

SENSITIVITY ANALYSIS ON PIPELINE WALL THICKNESS AND ON-BOTTOM STABILITY

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ABSTRACT

Oil and gas are the primary energy source to support human activities since the last century. Most of the exploration is done in the offshore. Pipeline is one of the best alternatives to transport the product from exploration in the offshore to the land. Pipeline is subjected to various environmental loads; therefore it has to be designed to withstand the entire loads. One of the aspects to be designed is pipe wall thickness and pipeline on bottom stability (concrete coating thickness). Pipe wall thickness and concrete coating thickness is affected by various parameters. Objectives of this study are to design the minimum wall thickness and concrete coating thickness, analyses how the parameters affect wall thickness and concrete coating thickness, and determine the most sensitive parameter for both aspects above. Case study in this paper is from PGN (*Perusahaan Gas Negara*) SSWJ (South Sumatra West Java) pipeline project. Wall thickness calculation and sensitivity analysis is done according to API RP 1111, while concrete coating thickness calculation and sensitivity analysis is done according to DNV RP E305. According to both codes, the minimum wall thickness is 14.94 mm and the minimum concrete coating thickness is 71 mm. From sensitivity analysis, wall thickness is directly proportional to diameter (D_s), pipe grade, and design pressure (P_d), while concrete coating thickness is directly proportional to pipe grade, significant wave heights (H_s), peak period (T_p), average velocity over pipe diameter (U_D), and inversely proportional to water depth (d). The most sensitive parameter for wall thickness is pipe diameter (D_s), and the most sensitive parameter for concrete coating thickness is the average velocity over pipe diameter (U_D).

INTRODUCTION

Offshore pipeline need to be designed to withstand loads acting against it in its service time. This paper will discuss about pipeline wall thickness and on bottom stability (concrete coating thickness) design. These two aspects are affected by various parameters. Should the parameters effect and the most sensitive parameter to wall thickness and concrete coating thickness is known, this will give a better insight to design and planning pipeline in coming project. Case study used in this paper is from PGN SSWJ pipeline project as shown in figure 1 below



Figure 1. PGN SSWJ Pipeline Project

Source: JFE Engineering [1]

Objectives of this paper is to design the minimum wall thickness and concrete coating thickness, analyze parameters effect, and determine the most sensitive parameter.

THEORY AND METHODOLOGIES

There are various recommended practice and code to design pipeline wall thickness and pipeline on-bottom stability. This paper will use API RP 1111 [2] for wall thickness design and DNV RP E305 [3] for pipeline on bottom stability design. This paper uses four failure criteria in wall thickness design. Those are burst due to internal pressure, collapse due to external pressure, buckling due to combined bending and external pressure, and propagation buckling. All these criteria are examined in installation, hydrotest, and operation condition. To avoid burst due to internal pressure, conditions below must satisfy:

$$P_t \leq f_d f_e f_t P_b \quad (1)$$

$$P_d \leq 0.80 P_t \quad (2)$$

$$P_a \leq 0.90 P_t \quad (3)$$

To avoid collapse due to external pressure, the collapse pressure of the pipe must exceed the net external pressure everywhere along the pipeline as follows:

$$(P_o - P_i) \leq f_o P_c \quad (4)$$

Buckling due to combined bending and external pressure can be avoided by satisfying condition below:

$$\frac{\varepsilon}{\varepsilon_b} + \frac{|P_o - P_i|}{P_c} \leq g(\delta) \quad (5)$$

To avoid propagation buckling, condition below must be fulfilled:

$$P_o - P_i \geq f_p P_p \quad (6)$$

Pipeline on bottom stability is divided into two parts, the vertical stability and horizontal stability. Pipeline submerged weight should make sure the pipeline is stable vertically and horizontally. Pipeline is considered vertically stable if:

$$\frac{W_s + B}{B} \geq 1.1 \quad (7)$$

And pipeline is considered horizontally stable if pipeline submerged weight W_s is greater than the required submerged weight W_{req} , where:

$$W_{req} = \left[\frac{(F_D + F_L) + \mu F_L}{\mu} \right] F_W \quad (8)$$

One of the ways to increase pipeline submerged weight is by adding concrete coating thickness.

Methodologies used in this paper are: Literature review, data collection and sampling, and data analysis and design.

RESULTS AND ANALYSIS

The minimum wall thickness which satisfies all criteria in all conditions is 14.94 mm. Sensitivity analysis is done to pipe diameter (D_s), pipe grade, and design pressure (P_d). Figure 2 is the minimum wall thickness in various D_s and pipe grade in $P_d = 8$ MPa

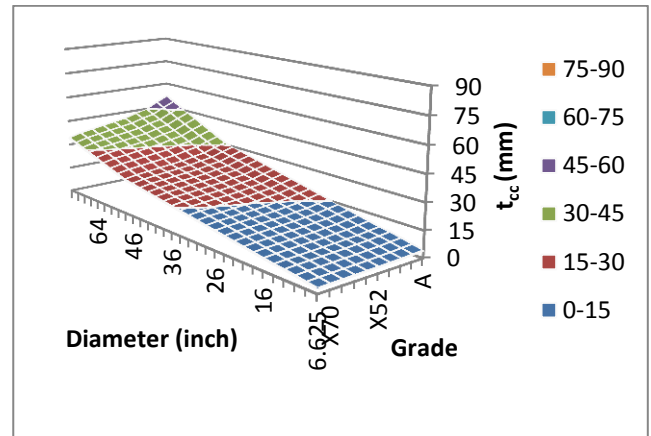


Figure 2. Minimum Wall Thickness, $P_d = 8$ MPa

Figures above shows that pipe wall thickness is directly proportional to pipe diameter (D_s). Pipe diameter determines the overall size of the pipe. The bigger the diameter, the area of the pipe will also be larger. For the same net pressure, pipe with larger area will be subjected to higher force than pipe with smaller area. Larger diameter pipe will need larger wall thickness to withstand the force.

Figure above also shows that wall thickness is directly proportional to pipe grade. Pipe grade determine the SMYS and SMTS of a pipe. Pipe with a higher grade has higher SMYS and SMTS, while pipe with lower grade has lower. SMYS and SMTS are the minimum stress that will cause plastic deformation (SMYS) and yield (SMTS) in the pipe. Pipeline with larger SMYS and SMTS will need larger stress to be plastically deformed and yield. Decrease in

minimum wall thickness is expected in higher grade pipe.

Wall thickness is also directly proportional to Design pressure (P_d). Design pressure is the pressure acting inside the pipe. Higher design pressure will lead to larger wall thickness. The wall thickness determines the strength to withstand the net pressure acting on the pipe. Therefore a larger wall thickness will be needed in a higher design pressure.

From figure 2, it can be concluded that the most sensitive parameter for pipeline wall thickness is the pipe diameter (D_s). Modification in pipe diameter affects the most to pipe wall thickness.

In this study, pipeline reaches its stability with 71 mm of concrete coating (t_{cc}). Sensitivity analysis is done to pipe diameter (D_s) and pipe grade, significant wave heights (H_s) and peak period (T_p), average velocity over pipe diameter (U_D), and water depth (d). Below are the results

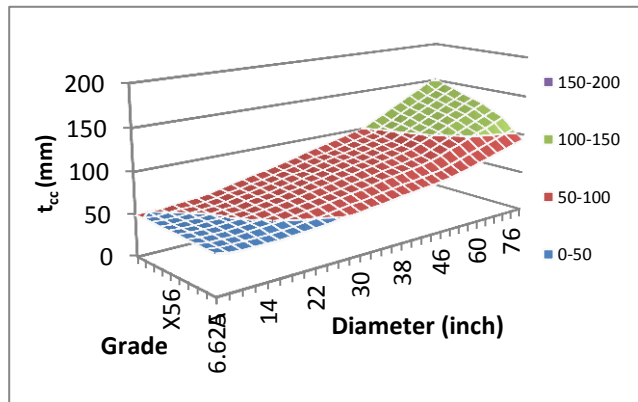


Figure 3. t_{cc} under various D_s and pipe grade

Figure 3 shows concrete coating thickness is directly proportional to pipe grade. Better pipe grade has thinner wall thickness. Thinner wall thickness will decrease the pipe submerged weight. Therefore a larger concrete coating thickness is needed in better pipe grade to increase its submerged weight.

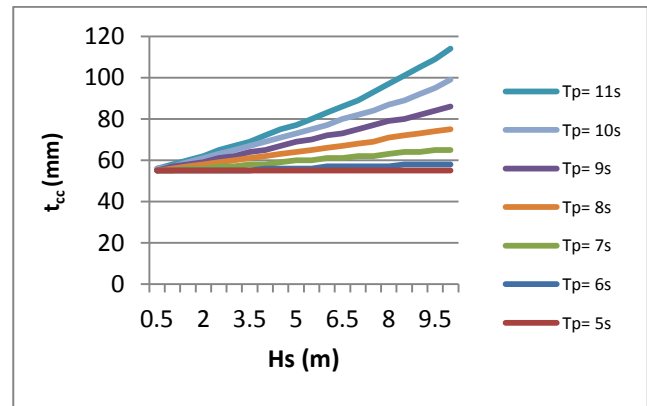


Figure 4. t_{cc} under various H_s and T_p

Figure 4 shows that increase of H_s will also increase the minimum concrete coating thickness. By definition, H_s is defined as the mean wave height of the highest third of the waves ($H_{1/3}$). It can be accepted logically that higher wave height will generate larger hydrodynamics forces, and the minimum concrete coating thickness will increase to meet the stability requirement.

T_p is defined as the wave period with the highest energy, determined by the inverse of the frequency at which a wave energy spectrum (wave spectrum) reaches its maximum. The longer the period the more energy it contains.

Therefore as figure 4 shows, longer T_p leads to larger concrete coating thickness because the pipe will need larger submerged weight to withstand the larger forces.

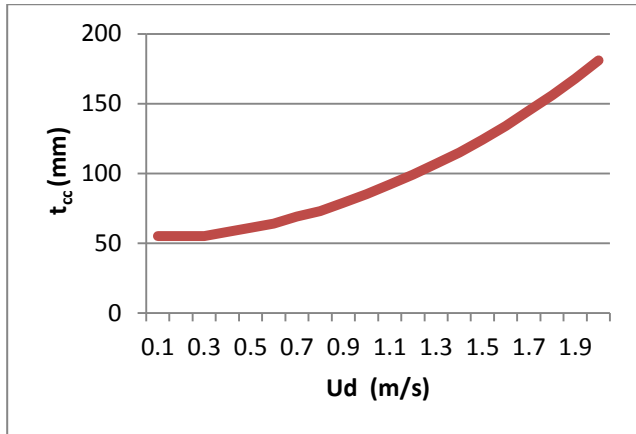


Figure 5. t_{cc} under various U_D

From figure 5 above, increase of U_D will also increase the minimum concrete coating thickness. Increase in U_D will increase the drag and lift force on the pipe, therefore the minimum concrete coating thickness will also increase to meet the stability requirement.

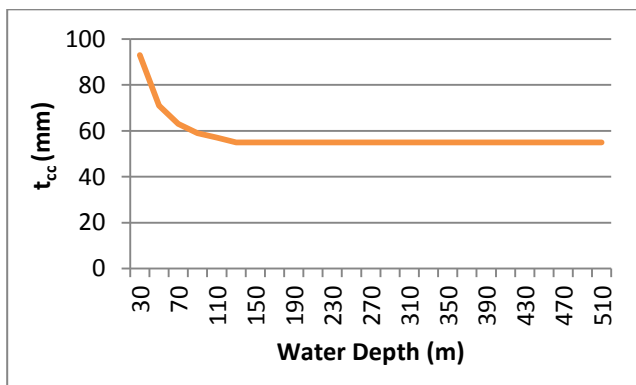


Figure 6. t_{cc} under various Water Depth

Figure 6 show that the water depth doesn't really affect the minimum concrete coating thickness if depth is increased. In this case, effect from water depth changes vanish when the depth are 130 m and above. In a deeper sea, the hydrodynamics forces are smaller, and vice versa. Therefore figure 6 shows larger concrete coating thickness in shallow water, and less concrete coating thickness in deeper water.

From figure 3 thru figure 6, it can be concluded that the most sensitive parameter for concrete coating thickness is the average velocity over pipe diameter (U_d). Increasing U_d to 2.7 times its initial value will increase the minimum concrete coating thickness to 2.55 times initial concrete coating value.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions from this study are:

1. Based on case study, the minimum wall thickness is 14.94 mm and the minimum concrete coating thickness is 71 mm
2. Below are the effect of each parameters to wall thickness and concrete coating thickness

Wall thickness: directly proportional to diameter (D_s), pipe grade, and design

pressure (P_d) this means when diameter, pipe grade, and design pressure are increased, wall thickness will also increase

Concrete coating thickness: directly proportional to diameter (D_s), pipe grade, significant wave heights (H_s), peak period (T_p), average velocity over pipe diameter (U_D), and inversely proportional to water depth (d). This means when diameter, pipe grade, significant wave heights, peak period, and average velocity over pipe diameter are increased, concrete coating thickness will also increase, and when the water depth is increased, concrete coating thickness will decrease.

3. Most sensitive parameter for wall thickness is diameter (D_s) affecting concrete coating thickness up to 316%, followed by design pressure (199%), and pipe grade (116%). Diameter modification gives more impact in $D_s \geq 48$ inch

Most sensitive parameter for concrete coating thickness is the average velocity over pipe diameter (U_d). Average velocity over pipe diameter can affect concrete coating thickness as high as 177%, followed by pipe diameter (145%), Pipe Grade (92%), T_p (83%), H_s (82%), and water depth (54%)

Recommendations from this study are:

1. In designing pipeline, use the most suitable code/ recommended practice based on the environmental condition where the pipeline will be constructed. Use the latest suitable code/ recommended practice if possible
2. In choosing the pipe grade, check if the grade modification will give significance effect to the wall thickness. Choose the most optimum grade either in pipeline serviceability and economic value
3. Further study in sensitivity analysis from this final project can be done by analyzing more parameters or analyzing other design process such as pipeline free span, cathodic protection, global buckling, thermal expansion, etc.

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