Dropped Object Protection Modelling for Subsea Equipment

by

Muhammad Zulfadli Bin Zulkifli

15991

Dissertation submitted in partial fulfillment of
The requirements for the
Bachelor of Engineering (Hons)
Mechanical Engineering

JANUARY 2016

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
32610 TronohPerak Darul Ridzuan.

CERTIFICATION OF APPROVAL

Dropped Object Protection Modelling for Subsea Equipment

By

Muhammad Zulfadli Bin Zulkifli

15991

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
In partial fulfillment of the requirements for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL)

Approved by,

…………………...........
(Assoc. Prof. Dr. Fakhruldin Mohd Hashim)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2016.

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgement and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

………………………………………………

MUHAMMAD ZULFADLI BIN ZULKIFLI

ABSTRACT

Subsea x-tree is located at the seabed and contain hydrocarbon. The water depth for subsea operation exceed 1000 m which make it impossible for mankind to do the maintenance tasks at the seabed. Usually, the maintenance operation is done by using Remotely-Operated-Vehicle (ROV) and the cost to operate using ROV is high. Thus, subsea x-tree need to be free from any malfunction or damage. Dropped object or trawling gear from fishing activities are the objects that can collide with the subsea x-tree. This type of collision can cause significant damage and may result in hydrocarbon release. Subsea x-tree need to be equipment with a protective structure so that it can withstand the impact of collision from the dropped object or trawling gear. In this project, a protective structure was design by following NORSORK U-001 and U-002 standards together with the improvement design from Glass Reinforced Plastic (GRP) protective cover from HighComp. The speed for commercial trawling activities is around 2 to 4 knots. The designed protective structure is able to withstand that amount of impact up to the safety factor of 3. The protective structure also equipped with the to resist trawling gear from fishing activities.

ACKNOWLEDGEMENTS

First of all, I would like to express my gratitude to Allah for his guidance and blessing for me to complete my final year project for 8 months duration. I also would like to thank my family for giving me support throughout this final year. Thus, giving me strength to finish this final year project successfully.

My acknowledgments of thankfulness to my supervisor, Assoc. Prof. Dr. Fakhruldin Mohd Hashim for trusting me to complete this project. Without guidance from him, I may not able to complete this project. I owe gratitude to him as his unwavering commitment to me for this final year project. Thank you for the supportive nature and for the concern for my professional and personal well-being.

Not to forget to all my friends that assist me in this project and for their unstoppable support to me for every problem that I faced throughout this project. In addition, thank the many who also took part in this project, but choose to keep themselves anonymous. Without all of them, I may not be able to accomplish my final year project entitled **'Dropped Object Protection Modelling for Subsea Equipment'**.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 Background of The Study

Since the mid of 1990s, deepwater oil and gas has experienced rapid growth. In the Gulf of Mexico itself, 80% of the oil and gas production comes from the deepwater field with exceed 1000 meters' water depth from the surface. In August 21. 2007, Malaysia marked a history when it first deepwater field which named as KIKEH field operated by Murphy Oil Corporation started the production of its first oil. Deepwater field production are driven by series of subsea facilities. The major components of subsea facilities are Christmas tree, Subsea Distribution Assembly (SDA), Umbilical, Manifold, Pipeline, Jumper and Riser. All these components are being placed in the seabed. All the hydrocarbons from the reservoir will be transported to the host platform via subsea delivery system. Since the fluid and gas inside the subsea system is a hydrocarbon, it need to be protected from any event of burst and leaking. There must be several protection measures in the process of designing the system in term of material selection and wall thickness but we need to also take a look at the unexpected events that can also bring impact to the subsea system. This unexpected events can be object drop, ship anchor hitting the equipment, trawling activities and also plane crash.

1.2 Problem Statement

Object may drop from the sea surface and hit the subsea equipment. The type of object dropped can be vary, it can be from the anchor of the ship, moving object in the sea, plane crash and many more. Sea also is the place for fishing activity and a large scale of fishing activity requires a trawling gear. Trawling gear is a heavy object that move at the seabed that can cause serious damage when the trawl gear hit any equipment at the seabed. In 1995, the total frequency for serious dropped object from offshore operation is 0.04 per year in United Kingdom. [13] Thus, protection system need to be designed in order to protect the subsea equipment.

1.3 Objective

1) To propose a design for subsea x-tree protection structures.
2) To conduct structural analysis of the designed subsea x-tree protection in order to comply with the appropriate design standard.

1.4 Scope of Study

Subsea facilities consist of few major equipment. Among the major equipment are subsea x-tree, manifold, jumper, umbilical and pipeline. This project will cover the protection system for subsea x-tree and jumper. The project will be conducted by producing the three-dimensional design of the protective structure for the subsea x-tree and jumper. The propose structure will be designed based on the characteristic of KIKEH region with approximate water depth of 1300 m. The possible type of dropped object are trawling gear and rupture members from offshore platform. Thus, the propose structure need to be able to withstand the loads from trawling gear and rupture members of offshore platform.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Subsea system is the new oil and gas production method in Malaysia. The only fields that used subsea system development are in Kikeh and Kanowit field which located in Sabah. Fishing activity is among the main economic asset of the government and also the occupation of the people in Malaysia. The fishing gear can be a small net until the large and heavy trawling gear. Combination factor of fishing activity and offshore operation can bring harm towards any equipment at the seabed especially with the equipment that contain hydrocarbon or any hazardous materials.

2.2 Subsea System

The oil and gas production will be at the greater depths since most of the "easy oil" has already been found. This included areas with a more complicated structure and in extreme environment. This scenario makes subsea system to be more favourable. [1]

In Malaysia, most of the production platforms are fixed structure. The fixed structures most likely are jacket type platform. This is because the water depth in Malaysia can be consider as swallow water. For example, in Peninsular Malaysia Operation (PMO), the water depths are from 20 meter – 70 meter. These depths are suitable for fixed platform. The higher water depth in Malaysia region is in the area of Sabah and Sarawak where they need to use floater type platform. Currently, there are also subsea development in Kikeh and Kanowit fields.

Subsea system can reduce the massive amount of cost to develop an offshore platform. It can combine all the smaller fields and channel it to one location whether it is tie back to the platform or channel it directly to onshore. For example, in the Na Kika field located at the Gulf of Mexico. It consists of five independent oil and gas fields, which are Ariel, Kepler, Fourier, Herschel and E Anstey. All the fields are tied back to a permanently moored floating host facility. This will reduce the cost of making five platforms to a single platform that gather the product from five different fields. But, this reduction of cost is only valid for deep water operation. When the water depth is in the shallow water category, the cost of making a fixed platform is cheaper than a subsea system development.

Deepwater developments include a host platform, an extensive number of seafloor structures, wide variety of foundation types and anchor. A subsea system then contains series of equipment on the seabed that collect the product from the reservoir towards host platform through riser. [5]

The components for subsea system can be specified as follow:

- Wells
- Subsea trees
- Manifolds and sleds
- Flowlines
- Umbilicals
- Control system

Most of the subsea components are control remotely from the control room. Control room also monitor the conditions of the components at the seabed. If there is any complication that cannot be to the seabed. For a very deep water operation, only ROV will be sent down because monitor from the control room, Remotely Operated Vehicle (ROV) and diver will be sent down diver has a limitation of depth than human body can withstand due to the pressure of the water. [4]

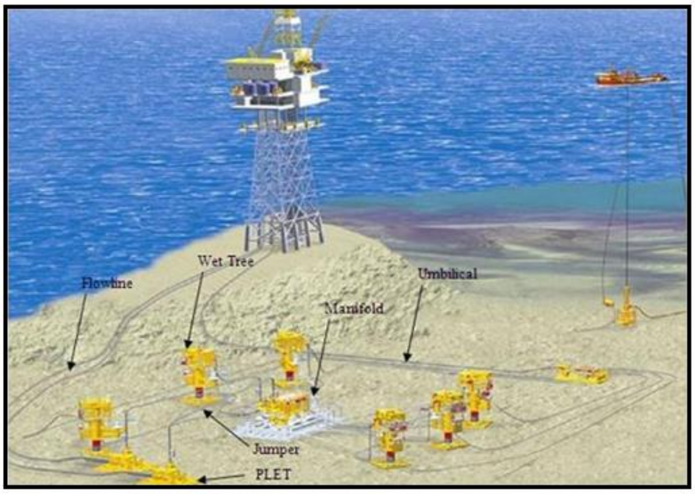


Figure 1: Subsea field architecture [2]

2.2 Trawling risk

Among the important issues in designing the pipeline so that it can withstand fishing gear are by making a description of the applied loads, their time history, and the pipeline description. The relation between pipeline and fishing gear is one of the most frequent cases for subsea system due to the severity of pullover, impact and hooking which is not properly described by the industry today. [6]

The high severity of the trawling gear force any equipment that is being placed at the seabed to be installed with protective structure especially with the equipment that involved hydrocarbon or any hazardous materials. As in Table 1, the mass of the Polyvalent trawl boards is 3500 which is very heavy. When there is a collision between trawling gear towards any subsea equipment or pipeline, this amount of moving mass will give a large impact and causes serious damage to the subsea equipment or pipeline and the trawling gear itself.

Table 1: Data of largest trawl boards in the North Sea

	Consumption		Industrial
	Polyvalent	V-Board	V-Board
Mass (kg)	3500	2300	1525
Length x breadth (m)	4.8 x 2.8	3.8 x 2.25	3.7 x 2.4
Trawl velocity (m/s)	2.8	2.8	1.8

There are two main reasons that trawling activities should be considered for offshore pipeline which are hazard of trawl gear hooking to the pipeline and the integrity of the pipeline due to loads from the trawl gear. [7]

Figure 2: The trawl gear arriving at the pipeline [10]

There are some places that apply the fishing free zone to protect the underwater pipeline. This will notify the fishing ship that this area is not permitted for any fishing activities.

2.3 Offshore Operation Risk

The greater risk of potential subsea dropped objects are during vessel, lifting and over side operations. An impact energy of than 30kJ can cause equipment damage but it will not result in a hydrocarbons release. For an impact of energy that is in between of 30kJ to 50kJ, it causes significant damage and release of hydrocarbons but the integrity of subsea tree can be maintained. If the energy impact is more than 50kJ, it has the capability to significantly damage any subsea equipment and cause hydrocarbons release. [2]

The major damage from object dropped typically can be seen from ruptured member. The damage is depending on the mass, shape and velocity of the dropped object. Proper study need to be conducted which required specialized techniques to address the dropped objects trajectory and subsequent of its hitting additional structure and equipment and also the subsequent impacts. [8]

All the dropped object incidents can happen during maintenance and production work. Lifting activity can be categorise as a major incident for dropped object because it involves of moving an item from one place to another. The faultiness of the platform also leads to unnecessary dropped object event from the ruptured member. The object from lifting activity and ruptured member usually can be consider as heavy. As a result, when the object falls to the seabed and hit any equipment, it can produce serious damage to the equipment.

In the scope for collision frequency, the highest collision risk frequency to semi-submersibles which is 0.193 per installation per year, comes from supply vessel. This frequency decrease when it comes to fixed structure due to the movement of the structure which is not moving compare to floater. The risk of collision between supply vessel and fixed platform is only 0.036 per platform per year. [9] The collision between platform and vessel caused damage of several member and will result to ruptured member.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The main point of this project is to design the protective structure for subsea Christmas tree and subsea jumper. The design will only focus on the design of external protective structure to cover the equipment from any impact of object dropped and can withstand fishing trawl board.

3.2 Project flowchart

Figure 2 show the key stages on the project development of an object dropped protection for subsea equipment. The key stages are:

i. Preliminary research work
ii. Literature review
iii. Morphological chart construction
iv. Design criteria selection
v. Model development
vi. Structural analysis
vii. Design Validation

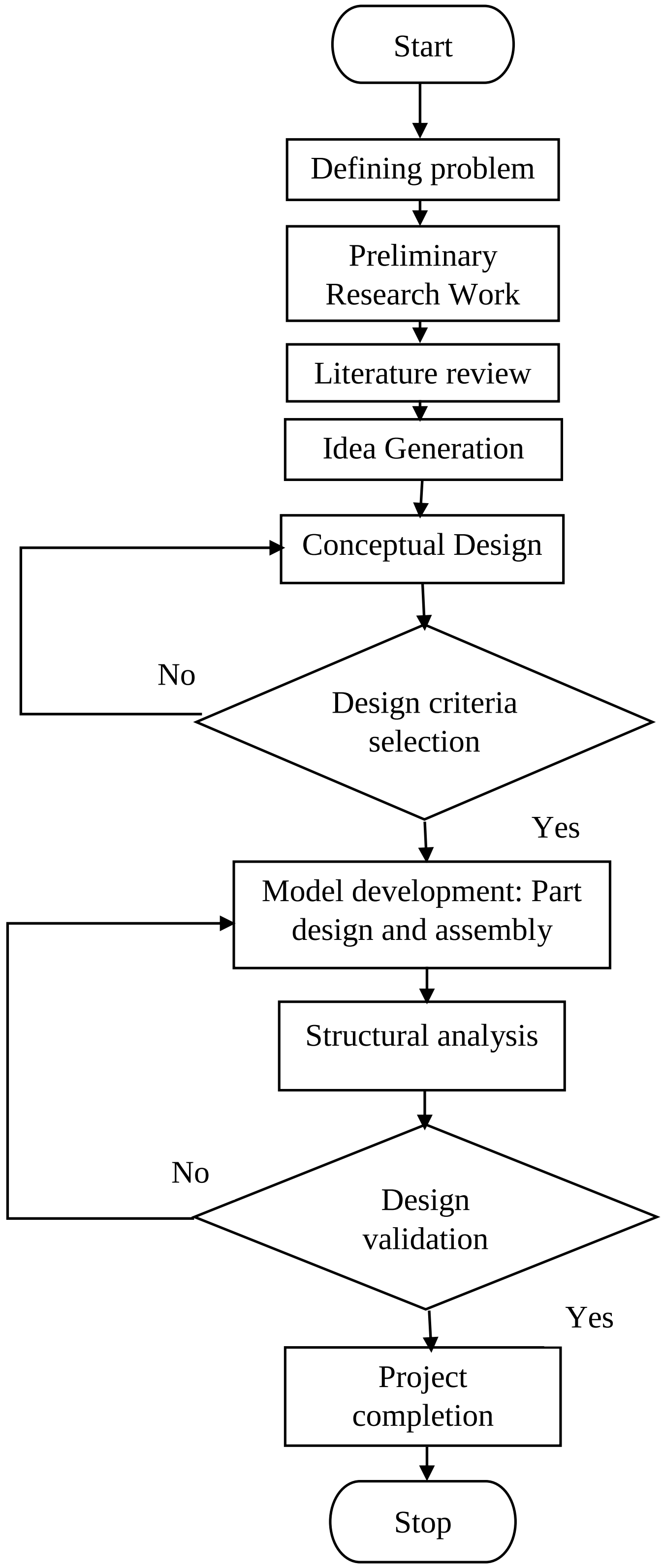


Figure 3: The flowchart of the Final Year Project

3.3 Gantt chart

Table 2: The Gantt Chart of the Final Year Project

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FYP1															
1	Defining Problem														
2	Preliminary Research Work														
3	Literature Review						1								
4	Idea Generation														
5	Conceptual design generation possibilities • Morphological Chart Construction														2
FYP2															
1	Design Criteria Selection • Parameters			3											
2	Model Development • Part design • Assembly Design						4								
3	Structural analysis														
4	Design Validation • NORSORK Standard														5

Key milestones

1. Completion of an Object Dropped Protection for Subsea Equipment literature review.
2. Completion of Idea Generation
3. Completion of an Object Dropped Protection for Subsea Equipment Design Parameters.
4. Model Development
5. Project Completion and Validation

3.4 Method of Joint

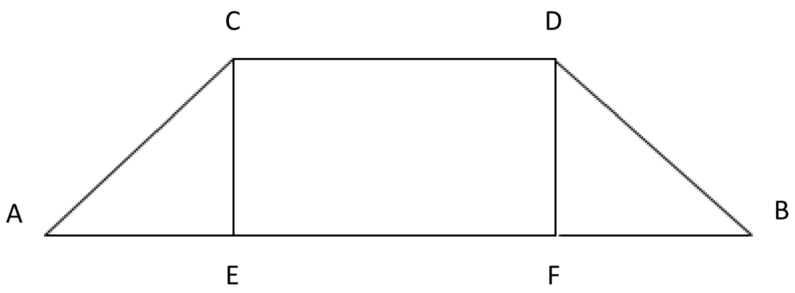


Figure 4: Truss structure

Figure is the simple structure of the truss. It is assume that the support reaction at A and B to be a fixed support reaction and an axial force is exerted on C. Thus, the free body diagram of the structure is shown in Figure below:

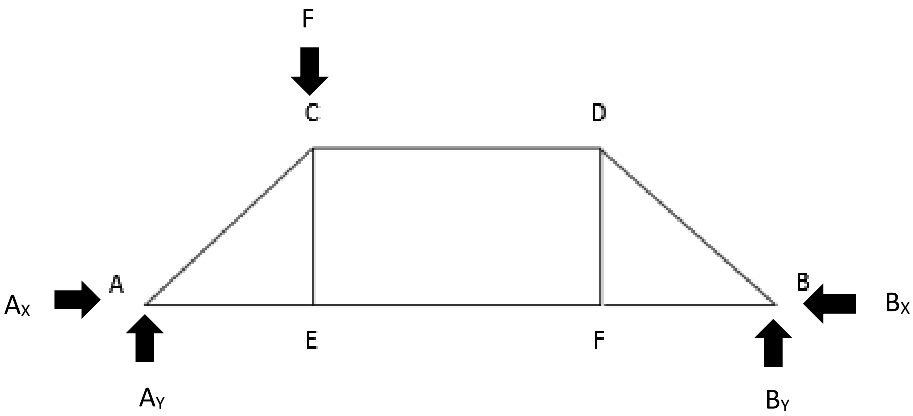


Figure 5: The reaction at the free-body diagram of the structure

Since no forces in x-direction, A_x and B_x are equally to zero. The forces in y-direction are determine using Equation 1 and assume the forces are equally distributed among the support reaction.

$$A_y + B_y = F;$$

$$A_y = B_y = F/2; \quad \textbf{(1)}$$

Next step is to choose a joint and draw its free-body diagram. In Figure *, Joint A is isolated by cutting members AC and AE. Now, the axial forces of T_{AC} and T_{AE} can be calculated by using Equation 2 and Equation 3.

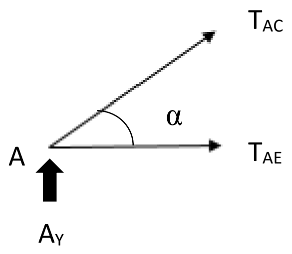


Figure 6: The free-body diagram at joint A

$$T_{AE} + T_{AC} \cos \alpha = 0; \quad \textbf{(2)}$$

$$A_y + T_{AC} \sin \alpha = 0; \quad \textbf{(3)}$$

3.5 Design Standard

3.5.1 NORSOK U-002 Standard

In designing the subsea equipment, the structure need to had the ability to withstand trawl board. The protective structure should able to deflect any sort of fishing equipment. The structure also need to be include with corner of maximum true angle of 58^{o} from the horizontal optimised. This will assist trawl and trawl wire deflection. The foundation of the structure such as corners and ramp will penetrate the seabed to avoid snagging from trawl warp lines and ground rope. Next, the overall structure geometry and the size opening will prevent the trawl doors from doors are prevented from entering the structure. The external members and edges shall be designed with minimum radius of 250 mm.

For the hatch design, the protective hatch need should be included with hinges so that it is replaceable and allow for controlled, safe and efficient operation. The hatch shall withstand dynamic forces induced by the wire during opening/closing with maximum of 7 tonnes.

3.6 Datum

3.6.1 KIKEH field

KIKEH is the first deep water oil discovery in Malaysia where it is located 120 km, Block K, northwest of the island of Labuan, offshore Sabah, East Malaysia. The water depth for KIKEH field is 4,400 feet or 1,341 meter. The field was discovered in July 2002 and the production started in August 2007.

Murphy Oil's is the operator of the field where it holds 80% of interest in the field and Petronas holds the other 20%. Since KIKEH is consider as depth water field, the platforms in the region are spar, Floating Production Storage and Offloading (FPSO) and Mobile Offshore Drilling Unit (MODU). This platform requires deepwater facilities which is the subsea equipment. Subsea x-tree is one of the subsea equipment that is used in this region for production purposes.

3.6.2 Glass Reinforced Plastic (GRP) Protective Cover

HighComp provided the subsea protective structure since 90's. This company also provided the protective structure for subsea Christmas tree and jumper protective cover. The protection system for both tree and jumper need to be designed for all relevant load condition arising from temporary as well as permanent life cycle phase.

The design life of the protection system should last for 50 years. It is also designed to comply the deep water specification. The degree of freedom of 2 should be considered with the entire load taken by 2 off lifting point. The design standards of the protective structure are NORSOK U-001 for environmental load and object dropped load. For the trawling load, it need to comply with NORSOK U-100. The protective cover shall be designed to accommodate stability for a 1 year return period storm condition prior to rock dumping of covers when applicable.

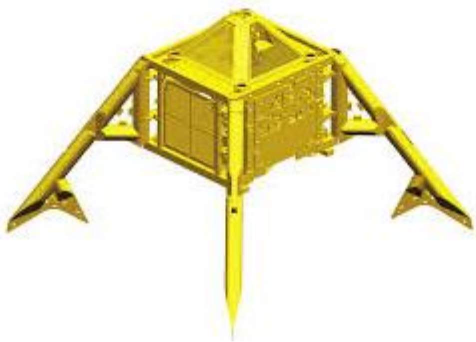


Figure 7: The protective structure for subsea Christmas tree [12]

CHAPTER 4

RESULT AND DISCUSSION

4.1 Morphology Chart

In the process of designing the subsea x-tree protective structure, decomposition chart was constructed to now the main requirements for the protective structure. As shown in Figure below, the main requirements for designing the x-tree protection structure are member design, frame design, foundation type and cover design template. The requirements from the decomposition chart will be the criteria for constructing the morphology chart. The criteria for the protective structure is selected based on the datum of GRP protective cover from HighComp.

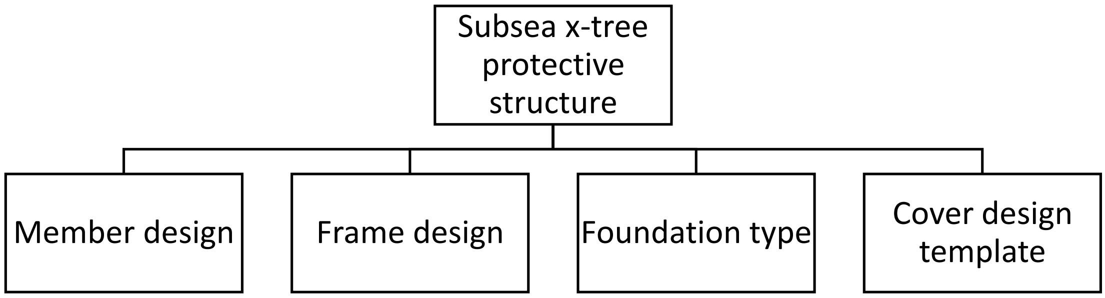
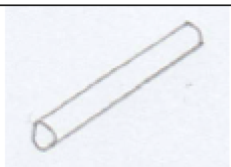
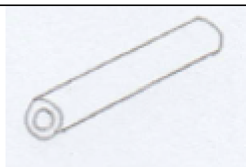
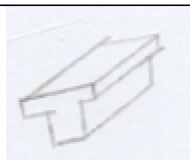
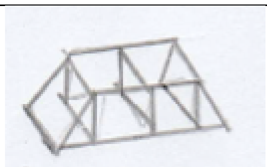
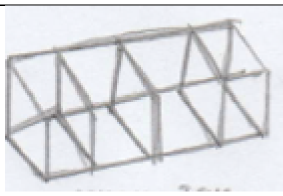
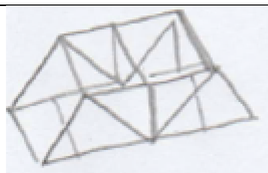
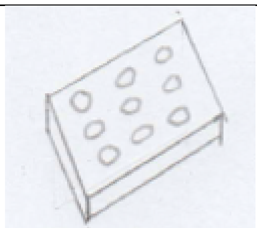
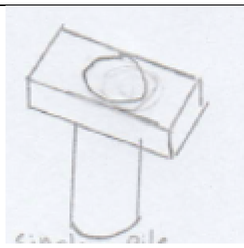
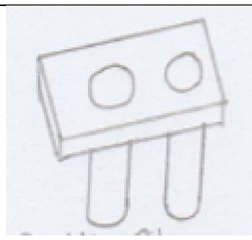


Figure 8: The decomposition chart for x-tree protection structure

Table 3: Morphology chart

	Option 1	Option 2	Option 3
Member design	 Rod Compact cylindrical structure	 Tube Cylinder with hollow in the centre.	 Beam Combination of plates that act as a load bearing structure. Can be in the shapes of T, I, H and L.
Frame design	 Queen Post Truss	 Square Truss	 King Post Truss
Foundation type	 Mud mat A plate with hollow patterns within the structure to hold the structure underwater. Applicable for light weight application	 Single pile A cylindrical tube that hold the structure at the seabed. Applicable for medium weight structure.	 Double pile Two cylindrical tubes that hold the structure at the seabed. Applicable for heavy weight application

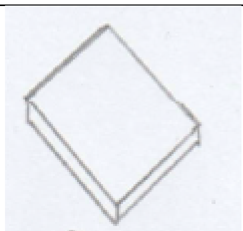
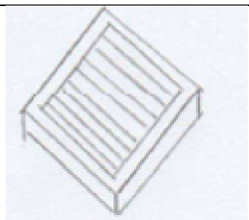
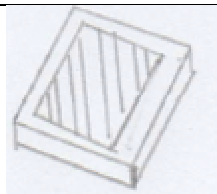
Cover design template	 Plate A rectangular shape metal	 Grating A cover with regularly spaced collection in parallel manner	 Diagonal grating A cover with regularly spaced collection in diagonal manner

Table 3 above is the list of possible outcomes of a conceptual design. By using Table 3, several conceptual designs can be produced. The design also need to be in line with NORSORK U-002 standard where it indicated that the structure should be able to withstand 7 tonnes of impact load and also had a overtrawlibility structure.

4.2 Conceptual Design

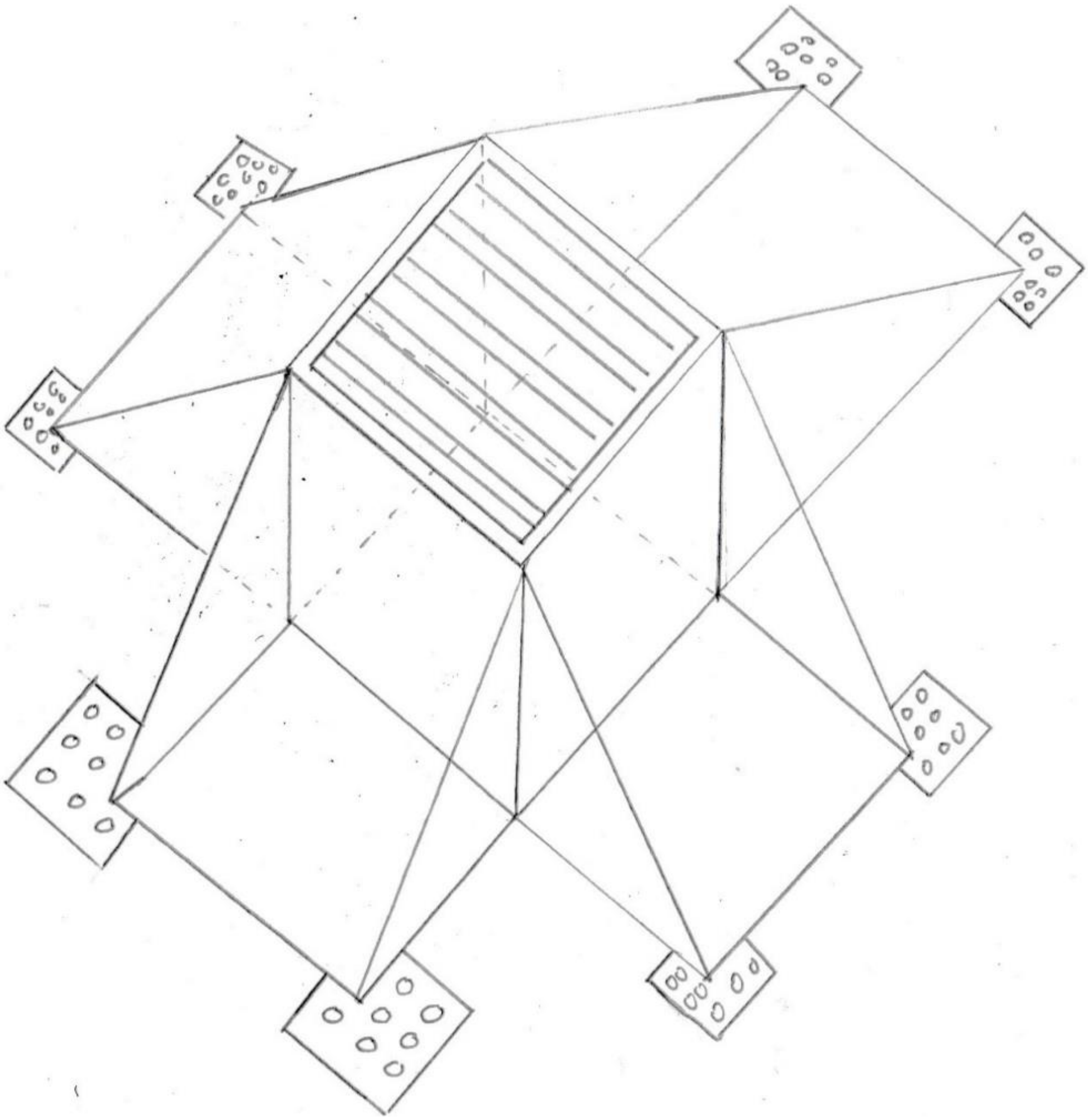


Figure 9: Conceptual design 1

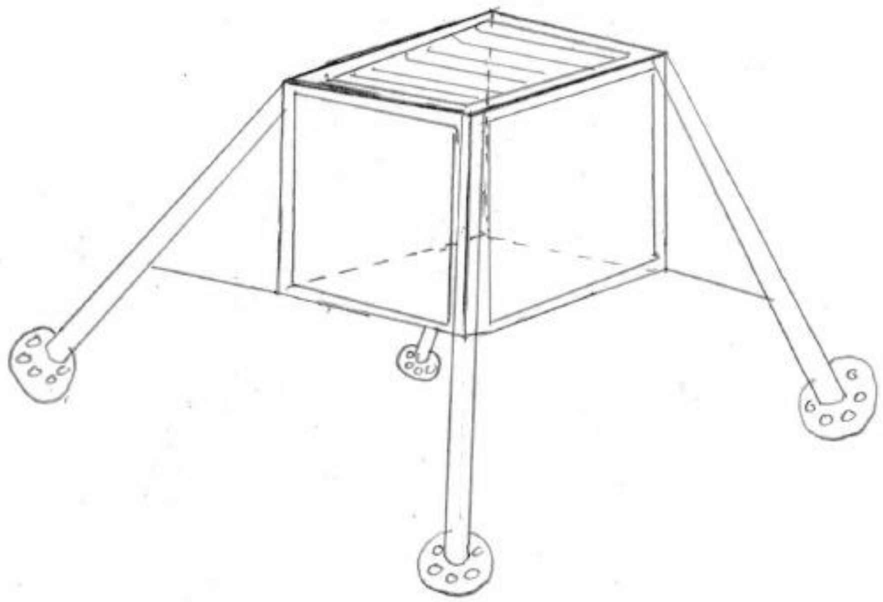


Figure 10: Conceptual design 2

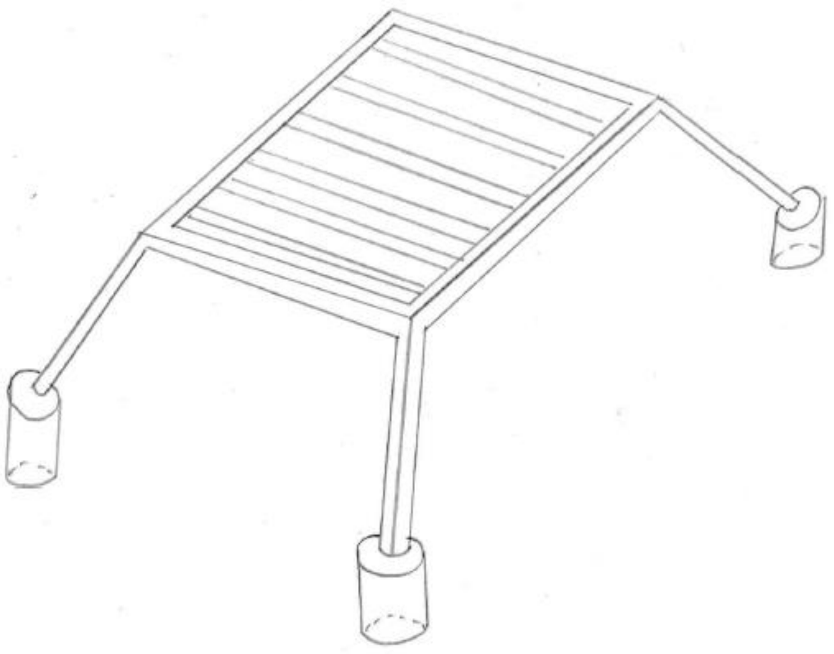


Figure 11: Conceptual design 3

4.3 Concept Evaluation

4.3.1 Objective Tree and Weighted Decision Matrix

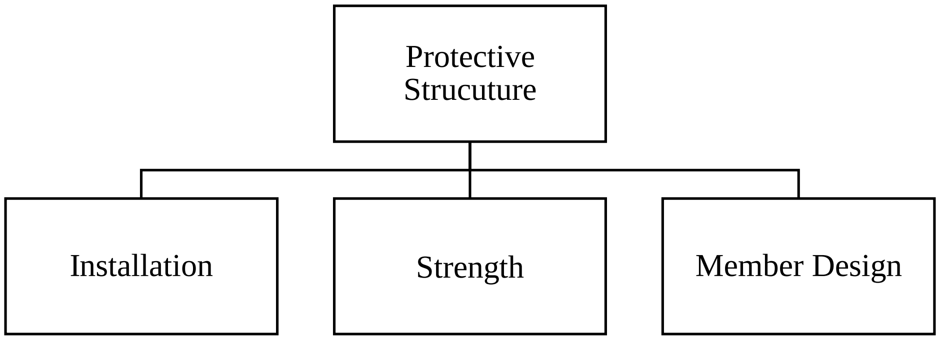


Figure 12: The objective tree for protective structure

Table 4: The weighted decision matrix for protective structure

Design Criterion	Weight Factor	Concept 1 Tubular Rod, Mud Mat		Concept 2 Rod, Mud Mat		Concept 3 Beam, Pile	
		Score	Rate	Score	Rate	Score	Rate
Installation	0.3	7	2.1	7	2.1	5	1.5
Strength	0.4	5	2.0	5	2.0	7	2.8
Member Design	0.3	7	2.1	5	1.5	5	1.5
Total	1	6.2		5.6		5.8	

4.4 Structural Analysis

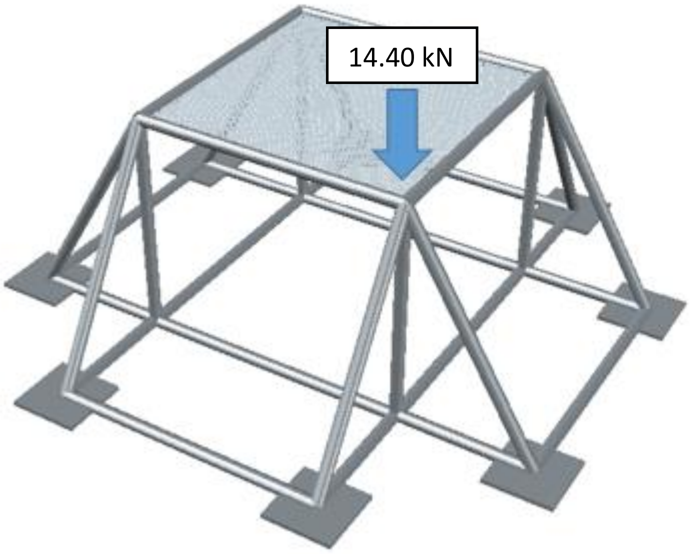


Figure 13: The force exerted at the structure

In Figure 13, It is defined that the force is acting on the top right edge of the structure. The force is acting in y-direction with the magnitude of 14.40 kN. The value was obtained from the calculation of the mass of the trawl gear which is define as 7 tonnes or 7000 kg and at the speed of 4 knots or 2.06 m/s. The speed of 4 knots was used because the range of speed for commercial fishing trawl are in between 2 to 4 knots.

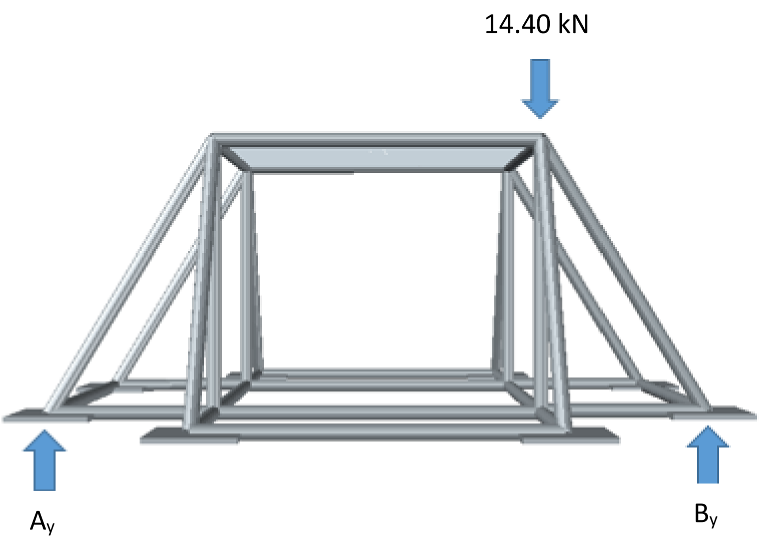


Figure 14: The side view of the protective structure

By using the concept of space truss, since no forces are acting in x and z-direction, the values for support reaction are only in y-direction. We consider that the mud mat to be the fixed support reaction and the forces are distributed equally among the support reaction. Thus, this problem can be demonstrated in 2-Dimensional (2-D) as shown in Figure 14.

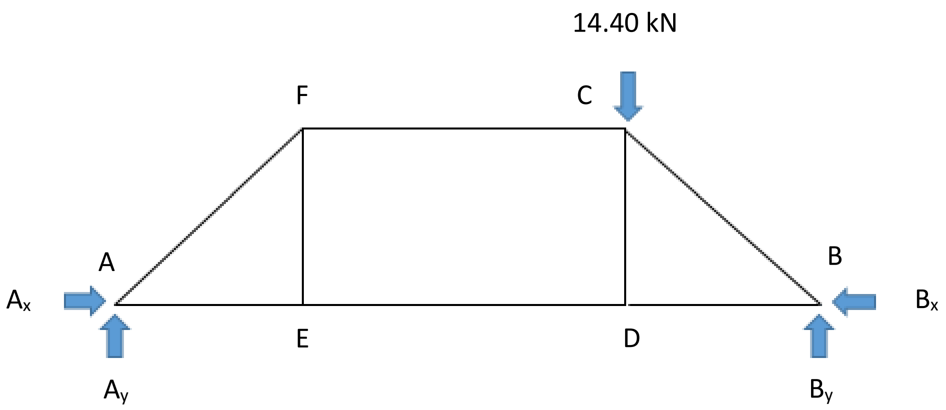


Figure 15: The free body diagram for the protective structure

Figure 15 is the free body diagram of the protective structure. Since no forces in x-direction, A_x and B_x can be omitted. Method of joint analysis is used in this stage to calculate the forces of each member. Table 5 below shown the force of each members.

Table 5: The force of each member

Member	Load (kN)
AF	0
AE	1.8
FE	0
FC	0
ED	0
CD	14.40
CB	0
DB	1.8

The largest force exerted is on member CD which is 14.40 kN. Hence, the value for pressure can be calculated using the force and area as shown in Equation 3 and Equation 4. For the area, since the force is exerted outside the pipe, the area can be consider as the area of the rectangle. Stainless steel A312 grade TP321 was selected to be the material of the protective structure. From Table 6, it is stated that the basic allowable pressure that the tube can withstand is 20 ksi at 37.8 ^{o}C.

$$A = W*H$$

$$A = 1.638 \text{ m}$$

$$P = F/A \quad \textbf{(4)}$$

$$P = 14400 \text{ N}/ 1.638\text{m}$$

$$P = 87.91\text{KPa} \quad \textbf{(5)}$$

Table 6: The allowable stress for stainless steel A 312 [14]

ASTM Spec No.	Grade	Min Temp ^{O}C	Metal Temperature, ^{O}C								
			37.8	149	260	371	454	538	621	704	760
			Basic Allowable Stress, ksi								
A312	TP 321	-325	20	20	19.3	17.5	16.7	16.2	5.0	1.7	0.8

According to NORSORK U-002, the structure should able to withstand 7 tonnes of impact load. From the calculation in Equation 3, the value of stress that the member experience is 0.706 MPa whereas the basic allowable stress for stainless steel A312 TP 321 is 20 ksi at 37.8 ^{O}C or 137.90 MPa. Thus, even with the safety factor of 3, which is 46.0 MPa, the member will be able to withstand that amount of pressure.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

All the subsea equipment and pipeline need to be protected from any source of impacts that can cause leakage of hydrocarbon from inside the equipment and pipeline. Among the source of the impacts are objects from the offshore operation and the trawl gear from fishing activities.

The objective of this project is to propose the suitable subsea x-tree protection structure to withstand the impact of the dropped object. This project was conducted by following the NORSORK U-001 and U-002 standard where it stated that the protective structure should be equipped with overtrawlibility structure and can withstand the impact of minimum 7 tonnes. This project also involved the improvement form the current design which is GRP protective cover from HighComp. Thus, from the analysis, even with the safety factor of 3, the propose design still able to withstand more than 7 tonnes of impact.

Since the project only involve the designing stage, it is recommended that the project can be transform into prototype. Risk assessment also should be conducted to enhance the protective feature of the structure hence the structure can efficiently withstand any type of impacts.

REFERENCES

[1] T. W. Knudsen, "When The Going Gets Tough - We Go Subsea," Bergen - Norway , 2014.

[2] S. Srl, "Subsea Technology and Equipments," 2014. [Online]. Available: http://www.oil-gasportal.com/subsea-technology-and-equipments/.

[3] Kaple, "Na Kika Oil and Gas Fields, United States of America," 2015. [Online]. Available: http://www.offshore-technology.com/projects/na_kika/.

[4] W. L. Leffler, R. Pattarozzi and G. Sterling, Deepwater Petroleum Exploration & Production, Oklahoma: PennWell, 2003.

[5] W. O. McCarron, Deepwater Foundation and Pipeline Geomechanics, U.S.A: J.Ross Publishing , 2011.

[6] Q. Bai and a. Y. Bai, Subsea Pipeline Design, Analysis, and Installation, Oxford : Elsevier , 2014.

[7] D. N. Veritas, Recommended Practice DNV-RP-C204 Design Against Accidental Loads, Det Norske Veritas, 2010.

[8] A. B. o. Shipping, "Guidance Notes on Accidential Load Analysis and Design for Offshore Structures," American Bureau of Shipping , Houston, February 2013.

[9] J.P.Kenny, "Protection of Offshore Installation Against Impact," Offshore Technology Information, London , 1998.

[10] SIMRAD, "TECHNOLOGY FOR SUSTAINABLE FISHERIES," Kongsberg Maritime AS , 2 April 2009. [Online]. Available: http://www.simrad.com/www/01/NOKBG0238.nsf/AllWeb/DAE B7455E3801C3BC125758C001B6719?OpenDocument. [Accessed 20 December 2015].

[11] PRONAL, "GRP COVER - COMPOSITE PIPE SUPPORT," PRONAL Elastomer Engineering , [Online]. Available: http://www.pronal.com/english/grp-cover---composite-pipe-support-mattress--_cd1_74.html. [Accessed 20 December 2015].

[12] U. K. B. Jura, Total E&P (UK), Aberdeen, U.K.: FMC Technologies , 2007.

[13] H. a. S. Executive, "Offshore Technology Report - OTO 96 951," Health and Safety Executive, Sheffield, 1997.

[14] A. M. Ltd, *Section 5 : Pipe and Tube Size,* Amari Metals Ltd, n.d.