BACHELOR THESIS - ME 141502

DRAGGED ANCHOR EFFECT TO BURIED SUBSEA PIPELINE ON VARIOUS CASES BASED ON NUMERICAL SIMULATION

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SKRIPSI – ME 141502

EFEK JANGKAR YANG TERSERET TERHADAP PIPA BAWAH LAUT YANG TERTANAM PADA BERBAGAI KASUS BERDASARKAN SIMULASI NUMERIK

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APPROVAL FORM

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BACHELOR THESIS

Submitted to Comply One of the Requirements to Obtain a Bachelor of Engineering Degree

In

Double Degree Marine Engineering (DDME) Program

Department of Marine Engineering – Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

Department of Maritime Studies

Hochschule Wismar, University of Applied Sciences

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SURABAYA

AUGUST, 2020

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Febrianto Anugrah Simanjuntak

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Dragged Anchor Effect to Buried Subsea Pipeline on Various Cases based on Numerical Simulation

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ABSTRACT

The potential of oil and gas in Indonesia is large enough, reaching 7.5 billion barrels of status per 30 June 2019. The installation of oil and gas pipelines became very important role in the oil and gas industry. One of the ways used to distribute natural gas is using subsea gas pipelines. Because the subsea pipelines are under the path of the ship traffic then this can pose a risk. Such failures can be caused by damage to the pipelines, dent, leakage, rupture, and others. Causes of damage to the pipeline can be caused by the decline of anchor (dropped anchor), dragged anchor, ship sinking, exposed nets/trawlers, natural events (tsunami, volcanic eruptions, etc.), and also other factors including pipe deformation caused by soil movements and vibration.

In this thesis, will analyze the cause of damage to the pipe caused by dragged anchor with a variety of anchor weight (kg) to variation to the pipe NPS (Nominal Pipe Size) variation (inch). The Data used is API Spec 5L X52, X 54, X 56, and X 60 on NPS (Nominal Pipe Size) 6, 8, 10, 12, 14, 16,18(inch). The scenario used is the heavy anchor variation and the anchor pull force against the subsea pipeline pressure. As for the weight of the anchors (kg) used on these thesis are 1590, 2100, 2640, 3300, 4050, 4890, 6000, 7350, 8700, 10500, 12300. By using Autopipe software then obtained the magnitude of pipe pressure due to the dragging of anchors using the standard ASME B 31.8.

Based on the simulation results of Autopipe and Standard ASME B 31.8, it is obtained NPS (Nominal Pipe Size) 12, 14, 16, 18 (inch) do not rupture due to pressure in the pipeline after simulated. Pressure on the pipeline does not exceed 90% SMYS Combined Stress Operation Design Condition.

***Keywords* –** Subsea pipeline , Dragged anchor , AutopipeSoftware

Efek Jangkar yang Terseret terhadap Pipa Bawah Laut yang Tertanam pada Berbagai Kasus berdasarkan Simulasi Numerik

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ABSTRAK

Potensi migas RI terbilang cukup besar, yakni mencapai 7,5 miliar barel status per 30 Juni 2019. Instalasi pipa migas menjadi sangat penting peranannya dalam industri migas . Salah satu cara yang digunakan untuk mendistribusikan gas alam menggunakan pipa gas bawah laut. Karena pipa berada dibawah jalur lalu lintas kapal maka hal ini dapat menimbulkan risiko.Kegagalan tersebut dapat disebabkan oleh kerusakan pada lapisan saluran pipa, saluran pipa penyok (denting), terjadi kebocoran (leaking), saluran pipa pecah/putus (rupture), dan lainnya. Penyebab kerusakan pada saluran pipa tersebut dapat diakibatkan oleh penurunan jangkar (dropped anchor), penarikan jangkar (dragged anchor), kapal tenggelam (ship sinking), terkena jaring/pukat (trawl), kejadian alam (tsunami, letusan vulkanik, dll), dan juga faktor lainnya termasuk deformasi pipa yang diakibatkan oleh gerakan tanah dan vibrasi.

Pada tugas akhir ini , akan menganalisa penyebab kerusakan pada pipa yang diakibatkan penarikan jangkar (dragged anchor) dengan berbagai variasi berat jangkar (kg) terhadap variasi NPS (Nominal Pipe Size) pipa (inch) . Data yang digunakan adalah API Spec 5L X52, X 54 , X 56, dan X 60 pada NPS (Nominal Pipe Size) 6, 8 , 10 , 12,14,16,18 (inch) . Skenario yang digunakan adalah variasi berat jangkar dan tarikan jangkar terhadap tekanan pipa bawah air .Adapun berat jangkar (kg) yang digunakan pada tugas akhir ini adalah 1590 , 2100 , 2640 , 3300 , 4050 , 4890 , 6000 , 7350 , 8700 , 10500 , 12300 .Dan menggunakan software Autopipe maka diperoleh besarnya tekanan pipa akibat tarikan jangkar menggunakan standard ASME B31.8.

Berdasarkan hasil simulasi autopipe dan Standard ASME B31.8 , maka diperoleh NPS (Nominal Pipe Size) 12 , 14,16,18 (inch) tidak mengalami pecah (rupture) akibat tekanan dalam pipa setelah dilakukan simulasi. Tekanan pada pipa tidak melebihi 90 % SMYS Combined Stress Operation Design Condition .

***Kata kunci* –** Subsea pipeline , Dragged anchor , AutopipeSoftware

PREFACE

Praise to Almighty God for his blessings and gifts, so that the author can complete this thesis entitled DRAGGED ANCHOR EFFECT TO BURIED SUBSEA PIPELINE ON VARIOUS CASES BASED ON NUMERICAL SIMULATION well.

This thesis was prepared to fulfill the requirements of completing the study in the Department of Marine Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh November Surabaya. This thesis discusses the damage to the underwater pipeline when affected by the pull of the ship's anchor with a weight variation of the anchor to the pipe size variation.

The author realizes that this bachelor thesis remains far away from perfect. Therefore, every constructive suggestion and idea from all parties is highly expected by author for this bachelor thesis correction and improvement in the future.The author hopes that this report is beneficial to readers.

Surabaya, August 2020

Febrianto Anugrah Simanjuntak

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CHAPTER I

INTRODUCTION

1.1 Background

Nowadays, the utilization of natural energy sources is very much developed to meet human needs. One of them is the utilization of oil and gas energy. Oil and gas are the natural resources found under the surface of the earth. Oil and gas can be processed into ready-made products for daily life needs, such as household, industrial power plant, and fuel vehicles.

To encourage the oil and gas industry needs more effective and economical use of pipelines to fluid transport. The underwater pipe is a hollow tube with diameter and length located at or embedded in the undersea(Ministry of Maritime and Fisheries,2016).

Pipelines are very susceptible to damage so it can lead to enormous risks. One of them is marine environmental pollution. The cause of underwater pipelines damage can be caused by several factors, including anchor drop, anchor drag , grounding , sinking , trawl and other factors . One of the cases that has happened is Young Lady accident.

A large vessel, dragging her anchor in heavy weather, dislodged a strategic pipeline carrying gas into the United Kingdom. Although, in this case, the risk of pollution was avoided, the pipeline was out of action for over 2 months.

At 2200 on 25 June 2007, the tanker Young Lady started to drag her anchor in Tees Bay; the wind speed was in excess of 40 kts and there was a heavy northerly swell. The master decided to weigh anchor and depart, but during the operation the windlass hydraulic motor exploded and the cable ran out to the bitter end. The vessel continued to drag her anchor until 2300 when, passing over the CATS gas pipeline, the anchor flukes snagged the pipe. The vessel was caught on the pipeline for about 10 minutes before a wide yaw caused the flukes to free themselves. Young Lady continued dragging until the anchor finally held as it rode over a shoal patch, 2.5 miles off a lee shore. There were no injuries sustained or damage caused by pollution. A subsequent survey of the pipeline showed that Young Lady’ s anchor had lifted the pipeline out of its trench and dragged it about 6m laterally. The pipeline suffered damage to the concrete coating and impact damage to the steel surface(Marine Accident Investigation Branch , 2008).

Reproduced courtesy of Fotoflite

Young Lady

Figure 1.1.Young Lady Vessel
(Marine Accident Investigation Branch , 2008)

The underwater pipe or the commonly called offshore pipeline has the potential for damage that can be considerably larger than on land pipelines, especially for environments that are under the sea. With a growing trend lately about Health, Safety and Environment, making a reason why the need for more attention for pipelines that are in the naked eye will be very difficult to monitor its existence.

This bachelor thesis will analyzes dragged anchor effect to buried subsea pipeline on various cases based on numerical simulation to prevent subsea pipeline accident caused by dragged anchor . This thesis create database of dragged anchor pipe with variation pipe and anchor witn Autopipe Software . Hopefully this bachelor thesis will be useful to reduce accidents due to dragged anchor pipes

1.2 Problem statement

By looking at the background of the problem above, the subject matter to be solved is:

a. How to make a simulated scenario and model of anchor variations and pipes on drag anchor using simulated software or numerical simulation ?
b. How to calculate pipe strength in subsea pipeline ?
c. How to calculate pipe damage caused by dragged anchor ?

1.3 Research limitation

The limitation of the problem that discussed on this bachelor thesis are:

a. On this bachelor thesis planned use a variation weight of anchor and variation NPS (NOMINAL PIPE SIZE) pipe with variation grade of pipe
b. This thesis analyzes hall stockless anchor types only
c. This thesis analyzes 2 meters buried subseapipeline simulation only
d. This thesis use Autopipe Software only for pipe stress analysis

1.4 Research objectives

The objectives of the problem that discussed on this bachelor thesis are:

a. This thesis analyzes steps of scenario of anchor variations and pipes on drag anchor simulationand modelling scenario drag anchor on pipe
b. This thesis analyzes pipe strength in sea
c. This thesis analyzes pipe damage caused by dragged anchor

1.5 Research contribution

The benefits of the research are the following:

a. To provide a recomendation of anchor and subsea pipe selection on sea
b. To show the effect of pipe damage caused by dragged anchor

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CHAPTER II

REVIEW OF LITERATURE

2.1. Pipeline

Offshore Pipeline typically serves to transmit hydrocarbons in the form of liquids or gases from reservoirs or exploratory facilitations that are off-shore.

A hydrocarbon is an organic chemical compound composed exclusively of hydrogen and carbon atoms. Hydrocarbons occur naturally and form the basis of crude oil, natural gas, coal, and other important energy sources. Hydrocarbons are highly combustible, producing carbon dioxide, water, and heat when burnt. Therefore, they are highly effective and sought after as a source of fuel (investopedia).

Due to the location of the reservoir located on the sea floor/seabed, then the pipeline should be placed under the sea anyway, to then transport it to the facility on the ground. Another term of the offshore pipeline is the subsea pipeline.

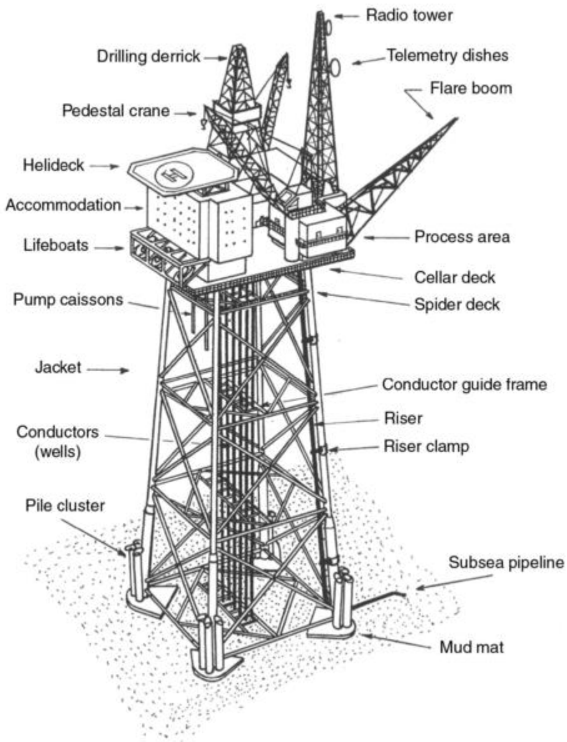

Figure 2.1 Traditional Large Steel Jacket Platform
(drillingformulas.com)

2.1.1. Government Regulations on subseapipelines

Ministerial decree Mining and energy No. 300/38/M.pe/1997 Article 13 paragraph 3 said the pipes held in the Sea depths of less than 13 m , Its position should be buried as deep as 2 m or more, while the pipes are held in the waters whose sea depth more than 13 m pipe can be held on the floor of the ocean (seabed) equipped with a system of weights so that the pipes do not shift or move the place.

2.2. Stress

Based on ASME B 31.8 code, stress can be grouped into two categories: Normal Stress and Shear Stress.

2.2.1. Normal Stress Component

1. Longitudinal Stress

Longitudinal stress is the stress that works in line with pipe axis.The longitudinal stresss consists of axial stress, bending stress and pressure stress.

The following descriptions of longitudinal stress include:

Axial stress (σ_{ax}) is the stress inflicted by the axial force (F_{ax}) that works in the direction of the pipe axis.

$$\sigma_{ax} = \frac{F_{ax}}{A} \quad (2.1)$$

$$A = \left(\frac{\pi(\,d0^2 - di^2)}{4}\right) \quad (2.2)$$

Description :

A = Pipe section area, mm^2

do = outer diameter of pipe, mm

in = diameter in pipe, mm

F_{ax} = axial Force along the pipe, N/mm^2

σ_{ax} = axial stress, PSI

The bending stress (σ_b) is the stress inflicted by the the moment (M) that works in the end of pipe .

$$\sigma_b = \frac{M\ x\ c}{I} \quad (2.3)$$

$$I = \left(\frac{\pi(\,d0^4 - di^4)}{64}\right) \quad (2.4)$$

Description:

c = Distance pipe wall to the neutral axis, mm

di = inner diameter of pipe, mm

do = outer diameter of the pipe, mm

I = Moment inertial cross section, kg/m^2

M = moment at the end of the pipe, lb/in

σ_b = bending stress, psi

A longitudinal press stress (σ_{Lp}) is a stress that caused by the internal press force (p) that works on the pipe wall unidirectional pipe axis. Formula based longitudinal tension press (ASME B 31.8) is as follows:

$$\sigma_{Lp} = \frac{P\,A_i}{A_m} = \frac{P\,d_i^2}{(do^2 - di^2)} = \frac{P\,d_i^2}{4td_m} = \frac{Pdo}{4t} \quad (2.5)$$

Description:

A_i = surface area in pipes, mm

A_m = area of average pipe surface, mm^2

do = outer diameter of pipe, mm

P = pressure on pipes, mm

T = thick pipe, mm

σ_{Lp} = longitudinal press stress, psi

2. Tangential stress (Hoop Stress)

Tangential stress (σSh) is inflicted by the internal pressure works tangentially and magnitude varies depending on the thickness pipe walls. Hoop stress based tension formula (ASME B 31.8) are as follows:

$$\sigma_{Sh} = \frac{P\,d_iL}{2tL} = \frac{P\,di}{2t} = \frac{P\,do}{2t} \quad (2.6)$$

Description:

do = outer diameter of pipe, mm

P = pressure on pipes, psi

t = thick pipe, mm

σ_{Sh} = the tangential tension (hoop stress), psi

2.2.2. Shear Stress

1. Torsional Stress

The torsional stress is the stress that occurs in a expanse of material with a fixed surface area subject to twisting at each end and the stretch of the object is said to be the shaft. For a shaft with a length L and radius r is subject to T torque with polar J inertia moment on surface area, torsional shear stress at a distance of C from the wide shaft axis surfaces are:

$$\sigma_t = \frac{T\,c}{J} \quad (2.7)$$

Description:

σ_t = torsional Shear stress, Psia

J = Moment of inertial polar, kg/m^2

c = distance from shaft axis, m

T = torque, lb/in

2.3. Anchor

An anchor is a device used to connect a vessel to seabed to prevent the ship change position cause wind or current.The ship's anchor equipment consists of anchors, anchor chains, stopper,and handling anchors. Anchors are designed in such a way that stuck at the water base. Anchors are usually made from cast iron material.
Anchor has several types as shown in figure 2.2.

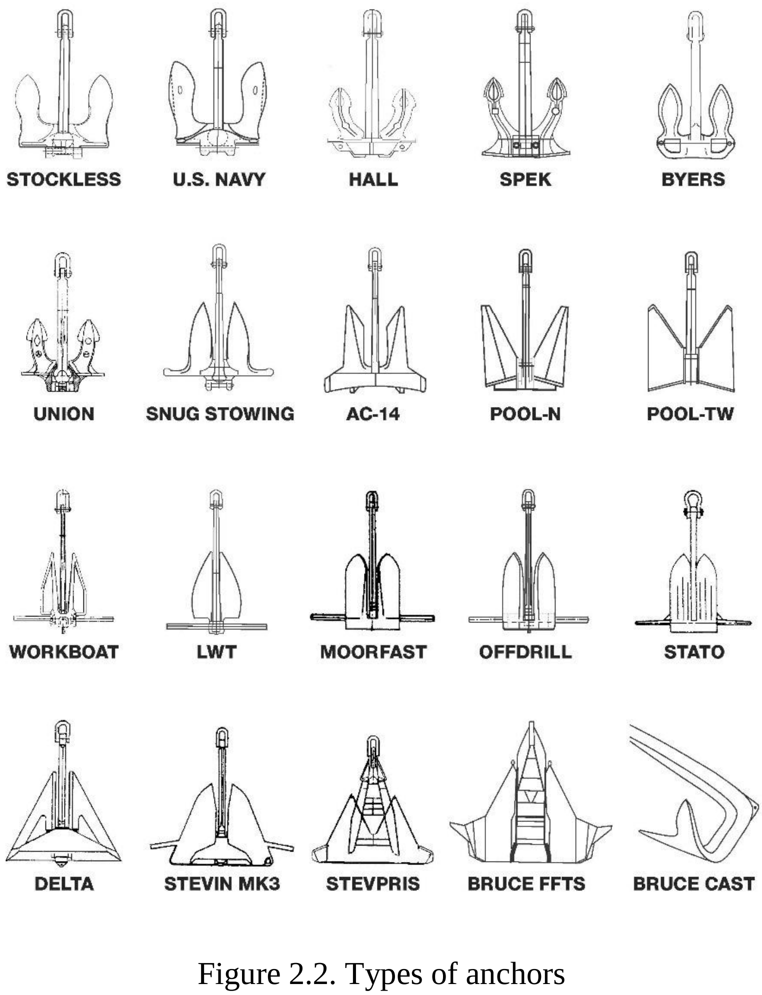

Figure 2.2. Types of anchors
(asmarines.com)

For how the anchor performance has been lowered to the seabed bite the bottom part of the sea as shown in Figure 2.3. It is important that the anchors and the chains are heavy enough to be able to stick on the seabed and will not be detached from the ocean floor unless pulled on board.

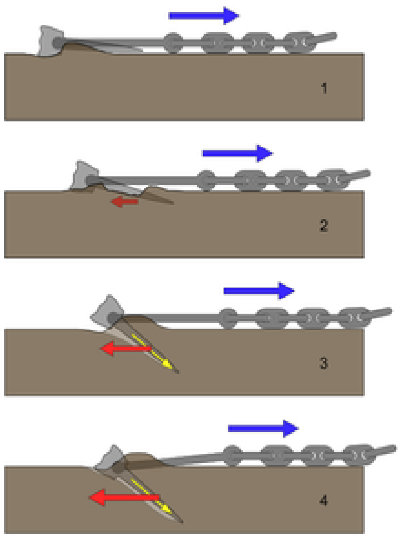

Figure 2.3. The action of a stockless anchor being set

(wikipedia.com)

2.3.1. Anchor Selection

This equipment includes anchors, anchor chains and rope intertwines where the provisions can be seen in Rules for Hull Volume II 2014 Edition amends Rules for Hull Volume II Edition 2013.

The equipment numeral Z_1 for anchors and chain cables is to be calculated as follows :

$$Z_1 = D^{\frac{2}{3}} + 2\,h\,B + \frac{A}{10} \qquad (2.8)$$

Description :

Z_1 = Equipment numeral

D = Moulded displacement [ton] (in sea water having a density of 1,025 t/m^3) to the summer load waterline

h = Effective height from the summer load waterline to the top of the uppermost house

h = $a + \Sigma h_1$

a = Distance [m], from the summer load water-line, amidships, to the upper deck at side

A = Area [m^2], in profile view of the hull, superstructures and houses, having a breadth greater than B/4, above the summer load waterline within the length L and up to the height h

Σh_1 = Sum of height [m] of superstructures and deckhouses, measured on the centreline of each tier having a breadth greater than B/4. Deck sheer, if any, is to be ignored. For the lowest tier, "h" is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck.

Where a deckhouse having a breadth greater than B/4 is located above a deckhouse having a breadth of B/4 or less, the wide house is to be included and the narrow house ignored.

(BKI - Rules for Hull – 2014 , Section 18 B.1)

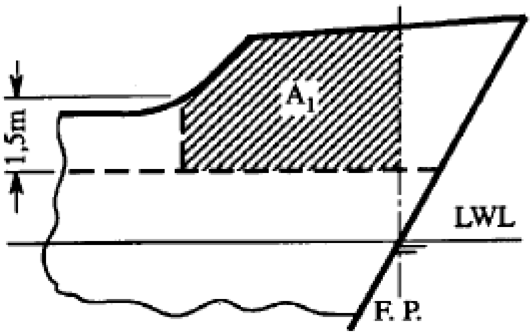

Figure 2.5. .Effective area A1 of bulwark

(Source : BKI - Rules for Hull – 2014 , Section 18 B.1)

2.4. ASME Standard

2.4.1. Asme B31 Pressure Piping

B31 Code for pressure piping, developed by American Society of Mechanical Engineers - ASME, covers Power Piping, Fuel Gas Piping, Process Piping, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids, Refrigeration Piping and Heat Transfer Components and Building Services Piping. ASME B31 was earlier known as ANSI B31.

No	ASME B31	Year	Description
1	B31.1	2012	Power Piping
2	B31.2	1968	Fuel Gas Piping
3	B31.3	2012	Process Piping
4	B31.4	2012	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
5	B31.5	2013	Refrigeration Piping and Heat Transfer Components
6	B31.8	2012	Gas Transmission and Distribution Piping Systems
7	B31.8S	2012	Managing System Integrity of Gas Pipelines
8	B31.9	2011	Building Services Piping
9	B31.11	2002	Slurry Transportation Piping Systems
10	B31.12	2011	Hydrogen Piping and Pipelines
11	B31G	2009	Manual for Determining Remaining Strength of Corroded Pipelines

Table 2.1. Asme B31 Pressure Piping

2.5. Autopipe Software

Autopipe is comprehensive and advanced software tool specialized in pipe stress analysis. Perform analyses to examine different loading scenarios including thermal, seismic, wind, and dynamic load cases. Instantly view stresses, deflections, forces, and moments.

The purpose of Pipe Stress Analysis is to ensure the stress experienced piping system does not exceed the stress of the permissible Code & Standard, evaluate the load in the nozzle equipment not exceeding allowable nozzle load, check the deflection of pipes do not cause with other pipes.

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CHAPTER III

METHODOLOGY

A framework of research or research methods is indispensable in drafting this scientific research. The research framework should be structured systematically and purposed to get the results of the right research target in accordance with the problem formulation of research objectives. The steps in this research process can be seen in Figure 3.1 as follows:

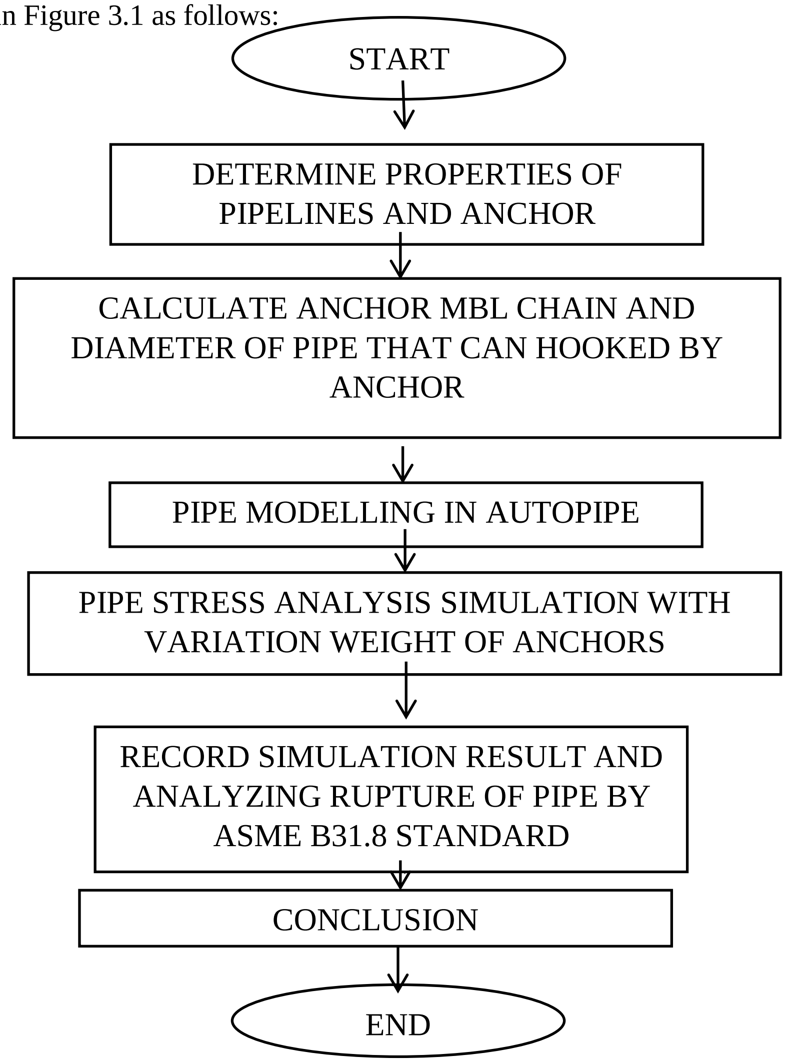


Figure 3.1.Methodology Flow Chart

3.1 Determine Properties Of Pipelines And Anchors

Pipe properties consist of pipe size, pipe material Schdule pipe, Outside Diameter pipe. On this final task uses variations in pipe sizes (inches) 6, 8, 10, 12, 14, 16,18. Variant of the pipe material used API 5 L x52, X56, X60, X65. While the properties for the analysed anchors are variations of anchor weight (kg), namely 1590, 2100, 2640, 3300, 4050, 4890, 6000, 7350,8700,10500, and 12300.

3.2 Calculate Anchor Mbl Chain And Diameter Of Pipe That Can Hooked By Anchor

Anchor chain MBL obtained from BKI Equipment Number.
Diameter of pipe that can hooked by anchor by formula ;.

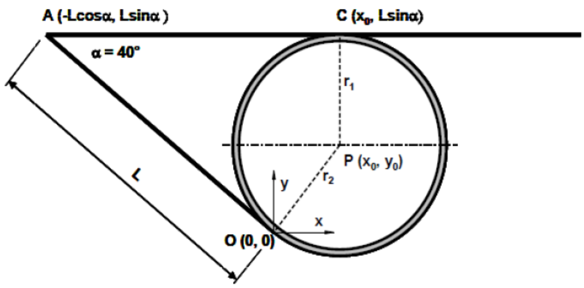


Figure 3.2. Pipeline hook by anchor

$$Dmax = \frac{2L(1-\cos\alpha)}{\sin\alpha} \quad (2.9)$$

Dmax : Diameter maximum of anchor fluke can hook pipe
(Pipeline Accidental Load Analysis , Stian Vervik 2011)

3.3 Pipe Modelling In Autopipe

At this stage, property of pipe will entered to Autopipe Software .

In this thesis , assumed pipe 20 feet span each point , operation pressure 100 psi and operating temperature 100 F.

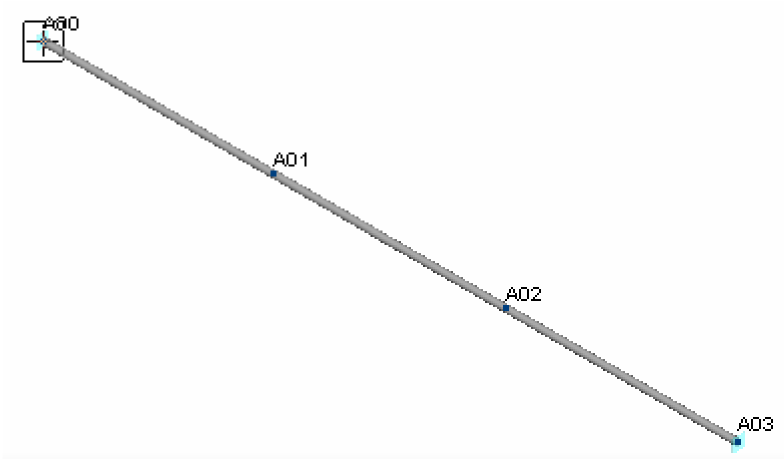


Figure 3.3. Pipe Model in Autopipe

3.4 Pipe stress analysis simulation with variation weight of anchors

Then pipe inserted additional weight from variant anchor weight and concentrated force from MBL Chain of the anchor .

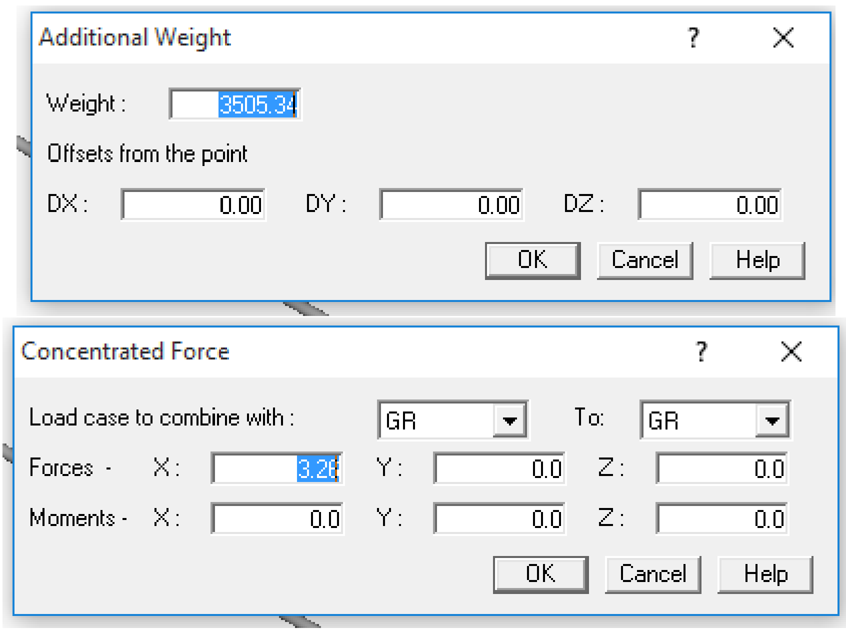


Figure 3.4. Additional Weight and Contentrated Dialog box in Autopipe

3.5 Record simulation result and analyzing rupture of pipe by ASME B31.8 standard

After get data Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL , then use ASME B 31.8 Standard to get rupture / no rupture condition of pipe .

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe .

Design Condition	Allowable		
	Hoop Stresss	Longitudinal Stress	Combined Stress
Operation	70 % SMYS	80 % SMYS	90 % SMYS
Hydrotest	90 % SMYS	72 % SMYS	96 % SMYS
Installation	72 % SMYS	80 % SMYS	90 % SMYS

Table 3.1. Allowable Stress ASME B31.8

3.6 Conclusions

This stage is the final stage in the research process that is the process of drawing conclusions from the entire series of research activities conducted. A structured conclusion should be in accordance with the research objectives that have been established.

CHAPTER IV

DATA ANALYSIS

4.1. Data Collection

4.1.1. Pipeline Data

The material and Grade API pipe 5L X56, X56, X60, X65 is used as an analysis material on this final task. The subsea pipe Data to be used on this research is as follows:

NPS (NOMINAL PIPE SIZE)	OD (in)	Grade	Sch No							
6	6,625984	X52	STD/40	XS/80	120	160	XXS			
		X56	STD/40	XS/80	120	160	XXS			
		X60	STD/40	XS/80	120	160	XXS			
		X65	STD/40	XS/80	120	160	XXS			
8	8,625984	X52	20	STD/40	60	XS/80	XXS	160		
		X56	20	STD/40	60	XS/80	XXS	160		
		X60	20	STD/40	60	XS/80	XXS	160		
		X65	20	STD/40	60	XS/80	XXS	160		
10	10,74803	X52	20	STD/40	XS/60	120	XXS/140	160		
		X56	20	STD/40	XS/60	120	XXS/140	160		
		X60	20	STD/40	XS/60	120	XXS/140	160		
		X65	20	STD/40	XS/60	120	XXS/140	160		
12	12,74803	X52	STD	40	XS/60	60	80	100	XXS/120	160
		X56	STD	40	XS/60	60	80	100	XXS/120	160
		X60	STD	40	XS/60	60	80	100	XXS/120	160

		X65	STD	40	XS/60	60	80	100	XXS/120	160
14	14	X52	STD/30	40	XS	80	140	160		
		X56	STD/30	40	XS	80	140	160		
		X60	STD/30	40	XS	80	140	160		
		X65	STD/30	40	XS	80	140	160		
16	16	X52	STD/30	XS/40	60	80	120			
		X56	STD/30	XS/40	60	80	120			
		X60	STD/30	XS/40	60	80	120			
		X65	STD/30	XS/40	60	80	120			
18	18	X52	XS	60	80	160				
		X56	XS	60	80	160				
		X60	XS	60	80	160				
		X65	STD/40	XS/80	120	160	XXS			

Table 4.1. Pipeline Data

4.1.2. Anchor Data

The Stockless Hall type anchors are used as analytical materials on this final task. The anchor Data to be used on this research is as follows:

No	Anchor Weight (kg)	Chain Size VL K3 (mm)	MBL Chain (kN)
1	1590	30	735
2	2100	36	1050
3	2640	40	1280
4	3300	46	1680
5	4050	50	1960
6	4890	54	2270
7	6000	60	2770
8	7350	66	3300
9	8700	73	3990
10	10500	78	4500
11	12300	87	5500

Table 4.2. Anchor Data

4.2. Software Analysis

4.2.1. NPS (Nominal Pipe Size) 6 Inch

By using Autopipe Numerical Simulation , get result of combined stress pipe data and shown in table below

a. Unburied pipe

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
6	STD/40	43373	53958	65166	78865	94431	111865	134904	162923	190943	228302	265562
	XS/80	32867	40159	47880	57317	68042	80053	95924	115228	134531	160269	186007
	120	28474	34379	40631	48272	56955	66681	79532	95162	110792	131632	152471
	160	27323	32243	37453	43820	51055	59159	69867	82891	95915	113280	130645
	XXS	23631	27972	32568	38186	44570	51720	61168	72660	84151	99472	114794

Table 4.3.Unburied Pipe 6 Inch

b. Buried pipe 2m

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
6	STD/40	16094	18885	21840	25452	29556	34152	38017	51079	64372	89819	118416
	XS/80	13710	15840	18095	20851	23983	27491	32126	38724	48438	65427	84273
	120	12626	14453	16387	18751	21437	24446	28442	33257	41512	55010	70173
	160	11193	12793	14487	16557	18910	21544	25026	29261	35835	47089	60511
	XXS	11323	12783	14329	16218	18365	20769	23947	27811	33499	43175	54662

Table 4.4.Buried pipe 6 Inch

c. Rupture Analysis

After get data Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL , then use ASME B31.8 Standard to get rupture / no rupture condition of pipe .

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe .

Design Condition	Allowable		
	Hoop Stresss	Longitudinal Stress	Combined Stress
Operation	70 % SMYS	80 % SMYS	90 % SMYS
Hydrotest	90 % SMYS	72 % SMYS	96 % SMYS
Installation	72 % SMYS	80 % SMYS	90 % SMYS

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe at Operation Condition , 90 % SMYS .

Variation Grade pipe with Operation Allowable Condition shown in table below

Design Condition	Grade			
	X52	X56	X60	X65
90 % SMYS	46800	50400	54000	58500

Rupture/No Rupture analysis is shown in table below

NPS in	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)																			
		1590	R/N	2100	R/N	2640	R/N	3300	R/N	4050	R/N	4890	R/N	6000	R/N	7350	R/N	8700	R/N	10500	R/N	12300	R/N
6	STD/40	16094	N	18885	N	21840	N	25452	N	29556	N	34152	N	38017	N	51079	R	64372	R	89819	R	118416	R
	XS/80	13710	N	15840	N	18095	N	20851	N	23983	N	27491	N	32126	N	38724	N	48438	R	65427	R	84273	R
	120	12626	N	14453	N	16387	N	18751	N	21437	N	24446	N	28442	N	33257	N	41512	N	55010	R	70173	R
	160	11193	N	12793	N	14487	N	16557	N	18910	N	21544	N	25026	N	29261	N	35835	N	47089	R	60511	R
	XXS	11323	N	12783	N	14329	N	16218	N	18365	N	20769	N	23947	N	27811	N	33499	N	43175	N	54662	R

Table 4.5. Rupture Analysis Pipe 6 Inch

R : Rupture
N : No Rupture

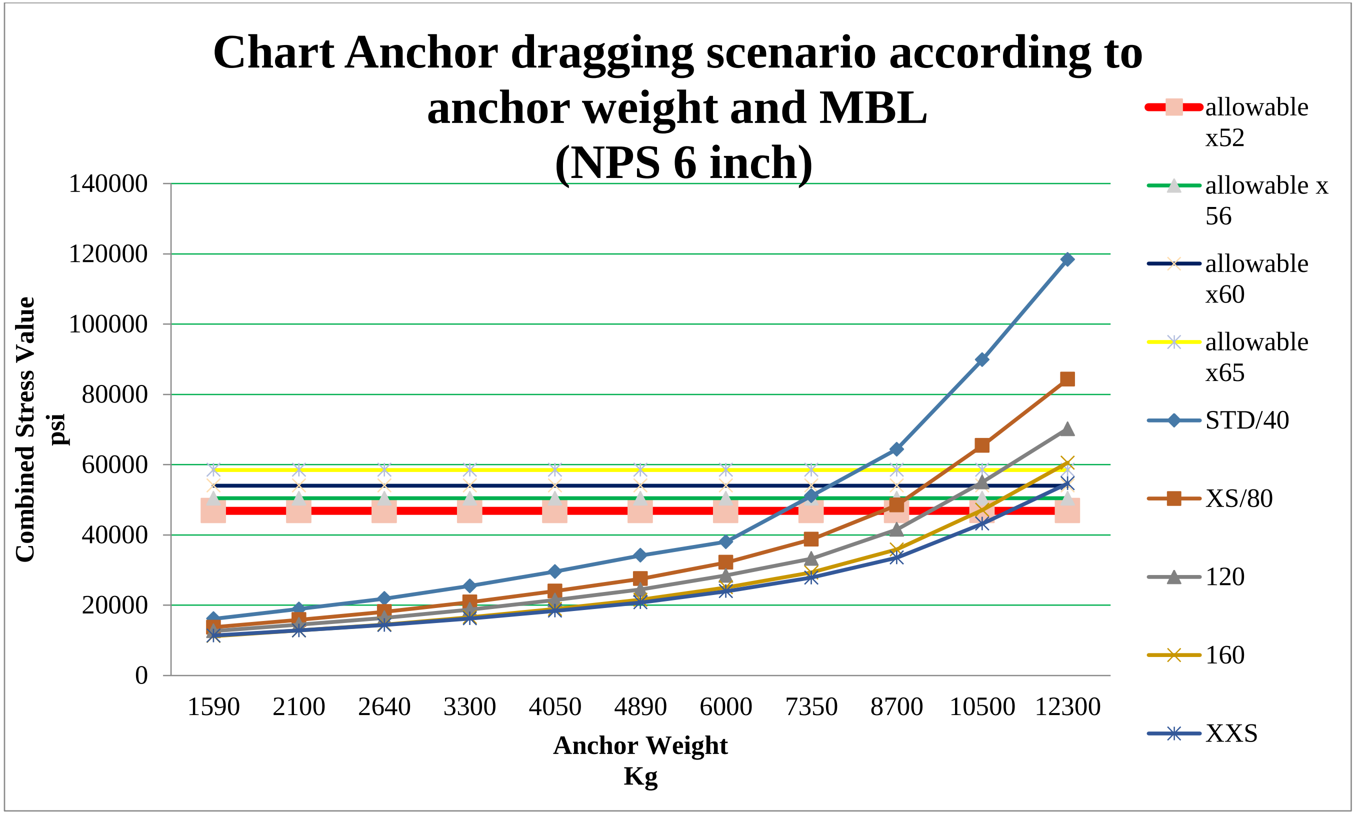


Chart 4.1. Chart Anchor dragging scenario to anchor weight and MBL (NPS 6 Inch)

4.2.2. NPS (Nominal Pipe Size) 8 Inch

By using Autopipe Numerical Simulation , get result of combined stress pipe data and shown in table below

a. Unburied pipe

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
8	20	31141	37887	45030	53761	63681	74739	89475	107333	125190	149000	172810
	STD/40	26475	31831	37503	44434	52311	61132	72790	86968	101146	120050	138953
	60	23207	27572	32194	37843	44263	51453	60954	72509	84064	99471	114878
	XS/80	20852	24502	28367	33091	38459	44471	52415	62077	71739	84662	97705
	XXS	16584	18924	21401	24428	27869	31722	36814	43006	49199	57456	65713
	160	16402	18684	21100	24052	27408	31165	36131	42171	48210	56263	64315

Table 4.6 .unburied pipe 8 Inch

b. Buried pipe 2m

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
8	20	14706	16882	19187	22003	25203	28788	33524	39285	47951	62599	80196
	STD/40	13336	15182	17136	19524	22238	25277	29293	34178	40516	51439	66019
	60	12635	13961	15650	17714	20060	22688	26160	30383	35128	44008	55821
	XS/80	11631	13035	14522	16339	18404	20716	23772	27489	31206	38795	48365
	XXS	11801	11201	12280	13599	15098	16776	18995	21693	24391	28804	34476
	160	10115	11116	12176	13471	14943	16592	18770	21419	24069	28349	33890

Table 4.7. buried pipe 8 Inch

c. Rupture Analysis

After get data Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL , then use ASME b31.8 Standard to get rupture / no rupture condition of pipe .

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe .

Design Condition	Allowable		
	Hoop Stresss	Longitudinal Stress	Combined Stress
Operation	70 % SMYS	80 % SMYS	90 % SMYS
Hydrotest	90 % SMYS	72 % SMYS	96 % SMYS
Installation	72 % SMYS	80 % SMYS	90 % SMYS

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe at Operation Condition , 90 % SMYS .

Variation Grade pipe with Operation Allowable Condition shown in table below

Design Condition	Grade			
	X52	X54	X56	X60
90 % SMYS	46800	50400	54000	58500

Rupture/No Rupture analysis is shown in table below

NPS in	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)																			
		1590	R/N	2100	R/N	2640	R/N	3300	R/N	4050	R/N	4890	R/N	6000	R/N	7350	R/N	8700	R/N	10500	R/N	12300	R/N
8	20	14706	N	16882	N	19187	N	22003	N	25203	N	28788	N	33524	N	39285	N	47951	R	62599	R	80196	R
	STD/40	13336	N	15182	N	17136	N	19524	N	22238	N	25277	N	29293	N	34178	N	40516	N	51439	R	66019	R
	60	12635	N	13961	N	15650	N	17714	N	20060	N	22688	N	26160	N	30383	N	35128	N	44008	N	55821	R
	XS/80	11631	N	13035	N	14522	N	16339	N	18404	N	20716	N	23772	N	27489	N	31206	N	38795	N	48365	R
	XXS	11801	N	11201	N	12280	N	13599	N	15098	N	16776	N	18995	N	21693	N	24391	N	28804	N	34476	N
	160	10115	N	11116	N	12176	N	13471	N	14943	N	16592	N	18770	N	21419	N	24069	N	28349	N	33890	N

Table 4.8 Rupture Analysis 8 Inch

R : Rupture
N : No Rupture

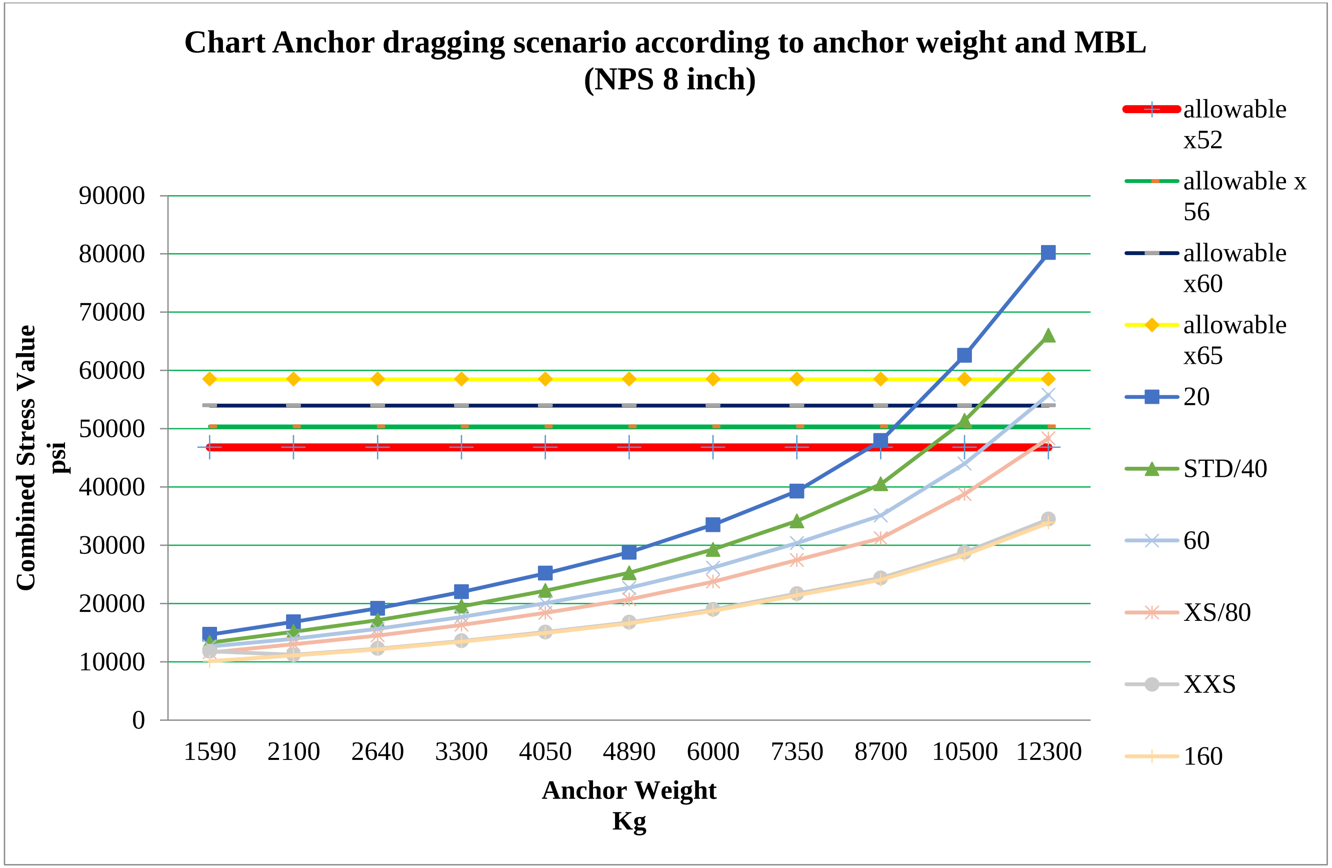


Chart 4.1 Chart Anchor dragging scenario accoridng to anchor weight and MBL (NPS 8 Inch)

4.2.3. NPS (Nominal Pipe Size) 10 Inch

By using Autopipe Numerical Simulation , get result of combined stress pipe data and shown in table below

a. Unburied pipe

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
10	20	23326	27603	32133	37668	43959	51005	60315	71638	82961	98058	113156
	STD/40	18858	21879	25077	28985	33427	38402	44976	52971	60966	71626	82287
	XS/60	16255	18535	20948	23898	27250	31004	35966	41999	48003	56078	64123
	120	13429	14897	16452	18352	20511	22929	26125	30011	33898	39080	44262
	XXS/140	12827	14116	15481	17149	19004	21167	23972	27384	30796	35345	39894
	160	12475	13657	14909	16439	18178	20125	22698	25827	28957	33129	37302

Table 4.9 Unburied pipe 10 Inch

b. Buried pipe 2m

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
10	20	13551	15229	17006	19178	21646	24410	28063	32506	36948	45429	56183
	STD/40	11876	13187	14575	16272	18200	20359	23212	26682	30152	35515	42662
	XS/60	10855	11926	13060	14446	16021	17784	20115	22950	25785	29564	34787
	120	9665	10441	11262	12266	13407	14685	16373	18427	20480	23218	26111
	XXS/140	9401	10104	10850	11761	12796	13956	15488	17351	19215	21699	24224
	160	9241	9901	10599	11453	12423	13510	14946	16692	18438	20767	23095

Table 4.10 Buried Pipe 10 Inch

c. Rupture Analysis

After get data Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL , then use ASME b31.8 Standard to get rupture / no rupture condition of pipe .

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe .

Design Condition	Allowable		
	Hoop Stresss	Longitudinal Stress	Combined Stress
Operation	70 % SMYS	80 % SMYS	90 % SMYS
Hydrotest	90 % SMYS	72 % SMYS	96 % SMYS
Installation	72 % SMYS	80 % SMYS	90 % SMYS

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe at Operation Condition , 90 % SMYS .

Variation Grade pipe with Operation Allowable Condition shown in table below

Design Condition	Grade			
	X52	X54	X56	X60
90 % SMYS	46800	50400	54000	58500

Rupture/No Rupture analysis is shown in table below

NPS in	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)																			
		1590	R/N	2100	R/N	2640	R/N	3300	R/N	4050	R/N	4890	R/N	6000	R/N	7350	R/N	8700	R/N	10500	R/N	12300	R/N
10	20	13551	N	15229	N	17006	N	19178	N	21646	N	24410	N	28063	N	32506	N	36948	N	45429	N	56183	R
	STD/40	11876	N	13187	N	14575	N	16272	N	18200	N	20359	N	23212	N	26682	N	30152	N	35515	N	42662	N
	XS/60	10855	N	11926	N	13060	N	14446	N	16021	N	17784	N	20115	N	22950	N	25785	N	29564	N	34787	N
	120	9665	N	10441	N	11262	N	12266	N	13407	N	14685	N	16373	N	18427	N	20480	N	23218	N	26111	N
	XXS/140	9401	N	10104	N	10850	N	11761	N	12796	N	13956	N	15488	N	17351	N	19215	N	21699	N	24224	N
	160	9241	N	9901	N	10599	N	11453	N	12423	N	13510	N	14946	N	16692	N	18438	N	20767	N	23095	N

Table 4.11 Rupture analysis 10 Inch

R : Rupture
N : No Rupture

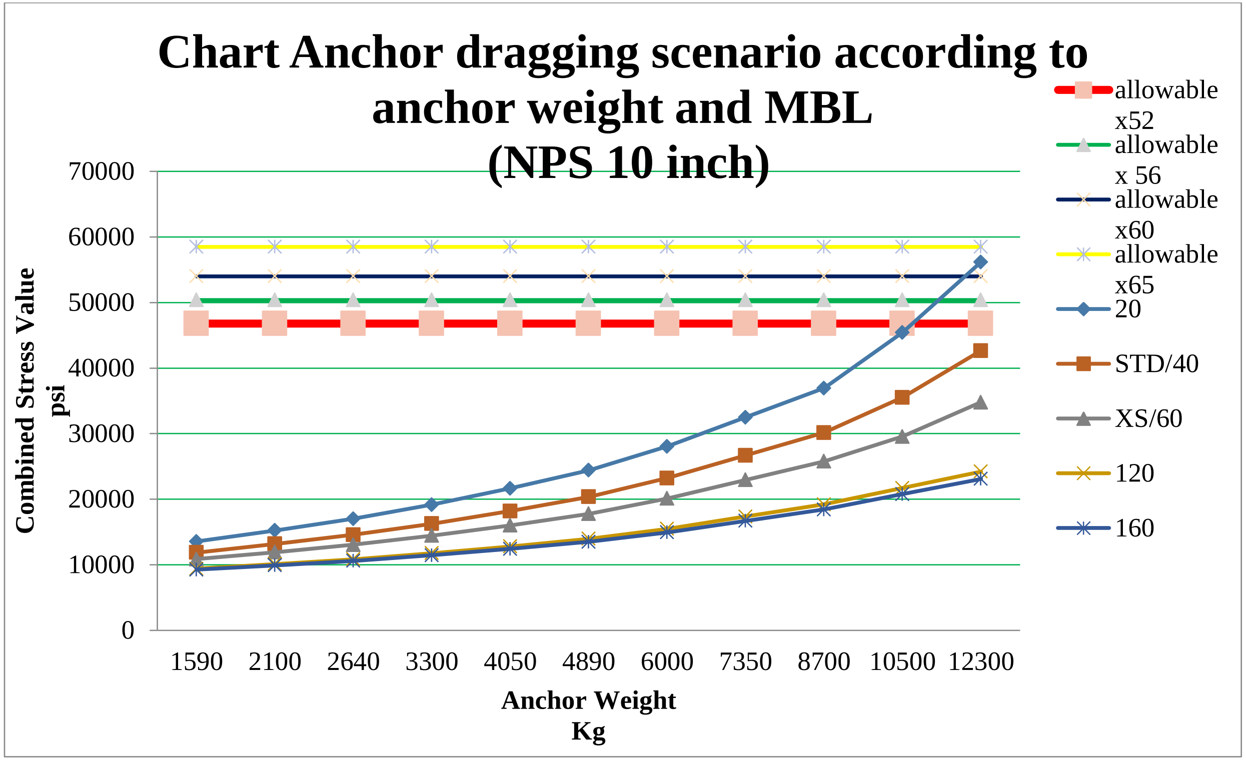


Chart 4.2 Chart Anchor dragging scenario accoridng to anchor weight and MBL (NPS 10 Inch)

4.2.4. NPS (Nominal Pipe Size) 12 Inch

By using Autopipe Numerical Simulation , get result of combined stress pipe data and shown in table below

a. Unburied pipe

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
12	STD	15805	17869	20054	22724	25759	29158	33649	39112	44574	51858	59141
	40	15257	17176	19208	21691	24513	27673	31850	36929	42009	48781	55554
	XS	13959	15549	17232	19289	21626	24244	27704	31911	36118	41728	47338
	60	13344	14775	16289	18140	20244	22600	25713	29499	33286	38334	43382
	80	12480	13680	14951	16504	18269	20245	22857	26034	29210	33446	37681
	100	11766	12776	13845	15153	16638	18302	20500	23174	25847	29412	32977
	XXS/120	11296	12177	13110	14251	15547	16998	18196	21249	23582	26692	29802
	160	10704	11421	12180	13108	14163	15344	16905	18803	20701	22232	25764

Table 4.12 Unburied pipe 12 Inch

b. Buried pipe 2m

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
12	STD	11345	12390	13497	14850	16388	18110	20385	23153	25920	29610	33689
	40	11090	12081	13131	14414	15872	17505	19663	22287	24911	28411	32095
	XS	10447	11310	12224	13341	14610	16032	17910	20195	22479	25525	28572
	60	10143	10941	11785	12818	13991	15304	17041	19152	21264	24079	26894
	80	9718	10419	11159	12064	13092	14244	15766	17617	19468	21936	24404
	100	9359	9973	10622	11416	12318	13328	14663	16287	17910	20075	22240
	XXS/120	9123	9675	10260	10975	11787	12697	13899	15361	16824	18773	20723
	160	8817	9288	9768	10395	11086	11861	12885	14130	15376	17036	18696

Table 4.13 Buried pipe 12 Inch

c. Rupture Analysis

After get data Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL , then use ASME b31.8 Standard to get rupture / no rupture condition of pipe .

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe .

Design Condition	Allowable		
	Hoop Stresss	Longitudinal Stress	Combined Stress
Operation	70 % SMYS	80 % SMYS	90 % SMYS
Hydrotest	90 % SMYS	72 % SMYS	96 % SMYS
Installation	72 % SMYS	80 % SMYS	90 % SMYS

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe at Operation Condition , 90 % SMYS .

Variation Grade pipe with Operation Allowable Condition shown in table below

Design Condition	Grade			
	X52	X54	X56	X60
90 % SMYS	46800	50400	54000	58500

Rupture/No Rupture analysis is shown in table below

NPS in	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)																			
		1590	R/N	2100	R/N	2640	R/N	3300	R/N	4050	R/N	4890	R/N	6000	R/N	7350	R/N	8700	R/N	10500	R/N	12300	R/N
12	STD	11345	N	12390	N	13497	N	14850	N	16388	N	18110	N	20385	N	23153	N	25920	N	29610	N	33689	N
	40	11090	N	12081	N	13131	N	14414	N	15872	N	17505	N	19663	N	22287	N	24911	N	28411	N	32095	N
	XS	10447	N	11310	N	12224	N	13341	N	14610	N	16032	N	17910	N	20195	N	22479	N	25525	N	28572	N
	60	10143	N	10941	N	11785	N	12818	N	13991	N	15304	N	17041	N	19152	N	21264	N	24079	N	26894	N
	80	9718	N	10419	N	11159	N	12064	N	13092	N	14244	N	15766	N	17617	N	19468	N	21936	N	24404	N
	100	9359	N	9973	N	10622	N	11416	N	12318	N	13328	N	14663	N	16287	N	17910	N	20075	N	22240	N

Table 4.14 Rupture Analysis 12 Inch

R : Rupture
N : No Rupture

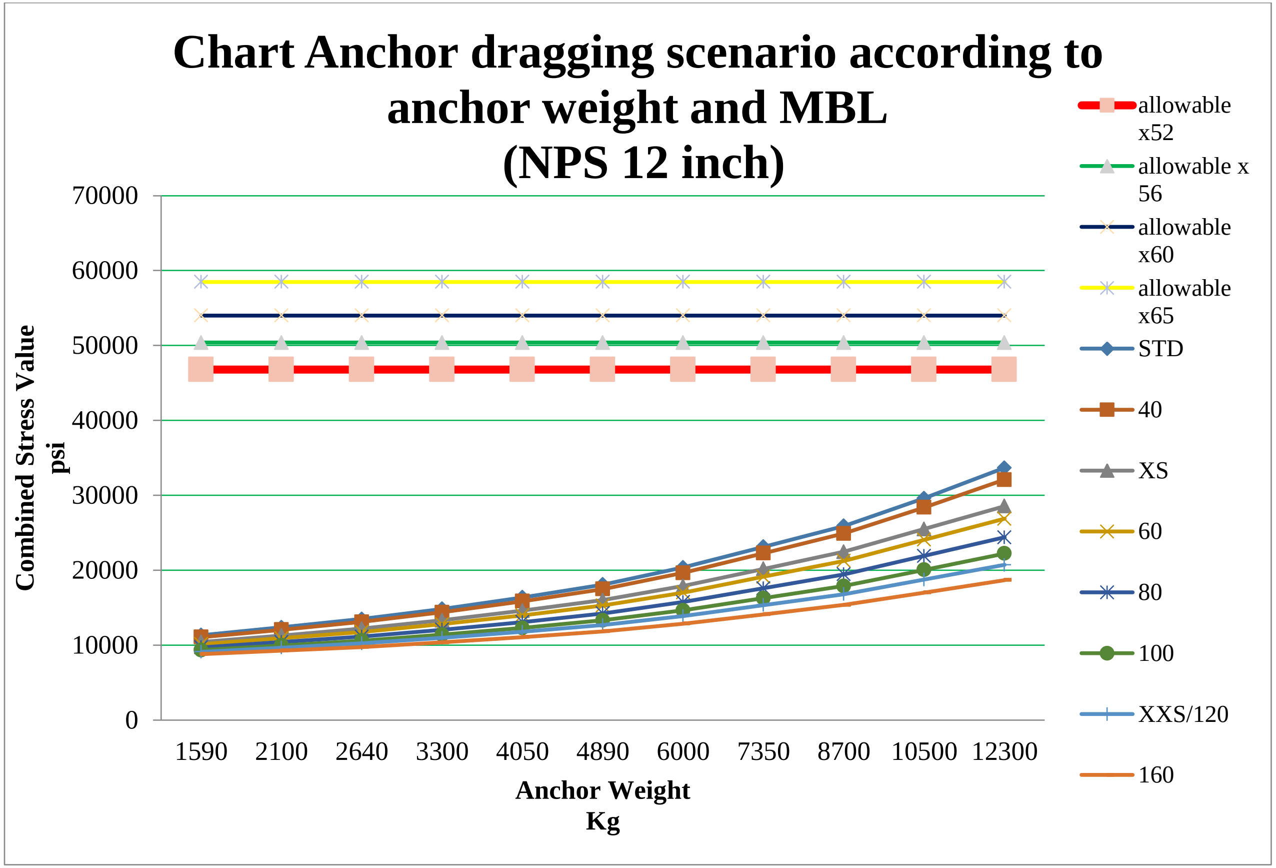


Chart 4.3 Chart Anchor dragging scenario accoridng to anchor weight and MBL (NPS 12 Inch)

4.2.5. NPS (Nominal Pipe Size) 14 Inch

By using Autopipe Numerical Simulation , get result of combined stress pipe data and shown in table below

a. Unburied pipe

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
14	STD/30	14664	16364	18163	20363	22863	25663	29362	33862	38361	44361	50360
	40	13751	15224	16784	18690	20856	22283	26489	30338	34228	39487	44686
	XS	13032	14338	15721	17412	19333	21484	24327	27785	31242	35853	40463
	80	11449	12361	13328	14508	15850	17353	19339	21754	24170	27390	30601
	140	10228	10830	11467	12246	13131	14123	15443	17026	18619	20743	22868
	160	10040	10592	11176	11889	12700	13609	14809	16269	17729	19675	21621

Table 4.15 Unburied Pipe 14 Inch

b. Buried pipe 2m

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
14	STD/30	11156	12086	13070	14273	15640	17171	19194	21655	24115	27396	30677
	40	10683	11518	12403	13485	14714	16090	17909	20121	22334	25283	28233
	XS	10282	11046	11855	12843	13966	15224	16886	18908	20929	23625	26320
	80	9431	10012	10627	11378	12232	13189	14453	15990	17528	19577	21627
	140	8761	9180	9623	10165	10781	11471	12383	13491	14600	16078	17557
	160	8658	9049	9462	9967	10542	11185	12035	13068	14102	15480	16858

Table 4.16 Buried pipe 14 Inch

c. Rupture Analysis

After get data Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL , then use ASME b31.8 Standard to get rupture / no rupture condition of pipe .

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe .

Design Condition	Allowable		
	Hoop Stresss	Longitudinal Stress	Combined Stress
Operation	70 % SMYS	80 % SMYS	90 % SMYS
Hydrotest	90 % SMYS	72 % SMYS	96 % SMYS
Installation	72 % SMYS	80 % SMYS	90 % SMYS

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe at Operation Condition , 90 % SMYS .

Variation Grade pipe with Operation Allowable Condition shown in table below

Design Condition	Grade			
	X52	X54	X56	X60
90 % SMYS	46800	50400	54000	58500

Rupture/No Rupture analysis is shown in table below

NPS in	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)																			
		1590	R/N	2100	R/N	2640	R/N	3300	R/N	4050	R/N	4890	R/N	6000	R/N	7350	R/N	8700	R/N	10500	R/N	12300	R/N
14	STD/30	11156	N	12086	N	13070	N	14273	N	15640	N	17171	N	19194	N	21655	N	24115	N	27396	N	30677	N
	40	10683	N	11518	N	12403	N	13485	N	14714	N	16090	N	17909	N	20121	N	22334	N	25283	N	28233	N
	XS	10282	N	11046	N	11855	N	12843	N	13966	N	15224	N	16886	N	18908	N	20929	N	23625	N	26320	N
	80	9431	N	10012	N	10627	N	11378	N	12232	N	13189	N	14453	N	15990	N	17528	N	19577	N	21627	N
	140	8761	N	9180	N	9623	N	10165	N	10781	N	11471	N	12383	N	13491	N	14600	N	16078	N	17557	N
	160	8658	N	9049	N	9462	N	9967	N	10542	N	11185	N	12035	N	13068	N	14102	N	15480	N	16858	N

Table 4.17 Rupture Analysis 14 Inch

R : Rupture
N : No Rupture

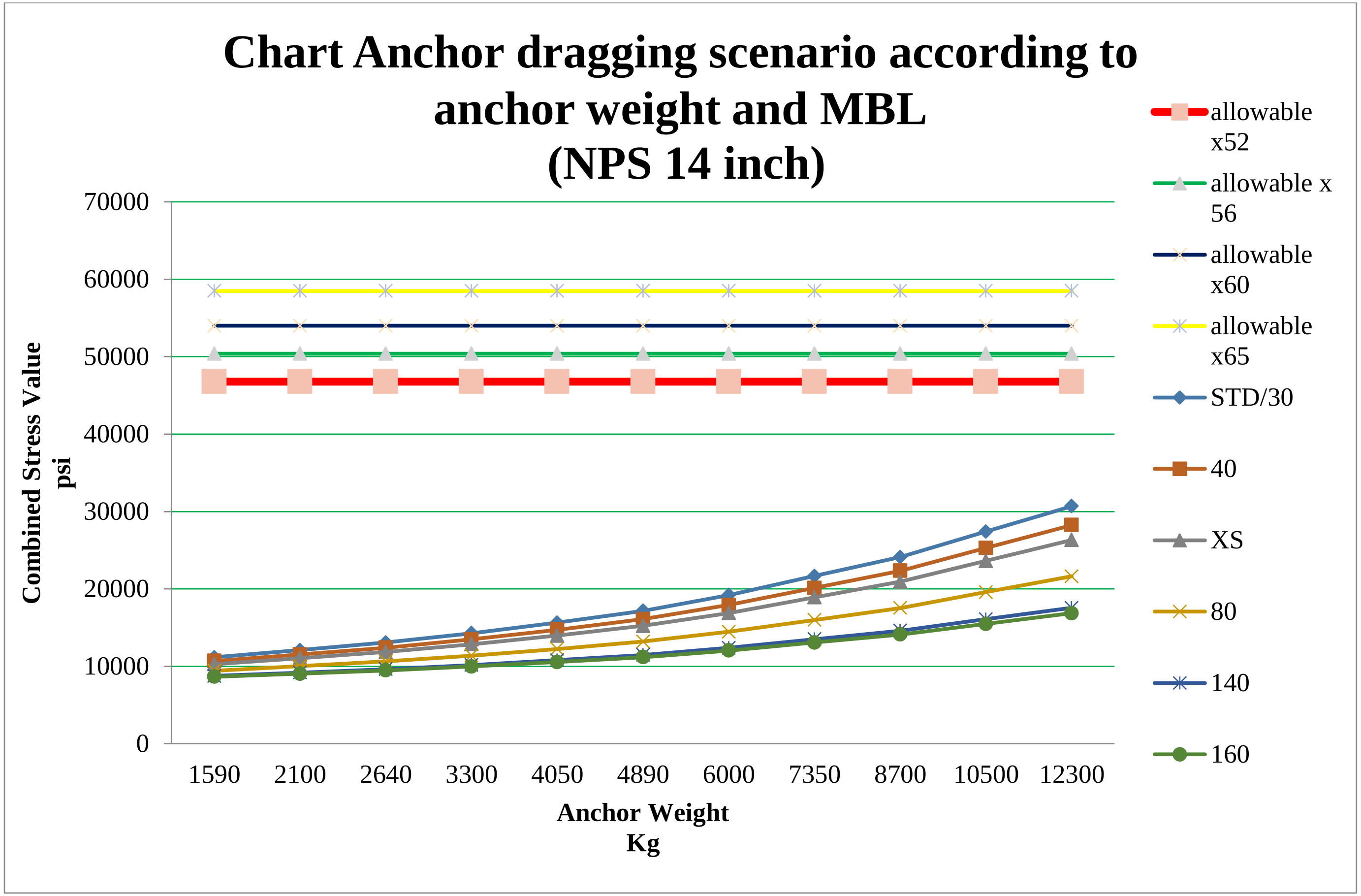


Chart 4.4 Chart Anchor dragging scenario accoridng to anchor weight and MBL (NPS 14 Inch)

4.2.6. NPS (Nominal Pipe Size) 16 Inch

By using Autopipe Numerical Simulation , get result of combined stress pipe data and shown in table below

a. Unburied pipe

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
16	STD/30	13422	14712	16078	17748	19645	21770	24578	27993	31408	35961	40514
	XS/40	12070	13058	14105	15384	16838	18466	20617	23234	25850	29339	32827
	60	11042	11815	12632	13632	14768	16040	17720	19765	21809	24535	27261
	80	10354	10973	11629	12430	13340	14359	15706	17345	18983	21168	23352
	120	9643	10099	10582	11173	11844	12595	13588	14796	16004	17614	19225

Table 4.18 Unburied pipe 18 Inch

b. Buried pipe 2m

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
16	STD/30	10964	11746	12573	13585	14734	16022	17723	19892	21861	24620	27379
	XS/40	10160	10798	11473	12298	13236	14286	15673	17361	19049	21299	23549
	60	9516	10042	10599	11279	12053	12919	14063	15455	16847	18703	20558
	80	9096	9537	10004	10754	11223	11949	12909	14076	15243	16800	18356
	120	8662	9006	9370	9816	10322	10889	11639	12550	13462	14677	15892

Table 4.19 Buried pipe 16 Inch

c. Rupture Analysis

After get data Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL , then use ASME b31.8 Standard to get rupture / no rupture condition of pipe .

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe .

Design Condition	Allowable		
	Hoop Stresss	Longitudinal Stress	Combined Stress
Operation	70 % SMYS	80 % SMYS	90 % SMYS
Hydrotest	90 % SMYS	72 % SMYS	96 % SMYS
Installation	72 % SMYS	80 % SMYS	90 % SMYS

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe at Operation Condition , 90 % SMYS .

Variation Grade pipe with Operation Allowable Condition shown in table below

Design Condition	Grade			
	X52	X54	X56	X60
90 % SMYS	46800	50400	54000	58500

Rupture/No Rupture analysis is shown in table below

NPS in	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)																			
		1590	R/N	2100	R/N	2640	R/N	3300	R/N	4050	R/N	4890	R/N	6000	R/N	7350	R/N	8700	R/N	10500	R/N	12300	R/N
16	STD/30	10964	N	11746	N	12573	N	13585	N	14734	N	16022	N	17723	N	19892	N	21861	N	24620	N	27379	N
	XS/40	10160	N	10798	N	11473	N	12298	N	13236	N	14286	N	15673	N	17361	N	19049	N	21299	N	23549	N
	60	9516	N	10042	N	10599	N	11279	N	12053	N	12919	N	14063	N	15455	N	16847	N	18703	N	20558	N
	80	9096	N	9537	N	10004	N	10754	N	11223	N	11949	N	12909	N	14076	N	15243	N	16800	N	18356	N
	120	8662	N	9006	N	9370	N	9816	N	10322	N	10889	N	11639	N	12550	N	13462	N	14677	N	15892	N

Table 4.20 Rupture Analysis 16 Inch

R : Rupture
N : No Rupture

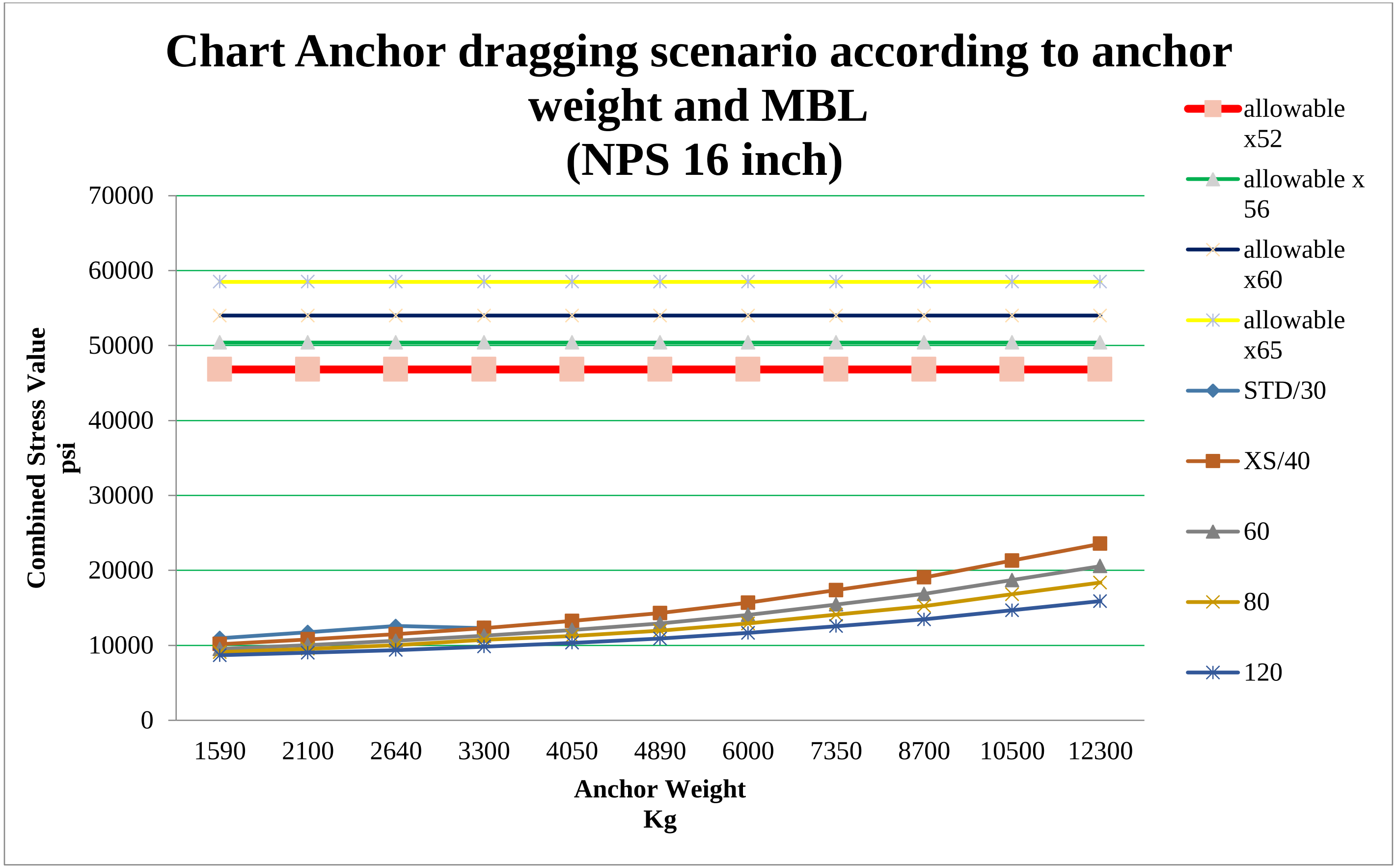


Chart 4.5 Chart Anchor dragging scenario accoridng to anchor weight and MBL (NPS 16 Inch)

4.2.7. NPS (Nominal Pipe Size) 18 Inch

By using Autopipe Numerical Simulation , get result of combined stress pipe data and shown in table below

a. Unburied pipe

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
18	XS	11422	12196	13015	14017	15155	16430	18114	20163	22212	24944	27675
	60	10152	10687	11253	11945	12732	13613	14777	16193	17609	19497	21385
	80	9665	10105	10570	11139	11785	12509	13465	14629	15792	17343	18894
	160	8795	9057	9335	9675	10061	10493	11064	11758	12453	13379	14305

Table 4.21 Unburied pipe 18 Inch

b. Buried pipe 2m

NPS (Nominal Pipe Size) Inch	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)										
		1590	2100	2640	3300	4050	4890	6000	7350	8700	10500	12300
18	XS	10064	10604	11176	11875	12669	13559	14734	16164	17594	19500	21407
	60	9193	9595	10019	10539	11129	11789	12663	13725	14786	16202	17618
	80	8863	9205	9566	10007	10509	11071	11813	12717	13620	14824	16028
	160	8314	8495	8728	9013	9336	9698	10177	10759	11342	12118	12894

Table 4.22 Buried pipe 18 Inch

c. Rupture Analysis

After get data Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL , then use ASME b31.8 Standard to get rupture / no rupture condition of pipe .

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe .

Design Condition	Allowable		
	Hoop Stresss	Longitudinal Stress	Combined Stress
Operation	70 % SMYS	80 % SMYS	90 % SMYS
Hydrotest	90 % SMYS	72 % SMYS	96 % SMYS
Installation	72 % SMYS	80 % SMYS	90 % SMYS

This thesis use Allowable Combined Stress as rupture/no rupture analysis condition in pipe at Operation Condition , 90 % SMYS .

Variation Grade pipe with Operation Allowable Condition shown in table below

Design Condition	Grade			
	X52	X54	X56	X60
90 % SMYS	46800	50400	54000	58500

Rupture/No Rupture analysis is shown in table below

NPS in	Sch No.	Combined Stress Value caused by Anchor dragging scenario to anchor weight and MBL (%SMYS/kN)																					
		1590	R/N	2100	R/N	2640	R/N	3300	R/N	4050	R/N	4890	R/N	6000	R/N	7350	R/N	8700	R/N	10500	R/N	12300	R/N
18	XS	10064	N	10604	N	11176	N	11875	N	12669	N	13559	N	14734	N	16164	N	17594	N	19500	N	21407	N
	60	9193	N	9595	N	10019	N	10539	N	11129	N	11789	N	12663	N	13725	N	14786	N	16202	N	17618	N
	80	8863	N	9205	N	9566	N	10007	N	10509	N	11071	N	11813	N	12717	N	13620	N	14824	N	16028	N
	160	8314	N	8495	N	8728	N	9013	N	9336	N	9698	N	10177	N	10759	N	11342	N	12118	N	12894	N

Table 4.23 Rupture Analysis 18 Inch

R : Rupture
N : No Rupture

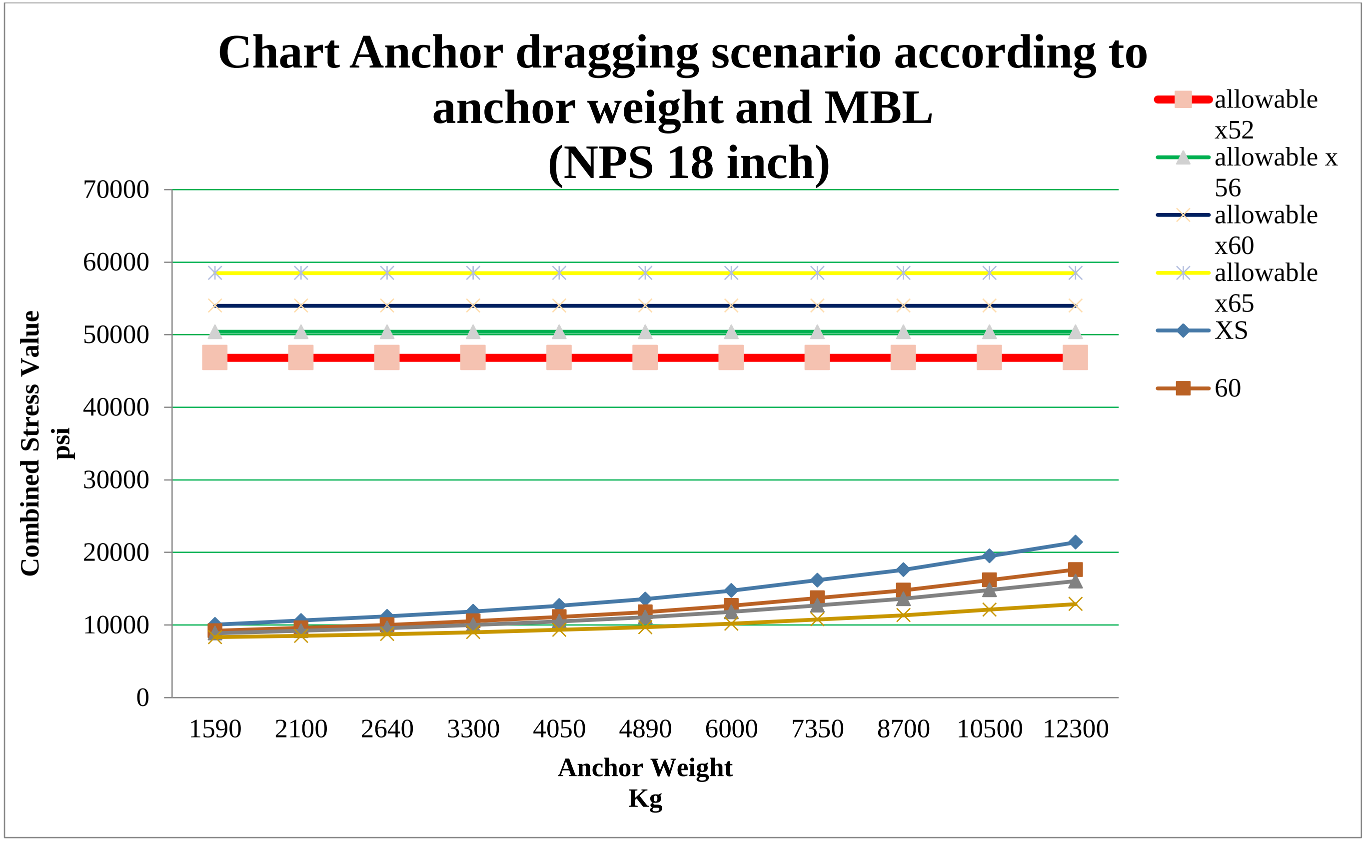


Chart 4.6 Chart Anchor dragging scenario accoridng to anchor weight and MBL (NPS 18 Inch)

4.2.8. Simulation Analysis Explanation

Based on the results of the pipe response analysis against the variant weight of anchor and the anchor force MBL Chain of the combined stress value simulated results autopipe Software such as the discussion that has been outlined earlier, it can be concluded as follows:

1. Simulated scenario and model of anchor variations and pipes on drag anchor using simulated software or numerical simulation explained below
   a. First , determine data used for simulated

No	Data	Description
1	Anchor	1590 ,2100, 2640, 3300, 4050, 4890, 6000, 7350, 8700, 10500, 12300 (kg)
2	NPS (Nominal Pipe Size) pipe	6, 8, 10, 12,14,16,18 (in)
3	Schedule pipe	STD,XS,XXS
4	Temperature	70 F (Ambient Temp.) , 100 F (Operating)
5	Piping Code	ASME B31.8
6	Grade Pipe	X52,X6, X60,X65

   b. Explain Use Case Defenition using Autopipe Software

No	Use Case	Description	Example
1	Insert piping Code	ASME B31.8	ASME B 3.18 2016
2	Insert Pipe Identifier	Insert NPS (NOMINAL PIPE SIZE) pipe and Schedule Pipe	6 STD
3	Insert Pipe material	Insert Pipe Material and Grade Material	5LX-X52
4	Insert Operating Pressure and Temperature	Insert Operating Pressure and Temperature	100 F and 100 psi
5	Insert Additional Weight	Insert the weight (point load)of a nonstandard or special component at current point	1590 kg (3505 lb)
6	Insert Concentrated Force	Insert external forces and moments to be applied at the current point	735 kN(3.26 lbf)
7	Insert Soil Properties	Insert soil properties to model support restraint offered by soil surrounding buried piping	Calculation Method american Lifeline Alliance (ASCE 2001) , Medium Sand soil type ,

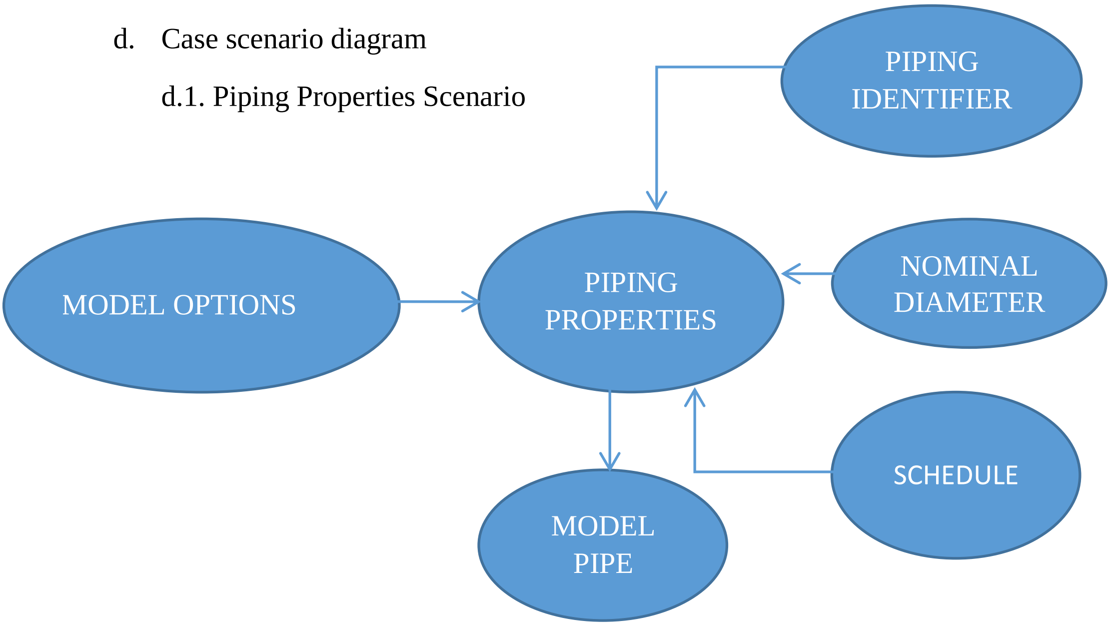
			Average Siffness
8	Insert Maximum Spacing		2 m (78.74 in)
9	Analysis	Analyze Model	Static Analysis
10	Result	Code Stresses	Combined Stress type 16094 psi

c. Third , Case Scenario Planned

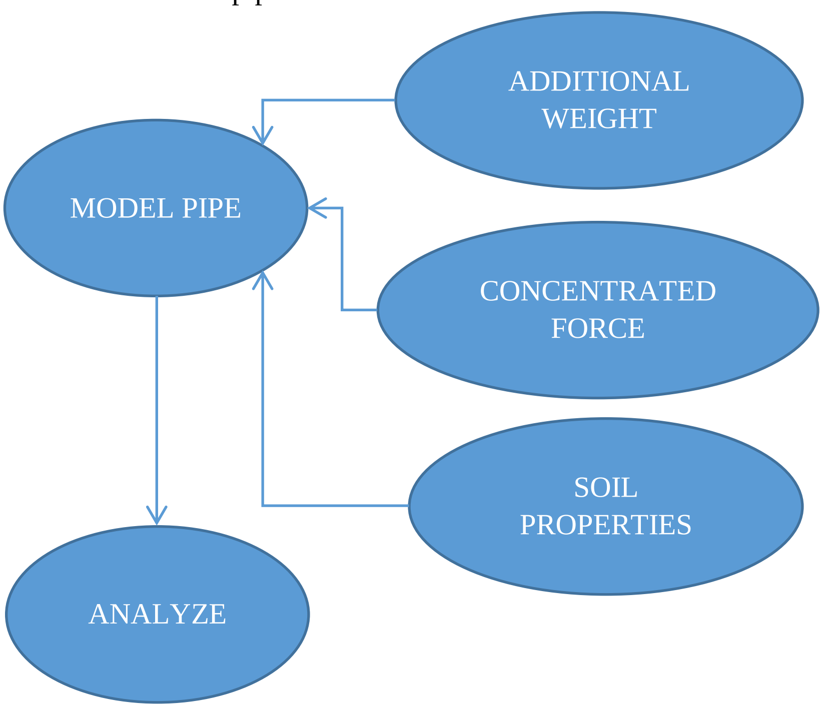
Action	**System Reaction**	**Descripttion Scenario**
1. Insert piping Code		Piping Properties
	2. Displaying Piping Code	
3. Insert Piping Identifier		
	4. Displaying Nominal Diameter and Schedule Pipe	
5. Insert Pipe Mateial		
	6. Displaying Pipe Material and Grade material	
7. Insert Operating Pressure and Temperature		
8. Insert Additional Weight		Analyze Model Pipe
9. Insert Concentrated Force		
10. Insert Soil Properties		
	11. Displaying Calculation Method , Soil Type , Soil Stiffness	
12. Analyze Model		Analysis Result
	13 . Displaying Code Stress	

d. Case scenario diagram

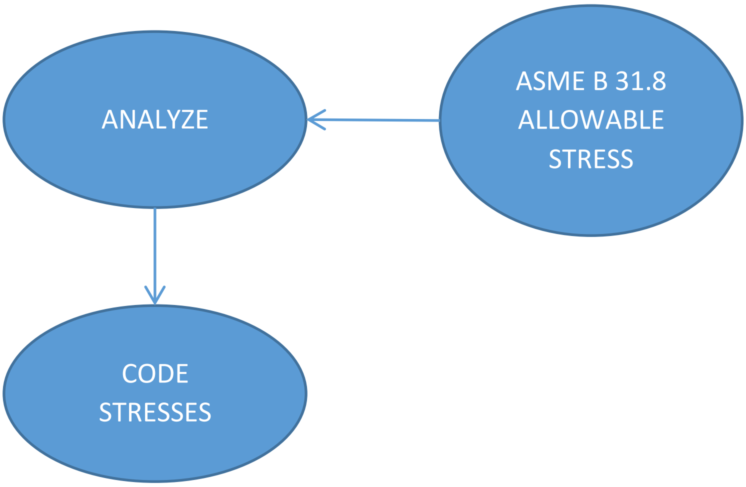
d.1. Piping Properties Scenario



d.2. Analize Model pipe Scenario



d.3. Analysis Result Scenario



2. To calculate strength of pipe using Pipe Analysis Stress by Autopipe Software and get result
    a. NPS (Nominal Pipe Size) 6
       Combined Stress Value range 23361 psi – 265562 psi
       After added soil properties 2 m , Combined Stress Value range 11323 psi – 118416 psi .
    b. NPS (Nominal Pipe Size) 8
       Combined Stress Value range 16402 psi – 172810 psi
       After added soil properties 2 m , Combined Stress Value range 10115 psi – 80196 psi.
    c. NPS (Nominal Pipe Size) 10
       Combined Stress Value range 12475 psi – 113156 psi
       After added soil properties 2 m , Combined Stress Value range 9241 psi – 56183 psi.
    d. NPS (Nominal Pipe Size) 12
       Combined Stress Value range 10704 psi – 59141 psi
       After added soil properties 2 m , Combined Stress Value range 8817 psi – 33689 psi.
    e. NPS (Nominal Pipe Size) 14
       Combined Stress Value range 10040 psi – 50360 psi
       After added soil properties 2 m , Combined Stress Value range 8658 psi – 30677 psi.

f. NPS (Nominal Pipe Size) 16
Combined Stress Value range 9643 psi – 40514 psi
After added soil properties 2 m , Combined Stress Value range 8662 psi – 27329 psi.

g. NPS (Nominal Pipe Size) 18
Combined Stress Value range 8795 psi – 27675 psi
After added soil properties 2 m , Combined Stress Value range 8314 psi – 21407 psi.

3. To calculate the damage of the pipe cause by anchor drag is using ASME B31.8 Standard for alllowable combined Stress , 90% SMYS .

Design Condition	Grade			
	X52	X56	X60	X65
90 % SMYS (psi)	46800	50400	54000	58500

a. At analysis of NPS (Nominal Pipe Size) 6 in,

a.1. Grade X52

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 7350 kg cause Pipe Schedule No 40 /STD rupture .
- Anchor 8700 kg cause pipe Schedule No 40/STD and XS/80 rupture .
- Anchor 10500 kg cause pipe Schedule No 40/STD , XS/80, 120 and 160 rupture .
- Anchor 12300 kg cause pipe Schedule No 40/STD , XS/80, 120 , 160 and XXS rupture .

a.2. Grade X56

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 7350 kg cause Pipe Schedule No 40 /STD rupture .
- Anchor 8700 kg cause pipe Schedule No 40/STD rupture .
- Anchor 10500 kg cause pipe Schedule No 40/STD , XS/80 and 120 rupture .
- Anchor 12300 kg cause pipe Schedule No 40/STD , XS/80, 120 , 160 and XXS rupture .

a.3. Grade X60

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 8700 kg cause pipe Schedule No 40/STD rupture .
- Anchor 10500 kg cause pipe Schedule No 40/STD , XS/80and 120 rupture .

- Anchor 12300 kg cause pipe Schedule No 40/STD , XS/80, 120 , 160 and XXS rupture .

a.4. Grade X65

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 8700 kg cause pipe Schedule No 40/STD rupture .
- Anchor 10500 kg cause pipe Schedule No 40/STD , XS/80 and 120 rupture .
- Anchor 12300 kg cause pipe Schedule No 40/STD , XS/80, 120 , 160 rupture .

b. At analysis of NPS (Nominal Pipe Size) 8 in,

b.1. Grade X52

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 8700 kg cause Pipe Schedule No 20 rupture .
- Anchor 10500 kg cause pipe Schedule No 20 and 40/STD rupture.
- Anchor 12300 kg cause pipe Schedule No 20, 40/STD ,60 and XS/80 and XXS rupture .

b.2. Grade X56

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 10500 kg cause pipe No 20 and 40/STD rupture.
- Anchor 12300 kg cause pipe Schedule No 20 , 40/STD and 60 rupture.

b.3. Grade X60

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 10500 kg cause pipe Schedule No 20 rupture .
- Anchor 12300 kg cause pipe No 20 , 40/STD and 60 rupture .

b.4. Grade X65

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 10500 kg cause pipe Schedule No 20 rupture .
- Anchor 12300 kg cause pipe No 20 and 40/STD rupture .

c. At analysis of NPS (Nominal Pipe Size) 10 in,

c.1. Grade X52

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 12300 kg cause pipe Schedule No 20 rupture .

c.2. Grade X56

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 12300 kg cause pipe Schedule No 20 rupture .

c.3. Grade X60

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- Anchor 12300 kg cause pipe Schedule No 20 rupture .

c.4. Grade X65

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- No pipe rupture .

d. At analysis of NPS (Nominal Pipe Size) 12 in ,14 in , 16 in , 18 in

d.1. Grade X52 , X56, X60 and X65

Pipe rupture cause its combined stress is bigger than allowable stresss based ASME B31.8 ,

- No pipe rupture .

CHAPTER V

CONCLUSION

5.1. Conclusion

1. Simulated scenario and model of anchor variations and pipes on drag anchor using simulated software or numerical simulation explained in subchapter 4.2.8. Analize Model pipe Scenarios used in this bachelor thesis are additional weight , concentrate force and soil properties .
2. To calculate strength of pipe using Pipe Analysis Stress by Autopipe Software and get result for unburied condition , highest combined stress value is 265562 psi at NPS (Nominal Pipe Size) 6 inch dragged by anchor 12300 kg and lowest combined stress value is 8795 psi at NPS (Nominal Pipe Size) 18 inch dragged by anchor 1590 kg . For 2 meters buried pipe condition , highest combined stress value is 118416 psi at NPS (Nominal Pipe Size) 6 inch dragged by anchor 12300 kg and lowest combined stress value is 8314 psi at NPS (Nominal Pipe Size) 18 inch dragged by anchor 1590 kg .
3. To calculate the damage of the pipe cause by anchor drag is using ASME B31.8 Standard for alllowable combined Stress , 90% SMYS . And get result Analysis at NPS (Nominal Pipe Size) 10 inch grade X65 , subsea pipeline is not rupture.. Analysis at NPS (Nominal Pipe Size) 12 inch , 14 inch , 16 inch , 18 inch ,with material Grade X52, X56, X60,and X65 , subsea pipelines are not rupture .

5.2. Suggestions

This Bachelor thesis topic can be developed and resumed again for subsequent research. Here are some suggestions that you can considered to be analyzed in subsequent studies:

1. Perform analysis by varying the depth of buried pipe
2. Perform analysis by varying simulated condition , such as dropped anchor
3. Perform analysis by another pipe stress analysis , such as CAESAR II , Abaqus

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Appendix A

Report on the investigation of

Young Lady

Dragging anchor 5 miles east of Teesport and snagging the CATS gas pipeline, resulting in material damage to the pipe 25 June 2007

Marine Accident Investigation Branch

Carlton House Carlton Place Southampton United Kingdom

SO15 2DZ

Report No 3/2008 February 2008

SYNOPSIS

A large vessel, dragging her anchor in heavy weather, dislodged a strategic pipeline carrying gas into the United Kingdom. Although, in this case, the risk of pollution was avoided, the pipeline was out of action for over 2 months.

At 2200 on 25 June 2007, the tanker *Young Lady* started to drag her anchor in Tees Bay; the wind speed was in excess of 40 kts and there was a heavy northerly swell. The master decided to weigh anchor and depart, but during the operation the windlass hydraulic motor exploded and the cable ran out to the bitter end. The vessel continued to drag her anchor until 2300 when, passing over the CATS gas pipeline, the anchor flukes snagged the pipe.

The vessel was caught on the pipeline for about 10 minutes before a wide yaw caused the flukes to free themselves. *Young Lady* continued dragging until the anchor finally held as it rode over a shoal patch, 2.5 miles off a lee shore. There were no injuries sustained or damage caused by pollution.

A subsequent survey of the pipeline showed that *Young Lady'* s anchor had lifted the pipeline out of its trench and dragged it about 6m laterally. The pipeline suffered damage to the concrete coating and impact damage to the steel surface.

The MAIB investigation found that:

- The master was aware that the anchorage was not recommended in the forecast conditions, and the decision to remain at anchor was inappropriate.
- There was no statutory requirement for anyone to monitor the area adjacent to the CATS pipeline, or to identify vessels anchoring too close.
- A number of strategic oil and gas pipelines run close to large

vessel anchorages. A breach of these pipelines could have significant implications for the United Kingdom's energy supply.

- The risks associated with large vessels anchoring or dragging over pipelines had not been fully assessed. Consequently, some strategic pipelines could be vulnerable to snagging by large anchors.

Recommendations have been issued to:

- The manager of *Young Lady,* designed to improve the information available to its masters when anchoring large vessels.
- The MCA, BPA and UKMPG, to review the criteria and procedures used by port administrations to ensure HM Coastguard receives early notification of developing situations.
- The DfT, DBERR and HSE to conduct a review of the risk assessment process for the protection of pipelines from surface vessel interaction.

Vessel details

Registered owner	:	Blenheim Shipping UK Limited
Manager	:	Scinicariello Ship Management, Italy
Port of registry	:	Douglas, Isle of Man
Flag	:	Isle of Man
Type	:	Crude oil aframax product carrier
Built	:	2000 Yokosuka, Japan
Classification society	:	Lloyd's Register
Construction	:	Higher tensile steel, double hull oil tanker
Length overall	:	239 m
Gross tonnage	:	56,204 tons
Deadweight tonnage	:	105,528 tonnes
Engine power and type	:	12000kW. Sulzer 6 cylinder two stroke
Service speed	:	15.2 kts
Manoeuvrability	:	Single screw, fixed pitch right handed propeller.

Accident details

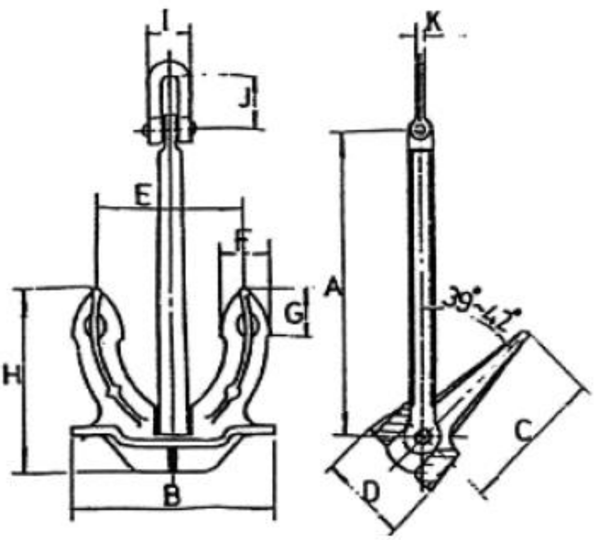
Time and date	:	2200 BST on 25 June 2007
Location of incident	:	Latitude 54° 40.5' N Longitude 001° 00.5' W
Persons on board	:	24
Injuries/fatalities	:	None
Damage	:	To the vessel - loss of the port anchor and cable and failure of the port windlass hydraulic motor To the pipeline - contact damage from the vessel's anchor.

Appendix B

Anchor Calculation

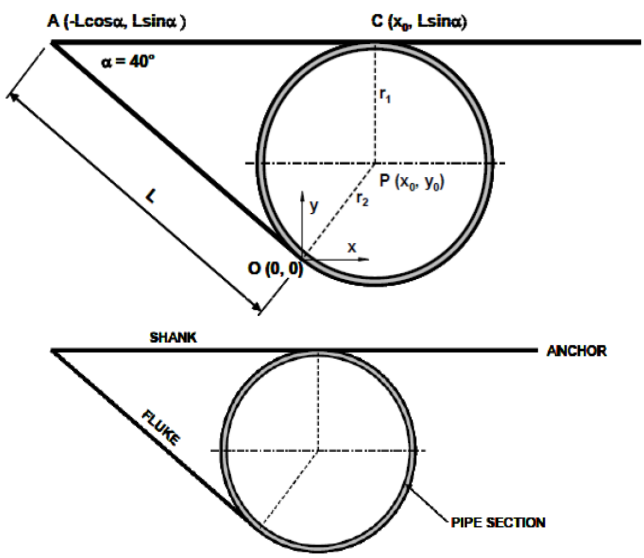
Saxton Marine Stockless Anchor

Hall Type



Anchor Weight		Dimensions (mm)										
lbs	**kg**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
1260	570	1330	950	700	408	670	219	249	862	170	221	52
1455	660	1400	1000	740	430	710	230	262	910	179	234	55
1720	780	1480	1060	870	456	750	244	278	960	189	247	58
1985	900	1550	1110	820	477	780	255	291	1009	199	259	61
2250	1020	1620	1160	860	500	820	267	304	1057	208	272	64
2515	1140	1680	1200	890	520	850	276	315	1094	215	281	66
2845	1290	1750	1260	920	540	880	288	328	1132	224	293	69
3175	1440	1820	1300	960	560	920	299	340	1181	234	306	72
3505	1590	1880	1340	990	580	950	308	351	1218	240	315	74
3835	1740	1930	1380	1020	600	980	318	362	1255	247	323	76
4230	1920	2000	1430	1060	620	1010	329	375	1303	257	336	79
4630	2100	2060	1470	1090	640	1040	338	385	1340	263	344	81
5025	2280	2110	1510	1120	650	1070	347	396	1377	270	353	83
5425	2460	2170	1550	1150	670	1100	357	306	1414	277	361	85
5820	2640	2230	1590	1180	690	1120	366	417	1450	284	370	87
6285	2850	2280	1630	1210	700	1150	375	427	1487	292	383	90
6745	3060	2340	1670	1240	720	1180	384	438	1524	299	391	92
7275	3300	2390	1710	1270	740	1210	393	448	1561	306	400	94
7805	3540	2450	1750	1290	750	1240	402	458	1588	313	408	96
8335	3780	2510	1790	1320	770	1260	412	469	1624	320	417	98
8930	4050	2650	1830	1350	790	1290	420	480	1661	328	429	101
9525	4320	2620	1870	1380	800	1320	430	490	1698	335	438	103
10120	4590	2670	1910	1410	820	1350	440	500	1735	342	446	105
10780	4890	2730	1950	1440	840	1380	448	510	1772	349	455	107
11575	5250	2800	2000	1480	860	1410	460	520	1820	358	467	110
12370	5610	2860	2040	1510	880	1440	470	530	1857	365	476	112
13230	6000	2930	2090	1540	900	1480	480	550	1895	384	489	120
14220	6450	3000	2140	1580	920	1510	492	560	1944	384	502	118
15210	6900	3070	2190	1620	940	1550	500	570	1992	390	510	120
16205	7350	3140	2240	1650	960	1580	520	590	2030	401	522	123
17195	7800	3190	2280	1680	980	1610	530	600	2068	407	530	125
18300	8300	3260	2330	1720	1000	1560	540	610	2116	417	540	128
19180	8700	3311	2365	1745	1017	1580	544	620	2147	423	553	130
19400	8800	3330	2380	1760	1020	1610	550	620	2165	426	560	131

Anchor Weight		Dimensions (mm)										
lbs	kg	A	B	C	D	E	F	G	H	I	J	K
20500	9300	3390	2420	1790	1040	1650	560	630	2201	433	570	133
20610	9350	3390	2420	1790	1040	1670	560	630	2201	433	570	133
21825	9900	3460	2470	1820	1060	1680	570	650	2240	442	580	136
23150	10500	3530	2520	1860	1080	1710	680	660	2288	452	590	139
24470	11100	3600	2570	1900	1100	1820	590	670	2337	459	600	141
25795	11700	3650	2610	1930	1120	1840	600	680	2374	468	610	144
27115	12300	3710	2650	1960	1140	1870	610	700	2410	475	620	146
28440	12900	3770	2690	1990	1160	1900	620	710	2447	482	630	148
29760	13500	3840	2740	2020	1180	1940	630	720	2486	491	640	151
31085	14100	3890	2738	2050	1200	1960	640	730	2520	498	650	153
31415	14250	3910	2790	2060	1200	1970	640	730	2534	499	650	153
32405	14700	3950	2818	2080	1201	1990	650	740	2560	504	659	155
33070	15000	3980	2840	2100	1220	2000	650	740	2560	504	659	156
33950	15400	4000	2860	2110	1230	2020	660	750	2596	511	667	157
34830	15800	4050	2890	2130	1240	2040	670	760	2621	517	680	169
34594	16100	4070	2900	2140	1250	2050	670	760	2634	520	680	160
36815	16700	4120	2940	2170	1260	2080	680	770	2670	529	690	162
37255	16900	4130	2950	2180	1270	2090	680	770	2682	528	690	162
38800	17600	4190	2990	2210	1280	2110	690	780	2720	536	700	165
39240	17800	4200	3000	2220	1290	2120	690	790	2730	537	700	165
40785	18500	4260	3040	2250	1310	2150	700	800	2770	544	710	167
41445	18800	4280	3060	2260	1320	2160	700	800	2780	547	718	168
44090	20000	4370	3120	2300	1340	2000	720	820	2831	559	730	172
47400	21500	4770	3190	2360	1370	2250	730	840	2902	572	750	176
50705	23000	4580	3270	2410	1410	2310	750	860	2966	586	770	180
54010	24500	4680	3340	2470	1440	2360	770	880	3038	598	780	184
57320	26000	4770	3410	2510	1470	2410	780	890	3089	609	800	187
60625	27500	4860	3470	2560	1490	2450	800	910	3150	621	810	191
63930	29000	4950	3530	2610	1520	2490	810	930	3211	632	830	194



$$Dmax = \frac{2L(1-\cos\alpha)}{\sin\alpha}$$

Dmax : Diameter maximum of anchor fluke can hook pipe
(Pipeline Accidental Load Analysis , Stian Vervik 2011)

No	Anchor Weight (kg)	Fluke Angle (Deg)	C (mm)	D	Shank width	Delta L	L modified	Dmax
1	1590	42	1068	698	99,71	108,80	959,20	1255,91
2	2100	42	1120	732	104,57	114,10	1005,90	1317,06
3	2640	42	1194	784	112,00	122,20	1071,80	1403,34
4	3300	42	1349	883	126,14	137,63	1211,37	1586,08
5	4050	42	1406	924	132,00	144,02	1261,98	1652,34
6	4890	42	1498	984	140,57	153,37	1344,63	1760,56
7	6000	42	1605	1054	150,57	164,29	1440,71	1886,37
8	7350	42	1752	1152	164,57	179,56	1572,44	2058,84
9	8700	42	1816	1195	170,71	186,26	1629,74	2133,86
10	10500	42	1970	1297	185,29	202,16	1767,84	2314,68
11	12300	42	2199	1446	206,57	225,39	1973,61	2584,11

Shank width assumed 1/7 length C
Delta L = Width /sin 45
L modified use to equation

Anchor fluke can hook pipe shown in table below

No	Anchor Weight (kg)	Dmax (mm)	Dragged Pipe Scenario (inch)						
			6	8	10	12	14	16	18
1	1590	1255,914213	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	2100	1317,060537	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	2640	1403,338617	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	3300	1586,08051	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	4050	1652,344898	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6	4890	1760,558253	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7	6000	1886,370724	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	7350	2058,842058	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9	8700	2133,86359	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10	10500	2314,683901	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11	12300	2584,112042	Yes	Yes	Yes	Yes	Yes	Yes	Yes

No. for Reg.	Equipment numeral Z_1 or Z_2	Stockless anchor			Stud link chain cables						Recommended ropes				
		Bower anchor		Stream anchor	Bower anchors				Stream wire or chain for stream anchor		Towline		Mooring ropes		
		Number [1)]	Mass per anchor		Total length	Diameter d_1	Diameter d_2	Diameter d_3	Length	Br. load[2)]	Length	Br. load[2)]	Number	Length	Br. load[2)]
			[kg]		[m]	[mm]	[mm]	[mm]	[m]	[kN]	[m]	[kN]		[m]	[kN]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
101	up to 50	2	120	40	165	12,5	12,5	12,5	80	65	180	100	3	80	35
102	50 - 70	2	180	60	220	14	12,5	12,5	80	65	180	100	3	80	35
103	70 - 90	2	240	80	220	16	14	14	85	75	180	100	3	100	40
104	90 - 110	2	300	100	247,5	17,5	16	16	85	80	180	100	3	110	40
105	110 - 130	2	360	120	247,5	19	17,5	17,5	90	90	180	100	3	110	45
106	130 - 150	2	420	140	275	20,5	17,5	17,5	90	100	180	100	3	120	50
107	150 - 175	2	480	165	275	22	19	19	90	110	180	100	3	120	55
108	175 - 205	2	570	190	302,5	24	20,5	20,5	90	120	180	110	3	120	60
109	205 - 240	2	660		302,5	26	22	20,5			180	130	4	120	65
110	240 - 280	2	780		330	28	24	22			180	150	4	120	70
111	280 - 320	2	900		357,5	30	26	24			180	175	4	140	80
112	320 - 360	2	1020		357,5	32	28	24			180	200	4	140	85
113	360 - 400	2	1140		385	34	30	26			180	225	4	140	95
114	400 - 450	2	1290		385	36	32	28			180	250	4	140	100
115	450 - 500	2	1440		412,5	38	34	30			180	275	4	140	110
116	500 - 550	2	1590		412,5	40	34	30			190	305	4	160	120
117	550 - 600	2	1740		440	42	36	32			190	340	4	160	130
118	600 - 660	2	1920		440	44	38	34			190	370	4	160	145
119	660 - 720	2	2100		440	46	40	36			190	405	4	160	160
120	720 - 780	2	2280		467,5	48	42	36			190	440	4	170	170
121	780 - 840	2	2460		467,5	50	44	38			190	480	4	170	185
122	840 - 910	2	2640		467,5	52	46	40			190	520	4	170	200
123	910 - 980	2	2850		495	54	48	42			190	560	4	170	215
124	980 - 1060	2	3060		495	56	50	44			200	600	4	180	230
125	1060 - 1140	2	3300		495	58	50	46			200	645	4	180	250
126	1140 - 1220	2	3540		522,5	60	52	46			200	690	4	180	270
127	1220 - 1300	2	3780		522,5	62	54	48			200	740	4	180	285
128	1300 - 1390	2	4050		522,5	64	56	50			200	785	4	180	305
129	1390 - 1480	2	4320		550	66	58	50			200	835	4	180	325

130	1480 - 1570	2	4590		550	68	60	52			220	890	5	190	325
131	1570 - 1670	2	4890		550	70	62	54			220	940	5	190	335
132	1670 - 1790	2	5250		577,5	73	64	56			220	1025	5	190	350
133	1790 - 1930	2	5610		577,5	76	66	58			220	1110	5	190	375
134	1930 - 2080	2	6000		577,5	78	68	60			220	1170	5	190	400
135	2080 - 2230	2	6450		605	81	70	62			240	1260	5	200	425
136	2230 - 2380	2	6900		605	84	73	64			240	1355	5	200	450
137	2380 - 2530	2	7350		605	87	76	66			240	1455	5	200	480
138	2530 - 2700	2	7800		632,5	90	78	68			260	1470	6	200	480
139	2700 - 2870	2	8300		632,5	92	81	70			260	1470	6	200	490
140	2870 - 3040	2	8700		632,5	95	84	73			260	1470	6	200	500
141	3040 - 3210	2	9300		660	97	84	76			280	1470	6	200	520
142	3210 - 3400	2	9900		660	100	87	78			280	1470	6	200	555
143	3400 - 3600	2	10500		660	102	90	78			280	1470	6	200	590
144	3600 - 3800	2	11100		687,5	105	92	81			300	1470	6	200	620
145	3800 - 4000	2	11700		687,5	107	95	84			300	1470	6	200	650
146	4000 - 4200	2	12300		687,5	111	97	87			300	1470	7	200	650
147	4200 - 4400	2	12900		715	114	100	87			300	1470	7	200	660
148	4400 - 4600	2	13500		715	117	102	90			300	1470	7	200	670
149	4600 - 4800	2	14100		715	120	105	92			300	1470	7	200	680
150	4800 - 5000	2	14700		742,5	122	107	95			300	1470	7	200	685
151	5000 - 5200	2	15400		742,5	124	111	97			300	1470	8	200	685
152	5200 - 5500	2	16100		742,5	127	111	97			300	1470	8	200	695
153	5500 - 5800	2	16900		742,5	130	114	100			300	1470	8	200	705
154	5800 - 6100	2	17800		742,5	132	117	102			300	1470	9	200	705
155	6100 - 6500	2	18800		742,5		120	107			300	1470	9	200	715
156	6500 - 6900	2	20000		770		124	111			300	1470	9	200	725
157	6900 - 7400	2	21500		770		127	114			300	1470	10	200	725
158	7400 - 7900	2	23000		770		132	117			300	1470	11	200	725
159	7900 - 8400	2	24500		770		137	122			300	1470	11	200	735
160	8400 - 8900	2	26000		770		142	127			300	1470	12	200	735
161	8900 - 9400	2	27500		770		147	132			300	1470	13	200	735
162	9400 - 10000	2	29000		770		152	132			300	1470	14	200	735
163	10000 - 10700	2	31000		770			137			300	1470	15	200	735
164	10700 - 11500	2	33000		770			142			300	1470	16	200	735
165	11500 - 12400	2	35500		770			147			300	1470	17	200	735
166	12400 - 13400	2	38500		770			152			300	1470	18	200	735
167	13400 - 14600	2	42000		770			157			300	1470	19	200	735
168	14600 - 16000	2	46000		770			162			300	1470	21	200	735

d_1 = Chain diameter Grade K 1 (Ordinary quality) (Special
d_2 = Chain diameter Grade K 2 quality) (Extra special
d_3 = Chain diameter Grade K 3 quality)

See also D

1) see C.1.
2) see F.1.2

DN Nominal Size		QUAL 2 High Strength (Q2-U2-K2-Grade 2) R>490 N/mm2 A%> 22		QUAL 3 Extra High Strength (Q3-U3-K3-Grade 3) R<690 N/m A%>17 Z%>40	
		Tension Proof Load	Breaking Load	Tension Proof Load	Breaking
mm	Inches	kN	kN	kN	kN
14	9/16	82	116	116	165
16	5/8	107	150	150	216
17.5	11/16	127	180	180	256
19	3/4	150	211	211	301
20.5	13/16	175	245	245	350
22	7/8	200	280	280	401
24	15/16	237	332	332	476
26	1	278	390	390	556
28	1 1/8	321	449	449	642
30	1 3/16	368	514	514	735
32	1 1/4	417	583	583	833
34	1 3/8	468	655	655	937
36	1 7/16	523	732	732	1050
38	1 1/2	581	812	812	1160
40	1 9/16	640	896	896	1280
42	1 5/8	703	981	981	1400
44	1 3/4	769	1080	1080	1550
46	1 13/16	837	1170	1170	1680
48	1 7/8	908	1280	1280	1810
50	1 15/16	981	1370	1370	1960
52	2 1/8	1060	1480	1480	2110
54	2 1/8	1140	1600	1600	2270
56	2 3/16	1220	1710	1710	2450
58	2 1/4	1300	1810	1810	2600
60	2 3/8	1380	1950	1950	2770
62	2 7/16	1470	2060	2060	2950
64	2 1/2	1560	2200	2200	3130
66	2 9/16	1660	2310	2310	3300
68	2 11/16	1750	2450	2450	3500
70	2 3/4	1850	2600	2600	3700
73	2 7/8	2000	2800	2800	4000
76	3	2150	3010	3010	4300
78	3 1/16	2260	3160	3160	4500
81	3 3/16	2410	3380	3380	4820
84	3 5/16	2600	3610	3610	5160
87	3 7/16	2750	3850	3850	5500
90	3 1/2	2920	4090	4090	5840
92	3 5/8	3040	4260	4260	6080
95	3 3/4	3230	4510	4510	6440
97	3 13/16	3350	4680	4680	6690
100	3 15/16	3530	4940	4940	7060
102	4	3660	5120	5120	7320

No	Anchor Weight (kg)	Chain Size VL K3 (mm)	MBL Chain (kN)	Dragged Pipe Scenario (inch)						
				6	8	10	12	14	16	18
1	1590	30	735	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	2100	36	1050	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	2640	40	1280	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	3300	46	1680	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	4050	50	1960	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6	4890	54	2270	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7	6000	60	2770	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	7350	66	3300	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9	8700	73	3990	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10	10500	78	4500	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11	12300	87	5500	Yes	Yes	Yes	Yes	Yes	Yes	Yes

NPS in	O.D mm	O.D in	W.T mm	W.T in	Kg/m.	API-id./ Sch no.
6	168,3	6,625984	7,11	0,279921	28,26	STD/40
			10,97	0,43189	42,56	XS/80
			14,27	0,561811	54,2	120
			18,26	0,718898	67,56	160
			21,95	0,864173	79,22	XXS
8	219,1	8,625984	6,35	0,25	33,31	20
			8,18	0,322047	42,53	STD/40
			10,31	0,405906	53,1	60
			12,7	0,5	64,63	XS/80
			22,23	0,875197	107,92	XXS
			23	0,905512	111,27	160
10	273	10,74803	6,35	0,25	41,77	20
			9,27	0,364961	60,31	STD/40
			12,7	0,5	81,55	XS/60
			21,44	0,844094	133,04	120
			25,4	1	155,15	XXS/140
			28,58	1,125197	172,33	160
12	323,8	12,74803	9,53	0,375197	73,88	STD
			10,31	0,405906	79,73	40
			12,7	0,5	97,46	XS
			14,27	0,561811	108,96	60
			17,48	0,688189	132,08	80
			21,44	0,844094	159,91	100
			25,4	1	186,97	XXS/120
			33,32	1,311811	238,76	160
14	355,6	14	9,53	0,375197	81,33	STD/30
			11,13	0,438189	94,55	40
			12,7	0,5	107,39	XS
			19,05	0,75	158,1	80
			31,75	1,25	253,56	140
			35,71	1,405906	281,7	160
16	406,4	16	9,53	0,375197	93,27	STD/30
			12,7	0,5	123,3	XS/40
			16,66	0,655906	160,12	60
			21,44	0,844094	203,53	80
			31	1,220472	286	120
18	457,2	18	12,7	0,5	139,15	XS
			0,75	205,74	60	60
			0,938189	254,67	80	80
			45,24	1,781102	459,59	160

AUTHOR’S BIOGRAPHY

Febrianto Anugrah Simanjuntak was born in Tarutung, North Sumatera on 11 February 1995 and was the second of five children. The author studied Elementary School at SD HKBP Pearaja Tarutung, Junior High School at SMP St. Maria Tarutung in 2007 and Senior High School at SMAN 1 Tarutung in 2010. Then the author continued the education at Double Degree at Department of Marine Engineering, Institut Teknologi Sepuluh Nopember - Hochschule Wismar in 2013 with registered number 4213101018. Various seminars and trainings have been followed by authors for self development. The author's bachelor thesis titled **DRAGGED ANCHOR EFFECT TO BURIED SUBSEA PIPELINE ON VARIOUS CASES BASED ON NUMERICAL SIMULATION** successfully completed the author on time.