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UNIVERSITI TEKNOLOGI PETRONAS

DEVELOPMENT OF INTEGRATED METHODOLOGY FOR RISK BASED DECISION MAKING USING EXPERT OPINION FRAMEWORK OF MOBILE MOORING SYSTEM

by

SILVIANITA

The undersigned certify that they have read, and recommend to the Postgraduate Studies Programme for acceptance this thesis for the fulfillment of the requirements for the degree stated.

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DEVELOPMENT OF INTEGRATED METHODOLOGY FOR RISK BASED DECISION MAKING USING EXPERT OPINION FRAMEWORK OF MOBILE MOORING SYSTEM

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SILVIANITA

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hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTP or other institutions.

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Date :

Dedicated to:

My beloved husband and my wonderful sons Rafa & Daffa

My loving parents, brothers & sisters

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ABSTRACT

Floating structures use mooring system for station keeping in any water depths. Mooring system is a vital component for the safety of floating structures. Mooring accidents can cause serious injury or damage to the vessel, and hence it is necessary to establish a systematic risk-based decision making method to minimize the risk failure. This study uses the mobile mooring system of a semi submersible pipe laying barge as a case study. The risk approaches used in this study consist of HAZOP (Hazard and Operability), FTA (Fault Tree Analysis), ETA (Event Tree Analysis) and AHP (Analytic Hierarchy Process). The reason why these method have been chosen as risk methods used in this study are because of their comprehensive, systematic and rigorous approach compare to other methods such as Checklist, FMEA and SWIFT. The benefits by using these methods are that methods can be integrated into MIVTA (Methodology for Investigation of Critical Hazards) and MIRBA (Methodology for Investigation of Risk Based Maintenance). MIVTA and MIRBA are comprehensive risk based decision making consists of risk identification, risk assessment, risk mitigation and risk based maintenance.

The primary aim of this study is to develop a MIVTA, which is carried out by the development of preliminary risk analysis using HAZOP to generate the root causes using FTA and to construct the sequence of the consequences using ETA. HAZOP is a systematic examination of a system helpful to identify and evaluate the risks related to accidents/incidents in mooring system. FTA is a deductive method useful to generate the potential causes of mooring system failure into undesired events. ETA is an inductive method helpful to define all possible outcomes of accident events.

The second aim of this study is to develop a MIRBA by using Bow Tie Analysis in order to classify the risk level and mitigation plan, and to select the best maintenance strategy using AHP. Bow tie analysis is the combination method of the

FTA on the left side and ETA on the right side. Bow tie analysis is used to classify the risk level of the mooring system. In order to select the best maintenance strategy for mooring system that has multi criteria to be considered, AHP is applied to determine the best maintenance strategy on the basis of likelihood and consequence. This study conducts risk-based decision making coupled with the knowledge of the experts of mooring system to evaluate the frequency of failure, class of consequence, mitigation measurements and maintenance strategy based on their knowledge and experience Based on the results of primary data analysis, the critical hazards for mobile mooring system are mooring line breakage (MLB) with the frequency of occurrence of 1.025011 per year which is classified as probable event, anchor failure (AF) 1.026011 per year classified as probable event, anchor handling failure (AHF) with the frequency of 0.034 per year considered as occasional event and appurtenance connection failure (ACF) with the frequency of occurrence of 1.01764 which is classified as probable events. The total frequency of occurrence of mobile mooring system hazards is 3.102662 per year and it is classified as probable event. The four critical hazards of mobile mooring system are classified as the medium level. The mitigation plans and maintenance strategy are being established. Mitigation plans are obtained based on each undesired events identified in the risk assessment. Based on AHP results, the best maintenance strategy on the basis of likelihood and consequences is PeM (Predictive Maintenance) with the priority vector of 35.6%. and 35.3% respectively.

The MIVTA and MIRBA investigated in this study are expected to enhance the risk-based decision making for a mobile mooring system. This identifies the potential causes and possible consequences, predicts the risk levels, mitigates the risk level and selects the best maintenance strategy. This study also provides a systematic methodology guideline for the risk-based decision making useful to manage and reduce the risk of accident occurring in offshore platforms. The validation of this study used Likert Scale in an attempt to determine the relative important index (RII). The experts have been asked to indicate how much they agree or disagree in the developing of MIVTA and MIRBA. The mean RII for all the criteria is 0.82 which considered important to conduct MIVTA and MIRBA.

ABSTRAK

Sistem *mooring* digunakan dalam struktur apungan untuk menjaga kestabilan dalam setiap kedalaman air. Sistem mooring adalah komponen penting sebagai sistem keselamatan dalam struktur apungan. Kemalangan yang disebabkan mooring boleh mengakibatkan kecederaan parah atau kerosakan yang teruk pada kapal. Maka sistem tersebut perlu diselerasakan melalui kaedah keputusan yang berasaskan risiko bersistematik untuk mengurangkan risiko kegagalan. Kajian ini mengunakan sistem mooring mudah alih yang terdiri daripada semi submersible yang meletakkan pipa sebagai kes kajian. Risiko pendekatan yang digunakan dalam kajian ini terdiri daripada HAZOP (bencana dan pengoperasian), FTA (Analisis Pokok Kesalahan), ETA (Analisis Pokok Kejadian) dan AHP (Analisis Hierarki Proses). Sebab mengapa kaedah ini telah dipilih sebagai kaedah risiko yang digunakan dalam kajian ini adalah kerana pendekatan yang komprehensif, sistematik dan ketat berbanding dengan kaedah lain seperti Checklist, FMEA and SWIFT. Faedah dengan menggunakan kaedah ini adalah kaedah yang boleh disepadukan ke dalam MIVTA (kaedah dalam penyelidikan untuk bencana yang kritical) dan MIRBA (kaedah dalam penyelidikan risiko berasaskan penyelenggaraan). MIVTA and MIRBA adalah berasaskan risiko membuat keputusan yang komprehensif terdiri daripada mengenal pasti risiko, penilaian risiko, pengurangan risiko dan penyelenggaraan berasaskan risiko.

Tujuan utama dalam kajian ini adalah untuk menbangunkan MIVTA, yang diawali pembangungan risiko awal menggunakan HAZOP, untuk mencetuskan masalah awal dengan menggunakan FTA dan untuk menjanakan akibat mengikuti urutan menggunakan ETA. HAZOP merupakan pengujian secara sistematis dalam sistem yang membantu untuk mengenal pasti dan mentafsir risiko-risiko yang berkaitan dengan kemalangan dalam sistem mooring. FTA merupakan kaedah deduktif yang berguna untuk mencetuskan masalah potensi dalam kegagalan sistem mooring dalam kejadian yang tidak diingini. ETA merupakan kaedah induktif yang membantu dalam pentakrifan segala hasil kemungkinan dari kejadian kemalangan.

Tujuan kedua dari kajian ini adalah untuk membangunkan MIRBA dengan menggunakan analisis bow tie (ikatan busur) untuk mengklasifikasikan tahap risiko dan rancangan mitigasi dan untuk memilih strategi penyelenggaraan yang terbaik menggunakan AHP. Analisis bow tie adalah kombinasi dari kaedah FTA di bahagian kiri dan ETA pada bahagian kanan. Analisis bow tie digunakan dalam mengklasifikasikan tahap risiko dalam sistem mooring. Dalam rangka pemilihan strategi penyelenggaraan terbaik untuk sistem mooring yang mempunyai pelbagai kriteria yang perlu diperimbangkan, AHP digunakan untuk menentukan strategi penyelenggaraan yang terbaik berasaskan kemungkinan dan kesannya. Kajian ini menjalankan keputusan berdasarkan risiko digabungkan dengan pengetahuan daripada pakar sistem mooring untuk mentafsirkan kekerapan kegagalan, kelas impaknya, ukuran mitigasi dan strategi penyelenggaraan berdasarkan kepada pengalaman dan pengetahuan mereka.

Berdasarkan hasil daripada analisis data utama, bencana kritikal untuk sistem mooring mudah alih ialah garis mooring yang pecah (MLB) dengan kekerapan kejadian iaitu 1.025011 setiap tahun yang mana diklasifikasikan sebagai kebarangkalian seharusnya, kegagalan sauh (AF) iaitu 1.026011 setiap tahun diklasifikasikan sebagai kebarangkalian seharusnya, kegagalan pengendalian sauh (AHF) dengan kekerapan iaitu 0.034 setiap tahun dipertimbangkan sebagai kebarangkalian seharusnya dan kegagalan sambungan appurtenance (ACF) dengan kekerapan kejadian iaitu 1.01764 yang mana diklasifikasikan sebagai kebarangkalian seharusnya. Keseluruhan kekerapan kejadian dalam bencana sistem mooring mudah alih ini ialah 3.102662 setiap tahun dan ianya diklasifikasikan sebagai kebarangkalian seharusnya. Bencana kritikal yang keempat dalam sistem mooring sistem mudah alih adalah diklasifikasikan sebagai tahap sederhana. Rancangan mitigasi dan strategi penyelenggaraan sedang ditubuhkan. Rancangan mitigasi akan diperolehi berdasarkan kepada setiap kejadian yang tidak diingini telah dikenal pasti dalam penilaian resiko. Berdasarkan daripada hasil AHP, strategi penyelenggaraan terbaik berdasarkan kepada kemungkinan dan kesan-kesannya ialah PeM (Ramalan Penyelenggaraan) dengan vektor utama masing-masing iaitu 35.6% dan 35.3%.

MIVTA dan MIRBA yang diselidiki dalam kajian ini adalah dijangka untuk meningkatkan penghasilan keputusan berdasarkan risiko untuk sistem mooring mudah alih. Hal ini adalah untuk mengenal pasti punca-punca potensi dan kesan-kesan yang berkemungkinan, meramalkan tahap-tahap risiko, mitigasi tahap risiko dan membuat pemilihan strategi penyelenggaraan yang terbaik. Kajian ini juga menyediakan kaedah garis panduan yang sistematik untuk membuat keputusan berdasarkan risiko yang mana berguna untuk mengatur dan mengurangkan risiko berlakunya kemalangan dalam pelantar-pelantar minyak. Pengesahan kajian ini menggunakan kaedah skala Likert yang bertujuan untuk menentukan relatif indek penting (RII). Pakar-pakar telah diminta untuk menunjukkan berapa banyak mereka bersetuju atau tidak bersetuju dalam membangun daripada MIVTA dan MIRBA. Rata-rata RII bagi semua kriteria ialah 0.82 yang dianggap penting untuk menjalankan MIVTA and MIRBA.

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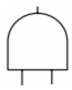
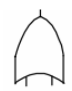
LIST OF ACRONYMS

ACRONYMS	DESCRIPTIONS
API	American Petroleum Institute
ABS	American Bureau of Shipping (ABS)
AHP	Analytic Hierarchy Process
ACF	Appurtenances Connection Failure
AEC	Adverse Environmental Condition
AF	Anchor Failure
AHT	Anchor Handling Tug
AHF	Anchor Handling Failure
CBM	Condition Based Maintenance
CI	Consistency Index
CM	Corrective Maintenance
CS	Cut Set
CR	Consistency Ratio
CT	Compliant Tower
DNV	Det Norske Veritas
DPL	DPL Fault Tree Software
ET	Event Tree
ETA	Event Tree Analysis
EC	Expert Choice Software
EOS	Expert Opinion Survey
EC & I	Electrical, Control and Instrumentation

ACRONYMS	DESCRIPTIONS
FI	Frequency Index
FT	Fault Tree
FTA	Fault Tree Analysis
FP	Fixed Platform
FPS	Floating Production Systems
FMEA	Failure Modes Effect Analysis
FPSO	Floating Production Storage and Offloading
HAZOP	Hazard and Operability
HAZID	Hazard Identification
HSE	Health Safety Environment
KSU	King Saud University
IE	Initiating Event
IMO	International Maritime Organization
ISO	International Organization for Standardization
MIVTA	Methodology for Investigation of Critical Hazards
MIRBA	Methodology for Investigation of Risk Based Maintenance
MLB	Mooring Line Breakage
MCS	Minimal Cut Set
MODU	Mobile Offshore Drilling Unit
PE	Pivotal Event
PM	Preventive Maintenance
QRA	Quantitative Risk Assessment
RI	Random Index

ACRONYMS	DESCRIPTIONS
RI	Risk Index
RII	Relative Importance Indices
RCM	Reliable Centered Maintenance
RFM	Run to Failure Maintenance
RBDM	Risk based decision making
SI	Severity Index
SS	Sea Star
SS	Subsea System
SP	SPAR Platform
SWIFT	Structured What If Technique
SCC	Stress Corrosion Cracking
TBM	Time Based Maintenance
TLP	Tension Leg Platform

NOMENCLATURES

SYMBOLS	NAME
α	Alpha
$\cup$	Union
$\cap$	Intersection
$\bullet$	Dot
ϕ	Phi
Ω	Omega
$\prod$	Pi
$\sum$	Sigma
λ	Lambda
	AND Gate
	OR Gate