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# The Effect of Bending Selection for Restrain Load Analysis Crude Oil Pipeline at Pig Launcher Area

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**Abstract**

Bending on the pipeline has a major influence on the value of the restraining load that occurs in the pipeline system in the pig launcher area. This study aims to evaluate the effect of the selection of bends on the pipeline to restrain the pipeline. Large load restrains on pipeline restraints often occur in the pig launcher area resulting from the selection of bent pipes. Restrain load analysis is carried out to ensure that the selection of pipeline bending does not result in a large load to reduce system failure in operating conditions. The working design pressure is 680 psi with a design temperature of 130 F. Analysis of the pipeline restrain load system using CAESAR II software to see the most effective bending angle comparison to use. The results of the analysis show that the impact of selecting a bending pipeline in the pig launcher area greatly affects the value of the load restrain that occurs. The selection of bending by using a varied bending angle in the pipeline system can reduce the restrained load that occurs. From the results of selecting the bending pipeline system, the bending angle of 90 degrees has the smallest load restrain value in every axis, the use of 30 degrees bend has the largest load restrain value in the X axis, and the use of 45 degrees bend has the largest load restrain value in the Y axis and Z axis.

**Keywords: Pipeline System, Restrain Load Analysis, Pipeline Bending Selection**

## 1. Introduction

Pipelines affect daily lives in most parts of the world [1]. Pipelines can be used to transport crude oil from oil fields to refineries, where the oil is processed into various products such as gasoline, diesel, crude oil, and jet fuel. They can also be used to transport oil from one refinery to another or to transport oil to terminals for storage or export. Pipeline systems are usually limited by launcher and receiver. A launcher is required at the upstream end of the section, and a receiver is required at the downstream end [2].

Selecting the bend degree of the pipelines, the engineer must take into account all the influencing factors to avoid failure, because the pipeline bend has a significant impact on the restraining load that the pipeline receives when operating. Design failure on the pipeline can occur because the restraining load is too large. Large load restraints are caused by internal and external factors such as pipe length, bending selection, internal pressure, soil conditions, and various other factors.

The thing that needs to be considered in designing a pipeline is the large load of restrain that occurs in the pipeline system at the pig launcher area. Restrain load analysis is very necessary for designing the pipeline system at the pig launcher area to check the value of the restraining load is not too large to optimize the restrained design. Designing this pipeline system using standard references and the ASME B31.4 code which discusses the pipeline transport system for liquids and slurries [3]. CAESAR II is software based on the theory of one-dimensional beam finite element stress analysis and is normally used for stress analysis and to check the load of the restrain in the research of long-distance pipelines [4].

The result of this study will provide valuable insights into the selection of bending for restraining load analysis of crude oil pipelines at the pig launcher area. This will enable pipeline engineer engineers to ensure the safety and reliability of designing and installing the most effective bending at the Pig Launcher Area to prevent failures and optimize the design of the restrain.

## 2. Method

### 2.1. Pipeline Data

Pipeline data parameters are needed to become the basic design of crude oil pipeline systems. The parameter data of the crude oil pipeline system that will be used as properties of pipeline system modeling in CAESAR II such as the material properties, line size, pressure, and temperature are shown below in Table 1. Pipeline System Data.

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The parameters data of the crude oil pipeline are shown in Table 1. Pipeline System Data is used as data input to pipeline system modeling in CAESAR II software. The rating class of this crude oil pipeline design refers to ASME B16.5 Table 2-1.1 Pressure-Temperature Ratings for Group 1.1 Materials [5].

Pipeline system most of it is underground, so the soil technical factor is also a consideration in the pipeline design. Soil data were obtained from the results of soil investigation to obtain the value of the geological and geotechnical characteristics of the soil [6]. The soil data values required for the underground pipeline are shown in Table 2. The soil data properties will be input into Caesar II where the soil type obtained from the soil investigation results is a type of clay soil.

**Table 1.** Pipeline System Data

| Description | Remark | Unit |
|---|---|---|
| Pipe Size | 20 | inch |
| Pipe Wall Thickness | 12.7 | mm |
| Pipe Material | API 5L Gr. B, PSL 2 | - |
| Yield Stress | 35000 | psi |
| Tensile Stress | 60000 | psi |
| Modulus of Elasticity | 207000 | Mpa |
| Poisson's Ratio | 0.3 | - |
| Corrosion Allowance | 3 | mm |
| Steel Density | 7850 | kg/m³ |
| Coating Thickness | 2 | mm |
| Coating Density | 930 | kg/m³ |
| Design Pressure | 680 | psi |
| Design Temperature | 130 | °F |
| Hydrotest Pressure | 1020 | psi |
| Class Rating | #300 | - |

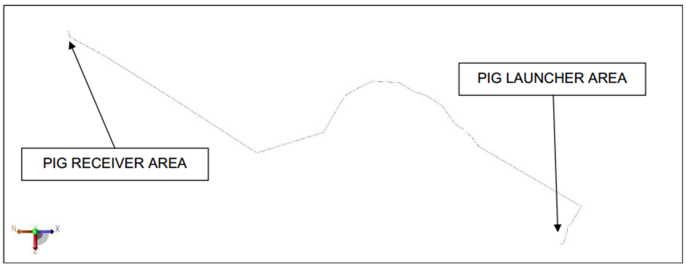


**Figure 1.** Pipeline Route

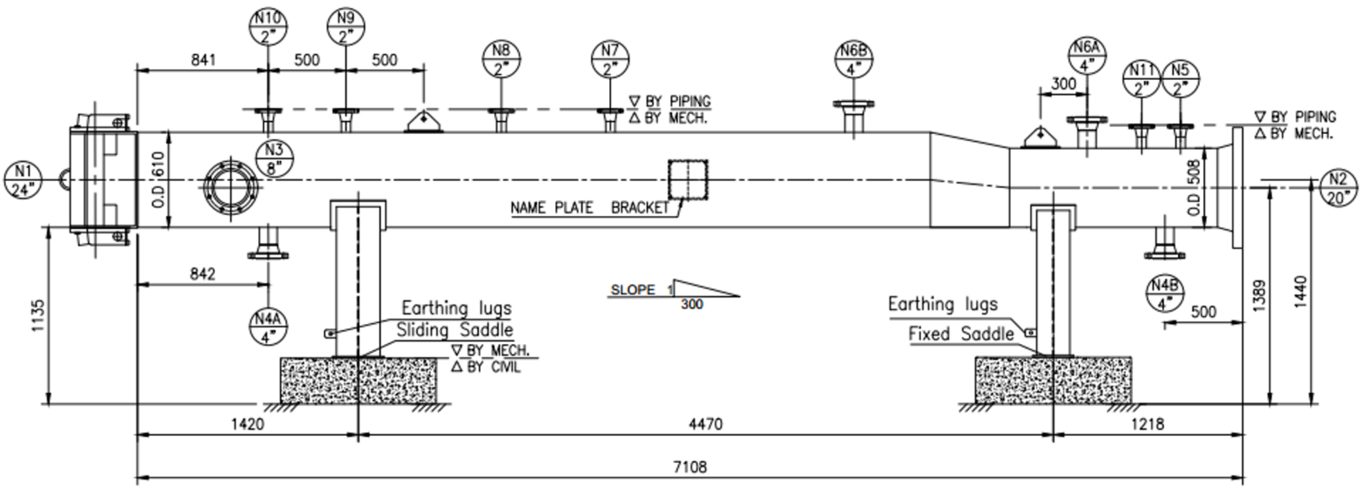


**Figure 2.** Pig Launcher Design

**Table 2.** Soil Data Properties

| Type of Soil | Soil Density (kg/cu.m) | Buried Depth of Pipeline (mm) | Friction Angle (deg) | Undrained Shear Strength (Kpa) | Overburden Compaction Multiplier | Yield Displacement Factor | Thermal Expansion Coefficient | Temperature Change (°F) |
|---|---|---|---|---|---|---|---|---|
| Clay | 1514 | 1500 | 9 | 5.1 | 8 | 0.015 | 6.230 | 80 |

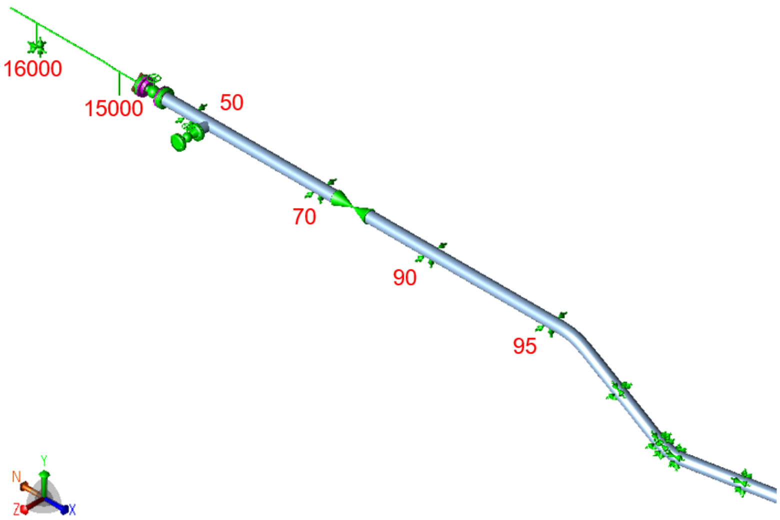


**Figure 3.** Bending Angle 30$^o$

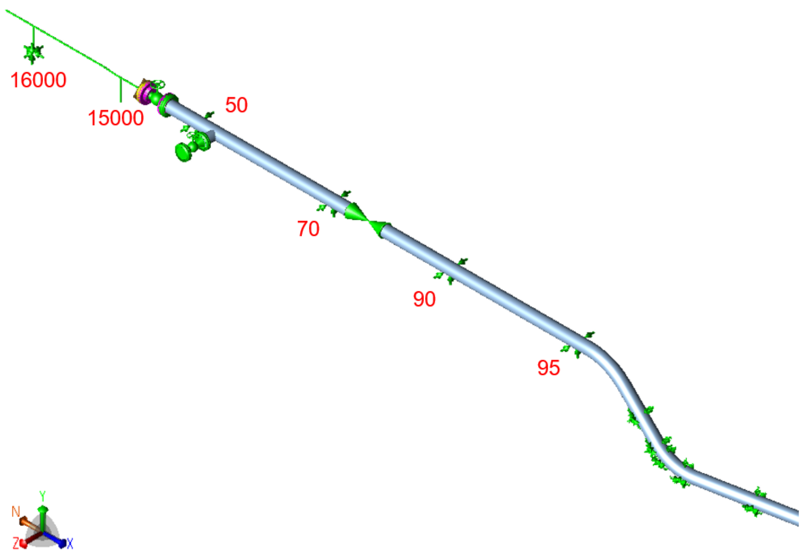


**Figure 4.** Bending Angle 45$^o$

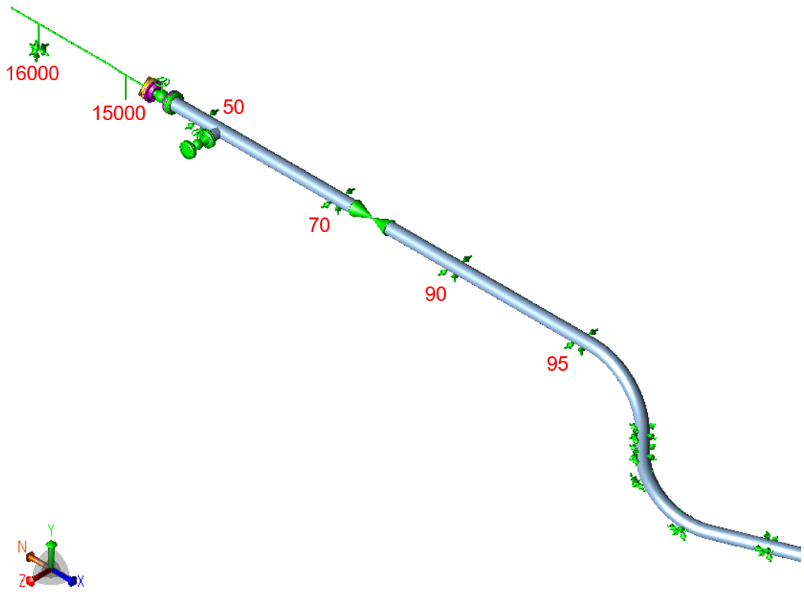


**Figure 5.** Bending Angle 90$^o$

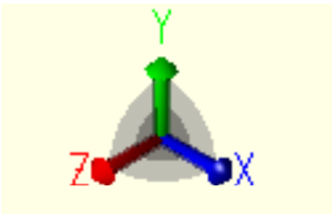


**Figure 6.** Caesar II Model Axis

The design of the pipeline system is 39 km long from the pig launcher to the pig receiver. The pipeline route is determined based on the results of a route survey conducted and considering the right of way (ROW), which is the land provided for the construction of the pipeline [7]. The route of the pipeline must be based on the area as shown in Figure 1.

The design of the pig launcher is modeled on the Caesar II as a rigid model that is connected to the pipeline. Pig Launcher is the equipment used to launch Pig which functions to clean the inside of the pipe to ensure that the fluid flow process is not hampered [8]. The pig launcher design used is shown in Figure 2.

### 2.2. Analysis Method

Restrain load analysis is carried out by modeling the pipeline system on Caesar II and entering input line pipe data according to the available area lines. The research was conducted by comparing the restrain load values received by the pipeline system at the pig launcher area due to the selection of bending angles, the bending angle variations are 30$^o$, 45$^o$, and 90$^o$. The pipeline modeling of Caesar II can be seen in Figure Figs. 3 to 5.

Load cases used in this restrain load analysis of the pipeline system at the pig launcher area are shown in Table 4.

Occasional load cases are loads that rarely occur such as wind loads, earthquakes, storms, and other natural phenomena. As an engineer, occasional loads must still be taken into account to ensure the piping system remains safe. One of the occasional loads is uniform loads. The uniform load can be defined either in terms of force per unit length or in terms of a magnifier of gravitational loading. In this study, the uniform load values used can be seen in Table 4.

The cartesian axis system in Caesar II is based on Figure 6. With 'Y' representing the vertical axis, 'X' representing the east direction, and 'Z' representing the south direction.

## 3. Results and Discussion

The failure of the piping system is also caused by the large restrain load on the pipe support. It is necessary to carry out a restrained analysis to obtain optimal restraint values in the pig launcher area. Restrain analysis begins with modeling the piping system and pig launcher in CAESAR II software, entering parameter data, entering pipe support, entering load cases to be used, and carrying out a restrained analysis on the pig launcher area for each bending design selection that is analyzed to see a comparison of results of the restrain loads.

**Table 3.** Load Cases Analysis

| Cases | Case Type | Stress Condition |
|---|---|---|
| L1 | Weight + Pressure (WW+P) | Hydrotest (HYD) |
| L2 | Weight + Temperature + Pressure (W+T+P) | Operating (OPE) |
| L3 | Weight + Pressure (W+P) | Sustained (SUS) |
| L4 | (W+T+P) – (W+P) | Expansion (EXP) |
| L5 | Weight + Temperature + Pressure + Seismic Acceleration along X axis (W+T+P+U1) | Occasional (OCC) |
| L6 | Weight + Temperature + Pressure + Seismic Acceleration along Z axis (W+T+P+U2) | Occasional (OCC) |

**Table 4.** Uniform Loads Value

| | **Value Vector** | | | **Unit** |
|---|---|---|---|---|
| | X | Y | Z | |
| **Uniform Load (U1)** | 0,5 | - | - | G's |
| **Uniform Load (U2)** | - | 0,5 | - | G's |
| **Uniform Load (U3)** | - | - | 0,5 | G's |

**Table 5.** Restrain Analysis Result Case 1

| **Node** | **Type of Support** | **Force (N)** | | | | | |
|---|---|---|---|---|---|---|---|
| | | Load Case | Maximum X | Load case | Maximum Y | Load Case | Maximum Z |
| 16000 | Sliding Support | L1 | 0 | L9 | -8049 | L5 | -6113 |
| 15000 | Fix Anchor Support | L9 | -300877 | L3 | -18083 | L5 | 20024 |
| 50 | Sleeper with Guide | L2 | 11277 | L3 | -45555 | L2 | -989 |
| 70 | Sleeper with Guide | L1 | 140 | L1 | -24228 | L1 | 69 |
| 90 | Sleeper with Guide | L1 | 219 | L1 | -19669 | L5 | 1171 |
| 95 | Sleeper With Guide | L1 | 400 | L1 | -22076 | L5 | 1433 |

**Table 6.** Restrain Analysis Result Case 2

| **Node** | **Type of Support** | **Force (N)** | | | | | |
|---|---|---|---|---|---|---|---|
| | | Load Case | Maximum X | Load case | Maximum Y | Load Case | Maximum Z |
| 16000 | Sliding Support | L1 | 0 | L9 | -5078 | L5 | -6106 |
| 15000 | Fix Anchor Support | L9 | -198566 | L3 | -12118 | L5 | 20062 |
| 50 | Sleeper with Guide | L2 | 14478 | L3 | -49293 | L2 | -268 |
| 70 | Sleeper with Guide | L1 | 136 | L1 | -24225 | L1 | 67 |
| 90 | Sleeper with Guide | L1 | 213 | L1 | -19677 | L5 | 706 |
| 95 | Sleeper With Guide | L1 | 387 | L1 | -21814 | L5 | 7102 |

**Table 7.** Restrain Analysis Result Case 3

| **Node** | **Type of Support** | **Force (N)** | | | | | |
|---|---|---|---|---|---|---|---|
| | | Load Case | Maximum X | Load case | Maximum Y | Load Case | Maximum Z |
| 16000 | Sliding Support | L1 | 0 | L3 | -5155 | L5 | -6344 |
| 15000 | Fix Anchor Support | L3 | -35052 | L3 | -25410 | L5 | -25410 |
| 50 | Sleeper with Guide | L2 | 9112 | L1 | -45500 | L1 | 116 |
| 70 | Sleeper with Guide | L2 | 8499 | L5 | -28509 | L2 | -790 |
| 90 | Sleeper with Guide | L1 | 253 | L1 | -18903 | L5 | 3056 |
| 95 | Sleeper With Guide | L1 | 462 | L1 | -23839 | L1 | 738 |

### 3.1. Restrain Analysis Result Case 1

Restrain load analysis of the pipeline system at the pig launcher area started analysis case 1. The result of the restraining load is shown in Table 5 Restrain Analysis Result Case 1.

Table 5 Restrain Analysis Result Case 1 shows the value of restrain load for bending selection 30 degrees that the greatest restrain load for the X axis occurs in node 15000 load case 9 with a load value is -300877 N, for the Y axis the maximum restrain occurs in node 50 load case 3 with a value of -45555 N, and Z direction the maximum restrain occurs in node 15000 load case 3 with a value of 20024 N.

### 3.2. Restrain Analysis Result Case 2

The result of maximum restrain load analysis in case 2 for bending selection 45 degrees is smaller than case 1 for the X axis, but for the Y axis and Z axis is larger. The Results of the restrain load analysis are shown in Table 6Restrain Analysis Result Case 2.

Table 5 Restrain Analysis Result Case 2 shows the value of restrain load for bending selection 45 degrees that the greatest restrain load for the X axis occurs in node 15000 load case 9 with a load value is -198566 N, for the Y axis the maximum restrain occurs in node 50 load case 3 with a value of -49293 N, and Z direction the maximum restrain occurs in node 15000 load case 3 with a value of 20062 N.

### 3.3. Restrain Analysis Result Case 3

The result of restrain load analysis case 3 with a bending selection of 90 degrees is shown in Table 7 Restrain Load Analysis Result Case 3.

The maximum restrain load value of case 3 is smaller than in case 1 and case 2. The greatest restrain load in the analysis result case 3 for bending selection 90 degrees is -35052 N for the X axis in node 15000 at load case 3, for the Y axis is -45500 N in node 50 at load case 1, and for the Z axis is -25410 in node 15000 at load case 5. The result of restrain load analysis in case 3 has the smallest load on every axis direction compared with the result of restrain load in analysis cases 1 for bending selection is 30 degrees and case 2 for bending selection is 45 degrees.

## 4. Conclusions

Based on the results of the restrain load analysis crude oil pipeline at the pig launcher area, it can be concluded that the highest value of restrain load analysis for the X axis occurs in the bending selection of 30 degrees, Y axis in the bending selection of 45 degrees, and Z axis in the bending selection of 45 degrees. The analysis result shows the optimal design that reduces the high restrain load is the highest bending of 90 degrees to ensure the maximum restrain does not fail the pipeline system at the pig launcher area.

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