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Mathematical Modeling and Torque Estimation

For a Uni Directional Flap Turbine

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Abstract – This document is intended to quantify the amount of torque that can be produced from a flap turbine shown in the figure. The flap turbine is a ocean turbine designed in such a way that the forward and the backward waves make the turbine to rotate in the same direction. The flap arrangement open and closes to create torque in one particular diirection even though the source of the torque i.e the wave change direction. The model considers a simple mechanics principle of momentum transfer before and after impact and the torque is estimated as a function of the turbine geometric parameters and the wave approach velocity.

Keywords – Flap turbine, torque, momentum, uni-directional.

I. INTRODUCTION

This turbine can convert the kinetic energy of the approaching ocean waves into electrical energy. The waves strike the turbine and make it rotate. This turbine is connected to a generator. When the turbine rotates, the generator also rotates, generating power.

II. GENERAL ARRANGEMENT OF FLAP TURBINE:

The turbine has four blades with flaps in them. Basically, the flaps are valves designed to operate in one direction. The four blades are placed at right angles to each other. These blades are rigidly attached to the central rod, and hence rotate it.

Structural Arrangement for the FlapTurbine

III. MECHANISM OR PRINCIPLE OF FLAP TURBINE:

As shown, when the flow is towards **north** the flap **opens**. When the flow is towards **south**, the flap **closes**. A pair of such flaps (at least) is placed on either side of the central pivot as shown in later diagrams.

Principle of Operation

The flow of waves direction is **Northwards** on the page.

With **left flap closed** and **right flap open**; more torque is generated on the **left** causing a **clockwise** rotation when viewed from the top.

Top view of the blades

The flow direction is **Southwards** on the page.

With **left flap open** and **right flap closed**; more torque is generated on the **right** causing a **clockwise** rotation when **viewed from the top**.

Thus the rotation is clockwise irrespective of flow direction

This is how the turbine looks to the wave or the view of the turbine from the

Close-up of the flap

The lower drawing in colour is a slightly enlarged version of the one above with the colour added to make the dotted lines of the edges and flaps clearer

It can be seen that after rotation the left flap (brown) comes to the right side. With flow into page, this opens while the blue one now on the left closes. i.e. no matter what, the flap on the right always opens to flow into the page. Thus the direction of rotation is clockwise when viewed from the top

It can also be seen that when flow is directed outwards from the page (for example when the wave goes back into the ocean) the right flap (blue) closes while the left flap (brown) opens. Thus the force exerted by the receding wave is also such that the rotation is clockwise when viewed from the top.

If we term the brown and blue pair together as a flap arm, with more such arms (say one normal to the plane of the paper) the rotation would be clockwise irrespective of flow direction.

TOP VIEW with an additional flap arm at right angles

IV. ANALYSIS AND ESTIMATION OF TURBINE PARAMATERS:

Turbine parameters

Here F is the force produced by the wave, v is the speed of the wave, ρ is the density of water, T is the torque produced.

This equation has certain assumptions:

- The force has been calculated assuming that the wave has completely transferred its momentum to the turbine blade and the wave has stopped completely.
- Due to this, the actual torque generated will be less than this value.
- The force is expressed as the rate of change of momentum.
- Frictional losses in the rotating shaft have been neglected.
- Wave is assumed to be striking continuously.
- The already existing rpm of the blade has been neglected.
- The wave has been assumed to hit all parts of the blade equally i.e. uniform load distribution.

V. MATLAB RESULTS AND CONCLUSION:

For $h=1$, $r=.5$

For $h=1$, $r=1$

For $h=2$, $r=1$

For $h=2$, $r=2$

Graphs between torque and wave speed for various turbine parameters

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