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JUDUL: **FREE SPANNING ANALYSIS AND DESIGN OF SUBMARINE PIPELINE**

SESI PENGAJIAN: 2006 / 2007

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FREE SPANNING ANALYSIS AND DESIGN OF SUBMARINE PIPELINE

NUR FARHANA BINTI MAT JELAN

Project report is submitted as a partial requirement for the award of the Bachelor Degree in Civil Engineering

Faculty of Civil Engineering
Universiti Teknologi Malaysia

APRIL 2007

"I declare that this project report entitled "Free Spanning Analysis And Design Of Submarine Pipeline" is the result of my own research except as cited in the references".

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Name	:	Nur Farhana Binti Mat Jelan
Date	:	23 April 2007

Especially dedicated to my beloved parents, brothers, sisters and friends for all their love, encouragement and faith.....

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ABSTRACT

Offshore oil and gas pipelines are being subjected to deeper water depths, more extreme environmental conditions, and harsher operating requirements than ever before. Given these conditions, free spanning pipelines are becoming more common and are often unavoidable during pipeline installation. Spanning situations may occur where a submarine pipeline crosses an irregular seafloor topography or where there is scouring or local differences in load bearing capacity of the soil. If the pipeline is exposed to wave or current forces the unsupported pipe span may be susceptible to flow-induced vibrations which could adversely affect its safety. Five analysis and design methods were developed utilizing numerous variation from different sources. Each methods address a particular loading on pipeline free spans. All methods were taken into consideration simultaneously in a Combine Analysis Method (CAM) to make a comprehensive and orderly analysis and design. The CAM was developed such that it could be performed by hand, if required, or with the assisstance of a computerized Microsoft Excel Spreadsheet. The computerized spreadsheet developed to determine the maximum allowable free span span length for a given set of conditions without spent a lot of time to make it.

ABSTRAK

Rekabentuk struktur talian paip di dasar laut yang mengalirkan minyak dan gas adalah dipengaruhi oleh beberapa faktor seperti kedalaman struktur talian paip itu di dalam laut, pendedahan keadaan persekitaran yang berisiko dan berbahaya serta keperluan rekabentuk pengoperasian yang sangat sukar. Di sebabkan faktor-faktor ini, salah satu struktur talian paip di dasar laut iaitu struktur rentang paip yang bebas tanpa sokong menjadi satu masalah biasa yang tidak dapat di elakkan semasa proses pemasangannya. Rentang paip bebas adalah terdiri daripada sebahagian rentang paip yang mana ia tidak disokong oleh permukaan dasar laut. Ia terjadi disebabkan keadaan topografi dasar laut yang tidak sekata atau apabila berlaku pembersihan tanah disebabkan oleh hakisan dari air laut ataupun jika terdapat perbezaan keupayaan galas beban daripada tanah di sekitar talian paip tersebut. Jika rentang bebas ini terdedah kepada daya daripada arus dan gelombang air laut, rentang paip bebas ini akan mudah menghasilkan getaran yang mana ia memberi kesan yang buruk terhadap kestabilannya. Lima analisis dan kaedah rekabentuk telah dibangunkan merujuk kepada pelbagai sumber. Setiap kaedah merujuk kepada setiap pembebanan yang khusus terhadap rentang paip bebas ini. Semua kaedah ini dipertimbangkan dengan serentak sebagai satu kaedah yang mengabungkan semua analisis yang dipertimbangkan bagi menghasilkan satu analisis dan rekabentuk yang tersusun dan menyeluruh. Kaedah yang mengabungkan setiap analisis ini dilakukan secara manual dan dengan bantuan sistem pengkomputeran *Microsoft Excel Spreadsheet.* Bantuan pengkomputeran *Microsoft Excel Spreadsheet* ini dibina bagi menentukan nilai maksimum panjang rentang bebas yang dibenarkan berdasarkan keadaan-keadaan yang tertentu tanpa memperuntukkan banyak masa untuk melakukannya.

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LIST OF SYMBOLS

D_0	-	Pipe Outside Diameter
D_i	-	Pipe Inside Diameter
D_{TOT}	-	Total Diameter of Pipe with Concrete Weigth Coating
t	-	Pipe Wall Thickness
E	-	Young's Modulus
v_o	-	Poisson's Ratio
S_y	-	Specified Minimum Yeild Strength of Pipe
t_c	-	Concrete Weigth Coating Thickness
ρ_{os}	-	Density of Steel
ρ_{oc}	-	Concrete Weigth Coating Density
ρ_{ocn}	-	Density of Pipeline Contents
ρ_{ow}	-	Density of Seawater
U	-	Sea Current Velocity for 100 Year Return Period Storm
v_k	-	Kinematic Viscosity of Sea Water
e	-	Gap Between Pipeline and Seafloor
P_{moap}	-	Maximum Allowable Operating Pressure
C	-	Free Span Fixity Constant
C_m	-	Added Mass Coefficient
Ψ_R	-	Natural Frequency Reduction Factor
Ψ_U	-	Extreme Current Variability
Ψ_D	-	Period Transformation Factor
γ_T	-	Safety Factor
T	-	Residual Pipe Tension
S_t	-	Strouhal Number
ζ	-	Dumping Ration
w	-	Submerge Weight of Pipe per Foot
I	-	Moment of Inertia

Z	-	Pipe Section Modulus
R_E	-	Reynolds Number
M	-	Dynamic Mass of Submerge Pipe
f_s	-	Strouhal Frequency
L	-	Maximum Allowable Free Span Length

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ABBREVIATIONS

API	-	American Petroleum Institute
ASME	-	American Society of Mechanical Engineers
CP	-	Cathodic Protection
DNV	-	Det Norske Veritas
MAOP	-	Maximum Allowable Operating Pressure
MAFSL	-	Maximum Allowable Free Span Length
MMS	-	Minerals Management Servive
ROV	-	Remote Operate Vehicle
VIV	-	Vortex Induced Vibration

NOMENCLATURES

Anode

Electrode from which electric current flows to an electrolyte (water,soil). On the surface an oxidation process takes place eg. metal to metal ions or hydroxyl ions to oxygen and water.

Cathodic Protection

Elecrochemical method of corrosion protection of metal structure, achieved by forcing an electric current from an anode through the surrounding electrolyte into the metal, which becomes a cathode.

Concrete Coating

Pipe coating of reinforced concrete, applied to increase the pipeline weigth and/or protect the steel pipe and its anti-corrosion coating against mechanical damage.

External Pressure

Pressure outside the pipe. May be given as absolute pressure or gauge pressure.

Free Span

A section of pipeline unsupported by the seabed.

Hoop stress

Normal stress acting in the circumferential direction.

Internal Pressure

Pressure inside the pipe. May be given as absolute pressure or gauge pressure

Linepipe

Steel material for welded pipelines.

Logitudinal stress

Normal stress acting parallel to pipe axis.

Marine Pipeline

Pipeline crossing a body of water (normally salt, but also fresh).

Maximum Allowable Operating Pressure

Maximum Pressure to which a piping system will be subjected in operation, which should include static pressure and pressure required to overcome friction.

Pipeline

Tubular conduit made from linepipe or flexible pipe transporting a medium, the driving force being a pressure differential between inlet and outlet.

Sacrificial anode

An anode which connectd to a structure can offer cathodic protection while it is consumed.

Safety Class

Classification of pipeline based upon the risk of human injury, environmental damage and economic loss. Pipeline are cllasified acording to category of transported medium, location class, and duration of exposure (temporary or operational phase).

Seabed Topography

The mapping of the seabed to give sufficient detail of uneveness and features such as spans along the pipeline route.

Vortex Shedding Response

A situation where a free span on a pipeline experiences periodic disturbing loading, due to unsteady fluid flow pass the pipe forming vorcities. This may lead to oscillations of the pipe normal to it axis.

Vortex Shedding Frequency

The frequency at which vorcities are formed, due to steady fluid flow past a pipe line.

CHAPTER I

INTRODUCTION

1.1 Introduction

The construction of marine pipelines is a relatively new field of engineering, having developed in the course of the last five decades. Yet, with more than 100 000 km of sub sea lines installed worldwide it must be regarded as a mature technology, although advances continue in extending the limits as regards pipe dimensions, pressures, installation methods, water depth and climatic environments [1]. Marine pipeline system is defined as a pipeline crossing a body of water (normally salt, but also fresh). It also can be defined as a pipeline section extending from an inlet point, typically an offshore platform to an outlet point, typically another offshore platform.

Marine pipelines are generally designed, fabricated and installed in accordance with guidelines issued by various certifying agencies and regulatory bodies, as well as national and international codes. The choice of design methods and construction

procedures should be left to the engineers responsible, relying on a general consensus of good engineering practice.

A large number of requirements may be included to design a marine pipeline such as determination of pipe size and wall thickness, hydrodynamic stability, free spanning evaluation, and corrosion prevention and insulation. This report should provide more background reading about free spanning, which is one of the important characteristic in analysis and design marine pipeline.

Free span is a section of pipeline unsupported by the seabed. Free spans occur as a result of irregular seafloor topography at installation or during pipeline operation as a result of vibration and scour. A method of assessing and analyzing sub sea pipeline free spans is an essential tool in designing new pipelines and troubleshooting existing pipelines.

1.2 Background of The Study

Free spanning often becomes a problem both in the design phase and during operation of pipelines. The spans may develop during laying due to several reasons such as installation on uneven seabed, or during the service life of the pipeline, due to scouring effects and in some cases, due to horizontal movement. Uneven areas in the seabed constitute serious problems for the structural safety of pipelines as they exchanged the formation of free spans. Such spans may be subjected to fatigue damage caused by direct wave and vortex induced vibrations.

Some of the free spans of the submarine pipelines near the mines are quite long, which are over 10-100 times their diameters, or even longer [2]. They may undergo large lateral deflections and experience high bending stresses when subjected to underwater explosion loading. Therefore, there exists the risk that the pipelines fail due to large bending deflections and high bending stresses. This damage mode, known as global damage, must be analyzed to make a safety design of submarine pipelines.

Beside that, seabed scouring can be one of the factors of pipeline movement. Pipeline movement poses a potential threat to pipeline integrity as it can lead to excessive strain in the pipe wall deformations as well as fatigue that can cause pipe rupture. For the above reasons it is important to monitor both the pipeline movement and the deformations caused by it.

Seabed scour in the vicinity of marine pipelines may cause the pipe to loose its contact points with the seabed and may develop progressively along the pipe. There are several potential threats of free spans on the safety of the pipeline which are vortex induced vibration in the wave/current action, which may results in fatigue break down or failure breaking of the pipes, excessive stress on the pipe wall may results in the large bending deformation, leading to pipeline breakage or leakage under the wave/current forces as well as its own weight and fatigue failure due to continuous wave/current actions in a long period.

1.3 Objective of Study

The objectives of this study are:

1. To study the procedure of pipeline design.
2. To study an orderly methods of subsea pipeline free span analysis and design.
3. To develop spreadsheet for the free spanning design.
4. To determine the maximum allowable free span length for a given set of conditions.

1.4 Scope of Study

All the objectives mentioned at above would determine the scope of research. The scope of this study will cover the analysis and design of marine pipeline focusing on free spanning evaluation. This study only considered the cross-flow vortex induced vibration by using Mineral Management Service (MMS) guideline and discuss only two main analyses which are static analysis and dynamic analysis.