T518 Yamaha Rightwaters Trash Interceptor

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Abstract

In 2019, Yamaha Motors created the Rightwaters Initiative to protect marine environments. Using an intercepting device, trash collection occurs in storm drains before it enters larger bodies of water. This stops pollution early in the cycle. Yamaha discovered that the first machine was too solid and heavy, making it difficult to move around. Similarly, the objective of this project is to create a trash interceptor to prevent waste from entering these large bodies of water. Collecting debris in storm drains will stop trash from reaching both oceans and rivers.

The team designed a new machine that is both cheaper and more readily available. Easy setup, sustainability, and being scalable are factors this new design addresses. The interceptor consists of a rotating basket wheel that will pick up trash and move it to a single collection site. A conveyor belt will move the trash from the collection site to a dumpster. For easy setup, the device will arrive on site in a few, simply assembled pieces. Once put together, the collector will rarely need human contact. The dumpster will be emptied according to a weekly pick-up schedule per city regulations. The collector will contain both a solar panel set and battery storage, so it will always have power. Solar panels will work during ideal weather, and the battery will provide power at all other times. By using renewable energy, the team further protects the environment. This helps to limit human input and reliance on outside power sources. The ability to scale the interceptor allows the device to operate in many environments. The expandable floating boom will allow the interceptor to scale to these different environments. To further improve performance, a water jet accelerator will pull the trash into the interceptor. The interceptor will collect trash before it spreads into larger water ways, allowing preservation of marine environments.

1. Introduction

1.1. Project Description

In 2019, Yamaha Motors created the Rightwaters Initiative to protect marine environments. Right now, it is estimated that for every three pounds of fish in the ocean, there is one pound of trash. By 2050, it is estimated to be a one-to-one ratio. It was determined that collecting trash in storm drains allows for trash collection early in the pollution cycle before the trash can reach larger bodies of water. This will allow trash to be collected before reaching rivers and oceans, therefore preserving marine environments. Yamaha wants to create a means of trash collection that is simple, yet effective and cost efficient.

1.2. Project Objective

The objective of this project is to implement an effective land-based trash interceptor that collects debris in storm drains to prevent trash from entering larger bodies of water.

1.3. Key Goals

A key goal for the trash interceptor is that it can scale to many different storm drains. Being scalable will result in the device being able to be used regardless of the water level in the storm drain, as well as different overall sizes of storm drains.

Another key goal is to design the trash interceptor so that it doesn't have to withstand major storms/hurricanes. However, the device will be able to withstand minor, everyday storms. This will allow the device to be expendable and easily replaced if damaged. Having the device be expendable will result in lower material costs, creating a more easily replaceable device as well as a more readily available product.

The final key goal of the trash interceptor is that the machine will be broken into modules of small subassemblies, which will result in easier deployment at the storm drain. Breaking the trash interceptor into modular subassemblies will result in lightweight modules, as well as being able to replace the specific module if damaged/broken.

1.4. Assumptions

There are assumptions that will be held as true throughout the entirety of this project; they will help control the scope of our project. There will be a stable embankment where the device is to be installed and operated, meaning that there would be a stable enough foundation for the device. Multiple people can install and uninstall the device without assistance from major machinery. Some source is present for varying sustainable energy sources, such as wind, sunlight, or geothermal energy that could be utilized to power the device. A person or persons are available to dispose of trash intermittently while the device is in operation. Minor disturbances to the land area around the device when being installed are permitted. These controls will guide our project by focusing our attention on what the team needs to address and consider throughout the design process.

2. Targets and Metrics

2.1. Scalability

To ensure that the trash interceptor is effective in all storm drains of various sizes there are two different ways in which must be scalable. Two targets were determined, horizontally must reach 20 feet and vertically it must collect from 2 feet to 7 feet above the surface of water. It was found from our customers needs they wanted to work with storm drains at most 20 feet wide, but also work in storm drains narrower. The target trash size being medium floating trash the interceptor must collect from the surface no matter the water level height. A target was set that the trash intercept needs to expand vertically 2 to 7 feet based on water level.

2.2. Collecting

The primary target trash size is only approximately 0.640 oz, however attempting to obtain a high cost per ton of trash, it should collect a high amount of trash per cycle of collection. So, a target was determined that the trash interceptor should collect up to 20 lbs of trash at a time. This target includes a factor of safety so that if branches broken during storms flow into the path trash interceptor.

2.3. Power

From our customers' needs of a renewable power source, there needs to be an evaluation of how much power is available for usage. Adding a significant factor safety, it was determined that to collect 50 pounds of trash at a time energy to move 50 lbs out of a storm drain was proven to be 700 lb-ft. The relative time to pick up the upper limit was decided to be 60 seconds. The required power for the device is therefore 11.67 lb-ft per second.

2.4. Deploying

To deploy the device, the trash interceptor must be deployed by at most three skilled contractors. According to MIL-STD-1472G, Section 5.8.6.2.5, "Individual portions of equipment shall not exceed 35 pounds, per person with load balanced equally." So, a modular style should be implemented, and each subassembly should not weigh more than 35 pounds per person.

3. Results & Discussion

3.1. Scalability

One of the main targets that team 518 has was to make sure the device was able to scale to many different depths of water. This was executed by implementing a flotation system. Two, 3-gallon jugs were attached to both legs to make sure that the device expanded at the same time to provide a level rotating shaft. Testing took place in the Wakulla River. The device was deployed into the river and was moved around to many different depths. At some depths the device was able to expand too high. This is when the buoys were able to be ballasted with water to provide the correct height. Through physical testing, it was confirmed that the device was able to expand the necessary 2 feet to 5 feet. This met the metric that was in place for the vertical expansion. The horizontal expansion will be done via floating boom that is scaled to each storm drain, as a pure adjustable design element there was no validation or testing performed.

Testing	Target	Actual	Method of Validation
Vertical Expansion	2-7 ft	2-5ft	Phsyical Testing Wakulla River
Horizontal Expansion	20 ft	-	N/A

Table 1: Scalability Targets Validation

3.2. Collecting

Another main target that the team put in place was that the trash interceptor had enough power to not only collect 20 pounds of trash at one time, but also to have enough power to rotate through the water. It was also very important to achieve at least a 70% collection efficiency in the first rotation of the basket. After testing the device with the motor, the motor did have enough torque to completely rotate the baskets while having 20 pounds of trash in it, while also rotating through the water. The torque required to collect 20 pounds of trash was found to be 144 lbf-in. The weight test was done by putting a 20 lb weight and examining if the model will semi rotate while holding the weight. Collection testing wasn't done with the weight so to no damage the model, as well as, the 20 lbs is primarily a safety factor for the device. This ensures that if a larger branch is intercepted the model wouldn't be hindered from rotating due to the weight of the branch.

Testing	Target	Actual	Method of Validation
Collection Weight	20 lbs	20 lbs	Static Weight Test
Collection Size	0.046 ounces/44 ounce cup	1.620 ounces/golf ball weight	Dry Test using substitute trash
Collection Efficiency per Cycle	70%	73.3%	Dry Testing using substitute trash

Table 2: Collection Targets Validation

The scaling of the prototype led the team to test with smaller sized trash such as dixie cups and golf balls. When testing with dixie cups and golf balls, it was determined that 73.3% of trash was being collected on the first rotation. The rest of the trash was being picked up with the subsequent rotations of the basket. The collection efficiency per cycle target was met with an approximate overshoot of 5%, however there are methods that the efficiency could be increased. The reason that the trash was missing the reservoir was hitting the end of the shaft and the friction due to dry testing. Dry testing was done so that testing and validating could be done in a controlled environment, but water flow during collection will lower the friction trash experiences each rotation and would increase the efficiency per rotation. Golf balls were chosen to mimic a lower friction factor, but this also led to more slip and errors. Another way to increase the efficiency would be shortening the protrusion of the shaft above the collection reservoir. All the testing for trash collection was physically tested using the trash interceptor model.

3.3. Power

Due to our device trying to preserve the environment, it was important for the trash interceptor to be powered via a renewable energy source. The team researched all different types of sources, but due to the device being placed primarily in the Southeast United States, solar energy was the most readily available. The team purchased one solar panel to test to determine the adequate amount of solar panel area that would be needed to power the interceptor. Through testing the one solar panel over multiple days, simulations were able to be done to determine how many solar panels, as well as how much area of solar panel would be needed to completely charge the battery and run the device. Accounting for error in solar panel efficiency and utilizing NREL data, seen in figure 1, the average global horizontal solar irradiance for winter months was used to simulate the power provided through solar energy. Through these simulations, it was determined that the device would need four, 36 cell solar panels with an efficiency between 15 and 20 percent. This will be enough to run the device for the amount of time that was set forth while creating targets and metrics.

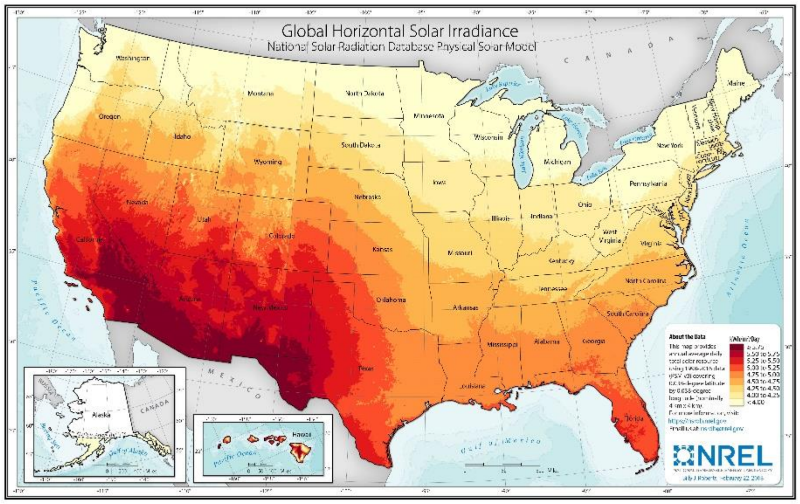

Figure 1: National Renewable Energy Laboratory

3.4. Deploying

According to MIL-STD-1472G, Section 5.8.6.2.5, "Individual portions of equipment shall not exceed 35 pounds, per person with load balanced equally." With that being said, the subassemblies of the trash interceptor could not surpass 105 pounds with only three contractors deploying the device. The target that team 518 put in place was that each subassembly would not surpass 100 pounds, to have a little bit of room to play with. With the heaviest subassembly that was created only weighed 61.4 lbs. This maximum weight allowed the device to be well under the target for the weight of each part. This was able to be validated by weighing each of the different subassemblies to ensure that they were under the weight limit.

4. Conclusion

Clearing trash and plastics from storm drains before allowing it to disperse into larger bodies of water will allow for cleaner oceans and lakes. Without the implementation of trash interceptors in storm drains, oceans will continue to fill up with trash and plastics. Team 518's trash interceptor provides an economical, expendable, and efficient way to rid these storm drains of plastics. Ultimately, the trash interceptor was created relatively successfully by intercepting 73% of trash via dry analysis on the first rotation.

As in all projects mistakes were made throughout the process. The largest errors came from lack of communication with the machinists. Simple discussions earlier on in the process would have help stop simple mistakes such as buying galvanized steel to be welded as the base of our device. This simple mistake in purchasing slowed down the manufacturing process by roughly a week as the team was required to find other machinists that were able to assist in assembling the galvanized steel. Another small mistake caused by the lack of communication with machinists that was made was reinventing a bearing housing that already existed. The bearing housing that was fabricated to attach the basket shaft to the inner concentric legs could have been easily bought. The third mistake that stems from the lack of communication with the machinists was that all four of the basket walls had holes cut out of them instead of just two. This mistake would have been easily avoided by proper documentation when going to the machinists.

4.1. Future Work

To continue building off the current trash interceptor, a full-sized model would need to be created for the interceptor to be implemented into small municipalities. Floating booms will need to be quoted to adhere to the dimensions of the storm drain. This will allow the trash to be funneled into the device to remove trash from the storm drain, before being able to reach the ocean.

Another stage of this project that can be continued would be to allow for the device to be controlled remotely from wherever the operator would be located. This would allow the operator to be prepared to turn the device on when a large storm is anticipated without having to go to the device and manually turn it on. The device would be able to be connected via and IoT (internet of things) device between the device and the operator.

A larger collection area in the basket can also be implemented, so that more trash can be collected in the first rotation of the basket. This could be executed by having larger baskets so that the slide can be lower down on the basket, hence increasing the collection area.

Lastly, the correct number of solar panels to provide the device with necessary power can be set up and wired to charge the battery. This will allow for the device to be powered via a renewable energy source. These will be set up with the battery underneath it, with wiring over to the motor.

4.2. Concluding Remarks

Looking back at this project many lessons have been learned and good experience has been gained. This project has bettered its members in many facets. The first being the progression of our intellectual studies taking the many lessons learned in the lecture halls and applying them to physical, tangible, real world problems. This has helped all involved ensure a deeper understanding of the lessons learned for future applications. The second being the strides we as a team have made in bettering each other as individuals. Working as a group and helping each other along the way so that we can all accomplish the same goal leads to growth within an individual that far exceeds things taught in a lecture. Then ultimately the third lesson learned was what it means to be a mechanical engineer. Being a mechanical engineer has so many intricacies within it. Its drawing diagrams and wiring diagrams and math, but it is also talking with a customer or a machinist, and so much more.

5. Acknowledgements

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References

[1] "National Renewable Energy Laboratory," 2021, [Online]. Available: https://www.nrel.gov/gis/solar.html.