The Fog Collector

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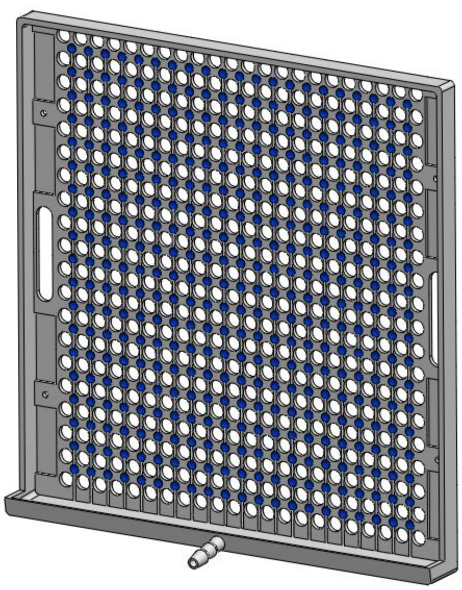

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1. Problem Statement and Scope

Across the globe, 785 million people lack a basic drinking water source, with a total of approximately 144 million who are dependent on surface water alone [1]. This project investigates the design and functionality of a fog collection device. A readily available and promising resource of drinking water is fog water. These micrometer-scale water droplets range in size from 1 to 10 μm and can be harvested from desert, coast and mountainous regions. Over the course of the last decade, fog collection has become an attractive solution to the freshwater crisis [2]. Developing an efficient collection device would serve as a source of drinking water for thousands of people around the world.

2. Functionality and Durability

This fog collection device's dimensional features can be easily modified, making the system extremely versatile. There is also installation versatility. The collection device can be installed as a single module or assembled in a group of modules. These devices can be bolted to a vertical surface or attached to poles using locking ties through the holes along the sides. The main functional requirements of a fog collection device include a relatively hydrophobic surface, a low re-evaporation rate of collected water and the rapid transportation of the collected surface water [2]. Additionally, an effort was made to maximize collector efficiency. Studies have shown that flat plate fog collectors are most efficient when 43 percent of the collector is open for air flow [3]. As a result, holes on the surface of the fog collector account for 43 percent of the surface area. A coupled CFD and structural analysis was done to study the fluid surface interaction for a moderate gale speed of 36 mph. From this analysis, the maximum force exerted occurred at the base of the collector and the maximum deflection that occurred was 0.90 mm. These results indicate that under severe wind speeds the fog collectors will not experience any permanent deformation.

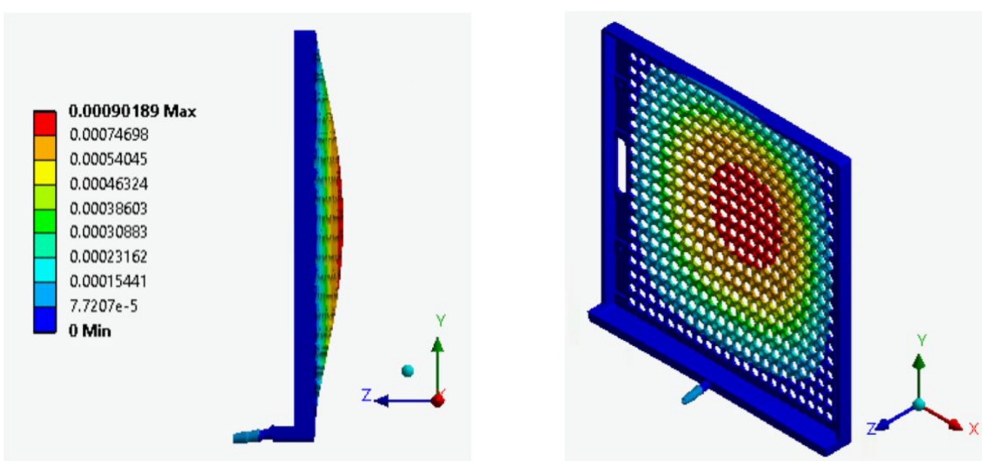

Figure 1: Fluid surface interaction results. Both images demonstrate the deformation (meters) of the device scaled by a factor of 7400.

3. Material Selection

The materials that will be used were strategically selected to facilitate effective fog collection. The majority of each module will be printed using acrylonitrile butadiene styrene (ABS), which is a hydrophobic material. ABS is a commonly used material in additive manufacturing, with attractive properties such as good mechanical strength and printability. The collection surfaces, or dimples of the device seen in Figure 2 will be manufactured using a hydrophilic polymer, polymethylmethacrylate (PMMA). PMMA is a durable material, with a water contact angle of approximately 67.8 degrees [4]. When a droplet of water contacts the hydrophilic dimples of the panel, the droplets will stick to the surface of the dimple and begin to accumulate a larger volume of water. When this mass of droplets becomes too large to be held by the dimple, it will fall, traveling through the hydrophobic channel adjacent to the dimple, and cascade down the panel to the collection area. The collection area will funnel water towards the center and through a barbed fitting that will fit common ¾ inch hoses.

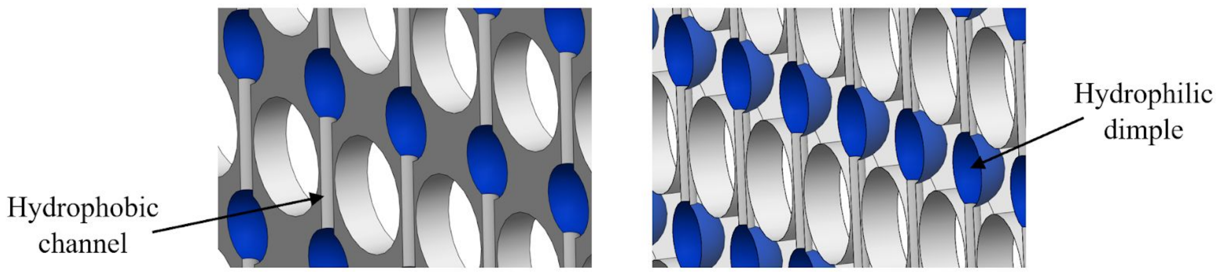

Figure 2: Hydrophilic dimples and hydrophobic channels on the surface of fog collection device, shown in solid (left) and transparent (right) views.

4. Utilization of AM Processes

Fused deposition modeling (FDM) was selected as the additive manufacturing process to produce the fog collector. In this process, a filament is melted and extruded through a nozzle onto a build platform where the model is built one layer at a time [5]. This method was selected, as it allows for models with complex geometries to be made efficiently and multiple extrusion nozzles can be used in tandem to create a single model constructed of multiple materials [6]. In the case of the fog collector, this characteristic of the FDM process was especially attractive, as it would allow for the collector to be built with both hydrophobic and hydrophilic materials. To create the highest quality model possible, the FDM process can be fine-tuned by changing extruder nozzle diameter. For this specific application, two extruder nozzles will be used, a 0.8 millimeter nozzle for the ABS material and a 0.4 millimeter nozzle for the PMMA.

5. Design Integration and Innovation

Additive manufacturing (AM) has a significant impact on the manufacturing process, as it is a start-to-finish process, creating complex geometries that otherwise could not have been made by traditional processes. A major benefit to AM is the reduction in waste, as compared to subtractive or other traditional methods of manufacturing. AM methods like fused deposition modeling, add material until the model is completed, this can result in up to a 75% reduction in material used as well as production time and costs reduced by as much as 50% [7]. AM processes like FDM allow for multiple types of materials to be printed concurrently. While some traditional methods such as injection molding can produce products containing multiple materials, manufacturing this product would be very costly and require specialized equipment. AM also makes the process of adjusting the current panel size (506.70 mm x 519.05 mm) much simpler, as new tooling would not need to be made. However, traditional methods of manufacturing require tooling changes that are costly and time inefficient. This AM process would also be significantly more portable than traditional methods and require fewer peripherals.

6. Cost Benefit/Value Analysis

The fused deposition modeling method is quite superior to traditional manufacturing techniques due to its reduced manufacturing costs and its added versatility. One significant benefit of FDM technology is its ability to print multiple materials in a single print. This attribute of FDM printing reduces cost as it allows for streamlining of the fog collectors manufacturing processes. FDM printers have been around for a number of years and even larger FDM printers have become increasingly affordable. Based on a build volume of 1134.58 cm^3, it is estimated that each fog collection module would require $2.04 of PMMA and $10.57 of ABS totaling a cost of $12.61 [8][9]. Additionally, the relatively low upfront cost of FDM printers ($7,000) would allow for production scalability. In comparison, a single molding tool for injection molding costs approximately $50,000. FDM printers are also extremely versatile and would allow for the fog collectors design to be adjusted, if needed, for specific applications. Finally, FDM printers are substantially more portable than traditional plastic manufacturing methods allowing for FDM printers to be deployed to natural disaster areas for on-site fog collector manufacturing. This would allow for those impacted by a natural disaster the ability to receive clean water in an extremely efficient manner.

7. Marketing

This product will be marketable to a variety of people, as it is extremely adaptable to a wide array of environments. It would work well for any individual or community that does not have a well for water or access to clean surface water. The collector that could also easily be fixed to the roofs of houses and apartment buildings in more urban areas to promote sustainability. Further, it could also be quickly deployed in rural areas. Many natural disasters would likely disrupt the normal method in which people acquire their water. As a result of the device's adaptability and low production cost, the fog collectors could be quickly deployed in those circumstances to meet the needs of those in areas where natural disasters have recently occurred.

8. Social and Environmental Impact

When water comes from an improved and more accessible source, there are several societal impacts that will follow. An increase in personal health and safety can also be seen, as the time and physical effort to take long trips for water will no longer be needed. One of the most important improvements that will be seen is a decrease in the illnesses from poor water sources. Additionally, some research suggests that clean water can lead to a reduced risk of non-waterborne illnesses [10]. This would also demonstrate a decrease in potential medical costs. The material selection of this project is also advantageous as both engineering plastics can be recycled. After being properly recycled from plastic components such as car parts or electronic equipment housings, ABS specifically can be made into a filament for additive manufacturing [11]. Thus, the panels could be printed with filament made of primarily recycled material. It is also important to note that compared to traditional methods, FDM can achieve very low ecological impacts and reduce the energy demand for the manufacturing of polymeric materials by 50% [12].

9. References

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