Problems and Solutions for mproving Competence and Quality of Submarine Pipeline: A Literature Review on Concepts, Applications, and Challenges

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Reliability Analysis Of Subsea Pipelines In High Wave Random Conditions

Abstract

To fulfil human energy needs, offshore oil and gas exploration requires an efficient distribution method for oil and gas products. This is because the operating costs of offshore exploration activities are prohibitive. One of the most efficient distribution methods is using underwater pipes. However, in the system, many obstacles pose a risk to pipe safety during installation. Therefore, pipes need to be designed to remain safe during installation. The pipes that are laid fulfil their design objectives as oil and natural gas distribution lines—the standards used in the design process are DnV OS F101 and DnV RP E305. The design and installation analysis process carried out in this study is a pipe with a diameter of 32 inches on the SSWJ-PGN project phase 1 zone 5. The pipe is designed to deal with design environmental parameters in the form of wave height and significant wave period with a return period of one year for installation conditions and a return period of one hundred years for operating conditions. Installation analysis was carried out through modelling in three directions of wave arrival, namely 0°, 45° and 90°. Next, a simulation is carried out with random variables in the form of wave height and steel yield strength to determine the effect of this randomness on the total stress in the pipe during the installation process. The random wave height variable is generated through a stochastic approach, assuming the waves follow the Rayleigh distribution shape. The random variable steel yield strength is generated based on the Log Normal distribution form [1] with a coefficient mean of 1.05 and a coefficient of variation of 0.1. The simulation process was carried out with 100 units of random data each for three directions of wave arrival.

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1. Introduction

Subsea pipeline networks are generally a medium for transporting oil and gas flows. Subsea pipelines are essential in oil and gas production, so installation and care must be planned first.

Thorough pipeline network construction planning can positively impact the pipeline network's resilience and existence. Subsea pipeline network construction is a construction that can experience scouring phenomena due to the influence of current speed and wave orbital speed on the seabed. For this reason, scouring analysis needs to be carried out [2].

In order to achieve an efficient oil and gas distribution method, subsea pipelines must be designed in such a way that they can last for the planned service life. Deterministic data such as significant wave height, design steel yield strength, maximum current speed, and significant wave period are used in the design process. In actual conditions, the forces The environment and material capacity are random variables, so a reliability analysis is carried out to review the impact of this randomness on the subsea pipe during the installation process. The random variables used are wave height and steel yield strength. Because the installation analysis is carried out influenced by random variables, the output of this analysis is the probability of pipe reliability under installation conditions.

The design process and reliability analysis were conducted on the SSWJ-PGN subsea pipeline project phase 1 in zone 5. The pipe design has an outer diameter of 32 inches at a maximum depth of 70.49 m. The design process refers to standards DNV OS F101 and DNV RP E305. In reliability analysis, a pipe is considered to have failed if the maximum total stress value that occurs is equal to or greater than the yield capacity of the pipe.

2. Theory And Methodology

The design process begins with designing wall thickness, which refers to standards OS F101, by checking the pipe for failure mode internal overpressure, external overpressure, propagation buckling, and combined loading. Then, proceed with the design. Concrete coating thickness refers to standards RP E305 by checking the vertical and lateral stability of the pipe. Continuing in the design process, static installation analysis is carried out to obtain the optimum support configuration for the installation process. The optimum support configuration is used to analyze dynamic pipe installations due to design waves with variations in wave direction of 0°, 45° and 90°. Installation analysis was carried out through modelling using OFFPIPE software. The output from this installation modelling is the total stress acting along the pipe where the maximum total stress must not exceed the permitted stress, namely 85% SMYS at overbend and 72%SMYS onsagbend.

The process of analyzing pipe reliability under installation conditions is carried out using simulation methods with the help of OFFPIPE software for the installation modelling process due to random variables. In simple terms, simulation Montecarlo using random variables are used as input, and then the performance equation is used to obtain the output from the combination of these random variables. The simulation is repeated until the entire random data set is checked against the performance equation. Random data used in this study are wave height and steel yield strength. Random wave height data is obtained through a stochastic wave height distribution Rayleigh approach. Random data on steel yield strength is obtained through the process number generated based on the Log Normal distribution form[4] with a coefficient mean of 1.05 and a coefficient of variation of 0.1. The systematics of the study are depicted visually in Figure 1. below.

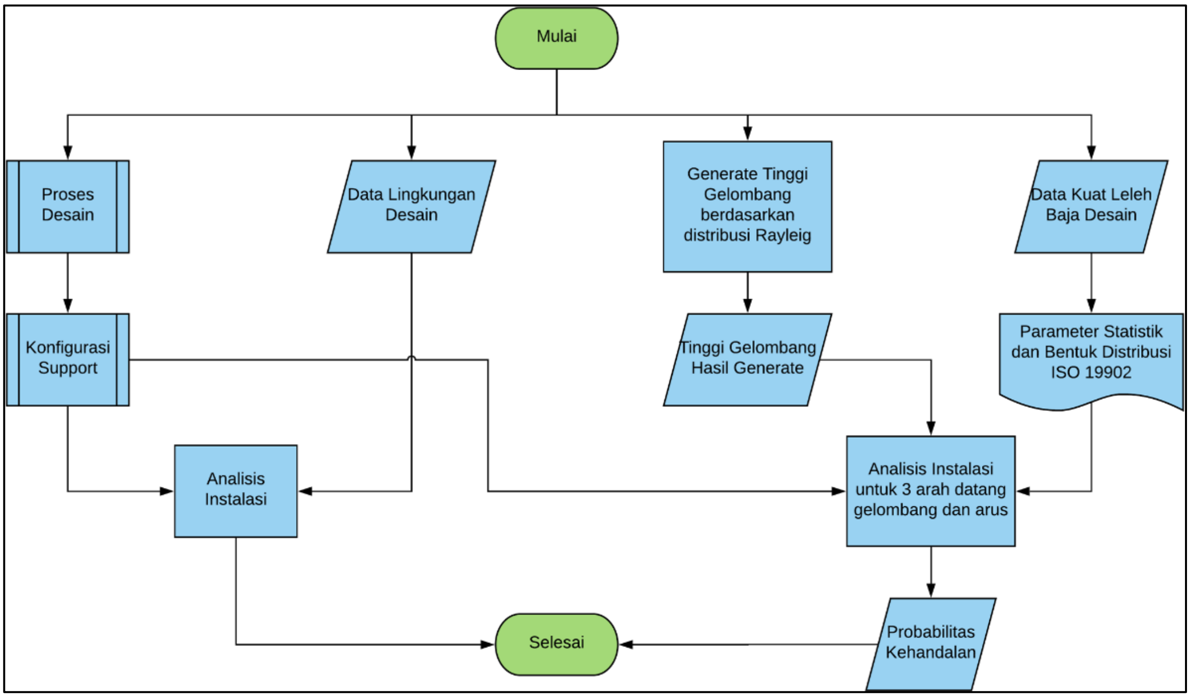

Figure 1. Systematic work

3. Result And Analysis

The design process is done by inputting the design pipe wall thickness and concrete cover thickness as initial inspection values. Next, an iterative process is carried out to determine the thickness of the pipe wall and concrete cover until the pipe's condition, which will fail according to the reference standard, is obtained. A summary of the design results of wall thickness is presented in Table 1, and a summary of the design results of concrete coating thickness is presented in Table 2 below.

Table 1. Design summary thickness

No.	Moda Kegagalan	Ketebalan Minimum	Satuan
1	Inernal Overpressure	0.593	In
2	External Overpressure	0.49	In
3	Propagation Buckling	0.866	in
Ketebalan Desain yang dipilih		0.875	in

Table 2. Design summary concrete coating thickness

No.	Condition	Thickness Minimum	Unit
1	Intallation	2.318	In
2	Operation	1.824	in
Selected Design Thickness		2.4	in

Pipe installation modelling is carried out for 3 conditions: static, dynamic with design waves, and dynamic with random variables. The total stress curve for static installation modelling is presented in Figure with a visualization of changes in support position to obtain the optimum configuration depicted in Figure 3 below.

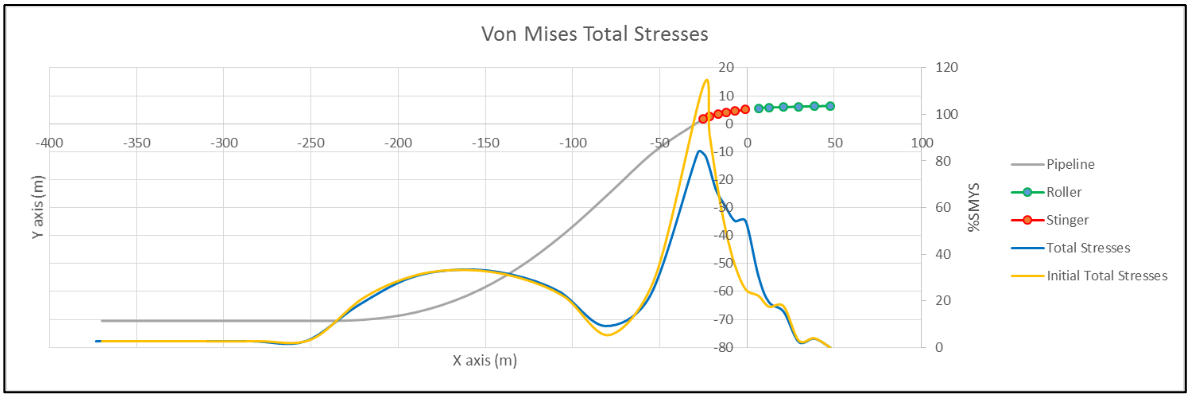

Figure 2. Total stress curve resulting from static installation modeling

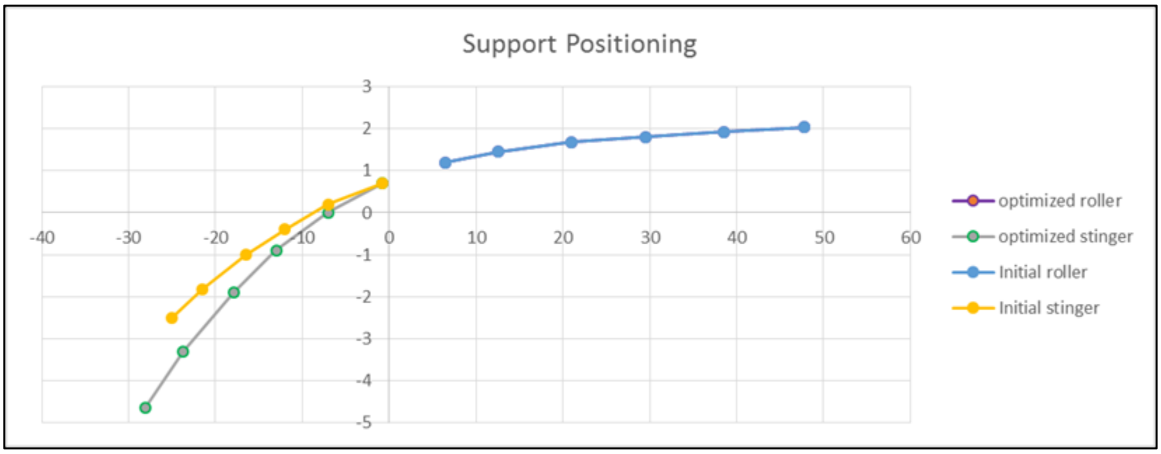

Figure 3. Support plot visualization

The total stress curve from the results of dynamic installation modelling with design waves for three incident wave directions is presented in Figure 4 and a summary of the maximum total stress is presented in Table 3.

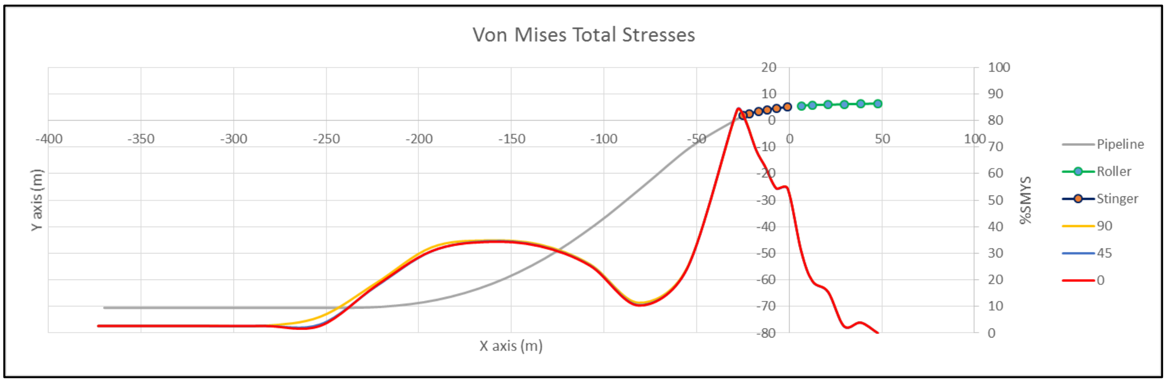

Figure 4. Total stress curve from dynamic installation modeling at 0°, 45° and 90°

Table 3. Summary of maximum totsal stress along the pipe modeling result dynamic

Corner	Maximum total voltage (%SMYS)
0	83.92
45	84.06
90	83.71

The results of dynamic installation modelling using wave data on a design basis for the three directions of wave arrival found that the total stress along the pipe meets the allowable stress criteria according to the standard. DNV OS F101 so that the pipe design is classified aslayable. It is also known that the difference in the direction of the wave does not significantly affect the difference in total stress that occurs along the pipe.

Summary of simulation results: Montecarloon, the area overbending for each incident wave direction is presented in Table 4.

Table 4. Summary of simulation result Montecarlo on overbend

No	Coming Direction Wave	Reliability F(b)	Reliability Index (b)
1	0	0.98	2.054
2	45	0.96	1.751
3	90	0.98	2.054

Analysis of pipe reliability under installation conditions for the are a sagbend was conducted analytically based on data from the results of each 100 simulations. Montecarlo indicates that the total voltage at sagbend does not exceed capacity. Statistical parameters of the total stress in the areas are shown in Table 5.

Table 5. Statistical Parameters and Distribution of Total Stress on Sagbend

Coming Angle Wave	Mean	St Dev	Variance	Coef F With	Minimum	Maxim one	zeta	lambda
0	33.413	3.535	12.496	10.580	20.912	51.418	2.174	1.146
45	33.035	3.457	11.948	10.460	21.504	52.347	2.169	1.145
90	32.995	3.581	12.825	10.850	19.157	53.202	2.186	1.108

Analytically [5] the probability of reliability and failure is obtained as shown inTable 6 the following.

Table 6. Reliability and Failure Probability In Sagbend

Coming Angle Wave	Reliability Index (b)	Kehandalan F (b)	Probability Failure
0	1.591	0.944	0.056
45	1.595	0.945	0.055
90	1.600	0.945	0.055

Conclusion

The design and reliability analysis of subsea pipelines are performed using specific standards (DNV OS F101 and DNV RP E305) to ensure the reliability of the pipeline during the installation process. Reliability analysis was performed considering random variables such as wave height and steel tensile strength. The analysis results show that the pipeline meets the reliability criteria set out in the standards, both for static and dynamic installation conditions with design waves. In addition, the reliability analysis also shows that the total stress in the pipeline does not exceed the capacity under operating conditions. Thus, the conclusion of this journal is that the subsea pipeline design meets the reliability requirements set out in the standards used.

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