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조수 및 소수력 발전을 위한 회수를 위한 중력엔진의 개념 및 에너지 정산

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A Concept and Energy performance of a Gravity Engine for Tidal and Hydro-Power

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Abstract

This paper is to propose a concept and performance of the gravity engine which could extract energy from sea or river as a clean and renewable and sustainable power, the tidal or hydro-power. The vertical motion of the buoyancy cylinder of the present gravity engine is converted to the mechanical work directly without any hydraulic loss. The increased gravity potential during high tide is harnessed proportional to the length of the buoyancy cylinder times tidal height which is greater than the conventional tidal power using water mill. This energy amplification results from the net energy gain between the resource energy and the imposed energy to extract water out of the buoyancy cylinder. Its efficiency is higher than the conventional water mill due to its direct mechanical conversion.

1. Introduction

Traditionally, the energy in the water has been extracted by the water mill or turbine. The sun transports water from the sea to the land through the evaporation and condensation process. The water in the high land would flow down to the sea again and its major driving cause is the potential energy. Another cyclic change has been experienced in the sea, the gravitational interaction between the earth and the moon changes the local sea water level. The sonic propagation of information in the water makes the nozzle convert the potential energy to the kinetic energy. Turbines, a mechanical energy convertor, has been used as an effective tool for extracting work from the fluid. In terms of entropy, both hydro and tidal energy is low in entropy. Also, it is renewable, sustainable, and clean[1,2].

Tidal energy is clean, renewable and sustainable and the technology is in place. Also, Korea has tremendous tidal energy in the Yellow Sea. Due to its high initial capital costs and the environmental consideration, private and Government sponsorship were not forthcoming. Recently, the International concern on the global warming makes a tax for the CO2 production. This tax could directly affect the price of energy and change the ranking of the energy sources. The Nuclear energy and other renewable energy from the Sun will have a strong point. In terms of

the substantiality and reality for the large power, tidal power is in the real domain.

Korea has concentrated on its most favourable site at Garolim having narrow entrance of 2 km, a reasonable depth for turbine installation, a mean tidal range of 5m and a basin area of 100 km^2. There would be 24 power units of 20MW each(480 MW in total) , the proposed turbines are doubly regulated and of 8m diameter[3].

There have been many proposals for optimum extraction of tidal energy. Fairly complex double-basin scheme and regimes involving generation on both flood and ebb tides have been proposed, aimed significantly spreading the generation period beyond the 25-30% maximum attainable in single basin schemes. A commonly proposed variation is to use the turbines as pumps at the top of the tide to add more water to that standing in the basin. The volume of the water is added at low head, and later released to generate through the turbines at higher head. The overall effect is particularly advantageous on heap tides and can yields some 10% increase in energy production. There is small room to improve the efficiency of the conventional tidal power.

It is natural to think about new device rather than the water mill for the tidal power. The purpose of this paper is to propose a new energy conversion mechanism, the gravity engine for the reduction of the capital cost of the tidal power and to make the net positive present value without considering the CO_2 tax or other side benefits. The best way is to reduce the size of dam needed which could be achievable by developing a efficiently energy conversion mechanism. The conventional turbine technology has small room to be improved. However, the present gravity engine could dramatically increase the energy extraction in the way of the increasing the added mass of the system.

2. The Working Principles

The gravitational engine has five parts including the buoyancy tank, drain pump, latch assembly, gear box, and electric generator. These parts are working together to extract electricity from the tidal potential energy from the gravitational interaction between the earth and the moon. As shown in Fig. 1, the present gravitational engine submerge the buoyancy cylinder into the water by opening the valve at the bottom of the cylinder at the low tide. A Special latch system locks the cylinder to prevent it from moving up at the high tide. The water in the cylinder is drained by the drain pump and air replace the volume. The buoyancy force due to the empty cylinder is released when the highest tide occurs.

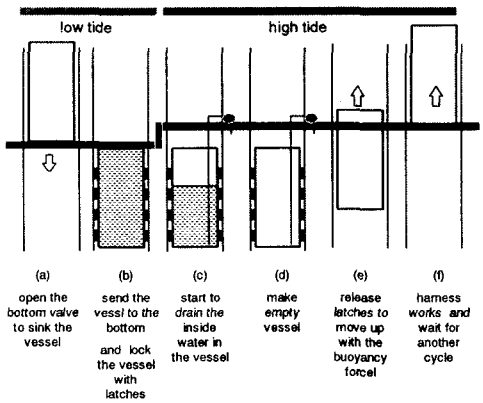

Fig.1 The operating procedure of the gravity engine

The energy from the upward motion of the buoyancy cylinder transferred to the electric generator

with the gear box assembly. The gravitational head due to tidal change could be amplified due to the added mass corresponding the amount of water inside the gravity cylinder. The driving mechanism to generate the added mass is the buoyancy force acting on the surface of the cylinder.

The vertical movement of the cylinder (A) is changed into the circular motion(B) by the gear assembly as shown in the Fig.2. Since the vertical moving force is exponential decay, a special gear assembly should be attached to get the uniform revolution of the electric generator. The adaptation of the energy storage system using the flywheel technology, compressed air, or the advanced Battery technology could be an alternative mechanism.

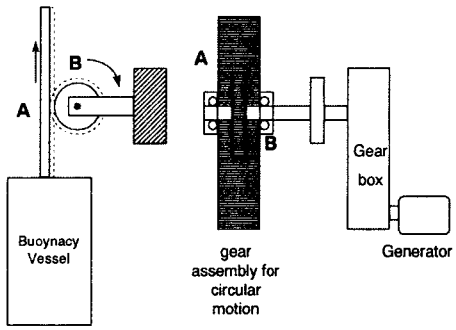

Fig.2 The energy conversion to electric generator

3. Modelling and Analysis

The benefit of the present gravitational engine is the direct extraction of the mechanical energy from the vertical motion of the gravity tank. Its efficiency is over 95% and higher than that of the turbine for the tidal power (in single stage). Another strong merit is that it could extract much energy than the turbine technology from the same area. In this section, the detailed energy calculation will be made on the basis of the energy conservation law.

3.1 Energy Extraction

The energy calculation is made to demonstrate the present gravity engine is more efficient than the conventional turbine technology. At first, energy balance for the one cycle operation is made and in the later part, the energy generation for the multiple cycle operations will be addressed.

(a) Single Cycle operation

When a buoyancy tank with the cross sectional area of A_b and the length of H is submerged under the water in depth of h which is the tidal height. As the water inside is extracted by the drain pump, the buoyancy tank is feeling the buoyancy pressure. Than the energy stored in the empty buoyancy tank could be obtained by integrating the buoyancy force from the bottom of the liner (-H-h) to the water surface(0). The energy of the empty buoyancy cylinder at high tide is

$$E_{work} = \frac{1}{2}(\rho_w - \rho_a) g A_b (H+h)^2 \qquad (1)$$

The above energy could be made from the empty cylinder submerged into the water. To make empty of the tank, we should supply energy to the system to drain out water inside of the tank

which could be calculated by integrating the buoyance force from the bottom (H+h) to the top of the cylinder(h):

$$E_{supply} = \frac{1}{2}\rho_w g A_b H^2 \tag{2}$$

If the energy stored in the empty cylinder is greater than the energy supplied to evacuate the tank, the present system could extract energy from the tidal movement. The net energy is made by subtracting Eq.(1) with Eq.(2):

$$E_{gain} = \frac{1}{2}(\rho_w - \rho_a) g A_b h^2 + (\rho_w - \rho_a) g A_b H h \tag{3}$$

The first term in the R.H.S is correspondent to the energy due to the water level change, h. The conventional tidal power plant with the turbine with an efficiency, η_{mill} to convert work form the potential energy:

$$E_{water\ mill} = \eta_{mill} \times \frac{1}{2}\rho_w A_{bay} h^2 \tag{4}$$

Since normally the efficiency is less than 20%, the tidal power plant needs large reservoir which is a strong cause of high construction cost. However, The present gravitational engine generates work in the mechanical form using a gear box whose efficiency exceeds 80%. Further, high efficiency could be achievable to the drain pump over 80%. The real net work from the gravitational engine is

$$E_{work} = \eta_{grv} \times \frac{1}{2}\rho_w g A_b \left((1 - \frac{1}{\eta_{drain}}) H^2 + 2Hh + h^2 \right) \tag{5}$$

The optimum length of the cylinder could be determined by finding the extremum condition of Eq.(5) :

$$H = \frac{\eta_{drain}}{1 - \eta_{drain}} h \tag{6}$$

Therefore, the optimum size of the buoyancy cylinder could be determined from the drain pump efficiency. Another limitation could be generated form the costs of construction.

The present gravitational engine is more efficient than the conventional turbine:

$$\frac{E_{grav}}{E_{water\ mill}} = \frac{\eta_{grav}}{\eta_{mill}} \left(\frac{A_b}{A_{res}} \right) \left((1 - \frac{1}{\eta_{drain}}) \frac{H^2}{h^2} + 2H + 1 \right) \tag{7}$$

Also, for the same energy, the present gravitational engine needs smaller area than the conventional tidal reservoir.

$$\frac{A_b}{A_{res}} = \frac{\eta_{mill}}{\eta_{grav}} \frac{1}{(1-\frac{1}{\eta_{drain}})\frac{H^2}{h^2}+2H+1} \tag{8}$$

If we use the buoyancy cylinder with 30 meter in height, H, and the efficiency of energy conversion , η_{grav}, of 0.8, the tidal height, h, of 6 m, the drain pump efficiency, η_{drain}, of 80%, and the efficiency of the turbine, $\eta_{water\ mill}$, of 0.2, the area reduction could be

$$\frac{A_b}{A_{res}} = \frac{1}{264} \tag{9}$$

That means for the same water area, the present gravitational engine harnesses the 264 times energy than the conventional tidal power plant.

(b) Cyclic Operation

Basically, the closed loop gravity engine is working in multiple cycles with many times. If N times cyclic operation is possible, the net work extracted form the present gravitational engine could be

$$E_{work} = \eta_{grv} \times N \times \frac{1}{2} \rho_w g A_b \left((1-\frac{1}{\eta_{drain}})H^2 + 2Hh + h^2 \right) \tag{10}$$

Its maximum could be made when the cross sectional area of the cylinder multiples by the number of cyclic operations is the water surface area of the reservoir:

$$A_{reservoir} = N \times A_b \tag{11}$$

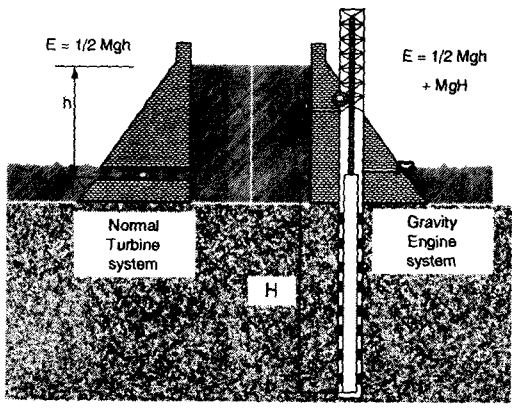

Fig.4 The energy extraction between the conventional water mill and the present gravity engine

Since the water in side the reservoir is

$$M_{water} = \rho_w A_{reservoir} h \tag{12}$$

The above equation is equal to

$$E_{work} = \eta_{grv} \times \frac{1}{2} M_{water} g h + \eta_{grv} M_{water} g H + \eta_{grv} (1 - \frac{1}{\eta_{drain}}) \times \frac{1}{2} M_{water} g \frac{H^2}{h} \quad (13)$$

So the present closed gravity engine could produce not only the work obtainable from the conventional turbine but also the additional energy form the buoyancy cylinder as shown in the second term in Eq.(13). This effect of the added mass is the key merit of the gravity engine. Also, needless to say, the efficiency of gear box, around 95%, is higher than that of the few stages turbine for water mill(around 20%). So, we could produce large energy with small reservoir. Considering the condition of the real estate in Korea, the area reduction in the reservoir is meaningful. So, If we replace the conventional turbines with the proposed gravity engine, the hyropower in Korea increase almost 250 times (in calculation) greater than now. Also, the development of the small hydro power could be reactivated. Also, the tidal energy in the Yellow sea could play an important role as a reliable resources.

5. Conclusions and Future studies.

In this study, a conceptual design of the gravitational engine is proposed and analyzed. The vertical motion of the buoyant material is converted to the mechanical work. To do this a buoyancy cylinder and latch assembly, and specific hydraulic system to control the water in and out side of the cylinder. The energy calculation on the basis of the first principle of the thermodynamic show that the present gravity engine could extract more energy than the conventional turbine. This is achieved not by improving the efficiency of the device but by finding additional energy. This additional energy is extracted by the added mass to the cylinder due to the buoyancy pressure. Future works to implement the present proposal are huge from design to experimental verification.

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