University of Sri Jayewardenepura
Faculty of Graduate Studies

Department of Mathematics

A STUDY ON THE EXTRACTION OF ENERGY FROM WATER WAVES USING A CONICAL FLOAT

A Thesis
by

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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Postgraduate Diploma
in
Industrial Mathematics

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ABSTRACT

The purpose of this project is to mathematically design a device to be installed in deep water for the extraction of water wave energy. To design this float, few reasonable assumptions from mathematical and engineering points of view have been taken into account. The Theory of Airy, which is used in this project has the minimum percentage of errors in water particle velocity (at still water level 3%, overall 3%) compared to the other wave theories. Since this Linearised Theory of Airy gives analytical solutions, the accuracy of the final result is very high.

PREFACE

In Sri Lanka, as in other countries, the demand for energy increases. To meet the demand there should be a substantial supply of power. As years go by, the demand will be greater. Oil and other primary sources of energy might be scarce and so the price of these will certainly go up considerably.

Energy from ocean waves can make a significant contribution to the country's requirements. If Sri Lanka, which is surrounded by an ocean, can make use of the ocean waves, it would certainly go a long way in helping to avert energy crises in the future. One of the earliest and most informative papers on wave power was presented at a meeting in 1892 by A. W. Stahl. It states that "an intelligent study of the possibility and practicability of utilizing the power of ocean waves presupposes a thorough knowledge of the geometry and mechanics of wave motion".

So far Sri Lanka has not made use of any device to extract wave energy. Ways of extracting energy from water waves with the help of a mathematically designed device should be carefully looked into. The idea is very feasible.

The process would not harm the environment. The difficulties, of course, have to be overcome. The expenditure of a project of this nature should be kept to a minimum. The advantages are many, if the project is sensibly worked out. If this device is properly installed at a favourable location, considerable benefits could be obtained. When designing this device the installation and the related expenses were considered.

Reference : Wave Energy a Design Challenge by Ronald Show.

CONTENTS

NOTATIONS

Notation		S. I. Units
a	wave amplitude	m
c	celerity or phase velocity	$m\ s^{-1}$
D	damping coefficient	$Kg\ s^{-1}$
E	energy	$Kg\ m^2\ s^{-2}$ or $N\ m$
Eff	efficiency	-
F	force	N
g	gravitational acceleration	$m\ s^{-2}$
H (= 2a)	wave height	m
h	depth of the sea	m
K	parameter equals to $2\pi / L$	m^{-1}
L	wave length	m
p	pressure	$Kg\ m^{-1}\ s^{-2}$ or $N\ m^{-2}$
q	resultant velocity	$m\ s^{-1}$
R	radius	m
T	wave period	s
t	Time	s
u	velocity component to the x – direction	$m\ s^{-1}$
v	velocity component to the y – direction	$m\ s^{-1}$
w	velocity component to the z – direction	$m\ s^{-1}$
m.w.l.(s.w.l.)	mean water level (still water level)	-
η	elevation of water above the still water line	m

ρ	density of the sea	$Kg\ m^{-3}$
σ	parameter equals to $2\pi / T$	s^{-1}
ϕ	velocity potential	$m^2\ s^{-1}$
ε	a function of $\left[\frac{[2\pi]^2}{T^2}\frac{R}{g}\right]$	-

SUBSCRIPTS

P	progressive wave
S	standing wave

DIRECTIONS OF THE CO-ORDINATE AXES

x	$\rightarrow$	horizontal
y	$\uparrow$	vertical
z	$\otimes$	

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ACKNOWLEDGEMENT

Whatever the project might be, it certainly will not be smooth sailing unless one gets a helping hand. To carry out this project I was fortunate in getting valuable advice and encouragement from kind and learned people.

Special mention has to be made of Dr. (Mrs.) Sunethra Weerakoon, The Coordinator of The Master of Science Degree in Industrial Mathematics in The University of Sri Jayewardenepura, Nugegoda, and also of Dr. G. K. Watugala, The Senior Lecturer of The Department of Mechanical Engineering in The University of Moratuwa, Katubedda, who was my principal supervisor.

The Head of The Engineering Mathematics in The Open University at Nawala, Dr. Arjuna de Zoysa is another to whom I am indebted for guiding me to the correct path.

Mr. E. A. T. A. Edirisooriya, The Senior Lecturer of The Department of Mathematics, University of Sri Jayewardenepura; Mr. Deranagama, The Director of The Energy Conservation Fund and Mr. P. V. Wijerathne of Lanka Hydraulic Institute Ltd were also immensely helpful with their kind cooperation and unstinted support.

CHAPTER 1. INTRODUCTION

Energy is the primary and universal measure of all kinds of work by human beings and nature. Everything that happens in the world is an expression of the flow of energy in one of its forms. Most people use the word energy for input to their bodies or to the machines and thus think about crude fuels and electric power.

By using solid fuels and liquid and gaseous fuels energy is produced. Energy is also extracted from solar, wind, water etc by using various methods. From water waves energy could be extracted if suitable devices are made.

1.1 ENERGY SOURCES

There are various sources of energy. These sources could be categorized mainly into two types, major sources and minor sources. Solid fuels, liquid and gaseous fuels are major or conventional energy sources. Solar, wind, geothermal, biomass, ocean thermal, tidal and wave come under minor sources or non – conventional energy sources.

Major Sources (**Conventional Energy Sources**)	**Minor Sources** (**Non-Conventional or Renewable Energy Sources**)
Fossil Fuels i.e. solid fuels (coal, anthracite, bituminous, brown coals, peats), liquid and gaseous fuels (petroleum and its derivatives and natural gases).	Solar
	Wind
	Geothermal
	Biomass (wood, agricultural residues, animal dung)
Energy stored in water.	Hydrogen Energy
Energy of nuclear fission.	Fuel cells
	Magneto Hydro – Dynamics Generator
	Thermonic Converter
	Thermo Electric Power
	Sea (ocean thermal,tidal, **wave**)

1.2 MAJOR OR CONVENTIONAL ENERGY SOURCES

Coal, oil, gas, uranium, hydroelectricity are commonly known as conventional energy sources. Most of the energy requirements of industrialized countries or developed countries are met from these sources.

Wood was the dominant source of energy in the pre-industrialization era. With the advent of industrialization, coal has been the most common source of energy. Use of coal

reached a peak in the early part of the twentieth century. Oil got introduced at that time and has taken a substantial share of the total sources of energy and now oil plays a major role not only in our economy, but in the world economy too.

Hydroelectricity has grown to a stable level in most of the developed countries. Water power is developed by allowing water to fall under the force of gravity. Potential energy of water is converted into mechanical energy by using hydraulic turbines. Although the capital cost of hydroelectricity power plants is high, their operating cost is quite low. But the development rate of hydropower is still low in Sri Lanka. Because in developing a project, it will take so many years for planning, investigation and construction. And sometimes selecting alternative areas for the villages that have to be abandoned is also a problem. Another factor is the high capital investment.

When producing nuclear energy, problems on high capital cost, limited availability of raw materials, difficulties associated with disposal of radioactive waste and lack of skilled technicians will arise. Consequently in Sri Lanka there is no nuclear energy power plant, and there are no plans to build one in the near future.

When using gas, gases such as acetylete, ethylene, methane, etc, are incompletely utilized at present and huge quantities are burnt-off in the oil production process. The reasons may be high transportation cost of the gas and non-availability of a ready market. But the supply of these major or conventional sources is limited.

1.3 NON- CONVENTIONAL OR RENEWABLE ENERGY SOURCES

As the conventional energy sources will get exhausted eventually, the alternative systems based on non- conventional or renewable sources were tried and are being tried by many

countries. Unlike the conventional energy sources, renewable sources cannot be exhausted. These are solar, wind, geothermal, biomass, river flows, sea, etc.

Solar can be a major source of power. Its potential is 178 billion MW, which is about 20,000 times the world's demands. But so far it could not be developed on a large scale. Wind energy uses the high wind velocity available in certain places. A minimum wind speed of 3 m/s is needed to extract wind energy economically. Geothermal energy is derived from the heat which lies embeded within the earth. Biomass is in the form of wood, agricultural residues and animal dung. The hydrological cycle results in rainfall, which causes river flows, that can be trapped behind dams to even out the variations in the river flows and thus convert into hydroelectric energy.

Energy from seas can be utilized as ocean thermal energy, tidal energy and wave energy. Ocean thermal energy conversion utilizes the temperature difference between the warm surface sea water and the cold deep sea water. The tide, which is the periodic rise and fall of the water level of seas due to the cycle of rising and setting of the sun and the moon, could be used to generate power. These minor or renewable energy sources may be necessary to be developed in the future for the economy and the better sources are wind, tide and wave energy.

1.4 WATER WAVE ENERGY

The power in the ocean and sea waves has been a part of human experience for thousands of years. Past attempts to exploit this power for human purposes has been extensive. Power crises prompted serious attempts at harnessing ocean waves for the production of electricity. Patents have been issued on a variety of devices and many schemes have been described conceptually. Some small scale prototype devices have been tested. Upto now