FATIGUE ANALYSIS OF CATENARY OFFSET BUOYANT RISER ASSEMBLY(COBRA) CONCEPT

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This is for everyone who has been with me throughout this journey

What a journey it has been

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In the name of Allah, the Entirely Merciful, the Especially Merciful. All praises are to Him. May He grant us all the serenity to accept the things we cannot change, courage to change the things we can and wisdom to know the difference.

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ABSTRACT

Steel Catenary Riser is the preferred solution to riser system in offshore oil & gas production. They are more structurally reliable, technically simple and cost effective compared to other types of riser. As the offshore oil & gas production move to deep and ultra-deepwater regions, the optimum solution have to be determined to overcome the challenges of steel catenary riser such as its weight and size. Hybrid riser seems to address some of the problems but they have complex bottom assembly that could prove technically challenging. Catenary Offset Buoyant Riser Assembly (COBRA) is a concept conceived to address most of the problem of steel catenary riser in deepwater. It combines the advantages of steel catenary and hybrid risers and is made up of two parts. The bottom part consists of a rigid steel pipe lain in catenary configuration and connected to a sub-surface buoy. A flexible jumper connects it to the floating structure. The flexible jumper and the buoy effectively absorbed the forces acting on the riser and floating structure essentially making the steel catenary undisturbed by the dynamic motions, thus improving its fatigue performance. This project will be focusing on numerically simulating the application of COBRA in a Malaysia deepwater project. The environmental conditions from the Kikeh Field is applied to determine the static, dynamic and wave fatigue analysis of COBRA. The static and dynamic analyses showed that. at the touch-down point, the tension for COBRA is about 50% smaller that for steel catenary riser. The simulation also has shown that COBRA has an excellent fatigue life. Therefore, the COBRA concept is suitable for application in deepwater projects in Malaysia

ABSTRAK

Riser Katenari Keluli adalah penyelesaian pilihan untuk sistem riser dalam pengeluaran minyak & gas luar pesisir. Ia lebih dipercayai dari segi struktur, secara teknikalnya mudah dan kos efektif berbanding dengan jenis riser lain. Apabila pengeluaran minyak & gas luar pesisir bergerak ke kawasan laut yang dalam dan ultra dalam, penyelesaian optimum perlu ditentukan untuk mengatasi cabaran riser katenari keluli seperti berat dan saiznya. Riser hibrid seolah-olah menangani beberapa masalah tetapi mereka mempunyai perhimpunan bawah yang kompleks yang boleh jadi secara teknikalnya mencabar. Catenary Offset Buoyant Riser Assembly (COBRA) adalah konsep yang diilhamkan untuk menangani kebanyakan masalah riser katenari keluli di lautan dalam. Ia menggabungkan kelebihan riser katenari keluli dan hibrid dan terdiri daripada dua bahagian. Bahagian bawah terdiri daripada satu paip keluli utuh dalam konfigurasi katenari dan disambungkan ke pelampung sub permukaan. Pelompat fleksibel menghubungkannya dengan struktur terapung. Pelompat fleksibel dan pelampung dengan berkesannnya menyerap daya-daya yang bertindak pada struktur riser dan struktur terapung membuatkan katenari keluli tidak terganggu oleh gerakan dinamik, dengan itu meningkatkan prestasi kelesuannya. Projek ini akan memberi tumpuan kepada simulasi mengikut simulasi COBRA dalam projek lautan dalam di Malaysia. Keadaan persekitaran dari Medan Kikeh digunakan untuk menentukan analisis statik, dinamik dan kelesuan ombak bagi COBRA. Analisis statik dan dinamik menunjukkan bahawa pada titik sentuhan-bawah, ketegangan untuk COBRA adalah kira-kira 50% lebih kecil untuk riser katenari keluli. Simulasi juga telah menunjukkan bahawa COBRA mempunyai keletihan yang sangat baik. Oleh itu, konsep COBRA sesuai untuk aplikasi dalam projek laut dalam di Malays

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LIST OF ABBREVIATIONS

API	American Petroleum Institute
BHRT	Bundled Hybrid Riser Tower
COBRA	Catenary Offset Buoyant Riser Assembly
DOF	Degree of Freedom
DNV	Det Norske Veritas
IFP	Institut Français du Petrole
JONSWAP	Joint North Sea Wave Project
FPSO	Floating Production, Storage, Offloading
PSC	Production Sharing Contract
RAO	Response Amplitude Operator
SCR	Steel Catenary Riser
SLOR	Single Line Offset Riser
TLP	Tension-leg Platform
TTR	Top-tensioned Riser
VIV	Vortex-Induced Vibration

CHAPTER 1

INTRODUCTION

1.1 Background

In offshore oil & gas engineering, risers are essentially pipes that connect an offshore floating structure and subsea wells to each other. They are the conduit through which fluids are transferred between the floating structure and the wells. A riser is a unique common element to many floating offshore facilities and is critical to safe field operations. Therefore, it must be designed to be able to maintain its integrity under external and internal loadings throughout its service life.

Risers can be categorized into two based on their type of operation. Drilling risers, as shown in Figure 1 are used to contain fluids for well control. Production risers are used to convey hydrocarbons from the seabed to the floating structure (Chakrabarti, 2005). The selection of riser solution for deepwater is governed by a set of much more intricate factors compared to shallow water, such as water depth, weight and size. As deepwater fields are becoming more important as the source of hydrocarbon, different concepts of risers have been conceived and studied to consider the limiting effects of these factors.

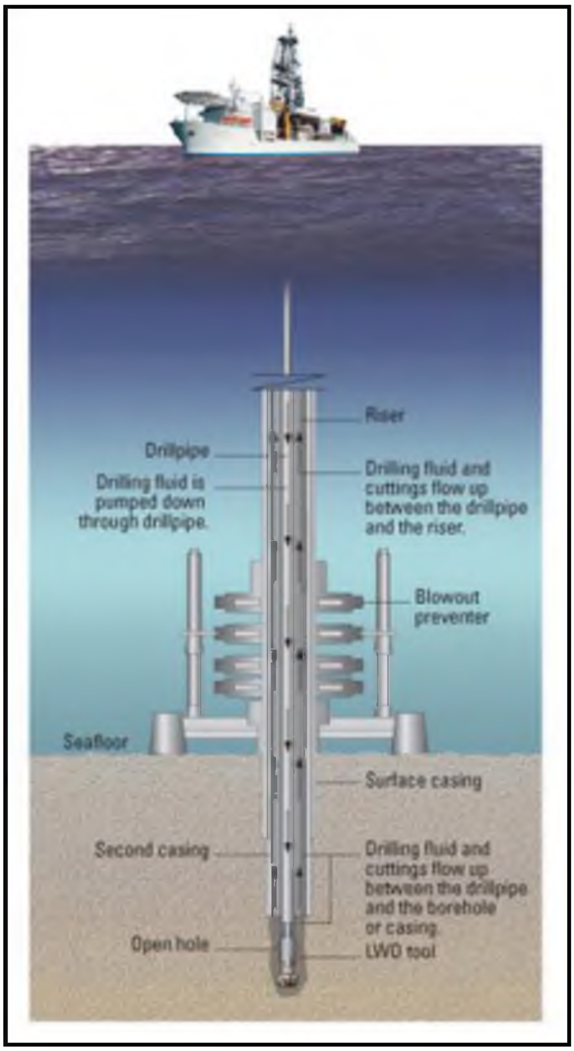

Figure 1: Drilling Riser (Source: Schlumberger)

Many shallow water oil & gas wells around the world have matured and depleted making deepwater as the new frontier for exploration and production activities. The International Energy Agency estimated that there could be around 270 billion barrels of recoverable oil alone in deepwater worldwide. Among the supermajors, Shell is at the foremost front of deepwater activities with more than 20 active projects throughout the world. Its Stone project in the Gulf of Mexico which started production in 2016 is the current record holder for deepest oil & gas project at around 2,900 m depth. Among the regions where deepwater activities are concentrated includes the Gulf of Mexico, Brazil and West Africa which forms the Golden Triangle, the North Sea and South and Southeast Asia as shown in Figure 2.

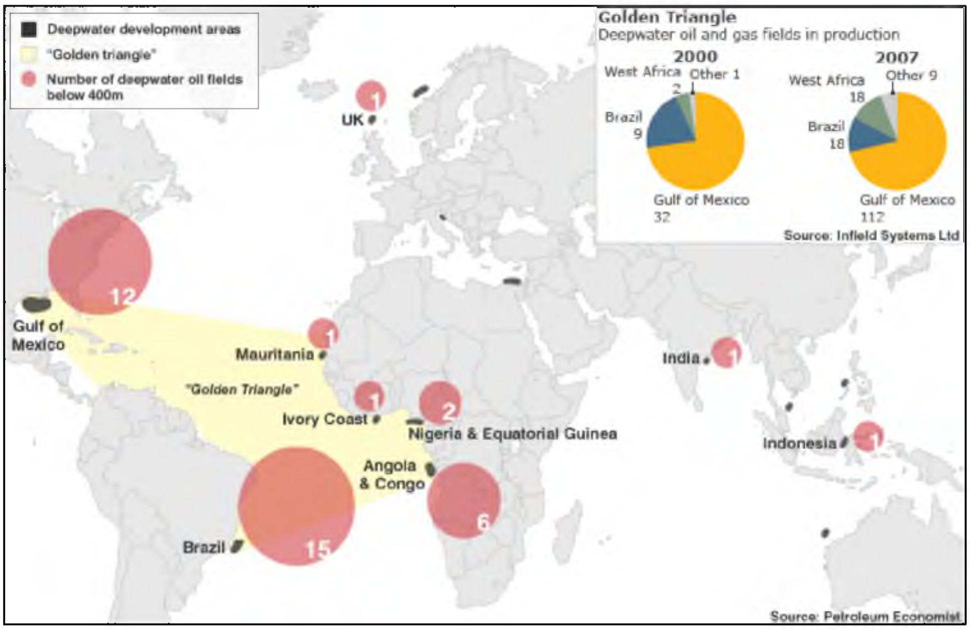

Figure 2: Map of the world showing deepwater oilfields in production (Source: BBC)

The impact of deepwater exploration and production trend is also felt in Malaysia. The estimated hydrocarbon deposit in deepwater fields in Malaysia is approximately 1 billion barrel of oil equivalent and 6 trillion cubic feet of gas. Deepwater resources are expected to contribute to about one third of national oil production by 2020 (Khalid, 2008). Petronas, in its effort to increase deepwater blocks exploration activities, introduced the first production sharing contract (PSC) for deepwater project in 1993. The first deepwater field discovered in Malaysia is the Kebabangan gas field in 1994 located in offshore Sabah. More deepwater oil & gas fields have been discovered since especially in Sabah and Sarawak including Kamunsu East, Kikeh & Limbayong, Gumusut & Kakap, Malikai, Ubah and Pisangan. The locations of these fields are shown in Figure 3.

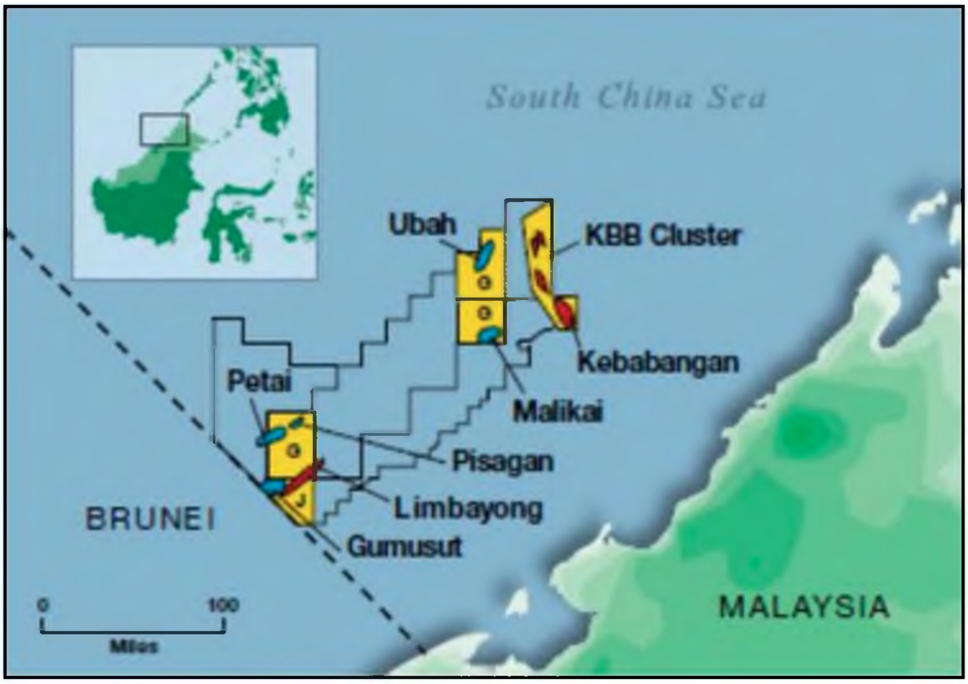

Figure 3: Deepwater field offshore Sabah (Source: offshoreenergytoday.com)

Kikeh is the first deepwater field to be developed in Malaysia. Discovered in 2002 at around 1350 m water depth, it produced the first oil in 2007. Murphy Oil developed the field by utilising an FPSO and the first SPAR to be deployed outside the Gulf of Mexico. Murphy will expand their deepwater portfolio in Malaysia by developing the Rotan gas field utilising the second floating LNG processing facility in Malaysia. Shell has developed two deepwater projects in Malaysia, the Gumusut-Kakap and Malikai oil fields. Each field are the pioneer of semi-submersible and Tension Leg Platform technology in Malaysia respectively. The Gumusut-Kakap field, which is located in around 1200 m water depth produced the first oil in 2014 while the Malikai field, which is located in around 500 m water depth produced the first oil in 2016.

A unique feature of deepwater projects in Malaysia, specifically in offshore Sabah is the challenge presented by the seabed topography. The seabed is dominated by the North-West Sabah Trough which begins less than 200 km from shore as shown in Figure 4. This North-East – South-West linear bathymetric feature with up to 2800 m water depth that continues farther than 300 km and reaches an average width of around 80 km. (Hazebroek and Tan, 1993). Most of the deepwater fields in Sabah are discovered here where the water depth may be considered as ultra-deep.

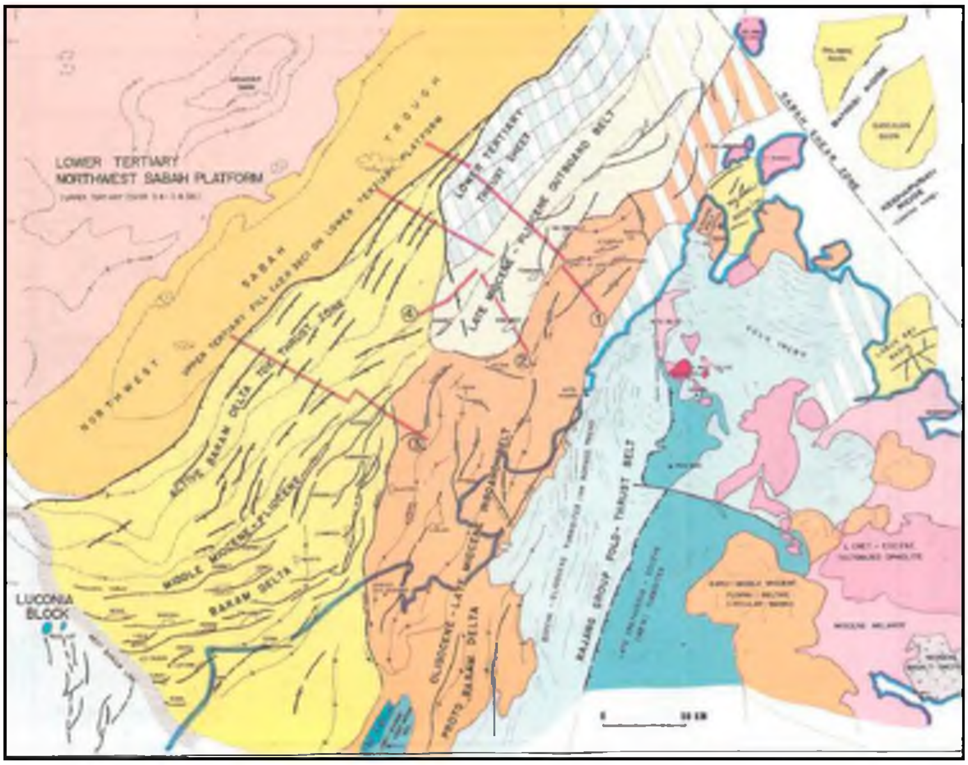

Figure 4: Tectono-stratigraphic provinces of NW Sabah (Source: Hazebroek and Tan, 1993)

As the industry moves further to deep and ultra-deepwater, the engineering challenges for riser from design to installation to maintenance become tougher as well. One particular challenge is the prevalent issue of the acceleration of riser fatigue particularly at the hang-off point and touch-down region (Marooka, 2011). The COBRA concept was conceived to address this issue.

This concept consists of a steel catenary riser section from the wellhead connected to a long, slender sub-surface buoy which in turn is connected to the floating structure via a flexible jumper (Karunakaran et al., 2011) as shown in Figure 5. It combines the conventional steel catenary riser with hybrid riser and inherits the desired advantages of both. Utilisation of this concept can be advantageous for deepwater project in Malaysia because of its good performance in harsh weather. Therefore, an in-depth study must be carried out to investigate the performance of the COBRA concept before it can be applied in deepwater projects in Malaysia.

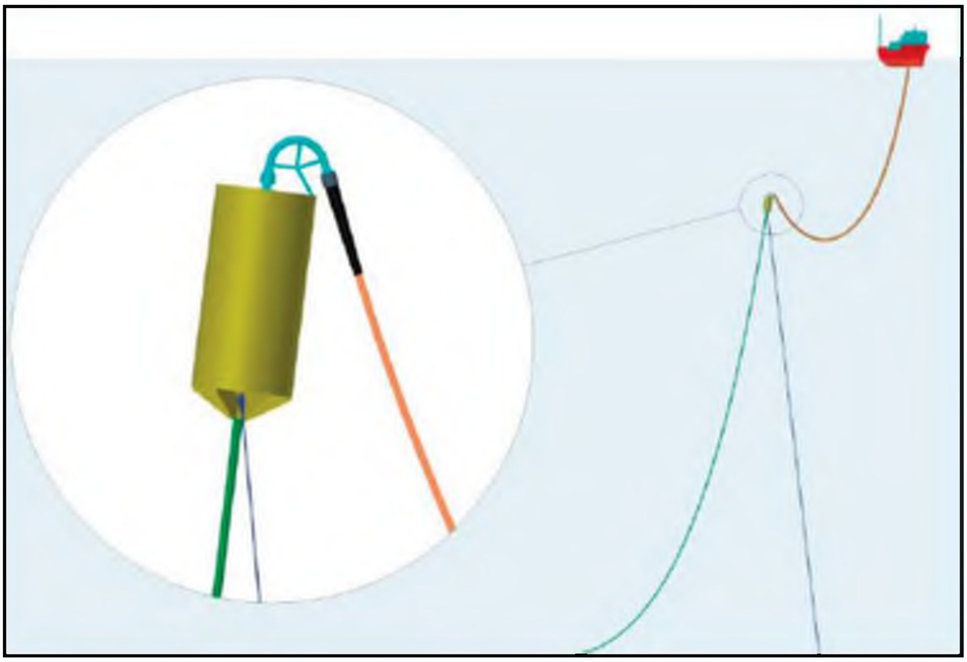

Figure 5: COBRA Concept (Karunakaran et al., 2011)

1.2 Problem Statement

The selection and design of riser concept for deepwater field development is a complex and challenging process. The selected concept must be able to maintain its integrity under various loadings during its service life. Among the factors that must be considered in the design process are water depth, riser weight and size. These factors will also influence the fatigue life of the riser. Particularly for deepwater riser, fatigue issue is prevalent at the hang-off point and touch-down region. As the medium of transportation for the hydrocarbon across the water depth, it is imperative to keep the riser intact for the safety of environment and operation. COBRA concept addresses the issues of deepwater riser and is a potential solution to be utilized in deepwater projects including in Malaysia. However, there has been insufficient research conducted to study its application in a Malaysian deepwater project. This project is carried out to investigate the performance of COBRA concept and its advantages in a deepwater project in Malaysia.

1.3 Objectives

The purpose of this research is to investigate the advantages of utilising the COBRA concept in a deepwater project in Malaysia. To achieve that, the following objectives are outlined:

1. To investigate the static, dynamic and fatigue performance of the COBRA concept in a deepwater project in Malaysia
2. To analyse the benefits of COBRA concept utilisation compared to other existing conventional riser concepts

1.4 Scope

The scope of this study is limited to:

1. Review of previous research conducted for deepwater riser concepts
2. Numerical study of global static & dynamic performance of COBRA concept in deepwater Malaysia
3. Numerical study of COBRA concept wave fatigue performance in deepwater Malaysia

1.5 Significance of the Study

Riser serves an important purpose in the offshore oil & gas production as the main conveyor of liquid from the well to the production facility and vice versa. Damage to the riser caused by any reason, including fatigue can cause serious effect to the operation and environment. COBRA concept has the potential to improve the fatigue life of riser in deepwater. Therefore, it is beneficial to investigate its performance so that deepwater projects in Malaysia can take advantage of this concept in order to reduce the probability of catastrophic disaster caused by riser failure.

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