STRUCTURAL ANALYSIS OF FLOATING OFFSHORE REMOTE TERMINAL
FOR DEEP SEA FISHING

ASMAWI BIN ABDUL MALIK

A thesis submitted in the fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Mechanical Engineering)

School of Mechanical Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

DECEMBER 2018
DEDICATION

"I can't change the direction of the wind, but I can adjust my sails to always reach my destination".

To the one and only Azura Ahmad Radzi... "your love is boundary-less"! You gives me strength and courage. You make me want to be a better man in your life.

To my son Aqiff Nuqman ...you kept me going no matter what.

To my daughter Azalea Eiman told ..."they tried to bury us, they didn't know we were seeds. We falls seven times, stand up eight".

To Aisyea Zayyan your words inspired me "good job, mate! It's challengin' work, outta doors. I knew you'd hit the target".

To my father, mother, father in law and mother in law...thank you very much.

And last but not least my mastermind; Associate Professor Dr. Mohd Zamani b. Ahmad (supervisor), "years teach us more than books and our relationship is a magical connection! Allah SWT shuts one door He opens another".

...awie 2018...Good onya, mate!
ACKNOWLEDGEMENT

In the name of Allah, the Most Benevolent, the most Merciful. First of all I wish to record immeasurable gratitude and thankfulness to the One and The Almighty Creator, the Lord and Sustained of the universe, and the Mankind in particular. It is only through His mercy and help that this work could be completed and it is ardently desired that this little effort be accepted by Him to be of some service to the cause of humanity.

I am grateful and would like to express my sincere gratitude to Associate Professor Dr. Mohd. Zamani bin Ahmad for his invaluable guidance, unlimited communication ways, never failed to response to my silly mistakes, fetch me up at Petron Seri Puteri on every morning I arrived in Skudai, continuous encouragement and constant support in making this research possible. The man who brings me to the way home and know Him. I also would like to express very special thanks to Professor Dr. Jamal Idris and Mrs. Nazila for their indirect help to thesis writing. I would like to express sincere gratitude to Universiti Teknologi Malaysia for providing research fund (IRPA No.: 03-01-02-SF0329) and also thanks to the Department of Automotive, Aeronautic and Offshore Engineering, Faculty of Mechanical, Universiti Teknologi Malaysia (UTM). My sincere thanks go to all the staff of Institut Sultan Iskandar UTM, and made my stay at Deputy Director Office pleasant and unforgettable. Dr Vivian, Dr Ahmad Faizal, Ir. Zamari, Dr. Sunarsih, Dr. Al-Syafiq, Hanani, Ismail, Nurain, Azrie Husainy and many more. Time spends in Classic Bundle in Kulai Town was pleasing and my best friend in JB, Mr. Nazrin Noh for the whole hospitality.

I acknowledge my sincere indebtedness and gratitude to my family for their love, dream and sacrifice throughout my life. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this study.
ABSTRACT

Productivity of offshore fishing can increase if there are offshore terminals providing services such as fish unloading and repair of crafts and gears to the fishing fleets. This research proposed the use of FORT (fishing offshore remote terminal) as a very large floating structure (VLFS). Structural analysis is key in the design of VLFS. The research developed an adaptable framework to simulate FORT’s hydroelastic interaction and motion using Newtonian’s harmonic method. The governing partial differential equation of motion including the effect of deformation and torsional inertia was expressed in a dimensionless form. A finite difference algorithm was employed to transform the differential equations into linear algebraic equations. Linear and nonlinear dynamic responses was obtained using Hamilton principle with modal superposition coupled with finite element methods. Sensitivity tests are performed to quantify the effect of changing numerical parameter. Variety of plate models is investigated. Techno-economic model is also developed. The solution for a selected load condition has been presented. The result on hydroelastic response for several wavelength $q$ (0.12, 0.23 and 0.43) to structural length ratios (1:1, 2:1 and 4:1) revealed longish FORT experiences higher elastic deformations as compare a square FORT for higher wavelength. In continuous springing freeboard reaction, the safe margin decreases from 4m to below 2m at higher wavelength ratio. At small wave length the hydroelastic response is the smallest for the lower ratio orientation. It is found that hydroelastic response is minimal as aspect ratio close to 1. Resultant stress on FORT stiffness when aspect ratio approaches 1 amplifies response amplitude by 35%. Sensitivity test indicates, for full load condition, larger structure will experience larger deformation stress (0.928 MN/m$^2$ for 250m, 1.035MN/m$^2$ for 500m, 1.035MN/m$^2$ for 1000m). Permanent plastic deformation starts occurring at 20° and worsen at 45° causing higher shear force and moment. Maximum torsional force exceeds 51.25N/m$^2$. For long crest of 0.43 maximum torsional deflection measured are 250m (19.32N/m$^2$ for 250m), 500m (27.55N/m$^2$ for 500m), and 1000m (28.63N/m$^2$ for 1000m). Net present value of FORT is NPV of 146mil, internal rate of return of 22.94% over 15 years. FORT as a new concept is thus techno economically feasible. The analytical model developed is a comprehensive tool for FORT designers.
ABSTRAK

Produktiviti perikanan luar pantai boleh ditingkatkan jika ada terminal luar pantai yang menyediakan khidmat seperti memungah ikan, pembalakan bot dan peralatan kepada armada penangkap ikan. Kajian ini mencadangkan penggunaan FORT (terminal penangkapan ikan jauh luar pantai) sebagai struktur terapung yang sangat besar (VLFS). Analisis struktur adalah utama dalam merekabentuk VLFS. Kajian ini membangunkan kerangka boleh sesuai untuk mensimulasi interaksi hidroelastik dan gerakan FORT dengan kaedah harmonik Newtonian. Persamaan gerakan pembezaan separa sebagai penentu kepada kesan ubah bentuk dan inersia kilasan telah dinyatakan dalam bentuk tanpa dimensi. Algoritma perbezaan terhingga digunakan untuk mengubah persamaan kebezaan ke persamaan algebra linear. Tindak balas linear dan bukan linear diperolehi dengan menggunakan prinsip Hamilton dengan superposisi mod dan kaedah unsur tak terhingga. Ujian kepekaan dilakukan bagi mengukur kesan perubahan parameter berangka. Pelbagai model plat dikaji. Model teknokonomi juga dibangunkan. Penyelesaian bagi keadaan beban penuh telah dibentangkan. Keputusan tindak balas hidroelastik bagi beberapa gelombang panjang, $p$ (0.12, 0.23 dan 0.43) pada nisbah panjang struktural (1:1, 2:1, dan 4:1) menunjukkan FORT yang panjang mengalami ubah bentuk anjali yang lebih tinggi berbanding FORT segiempat pada gelombang yang lebih tinggi. Bagi tindak balas lambung bebas pegas berterusan margin keselamatan menurun dari 4m ke bawah 2m bagi nisbah panjang gelombang yang lebih tinggi. Bagi panjang gelombang yang kecil tindak balas hidroelastik adalah terkecil untuk orientasi bernisbah yang lebih rendah. Juga ditemui tindak balas hidroelastik adalah minimum bila nisbah aspek menghampiri 1. Tekanan paduan pada kekakuan FORT bila nisbah aspek menghampiri 1 menguatkan amplitud tindak balas sebanyak 35%. Ujian kepekaan menunjukkan bagi keadaan beban penuh, struktur yang lebih besar akan mengalami tekanan perubahan bentuk yang lebih besar ;0.928 MN/m$^2$ (250m), 1.035MN/m$^2$ (500m) dan 1.035MN/m$^2$ (1000m). Perubahan bentuk plastik kekal mula pada 20° dan bertambah buruk pada 45° dan menyebabkan daya ricih dan momen yang tinggi. Daya kilasan maksimum melebihi 51.25N/m$^2$. Bagi puncak maksimum 0.43 pesongan kilasan maksimum ialah 19.32N/m$^2$ (250m), 27.55N/m$^2$ (500m) dan 28.63N/m$^2$ (1000m). Nilai masa kini FORT ialah RM 146juta dan kadar pulangan dalaman 22.94% untuk tempoh 15 tahun. Dengan ini FORT sebagai konsep baru adalah, secara tekno ekonomik boleh dilaksanakan. Model analitikal yang dibangunkan adalah alat menyeluruh bagi pereka FORT.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td>ii</td>
<td></td>
</tr>
<tr>
<td>DEDICATION</td>
<td>iii</td>
<td></td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>iv</td>
<td></td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>v</td>
<td></td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>vi</td>
<td></td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>vii</td>
<td></td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xi</td>
<td></td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xiv</td>
<td></td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xviii</td>
<td></td>
</tr>
<tr>
<td>LIST OF SYMBOLS</td>
<td>xxi</td>
<td></td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>xxv</td>
<td></td>
</tr>
</tbody>
</table>

1 INTRODUCTION 1
1.1 Introduction 1
1.2 Research Background 2
1.3 Problem Statement 6
1.4 Research Objectives 7
1.5 Floating Offshore Remote Terminal (FORT) 8
1.6 Research Approach and Scope 8
1.7 Thesis Motivation 9
1.8 Research Significance 9
1.8 Overview of Thesis Structure 10

2 LITERATURE STUDIES 11
2.1 Introduction 11
2.2 Basic Structural Hydroelastic Model 12
2.3 Hydroelastic Characteristics 15
2.4 Plate Theory and the Governing Equation 16
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 Structure Deformation</td>
<td>20</td>
</tr>
<tr>
<td>2.6 Harmonic Motion</td>
<td>27</td>
</tr>
<tr>
<td>2.7 Solid Plate Stresses</td>
<td>29</td>
</tr>
<tr>
<td>2.8 Structure Size Effect and Slenderness Ratio</td>
<td>34</td>
</tr>
<tr>
<td>2.9 Water Motions and Governing Equations</td>
<td>36</td>
</tr>
<tr>
<td>2.10 Mathematical Modelling</td>
<td>38</td>
</tr>
<tr>
<td>2.11 Hamilton’s Principle</td>
<td>40</td>
</tr>
<tr>
<td>2.12 Finite Element Method</td>
<td>43</td>
</tr>
<tr>
<td>2.13 Element Size and Component</td>
<td>44</td>
</tr>
<tr>
<td>2.14 Sensitivity Analysis</td>
<td>45</td>
</tr>
<tr>
<td>2.15 Methods on Station keeping for Floating Structure</td>
<td>46</td>
</tr>
<tr>
<td>2.16 Seakeeping</td>
<td>47</td>
</tr>
<tr>
<td>2.17 Other Requirement for Fishing Terminal</td>
<td>49</td>
</tr>
<tr>
<td>2.18 Methods on Economic Evaluation for Floating Structure</td>
<td>49</td>
</tr>
<tr>
<td>3 RESEARCH METHODOLOGY</td>
<td>50</td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>50</td>
</tr>
<tr>
<td>3.2 Research Methodology Flowchart</td>
<td>50</td>
</tr>
<tr>
<td>3.3 Identification of FORT Properties and Variables</td>
<td>52</td>
</tr>
<tr>
<td>3.4 Optimization of Principal Dimensional</td>
<td>55</td>
</tr>
<tr>
<td>3.5 Input Parameters</td>
<td>58</td>
</tr>
<tr>
<td>3.6 Development of FORT Algorithm</td>
<td>77</td>
</tr>
<tr>
<td>3.6.1 Linear Hydroelastic – Structural Algorithm</td>
<td>78</td>
</tr>
<tr>
<td>3.6.2 Development of Non-Linear Hydroelastic – Structural Algorithm</td>
<td>91</td>
</tr>
<tr>
<td>3.6.3 Economic Algorithm Development</td>
<td>97</td>
</tr>
<tr>
<td>3.7 Verification of FORT Model</td>
<td>104</td>
</tr>
<tr>
<td>3.8 Model Test Preparation and Particulars</td>
<td>107</td>
</tr>
<tr>
<td>3.9 Simulation Condition</td>
<td>108</td>
</tr>
<tr>
<td>3.10 Description of Data Test Analysis</td>
<td>108</td>
</tr>
</tbody>
</table>
4 RESULTS

4.1 Introduction 113
4.2 Geometry and Mesh 114
4.3 Linear Assessment 116
  4.3.1 Natural Amplitude 116
  4.3.2 Energy Distribution 118
  4.3.3 Freeboard Movement 119
  4.3.4 Displacement Response 120
  4.3.5 Results of Strength Analysis 121
  4.3.6 Hydroelastic Response 125
4.4 Nonlinear Assessment 126
  4.4.1 Hydroelastic - Torsional Analysis 127
  4.4.2 Decay Analysis 134
  4.4.3 Motion Analysis 135
  4.4.4 Impact Motion Analysis 136
  4.4.5 Results of Catenary Mooring Calculation 137
  4.4.6 Results of Seakeeping Analysis 141
  4.4.7 Results of Sensitivity Analysis 145
4.5 Results of Economic Evaluation 147
  4.5.1 FORT Economic Model 147
  4.5.2 Results of Economic Viability Evaluation 147

5 DISCUSSION 152

5.1 Introduction 152
5.2 Development of FORT as a Reliable Satellite Model 153
5.3 Discussion on Results and Finding of the Research 154
  5.3.1 Reliability of FORT Main Parameters 155
  5.3.2 Wave Load Stability of FORT 158
| 4.22 | Average 300 Metric Tonne per Day for FORT 500m | 150 |
| 4.23 | Average 150 Metric Tonne per Day for FORT 1000m | 151 |
| 4.24 | Average 300 Metric Tonne per Day for FORT 1000m | 151 |
| 5.1  | FORT Area Size | 156 |
| 5.2  | FORT Building 1 – Level 1 Area Size | 157 |
| 5.3  | FORT Building 1 – Level 2 Area Size | 157 |
| 5.4  | FORT Building 1 – Level 3 Area Size | 157 |
| 5.5  | FORT Building 2 – Area Size | 157 |
| 5.6  | Summary of Economic Appraisal and Projection of 150 MT/day | 167 |
| 5.7  | Summary of Economic Appraisal and Projection of 300 MT/day | 168 |
3.24 Technical Validation Input Parameters 107
3.25 Waves Input Parameters 108
3.26 VLFS, FFSF and FORT Input Parameters 112
4.1 Value of Deflection & Maximum Stress Amidships 122
4.2 Summary of SA on 250m with 100% Loading 123
4.3 Summary of SA on 500 m with 100% Loading 123
4.4 Summary of SA on 1000 m with 100% Loading 124
4.5 Value of Area and Moment 124
4.6 Summary of hydroelastic – torsional analysis on 250m at 0.12 crest ~ Slenderness (1:1) 131
4.7 Summary of hydroelastic – torsional on 500m at 0.12 crest ~ Slenderness (2:1) 131
4.8 Summary of hydroelastic – torsional on 1000m at 0.12 crest Slenderness (4:1) 131
4.9 Summary of hydroelastic – torsional analysis on 250m at 0.23 mid crest ~ Slenderness (1:1) 132
4.10 Summary of hydroelastic – torsional analysis on 500m at 0.23 crest Slenderness (2:1) 132
4.11 Summary of hydroelastic – torsional analysis on 1000m at 0.23 crest Slenderness (4:1) 132
4.12 Summary of hydroelastic – torsional analysis on 250m at 0.43 crest Slenderness (1:1) 133
4.13 Summary of hydroelastic – torsional analysis on 500m at 0.43 crest Slenderness (2:1) 133
4.14 Summary of hydroelastic – torsional analysis on 1000m at 0.43 crest Slenderness (4:1) 133
4.15 Time to Heave Analysis 138
4.16 Time to Roll Analysis 139
4.17 Time to Pitch Analysis 140
4.18 Result of analysis data 141
4.19 Average 150 Metric Tonne per Day for FORT 250m 149
4.20 Average 300 Metric Tonne per Day for FORT 250m 149
4.21 Average 150 Metric Tonne per Day for FORT 500m 150
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.22</td>
<td>Average 300 Metric Tonne per Day for FORT 500m</td>
<td>150</td>
</tr>
<tr>
<td>4.23</td>
<td>Average 150 Metric Tonne per Day for FORT 1000m</td>
<td>151</td>
</tr>
<tr>
<td>4.24</td>
<td>Average 300 Metric Tonne per Day for FORT 1000m</td>
<td>151</td>
</tr>
<tr>
<td>5.1</td>
<td>FORT Area Size</td>
<td>156</td>
</tr>
<tr>
<td>5.2</td>
<td>FORT Building 1 – Level 1 Area Size</td>
<td>157</td>
</tr>
<tr>
<td>5.3</td>
<td>FORT Building 1 – Level 2 Area Size</td>
<td>157</td>
</tr>
<tr>
<td>5.4</td>
<td>FORT Building 1 – Level 3 Area Size</td>
<td>157</td>
</tr>
<tr>
<td>5.5</td>
<td>FORT Building 2 – Area Size</td>
<td>157</td>
</tr>
<tr>
<td>5.6</td>
<td>Summary of Economic Appraisal and Projection of 150 MT/day</td>
<td>167</td>
</tr>
<tr>
<td>5.7</td>
<td>Summary of Economic Appraisal and Projection of 300 MT/day</td>
<td>168</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>FORT Building 1 – Level 1 Area Size</td>
<td>3</td>
</tr>
<tr>
<td>1.2</td>
<td>Mapping of global response of floating structures (Suzuki, 2006)</td>
<td>3</td>
</tr>
<tr>
<td>2.1</td>
<td>Fluid-structure global interaction model</td>
<td>13</td>
</tr>
<tr>
<td>2.2</td>
<td>Micro plate and strip portion for the floating structure (Wang and Tay, 2010)</td>
<td>13</td>
</tr>
<tr>
<td>2.3</td>
<td>Fluid-structure coupling (Gao et al., 2013)</td>
<td>14</td>
</tr>
<tr>
<td>2.4</td>
<td>Structure frame illustration</td>
<td>14</td>
</tr>
<tr>
<td>2.5</td>
<td>Plate axis</td>
<td>20</td>
</tr>
<tr>
<td>2.6</td>
<td>Plate torsion</td>
<td>20</td>
</tr>
<tr>
<td>2.7</td>
<td>Cartesian coordinates system on plate</td>
<td>21</td>
</tr>
<tr>
<td>2.8</td>
<td>Forces and Torsion moment acting on plate</td>
<td>22</td>
</tr>
<tr>
<td>2.9</td>
<td>Plate shear force and twisting moment</td>
<td>24</td>
</tr>
<tr>
<td>2.10</td>
<td>Plate principal stresses</td>
<td>29</td>
</tr>
<tr>
<td>2.11</td>
<td>Plate forces</td>
<td>30</td>
</tr>
<tr>
<td>2.12</td>
<td>Mesh used for discretizing the structure</td>
<td>44</td>
</tr>
<tr>
<td>2.13</td>
<td>Mesh elements</td>
<td>45</td>
</tr>
<tr>
<td>2.14</td>
<td>Motions of a large concrete platform</td>
<td>47</td>
</tr>
<tr>
<td>2.15</td>
<td>Motion models based on seakeeping theory</td>
<td>47</td>
</tr>
<tr>
<td>2.16</td>
<td>Wave theory selection chart</td>
<td>48</td>
</tr>
<tr>
<td>3.1</td>
<td>Research Methodology Flowchart</td>
<td>51</td>
</tr>
<tr>
<td>3.2</td>
<td>FORT’s proposed location</td>
<td>54</td>
</tr>
<tr>
<td>3.3</td>
<td>Port and harbour location (Lundin Petroleum, 2014)</td>
<td>54</td>
</tr>
<tr>
<td>3.4</td>
<td>Optimal length illustration</td>
<td>58</td>
</tr>
<tr>
<td>3.5</td>
<td>FORT Size Plotted</td>
<td>58</td>
</tr>
<tr>
<td>3.6</td>
<td>Prediction domain in (a) East China Sea; (b) South China Sea</td>
<td>60</td>
</tr>
</tbody>
</table>
4.13 FORT displacement model in wave height measurement 121
4.14 FORT bending moment tabulation at 100% loading 122
4.15 FORT (250m) hydroelastic response in various wave length 125
4.16 FORT (500m) hydroelastic response in various wave length 125
4.17 FORT (1000m) hydroelastic response in various wave length 126
4.18 Hydroelastic – torsional effects of structure at 0% loading 127
4.19 Hydroelastic – torsional effects of structure at 100% loading 127
4.20 Hydroelastic – torsional effects on centreline deflection at 100m water depth for (a) 250m, (b) 500m and (c) 1000m 128
4.21 Inclination Angle vs Torsional Moment at different slenderness value 129
4.22 Hydroelastic – torsional effects Model comparison to Yago and Endo (1996) (Yago and Endo, 1996) 130
4.23 Decay analysis without wind 134
4.24 Decay analysis with wind 134
4.25 Heave motion in time 135
4.26 Pitch motion in time 135
4.27 The time history comparison of structural displacement at 45° due to impact load under short wave effect. 136
4.28 The time history comparison of structural displacement at 45° due to impact load under mid wave effect. 136
4.29 The time history comparison of structural displacement at 45° due to impact load under long wave effect. 136
4.30 FORT 4-mooring line arrangements 137
4.31 FORT Base – Wave effects in 600s of short wave 142
4.32 FORT Base – Wave effects in 600s of long wave 142
4.33 FORT Spectra Analysis of Short Waves 143
4.34 FORT Spectra Analysis of Long Waves 144
4.35 FORT Torsional Sensitivity Analysis of Slenderness Ratio: 1 145
4.36 FORT Torsional Sensitivity Analysis of Slenderness Ratio: 2 146
<table>
<thead>
<tr>
<th>4.37</th>
<th>FORT Torsional Sensitivity Analysis of Slenderness Ratio: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.39</td>
<td>The results of FORT’s economic verification</td>
</tr>
<tr>
<td>5.1</td>
<td>Routine 1: One-week cycle</td>
</tr>
<tr>
<td>5.2</td>
<td>Routine 2: Multi-week cycle</td>
</tr>
<tr>
<td>5.3</td>
<td>Present value versus Operational Year</td>
</tr>
<tr>
<td>5.4</td>
<td>Vessel Travelling Time (Tn) and Distance (Ln) from Shoreline to Fishing Ground</td>
</tr>
</tbody>
</table>
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_C$</td>
<td>Operational Cost / Expenditure</td>
</tr>
<tr>
<td>$A_I$</td>
<td>Income</td>
</tr>
<tr>
<td>$A_{IM1}$</td>
<td>Cluster 1</td>
</tr>
<tr>
<td>$A_{IM2}$</td>
<td>Cluster 2</td>
</tr>
<tr>
<td>$A_{IM3}$</td>
<td>Cluster 3</td>
</tr>
<tr>
<td>$A_{IM4}$</td>
<td>Cluster 4</td>
</tr>
<tr>
<td>$A_{IM5}$</td>
<td>Cluster 5</td>
</tr>
<tr>
<td>API</td>
<td>American Petroleum Institute</td>
</tr>
<tr>
<td>CAPEX</td>
<td>initial and capital expenditure</td>
</tr>
<tr>
<td>DCG</td>
<td>Clean &amp; Green</td>
</tr>
<tr>
<td>DL</td>
<td>Legal Requirement</td>
</tr>
<tr>
<td>DNV</td>
<td>Det Norski Veritas</td>
</tr>
<tr>
<td>DOFM</td>
<td>Department of Fishery, Malaysia</td>
</tr>
<tr>
<td>DR</td>
<td>Remedy</td>
</tr>
<tr>
<td>DW</td>
<td>Wrecking</td>
</tr>
<tr>
<td>DWL</td>
<td>Designed Water Line</td>
</tr>
<tr>
<td>EEZ</td>
<td>Exclusive and Economic Zones</td>
</tr>
<tr>
<td>EN</td>
<td>Equipment number</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>FORT</td>
<td>Floating offshore remote terminal</td>
</tr>
<tr>
<td>GA</td>
<td>General arrangement</td>
</tr>
<tr>
<td>IACS</td>
<td>International Association of Classification Societies</td>
</tr>
<tr>
<td>IRR</td>
<td>Internal Rate of Return</td>
</tr>
<tr>
<td>LCC</td>
<td>life cycle cost</td>
</tr>
<tr>
<td>LCCA</td>
<td>life cycle cost analysis</td>
</tr>
<tr>
<td>LKIM</td>
<td>Lembaga Kemajuan Ikan Malaysia</td>
</tr>
</tbody>
</table>
M1FT - Fresh fish trades
M1LU - Loading and unloading
M1PF - Processed/ Frozen Fish
M1TS - Storage
M2ES - Emergency / Salvage
M2MA - Fishing Gears
M2MS - Vessel Modification
M2R - Vessel Maintenance & Repair
M3A - Accommodation
M3AR - Area Rental & Shops
M3FB - Cafeteria for Foods & Beverage
M3T - Tourism
M4B - Vessel Bunkerage
M4H - Vessel household items
M4HC - Health Care
M4L - Vessel Anchorage
M5P - Entrance Fee & Membership
M5V - Vessel Entry
MOF2S - Mega offshore floating structures
MS - Sell Structure
MSM - System, Machineries, Outfitting & Tools
NPV - Net present value
OD - Concept and Details Design
O_H1 - Overhead 1 -Administrative
O_H2 - Overhead 2 -Crew
O_H3 - Overhead 3 -Utilities
O_H4 - Overhead 4 -Onboard
O_H5 - Overhead 5 - Disposal
OID - Infrastructure Development
OL - Legal requirement
OMS - Main system and machineries
OPEX - operating expense
OSS - Supporting system and tools
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OT</td>
<td>Transportation</td>
</tr>
<tr>
<td>PP</td>
<td>Payback Periods</td>
</tr>
<tr>
<td>ROI</td>
<td>return on investment</td>
</tr>
<tr>
<td>SA</td>
<td>Administration</td>
</tr>
<tr>
<td>SB</td>
<td>Crew Benefits</td>
</tr>
<tr>
<td>SC</td>
<td>Communication</td>
</tr>
<tr>
<td>SCI</td>
<td>Consultation for Improvement</td>
</tr>
<tr>
<td>SCM</td>
<td>Crew Mobilization</td>
</tr>
<tr>
<td>SCS</td>
<td>Security</td>
</tr>
<tr>
<td>SFS</td>
<td>Water</td>
</tr>
<tr>
<td>SL</td>
<td>Legal &amp; Fees</td>
</tr>
<tr>
<td>SM</td>
<td>External Administrative</td>
</tr>
<tr>
<td>SML</td>
<td>Mortgage / Loan / Insurance</td>
</tr>
<tr>
<td>SP</td>
<td>Promotion</td>
</tr>
<tr>
<td>SPST</td>
<td>Part (s) / System/ Tools</td>
</tr>
<tr>
<td>SS</td>
<td>Fuel</td>
</tr>
<tr>
<td>ST</td>
<td>Capital Development &amp; Training</td>
</tr>
<tr>
<td>SfRM</td>
<td>Structure Repair &amp; Maintenance</td>
</tr>
<tr>
<td>SUE</td>
<td>Electrical</td>
</tr>
<tr>
<td>SWH</td>
<td>Significant wave height</td>
</tr>
<tr>
<td>SWH</td>
<td>Significant wave height</td>
</tr>
<tr>
<td>SWI</td>
<td>Salary/Wages</td>
</tr>
<tr>
<td>SyRM</td>
<td>System Repair &amp; maintenance</td>
</tr>
</tbody>
</table>
LIST OF SYMBOLS

$A_j$ - the annual cash flow of the investment

$CF_0$ - is the initial investment

$DCG_{total}$ - Disposal – Clean and Green

$DL_{total}$ - Disposal – Legal

$DR_{total}$ - Disposal – Remedy

$DW_{total}$ - Disposal – Wrecking

$M1FT_{total}$ - Cluster 1 Income: Fish Trade

$M1LU_{total}$ - Cluster 1 Income: Loading Unloading

$M1PF_{total}$ - Cluster 1 Income - Processed Fish

$M1TS_{total}$ - Cluster 1 Income - Storage

$M2ES_{total}$ - Cluster 2 Income – Emergency / Salvage

$M2MA_{total}$ - Cluster 2 Income – Fishing Gears

$M2MS_{total}$ - Cluster 2 Income – Vessel Modification/Alteration

$M2R_{total}$ - Cluster 2 Income – Vessel Maintenance & Repair

$M3AR_{total}$ - Cluster 3 Income - Area rental & Shops

$M3A_{total}$ - Cluster 3 Income – Accommodation

$M3FB_{total}$ - Cluster 3 Income – Café

$M3T_{total}$ - Cluster 3 Income – Tourism

$M4B_{total}$ - Cluster 4 Income - Vessel Bunker

$M4HG_{total}$ - Cluster 4 Income – Healthcare

$M4H_{total}$ - Cluster 4 Income – Vessel Household items

$M4L_{total}$ - Cluster 4 Income – Vessel Anchorage

$M5P_{total}$ - Cluster 5 Income - Entrance Fee and membership

$MOT_{total}$ - Vessel Entry

$MSM_{total}$ - Sell – System, Machineries, Outfitting & Tools

$MS_{total}$ - Sell Structure
\( OD_{\text{total}} \) - Total of initial investment – design
\( OID_{\text{total}} \) - Initial Investment - Infrastructure Development
\( OL_{\text{total}} \) - Initial Investment - Legal requirement
\( OMS_{\text{total}} \) - Initial Investment - Cluster main system and machineries
\( OSS_{\text{total}} \) - Initial Investment - Cluster supporting system and tools
\( OT_{\text{total}} \) - Initial Investment –Transportation
\( SA_{\text{total}} \) - Operating cost – administration
\( SB_{\text{total}} \) - Operating Cost - Crew Benefits
\( SCI_{\text{total}} \) - Consultation for Improvement
\( SCM_{\text{total}} \) - Operating Cost - Crew Mobilization
\( SCS_{\text{total}} \) - Operating Cost – Communications
\( SFS_{\text{total}} \) - Operating Cost – Water
\( SL_{\text{total}} \) - Operating Cost – Legal & Fees
\( SML_{\text{total}} \) - Operating Cost – Mortgage / Loan / Insurance
\( SM_{\text{total}} \) - Initial Investment – External Administrative
\( SPST_{\text{total}} \) - Part /System/Tools
\( SP_{\text{total}} \) - Operating Cost – Promotion
\( SS_{\text{total}} \) - Operating Cost – Fuel
\( ST_{\text{total}} \) - Operating Cost – Capital Development & Training
\( SUE_{\text{total}} \) - Operating Cost – Electrical
\( SWI_{\text{total}} \) - Operating Cost - Salary/Wages & Incentives
\( StrM_{\text{total}} \) - Structure Repair Maintenance
\( SyRM_{\text{total}} \) - System Repair Maintenance
\( \Delta \) - moulded displacement
\( A \) - vertical projected area of each surface exposed to wind
\( AP \) - aft perpendicular
\( B \) - greatest moulded breadth
\( CB \) - Block coefficient
\( C_{cs} \) - current force coefficient
\( C_{cy} \) - current force coefficient on the beam
\( Ch \) - height coefficient
\( CS \) - shape coefficient
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(d)</td>
<td>estimated operational depth</td>
</tr>
<tr>
<td>(D)</td>
<td>Plate flexural rigidity, (N/m)</td>
</tr>
<tr>
<td>(Df)</td>
<td>freeboard depth</td>
</tr>
<tr>
<td>(E)</td>
<td>the elastic modulus, (N/m^2)</td>
</tr>
<tr>
<td>(f_1)</td>
<td>materials factor depending on materials strength group</td>
</tr>
<tr>
<td>(F_{CN})</td>
<td>Current force on the bow</td>
</tr>
<tr>
<td>(F_{CY})</td>
<td>current force on the beam</td>
</tr>
<tr>
<td>(FP)</td>
<td>forward perpendicular</td>
</tr>
<tr>
<td>(f_T)</td>
<td>proposed freeboard</td>
</tr>
<tr>
<td>(F_W)</td>
<td>wind force</td>
</tr>
<tr>
<td>(g)</td>
<td>Gravitational acceleration, (9.81m/s^2)</td>
</tr>
<tr>
<td>(G)</td>
<td>Shear modulus, (N/m^2)</td>
</tr>
<tr>
<td>(h)</td>
<td>effective height or thickness, (m)</td>
</tr>
<tr>
<td>(H)</td>
<td>Water depth, (m)</td>
</tr>
<tr>
<td>(H_w)</td>
<td>Non-dimensional water depth, (H/L)</td>
</tr>
<tr>
<td>(I)</td>
<td>value of total inertia about the neutral axis</td>
</tr>
<tr>
<td>(k)</td>
<td>ratio value</td>
</tr>
<tr>
<td>(L)</td>
<td>the length of FORT</td>
</tr>
<tr>
<td>(L_f)</td>
<td>freeboard line</td>
</tr>
<tr>
<td>(M)</td>
<td>amidships</td>
</tr>
<tr>
<td>(M_y)</td>
<td>bending moment</td>
</tr>
<tr>
<td>(N)</td>
<td>Number of modes</td>
</tr>
<tr>
<td>(p_w)</td>
<td>Wave pressure</td>
</tr>
<tr>
<td>(r)</td>
<td>the discount rate</td>
</tr>
<tr>
<td>(s)</td>
<td>length of catenary line</td>
</tr>
<tr>
<td>(S)</td>
<td>wetted surface</td>
</tr>
<tr>
<td>(t)</td>
<td>the life time of the investment</td>
</tr>
<tr>
<td>(T)</td>
<td>mean moulded summer draught</td>
</tr>
<tr>
<td>(V_c)</td>
<td>current speed</td>
</tr>
<tr>
<td>(V_w)</td>
<td>wind speed for South China Sea</td>
</tr>
<tr>
<td>(w)</td>
<td>submerged weight of catenary chain per meter</td>
</tr>
<tr>
<td>(Z)</td>
<td>section modulus</td>
</tr>
<tr>
<td>(Z_o)</td>
<td>section modulus</td>
</tr>
</tbody>
</table>
\( \delta \) - vertical deflection
\( W, y_x, y_y \) - Plate deflection, rotations about \( x \) and \( y \) axes
\( x, y, z \) - Cartesian coordinates
\( x = (x,y,z) \) - Field points
\( \zeta \) - Source points
\( G(x) \) - Three-dimensional free surface Green function
\( a \) - wavelength-to-structure length ratio
\( \nu \) - Poisson’s ratio
\( \omega \) - Wave frequency, \( \text{rad}/s \)
\( \lambda \) - wavelength, \( m \)
\( \phi \) - Velocity potential of the fluid
\( \varepsilon_{xx}, \varepsilon_{yy}, \varepsilon_{zz} \) - Normal strains
\( \gamma_{xy}, \gamma_{yx}, \gamma_{zx} \) - Shear strains
\( \tau_{xy}, \tau_{yx}, \tau_{zx} \) - Shear stresses
\( \sigma_{xx}, \sigma_{yy}, \sigma_{zz} \) - Normal stresses
\( [K_f] \) - Global flexural stiffness matrix
\( [K_s] \) - Global shear stiffness matrix
\( \lambda \) - Length between wave crests
\( \kappa \) - Wave Number \( (2\pi/\lambda) \) units of 1/length
\( \omega \) - Angular Frequency \( (2\pi/T) \) units of 1/time
\( 2a \) - Wave Height or twice wave amplitude


**LIST OF APPENDICES**

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Size ratio</td>
<td>190</td>
</tr>
<tr>
<td>B</td>
<td>Catenary Estimation</td>
<td>191</td>
</tr>
<tr>
<td>C</td>
<td>Torsional Simulation</td>
<td>192</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Introduction

Recently, very large floating structures (VLFS) have received considerable attention in civil and ocean engineering fields (Tripathy and Pani, 2014). These floating structures have great width and length and relatively small flexural rigidity. There is an extensive attention to understand the anomalies of wave interaction with floating structures to build infrastructures. The VLFS concepts are unique ocean structures primarily because of unprecedented lengths and displacements which consequently, hydroelastic response becomes dominant and has driven supporting research and development in global analytical methods for VLFS. Therefore, this chapter highlights the importance of structural hydroelastic effects in modelling of VLFS under multi parametric value. The research problems were extracted and compensated in this research for the inadequacy of previous works. The objectives have been defined in providing the resolution for the problem identified. The scope of the study and the significance the research has all been elaborated in show casing the research boundary and its contribution respectively within the state of the art of theories, concepts and fundamentals. The thesis has been structured in normal research approach in identifying, formulating, attaining, synchronizing and delivering the research deliverables are accessible.
1.2 Research Background

Very large floating structures (VLFS) have attracted the attention of architects, planners, and engineers because they provide an exciting and environmentally friendly solution for land creation from the sea as opposed to the traditional land reclamation method. The applications of VLFS such as piers, hotels, fuel storage facilities, bridges, airports, and even floating cities have triggered extensive research studies in the past two decades. The VLFS technology has developed considerably and there are many innovative methods proposed to minimize the structure motion, especially on elasticity behaviour as illustrated in Figure 1.1. These characteristics of the global response with respect to the characteristic length are summarised in the map of Figure 1.2 (Suzuki, 2005). Therefore most researches were concentrated on mooring system and structural integrity of the VLFS (Wang and Tay, 2011). The size (Thai et al., 2017) of a VLFS presents an essential challenge since it is difficult to scale directly the structural and hydrodynamic properties. A brief overview of the history, application and uniqueness of very large floating structures and the recent developments in the scientific arena of VLFS as well its significance level are in future scope of work (Tripathy and Pani, 2014). Collectively, the research on hydroelastic analysis of pontoon-type very large floating structures can be summarized to include, but not limited to wave forces, non-wave forces, VLFS models, VLFS shapes, mooring system, breakwaters, profiles of seabed, and anti-motion devices (Watanabe et al., 2004a).

Figure 1.1: Global response under load (Suzuki et al., 1996)
Computational method had achieved its maturity during the last three decades and efficient enough especially for preliminary design purposes. Currents works focused on developing efficient numerical tools by simplifying the structural model. Among the numerous numerical methods on the hydro elasticity of a VLFS, most of them are within the scope of linear wave theory and in frequency domain or time domain. There are only a few numerical models that consider the global hydroelastic response of a VLFS in nonlinear waves, which is a naturally complicated phenomenon. In linear hydro elasticity analysis of a mat-type VLFS, the flow is usually assumed to be governed by linear potential theory. A VLFS is generally modelled as an elastic plate and only the vertical motion is considered. It is also assumed that there is no gap between the VLFS and the free surface, i.e., no slamming is allowed. Most of the researcher works on beam method, water depth technique (Mei and Black, 1969, Andrianov and Hermans, 2003, Lee and Liew, 2014, Chen et al., 2016) for both the case of finite and infinite water depths, the application of Eigen function expansion (Gasimov et al., 2016) and orthogonal mode coupling relation, the behaviour of a flexible, porous, floating breakwater connected by mooring lines kept under tension by small buoyancy chamber at the tip (Wang and Tay, 2011). The wave induced responses was also explored (Wu et al., 2014a), the elastic plate using Eigen function expansion (Kim and Ertekin, 1998) and modal expansion matching method (Sengupta et al., 2017).
More often, the hydroelastic analysis is carried out in the frequency domain (Wei et al., 2017, Lin, 2016) since this is more straightforward than it would have been in the time domain. The fluid problem is generally solved by the boundary-integral method, i.e., by use of the Green function or by use of quantum mechanics Hamiltonian. The plate response is often solved by the finite element method (FEM), or alternatively, as part of the boundary-element of the fluid domain. There have been two major approaches to the frequency-domain analysis: the modal expansion method and the direct method. Modified modal functions have been introduced by many authors, primarily to increase the numerical efficiency of the computations. The common approaches for time-domain analysis of VLFS can be categorized as the two-dimensional direct integration method (Liu et al., 2015). The two-dimensional nonlinear model to simulate the hydroelastic response to random waves, and non-periodic nonlinear waves such as a tsunami. However, the frequency domain analysis is not valid in extreme situations such as in a large storm. Such extreme events have to be considered in the VLFS design for safety and survivability reasons. More work should be done to investigate the non-linear responses such as the transient response of VLFS under large wave impact (Wang and Tay, 2010). Thus, it shows that higher-order analysis such three dimensional approach play an important role in the prediction of VLFS response to non-linear waves (Lin, 2016) and a more sophisticated approach could resolve that issue (Taylor, 2007).

Therefore, there is no extrapolation or even modification has been done based on Mindlin plate models that use various aspect ratio in both linear and non-linear conditions. Implies that the available models insufficient in demonstrating offshore floating structure behaviour especially for deep sea fishing application with its special boundary and operational conditions. As a result, the structural behaviour predictions have been under estimated and could result violating the Det Norske Veritas Classification Standards and criteria (Veritas, 2012). The present work is a study on a floating offshore remote terminal (FORT) which aims to provide researchers and engineers with an unambiguous method for obtaining structural responses using Mindlin plate analysis for both linear and non-linear perspectives as a fluid-structure interaction problem. Following this, the boundary element method (BEM), finite-element method (FEM), quantum mechanics of Hamilton’s principle and linearization
are introduced, and the solution approach is detailed. Finally, the results for both the linear and cnoidal wave (Ertekin and Xia, 2014) solutions of the problem and emphasize the importance of nonlinearity in the structural response predictions of a FORT in mathematical analysis and computational approach. Hence, expected use of thick plate theory (Wu et al., 2014a) should improves on hydro elasticity behaviour especially on torsional effects at end and mid location of the structure (Wang and Tay, 2011). However, the hydroelastic analysis requires a huge amount of computational time and cost. A numerical model of typical VLFS says of 300m length has more than 70,000 DOF. Many researchers have tried to reduce computational time. Nevertheless, the cost for hydroelastic analysis is still three or more times larger than only for numerical analysis of structures with the same DOF. This fact makes it hard to directly use hydroelastic analysis tools in real design procedures of VLFS (Jingyun Kim, 2011).

1.3 Floating Offshore Remote Terminal Structure (FORT)

FORT is a genuinely new concept proposed with the intention to bring all the services the offshore fishermen require closer to their fishing grounds. These services include fish landing terminal, packing, packaging and storage, business area, maintenance and services facilities, supplies and refuel centre, health and recreational services, accommodation and tourism, etc. With adequate technical and structure analysis, FORT will be strategically anchored in the middle of the ocean, close to the offshore fishing grounds. FORT will ultimately be a technology development for ocean space utilization. FORT proposes the integration of the required functions. It is expected to improve the logistics management and ensure operational effectiveness. FORT is expected reduce the ‘distance barrier’ and many more. Instead of the harvested fish need to be stored at limited storage capacity, and brought back to main land terminal, FORT will hold, process and keep the fish quality. At the same time is able to supply resources such as fuel, fresh water, fishing gears to the fishing vessels.
1.4 Research Gap

Figure 1.3 chronologically registers all research works directly related to studies on structural analysis of VLFS. The fundamental difference between one and the other is on method of analysis. Based on this the research works can be categorised into three groups; beam method, thin plate method and thick plate method. Subcategorisation within each of the three group is also apparent on the basis of either the mathematical methods employed or the modelling boundaries and conditions.

Figure 1.3: Past research related to FORT structural analysis

Structural analysis of VLFS using beam method was pioneered by Mei and Black (1969) but constrained it for finite water depth only. Che et al. (1994) used modified beam model and analyse within 2D condition using polynomial function.

1.5 Problem Statement

Floating offshore remote terminal (FORT) as a thick plate in linear and non-linear operations involves static and dynamic wave height representing various operating condition, such as loading and unloading. However, comparison of mathematical modelling using vector mechanics or variational and energetic principles, indicates that the thin plate disposed the differential element which are
summed to obtain the equilibrium or motion equations (Ismail, 2016). Meanwhile, in obtaining equation for the energetic methods, the thick plate includes various types of virtual work principles, such as minimum potential energy or the complementary potential energy. Structurally, the thick plate will show a softer crystallization deformation behaviour due to the presence of potential energy. Such simplistic practise which is presumably due to the inadequacy of data and knowledge in the field inevitably causes large errors in the predictions as much as 10 to 20% difference in the relative error of the displacement in the middle of the plate (Vrabie and Baetu, 2013). As a result, the predictions violate the Det Norske Veritas Classification Standards and criteria (Veritas, 2012). Additionally, the current approaches has led to underestimation of properties as non-linear wave approaching and hitting the structure (Wang and Tay, 2010). The effect of nonlinear waves has to be considered as it is common practice of linear waves analysis and it is not valid in extreme situations such as large storms (Andrianov, 2005). Despite its utmost importance to reliability of the prediction results and convenience of the modelling, until now no mathematical model has specifically added the hydroelastic torsion formulas and aspect ratio in wave propagation. Therefore, this research begins with the hypothesis that bounding the hydroelastic torsion formulas and aspect ratio will significantly improve the modelling of structural effects under energy equilibrium perspective. It is already mentioned that hydroelastic analysis using Navier-Stokes equation are usually neglected in the hydroelastic analysis (Wang and Tay, 2010) especially within deep or offshore water where the waves with longer wave length will move faster.

1.6 Research Objectives

This research work is utilizing the thick plate theory addressing offshore fishing issues via technology and advancement in floating structure application. The study aims:
i. To develop a typical design of FORT structure

ii. To develop a mathematical model for the identification of loading variable in linear and non-linear under thick plate theory

iii. To simulate of FORT behavior under selected conditions

1.7 Research Approach and Scope

The general research approach is sequentially as follows:

i. FORT as a concept its required functions are developed through knowledge and understanding gathered on the current process of pre-to-post catching activities.

ii. The elements of FORT system are identified based on (i) above so that all the various subsystems are in place and their interrelationships established.

iii. Hardware and software systems for FORT selected based on a sound method and detailed out to the extent of estimating their cost magnitude.

iv. The thick plate model is developed based on established methodology and comprehensive enough to capture the elements of sustainability.

v. The model developed is validated by empirical validation method.

1.8 Thesis Motivation

Applying ecosystem approach to fisheries management is considered the preferred option and best practice under the Coral Triangle Initiative. The idea of having FORT as intermediate terminal is new to its application. Therefore, the structural integrity must be evaluated based on good practice framework by using higher order modelling (Li et al., 2016) approach and simulation capability (Loukogeorgaki et al., 2012). Moreover, the inclusion of the symmetric generalized
added mass matrix and the non-symmetric generalized hydroelastic in fluid-structure interaction. On the other hand, FORT is created and motivated for the research is traceable to the real shortage in fish supply in Malaysia. Malaysia has the economic ground to be explored further as done by many developing countries to pursue offshore fisheries development strategies (James et al., 2005). The research is also made in line with the blueprint for the full implementation of an ecosystem approach to fisheries management in Malaysia in 2016 (Pomeroy et al., 2015).

1.9 Research Significance

The research significance of the work developed in this thesis is the implementation of a thick plate theory on wave-structure formulation into a plate model. By identifying and implementing structure loading component procedure in the existent linear and non-linear, the FE program it is possible to perform frequency and time-dependent and evolutive construction analyses of structures under significant wave height. As the formulation is based on the fixed loading approach, the effects of structure reinforcement in the resistant mechanism of plate components are properly simulated, in contrast with existent research works. By these means and motivated by its computational efficiency, it is intended to create an alternative numerical tool to the high complex 2D/3D FE models for the linear and nonlinear assessment. Also, the proposed model aims to be a practical engineering tool to accurately assess the structural behaviour and also serving as a decision tool for floating structure-based development.

1.10 Overview of Thesis Structure

The present thesis is divided into 7 chapters. After this first opening chapter that points out the overall context, the most relevant motivations and objectives of
the research work, an overall description of the state-of-the-art is presented in Chapter 2. This second chapter is focused on the topics that are essentially related with the ambit of the research work carried out in this thesis. Being so, it makes a generally description of the plate models and the very high advanced state they reached for the case of wave effect analysis.

Afterwards, the complexity of the phenomenology and modelling of the structural mechanism of plate elements is revised. Existent forces, kinematic and constitutive theories are discussed, as well, as its adaptability to plate models. Subsequently, a general view on the subject of new algorithm is presented, focussing on the importance of linear and non-linear models able to assess the actual state of the structures to predict the efficiency of structure behaviour projects. Finally, a general discussion on the state-of-the-art is presented. The context in which the present research is inserted in, and the gap of knowledge that it pretends to fill, are remarked. Accordingly, the options taken in the development of the numerical model, which were supported by previous findings reported in the literature, are highlighted. It detailed down discussion on design comprehensiveness. The conclusions of the present study are summarized and presented in chapter 6. Suggestions and recommendations for future work are also included in this chapter. Finally, list of the references are given at the end of this thesis.
REFERENCES


Fokiali, A. P. D. P. & Moustakas, L. 2009. Techno-Economic Approaches to Environmental Actions: A Case Study For The Establishment of a Centre For


International Association of Classification Societies, I. 2014. Requirements concerning Mooring, Anchoring and Towing.


Ittc, M. C. 2002. ITTC Recommended Procedures for Testing and Extrapolation Methods and Validation of Simulation Model.


Ooi, J.-B. 1990. Development problems of an open-access resource: the fisheries of Peninsular Malaysia. *Institute of Southeast Asian Studies. ASEAN Economic Research Unit, Institute of Southeast Asian*.


Sa'at, N. H. 2011. Mobiliti Sosial Dalam Kalangan Komuniti Pesisir Pantai (Kuala Terengganu)


Tao, W., Hui, W., Xi, L. & Guohua, X. 2017. Factors influencing the mechanical properties of lightweight aggregate concrete.


Tongzon, J. Port choice determinants in a competitive environment. Proceedings of Annual Conference and Meeting of the International Association of Maritime Economists-IAME, 2002 Panama.


Yuan, M., Chen, L., Li, Y., Liang, Y., Sun, X., Li, H. & Xie, W. Design Considerations of Liwan 3-1 Topside Float-over Mating Analysis. The
International Society of Offshore and Polar Engineers.


