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Review on Design of Oil Subsea Pipeline in Kikeh Field, Malaysia

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ABSTRACT

The encourage and positive development of oil and gas project in Malaysia deep water sea has led to the exchange of the underwater exploration from the shallow water depth to deeper water depth. However, this changes have raises the issue on deep water challenges for the submarine pipeline design. Designing a subsea pipeline is a challenge task and the process requires a detailed study and assessment of relevant pipeline design consideration and pipeline failure criteria. "Design of Deep Water Oil Subsea Pipeline in Malaysian Seas" project discuss a number of issues that need to be taken into account when designing a deep water subsea pipeline for Malaysian waters, mainly related to the excessive external pressure on the pipeline. Problems of high external pressure will results in pipeline failure such as system collapse and propagation buckling of a pipeline. In addressing these issues, consideration towards pipeline wall thickness design is being taken and the design process of the pipeline will be made in accordance to DNV class rule. Apart from that, a case study related to existed oil and gas project in Malaysia has being carried out, where Kikeh Gas Pipeline project from Kikeh oil field was selected as a study subject. By referring to the case study, a decent subsea pipeline design will be carried out and analyze so that it can suite to operate for Malaysian deep water seas.

KEY WORDS: *Offshore, Pipeline, Deep Water, Malaysian's Sea.*

1.0 INTRODUCTION

Malaysia is one of the main players in oil and gas industry among other big Asia-Pacific countries. Malaysia was ranked as the 4th highest reserves after China, India and Vietnam, with proved reserves of 4 billion barrels as of January 2014. For overall total petroleum production in the year 2014, Malaysia is ranked at 26th, after big countries such as China, Russia, Saudi Arabia and United States. Study by Frost & Sullivan in 2014 estimated that Malaysia's deep water will contribute to 30 percent of total oil production in the year 2020.

As up to these day, Malaysia's deep water for oil and gas activities has covered up to the depth of approximately 1400 meters for its first deep water project, Kikeh Field in 2006. The trend of deep water development is prone to conduct of offshore of Sabah state. Currently, all four existed deep water project on Malaysia are developed in Sabah's deep water. Table.1 listed a brief detail on all deep water projects in Malaysia.

Table.1: Deep water projects in Malaysia's seas

Project	Location	Approximate depth	Operator
Kikeh (2007)	Block K and P, 120Km northwest of Labuan island.	1400m	Murphy Sabah Oil Company, Petronas Carigali
Gumusut-Kakap (2015)	Block J and K, 120Km offshore from Sabah state	1200m	Sabah Shell (Gumusut), Murphy Oil (Kakap), ConocoPhillips Sabah, Petronas Carigai

Malikai (2017)	Block G, 100Km off the coast of Sabah	500m	Shell, ConocoPhillips, Petronas Carigali
Siakap North-Petai (2014)	Block K and G, offshore Sabah	1300m	Murphy Oil, ConocoPhillips, Shell, Petronas Carigali

2.0 LITERATURE REVIEW

2.1 Deep Water Challenges

As the water depth goes deeper from shallow water to deep water, the governing main challenges are related to the high external pressure and potential collapse of pipeline. High external pressure means pipeline collapse failure mode governs wall thickness design rather than pressure containment. Pipeline wall thickness design is one of the most critical design considerations that have to be done before pipeline construction.

2.2 Pipe Wall Thickness Design Criteria

As external pressure becomes dominant, the wall thickness design will be governed by the pressure containment criterion, collapse, combined pressure and bending and buckle propagation. Hence, during the designing state the selection of pipe and material properties should satisfy the following requirements:

- Allowable Hoop stress
- Pressure containment (Burst design)
- Collapse Pressure
- Combined load of loading and external pressure

2.3 Material Selection and Wall Thickness Design

The use of higher steel grades has a significant effect on the required wall thickness to avoid collapse for deep water pipelines. The effect on wall thickness reduction is higher with increasing depths.

Higher strength steel grade has a higher effect on wall thickness requirements especially for deeper water compared to shallow water. Wall thickness generally will affect both cost and weight and by using higher steel grade these both parameters can be greatly reduced especially when involving high external pressure.

3.0 DESIGN METHODOLOGY

The following steps are the mechanism done for this study:

1. Identify problem statement, objectives and literature review.
2. Discuss challenges involves for deep water pipeline design.
3. Perform study on deep water subsea pipeline design based on DNV class rule.
4. Study on Kikeh Gas Pipeline, Kikeh Oil Field and collecting data.
5. Code development for pipeline's wall thickness design using Microsoft Visual Basic 2010.
6. Analyzing and comparing data.
7. Results, discussion and conclusion.

3.1 Design Criteria

The main design criteria in designing the deep water subsea pipeline in this study are as follows:

1. To have a minimum wall thickness for deep water subsea pipeline which satisfies the required pipe wall thickness to contain collapse pressure and propagation pressure.
2. To design a deep water subsea pipeline with the consideration of safety factor, location factor and load effect factor which suited to Malaysian deep water seas.

3.2 Design Limit States, Classes and Load Effect Factor

In this study, a selection towards the design limit states, safety and location classes, and load effect factor are chosen based on the case study of Kikeh Oil Field. The selected design criteria are as follows:

- **Limit State**: Ultimate Limit State (ULS). A condition which, if exceeded, compromises the integrity of the pipeline.
- **Safety Class**: Low. A condition where failure implies insignificant risk of human injury and minor environment and economic consequences.
- **Location Class**: Location 1. The area where no frequent human activity is anticipated along the pipeline route.
- **Condition Load Effect Factor**: Pipeline resting on uneven seabed.
- **Load Effect Combination**: ULS – system check. The condition where the combination of functional loads and environmental load could affect or jeopardized pipeline's operation and integrity.

4.0 KIKEH FIELD DEVELOPMENT

In verifying the validity of the developed program and suitability of selected design parameter towards Malaysian seas usage, a comparison is being made between the calculated data with the actual data. Simulation results verification were done using the actual field data from existed deep water project in Malaysia. And for this reason, Kikeh Gas Pipeline of Kikeh Field project is selected for case studying project.

Table.2: General Details on Kikeh Gas Pipeline Design (Source: Sapura Acergy)

Location	Kikeh Field / Offshore Labuan, West Malaysia
Water Depth (Sapura 3000 Start-up @ KP90)	50 m
Water Depth (at PLET/PLEM)	1340 m
Max. Operating Water depth	1410 m
Pipeline Material	Carbon Steel API 5L (PSL2) Grade X65 Seamless Applicable for sour and non-sour service
Pipe Size	Line pipe:

	Zone II: 339.7 mm OD x 27.3 mm WT (LFP – 1.5 km) Zone I: 323.9 mm OD x 18 mm WT (1.5 km (from LFP) – KP 0)
Average Joint Length	11.9m – 12.5m
Estimated no. of Joint	11270
Design Pressure (Operating)	358.6 barg / 5200 psig (relative to LAT) 413.8 barg / 6000 psig at PLEM piping
Design Pressure (Hydrotest)	1.25 x design pressure
Design Maximum Temperature and Minimum Temperature	Max. Temperature: 60°C Min. Temperature: -10°C
Pipe Ovality, Fabrication Tolerance, Fabrication Factor, Material Strength Factor	See API5L
Pipe Content and Density	Sour Gas (0.33 kg/m^3)
Pipe's Design Lifespan	50 years

Malaysia has a relatively limited oil pipeline network and relies on tankers and trucks to distribute products onshore. Malaysia's main oil pipelines connect oil fields offshore Peninsular Malaysia to onshore storage and terminal facilities. The 124-mile Tapis pipeline runs from the Tapis oil field and terminates at the Kerteh plant in Terengganu, as does the 145-mile Jerneh condensate pipeline. The oil pipeline network for Sabah connects offshore oil fields with the onshore Labuan Crude Oil Terminal.

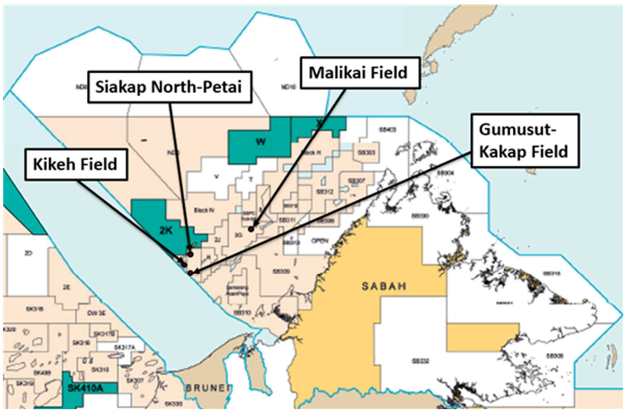

Figure.2: Location of Malaysia's deep water project

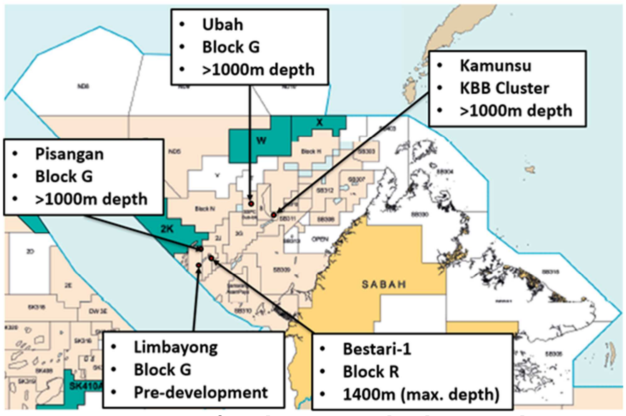

Figure.3: Location of Malaysia's on-development deep water project

Malaysia has one of the most extensive natural gas pipeline networks in Asia, totaling about 1,530 miles. The Peninsular Gas Utilization (PGU) project, completed in 1998, expanded the natural gas transmission infrastructure on Peninsular Malaysia. The PGU system spans more than 880 miles and has the capacity to transport 2 billion cubic feet per day (Bcf/d) of natural gas. Other gas pipelines run from offshore gas fields to gas processing facilities are at Kertih. Also, a number of pipelines link Sarawak's offshore gas fields to the Bintulu LNG facility.

Designing a decent pipeline for the deep water usage activities are more challenges as compared to for shallow water pipeline. At deep water depth, more than 300 meters, the pipeline will experience high external pressure. External pressure experience by the pipelines is directly proportional to its operational depth. Hence, designing a subsea pipeline for deep water in Malaysian seas should give big consideration and attention to the external pressure since it will give bigger impact and effect on the pipelines as compared to the shallow depth's pipelines.

Pipeline installed at deep water depth will have a high potential to collapse compared to if installed at shallow depth. The potential of collapse is due to the high external pressure experienced by the pipeline. Hence, a decent design should be done, together with a suitable design criteria and consideration that can overcome the collapse failure of the pipeline in deep water depth.

5.0 SIMULATION RESULTS

5.1 Failure Mode and Wall Thickness Design Analysis

For this analysis, the failure mode for deep water pipeline are being investigated on which mode is the main failure that govern the wall thickness of the pipeline. Two types of failure mode which is system collapse and propagation buckling of the pipeline is evaluated in this analysis. The analysis is done for three different deep water depths with the use of material grade type X65 for the pipeline. The remarks are made based on the required wall thickness for both type of failure.

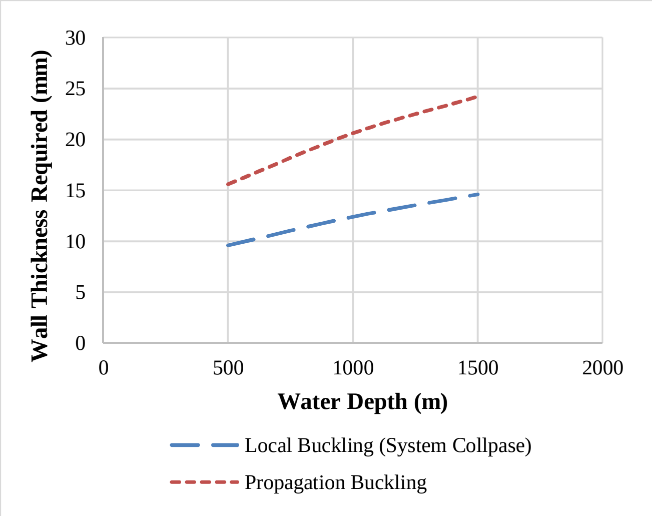

Figure.4: Wall thickness design towards failure modes

From the result and the generated graph we can conclude that,

1. Containing the propagation buckling of the pipeline requires bigger or thicker wall thickness compared to the system collapse failure.
2. Propagation pressure was experienced by the pipeline at the deep water depth are bigger and higher compared to the collapse pressure.
3. At deep water depth, the propagation buckling is the main failure mode that governs the pipeline wall thickness design compared to the system collapse failure.
4. Designing a pipeline wall thickness according to propagation buckling requirement will able to help sustain both system collapse and propagation buckling failure.

5.2 Material Grade Effect Analysis

For this analysis, the effect on the material grade selection for the deep water pipeline was being investigated. Three different quality of API material grade comprising X60, X65 and X70 type are used in this analysis and only cover for the propagation buckling failure mode, since it is the main mode that governs deep water pipeline failure. The main focus on the analysis is to evaluate the effect of the material grade quality that used in pipeline design towards the required wall thickness of the pipeline.

From the result and the generated graph we can conclude that,

1. Material grade selection give effects on the pipeline wall thickness design.
2. Increase in material grade quality will be able to help reducing the required wall thickness of the deep water pipeline design.
3. Increase in yield stress and tensile strength of a material used in pipeline design give effect on the pipeline durability for deep water operation.
4. As the pipeline's operation depth goes deeper, the importance of the material grade selection for the pipeline design will become more significant.
5. The use of high quality material grade will give most effect on the wall thickness required especially for deep water depth compared to shallow water depth. Reduction in wall thickness requirement then can greatly help to reduce the production cost and weight of the pipeline, especially for the pipeline in deep water depth usage.

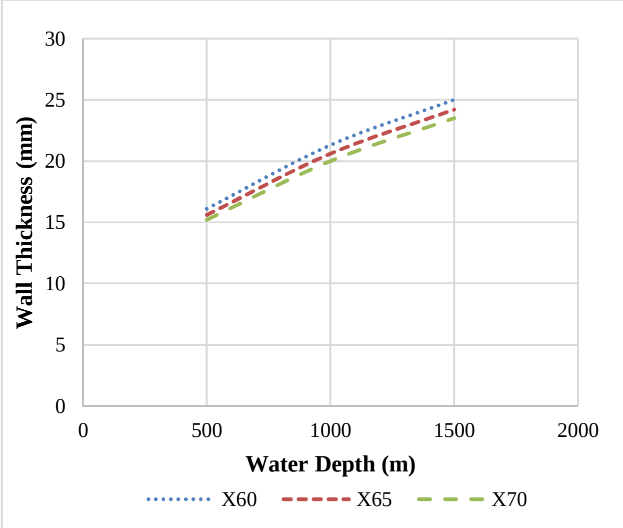

Figure.5: Effect of material grade selection towards wall thickness design

5.3 Subsea Pipeline Stress Analysis

For this part, the analysis is done based on the case study of Kikeh Gas Pipeline. The actual data of the pipeline from the Kikeh Oil Field will be used as a parameter in this analysis. This analysis was carried out using two simulation programs which are developed for analyzing pipeline design. The first program used are called UGP Pipeline which have been developed through this study by using DNV class rule while the second program used is an established pipeline design analysis software named Subsea Pro which have been developed by using safety margin design. The UGP Pipeline program have been developed using the design factor, design load and design safety which are choose to suite the application towards Malaysian deep water seas. Through this analysis, the evaluation then was being made on the reliability and suitability aspect of the designed pipeline for the use in Malaysian deep water seas.

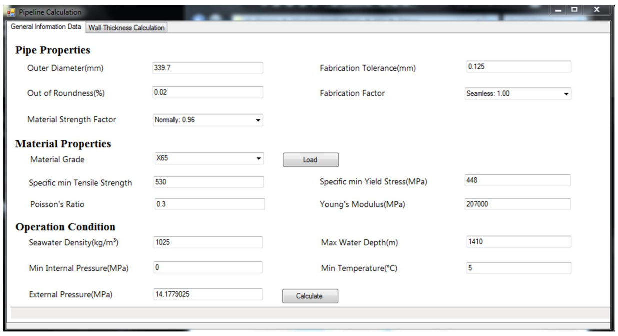

Figure.6: Analysis using UGP Pipeline program.

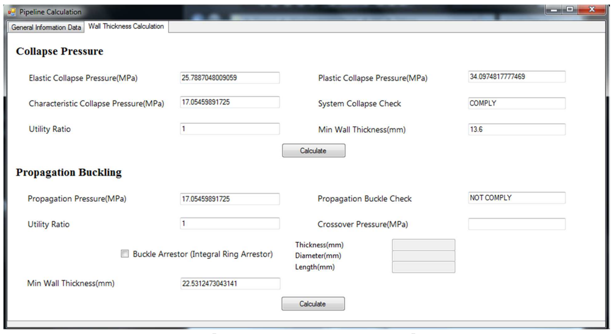

Figure.7: Analysis using UGP Pipeline program.

Table.3: Result from UGP Pipeline program

	Local Buckling (System Collapse)	**Propagation Buckling**
Required Wall Thickness	13.6 mm	22.6 mm

Considering the failure mode and wall thickness analysis that have being done at in Section 8.3, the minimum wall thickness required to contain both failure will be equal to 22.6 mm, taken from propagation buckling mode. In addition to that, to comply with the Kikeh case study, the corrosion allowance thickness will be taken into account, where corrosion allowance rate are taken at 0.1 mm/year.

Table.4: Corrosion allowance calculation

Min. Wall Thickness	**22.6 mm**
Corrosion Allowance	0.1 mm/year x 50 year (Kikeh pipe's design lifespan) = 5 mm
	27.6 mm

Table.5: Wall thickness comparison

	UGP Pipeline Program	Subsea-Pro Program	Kikeh Gas Pipeline (Actual Data)
Class Rule	DNV	Design by Safety Margin	-
Design Life Span	50 Years	50 Years	50 Years
Wall Thickness Required	27.6 mm	27.83 mm	27.3 mm

Figure.8: Subsea Pipeline analysis using Subsea Pro Simulation.

From the results and comparison above we can conclude that:

1. The developed program, UGP Pipeline program showed good result.
2. The selected design factor, design load and design safety for the UGP Pipeline program are suite to the pipeline design for Malaysian deep water seas.
3. The importance of safety factor, location factor and load effect factor for deep water project in Malaysian seas can be applied thoroughly when designing a pipeline using DNV class rule.
4. The result illustrate the capability of the developed program and DNV class rule in designing a decent pipeline for deep water depth operation in Malaysia seas.
5. Although the wall thickness requirement by UGP Pipeline program are slightly thicker compared to actual data, this however should never being concerned, because in a case of selecting between two different wall thickness of the subsea pipeline, we as a designer will always take the thicker one due to the consideration in pipe's safety and strength aspect.
6. The minimal difference in wall thickness value between the developed UGP Pipeline program and established Subsea Pro program give means that the developed program can be considered reliable in designing the wall thickness for the deep water pipeline.

6.0 CONCLUSION

As a conclusion from this study, a decent and appropriate design consideration have being successfully being implemented in designing the deep water subsea pipeline for Kikeh oil field on Malaysian seas. Some major issues relate to the deep water pipeline challenges were able being discussed through this study. It is now understood that the challenges for the deep water depth are differs and more critical than for shallow waters where for the deep water depth, the failure threat are comes from local buckling due to collapse and propagation buckling of the pipeline.

The results from the developed program have showed good agreement with the actual data and Subsea Pro simulation results. Through the analysis that have being done using the developed program, it is now obvious and can be clarify that the main failure mode that governs the pipeline wall thickness design is the propagation buckling. Meeting the wall thickness requirement for propagation buckling can be considered sufficient to contain both failure mode that governs deep water pipeline which is system collapse and propagation buckling. In addition to that, the effect on the material grade selection towards the wall thickness requirement has also being justified. It is proved that the use of higher material grade can give help in reducing the required wall thickness design for deep water subsea pipeline.

The analysis of the case study on Kikeh Gas Pipeline has proved the suitability and compatibility of the chosen design safety, design factor and design load towards the application on Malaysia deep water seas. This founding has shown the importance of safety factor, location factor and load effect factor as part of pipeline design consideration that need to be taken as recommended by the DNV class rule. This also shows the reliability and conformity of DNV class rule in designing the deep water subsea pipeline in Malaysian sea.

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