MORPHODYNAMICS STUDY OF COASTLINE REGION USING SMOOTHED PARTICLE HYDRODYNAMICS AND PARTICLE IMAGE VELOCIMETRY

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UNIVERSITI SAINS MALAYSIA

2020

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by

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Thesis submitted in fulfilment of the requirements for the degree of Master of Science

January 2020

ACKNOWLEDGEMENT

Alhamdulillah and praise to Allah the Al-Mighty as with His blessings, I was able to finish writing my thesis and my research. Without His guidance, I might not able to complete writing this thesis on time. I am truly grateful that I have managed to finish it. Firstly, I would like to express deepest appreciations to my lovely parents: Azman Bin Asmoi and Fai’zah Binti Suhod, and my siblings for their prayers and continuous support throughout my life.

I want to express my deeply gratitude to my supervisor, Dr. Mohamad Aizat Bin Abas for giving me endless guidance throughout the completion of this research. Working with him even in this period has made me realize that no matter how high our academic level is, there is always room for more and for improvement. Regarding this project, he has guided me on the steps I should take in order to achieve the objectives. Also, a big thanks to Dr. Norizham Bin Abdul Razak, he has taught, guide and help me during experiment testing.

I also want to say thank En. Zulkhairi, En. Mahmud and all my friends (Hafiz, Hazwan, Haziq Abu Bakar, Faiz and Haziq Jumaat) in providing me their assistance throughout my study. Thank you very much, without your help I would not able to do it on my own. Again, I am truly grateful that this research is completed. I hope everything will end well for everyone. Thank You.

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LIST OF SYMBOLS

L	Characteristic length
L_0	Deep-water wavelength
ξ	Iribarren number
Fn_L	Froude number
ρ	Density of the fluid
v	Velocity of the fluid flow
p	Fluid pressure
μ	Apparent viscosity
μ_p	Viscosity of the suspending fluid
$\dot{\gamma}$	Shear rate
$\dot{\gamma}_c$	Critical shear rate
d_f	Fluid depth
f	Frequency
α	Slope angle
ρ^s	Density of the structure
$\overline{m}_T$	Average total mass
$\overline{m}_{T_{loss}}$	Average total mass loss
$\bar{v}_f$	Average velocity of fluid
δ	Delta SPH
Δx	Particles displacement
Δt	Time interval between the two consecutive images
σ_u	Standard deviation of velocity

LIST OF ABBREVIATIONS

3D	3-dimensional
2D	2-dimensional
SPH	Smooth Particle Hydrodynamics
WCSPH	weakly compressible SPH
CAD	Computer Aided Design
CFD	Computational Fluid Dynamic
CNC	Computer Numerical Control
Dp	Distance Particle
PIV	Particle Image Velocimetry
GPU	Graphics Processing Unit
Fps	Frame per second
FEM	Finite Element Method
FVM	Finite Volume Method
LBM	Lattice Boltzmann method
EOS	Equation of State
LED	Light Emitting Diode
CFL	Courant–Friedrichs–Lewy
PDE	Partial Differential Equation
HBP	Herschel-Bulkley-Papanastasiou
MPPD	Majlis Perbandaran Port Dickson
TNB	Tenaga Nasional Berhad

KAJIAN MORPHODINAMIK DI PERSISIRAN PANTAI MENGGUNAKAN KAEDAH ZARAH HIDRODINAMIK LANCAR DAN GAMBARAN HALAJU ZARAH

ABSTRAK

Hakisan merupakan salah satu fenomena yang berlaku pada kawasan pantai yang boleh menyebabkan kegagalan pada struktur binaan yang berhampiran dengan kawasan pantai. Kajian terhadap hakisan sangat penting dalam mengatasi masalah hakisan yang berlaku berhampiran Kawasan pantai. Kebanyakkan penyelidik hanya menggunakan pendekatan 2-dimensi (2D) untuk menyelesaikan masalah cecair-enapan yang boleh terlebih memudahkan dan mengurangkan kerumitan topografi kawasan pantai. Simulasi di antara dua fasa iaitu cecair dan enapan model berangka menggunakan berasaskan Zarah Hidrodinamik Lancar (SPH) untuk aplikasi pada kawasan pantai. Pada permulaan, kajian awal telah diuji sebelum diaplikasi pada kes sebenar. Kod SPH telah dibina melalui perumusan daripada Monaghan yang telah dimodifikasi mengikut keadaan model yang diperlukan untuk diselesaikan. Kod tersebut kemudiannya dihitung dengan mengunakan Unit Pemprosesan Grafik (GPU), Nvidia Quadro P4000 dengan 14 teras multipemproses. Kesan hakisan telah diselidik dalam kajian ini melalui perumusan pengankutan enapan berpandukan model Herschel-Bulkley-Papanatasiou (HBP). Model awal telah menggunakan gelombang sinus dengan variasi frekuensi yang telah diaplikasikan pada sempadan untuk menghasilkan gelombang air laut yang kemudiannya boleh mengakibatkan enapan terhakis atau terakresi pada garis pantai. Kajian awal tersebut dihitung secara berangka dengan mengunakan simulasi SPH dan kemudian telah mengesahkan menggunakan data eksperimen PIV. Perbandingan antara simulasi SPH dan eksperimen PIV menunjukkan penerimaan yang baik pada magnitud halaju maksimum dan kontur dengan purata perbezaan peratusan sebanyak 5%. Lebih daripada itu, hubung kait antara dua nombor tak berdimensi iaitu nombor Iribarren dan Froude telah dihitung dengan memanipulasikan gelombang frekuensi-frekuensi dan sudut kecerunan untuk menentukan jenis pemecah ombak. Kawasan kajian telah dipilih berhampiran dengan pusat janakuasa Tunku Jaafar, Tenaga Nasional Berhad (TNB) untuk mengenal pasti hentaman air laut terhadap pengangkutan enapan. Berpandukan kajian sebenar, Kawasan yang terpilih telah dianalisis bertujuan untuk mengurangkan kerumitan kajian dan secara terus dapat menyelesaikan masalah pengangkutan enapan. Hasil dapatan mendapati, kawasan C mengalami pengangkutan enapan yang tinggi untuk kajian gelombang malar berbanding dengan kawasan A dan B. Akresi pada kawasan C adalah 904.01 kg pada 90 s manakala hakisan jisim adalah 906.24 kg pada 91 s. Berbanding dengan region B, akresi jisim adalah 902.24 kg pada 90 s manakala hakisan jisim adalah 903.24 kg pada 91 s. Tambahan pula, kawasan A terakresi dengan jisim sebanyak 788.51 kg pada masa 24 s manakala menghakis dengan jisim sebanyak 790.01 kg pada masa 23 s. Hasil dapatan pada kawasan A, B and C diramal dalam tempoh 10 tahun mengunakan pemadanan keluk Fourier dengan order 8 untuk cerapan arah aliran pengangkutan enapan. Ramalan tersebut mendapati, kawasan C juga mengalami pengangkutan enapan yang tinggi dengan akresi jisim sebanyak 7343.54 kg pada tahun 1.37 untuk gelombang malar dan 876.44 kg pada tahun ke 10 untuk kajian surut.

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ABSTRACT

Scour is the one of phenomena that occurs at coastal area which can cause catastrophic failure to structure near to the coastal area. The study of the scour in the coastal area is important in order to overcome the erosion occur near to coastal area. There is limited study which simulates liquid-sediment at coastal area. Most of researcher using 2-dimensional (2D) problem to solve liquid-sediment problem which will over simplify and reduce the complexity of the topography of coastal area. Consequently, this thesis simulates a 3D two-phase liquid-sediment numerical model by using particle based Smooth Particle Hydrodynamics (SPH) for application at coastal area. Initially, a preliminary study has been tested before application to real case. The SPH code is constructed based on formulation from Monaghan that is modified according to the desired model to be solved. The code is then computed by using single Graphic Processing Unit (GPU), Nvidia Quadro P4000 with 14 cores multiprocessors. The effect of scouring is investigated in this research through the formulation of sediment transport based on Herschel-Bulkley-Papanastasiou (HBP) model. An early model that used sine wave with varying frequencies are applied to the boundary to create sea wave effect that will then cause either sediment erosion or accretion at the coastline. The preliminary study of liquid-sediment interactions is computed numerically using SPH simulation which is then validated using PIV experimental data. The comparisons between SPH simulation and PIV experimental showed good agreement in the maximum velocity magnitude and contours with average percentage difference of 5%. Moreover, the correlation between two dimensionless numbers which are Iribarren and

Froude number have also been calculated by manipulating frequencies of wave and slope angles to determine the type of wave breaker. The research area was chosen near to Tenaga Nasional Berhad (TNB) Tuanku Jaafar power station to analyse the impact of sea wave to sediment transport. Based on real case study, the selected regions were analysed in order to reduce the complexity of the studies and directly captured the sediment transport. Based on the findings, region C experienced high sediment transport for constant wave study as compared to region A and B. The accretion at region C is 904.01 kg at 90 s while the mass erosion is 906.24 kg at 91 s. Compared to region B, the mass accretion is 902.24 kg at 90 s while the mass erosion is 903.24 kg at 91 s. Additionally, region A accreted a mass of 788.51 kg at a time of 24 s while eroding with a mass of 790.01 kg at a time of 23 s. The results for region A, B and C have been forecasted for the period of 10 years by using Fourier fitting curve with 8^{th} order to observe the sediment transport trend. The prediction found that region C also experienced highest sediment transport with accretion mass of 7343.54 kg in 1.37 year for constant wave study and 876.44 kg at year 10 for low tide study.

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter will discuss research background, research scope and the thesis outline. The problem statements and objectives are then presented in section 1.3 while the research scope will be discussed in section 1.4. Section 1.5 will then present the outline of the thesis.

1.2 Research Background

1.2.1 Coastal Zones

Coastal zones are dynamic interface between land and water which are subjected to frequent natural hazards such as flooding, storm impacts, coastal erosion and tsunami inundation. The nearshore or in other term called littoral zone is the most active environment of the coast and one in which constant mobility of sediment is observed. The migration of material in this zone depends mainly on three factors such as the nature of material available for transport, orientation of the coast and the angle of wave approaches. These obliquely incident breaking waves generated longshore current which plays an important role in transporting sediment in the littoral zone and the current velocity varies, reaching a maximum value close to the wave-breaking point.

The longshore transport is a major contribution which moves the sediment along the coast which particularly occur in the surf zone and along the beaches. Sediment moves along the coast until it reaches a place of permanent removal from the transportation system into a beach, dune, tidal delta or offshore. This wave-induced sediment transport causes changes in beach morphology due to cross-shore and material transported phenomena called littoral drift. The impacts of human activities such as infrastructure development, intensive agricultural expansion and coastal development