# Energy management of the Archimedean pump system

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**Abstract.** We tackled to study a fusion of ancient technologies such as an Archimedean pump which plays a role of pump as well as a role of generator and modern technologies as represented by renewable energies like solar and winds. An Archimedean pump which was invented by Archimedes, ancient famous Greece scientist, is one of lifting water pumps and also energy converters as small waterpower. The pump has some advantages such as a low noise and a high mechanical reliability simple structure, so that it is suitable for converting rotary movement into translational movement efficiently. Although, an Archimedes pump suffers from some disadvantages of a limit of the usage and a difficulty of accurate lifting quantity, and therefore it was gradually replaced by other-type pumps. However, world revives interest in the pump these days, because of the development and utilization of clean, renewable energy, such as using with solar, wind and water power and so on. We have developed the water pumping system as a pilot case used by solar energy. We confirmed that the system worked well with a situation of electric power saving and a circulation is important to keep water quality at a closed-water area qualitatively.

**Keywords:** Environmental engineering, Energy management, Archimedean screw, Renewable energy

## 1. Introduction

Recently, we have many global problems such as environmental issues, population issues and water issues, and these problems relate each other. In these problems, water issues are the most serious problem in human life. Some factors that the water demand escalates rapidly are thought to be mainly related to the followings: "growth of population", "increase of necessary food quantity" and "diversified public life style". For instance, the amount of world population is about 6 billion now, and expansion of population in the world is about 100 million year by year that the water demand is also increasing to produce foods or to bring up farm animals.

However, water resources in our earth are almost sea water, and water to keep our life is only 0.1 percent, which depends on rain water. There are growing fears of future water shortages, especially for agricultural use, as the world's population increases. Experts of water issues offer the most recent projections for global water demand and supply in this century, based on the latest estimates of terrestrial water flux, which incorporates human impact.

On the other hand, the water shortage, great floods due to heavy rain have also increased as represented by Ibaraki in Japan, Bangkok in Thailand, and Henan in China, recently. It seems that a local climate change is happening on a global scale. In addition, industrialized nations are faced with mounting energy problems, including high crude-oil prices, disposal of nuclear waste and delays in the development of alternative forms of energy; all problems that require global cooperation. It is essential that we work to make the environment safe for the survival of mankind in the new century, and to make agricultural, forestry and fisheries industries least harmful to the natural world, and achieve sustainable economic growth.

Considering water issues and energy issues, we decided that trying to make the environment which people are interested in these issues and making useful system as technical and social approaches. As a result, we decided to study a fusion of ancient technologies such as Archimedes pump which plays a role of pump as well as a role of generator and modern technologies as represented by renewable energies like solar and winds.

An Archimedes pump that is one of the oldest machines still in use is classified a screw-type or a helical-tube-type (tube-type), an apparatus for lifting water for irrigation and drainage purposes. Its invention has traditionally been credited to Archimedes. This method is very simple principle to understand and is used by its rotary motion to lift water. The tube-type Archimedes pump is made of waste materials such as a hose, a metallic tube and metallic pipes. This pump was made roughly, but it has enough ability to lift water up.

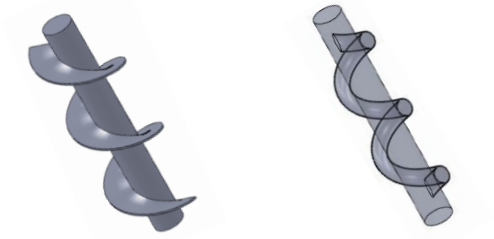
In this paper, we report the development of the water pumping system as a pilot case with tube-type Archimedes pump and using renewable energy and its performance assessment.

## 2. Principle of Archimedes Pump

An Archimedes pump which was invented by Archimedes, ancient famous Greece scientist, is one of lifting water pumps and also energy converters as small waterpower. The pump has some advantages such as a low noise and a high mechanical reliability simple structure, so that it is suitable for converting rotary movement into translational movement efficiently. Although, an Archimedes pump suffers from some disadvantages of a limit of the usage and a difficulty of accurate lifting quantity, and therefore it was gradually replaced by other-type pumps. However, world revives interest in the pump these days, because of the development and utilization of clean, renewable energy, such as using with solar, wind and water power and so on.

### 2.1 Types of Archimedes Pump

There are two type of Archimedes pump such as a screw-type and a tube-type shown in Figure 1. In generally, a screw-type is popular, but it is heavy and large size so that we chose the tube-type pump which can be made it easily. Additionally, unlike the operation of screw-type pump, that of tube-type has yet to be revealed clearly. It is interested to know that operations of the tube-type pump.



(a)Screw-type (b) Tube-type

Figure 1: Types of Archimedes pump

### 2.2 Lifting principle of Tube-type Pump

The feature of Archimedes pump is to lift water up by rotary motions, then it excel in a low noise motion and an energy saving. But, it is necessary to use its body diagonally. Figure 2 shows the principal of a tube-type Archimedes pump. Increasing a rotation angle, water in the tube is lifted gently from low level to high level by a rotation of the tube.

Current industrial pump to operate efficiently needs certain rated electric power. However, there is unless rated power, the pump cannot work. On the other hand, an Archimedes pump can expect good compatibility with natural energy and use of an unstable situation of electric power, i.e., solar batteries and wind force power generations. In other words, to work an Archimedes pump, it is capable of using the energy which are unavailable energies or wasted energies in the past. An Archimedes pump continues to work depending on the amount of given energy. In our daily life, not industrial plants, it has many suitable situations like this

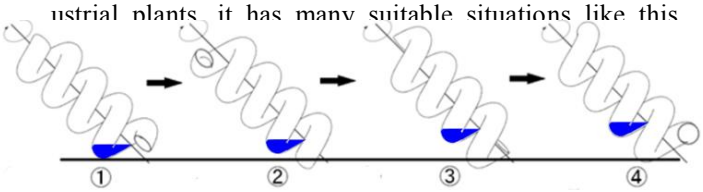



Figure 2: Principle of tube-type Archimedes pump

## 3. Water Pumping System Configuration

Before designing and developing the system, we considered pump's usability and operability. Generally, Archimedes pump is necessary to support both ends of shaft, so it has several restrictions for use. In order to alleviate these constraints, we devised a flexible support part to take to support the body part of pump. Thus, it is easy to change the lift of the pump, and it is possible to install relatively easily than conventional support method. The flexible support part at the pomp is shown in Figure 3.

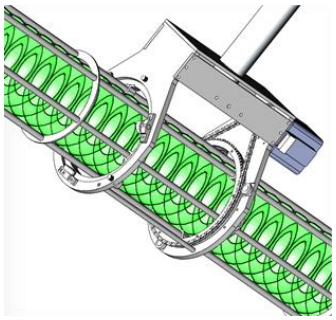


Figure 3: Structure of the flexible support part

To design the support part, three-dimensional CAD software SolidWorks 2010 (SOLIDWORKS Inc.) was used in Figure 3. And then, we designed and developed the water pumping system. The overview of the water pumping system and the diagram of the system are also shown in Figure 4 and Figure 5 respectively.

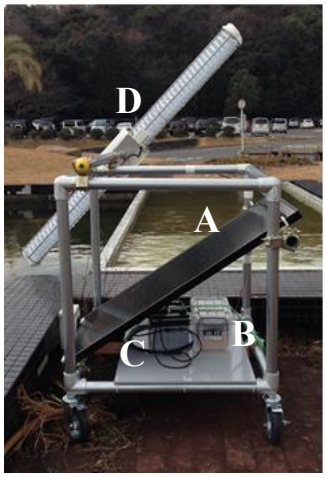


Figure 4: Overview of the water pumping system

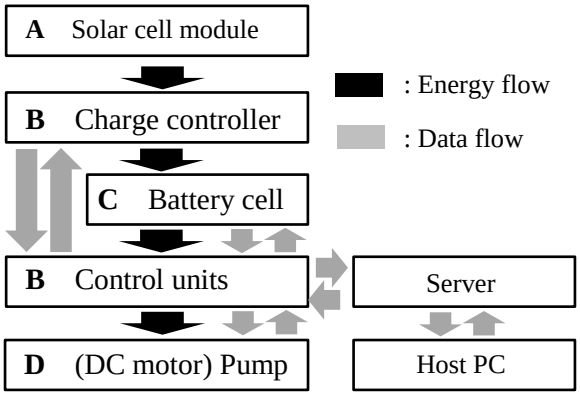


Figure 5: Diagram of the water pumping system

There are two aims of developing this system that pumping amount is over 180 liters per hour and power consumption is under 5W without commercial power supply. The spec of actual pump part (see D in Figure 4) and the components of the system are shown in table 1 and table 2 respectively.

Table 1: Spec of actual pump part (D in Figure 4)

| Items | Quantities |
|---|---|
| Total length | 2,000mm |
| Total mass | 18 kg |
| Internal diameter of pump | 141mm |
| Helical diameter of tube | 103mm |
| Internal diameter of tube | 31.8mm |
| External diameter of tube | 38mm |

The pump body was made of thickness of 6mm stainless steel. This system consists of 3 sections such as a power supply section, a controlling section and a mechanical lifting section. A communication method on this system within control units between each section is a wired and a communication unit within control units connects with external server via 3G network to monitor or control the system.

Table 2: Components of the water pumping system

| Items | Components |
|---|---|
| Solar cell | SFL95-C 95W (Solar Frontier) |
| Charge controller | Solarix PRS3030 (Steca) |
| Battery cell | XEX A19R 24Ah (Panasonic) |
| Control unit | Arduino Uno R3 (Arduino) |
| Communication unit | 3G Shield (TABrain) |
| DC blush-less motor | CBA-30 DC24V 12pulse/rev (Plexmotion) |
| Server | xively.com (free server) |

## 4. Results and Discussions

To perform assessment of the water pumping system, we installed it to a pond. As experimental conditions, the angle of pump rotation axis was fixed angles 60 degrees from a horizontal plane of water surface. And, the lifting height was 1.1m from water surface. It meant that part of pump hide under 0.6m from the water surface. In the conditions, we measured several factors of it during operation of the pump rotation speed at constant as about 40rpm.

The results of the experiment were as we obtained about 189 liters per hour at pumping amount and about 3W at power consumption. The operation noise was measured by Ono Sokki Co. Ltd. LA-5560. Measurement position was a distance of 1m at the same height as the outlet of pump top. The operation noise level was fluctuated range from 55dB to 65dB, when the outdoor natural noise level was fluctuated range from 40dB to 45dB. This fluctuation of the pump was mainly due to its principle of an intermittent pumping. Note that the noise level at 15m far from the pump was the same level of the natural noise level from 40dB to 45dB. Then, we summarized features of the system based on experiment in Table 3.

By the way, voltage values and current values measured by the measuring unit each a minute, were integrated for each 10 minutes mean value by control unit. This value after level conversion was transmitted from the 3G shield to the external server.

Table 3: Features of water pumping system

| Excellent features | Contents |
|---|---|
| Operating performances | Low-power drive and low noise<br>Unneeded priming water |
| Maintainability | Simple structure<br>Small number of parts |
| Environmental performances | Mild to ecosystem<br>Easier Installation |

Xively.com was used as an external server. By used the 3G network and a free external server, communication costs was saved and the system was able to introduce inexpensively. Figure 6 and 7 show the battery voltage values and the rotation speed of the pump which stored on the server. The vertical line shows the battery voltage value and the horizontal one time in Figure 6, and the vertical line shows the rotation speed and the horizontal one time in Figure 7 respectively. The time of both Figure was displayed UTC. There is a time difference of + 9 hours between JST and UTC.

In figure 6, we confirmed that the voltage values began to decline at sunset time 7:00 UTC (16:00 JST) and it began to charge again at sunrise time 22:00 UTC (7:00 JST). And in figure 7, we also confirmed that the pump stopped to rotate suddenly at midnight time 14:00 UTC (23:00 JST). The cause of the pump stop was a charge controller. For battery protection, the charge controller was set to cut off the power supply to the motor if the battery voltage fell under 22V. As results, we confirmed that the water pumping system worked well and achieved aiming performances in advance.

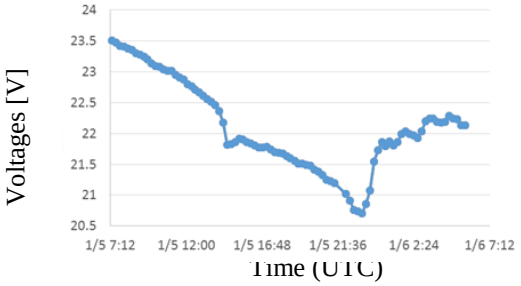



Figure 6: Measurement results of the battery voltages

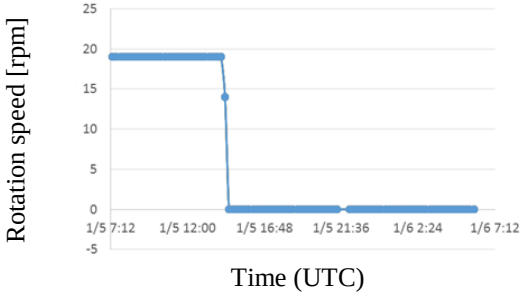



Figure 7: Measurement results of the rotation speed

## 5. Conclusions

To consider water issues and energy issues, we focused on a tube-type Archimedes pump. We confirmed that the pump has some advantages such as a low noise and a high mechanical reliability simple structure, so that it is suitable for converting rotary movement into translational movement efficiently. And then, to improve pump's usability and operability, we devised a flexible support part to take to support the body part of pump. Thus, it is easy to change the lift of the pump, and it is possible to install relatively easily than conventional support method. We developed the water pumping system as a pilot case used by solar energy. We confirmed that the system worked well with a situation of electric power saving and a circulation is important to keep water quality at a closed-water area qualitatively. The operation of water pumping is able to do for a couple of days continuously if the battery was full charge.

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