane, butane and octane shows that the temperatures, which correlate with the fuel's ability to drive a piston in an engine, are similar given the same conditions (Appendix D). However it should be noted that dry combustion analysis and adiabatic flame temperatures are based on ideal conditions and are only used to help the design team make informed decisions without the ability to test a given fuel. With the above information it has been determined that propane would be an adequate fuel when paired with an engine designed to run on propane.

5.0 SHELL ANALYSIS

Initially, the shape of the outer shell was similar to a boomerang. After estimating the drag force that the Aqua Scooter would experience with the boomerang as the shell, it was determined that a reiteration of the design was necessary to decrease the drag force. The formula for the drag force is dependent upon the drag coefficient which has been estimated for various shapes. Drag coefficients along with the formula can be seen below:

$$F = 0.5\rho V^2 C_d A \quad (12)$$

Where:

F=$Drag\ force$ $[N]$

ρ=$Density$ $[kg/m^3]$

V=$Velocity$ $[m/s]$

C_d=$Drag\ Coefficient$ [unitless]

A=$Area\ orthogonal\ to\ flow$ $[m^2]$

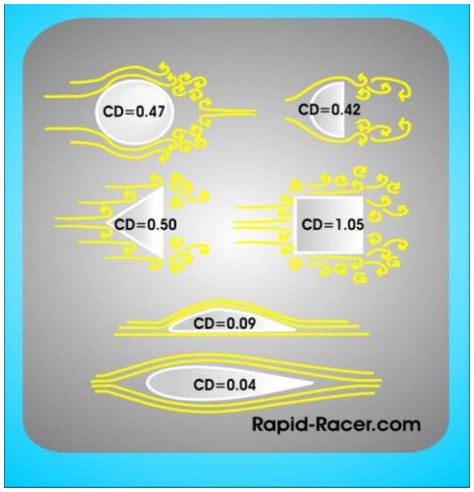


Figure 6: Example coefficients of drag and corresponding shapes

5.1.1 Boomerang

Coefficient of Drag Assumptions

$C_d = 0.5$

$A = 1106.3in^2 = 0.714m^2$

$\rho = 999\frac{kg}{m^3}$

$V_e = 2.235\frac{m}{s}$

Coefficient of Drag Calculations

$$F = 0.5\rho V^2 C_d A \quad (13)$$

$$F = 0.5(999)(2.235^2)(.5)(0.714) \quad (14)$$

$$F = 890.75\ N \tag{15}$$

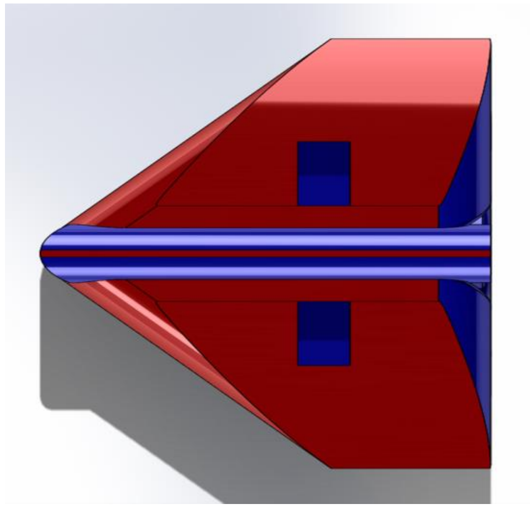


Figure 7: Final boomerang design with handlebars on the top.

5.1.2 Triton

Coefficient of Drag Assumptions

$C_d = 0.10$
$A = 513.20in^2 = 0.3311m^2$
$\rho = 999\frac{kg}{m^3}$
$V_e = 2.235\ \left[\frac{m}{s}\right]$

Coefficient of Drag Calculations

$$F = 0.5\rho V^2 C_d A \tag{16}$$

$$F = 0.5(999)(2.235^2)(.1)(0.3311) \tag{17}$$

$$F = 82.6N \tag{18}$$

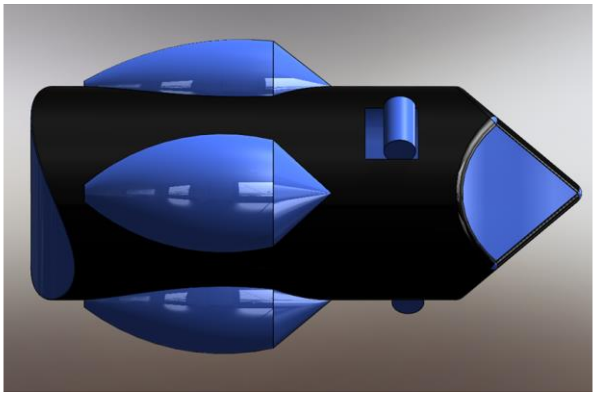


Figure 8: Final Triton design modeled after teardrop concept.

5.2.1 Power Calculations for Boomerang and Triton

The power calculations performed confirmed that the boomerang design vs. the triton design would not be as hydrodynamic; therefore, making the decision process for the final design simple.

$V_e = 2.235 \left[\frac{m}{s}\right]$

$$\mathcal{P}_d = \boldsymbol{F}_d \cdot \boldsymbol{v} \tag{19}$$

$$= \frac{1}{2}\rho v^3 A C_d \tag{20}$$

$$\mathcal{P}_{d(boomerang)} = 1990.82W = 2.669hp \tag{21}$$

$$\mathcal{P}_{d(Triton)} = 184.611W = 0.2475hp \tag{22}$$

6.0. CONCLUSION

The client, R.S.W. /D.I. Inc. currently manufactures a product that does not meet current United States' EPA regulations. The objective of this project is to design, engineer, and test an engine that will exceed the current EPA regulations. The most important points to consider for the design of a prototype are to adhere to the EPA regulations, keep dry weight of device under 18 lbs. and provide a capacity of a minimum of 50 lbs. of thrust. Additionally, the team must keep the manufacturing cost per scooter under $450. The team's decision matrix assisted in providing potential solutions for the client. Two concepts were selected and will be analyzed to assess feasibility.

These two concepts were initially analyzed for feasibility. After some analysis the two propeller design was ruled out and a single propeller was chosen for full analysis. The engine chosen for analysis was the 4-stroke Honda GXH50 engine. The feasibility of using butane and propane gases for engine was calculated and researched. The calculations show that both of these gases are able to propel the Aqua Scooter effectively.

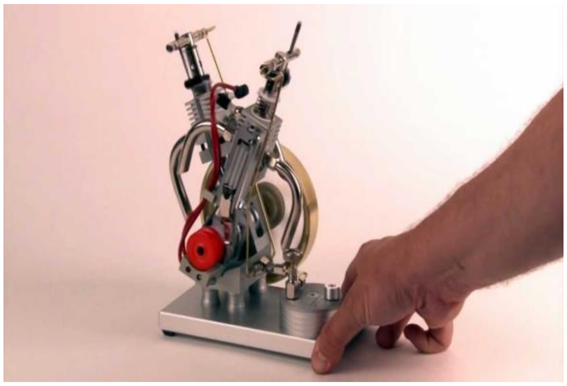


Figure 9: Possible engine design converted for gas fuel.

The boomerang outer shell design was analyzed for the coefficient of drag and the drag force needed to propel the scooter. Since the drag coefficient significantly increased the amount drag force which impedes the efficiency. The drag coefficient is highly correlated with the amount of power required to overcome drag, which for this project is limited to 2hp. As a result of these calculations the design chosen for further testing is the Triton shown in Figure 9. The team's next step is to confirm with the client the need for a working 4-stroke engine which can be used for further analysis.

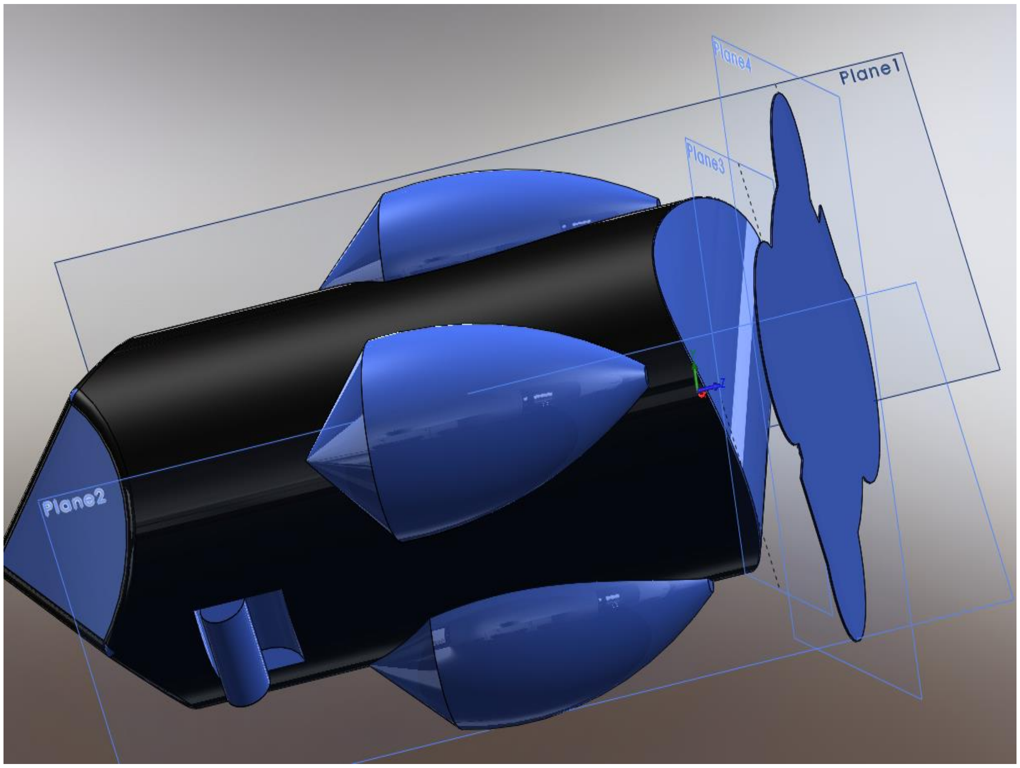


Figure 10: Final Triton design with area used for analysis.

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APPENDIX A: Aqua Scooter Components

1 - AIR TANK
2 - AIR TANK PLUG FOR SNORKEL CONNECTION
3 - FUEL TANK PLUG
4 - FUEL TANK
5 - FUEL VALVE
6 - EXHAUST GAS OUTLET
7 - FUEL PIPE
8 - STARTER HANDLE
9 - STEERING HANDLE
10 - THROTTLE LEVER

Figure A1: List of components of Aqua Scooter

11 - "**AVVIAMENTO - START - STOP"** POSITIONS
12 - CARBURETTOR TO CARB - EPA STANDARDS
13 - "START AND RUN" LEVER
14 - "**RUN/MARCIA"** POSITIONS
15 - PROTECTIVE GRILLE CE
16 - FUEL TANK BREATHER PIPE
17 - PROPELLER GUARD AND WATER DEFLECTOR CE
18 - CARRY HANDLE
19 - SPARK PLUG
20 - AIR INTAKE TUBE (SNORKEL)
21 - SNORKEL EXTENSION
22 - RUBBER BUMPER

Figure A2: Additional list of components for Aqua Scooter

APPENDIX B: Volume Calculations for Butane and Propane

Propane

```
%Propane volume calculator

Hp = input('Enter horsepower here\n'); %User input for engine horsepower

Bhr = Hp*2544.43358; %[Btu/hr] Converts input horsepower to Btu/hr

t = 3; %[hr] Time that aquascooter needs to run from full to empty fuel tank

B = Bhr*t; %[Btu] Energy needed from propane for aquascooter to run for time
t

IE = 84250; %[Btu/gal] Internal energy of propane

V = B/IE; %[Gal] Volume of propane needed to provide the energy for the
aquascooter

rho = 65.8285503; %[oz/gal] Density of propane

W = rho*V; %Weight of propane needed to run for time t

fprintf('The weight of propane needed is %4.2f oz.\n',W);
```

Butane

```
%Butane volume calculator

Hp = input('Enter horsepower here\n'); %User input for engine horsepower

Bhr = Hp*2544.43358; %[Btu/hr] Converts input horsepower to Btu/hr

t = 3; %[hr] Time that aquascooter needs to run from full to empty fuel tank

B = Bhr*t; %[Btu] Energy needed from propane for aquascooter to run for time
t

IE = 102600; %[Btu/gal] Internal energy of butane

V = B/IE; %[Gal] Volume of propane needed to provide the energy for the
aquascooter

rho = 79.9823563; %[oz/gal] Density of butane

W = rho*V; %Weight of propane needed to run for time t

fprintf('The weight of butane needed is %4.2f oz.\n',W);
```

APPENDIX C: Thrust

```
function thrust
RPM=input('What is the required RPM?\n');
Vo=input('What is the required speed (in miles/hour)[Vo]?\n');
Vo=Vo*(0.44704);    % mi/hr  ---->0.44704 m/s
P=input('What is the required Pitch [P]?\n');
F=input('What is the required minimum thrust (in lbs) [F]?\n');
F=F*(4.448);     % Lbs ----->4.448 N
syms d

d1=solve(F==1.225*(pi*(0.0254*d)^2)/4*((RPM*0.0254*P*(1/60))^2-
(RPM*0.0254*P*(1/60))*Vo)*(d/3.29546*P)^1.5,d,'Real',true);
d2=solve(F==4.392399e-8*RPM*(d^(3.5)/sqrt(P))*(4.23333e-4*RPM*P-
Vo),d,'Real',true);
fprintf('The full equation gives the diameter needed as %g \n',double(d1));
fprintf('The short equation gives the diameter needed as %g \n',double(d2));
```

APPENDIX D: Adiabatic Flame Temperatures using interactive thermodynamics

```
TR = 50 // sea water temp in F

//Propane anaysis for adiabatc flame temp
//evaluate reactant and product enthalpies hR and Hp
hR = hC3H8 + 5*hO2_R + 18.8*hN2_R
hP = 3*hCO2_P + 4*hH2O_P + 18.8*hN2_P

hC3H8= -44680
hO2_R = h_T("O2",TR)
hN2_R =  h_T("N2",TR)
hCO2_P = h_T("CO2",TP)
hH2O_P = h_T("H2O",TP)
hN2_P = h_T("N2",TP)

hP=hR
TP = 3833 // adiabatic flame temp in F
////////////////////////////////////////////////////////////////
TR = 50 // sea water temp in F

//Butane anaysis for adiabatc flame temp
//evaluate reactant and product enthalpies hR and Hp
hR = hC3H8 + 9*hO2_R + 33.84*hN2_R
hP = 4*hCO2_P + 10*hH2O_P + 33.84*hN2_P

hC3H8= -44680
hO2_R = h_T("O2",TR)
hN2_R =  h_T("N2",TR)
hCO2_P = h_T("CO2",TP)
hH2O_P = h_T("H2O",TP)
hN2_P = h_T("N2",TP)

hP=hR

TP = 3931 // adiabatic flame temp in F
///////////////////////////////////////////////////////////////////
TR = 50 // sea water temp in F

//Propane anaysis for adiabatc flame temp
//evaluate reactant and product enthalpies hR and Hp
hR = hC8H18 + 12.5*hO2_R + 47*hN2_R
hP = 8*hCO2_P + 9*hH2O_P + 47*hN2_P

hC8H18= -107530
hO2_R = h_T("O2",TR)
hN2_R =  h_T("N2",TR)
hCO2_P = h_T("CO2",TP)
hH2O_P = h_T("H2O",TP)
hN2_P = h_T("N2",TP)

hP=hR
TP = 3833 // adiabatic flame temp in F
```