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Review on Deep Water Flowlines of Gumusut-Kakap, Malaysia

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ABSTRACT

The Gumusut-Kakap field is located at offshore Sabah Blocks J and K at 1200 m of deep water. This paper discussed on production, gas injection and water injection flowlines of Gemusut-Kakap field development using Subsea Pro Simulation. The study was to determine wall thickness and stress and also to determine the deformation due to buckling of pipeline.

KEY WORDS: *Gumusut-Kakap Malaysian Deep Water; Subsea Production Flowlines*

NOMENCLATURE

MBOED Million Barrels Oil Equivalent per Day
PSC Production Sharing Contract
NW North West
SMYS Specified Minimum Yield Stress
SMTS Specified Minimum Tensile Stress

1.0 INTODUCTION

The major oil and gas reservoirs in Malaysia are located in the sedimentary basins with potential hydrocarbon deposits underneath the rock layers. Geologically Malaysia's continental shelf is made up of six major sedimentary basins as shown in the Figure.1, located offshore of Malaysian waters for the creation of hydrocarbons which are

1. Malacca Strait basin,
2. Malay basin: The Malay Basin in the offshore east covers more than 12,000 metres,
3. Penyu basin: The Penyu Basin in the south covers an area of 5,000 square kilometres,
4. Serawak basin,
5. Sabah basin: The Sabah Basin cover Northeast Sabah Basin and Southeast Sabah Basin,
6. Sandakan basin

The six sedimentary basins in Malaysian deep waters may be a great source of oil and gas energy if these resources can be properly obtained.

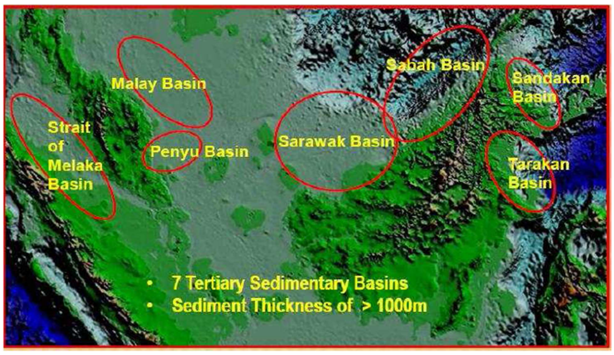

Figure.1: Seven sedimentary Malaysia basins [15].

The major ongoing oil and gas exploration and production activities are Malay basin, Serawak basin and Sabah basin, but the majority of the country's reserves are located at offshore Sabah and Sarawak basins. The amount of oil reserves from these basins are around 68%. Furthermore, offshore Sarawak and Sabah meet the 48% and 38% reserves of natural gas, respectively.

Malaysia produces very light and sweet crude oil known as Tapis Blend, where it has low sulphur content and lesser impurities compared to other crude oil with gravity of 44◦ and sulfur content of 0.08% by weight. More than 50% of the total Malaysian oil production comes from the Tapis field.

In 1910, Shell discovered the first Malaysia's first oil well on Canada Hill in Miri, Sarawak which produced approximately 80 million barrels of oil [7]. Then, there were no other drilling activities elsewhere in Borneo or Peninsular Malaya until the 1950s.

In the late 1960s, few foreign petroleum companies such as Esso and Conoco had received concession for oil and gas off the east coast of the Peninsula. Then, based 1974 Petroleum Development Act, PETRONAS received power that granted PETRONAS ownership and exclusive rights and powers over Malaysia's hydrocarbon resources and comes under direct purview of the Prime Minister.

The first deep-water oil was discovered in 2002 by Murphy Oil in Kikeh area, lies in around 1340 metres in offshore Sabah, which produced 440 million barrels [7]. Currently, there are many existing deep water projects in Malaysia are developed in Serawak and Sabah's deep waters. Table.1 shows listed a brief detail on all deep water projects in Malaysia.

Table.1: List oil and gas field developments in Malaysia's seas

Project	Location	Approximate depth	Operator
Kikeh (2007) 536 MBOED	Block K and P, 120Km northwest of Labuan island.	1340m	Murphy Sabah Oil Company, Petronas Carigali
Gumusut-Kakap (2015) 620 MBOED	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
Kebabangan (2007) 130-140 MBOED	130km offshore Sabah	100 -400m	Conoco P.
Jangas 81 MBOED		>1000	Murphy oil
Ubah Crest 215 MBOED		>1000	Shell
Pisangan 56 MBOED		>1000	Shell
Kamunsu		>1000	Shell

2.0 EAST MALAYSIA OIL AND GAS RESERVOIR

Currently, Malaysia has approximately 615,100 square kilometers of acreages available for oil and gas explorations in which 36 percent of these total acreages are currently covered by Production Sharing Contract (PSC). Exploration drilling by the PSCs has resulted in the discovery of 163 oil fields and 216 gas fields.

In 2005-2012, several data sets of wildcat wells were established to provide hydrocarbon evaluation, to give a better understanding of regional structural features and also to explore the hydrocarbon potential of deep-water NW Sabah. The NW Sabah Basin is an offshore of predominantly Middle Miocene age sedimentary basin that underlies the continental margin off Western Sabah and continues to the Sabah Trough and the Dangerous Ground provinces. Figure.1 shows oil and gas field location at Sabah basin

The Sabah Trough is also known as the Borneo Trough/Nansha Trough to the southwestern part and the Palawan Trough/Trench to the north-eastern part with bathymetric featuring water depths of the depression that varies from 2410 m to about 2900 m, extends over 300 km in length with an average width of 80 km as shown in Figure.2. Figure.3 shows location of deep water projects in East Malaysia.

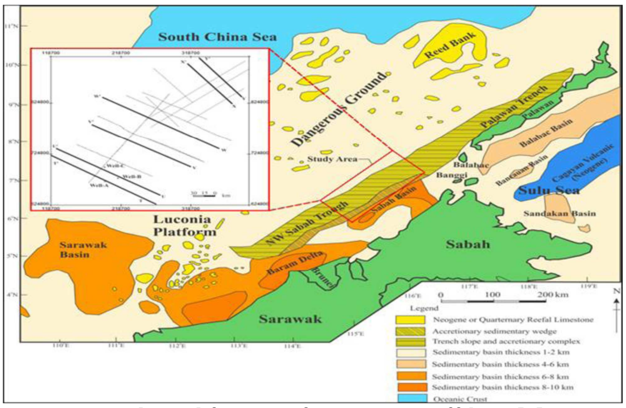

Figure.2: Geological features of NW Borneo offshore [5].

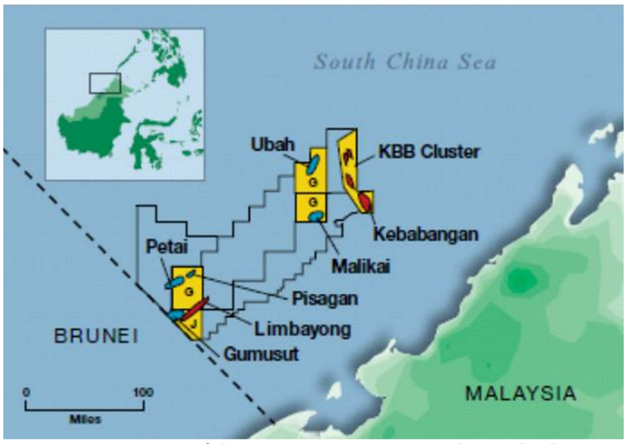

Figure.3: Location of deep water projects in Malaysia [16].

2.0 CHALLENGES OF EAST MALAYSIAN DEEP WATER

Malaysia's deep water oil and gas exploration presents unique and challenges. There several main factors such as Complicated Seabed Relief, Long Thin Fields and Long Thin Tieback

2.1 Complicated Seabed Relief

- The Shelf covers circa 100-120 km wide with folding belt or slope and instability issues which is circa 60-80 km wide North Malaysia, shallow hazards, hydrate management as shown in Figure.4.
- It is required special ability to install flowlines and facilities on steep slopes -allowing for more direct routes-.
- High CO_2 content in gas

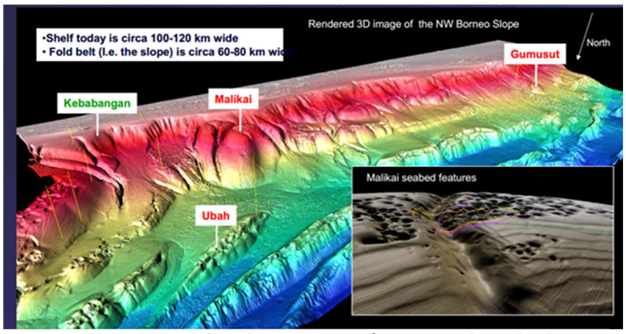

Figure.4: Rendered 3D image of Borneo Slope [18].

2.2 Long Thin Fields

- Most fields require 2-4 drill centers with a high well count to develop, as shown in Figure.5
- Need to reduce number of drill centres through ERD capability, or low cost wells

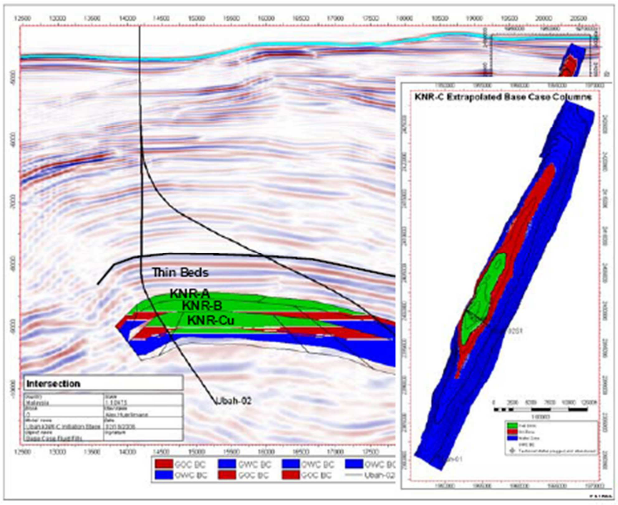

Figure.5: Long Thin Fields of Malaysia deep water exploration [18]

2.3 Long Distance Tiebacks:

- It is required 25 -50 km tieback distances, as shown in Figure.6
- Flow assurance with waxy crudes
- Need for subsea separation and boosting technologies

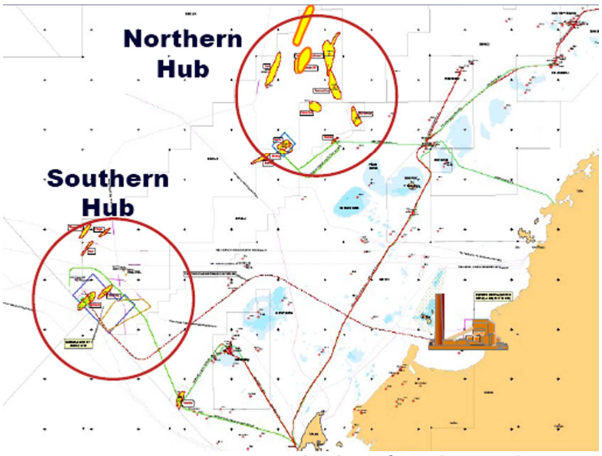

Figure.6: Long Distance Tiebacks of Malaysia deep water exploration [18]

3.0 GUMUSUT-KAKAP FIELD DEVELOPMENT

3.1 Subsae Flowlines

The Gumusut-Kakap Field is operated by Sabah Shell Petroleum Company Limited (SSPC), which owns a 33% stake, in partnership with ConocoPhilips Sabah (33%), Petronas Carigali (20%) and Murphy Oil (14%).

The Gumusut-Kakap field is located at offshore Sabah Blocks J & K at 1200 m of deep water, will embrace the regions' first deep water floating production system with a processing capacity of 150,000 barrels a day from 19 sub-sea wells.

The Gemusut-Kakap field was estimated to contribute up to 25 percent of the country's oil production. The oil extracted from the 19 subsea wells will be exported to the onshore Sabah Oil and Gas Terminal (SOGT) at Kimanis, Sabah via 200 km long pipeline as shown in Figure.7.

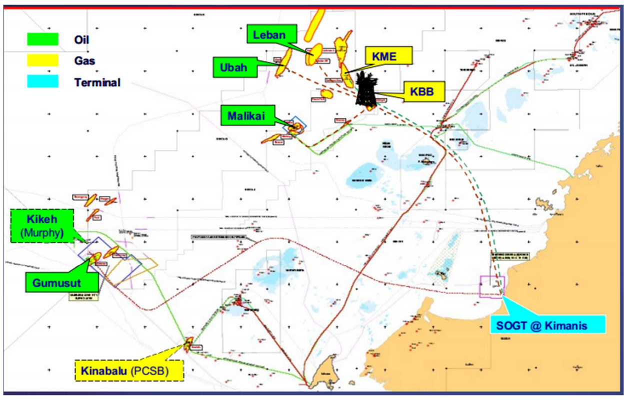

Figure.7: Gemusut-Kakap Subsea Oil export pipeline [18].

Initially, there are 7 wells out of 19 wells that needed to be operated which included three production wells, three water injection wells and a gas injection well. This particular project used 7 subsea manifolds for each wells. Table.2 shows particular dimension of Gemusut-Kakap subsea flowlines.

Table.2: Sizing of the flowlines according to type of wells.

Flowlines	Outside Diameter	Length
Production Flowlines	203.2 mm	31miles
Gas Injection Flowlines	254.0 mm	11 miles
Water Injection Flowlines	304.8 mm	7 miles

3.2 Subsea Tree Systems

The field development utilized the modular EVDT tree concept with standardized tree materials allowing for interchangeability for production, water injection and gas injection tree styles. The primary difference is the FMC Technologies retrievable flow control module (FCM) which allows easy conversion between tree systems to allow project flexibility. The production FCM includes a bolted bonnet choke with multiphase meter packaged in a single unit and included insulation to achieve a 10-hr thermal cool-down performance

The Gumusut-Kakap utilized FMC Technologies' 5"x2" 10K modular EVDT tree system configured in different ways to accommodate the needs of the field. The modular EVDT tree concept with standardized tree materials allows for interchangeability for production, water injection, and gas injection tree styles as shown in Figure.8.

All trees will be provided for API Material Class HH utilizing CRA cladding on all production-wetted surfaces. The maximum flowing temperature condition is 210 F (99 C) and anticipated flowing pressures up to 6000 psi (41.37 MPa). Table.3 shows characteristics of subsea tress of Gemusut-Kakap field development.

Table.3: Characteristic of subsea trees

Parameter	Description
Tree Pressure:	10000 psi
Tree Type:	EVDT
Tree Count:	15
Tree Bore Size:	5" x 2"

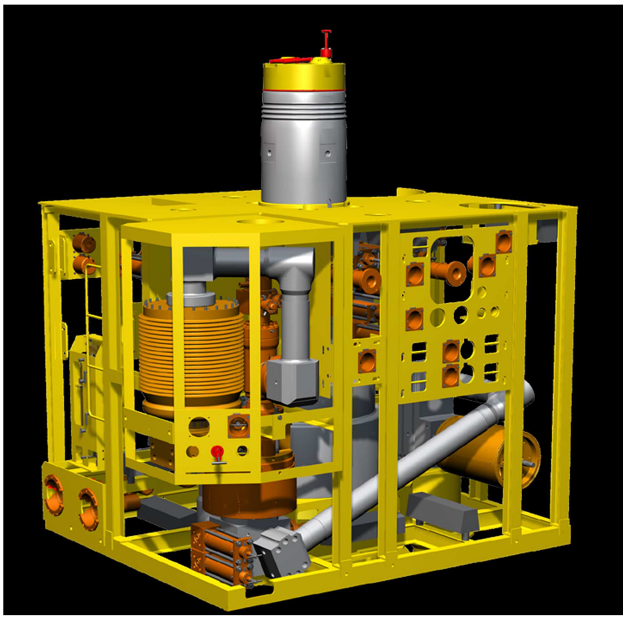

Figure.8: Modular EVDT Tree installed at Gemusut-Kakap Subsea Field [11].

The Gumusut-Kakap field development provided Shell with state-of-the-art high-speed communications using FMC Technologies 200e protocol. FMC Technologies' 200e system provides a minimum communication rate of 9600 with full duplex point-to-point communications. This enhances the performance of data flow between the FPS and subsea architecture, and the system is designed to operate and control up to 40 SCMs, which will cover the current requirements and future phases.

The field comprises three unique manifold styles. Three production manifolds are provided with dual 8-inch headers and 6-inch branches completed with API material class HH trim components and novelistic insulation for production, water injection and gas injection configurations. The manifold utilizes hydraulically actuated M3000 valves controlled by a manifold mounted subsea control module. The jumper connection systems utilize field-proven Torus-III connector systems with integral hydraulics and MC metal-to-metal gaskets.

4.0 FLOWLINES OF GUMUSUT-KAKAP FIELD

4.1 Design Parameters

Design parameters of flowlines used in the present study is shown in Table.3. Material grade used for this project is X60 with density of 7850 Kg/m^3. Operating temperature and pressure are assumed to be 99 ^{0}C and 41.37 MPa.

Table.3: Design Parameters for flowlines.

Parameter	Unit	Value
Pipe Material Grade	-	X65
Steel Density	Kg/m3	7850
SMYS	MPa	448
SMTS	MPa	530
Poisson Ration (v)	-	0.3
Young's Modulus (E)	GPa	207
Thermal Expansion Coef. (a)	C^{-1}	1.17 x 10E-05
Content Density (Oil)	Kg/m3	855
Design Pressure	MPa	41.37
Operating Temperature	^0C	99
Seawater Density	Kg/m3	1027
Target Life	Years	50

4.2 Safety Margin Theory

Simulation is done by using Subsea Pro Simulation based on Safety Margin Theory. Safety margin of pipeline wall thickness is a minimum wall thickness selection based on either internal or external pressure as shown in the Figure.9. The Subsea Pro Simulation was developed by Joint International Research Center (JIRC).Figure.9 demonstrates wall thickness of subsea pipeline versus burst and collapse pressures. External pressure was calculated using hydrostatic equation with different water depth level such as shallow, deep and ultra-deep. The burst and collapse pressures of pipeline were calculated according to API RP 1111 rule.

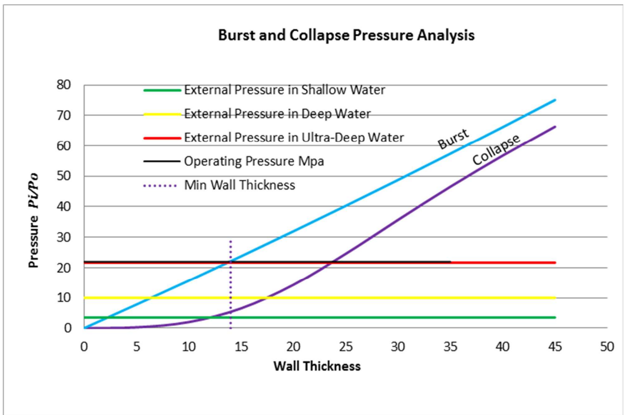

Figure.9: Burst and collapse pressures analysis.

The burst pressure refers to the internal pressure that causes a pipe to burst or fracture. The Specified Minimum Burst Pressure (P_b) which can be written as

$$P_b = 0.90(SMYS + SMTS)\left(\frac{t}{D-t}\right) \quad (1)$$

Where; t is wall thickness of flowline and the D is outside diameter of flowline for D/t >15

The hydrostatic pressure test, then the design pressure is written as:

$$P_d \le 0.80 f_d f_e f_t P_b \ge P_{Internal} \quad (2)$$

Where; f_d is the burst design factor of internal pressure 0.90 for pipeline and 0.75 for riser, f_e is the joint factor of weld and f_t is the temperature derating factor.

The critical stress is corresponding to the critical pressure in the equation below:

$$P_{cr} = \frac{P_e P_y}{P_e + P_y} \ge P_{external} \quad (3)$$

4.3 Results and Discussion

In the present study, stress and buckling of flowlines were calculated using Subsea Pro Simulation. Table.4 shows wall thickness and slipping length of flowlines which are explained in Figures.10 – 19.

Table.4: Wall thickness and buckling of flowlines.

Flowlines	Outside Diameter	Wall Thickness	Slipping Length
Production Flowlines	203.2 mm	18.59 mm	123.25 m
Gas Injection Flowlines	254.0 mm	22.00 mm	161.76 m
Water Injection Flowlines	304.8 mm	25.41 mm	

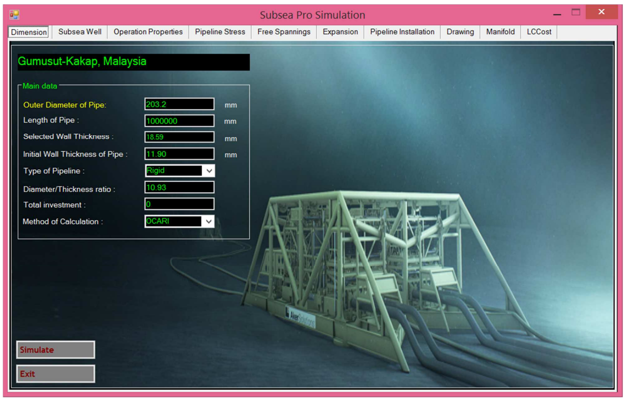

Figure.10: Minimum thickness of production flowlines.

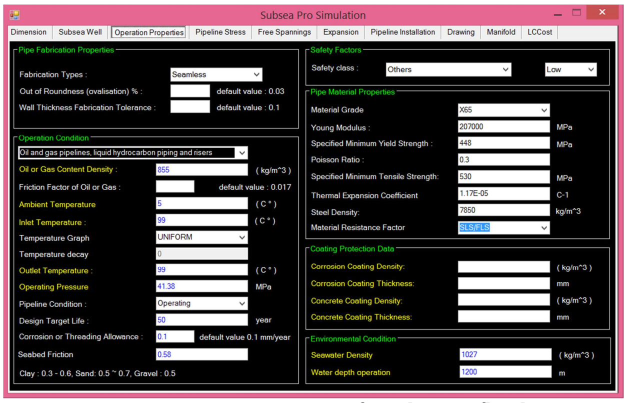

Figure.11: Design parameters of production flowlines.

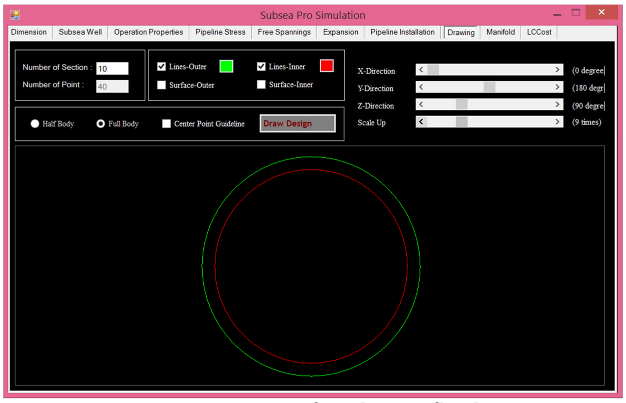

Figure.14: Drawing of production flowlines.

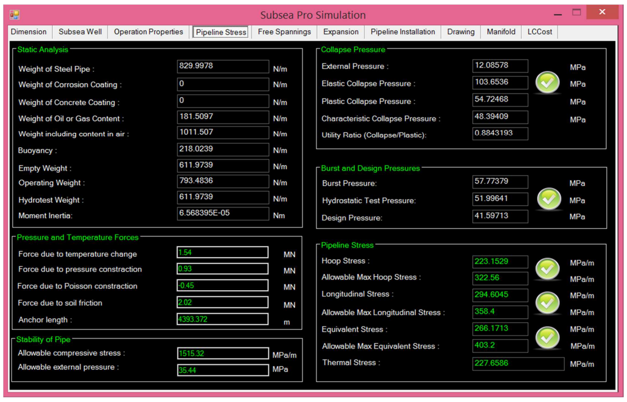

Figure.12: Pressure and Stress of production flowlines.

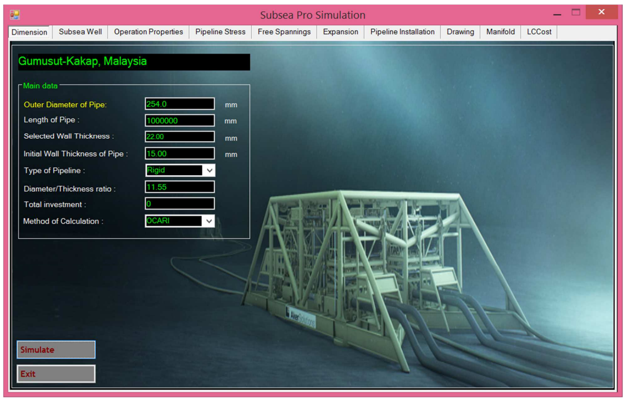

Figure.15: Minimum thickness of gas injection flowlines.

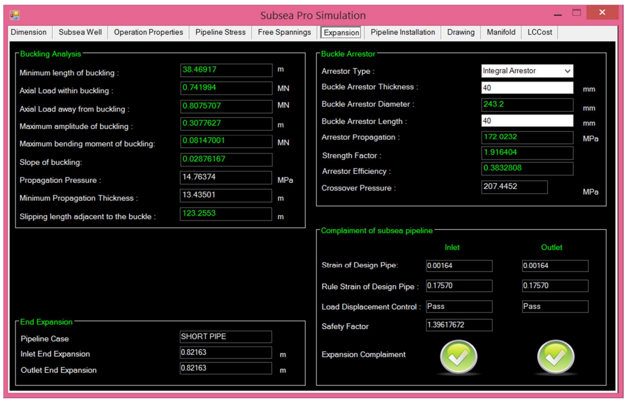

Figure.13: End expansion safety factor of production pipelines.

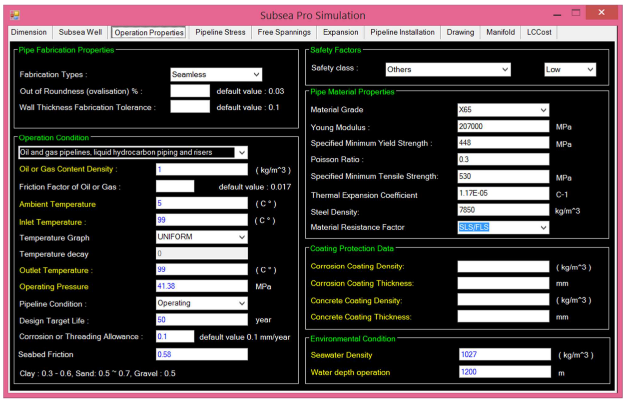

Figure.16: Design parameters of gas injection flowlines.

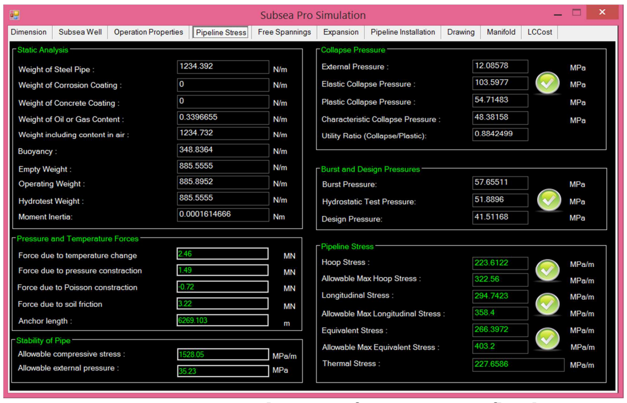

Figure.17: Pressure and Stress of gas injection flowlines.

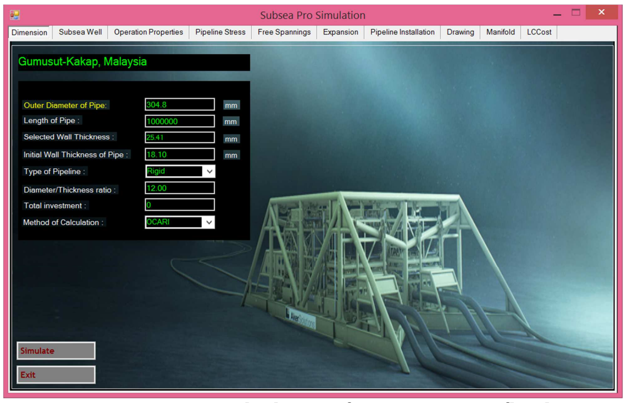

Figure.20: Minimum thickness of water injection flowlines.

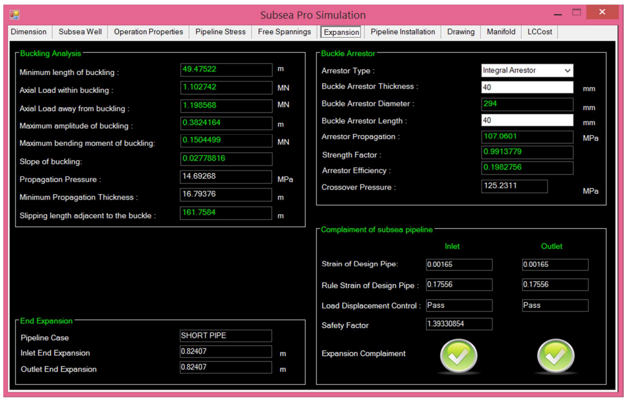

Figure.18: End expansion safety factor of gas injection pipelines.

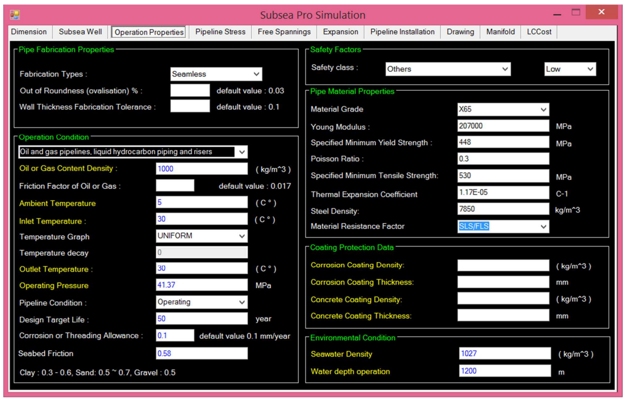

Figure.21: Design parameters of water injection flowlines.

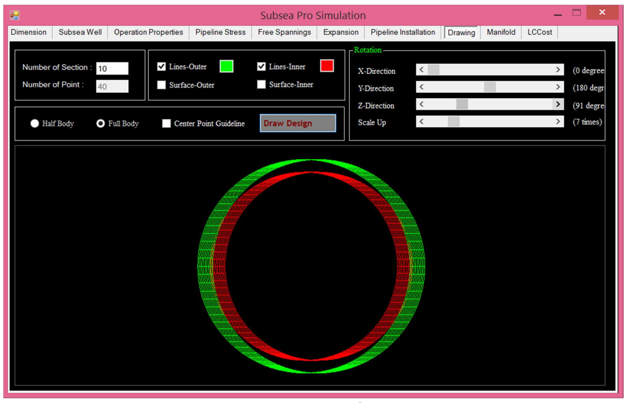

Figure.19: Drawing of gas injection.

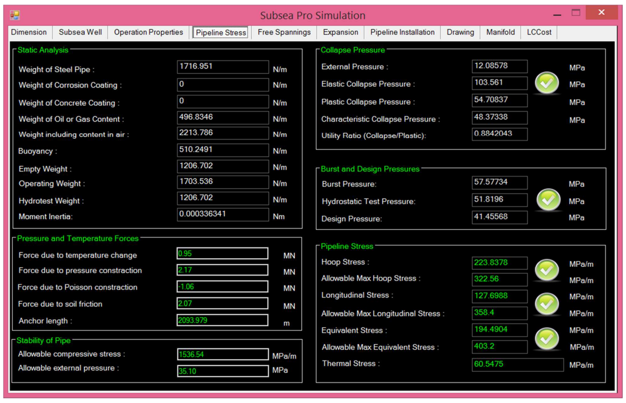

Figure.22: Pressure and Stress of water injection flowlines.

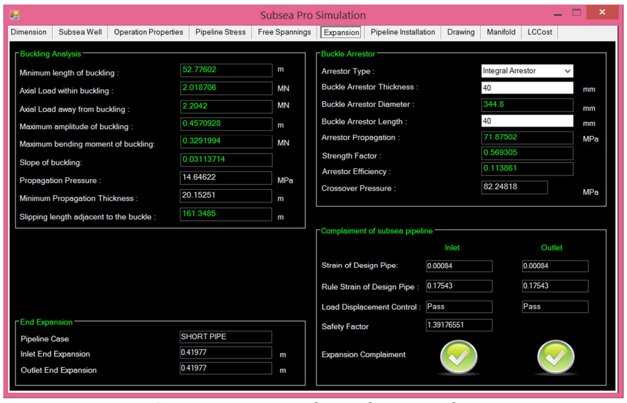

Figure.23: End expansion safety factor of water injection pipelines.

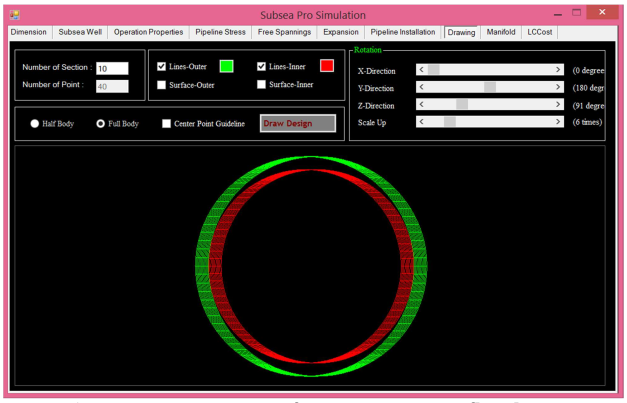

Figure.24: Drawing of water injection flowlines.

5.0 CONCLUSION

In conclusion, this paper discussed subsea pipeline of Gemusut-Kakap field development, Malaysia. Wall thickness and stress of the production, gas injection and water injection flowlines were analyzed using Subsea Pro Simulation.

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