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Design Optimisation of Fog Collector

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Abstract-
Water is one of Earth's most precious resources. Unfortunately, we are living in a time where access to fresh water has become unreliable in many parts of the world. Given this, the urgency for implementing innovative approaches to sustainably harvest clean water has become even more urgent.NBD Nanotechnologies (pioneer developer of oleo phobic & hydrophobic materials) is developing a new generation of fog collecting nets to help provide relief for drought-affected areas around the world. Fog harvesting has been used for centuries in places like South America, proving plenty of clean drinking water for remote villages. Unfortunately, the ripe conditions for fog harvesting that are used presently are not prevalent in most places of the world. Conventional nets simply don't work..By coating meshes with NBD Nano's hydrophobic coating, NBD Nano is able to consistently increase the rate of fog harvesting in coastal areas. The Purpose of this paper is to develop a new setup for the frame/structure to secure and test its fog collecting meshes. The current preliminary setup is time-consuming and very basic in appearance although extra robust. The meshes are stainless steel wire cloth; with wire diameter of 0.01".At present the fog meshes will be set up along coastal and in-land regions that receive heavy fog. The fog meshes are then installed on-site for testing by affixing each mesh onto the frame/structure. The idea is to redesign and optimize the process, by strategically redesigning a frame structure where much emphasis is given on light weight, robust, easily installable frame /structure in which water is collected from the fog needs to be drained into a reservoir and could be used for irrigation. The proposed design has mesh taut against wind gusts up to 70 mph with minimal distortion and efficiently drains collected water into reservoir. By coating meshes with NBD Nano's hydrophobic coating it can improve capture rates by 5 times in fog events. Some optimal features such as automatic rotation towards wind direction, storage reservoir for efficiently drainage of fog water is added to design.

Keywords- fog collection, woven mesh, fluid mechanics, surface wettability, droplet deposition

1. INTRODUCTION

Overview

The collection of fog for the purpose of the production of clean water has attracted increasing attention over the past few decades. Only if fresh water is sparse, is there a motivation to set up a system for fog water collection. In other words, only if rain is a very limited (in many cases virtually non-existent at least for a significant time period of the year) source of fresh water, and groundwater is an unsustainable expensive source, fog collection projects make sense. It is a simple and sustainable technology with the potential to produce precious water in some regions of the world. It is achieved by exposure of mesh material to foggy air masses. There are numerous projects on five continents to collect fog water, of which some are more successful than others. The beneficiaries are often poor people, although successful projects also exist in more prosperous regions`

These traditional fog collectors namely SFC (Standard Fog Collector) , LFC (Large Fog collector) has mesh which could bear the high wind speed , height could not be adjusted easily, required proper orientation according to wind direction, types of mesh used , replacement of mesh were time-consuming and laborious.

The scope of this thesis is to synthesize the current understanding of fog collector (SFC) and to optimize the design &analyze its potential for future development. Note that the science of fog physics, chemistry, and its role in the hydrological cycle, which extends to a much wider climatic range than the 'fog collection 'addressed here, is not within the focus of this thesis.

Research Methodology

The information presented in this paper is a distillation and synthesis of material gathered by an extensive search of relevant and up-to-date material published in books, journals and on the internet. This is reinforced with information gained in discussion of the subject with leading authorities and workers in the field of fog water harvesting.

Tecnology overview

Collection of fog or cloud is achieved by the collision of suspended droplets on a mesh. The droplets coalesce on the mesh and rundown in to a collecting drain and then into a tank or distribution system. Fog collection can be thought of as an aerial spring; the piping and delivery system is no different from a standard spring-fed gravity water supply as outlined in standard texts.

Basic Concepts

The mesh is typically suspended 1.5m above the ground between two vertical posts. The size of the collector depends on topography and the intended use of the water. Details of collector design are covered in Section 3.

Good access to the site is required for installation, maintenance and monitoring.

Advvantages

- Quick and simple design and construction. Installation requires little time or skill.
- Un-patentable technology (except some mesh designs).
- Modular system that can grow in line with demand or available funds.
- Passive collection systems requiring no energy input to operate.
- Cheap and easy to maintain and repair.
- Low capital investment and other costs compared to conventional sources of potable water in mountainous and arid areas.

Future Development Requirements

- More efficient meshes and flexible designs are needed to increase the per square meter yield to keep costs and space requirements down patentable technology (except some mesh designs).
- Greater awareness of fog-harvesting technology is needed in the rural water supply sector and good understanding of its opportunities and constraints.
- More research is needed on the dynamics and chemistry of fog in order to optimize quality and yield.

2. Initial Survey

Background

The collection of fog water is a simple technology. A mesh is exposed to the atmosphere, and the fog is pushed through the mesh by the wind. A fraction of the fog droplets is deposited on the mesh material by impaction. When more and more fog droplets deposit, they combine to form larger droplets, rundown the mesh material in to gutters and eventually in to a storage tank. Differences between various fog collector designs exist regarding their size and shape, as well as the mesh material used.

Figure 1. Traditional 18 square meter flat-panel fog collector.

Standard Fog Collector (SFC)

A fog collector is simply a frame that supports a section of mesh in a vertical plane. The large, operational fog collectors are typically made of two supporting posts, and cables on which the mesh suspended. In addition, there is a network of guy wires to support the posts, a plastic trough to collect the water, and pipes to move water from the troughs to a reservoir or cistern. It is mainly used in exploratory studies to evaluate the amount of fog water that can be collected at given sites.

The SFC has a 1 square meter surface, with a base 2m above ground and is installed perpendicularly to the wind direction that is associated with the occurrence of fog. The large collectors are usually 12 m long and 6m high. The mesh covers the upper 4mof the collector. This gives a collecting surface of 48 square meter and typical water production rates from one collector of from 150L per day (liters a day) to 750L/day depending on the site. Sustained production rates over periods of two and one-half months in the Sultanate of Oman were as high as 70L per square meter/day or 3360 L per collector per day. The 48 square meter fog collectors cost about Rs 24000 each to build arrays for villages' number from 30 to 80 collectors. The 1 square meter Standard Fog Collectors cost from US$10 to US$20 to build depending on the country and the materials. It has now been used to measure fog fluxes in about 40 countries.

The Large Fog Collector (LFC) has been widely used for fog collection. The principle is identical to that of the SFC. It is, however, much larger. In most cases, the mesh is 4m high and 10m wide. The lower edge of the mesh, with the attached gutter, should be as high of the ground as possible (typically2m) in order to increase the collection rate.

In the SFC design, the mesh is stretched over a rigid frame. For the LFC, the mesh is supported by a frame made of cables, which are held tightly between two vertical posts.

Present Scenario

Till now there is no such consideration given to structure of SFC's ,but only to the collecting efficacy of various mesh materials, different types of weaving patterns, climatic conditions, coatings on the mesh. So this paper is focused mainly to the efficacy improvement on the basis of its mesh frame and its supporting structures ,considering its flexibility and that too economically.

3. Pilot Study

The objective of the Pilot Study is to get sufficient assessment and propose required modification of standard fog collectors. It is important to deduce the best placement and orientation of the large collectors for greatest yield. This information is vital to design process, to ensure best performance at an affordable cost.

Design Factors

Certain factors which influences the design data of SFC's supporting frame and stand which is responsible for its flexibility, mobility, compactness and its feasibility.

- Wind Velocity and Direction
- Mesh Material
- Space Requirement
- Ease of installation and replacement
- Ease of transport
- Ease of Maintenance and operation

Identification of potential modifications

- Arrangement for orientation of mesh according to the wind direction.
- Special mesh coating for better fog collection for Same water collecting capacity with smaller size collector
- Ability of sustaining high wind speed
- Easy adjustment of dimension of contacting surface
- Easy installation and replacement

4. Proposed Design detail

By gaining knowledge from pilot study, modification in design has been proposed to eliminate their drawbacks and further improving its performance, which is dealt in this thesis, whose features are as follows:

- Telescopic height adjustment according to the variation in fog density of wind
- 360 degree rotation of mesh so as to get maximum area for impacts
- Optimized design for sustaining in higher wind speed.
- Easy replacement of entire frame with the help of nut and bolt arrangements.
- Coating of NBD hydrophobic material over the mesh to increase the amount of water.
- Concrete foundation (optional)

5. Construction

Orientation with respect to wind direction

To maintain the flexible design ideology a rotating joint was incorporated into the bottom of the support stand. This joint allows for rotation of the fog net a full 360 degrees in 12 or possibly more increments. The joint is clamped into position once selected through the use of screws and nuts because of the large moment that is generated at this point. This is not an active direction changing mechanism, again due to the large forces generated at full wind speed.

The direction of the fog net can be changed by a person based on weather forecasts, or the entire top assembly (Fog Net Frame) can be removed and taken into shelter if abnormal weather is forecasted. . This would include tornados or hurricanes, the anchoring system could remain in the ground and the fog net would be easily installed after the inclement weather passes.

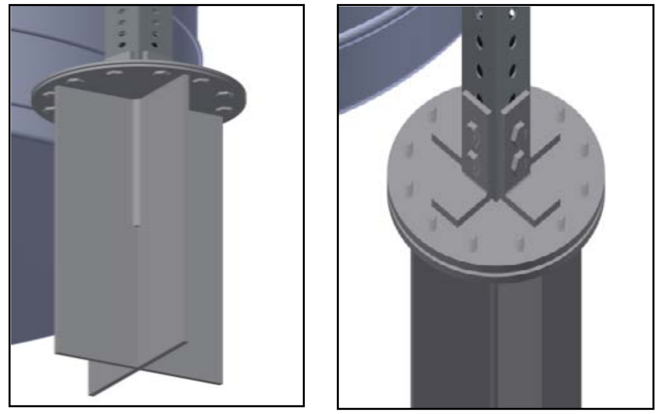

Figure 2. Bolt joints for 360 deg rotation

Height adjustment

The net height adjustment takes place through two quick adjustment pins and the sliding of the two vertical members that support the fog net. This allows the net to reach up to 5m grabbing potential more humid air.

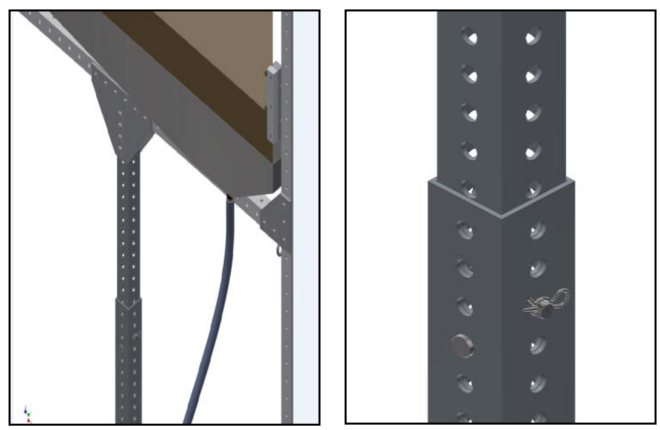

Figure 3. Telescopic arrangement

Fog net area adjustment

The fog net area adjustment allows fog net 1 to 3 m^2 to be used. The steps between the limitson fog net area are very fine due to the 1.5 inch center to center dimension of the framing material.

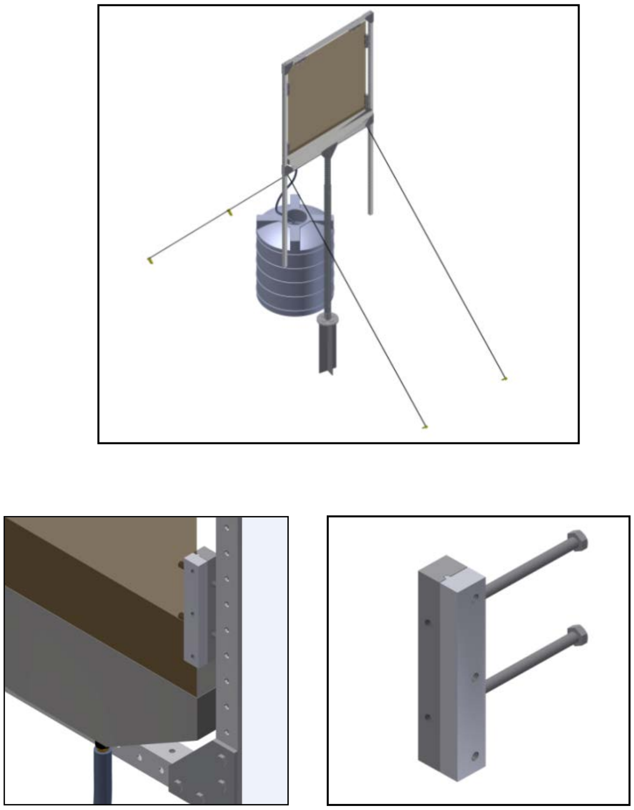

Figure 4. Fog net area arrangement and its Adjustable screen clamp

For sustaining high wind speed

The first calculation is for the force exerted on a fog net with the required wind speed of 70 mph. The force was calculated at the largest available net area for the concept presented. This force was to be used to appropriately size the anchoring components and frame components of the fog net.

See the equations below for the calculations

Force Calculation:

$$F_d=12\rho v^2 A C_d$$

$$F_d=Force\ on\ net\ from\ wind$$

$$\rho=Density\ of\ air\ at\ sea\ level=1.2kgm^3$$

$$v=Velocity\ of\ air=70\ mp/s=31.3m/s$$

$$A=Area\ of\ net=1\ to\ 3\ m^2\ (for\ my\ design)$$

$$C_d=Coefficient\ of\ drag\ for\ flat\ plate=1.28$$

$$F_d=12.1.2.\ 31.3^2.\ 3*(1.28)$$

$$F_d=2257.2\ Newtons$$

With the force on the net calculated for the worst case scenario all of the fasteners and support equipment could be appropriately sized. The idea behind the design was to offer a large range of adjustability. Use of Perforated square framing tubes which allows for large ranges of adjustability and are readily available at low cost. The square tubing is chosen due to a stress analysis on the vertical beam. A snapshot of the stress analysis software is shown.

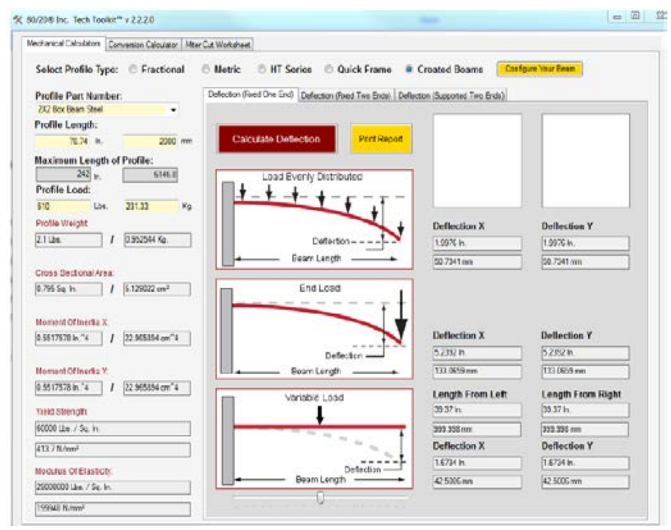

Figure 5. Calculation of Deflection using software

The deflection was minimised within reasonable amount ,however it was still determined that for worst case conditions (largest net area, extended height and gusty winds) that addition support is needed. This lead to the addition of eye-bolt in the design. Anchors can be tethered to these similar to how a cover is held down on a tent, this would minimize deflection in the worst case scenarios.

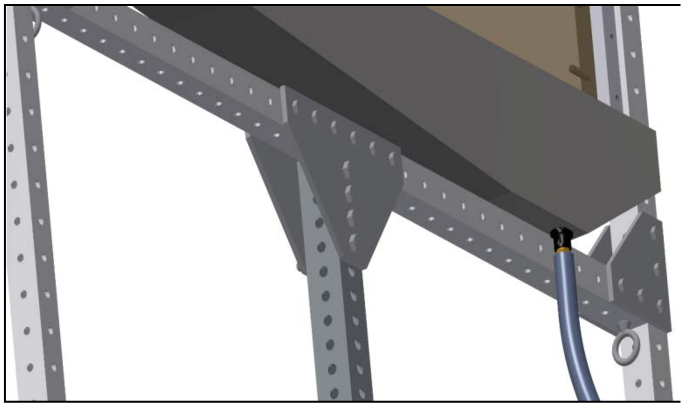

Figure 6. Perforated square framing tubes

Some additional features

- The framing members are connected together using nuts and screws, like the rotating joint. Fasteners allow for strong joints that can be taken apart for transportation
- Tools to work on the fasteners are also readily available around the world (i.e. adjustable wrenches).
  The drip pan is also bolted to the fog net frame for a security.

- Fabrication parts include the rotating joint components, drip pan, vertical member to frame gusset and the fog
  net clamping mechanisms. These mechanisms are a custom fabrication that eliminates the need for punching holes in the fog capturing screens and easily mounts the net to the frame and is adjustable for net tension

- The number of clamps depends on the fog net area, but they are easily installed and changed with changes in the fog net frame. The clamp tooth clamps down on the

- 0.01" thick mesh and securely locks it into position with three socket head cap screws. These devices will eliminate much of the installation time associated with the current concept.
- For logistics this design also improves on the transportation and costs of the current concept. The frame components are lighter than steel angle iron, and there is no need for concrete.

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