Design and Develop of Sea Wave Power Plant

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Abstract

The energy of sea waves can be absorbed by wave energy converters in a variety of manners, but in every case the transferred power is highly fluctuating in several time-scales, especially the wave-to-wave or the wave group time-scales. In most devices developed or considered so far, the final product is electrical energy to be supplied to a grid. This paper discusses the use of sea wave energy with the help of oscillating column. The mechanism converts the wave energy in to electrical power by converting the oscillating motion of waves in to rotary motion. Using compression ring we can store the power produced by the impact. This stored energy can be utilized in other strokes. The sea, which covers three quarters of the world's surface, has been little utilized to meet the peoples' energy needs.

Keywords: Wave Energy, Oscillating Column, Floating Column, Wave Spectrum, Pelton Turbine.

1. INTRODUCTION

When the wind blows over the sea surface it generates waves with a wide variety of shapes, sizes, and speeds. It is difficult to relate the complicated surface of ocean waves to the much simpler wave forms studied by mathematicians, but the larger waves that dominate the pattern agree with the theory: the longer the time interval between successive wave crests (the period), the greater the interval distance between successive wave crests (the wavelength) and the greater the wave speed. The wave speed is proportional to the period; the wavelength to the square of the period. Typically, the period of a long swell wave is 20 seconds, its length 624 m (2,040 ft), and its speed, 31.2 m/sec (102.3 ft/sec); a swell wave has a period of 10 seconds, a length of 156 m (510 ft), and a speed of 15.6 m/sec (51 ft/sec); and a wind sea wave has a period of 7 seconds, a length of 76 m (246 ft), and a speed of 10.9 m/sec (35.7 ft/sec). Waves in bays have rather shorter periods of about 3 seconds, and are 14 m (45 ft) long, with a speed of 4.7 m/sec (15.4 ft/sec); and ripples on ponds have periods of 0.5 seconds, and are 0.4 m (1.3 ft) long, with a speed of 0.8 m/sec (2.6 ft/sec).

The wave height of the dominant waves (the vertical distance between a trough and the next crest) is more difficult to understand. It is controlled mainly by the strength of the wind, the time for which it has been blowing, and the fetch, which is the length of water over which the wind has blown. In the open sea the fetch is often long, and the strong winds of a depression blowing for a long time can generate long, high wind waves. These travel in various directions (mainly in the same direction as the wind) until they leave the area of strong winds. The development of the wave spectrum in relation to wind speed and fetch is now reasonably well understood; given good meteorological wind forecasts, computer models can produce useful forecasts of wave conditions. Their output can be checked against visual observations by mariners, against instruments on some research ships and on buoys, and against wave heights obtained using a radar altimeter in an orbiting satellite.

Waves get their energy from the wind: some of it is dissipated in whitecaps and turbulence, while some travels to the coast to be dissipated in breakers and in generating area) and thereafter travel as swell, which is the term used for a wave that is no longer under the influence of the wind. As the swell waves travel away from the generating area, the energy of the waves with the largest wavelength and longest period travels fastest (at half the wave speed), and therefore arrives first at a distant coastal wave-measuring station. By monitoring the time at which the slower swell waves arrive, the distance to the generating area can be estimated. It is found that swell waves can be detected at large distances from where they were generated. Some have been found to travel almost half-way round the world.

Conditions in the generating area are more difficult, because of the effects of the wind and of waves breaking to form whitecaps as a result of air bubbles in the water. Useful results can be obtained by treating the ever-changing surface as the sum of a large number of non-interacting, simple waves. Methods are available for sorting out a complicated pattern into its component parts, by assessing the energy (and sometimes the direction of travel) associated with simple waves of a given period. A diagram of wave energy against the period or, more commonly, against the reciprocal of the period (1/period), the frequency, is known as a wave spectrum.

Friction on the shore. To convert some of this wave energy to electricity is an attractive possibility and several types of mechanical devices have been designed to make use of wave power. However, as the engineering problems are considerable, none is yet in routine operation.

When the swell from wind waves has a wavelength less than the water depth, it is known as a short wave. There are many other classes of wave on and in (and at the boundaries) of the oceans, notably the long waves, which are those whose wavelength is greater than the water depth. The speed of travel of long waves does not depend on their wavelength but only on the water depth. Long waves are found on many scales from the oscillations of sea-level scales in harbors and bays to the extremes of the ocean wide tides. An important example is tsunami. These are long waves, generated by undersea earthquakes that cross the ocean at high speed (typically 200 m/sec (654 ft/sec)). There is an international tsunami warning system as, although they are not noticed by ships at sea, they can have devastating effects when they reach land—especially oceanic islands.

2. Power from Wave Energy

A progressive wave is a wave whose crest line moves in the direction of propagation of wave. The wave repeats after a period. The direction of propagation is perpendicular to the crest line. For calculation, a certain width is selected arbitrarily. An ocean wave is assumed to be sinusoidal wave having certain frequency (f), wave length (λ) period, amplitude (a), velocity etc. All these parameters characterize the wave.

The potential energy,

$$PE = 1/4Da^2 \lambda W g$$

Where, D=density of water

W=width along crest line

g=acceleration due to gravity

The Kinetic energy,

$$KE = 1/4Da^2 \lambda W g$$

$$\text{Energy density} = 1/2a^2 g$$

$$\text{Power density} = 1/2a^2 f \lambda D g$$

2.1. Methodology

We are going to utilize the energy of sea wave with the help of oscillating column. Our project consist a base like structure on which fluid will flow with decreasing cross section of jet so that maximum velocity can be obtained. This high velocity jet will strike the column and it will start oscillating about a point. This oscillation can be converted into one side rotation with the help of gear arrangement. Hence we can generate electric power with the help of alternator. Using compression ring we can store the power produced by the impact of jet to water column. This stored energy can be utilized in other strokes.

2.2. Observation wave data

We use the buoy data from Japan "SATA Cape", "Fukue Island" and Korea "Cheju Island" to validate the simulated wave data. Buoy data from Japan "SATA Cape" and "Fukue Island" [2Japan Meteorological Agency, 2009] mainly includes hourly SWH and wave period, with the time range from January 2005to the present. And the "SATA Cape" station siteis31.051N,130.751E, the "FukueIsland" station site is 32.751N, 128.611E. Buoy data from Korea "Cheju Island" [3Korea Meteorological Agency, 2009] mainly includes hourly SWH, wave period and sea surface wind speed, available from January 2006 to the present. The station site is 33.081N, 126.031E.[1 *etal* 1988-2009]

- Factors affecting the suitability of the Site for sea wave power plant.
- For economical power production the minimum tide range is 4.6m or more.
- Silt index of water should be as small as possible to avoid the siltation trouble.
- The site should not create interruption to the shipping traffic running through the estuary otherwise the cost of the plant will increase as locks are to be provided.
- The waves should be generated at the regular time interval.

3. Model description and configuration:

The setup for converting the wave energy into electrical energy consists of many components. These components plays very important role in this energy conversion from mechanical to electrical energy. Some of the major components are discussed here.

3.1. Major Components of Mechanism:

- Base
- Oscillating Column
- Clutch
- Key
- Bearing
- Compression spring
- Flywheel
- Bevel gearing
- Alternator
- Alternator Shaft
- Lever

3.1.1 Base

Base is the structure on which fluid flow with decreasing cross section. Base will be made up of concrete structure on which metal plate will be imposed for smooth fluid flow. It will decrease the resistance to fluid flow. We can also use a series base structure for more than one oscillating column.

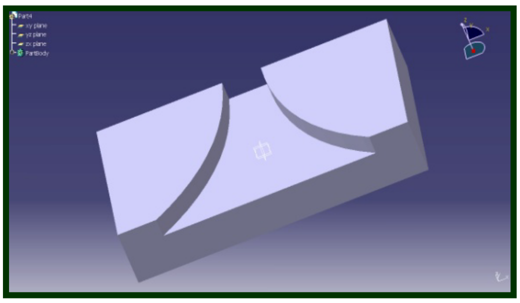

Fig .1: Base Structure

3.1.2 Oscillating Column

Oscillating column is very important part. It will utilize the sea wave power and oscillate about a fixed point. Weight of column is very important factor to be considered in designing process. If the weight of column is very low the speed of oscillation will be high but torque produced will be low. And if weight is very high speed of oscillation will be low. And large power will be required to oscillate the column.

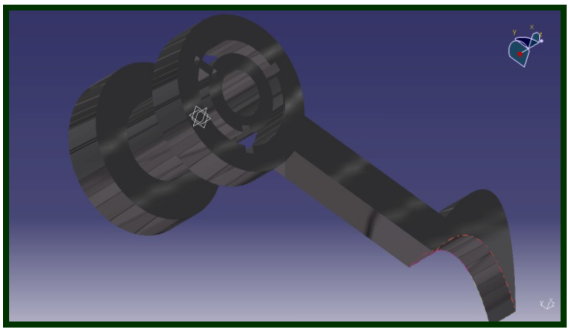

Fig.2 FLOATING Column with Keyway Arrangement

The force exerted by the jet on the plate in the direction of jet (Fx) = Rate of change of momentum in the direction of force

Fx = (initial momentum-final momentum)/time = mass (initial velocity-final velocity)/time.

The fluid comes out in the form of waves with some pressure. This high velocity wave will exert some force on oscillating wave. This force is obtained from Newton second law of motion or from impulse momentum equation. We can calculate the angle of oscillation.

Consider a wave coming out with a velocity v and striking the column which is hinged at O. Due to the force exerted by the waves on the column, the column will swing through some angle about the hinge.

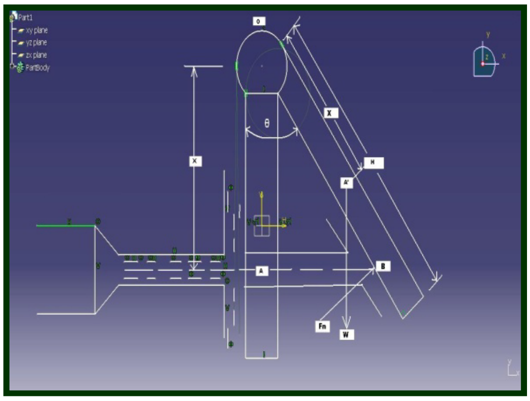

Fig.3: Impact of Jet on a Hinge Column

Let x=distance from hinge O where the wave strikes.

Θ=angle of swing about hinge

W= weight of column

The dotted lines shows the position of the column before the waves strike the column .the point A on the column will be A’ after the waves strikes the column. The distance OA=OA’=x. let the weight of the column is acting at A’. When the column is in equilibrium after the waves strike the column, the moment of all the forces about the hinge must be zero. Two forces are acting on the column.[4 R.K Bansal 2009]

Force due to waves normal to the plate

$$Fn = \rho\, a\, v^2 \sin \Theta'$$

Where Θ’= angle between waves and column= (90 – Θ)

Weight of the plate W

Moment of the force about hinge

$$Fn * OB = \rho\, a\, v^2 \sin(90-\Theta)*OB$$

$$= \rho\, a\, v^2 \cos\Theta*(OA/\cos\Theta)$$

$$= \rho\, a\, v^2 X$$

Moment of weight W about hinge

$$W*OA' \sin\Theta = W*X*\sin\Theta$$

For equilibrium of the column

$$\rho\, a\, v^2 X = W*X*\sin\Theta, \quad (\sin\Theta = \rho\, a\, v^2/W)$$

3.1.3 Clutch

A clutch is a machine member used to connect a driving shaft to a driven shaft so that the driven shaft maybe started or stopped at will, without stopping the driving shaft. The use of a clutch is mostly found in automobiles. A little consideration will show that in order to change gears or to stop the vehicle, it is required that the driven shaft should stop, but the engine should continue to run. It is, therefore, necessary that the driven shaft should be disengaged from the driving shaft. The engagement and disengagement of the shafts is obtained by means of a clutch which is operated by a lever. [6 R.S.Kurmi *etal* 2010]

3.1.4 Key

Key is used to connect the oscillating column with alternator shaft. Depending on the force exerted and strength of the key one or multiple key may be used. We know that key should be attached jet would impact on column and anticlockwise motion of column will be transmitted to the alternator shaft. Lever attachment will be used to connect and disconnect the key and bevel gear. [6 R.S.Kurmi *etal* 2010]

3.1.5 Compression spring

The thrust power produced by sea wave will be very large and it is very necessary to store this energy for further strokes of oscillation. Hence to absorb excess energy compression springs are used. Compression spring compress due to force exerted by column and then release this stored energy back to column.

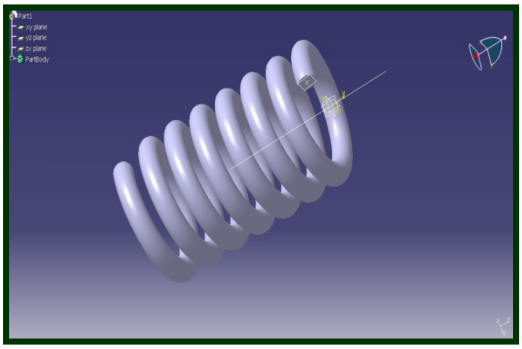

Fig.4 Compression spring

Diameter, pitch and length of spring should be carefully calculated on the base of force exerted on spring. And on the bases of data the deflection of the spring can be calculated by this formula. [6 R.S.Kurmi *etal* 2010]

Deflection = $8WD^3n/Gd^4$

And hence we can also calculate the energy absorbed by helical spring is

Energy absorbed = ½(W x deflection)

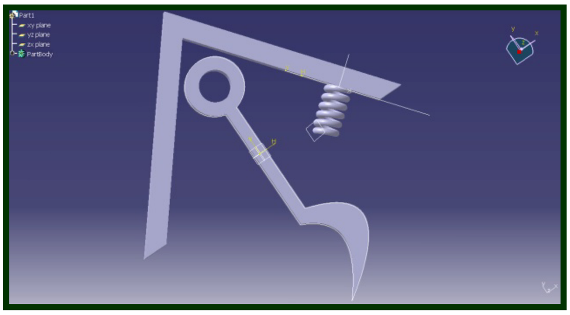

Fig.5 Arrangement of compression spring

3.1.6 Flywheels

A flywheel used in machines serves as a reservoir which stores energy during the period when the supply of energy is more than the requirement and releases it during the period when the requirement of energy is more than supply.

In case of steam engines, internal combustion engines, reciprocating compressors and pumps, the energy is developed during one stroke and the engine is to run for the whole cycle on the energy produced during this one stroke. For example, in I.C. engines, the energy is developed only during power stroke which is much more than the engine load, and no energy is being developed during suction, compression and exhaust strokes in case of four stroke engines and during compression in case of two stroke engines. The excess energy developed during power stroke is absorbed by the flywheel and releases it to the crank shaft during other strokes in which no energy is developed, thus rotating the crankshaft at a uniform speed. A little consideration will show that when the flywheel absorbs energy, its speed increases and when it releases, the speed decreases. Hence a flywheel does not maintain a constant speed ,it simply reduces the fluctuation of speed.

In machines where the operation is intermittent like punching machines, shearing machines, riveting machines, crushers etc., the flywheel stores energy from the power source during the greater portion of the operating cycle and gives it up during a small period of the cycle. Thus the energy from the power source to the machines is supplied practically at a constant rate throughout the operation. [6 R.S.Kurmi *etal* 2010]

3.1.7 Bevel gear

We know that anticlockwise motion of column will be transmitted to the alternator shaft through key. And after striking to the compression ring column will come back in Clockwise direction hence this clockwise direction motion should be converted into anti- clockwise direction. For this purpose we are using bevel gears as used in differential gear of car. Thus when the oscillating column comes back after striking to compression spring the key will be disconnected and with the help of lever system the bevel gear will be attached at the same time and the reverse direction motion of the column will be converted into anticlockwise direction and hence unidirectional motion will be obtained to the alternator shaft. [6 R.S.Kurmi *etal* 2010] [7 R.S.Kurmi *etal* 2009]

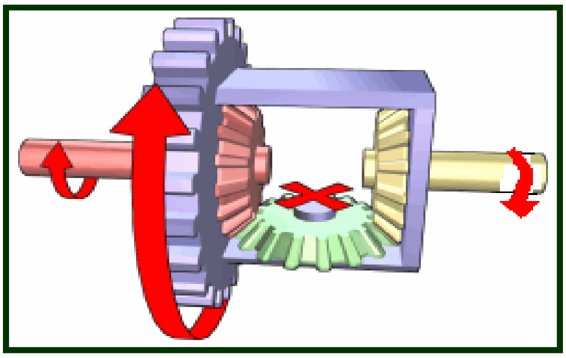

Fig.6..conversion of direction of rotary motion by bevel gears

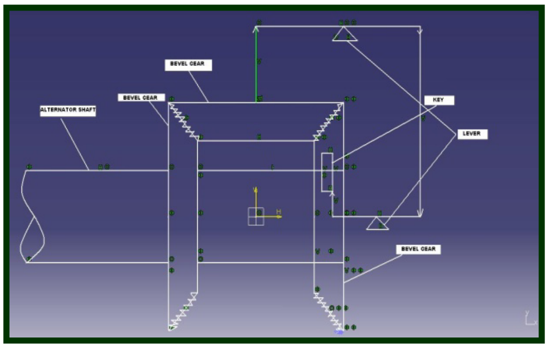

Fig.7 bevel gear mechanism

3.1.8Alternator

An alternator is an electromechanical device that converts mechanical energy to electrical energy in the form of alternating current. Most alternators use a rotating magnetic field but linear alternators are occasionally used. In principle, any AC electrical generator can be called an alternator, but usually the word refers to small rotating machines driven by automotive and other internal combustion engines. Alternators in power stations driven by steam turbines are called turbo-alternators. Alternators generate electricity by the same principle as DC generators, namely, when the magnetic field around a conductor changes, a current is induced in the conductor. Typically, a rotating magnet called the rotor turns within a stationary set of conductors wound in coils on an iron core, called the stator. The field cuts across the conductors, generating an induced EMF, as the mechanical input causes the rotor to turn. The rotating magnetic field induces an AC voltage in the stator windings. Often there are three sets of stator windings, physically offset so that the rotating magnetic field produces three phase currents, displaced by one-third of a period with respect to each other.

The rotor magnetic field may be produced by induction (in a "brushless" alternator), by permanent magnets (in very small machines), or by a rotor winding energized with direct current through slip rings and brushes. The rotor magnetic field may even be provided by stationary field winding, with moving poles in the rotor. Automotive alternators invariably use a rotor winding, which allows control of the alternator generated voltage by varying the current in the rotor field winding. Permanent magnet machines avoid the loss due to magnetizing current in the rotor, but are restricted in size, owing to the cost of the magnet material. Since the permanent magnet field is constant, the terminal voltage varies directly with the speed of the generator. Brushless AC generators are usually larger machines than those used in automotive applications.

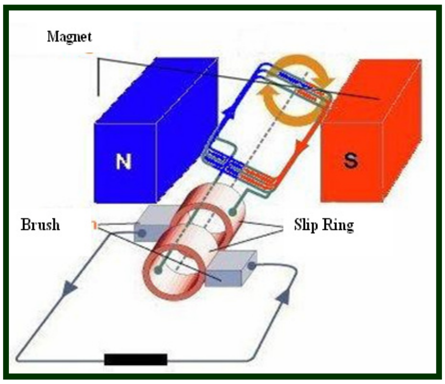

Fig.8 working principle of alternator

The generated emf per phase of alternator can be calculated by this equation.

$$E_{rms}/\text{phase} = 2.22f\Phi Z \text{ volt.}$$

f = frequency = NP/120

Φ = flux per pole in Webbers

Z = no of conductor or coil sides in series per phase

P = no of poles

N = rotor speed

3.1.9 Alternator Shaft

A shaft is a rotating machine element which is used to transmit power from one place to another. The power is delivered to the shaft by some tangential force and the resultant torque set up within the shaft permits the power to be transferred to various machine linked up to the shaft. In order to transmit the power from one shaft to another, the various members such as pulley, gears etc are mounted on it. In other words we may say that a shaft is used for the transmission of torque and bending moment. The various members are mounted on the shaft by means of keys and spines.

3.1.10 Lever arrangement

A lever is a rigid rod or bar capable of turning about a fixed point called fulcrum. It is used as a machine to lift a load by the application of a small effort. The ratio of load lifted to the effort applied is called mechanical advantage. Sometimes, a lever is merely used to facilitate the application of force in a desired direction. A lever may be straight or curved and the forces applied on the lever (or by the lever) may be parallel or inclined to one another. The principle on which the lever works is same as that of moments.
Consider a straight lever with parallel forces acting in the same plane as shown. The points A and B through which the load and effort is applied are known as load and effort points respectively. F is the fulcrum about which the lever is capable of turning. The perpendicular distance between the load point and fulcrum (l1) is known as load arm and the perpendicular distance between the effort point and fulcrum (l2) is called effort arm. According to the principle of moments,

$$W \times l1 = P \times l2 \text{ or}$$
$$w/p = l1/l2$$

i.e. Mechanical advantage,
M.A. = W / P = $l2/l1$
The ratio of the effort arm to the load arm *i.e.* $l2/l1$ is called *leverage*.
A little consideration will show that if a large load is to be lifted by a small effort, then the effort arm should be much greater than the load arm. In some cases, it may not be possible to provide a lever with large effort arm due to space limitations. Therefore in order to obtain a great leverage, compound levers may be used. The

compound levers may be made of straight pieces, which may be attached to one another with pin joints. The bell cranked levers may be used instead of a number of jointed levers. In a compound lever, the leverage is the product of leverages of various levers. [6 R.S.Kurmi *etal* 2010]

4. Working principle

Our project works on the same principle as the pelton turbine works with a difference that there is not a continuous jet striking on multiple blades but there is a high wave impact force striking on a single bladed oscillating column. We know that in pelton turbine rotate continuously in one direction after the jet strike the blade but here the impact force applied by high velocity jet will be utilized to rotate the output shaft.

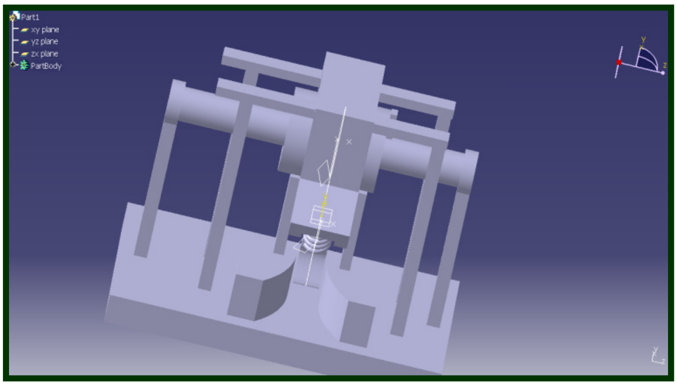

Fig.9 working modal view

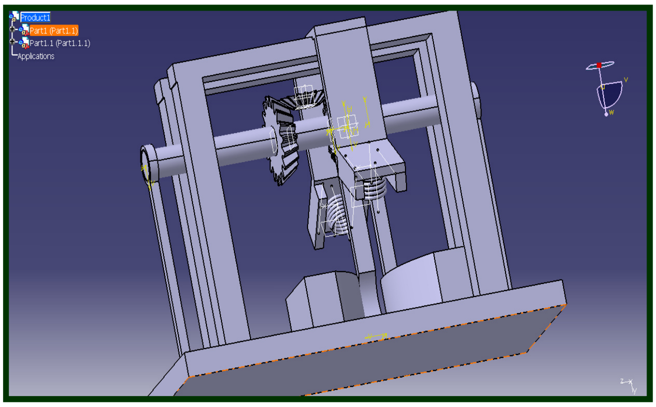

Fig. 10 working modal with bevel gear

As in fig.4 when the high velocity waves strike the blade the oscillating column will move with its maximum velocity in anticlockwise direction at this time the centrifugal clutch on output shaft is engaged with oscillating column hence the power is transmitted to the output shaft with the help of clutch. As the oscillating column strike to the compression spring the compression spring will store the energy and during this time the clutch will also disengage with the output shaft and at the same time bevel gear will be engaged with the output shaft with the help of lever arrangement. Hence when the compression spring will thrust back the oscillating column the clutch will disengage and bevel gear will be engaged hence the clockwise rotation will also convert into anticlockwise rotation hence the output shaft will rotate in one direction.

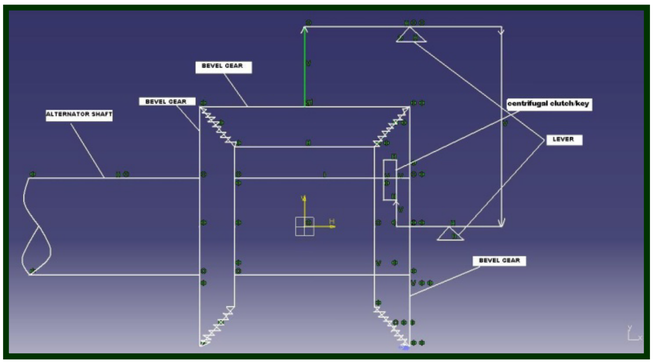

Fig. 11 Attachments

Hence this mechanical energy produced with the help of sea wave can be utilized to produce electrical energy or for pumping water. We know that there are several other methods utilizing the sea wave power but this project will generate more power. And the problem of silt is also reduced a lot because there is only single blade and can be easily replaced. Here the utilization of sea wave power is maximum because the sea wave thrust power is directly converted into mechanical energy with the help of oscillating column.

5. Conclusion

In the present era, conventional energy resources are limited on the earth, these resource are very expensive. So it is essential to utilize non conventional energy resources for power generation, we know that sea is the large sources of energy. Sea wave power plant is the technique of utilizing the sea wave energy and converting it into the electrical energy. We are using oscillating column to convert the wave power to oscillate motion and with the help of gear and key we convert oscillatory motion into unidirectional rotary motion, this rotational energy into the electrical energy with the help of alternator. The advantages of sea wave power plant are given below:
It is small in size comparative to the conventional power plant. It does not create the pollution. But there are some limitations of this plant like establishing the plant at the beach of the sea is very difficult, it need advance technology which will increase its initial cost. It is also difficult to predict the sea wave generation and interval of successive sea waves, which is the main limitation of this plant.

6. Future scope

The biggest problem we are facing at the present scenario is development at the cost of hurting our dear environment, because we need to generate certain alternatives so that we can fight against the odds and also have sustainable development i:e keeping in view the need for the future. As we know the earth has $2/3^{rd}$ of its portion covered up with water so definitely we too have shore and thus the sea wave power plant comes into play with certain advantages that stands unique from rest of the power plant.

- It has a tremendous scope at low level production n large level production too.
- Its non conventional source of energy.
- It has great scope for further modification.
- Its output can be used for numerous machines for improving efficiency.
- The power produced by the project may be directly utilized or stored in the battery.
- The power can also be utilized to pump the water from sea to certain height and then this water can be utilized on conventional turbine to generate power.
- We can use two or three oscillating column to have certain angle difference so that continuous power can be generated. It uses the water power having humungous potential as known.

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