# ARTIFICIAL WAVE PRODUCER

CARREY CHIANG WAI LIONG

BACHELOR OF MECHATRONICS ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

ARTIFICIAL WAVE PRODUCER

CARREY CHIANG WAI LIONG

**A report submitted**
**in partial fulfillment of the requirements for the degree of**
**Bachelor of Mechatronics Engineering with Honours**

**Faculty of Electrical Engineering**

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

## DECLARATION

I declare that this thesis entitled "ARTIFICIAL WAVE PRODUCER is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

| | | |
|---|---|---|
| Signature | : | |
| Name | : | CARREY CHIANG WAI LIONG |
| Date | : | 18 - 06 - 2019 |

## APPROVAL

I hereby declare that I have checked this report entitled "title of the project" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature :

Supervisor Name : MR. SYED MOHAMAD SHAZALI BIN SYED ABDUL HAMID

Date : 18 - 06 - 2019

# DEDICATIONS

To my beloved mother and father

## ACKNOWLEDGEMENTS

In preparing this report, I was in contact with many people including staffs and seniors. They have helped me in my understanding and thoughts. In other words, I wish to express my sincere appreciation to my main project supervisor, Mr. Syed Mohamad Shazali bin Syed Abdul Hamid, for encouragement, guidance, critics, advices and motivation. Besides, I would like to thank the panels PM Dr. Chong Shin Horng and Dr. Hyreil Anuar Bin Kasdirin for their feedback and critics on my research for improvements.

Apart from that, I would also like to express my gratitude to lecturers in Electrical Faculty of UTeM (FKE), PM Dr. Ahmad Zaki Bin Shukor, Dr. Fariz Bin Ali, and other lecturers who were involved in guiding for a proper report writing and research study with integrity.

My sincere appreciation also extends to my parents, course mates and others who have provided assistance, views and tips which had helped me in completing this project research.

# ABSTRACT

The research was driven by the unavailability of an Artificial Wave Producer in the Underwater Research Lab in Faculty of Electrical Engineering (FKE) in Universiti Teknikal Malaysia Melaka (UTeM) besides with an increasing use of Remotely Operated Vehicle (ROV) in deep sea exploration and underwater tasks. The high cost and large scale of existing wave producer has been a problem as it is pricey and occupies large space in laboratory. The objectives of the research was to develop a low cost and small scale Artificial Wave Producer and to evaluate its performance in terms of generated wave amplitude and wavelength. The method used in this research is by operating an oscillating plunger in a water tank of size 2 m x 1 m of length and width with 0.5m depth of water which is already available in the lab. The concept of producing wave with the Artificial Wave Producer was by using the Scotch Yoke mechanism to convert rotational motion to reciprocating motion and the performance of the Artificial Wave Producer were determined by the result of wave amplitude through changes of submerged plunger depth and result of wavelength from different plunger frequency where the wave amplitude produced by the triangular plunger is smaller than that of the half circular plunger even though with same submerged depth while the wavelength of both plunger shows the same exponential graph pattern against the plunger frequency axis. The comparison of theoretical calculation and experimental results were conducted to determine the error of the Artificial Wave Producer and comparison of theoretical plunger velocity with generated wave velocity were found to be lower in experimental wave velocity which was due to friction loss in the Scotch Yoke mechanism.

# *ABSTRAK*

Penyelidikan ini didorong oleh ketiadaan Pengeluar Gelombang Buatan dalam Makmal Penyelidikan Bawah Air di Fakulti Kejuruteraan Elektrik (FKE) di Universiti Teknikal Malaysia Melaka (UTeM) di samping peningkatan dalam penggunaan kendalian kenderaan jauh (ROV) dalam penerokaan laut dalam dan tugas bawah air. Kos yang tinggi dan skala besar pengeluar gelombang sedia ada telah menjadi masalah kerana harga yang tinggi dan memerlukan ruang simpanan yang besar di makmal. Objektif penyelidikan ini adalah untuk menghasilkan Pengeluar Gelombang Buatan kos rendah dan berskala kecil serta untuk menilai prestasi fungsinya dari segi amplitud dan jarak antara gelombang yang dijana. Kaedah yang digunakan dalam penyelidikan ini adalah dengan mengendalikan pelocok berayun dalam tangki air saiz 2 m panjang dan 1 m lebar bersama dengan kedalaman air sebanyak 0.5m yang sedia ada di makmal. Konsep penjanaan gelombang air adalah berasaskan mekanisma "Scotch Yoke" di mana penukaran dari tenaga putaran ke tenaga linear and prestasi Pengeluar Gelombang Buatan ini ditentukan melalui penjanaan ketinggian amplitud gelombang dengan perubahan kedalaman pelocok ke dalam air yang didapati ketinggian gelombang adalah lebih kecil dengan pelocok segi tiga berbanding pelocok separa bulatan manakala eksperimen mengenai perubahan kepanjangan gelombang melalui perubahan frekuensi pelocok bagi kedua-dua pelocok mempunyai corak graf eksponen. Pengiraan secara teori dibandingkan dengan keputusan ekperiment bagi mengenalpasti peratusan kepincangan Pengeluar Gelombang Buatan ini dengan bandingan halaju gelombang adalah lebih rendah daripada halaju pelocok yang disebabkan kehilangan tenaga daripada geseran mekanisma "Scotch Yoke".

## TABLE OF CONTENTS

# LIST OF TABLES

## LIST OF FIGURES

## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| f | - | Frequency |
| d | - | Water depth |
| λ | - | Wavelength |
| T | - | Period |
| v | - | Velocity |
| r | - | Radius |
| ω | - | Angular velocity |
| DC | - | Direct current |
| ROV | - | Remotely operated vehicle |
| IEEE | - | Institute of electrical and electronics engineers |
| AWAS | - | Active wave absorption system |
| PWM | - | Pulse width modulation |
| DAS | - | Data acquisition system |
| SRDC | - | Subsea research and development center |
| PLC | - | Programmable logic controller |
| NPS | - | Naval postgraduate school |

## LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Artificial Wave Producer is a system that generate water waves which resembles natural water waves by means of a wave maker system and it is important for underwater research. The first wave-making model was created by Phil Dexter back in 1966 [1] as shown in Figure 1.1 and a first wave pool was opened by him in Big Surf Waterpark two years later. The operational mechanism reported from TIME Magazine on 10th October 1969 of Dexter's design in Big Surf Waterpark wave pool was by pumping millions of gallons of water into a reservoir made out of concrete using hydraulic pumps. Waves were created from releasing of water from the reservoir underwater gates [2]. The wave size was controlled by the volume of water released hence by releasing more water, larger wave size can be produced.

Figure 1.1 The first wave-making machine [1]

The existence and further development of the first wave-making machine had led to commercial use especially in water theme park. On the other hand, experimental researchers mainly in coastal engineering conduct researches on water waves requires wave maker system and the mechanism varies depending on the system itself. The existence of the wave maker system is vital as it is not only for commercial use but also for the study of different type of water wave characteristics which could help in prediction at offshore such as tsunami warnings.

## 1.2 Motivation

The need of producing a controlled and small scaled artificial wave is vital for underwater research as it could help to save laboratory space and able to generate a similar to natural wave. The unavailability of a small scale Artificial Wave Producer in FKE Underwater Research Laboratory had driven the conduct of this research project.

## 1.3 Problem Statement

The current existing wave producer occupies large space and is high in cost which affect the affordability of purchasing and locating an artificial wave producer in the laboratory for research and study purposes.

## 1.4 Objectives

Upon completion, this project will achieve the following objectives:-

1. To develop a low cost and small scale Artificial Wave Producer
2. To evaluate the performance of the Artificial Wave Producer in terms of wavelength and amplitude with value in between range of 1cm to 1m for wavelength and wave amplitude of below 5cm respectively.

## 1.5 Scope

A list of focused segment for the project is as follow:-

1. Varying of PWM value of oscillating plunger

a. From 150 to 250 with an increment of 25 for every reading

2. Varying the depth of water displaced by plunger

   a. From 1.0 cm to 5.0 cm with an increment of 1.0 cm for every reading

3. Plunger wave generator

   a. Half circular plunger

   b. Triangular plunger

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Research Background

Water waves are formed from disturbing force where the wave height is the vertical distance between the wave crest and the adjacent trough and wavelength is the horizontal distance between two successive crests (or troughs) [3] while the wave amplitude is the halved of the wave height. The wave characteristics is shown in Figure 2.1.

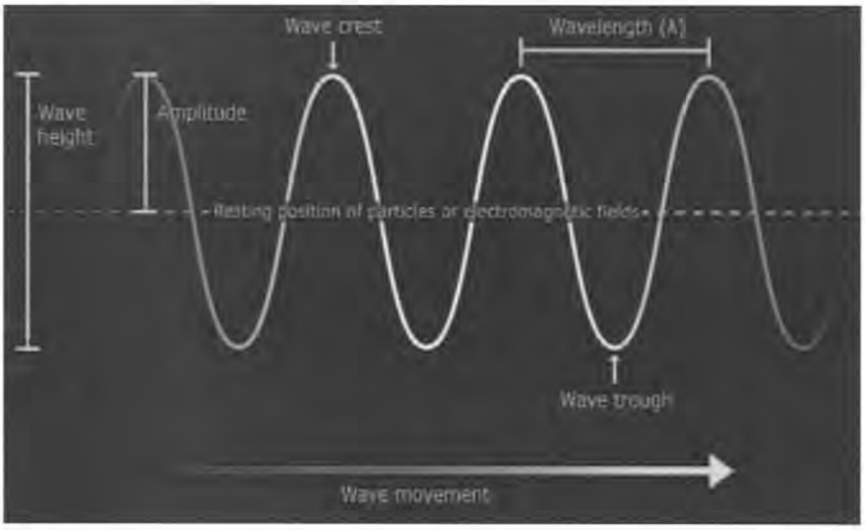


Figure 2.1 Wave characteristics [4]

Water depth of less than 5% of the wavelength is defined as shallow water where the wave behavior is influenced by the waves interact with the bottom and depth between 5% and 50% of wavelength is considered to be intermediate waves while deep water is depth above 50% of water wavelength [5]. (2.1) can be used to determine on wether the condition is deep where the "d" is the water depth and "λ" is the wavelength.

$$\frac{d}{\lambda} > 0.5 \tag{2.1}$$

The wavelength can be calculated using (2.2) if the result from (2.1) is true. The "T" in (2.2) is the wave period.

$$\lambda = 1.56T^2 \tag{2.2}$$

From wave period, the frequency of a wave can also be determined by using (2.3) where "f" is the wave frequency.

$$f = \frac{1}{T} \tag{2.3}$$

## 2.2 Type of Waveform

Several type of waves were produced through various wave maker system which include regular, irregular, linear and circular. Progressive wave is the common type of wave generated as it depicts the motion of wave front through the medium. Progressing wave was produced by Horst Punzmann et al. with vertically oscillated plunger and the motion of fluid was observed using buoyant tracer particles that were dispersed all around the fluid surface [6]. A research by David Aknin and Johannes Spinneken involved several wave amplitude set with the alteration of displacement and force using piston type wave maker to generate regular waves [7]. Based on a study by P.C. de Mello et al., generated regular and irregular waves with the flap wave maker automation system that is controlled by PLC for comparison between theoretical and experimental transfer function of wave generation for the automation system performance validation [8].

## 2.3 Type of Wave Maker

Plunger type was used to produce regular and irregular waves in the research for the surface elevation measurement with and without the activation of absorption by YANG et al. [9] while a study research done by Ishmam et al. in "Construction of a Plunger Type Experimental Wave Tank for Validation Study" uses vertically oscillated plunger for regular and irregular wave generation [9] in the research of wave absorbing beach. The variables of the research were the presence of wave absorbers on the effect of measured continuous waves. Piston, plunger and flap maker are the most general method of producing waves as shown in Figure 2.2. Flap and piston generate waves from bottom to top and are more suitable for deep water while plunger type generates water waves through top to bottom water surface contact.

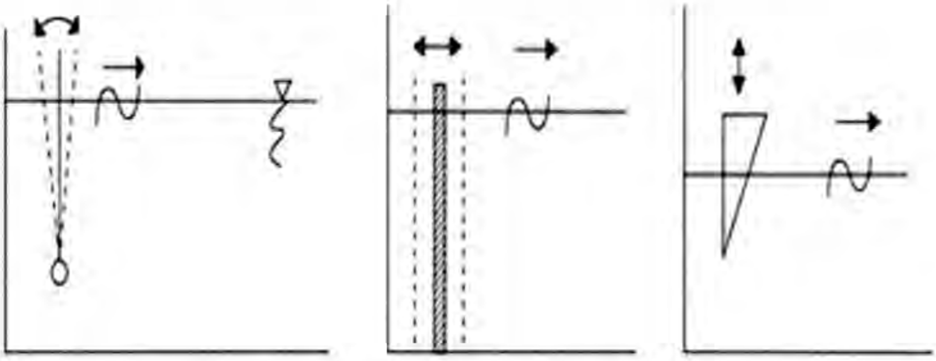


Figure 2.2 Type of wave generators [6]

## 2.4 Measuring Devices

Ultrasonic probes were used by several researchers as a measuring method for wave height from the oscillating wedge according to a research by Leo M Jones [5]. Study [5] involved varying the frequency of oscillation to the wave amplitude and data were collected via MATLAB routine from voltage reading of each probes. The research of [8] to measure the distance between transducer and the water surface using ultrasonic wave height meter that operates via pulse-echo technique. The data from experimental result were almost similar to the theory of wave flap response transfer function for phase and magnitude relation relative to varying frequency.

In the "Determination of a Plunger Type Wave Maker Characteristice in a Towing Tank" by Sayed et al., resistive type of probes with transducer were used as a measuring method for wave height that converts into electrical signal [11]. The research also include the comparison of data acquisition system (DAS) with ruler and camera of 25 fps for characteristic curve of plunger type wave maker of Subsea Research and Development Center (SRDC) and the results of both method was found to be quite closed [11]. Different types of probes for measurement whether through the changes of voltage output or duration for reflected ultrasonic wave receiver helps to obtain a more accurate and reliable result for wave height and frequency but a more conventional way of using ruler and camera could obtain almost similar wave height result.

## 2.5 Wave Absorbers

In [13], passive nylon beach was used as a wave absorber. The reflected energy must be absorbed by the same wave generator, whose movement is modified to cancel out the reflected waves called Active Wave Absorption System (AWAS) [14] was carried out by Altomare et al., dissipative beach or horizontal sponge wall were used as passive wave absorber. The Active Wave Absorber System (AWAS) was used by absorbing reflected energy by the same wave [14]. In the research of "Evaluation of a Source-Function Wave maker to Accurately Generate Random Directionally Spread Waves" by Suanda et al. had observed monochromatic waves with sponge layers placed at the side to absorb waves [15]. Research [9] uses absorption algorithm to produce an opposite phase of equal amplitude to eliminate the re-reflected wave. Wave absorber is important in the design for a better wave generation for significant disturbance of reflected waves as it helps to absorb remaining wave and prevent reflected wave that will affect the data validity.

## 2.6 Small Scale Wave Maker System

Research [9] by Ishmam et al. in validation studies on plunger type experimental wave tank uses waveflume design of size 1.75m x 0.25m x 0.3m. The system operates with a plunger wedge controlled via Variable Frequency Drive (VFD). The VFD varies the motor input frequency in order to control the motor speed. Regular and irregular waves are able to be generated with the installed wave maker within a range of time period. The system uses gear to convert rotational motion of motor into a reciprocating motion of the actuator as shown in Figure 2.3. A study in research [6] uses a smaller waveflume of size 1.5m x 0.5m x 0.08m using vertical oscillation of different plunger shape consisting of conical, cylindrical, triangular and square pyramidal. With plunger frame, the vertically oscillating plunger was attached to the electromagnetic shaker on the table. Small scale wave maker system could be concluded to common use of plunger besides able to save laboratory space as it only requires small size of waveflume.

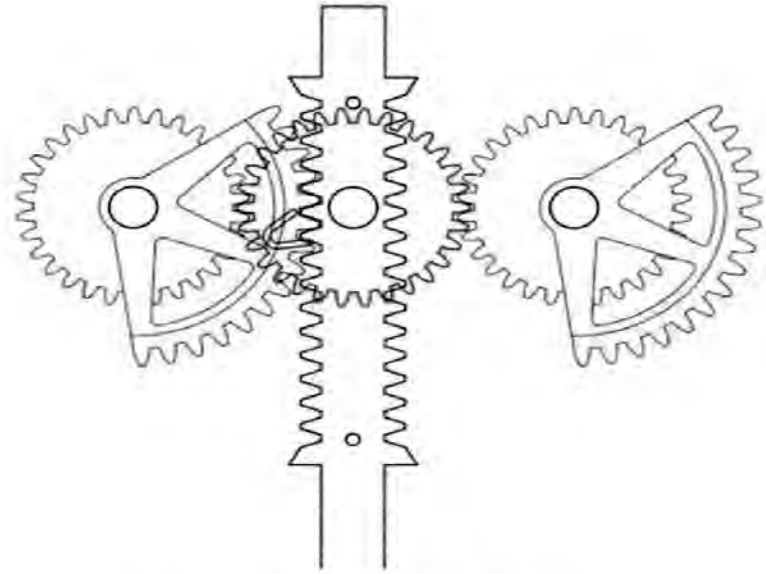

Figure 2.3 Wave maker mechanism [7]

## 2.7 Large Scale Wave Maker System

It is wideused of large scale wave maker system to produce artificial wave in the laboratory where the significance of the large scale is depicted with the use of large waveflume. The research in [8] by P.C. de Mello et al. uses basin of size 14m x 14m x 4m which uses wave maker system of hinged flap that consist of 148 actuators controlled using PLC as shown in Figure 2.4. The wave maker system consist of transmission system using ball-screw linear system and each hinged flap powered by a 1HP servo-motor as depicted in Figure 2.5. Besides, each immersed flap is as large as 1.21m for regular wave generation and could generate high wave amplitude as the flap is immersed deep into the basin. A 10.9m x 0.9m x 1.2m of waveflume was used in Naval Postgrduate School (NPS) with wave maker system of sized 0.6m in height and 0.9m wide using linear actuator for wedge motion control controlled by Modusystems Pulse/Dir controller as shown in Figure 2.6. From the wave maker system, the maximum stroke of linear actuator is 0.6096m with a maximum thrust of 1779.3N [5]. With large basin, deep immersed flap and long stroke of wave maker, larger water wave amplitude can be produced but requires a bigger space in the laboratory for the system to operate.

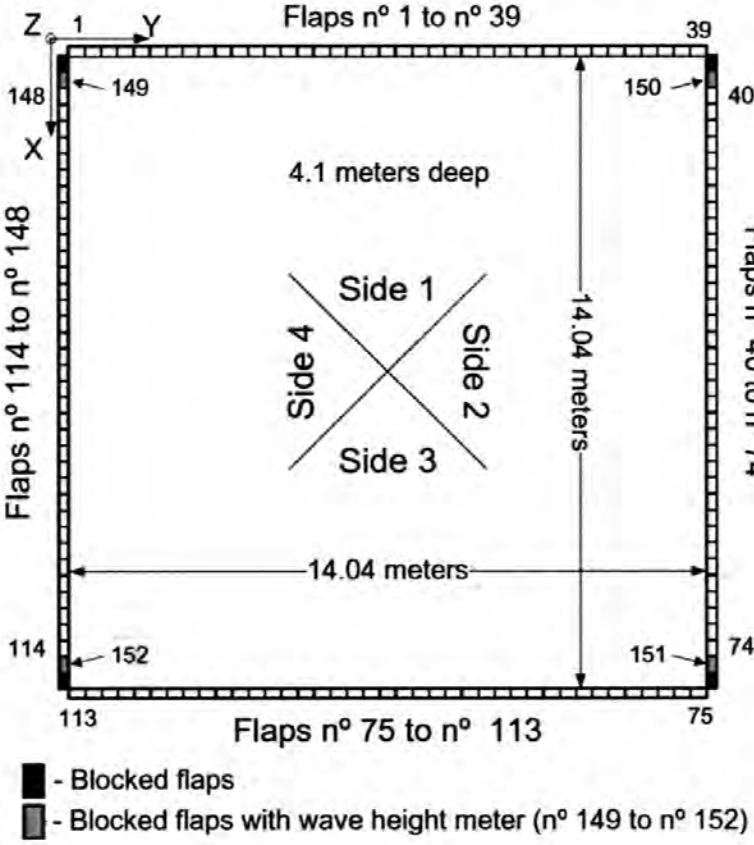


Figure 2.4 Numerical Offshore Tank (TPN) wave basin [8]

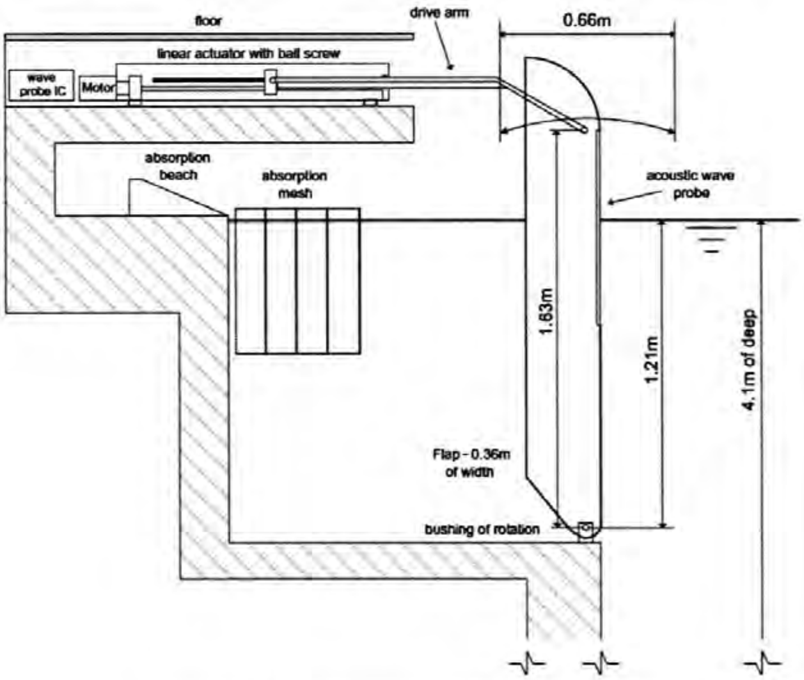


Figure 2.5 Mechanism of hinged flap [8]