# OSCILLATING WATER COLUMN: DESIGN AND PROTOTYPE DEVELOPMENT

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**Abstract -** *Renewable sources have become an important part for generating electricity and to reduce carbon emission. Tidal energy of oceans, being one of the largest renewable sources, can be used to generate electricity. In this work power generation using Oscillating Water Column (OWC) is proposed. The OWC is a kind of Wave Energy Converter which uses Air flow produce by Ocean waves. Work of various related research papers are shown for better understanding of the OWC. The design for prototype by using one of 3-D modelling application is developed. The formulation of wave energy generation is proposed. The prototype model of OWC is fabricated as per design. The experiments are conducted on model. Waves are generated manually, and the power generated with turbine are measured.*

***Key Words***: Wave energy, Oscillating water column, Turbine, Inclined chamber.

## 1.INTRODUCTION

For generating electricity, we were using non-renewable resources such as: coal, fossil fuel, petroleum, natural gas, etc. But because of that non-renewable resources depleted, and it also create tremendous amount of pollution in the environment. To overcome this situation renewable energy were used, Such as: solar, wind, biogas, geothermal, nuclear, hydro, ocean energy. There is limitation of using solar and wind energy such as: solar energy works only when there is sunlight and in case of wind energy can be used only at mountainous region and when there is a heavy wind. About 71% of earth is covered by ocean it can be a great source of energy. So, we can use ocean energy (wave energy) in India and all around the world because it is available all the time and also it is under development and unfavourable. In future it has very vast potential.

In next section, various research papers had studied and brief literature review about column and turbine is presented. Later, design and 3D model OCW was developed and successfully implemented in making of prototype.

## 2. LITERATURE REVIEW

As seen from column literature review, we cannot use tension leg platform and spar buoy OWC because they are offshore column, and we are doing project on onshore oscillating water column so because of that leg-platform and spar-buoy column are elixated on the spot and cannot be used. So, the options available are vertical and inclined column. In inclined column due to inclination section air efficiency is more as compared to vertical column. And for more air flow through column, they are specifically made inclined.so because of having more advantages and more efficiency in air flow we see going to use inclined column. The various turbines used by investigators/researchers are shown in table 2.1.

Table 2.1 Column review

| Types of column | Description | Cost | Maintenance | Application | Remarks |
|---|---|---|---|---|---|
| Inclined column [1,2] | Higher air flow | Lowcost compared to vertical column | Moderate maintenance | Used as onshore column | Moderately difficult to Construct. At 30degree angle inclined column has optimum angle for air flow.[4] |
| Vertical column [3] | Lower air flow | Chea p | Lower maintenance | Used as onshore column | Easily Constructed |

| | | | | | |
|---|---|---|---|---|---|
| **Tension-leg platform [4]** | **Moderate air flow** | **Costly** | **Higher maintenance** | **Used as offshore column** | **Difficult to construct** |

Table 2.2 Turbine review

| Types of turbine | Description | Cost | Efficiency | Application | Remark |
|---|---|---|---|---|---|
| **Well turbine [5,6,7,8]** | Design, Numerical modelling, Fabrication | Cheap | Lower | Used for oscillating water column | Easy construction, Low maintenance, Easy to design. High productivity. Low specific energy. |
| **Impulse turbine [9,10,11, 12]** | Design, Numerical modelling, Fabrication | Costly | Higher than well turbine by 45% | Used for oscillating water column | Difficult construction, High maintenance, Low productivity. High specific energy. |
| **Savonius turbine [13,14]** | Design, Numerical modelling, Fabrication | Cheap compared to impulse turbine | Moderate | Used for oscillating water column | Moderate construction. Moderate maintenance. Medium productivity. Moderate specific energy. |

As from the above literature review, we can see that well turbine is frequently used in the oscillating water column, but the efficiency of the well turbine is less as compared to radial impulse turbine and Savonius turbine. Radial impulse turbine has highest efficiency compared to all the turbines mentioned in the table, but its production cost is high, it is difficult to construct, maintenance is high, etc. And bidirectional turbine is more scalable compared to all the above turbine mentioned in above literature review, but its efficiency is less because it is bidirectional turbine and not unidirectional turbine. Its efficiency is high compared to well turbine and bidirectional turbine and its efficiency is less as compared to radial impulse turbine, but its production cost and maintenance cost is less compared to radial impulse turbine and it is also easy to construct. So, it is better to choose Savonius turbine for proposed work. Thus, from above review, **Savonius turbine** with **Inclined column** seems to be more suitable for our work.

## 3. DESIGN OF OSCILLATING WATER COLUMN

An oscillating water column (OWC) is a wave energy converting technology that can be installed onshore as well as offshore as shown in fig. 1. The device consists of large wave chamber, lip, wing wall, platform for turbine and air chamber. When waves approach, wave enter under the partially submerged lip that traps air in an air chamber, forcing the air upwards through the air turbine. This air pressure forces the turbine to spin, which produces torque thus rotational energy is generated which then rotates shaft of generator motor and generator motor converts rotational energy into electrical energy which is then reserved into battery or directly supplied for various applications. As the waves is retreating, air enters back into the air chamber from the other side of the turbine, thus repeating the process.

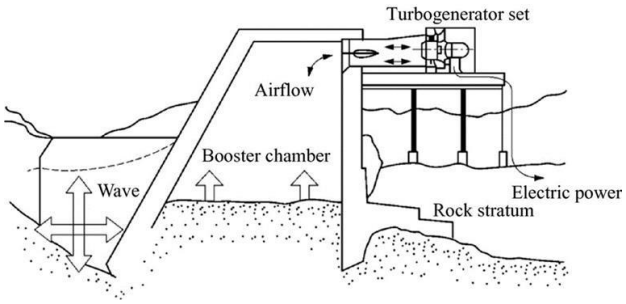



Figure 1: Oscillating water column.

The schematic of model is shown in fig.2, is a 3D model developed from Autodesk fusion 360 before constructing a prototype.

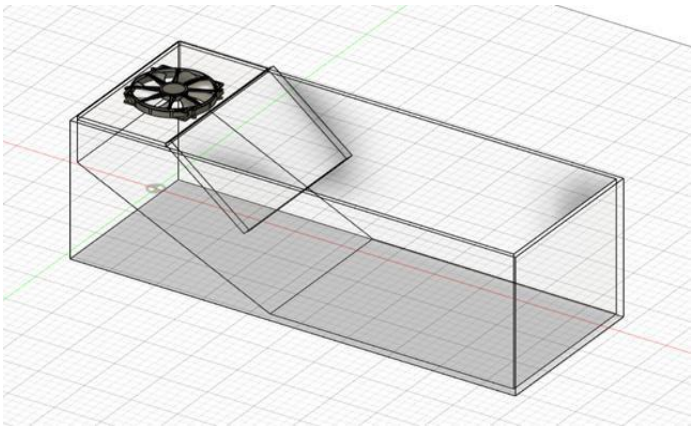
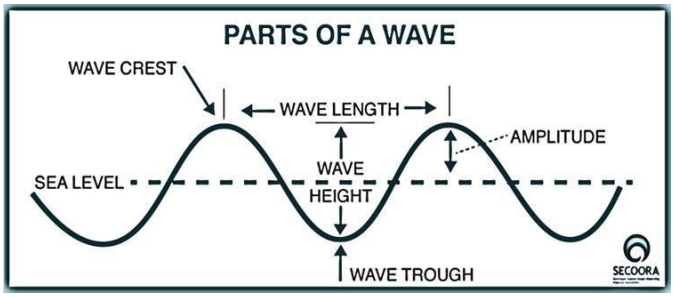


Figure 2: 3D MODEl

## 4. FORMULATION




The regular wave function equation shown in eq. 1 is given with two variables.

$$\eta(x,t) = a\sin(\frac{2\pi}{T_p}t - \frac{2\pi}{\lambda}x) \quad \text{-(1)}$$

Where $a$ is the amplitude, $\omega, \frac{2\pi}{\lambda}$ is the angular frequency is the wave number , $T_p$ is wave period and is $\lambda$ the wavelength. Where $H_w$ is the wave height, $D$ is the water depth, $h_c$ is the crest height, $h_t$ is the trough height and $\lambda$ is the wavelength.

Ocean wave energy ($E_w$) is the amount of energy that is transmitted in a horizontal wavefront, perpendicular to the direction of wave.

$$E_w = \frac{\rho g {H_w}^2}{16} \quad \text{-(2)}$$

Wave to pneumatic energy

For analysing the proposed OWC model for energy balance equation is applied. By energy balance equation

$$E_I = E_W + E_R + E_L$$

Where: $E_I$ – The incident-wave energy $E_W$ – The energy transmitted to the pneumatic chamber. $E_R$ – The reflected wave energy $E_L$ – The frictional energy loss due to viscosity and turbulent motion of the waves Turbine torque measurement

$$P = M * \omega \quad \text{- (3)}$$

P = Output in Nm/s (1N•m/s = 1 W = 0.00136 metric hp)

M = Torque in N m ω = Angular speed in s-1 N = Rotational speed in rpm

$$\omega = \pi * \frac{n}{30} \quad \text{-(4)}$$

Thus, the equation of Torque, the quantity to be measured is given by,

$$M = \frac{P}{n} * \frac{30}{\pi} \quad \text{- (5)}$$

Output Power (P) = Voltage * Current -(6)

Efficiency (ɳ) = Output Power/Input Power -(7)

## 5. FABRICATION

To make our prototype, we first develop the tank of dimension 36x12x18 inches by taking glass as our base material. Then to make our column we used two acrylic sheets of size 19x12 inch and 12x12 inch which were attach at 30 degree and 60 degree at bottom and the upper section of the tank. To mount out turbine we made a hole of 2.5-inch diameter on the acrylic sheet of 8x12 inch and which was then glued together with the upper column. We created our waves manually. The turbine was connected with generator motor which is further connected to the multimeter. So the mechanical energy of turbine is converted in electrical energy by the help of generator motor. The multimeter is used to measure current and voltage. The overall developed prototype is shown in Figure 4.

Figure 4. Prototype model

## 6. RESULT AND DISCUSSION

Waves are generated manually, and the power generated with turbine are measured. The results so obtained are shown in Table 3.

Table 3 Results

| Observation | Angle (α) | Amplitude (cm) | Voltage (V) | Current (A) | Output Power (W) | Input Power (W) | Efficiency (η) |
|---|---|---|---|---|---|---|---|
| 1<br>2<br>3<br>4 | 300<br>300<br>300<br>300 | 8<br>8<br>14<br>14 | 2.53<br>5.67<br>3.43 | 0.35<br>0.25<br>0.44<br>0.72 | 0.75<br>0.75<br>2.5<br>2.47 | 1.96<br>1.96<br>6<br>6 | 41.67<br>41.67<br>41.58<br>41.16 |

Therefore, from Equation 1 the Ocean wave energy generated is calculated.

Therefore, **Input power** by Ocean wave energy is measured by multiplying with time which is 2 sec for each wave.

The **Voltage** and **Current** are measured by multimeter.

The **Output power** is calculated from eqn6. As we have used inclined columns, for which inclination angle cannot be changed.

When column is inclined at different angles the air stored in chamber might increase or decrease due to which the air required to rotate turbine will change and different output power is available.

If angle is **30 degrees**, the air flow will increase, and turbine will be rotated at high speed which may give high output power.

Therefore, from equation 7 **Efficiency** of prototype is 41.67%.

## 7. CONCLUSION AND FUTURE SCOPE

Ocean energy can be used to produce electricity. The rotation of turbine depends upon the air, which is trapped in the chamber, more the air trapped the more will be the rotation of turbine and more will be the power generated. To trap more air the inclination of column can be change to certain degree (i.e., at 30 degrees), which will increase the generation of electricity. Electricity generating column does not need any fuel to produce power. It just uses the energy that is not used and is lost by the human. This lost energy can be helpful in reducing power crisis Then this wave energy can be viewed as a next promising source of generating power, especially in a country like India, where we have a lot of power crisis, and population explosion. Spreading this technology on large scale would be much cheaper and efficient than any other renewable sources of energy, and it should be highly recommended. This technology is completely harmless to life of any sort, and the environment, and highly beneficial, especially in our developing nation.

Further research can be done on materials, and the design, to improve the efficiency. It can generate electricity for the underdeveloped nearby region (village). It can also be a tourist point and can also be used for the source of income for the nearby regions. It can also be act as flood breaker at time of flood. And it can also use in full utilization of energy of the ocean, sea and river which are currently going as a waste and is not used to generated electricity.

The prototype developed can be used to simulate experiments on small scale. It can be used further with wave generator equipment, sensors, altering water column, inclination angle etc. and measure its effect on power generation.

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