MONSOON EFFECT TO WAVE POWER FOR WAVE ENERGY CONVERTER IN MANDI DARAH ISLAND, MALAYSIA

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MASTER OF SCIENCE
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ABSTRACT

Malaysia is surrounded by the sea, which brings on an important part of ocean energy research especially in the aspect of wave power. Malaysia has been engaged in the recent growth of renewable energy and has contributed to utilising ocean energy through wave energy converters (WEC). To assess the ocean energy needed for a WEC, research was conducted to measure the wave power potential near Mandi Darah Island. Mandi Darah Island was utilising a generator to power the village at the time, which deemed insufficient. WEC was discovered to be another approach to sustain energy supply for the entire village in order to address this difficulty. From June to December 2018, wave height and wave period data were collected and analysed with an Acoustic Doppler Current Profiler (ADCP) to evaluate wave power. The wave power potential was derived from the observation data using the wave power equation and determine the effects of the Northeast Monsoon (NEM), Southwest Monsoon (SWM) and inter-monsoon period, especially on the nearshore in northern Sabah. The wave power analysis from ADCP was compared with wave power from third-generation wave model (MRI3_S) during the same period. The maximum wave power potential during the NEM was far greater than during the SWM and the inter-monsoon season, while the MRI3_S overestimated it by 7%. Wind speed data during the monsoon was acquired through the same period with value 6.68 m/s during the NEM. The six-month study period revealed wide ranges in wave height and wave power potential during the NEM, with the highest wave power and wave height observed to be 1.57 kW/m and 0.49 m, respectively, during the period. From the comparison of wave power between ADCP and MRI3_S, the research successfully proved that

monsoon effect the wave power. The findings of this study can be conducted at any place to evaluate the potential of WEC project.

ABSTRAK

Malaysia dikelilingi oleh laut, yang membawa bahagian penting dalam penyelidikan tenaga lautan terutamanya dalam aspek kuasa ombak. Malaysia telah terlibat dalam pertumbuhan tenaga boleh diperbaharui baru-baru ini dan telah menyumbang kepada penggunaan tenaga lautan melalui penukar tenaga gelombang (WEC). Untuk menilai tenaga lautan yang diperlukan untuk WEC, penyelidikan telah dijalankan untuk mengukur potensi kuasa gelombang berhampiran Pulau Mandi Darah. Pulau Mandi Darah sedang menggunakan generator untuk membekalkan tenaga kepada kampung pada masa itu, yang dianggap tidak mencukupi. WEC didapati sebagai satu lagi pendekatan untuk mengekalkan bekalan tenaga untuk seluruh kampung bagi menangani kesukaran ini. Dari Jun hingga Disember 2018, data ketinggian gelombang dan tempoh gelombang telah dikumpul dan dianalisis dengan *Acoustic Doppler Current Profiler* (ADCP) untuk menilai kuasa gelombang. Potensi kuasa ombak diperoleh daripada data cerapan menggunakan persamaan kuasa ombak dan menentukan kesan Monsun Timur Laut, Monsun Barat Daya dan tempoh antara monsun, terutamanya di pantai berhampiran di utara Sabah. Analisis kuasa gelombang daripada ADCP dibandingkan dengan kuasa gelombang daripada model gelombang generasi ketiga (MRI3_S) dalam tempoh yang sama. Potensi kuasa gelombang maksimum semasa Monsun Barat Daya adalah jauh lebih besar daripada semasa Monsun Timur Laut dan musim antara monsun, manakala MRI3_S melebihkannya sebanyak 7%. Data kelajuan angin semasa monsun diperoleh melalui tempoh yang sama dengan nilai 6.68 m/s semasa Monsun Barat Daya. Tempoh kajian selama enam bulan mendedahkan julat luas dalam ketinggian gelombang dan potensi kuasa

gelombang semasa Monsun Barat Daya, dengan kuasa gelombang tertinggi dan ketinggian gelombang diperhatikan masing-masing ialah 1.57 kW/m dan 0.49 m, dalam tempoh tersebut. Daripada perbandingan kuasa gelombang antara ADCP dan MRI3_S, penyelidikan berjaya membuktikan bahawa monsun memberi kesan kepada kuasa gelombang. Dapatan kajian ini boleh dijalankan di mana-mana tempat untuk menilai potensi projek WEC.

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APPROVAL

The Examination Committee has met on **13 January 2022** to conduct the final examination of **Nur Syafiqa Aifa binti Shahrom** on his degree thesis entitled **Monsoon Effect to Wave Power for Wave Energy Converter in Mandi Darah Island, Malaysia.**

The committee recommends that the student be awarded the of Master of Science (Maritime Technology).

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Academic session	: March 2019

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

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LIST OF ABBREVIATIONS

ADCP	- Acoustic Doppler Current Profiler
AST	- Acoustic Surface Tracking
AWAC	- Acoustic Wave Acoustic Current
CS	- Cold Surge
DIA	- Discrete Interaction Approximation
ECMWF	- European Centre for Medium-Range Weather Forecast
EDIA	- Extended-DIA
EIA	- Environmental Impact Assessment
ENSO	- El Niño Southern Oscillation
GMT	- Greenwich Mean Time
IEA	- International Energy Agency
JMA	- Japan Meteorological Agency
MAE	- Mean Absolute Error
ME	- Mean Error
MMD	- Malaysian Meteorology Department
MRI	- Meteorological Research Institute
MRI3_S	- Third-Generation Ocean-Wind Wave Model Shallow Mode
MRI-III	- Third-Generation Ocean-Wind Wave Model
NCEP	- National Centers for Environmental Prediction
NEM	- Northeast Monsoon
NEMI	- Northeast Monsoon Index
PDF	- Probability Density Function

RDI	- RD Instruments
RMSE	- Root Mean Square Error
SI	- Scatter Index
SWM	- Southwest Monsoon
WAM	- WAve Model
WEC	- Wave Energy Converter
WSI	- Wind Steadiness Index

LIST OF SYMBOLS

F, f	- Frequency
°	- Degree
θ	- Direction
v	- Velocity
P	- Power
g	- Gravity acceleration
ρ	- Water specify weight
λ	- Wavelength
km^2	- Kilometres squared
km	- Kilometre
m	- Metre
H_{m0}	- Significant wave height
T_p	- Peak period
kW/m	- Kilowatt per metre
s	- Second
m/s	- Metres per second

CHAPTER 1

INTRODUCTION

1.1 Research Background

The monsoon is defined as a seasonal wind change accompanied by commensurate changes in precipitation caused by asymmetric heating of the land and sea (Geen et al., 2020). The monsoon also refers to the rainy season (Singh et al., 2014) as part of a seasonally changing pattern. Although the wind in Malaysia is generally weak and its direction is changeable, there are regular changes in wind blowing patterns (Azhar, 2011). The key features of the climate in Malaysia are uniform high humidity and rainfall throughout the day. Malaysia is also characterised as having uniform temperatures, light winds, high humidity and four monsoon phases. Four monsoon seasons can be distinguished: the Northeast Monsoon (NEM), the Southwest Monsoon (SWM) and two short-term inter-monsoon periods (Saadon et al., 1999). The NEM lasts from November to March, when the wind generally comes from the northeast of Malaysia (Muthurajah et al., 2021). The wind speed during the NEM is between 10 and 30 knots. Monsoon weather systems that develop in conjunction with cold air outbreaks from Siberia produce heavy rains that often cause severe flooding in many countries. The SWM phase lasts from May to September, when the wind generally comes from the southwest and the wind speed is below 15 knots (Muthurajah et al., 2021). The SWM is the driest season for most states except Sabah (B. W. K. Chong et al., 2020). Most states experience the minimum monthly rainfall at this time, which can be characterised by relatively stable atmospheric conditions in the equatorial region. The two short-term inter-monsoon periods last from the end of March until early May and from October until the middle of November (Geen et al., 2020). During these periods, the wind is slow in all directions. Between April and November, typhoons frequently form in the western Pacific and move westwards across the Philippines. Northeasterly winds in the northwest regions of Sabah and Sarawak strengthen and can reach 20 knots or more (B. W. K. Chong et al., 2020; Muthurajah et al., 2021). The wind created monsoon give effect to oceanographic.

Most oceans are influenced to a considerable extent by the monsoon system. In fact, every oceanographic environmental feature is influenced by the monsoon (J. Huang et al., 2018). Two basic approaches can be used to determine wave properties. The first is related to physics-based approaches (Teller et al., 2002), which use an ocean wave model, and the second is related to statistical approaches, which analyse wave data patterns using interpolation methods. In this research, a physics-based approach was used to investigate wave power in a coastal area because it offers an advantage of being able to depict water dynamics consistently across the entire domain, not only where it was calibrated (Vadyala et al., 2022). Wave power, a renewable energy source transported by ocean waves, is highly eco-friendly and easily accessible (Maulud & Saidi, 2012). Wave exploration has become a new topic of interest to researchers worldwide, including in Malaysia. Wave energy is related to solar energy in that the sun's energy is stored in the oceans as thermal energy and mechanical energy is stored in ocean waves (Pradhan., 2016) and provides a number of advantages over other renewable energy sources, including high availability compared to other resources, resource predictability, high power density, relatively high consumption factor, and low environmental and visual impacts (Am et al., 2010). Furthermore, as a result of substantial recent research in the production of wave energy converters, wave energy is approaching practicality as a commercial power source (Carballo et al., 2014).

In particular, wave energy is progressively seen as a significant and promising resource in Sabah, as the state is surrounded on three sides by sea: the South China Sea, the Sulu Sea and the Celebes Sea (Ejria et al., 2010). Geographically, Mandi Darah Island is a small island located in Kudat Division (Monaliza & Samsur, 2011), which is in the northern area of Borneo Island at latitude 6°55'44.52" N and longitude 117°20'2.37" E. Mandi Darah Island is exposed to monsoon winds, especially the Northeast Monsoon (NEM), and experiences slight storms in some seasons. This is because Mandi Darah Island is surrounded by the Sulu Sea. The Sulu Sea, like the Mediterranean, is an enclosed sea and is separated from the surrounding waters by a chain of islands: Borneo Island to the southwest; Palawan to the west; Busuanga and Mindoro to the north; Panay, Negros and Mindanao to the east and the Sulu Archipelago to the southeast (Ejria et al., 2010). The inhabitation of Mandi Darah Island is limited, with about 35 houses constructed on the beach and where between 40 and 75 people remain. Due to the lack of infrastructure, wave energy is used to supply electricity to the villages and the army camp situated on Mandi Darah Island.

(a) Waves have certain characteristics and energy densities in different locations (Melikoglu, 2018). The evaluation of wave energy resources is not only a basic