STRUCTURAL DYNAMIC ANALYSIS OF OIL AND GAS TRANSMISSION PIPE

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ABSTRACT

This project was carried out as a study of structural dynamic analysis using ANSYS to simulate the system vibration. The objective of this project is to obtain dynamic characteristics of oil and gas transmission pipeline. In order to get the dynamic characteristics, the pipeline system should be designed to be used for the experiment and simulation test. Following the design system, setting the PVC material, then import the pipeline system into ANSYS to make modal analysis. Simulating the vibrate variation from 0 Hz to 600 Hz. According to the deformation of the pipeline system, to find where is the most serious deformation place. So the point what we find is the damping point, the frequency at this point is the natural frequency. Collecting all data of the natural frequency and mode shapes at the damping points. The second part is the experiment. Following the design system, assemble the entity system. Use the accelerometer sensor to convert pipeline system vibration to electrical as input data. Following the accelerometer, use the instrument driver to connect the accelerometer with the laptop. Lastly to start the experiment by the impact hammer knock the pipeline system, and then collect the data of natural frequencies, mode shapes and damping of the structural dynamic of the pipeline system. Comparing the mode shapes to select the natural frequency with the same mode shapes from the experiment and simulation.

ABSTRAK

Projek ini dijalankan sebagai satu kajian analisis dinamik struktur yang menggunakan ANSYS untuk meniru getaran sistem. Objektif projek ini adalah untuk mendapatkan ciri-ciri dinamik struktur paip bagi penghentaran minyak dan gas. Dalam usaha mendapatkan ciri-ciri dinamik, sistem saluran paip direka untuk simulasi dan eksperimen. Selepas mencipta sistem rekabentuk dan menetapkan bahan PVC, sistem talian paip dimport ke ANSYS untuk membuat analisis mod. Simulasi untuk getaran berubah dari 0 Hz hingga 600 Hz. Menurut ubah sistem perancangan, tempat ubah bentuk kritikal perlu dicari. Tempat ubah bentuk kritikal ralah titik redaman, frekvensi pada ketika ini adalah frekvensi semula jadi dan bentuk mod dikumpul di mata redaman. Bahagian kedua adalah eksperimen. Mengikati system relca bentuk, sistem entiti dipasang. Sensor percubaan digunakan untuk menukar sistem getaran paip untuk elektrik sebagai input. Alat pemandu digunalcan untuk menyanbang pecutan dengan laptop. Akhir sekali eksperimen dimulakan dengan mengguna impak tukul dan mengumpul data frekuensi semulajadi, bentuk mod dan redaman dinamik struktur sistem perancangan. Perbandingan mod membentuk untuk memilih frekuensi semula jadi dengan bentuk mod sama dari eksperimen dan simulasi.

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A	Area
ω	natural frequency
D	Pipe diameter
K	resistance coefficient
L	entry length
Ρ	density
Re	Reynolds number

LIST OF ABBREVIATION

PVC	Polyvinyl chloride
FRF	Frequency response function
F&D	Frequency and damping
NI	National Instruments
L	L shape
T	T shape

CHPATER 1

INTRODUCTION

1.1 Introduction

With the rapid development of modern technology, industrialization progress unceasingly strengthens; pipeline in people's life is playing the more and more important role. City heat supply, gas supply pipe main and long oil and gas pipeline and so on a variety of related to people all aspects of life all have the form of pipeline. Pipeline transport， it was known as one of the five transportation industry. And it is phase parallel with railway, aviation, highways, marine transportations. It is a huge energy transport tool. Pipeline, its definition is usually to use various materials made of pipe. Pipeline is to use pipe, pipe connecting parts and valve connection into for conveying gas, liquid or solid particles with the fluid flow unit. Usually, fluid the blower, compressors, pumps and boiler etc booster, from the high place of the pipe flow to the low pressure place. It also can be used to fluid by their stress or gravity delivery.

Pipeline can generally be divided into: according to use: gas pipe, water pipe, oil pipe. According to the material: steel, aluminum gold, polyvinyl chloride (PVC), etc.; According to the pressure, pressure pipe, not pressure pipe; According to the pressure level: the low pressure pipeline, high pressure pipe.

Pipeline transport，it was known as one of the five transportation industry. And it is phase parallel with railway, aviation, highways, marine transportations. It is a huge energy transport tool. . For example, Crude oil pipeline transport crude oil 90 million tons in Alaska, it is quite to the transportations by trains. Pipeline transport dangerous goods of oil and gas, especially a large number of natural gas transportation, it is irreplaceable transportation with other transportation tools. This energy transport function is better than other transportation to finish the transportation.

Pipeline transport is also known as civilization transportation, because only when the country development to a civilization, a pipeline will be emergence. It is a kind of do not produce noise transportation, so called civilization transport. For a industrial nations, the more developed industry, the people's living standard is higher, the greater the energy consumption, relying on the pipeline transport is the greater. For example, the consumption energy in 1955 year, 1965 year, 1975 year, 1985 year in Italy, the proportion of refined oil were 33%, 63%, 67%, 69%; The proportion of natural gas were 8%, 8%, 15% 17%, so as show as we can know from this, the product oil and natural gas consumption is increasing year by year, most of the transportation is pipeline transportation. It also shows that pipeline transport plays the huge role of energyfor developed industrial nations (Zhang, 2008).

Natural gas is the world's second energy. It is only can rely on pipeline transport to convey a large number of gas on the land. In this field plays a dispensing effect between internationals and even among the intercontinental. Such as the Soviet union Yamel pipeline built through the arctic permafrost zone and thousands of kilometers of marshes leads to Europe, total length of 9000 km, tube diameter of 1420 mm, 32 billion cubic meters of natural gas transport every year, except for the original eastern Europe eight countries outside, every year, 10 billion cubic meters for Germany, France 10 billion cubic meters, Italy 8 billion cubic meters, played the international energy adjustment effect. In the intercontinental, such as African countries Algerian pipeline for 1220 mm diameter of natural gas pipeline length is 1200 km. Every year transport natural gas quantity is 12.5 billion cubic meters, crossing the water depth that is 600 meters of the Mediterranean, delivery to northern Italy. It is a famous pipeline crossing the Mediterranean (Ge, 2011).

1.2 Problem Statement

The pipeline system is very important in the oil and gas transmission. It is concern greatly nowadays since will affect the ratio of the accident happened. It is so dangerous that the pipeline resonance happen when the oil and gas transmit in the pipeline.

Vibration on pipeline is a dynamic load for the pipeline system.

The harm of pipeline vibration:

a. Haste material fatigue damage and shorten the life of the material
b. Cause pipe fracture, cracking or even take over the seat pipe burst, causing a catastrophic accident
c. Damage to the pipeline valves, valve head vibration velocity higher than the speed of the pipe vibration, easy to shake loose valve components result in loss of control or leak, may result in system downtime
d. Damage to the pipeline on the meter pipes, meters and other equipment, resulting in failure of the control system

On the other hand, the pipeline system also will affect the oil and gas transmission efficiency. Sometimes the improper pipeline system may cause the oil and gas translate lately to the destination, even through cannot reach to the destination. So my study is aim for finding out the nature frequency, mode shape, and damping of the oil and gas transmission pipe to avoid the pipeline system accident.

1.3 Objective of study

To determine the dynamic characteristics of oil and gas transmission pipeline using modal analysis and vibration experiment.

1.4 Scope of the study

The scopes of study for this research are:

1. Utilize FRF modal analysis the pipeline system
2. Obtain the natural frequencies of the structure to analyse the dynamic mathematical model of the pipeline.
3. Obtain the mode shapes of the structure to analyse of dynamic mathematical model of the pipeline.
4. Obtain the damping of the structure to analyse of dynamic mathematical model of the pipeline.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter I will briefly explain about frequency response function (FRF), structure dynamic analysis, vibration in pipeline, and modal analysis. I need use the ANSYS software through FRF to make the modal analysis of structure dynamic, to get the result of nature frequencies, mode shapes, and damping of the structural dynamic of the pipeline system. All this information is important to achieve what my objectives and make sure my experiment property conducted.

2.2 Frequency Response Function

Our research problem is continuous time in the vibration. The general input is the extra force, also called vibration force, or vibration load. Force is a vector. It is made of different frequency components of something that we facilitate research of typical function (generally trigonometric function) composition; the vector of the force to frequency domain (that is the independent variable for frequency) is a transformation to complete. And the output is commonly equipment or is the research object of the displacement or vibration, this volume obviously also can transfer into frequency domain.

Then our research is for the system, but we research for the equipment itself is unavailable. So we need to through put into a input to measure the reaction (namely response). So we find the ratio between the input and output to represent some properties of function of the system. This function is frequency response function.

In fact, we know that do a function of deduct, the most basic that is the premise of their argument “synchronicity”, that is to say the two deduct function only when it is in the independent variable of the same time, can they work. This is why the time domain does work. And the frequency domain has an important characteristic that is the input and output function frequency is fixed. Only change the amplitude and phase, which is exactly what we want to research (Cao, 2008).

2.2.1 Transfer function

Transfer function H(s) and the frequency response function relationship:
For constant linear system, frequency response function $H(\omega)$

$$H(\omega) = \frac{b_m(j\omega)^m + b_{m-1}j\omega^{m-1} + \cdots + b_1(jw) + b_0}{a_m(j\omega)^m + a_{m-1}j\omega^{m-1} + \cdots + a_1(jw) + a_0} \tag{2.1}$$

Where of $j = \sqrt{-1}$

If in the time t=0 the input signal access time-invariant linear systems, make $s = j\omega$ substituting Laplace transform, is actually the Laplace transform into Fourier transform. And because the system of the initial condition is zero, so the system Frequency response function H (ω) will become output y (t) , input x (t) the Fourier transform Y (ω), X (ω) the ratio

$$H(\omega) = \frac{Y(\omega)}{X(\omega)} \tag{2.2}$$

The type tells us that in the measured output $y(t)$and input $x(t)$, by the Fourier transform$Y(\omega)$ and$X(\omega)$. The frequency response function can be obtained as

$$H(\omega) = {Y(\omega)}/{X(\omega)} \tag{2.3}$$

Need to pay attention to, the frequency response function is to describe system harmonic input and the steady-state output relationship in measurement system frequency response function, must in the system response to achieve steady stage to measurement.

Frequency response function is complex, and it can be rewritten for

$$H(\omega) = A(\omega) \cdot ej\varphi(\omega\ ) \tag{2.4}$$

Where: $A(\omega)$ is a system amplitude frequency characteristic; $\varphi(\omega)$is the system phase frequency characteristic.

From the foregoing, the system frequency response function $H(\omega)$ or the amplitude frequency characteristics $A(\omega)$, phase frequency characteristics $\varphi(\omega)$, all is the harmonic input frequency Function.

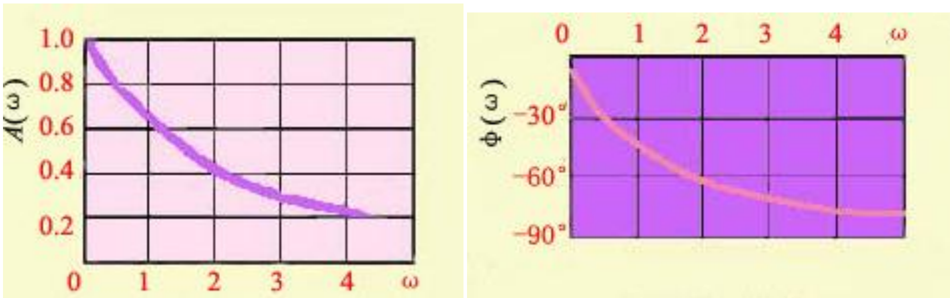
As the research problem is convenient, sometimes used to describe the curve of the transmission characteristic of system.$A\ (\omega)$ curve and $\varphi(\omega)$ curve respectively called system amplitude frequency characteristics curve and phase frequency characteristic curve. Curve, respectively called logarithmic amplitude frequency curve and logarithmic phase frequency curve, the total called Bode diagram

If the $H\ (\omega)$ According to the real part and imaginary part rewrite, there is $P\ (\omega)$and $Q\ (\omega)$ are ω the real function, curve $P\ (\omega)$and $Q\ (\omega)$ respectively called system real frequency characteristics and virtual frequency characteristic curve. If the $H\ (\omega)$ The imaginary part and real component respectively as a vertical and horizontal coordinates, the curve called $Q\ (\omega)\ - P\ (\omega)$Nye chief Gustavo diagram (Nyquist Chart).There are obviously

$$A(\omega) = \sqrt{P^2(\omega) + Q^2(\omega)} \tag{2.5}$$

$$\varphi(\omega) = arctg\frac{Q(\omega)}{P(\omega)} \tag{2.6}$$

Vice frequency curve and Phase frequency curve



(a) Amplitude-frequency curve (b) Phase frequency curve

Figure 2.1: Amplitude-frequency and Phase frequency curve (Shi, 2008).

2.2.2 Frequency response function

$$H(\omega) = \frac{s_0}{\left[1-\left(\frac{\omega}{\omega n}\right)^2\right]+j2\xi\frac{\omega}{\omega n}} \tag{2.7}$$

Amplitude frequency characteristics and phase frequency characteristics

$$A(\omega) = \frac{S_0}{\sqrt{\left[1-\left(\frac{\omega}{\omega n}\right)^2\right]+4\xi^2(\frac{\omega}{\omega n})^2}} \tag{2.8}$$

$$\varphi(\omega) = -arctg\frac{2\xi(\frac{\omega}{\omega_n})}{1-(\frac{\omega}{\omega_n})^2} \tag{2.9}$$

2.3 The experiment principle

Frequency response function is to describe and study the characteristics of the system in frequency domain, the use of it and the transfer function relation, and very easy to find the transfer function. It is the study of the system characteristics of the important tool.

Steady system in simple harmonic excitation signal, the steady-state output signal and the input signal amplitude ratio as the system amplitude characteristics, recorded as A(ω); Steady-state output signal to the input signal of the phase difference is defined as the system phase frequency characteristics, both collectively referred to as frequency characteristics of the system. So the system frequency response refers to the system in simple harmonic excitation signal, the steady-state output to lose the amplitude ratio and phase difference with the excitation frequency ω change characteristic.

2.3.1 First-order system for the amplitude frequency characteristics

$$A(\omega) = \frac{S_0}{\sqrt{1+(\tau\omega)^2}} \tag{2.10}$$

Phase frequency characteristics for

$$\varphi(\omega) = -arctg(\omega) \tag{2.11}$$

Change the characteristics of the system parameter τ can observe the corresponding characteristic curve.

2.3.2 Second order differential equation

With the second order differential equation said second order system characteristics, the amplitude frequency characteristics and phase frequency characteristics respectively

$$A(\omega) = \frac{S_0}{\sqrt{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]+4\xi^2\frac{\omega}{\omega_n}^2}} \quad (2.12)$$

$$\varphi(\omega) = -arctg\frac{2\xi(\frac{\omega}{\omega_n})}{1-(\frac{\omega}{\omega_n})^2} \quad (2.13)$$

Influence of second-order dynamic characteristic parameters are natural frequency and damping ratio, in common use in the frequency range, and with the influence of the inherent frequency is the most important. So the second order system natural frequency ω n should be selected with its working frequency range for basis. In ω $=\omega_n$near, system amplitude frequency characteristics by damping ratio has great influence, when $\omega \approx \omega_n$ when, the system resonance occur. So as a real Use device, rarely choose this kind of frequency relations. But this kind of relations in the determination of the parameters of the system itself, it is very important.

Change the parameters of the system and observe the change of system parameters.

2.3.3 Error of measurement precision

Error of measurement precision is a kind of evaluation or described, in the test work, usually use accuracy, precision and accurate degree, respectively to describe system error and random error and the sum of the two.

The difference is as follows:

Accuracy: a measured value and the real value of the close degree, is a measure of the size of the system error reflect. System error is smaller, the higher the accuracy.

Precision: refers to the same under the same conditions is measured repeatedly repeated measurement, the measurement value of the degree of repetition, is a measure of the size of the random error reflecting. Random error is smaller, the higher the precision.

In eliminate system error, precision and accuracy is consistent, collectively referred to as accuracy.

In the signal sampling process, will be due to the sampling signal spectrum changing and appear high and low frequency component happen confusion, such a phenomenon is called frequency mixing lap. This experimental design the exponential function and carries on the sampling, and then change the sampling frequency, observation frequency mixing phenomenon (Gu, 2008).

2.4 Structural dynamic analysis

Structural analysis is mainly concerned with finding out the behavior of a structure when subjected to some action. This action can be in the form of load due to the weight of things such as people, furniture, wind, snow, etc. or some other kind of excitation such as an earthquake, shaking of the ground due to a blast nearby, etc. In essence all these loads are dynamic, including the self-weight of the structure because at