The Utilization Of A Windmill For The Extraction of Water From Wells In Western Kenya

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Introduction

Throughout most of the Western world, the generalization that underdeveloped countries lack access to water is unanimously understood. In response, multiple governmental and nongovernmental organizations have taken on the feat of permanently eliminating this issue. The issue being that water is currently obtained in most villages by an individual tossing a container into a deep hole, and pulling out the collected water. Most commonly, the solution would include aid workers digging a well in a densely populated village, and attaching some rendition of a lever-action pump to the enclosed top surface. Unfortunately, this approach dwells a number of problems, including its financial setback, inefficiency, functionality, feasibility, lifetime, and overall social impact. Taking this into consideration, and also from the inspiration of William Kamkwamba, the project completed through Lehigh University's Sustainable Development Laboratory consisted of developing an entirely sustainable and simple, wind-driven water extraction system. More specifically, the product is a windmill that uses mechanical energy to drive a spool containing a string of cups holding water out of a well and into a separate reservoir for easy and unlimited access. Except for two elements, the system is composed of natural resources found throughout Western Kenya, the primary area of focus. The setup incorporates bamboo, sisal (rope), plywood, two steel bearings, and a steel rod. In essence, the mission of the project was to develop a do-it-yourself manual for the construction of a windmill out of natural resources in sparsely populated regions of Kenya. Which in turn, will provide an efficient means for pumping water out of pre-existing wells. The creation of such a product will supply villages with malleable instructions to promote ingenuity, save young women and the elderly the struggle and time of attaining water from both the bucket-extraction mechanism and inefficient pumps, and equip villages with the ability to formulate a good that can be maintained and improved upon based off the capacity and potential of the village itself rather than a foreign group. The result of the 10-week period included the generation of all parts necessary for the final assembly of the windmill.

Results

After the completion of 10 weeks of work, the results of the project include extensive research on wind power and the country of Kenya as a whole, as well as all parts fabricated for the final assembly of the proposed windmill. Additionally, the task of making preparations for future work was initiated. For this particular project, the basic design behind a typical farmers windmill was used as a template since it is attempting to achieve a similar goal. Therefore, there was no reason to reinvent the wheel. The problem was tackled by initially constructing the bucket system, which includes sisal, bamboo cups and small rods for stability when maneuvering over the spool.

By using the mass of this system, the following formula was applied to determine the sweep area of the windmill; essentially, the necessary lengths of the blades in order to theoretically function:

$$Power = \frac{mgh}{t} = \frac{1}{2}\rho A v^3 Cp$$

m	Mass of Bucket System (kilograms)
g	Acceleration Due to Gravity (meters/second^2)
h	Height of Central Hub (meters)
t	Time (seconds)
ρ	Air Density (kilograms/meters^3)
A	Sweep Area (meters^2)
v	Wind Speed (meters/second)
Cp	Betz Limit-Coefficient of Performance (0.5926)

The table below includes average values of Kisumu, which is an exceptional site for the windmill due to its high winds from Lake Victoria, elevation, and saturation of nearby villages with a lack of water:

Temperature	296 Kelvin
Wind Speed	12 kilometers/hour
Elevation	1145 meters
Atmospheric Pressure	100 kilopascal

Using the above values, the density of air for Kisumu was found and plugged into Equation 1 to find the sweep area. The sweep area was then used to find the radius of the windmill blades by using the equation:

$$Sweep\ Area = \frac{\pi}{4} D^2$$

When using a windmill with 51 cups and 34 cups, the final blade length came out to be 1.546 meters and 1.364 meters, respectively. Using this calculation, the theoretical lengths of the blades were found, however, there is the issue of concluding the optimal width of the blades. Unfortunately, the only way to predict this value is through trial and error. The basic format for the blades, nonetheless, would be to have a diameter smaller at the central hub end, and larger at the end away from the hub. The fabricated blades have diameters of 2.5 and 4.5 inches as a starting point for the initial testing. This concept increases the potential to promote lift and drag. Finally, the number of blades is also a problem to solve during testing. Considering the work that the windmill will be completing in a given day, generating enough torque is essential; this again, is done by the same methods employed by the farmer's windmill. That is, having many more blades compared to the typical 3-blade wind turbine, which is used for the production of electrical energy. More blades develop more torque for continuous rotation. Additionally, an odd number of blades is commonly used to offset the vibrations produced from windmills with an even number of blades. Thus, for testing, seven blades have been cut to the dimensions previously stated.

Impact

The significance of the windmill project and its associated goals can be broken down into both a macroscopic and microscopic level. Broadly, the intentions of the project impact the underdeveloped regions of Africa in terms of its water shortage. Limited supplies and resources relinquish the fate of access to drinking water to the work of humanitarian organizations and the perseverance of select villagers. Currently, the commonly employed method is for laborers to dig a hole into the ground until an aquifer is found. Subsequently, various containers are tied to rope and utilized in extracting water; simply, by tossing in the container and pulling the rope back up. Not only is this process inefficient, but it is also takes a large toll in an individuals time allotment; which in this case, tends to be the time of young women. Consequently, causing them to miss school and hinder their process for attaining an education because they are not only walking great lengths to acquire the water, but are also usually waiting in line for their turn to collect. Thus, the impact of the windmill project is that it subsides the numerous frustrations associated with water gathering by autonomously pumping water 24/7.

Future Work

As a result of the work completed throughout the summer, there are a few routes that the project can and will take. First, a prime location for the windmill will be found for its permanent placement. This location will need to mimic that of West Kenya. Thus, there will need to be a large body of water to represent the winds of Lake Victoria, as well as limited obstructions from buildings and large households, as that of common Kenyan villages. Once the windmill is mounted, its performance can be tested and optimized by modifying the key components of the design. Once complete, the second objective will be to develop an easy to comprehend instruction manual for village distribution. The most efficient plan will include partnering with a nonprofit organization already established in the area of interest, such as The Feed Project, to aid in circulating our documents amongst local and remote villages. Finally, as Kenyans, and Africa in its entirety, learn to use our sustainable windmill, a common theme as to why wells built by outside organizations break down within the first 1.5 years can be investigated. That is to say, the final goal would be to invent a universal tool or part necessary to maintain the functionality of these wells and dramatically enhance their overall lifetime.