MEASUREMENT AND VALIDATION OF FLUID STRUCTURE INTERFACE

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ABSTRACT

This thesis is done to study about structure of pipeline network when it vibrated. The vibration of the structure can lead to problem. The objectives of the study are to determine the mode shape and natural frequency when the structure is vibrated. Besides that, in this study we also need to verify the data that obtain. The method that will be use to conduct this study is experimental and simulation of pipeline network. In experimental we need to build the pipeline network structure. The design must consider the workplace. In simulation we need to draw the design of pipeline network in solidwork software, the parameter must follow in experimental method. This is because if use different parameter the data between both will be different. After that, comparison of the data between these two methods must be done, this is because the data must be verify whether it valid or not. The result will show the mode shape and natural frequency of structure. If the data is not valid the experiment need to be repeat until get the same data or approximately same. The data will be valid if the error between these two results is below than 5%.

ABSTRAK

Tesis ini dilakukan untuk mengkaji tentang struktur batang paip apabila bergetar. Getaran pada batang paip boleh menyebabkan masalah. Objektif kajian ini adalah untuk mengenal pasti bentuk modal dan kekerapan apabila struktur bergetar. Disamping itu, tujuan kajian ini dibuat adalah untuk mengesahkan data yang diperolehi. Cara yang digunakan dalam kajian ini adalah eksperimen dan simulasi. Di dalam eksperimen kita perlu membina bahan kajian. Bentuk bahan kajian mestilah sesuai dengan tempat kita melakukan kerja. Didalam simulasi kita perlu melukis mengunakan perisian solidwork, data didalam lukisan mestilah same dengan data didalam eksperimen. Jika data berlainan kita akan mendapat keputusan yang belainan. Selepas itu, kita perlu membangdingkan data yang diperolehi diantara eksperimen dan simulasi. Pembangdingan perlu dilakukan untuk mengesahkan data yang diperolehi. Data yang diperolehi sah jika peratusan di antara simulasi dan eksperimentdi bawah 5 peratus.

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LIST OF SYMBOLS

^{o}	Degree
μ	Micro
%	Percentage
c	Celsius

LIST OF ABBREVIATIONS

Hz	hertz
FRF	Frequency response function
mg	milligram
mm	Millimeter
m	Meter
CFD	Computational fluid dynamic
FSI	Fluid structure interaction
Pa	Pascal
kg	kilogram

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Measurement and validation of fluid structures in pipe line is important nowadays. Measurement in fluid structural interface is to defined the properties of leakages, besides that to defined the boundary condition if leakages in the pipeline system. After that, we need to study to make a validation the properties and boundary condition that had been defined using experimental result and simulation. This is because in the industry of oil and gas is growing faster all over the world. It had been a decade that pipe had been used to transfer the oil and gas from the bottom sea to the ship, and from the ship to the land. This is because it the easy way and more effectives. Industry of oil and gas had been the most benefit financial for all over country. This is because industry of oil and gas had been use in daily life such gas vehicle oil and to make the product that use at home. Therefore if the pipe that uses to transfer the oil and gas is leak it will cause a big disaster to the company. This because can lead to the financial and natural issue. Besides that, it also will cause a problem to the environment. There are methods that we can use to avoid the problem from happen such as make a study what will make the piping system fatigue. From the method we can define the properties of pipe that can show us the pipeline system is leak. The method that we can use is fluid structural interaction. Besides that, we also can simulate module of pipeline network. From the module we can obtain instantaneous properties of data and analyzed it. To analyze it we will use finite element method that is Fluid Structural interaction (FSI). Finite element is approach for studying such a highly nonlinear problem in order to investigate the effect of fluid structure interaction (FSI) in pipe lines. The FSI has got great attention in recent years because of safety issue, reliability of plant set up, environmental concern in pipe delivery system and plant performance. The Fluid Structure interaction process basically deals with transfer of momentum and forces to pipe system and fluid contained in it in an unsteady. The excitation process may be caused by sudden change in flow and pressure or by some mechanical action namely sudden closure of valve. The resulting load is transferred to pipe supporting system. The friction coupling because of transient liquid stress will act between pipe wall and fluid cause by the axial motion, (Suyash mishra, May 2012).

1.2 OBJECTIVES

The objectives of this project are to determine the leakage boundary that may have in pipeline network. The study method that we will use in this project is simulates the module of pipeline network by using the fluid structural interaction software; the software that will use is Assy. In simulate the module of pipeline we need to conduct the experiment to define the properties of pipe leakages. Besides that, we also need to define the boundary condition of the experiment. Furthermore we also need to define the operational deflection shape that has in the fluid structural interaction. In the operational deflection shape we need to define the boundary condition that will be used in the experiment. Besides that, in this experiment we need to define the mode shape and natural frequency that generate by the pipeline system. After that, we need to verify whether the result that we obtain from experiment is valid or not.

1.3 PROBLEM STATEMENT

In the pipeline network it is hard to find the defect that may have. The defect that may have is leakages and corrosion in the pipeline network. This will give a serious issue to financial and natural resources. We need to conduct some study to define the properties of data that can show the defect may have in pipeline. We can obtained the data when do some study in the pipeline system. In this study we need to find the properties of pipe leak by using experimental and simulation of the pipeline network. The method that we will use to conduct this study is by using the modal analysis. In fluid structure interaction analysis (FSI), we need to simulate the module of pipeline network. When do the simulation of the module in pipeline network. We need to define the properties of the pipe that we will use. Modal analysis testing also can be use to determine the properties in pipeline network.

1.4 SCOPE OF STUDY

In this study, we need conduct experiment by using test rig that we design. The design must follow the real pipeline network. After that, we must do simulation of the pipeline network. The aim of the experiment is to define the properties of pipe leak in the pipeline system. We also can define the boundary condition with the experiment method. In the experimental and the simulation we will use modal analysis. From both we need to define the mode shape and natural frequency of the pipeline system. To simulate the pipeline network we will use fluid structure interaction simulation, the interaction process deals with transfer of momentum and forces to pipe system and fluid contained in it in an unsteady. In fluid structure interaction analysis (FSI) we will analyze the axial motion of the fluid at the pipe wall. Fluid structure interaction also can analyze the structures condition of the pipe at certain natural frequency and mode shape of the structure. The mode shape will show the movement of the structure at the certain frequency, from this result we can predict where the fatigue can happen.

After that, comparison of the result from the experiment and simulation must be done, this is because we need to verify the result that we obtain is valid or not.

1.5 OVERVIEW OF STUDY

There is some chapter in this study. The overview of this study is to help reader to better understanding. Chapter one is introduction, in this chapter it consists of objective, problem statement and scope of study. Chapter one is important to help reader understand why this study is done. Chapter two is about literature review, literature review the summary of the journal from other thesis that had done the study. Chapter three is methodology, in this chapter it consists of flow chart, gannt chart and procedure. From this chapter we can know how the study is being conduct and the software that use to conduct the study. Chapter four is the result of the study, at this chapter it shown the result that obtained from experiment and simulation. The last chapter is conclusion, from this chapter it consist of the conclusion that be made after done the experiment and the suggestion about the study.

CHAPTER 2

LITERITURE REVIEW

2.1 INTRODUCTION

Fluid structure interaction is a method that commonly use all over the world to do an experiment on the pipe or hollow material. Fluid structure interaction occur when the fluid interrelate with the wall of the solid structure, this interface will produce waves and apply the pressure the pressure on the surface of the solid structure and cause the deformation of the solid structure and alter the flow by itself. The fluid interaction in the pipeline may be coupling or axial loading and such of the interaction may be stable or oscillatory, a crucial consideration in the design of many engineering system such as aircraft. Fluid structure interaction is multifaceted physics problems happen in the flow of the fluid causes the deformation of fluid structure that changes the boundary condition of fluid problem. The concept of fluid structure interaction is flexible solid structure that interaction of flowing flow is subjected to a pressure that can cause the deformation in the structure of subject. When the interaction happen the solid structure will deformed the structure follow the flow field. The flowing flow then will produce another form of pressure on the structure and repeat the process; this interaction is called fluid structure interaction (FSI). The fluid structure interaction can be divide into two that is strong and weakly coupled. The first one is weakly couple system, if structure in the flow field or containing fluid deform slightly or deform with the small amplitude, the effect will not be considered the flow field because it has the low pressure. But the thermal stress in the in the solid may be produce by the thermal gradient in the flow field, the flow field will has small effect if the solid is deformed is too small. The second is strongly coupled fluid structure system, if the alteration of the flow field due to big deformation or high amplitude vibration of the structure cannot be neglected, large structure deformation or displacement result in significant alteration of the original field but both altered and original flow field cannot be linearly super imposed to each other, (Jong Chull Jo)**.**

2.2 FLUID STRUCTURAL PHENOMENON

Fluid structure interaction in liquid filled system comprise two separate analysis that undertaken sequentially. Usually a fluid transient code is use to defined the pressure and flow velocities of the liquid, that are used as a input in a structure dynamic code that is call uncoupled. The dynamic code has some limitation because it neglected the crucial interaction between the liquid and the pipe. Pressure pulsation and mechanical vibration in liquid transporting pipe system had an effect that affects the performance and the safety of the pipeline system. The pipe motion contributes to the dynamic pressure to the less restrained system. It will because the analyses of the fluid structure interaction cannot be properly consider independent. When we compared the conventional analyses, it may lead to higher or lower extreme pressure and stress in fluid structure interaction analyses. Because of the change in natural frequencies there are more damping and dispersion in the pressure and stress. There are many factor that need to be consider when do fluid structure interaction, the factors that need to be consider is sources of excitation or on possible responses to an citation. Excitation can be categorized into single larger event or repetitive excitation. The factor that can be neglected liquid pipe coupling, there are three type of liquid pipe coupling; friction, Poisson and junction coupling. Friction and junction coupling happen along entire pipe also call as distributed force. Junction coupling happens at the specific point (local forces) in the network. Poisson coupling relate pressure in the liquid to axial stresses in the pipe through the radial contraction and lead to precursors waves. Friction coupling is happen when there are interaction between the pipe wall and the fluid, (D.J Leslie & A.E, 2001).

2.3 Fluid structure interaction coupling

The vibration in the piping system cannot be well understood by many pipework designers, this because piping system has a complex phenomenon. Besides that, there are just few guidelines to assist and no standard to help pipework designer to determine if the system is at risk or not. Fluid structure interaction is use for unsteady flow that interacts with the pipe vibration. The stationary flow can be consider as time averaged, that because it includes turbulences and vortices, besides it contributed small velocity and pressure fluctuation. There are four interaction mechanisms that caused the fluid structure interaction on the liquid pipe system; the mechanism is friction coupling, Poisson coupling, junction coupling and bourdon coupling. The friction coupling is act between the liquid and axially vibrating pipe wall and it is mutual friction. Poisson coupling is related to the pressure in the liquid that interact to the axial stress in the pipe through the radial displacement of the pipe wall. Friction and Poisson coupling is act along the entire pipe. Besides that, junctions coupling act where there is local force or change in area or flow direction. Bourdon coupling just happen in the curved fluid filled tubes of non circular cross section. The fluid flow will be changes if the internal fluid pressure bend the tubes and externally imposed bending. In the transient event dimensional or multi scale analysis will show the friction coupling is not important. Although the Poisson coupling is small, it is important for modes of vibration that are predominantly in the axial direction of the individual pipe because their effect may accumulate in time. In junction coupling it is important when the excitation is to generated to generate large unbalanced pressure forces in piping system. The axial, radial, lateral and torsion direction is the direction of the pipe system vibrates. Pipe and fluid will act together through Poisson and friction coupling in the axial vibration. The liquid will act as added mass in the lateral vibration. But the liquid is not affecting the torsion vibration, (A.S. Tijesseling, May 2002).

2.4 90^o elbow in pipeline

90 elbows are to study the internal two phase flow induces variable forces on the pipe bend. When separating the natural frequency of test section from the predominant frequency of excitation forces we can obtain directly from force sensor the dynamic force signal. When the gas flow rate increased and reached it maximum in annular flow regime the root meant square value of force fluctuation also continuously increased. In the recent year the internal two phase flow induced vibration on piping element had giving awareness. The two phase flow is the fundamentally unbalanced in term of local fluctuation of phase density, velocity, pressure, momentum flux among other hydrodynamic parameter. The fluctuation may obligatory periodic forces on the piping element that will transmit the fluid. When the piping natural frequency is close to the excitation force the resonance may happen. Therefore to have a safe design and operating of piping system we need to understand two phase internal flow induced vibration mechanism. Yih and Griffith had been done to an experiment about momentum flux fluctuation in two phase flow. Their do the experiment to measured the interaction of response of a beam structure under the impact of two phase sup flow coming out of vertical ducts. When they do the experiment by take the inverse transform of the beam response they obtained the momentum flux of beam response. The result of the experiment show that the maximum momentum fluctuation will be shown either in high void slug or low void annular flow regime for a given total volumetric flow rate. The unbalanced of momentum fluxes in small pipe was found to be better compared to large pipe. In the experiment they also determine that system pressure, duct size and shape did not have effect to the predominant fluctuation frequencies that less than 30 Hz, (Yih and Griffith 1968). Tay and Thorpe was doing the experiment on 90 degree horizontal elbow. Their objectives are the effects of liquid viscosity and surface tension on the maximum forces interact on the elbow in oil pipeline. The results from the experiment show that there is no significant effect on the maximum force with the change of another property, (Tay and Thorpe 2004), (Yang liu, Shuichiromiwa, Takashi hibiki, Mamoru ishii, Hideyuki morita, Yoshiyuki kondoh and Koichi tanimoto, 2012).

2.5 Fluid interaction on non rigid pipeline

Fluid structure interaction in non rigid pipeline system is following the water hammer theory for the fluid coupled with beam theory for the pipe. Wave propagation phenomena in the fluid and pipe wall induced transient. The axial, bending, shear and torsion stress in the pipe wall will interact with the pressure waves in the fluid. When the interaction between axial stress waves and fluid pressure happen it will also interact with the radial expansion and contraction of the pipe wall. Besides that, interactive coupling also will induce all type of wave at the junction, (A.G.T.J Heinsbroek, 1997).

2.6 Numerical method

The numerical method procedure is use get to get approximated solution for one dimensional fluid structure interaction model. It has been use to analyses the transient in the liquid filled piping system. Fluid structure interaction model is simulating by hyperbolic partial differential equation system. Besides that, to describe and do simultaneously pressure waves propagation in liquid as the axial, shear, and bending waves that travelling in the pipe wall. Piping system is flowing liquid that follow the line to some transient loading, when the momentum liquid in the piping change or piping structure are abruptly happen because of in planning or accidental. Numerical method also uses to precisely to calculate the hydrodynamic loading in the fluid as well as the stress level and vibration in the piping. Three coupling mechanism had been determine that is responsible for the induced of mechanical energy transfer between the fluid and pipe, the three coupling are friction coupling, Poisson coupling and junction coupling. The friction and Poisson coupling is act along the pipe and the junction coupling is at the localized site such as elbow. Fluid transient shear stress induced the friction coupling but it has less important than Poisson and junction coupling. The interaction between the pressure pulse and the axial stress waves on the pipe wall is induced by the Poisson coupling and it produce the Poisson ration coefficient. Junction coupling will induced the pipe vibration, giving rise the existences, propagation and interaction of differ type mechanical effort in the pipe, (RogerioGomes da Rocha and Felipe bastos de FreitasRachid).

2.7 Flexible liquid filled piping

Fluid structure interaction in piping system consists of conveys of momentum and forces between piping and contains liquid through unsteady flow. Rapid change in flow and pressure or mechanical accomplishment of the piping system may induce excitation mechanism. The interaction on the wall of the pipe is manifested in pipe vibration and perturbation in velocity and pressure of the liquid. Numerical advantages allowed the practitioner to revert to the manner in which the interaction between the piping and contained liquid to modeled. It is the enhanced technique that can help to predict fluid structure interaction. The phenomenon of pipe movement is related to unbalanced fluid flow. When there is change in flow, pressure or by mechanical motion of the piping system it can produce excitation mechanism. The interaction of piping system produces pipe vibration and perturbation in velocity and pressure of the liquid. Poisson coupling, friction coupling and junction coupling is the mechanism that been induced in piping system. Closed end, at the dead end of the pipe the pipe may experiences some fluid forces. Because of that the pressure at the end will be double because the deflection of the fluid. At the T section, the transmission and reflection of pressure and stress waves' unrestrained t shape. This because the mass and dimension of the T piece is not been consider due to change in liquid momentum. The angle of the T shape is assumed at 90 degree and it has no fluid structure interaction mechanism. Column separation, dangerous liquid mat be created due to ambient pressure, (D.C Wiggert and A.S Tijsseling, May 2001)**.**

2.8 OPERATIONAL DEFLECTION SHAPE

Operating deflection can be defined as deflection of a structure at a particular frequency. Besides that, operating deflection shape also can be define as any forced motion of two or more point on a structure, from operating deflection shape we also can get mode shape, this is because mode shape and operating deflection shape are related to each other. Operating deflection shape and mode shape is inducing from the vibration of the structure. Operating deflection shape and mode shape only induced in the resonant vibration that has two degree off freedom vibration. Resonant vibration is the factor that vibration problem occur in the structure. Vibration that happens in the structure is the combination of two or more two degree of freedom force and resonant vibration force. If we want to understand the vibration structure problem that happen, we need to defined the resonant. The resonant that has in the structure that induced vibration is natural frequency, modal damping and mode shape. The resonant vibration is induced when there is interaction between the inertial and elastic properties in the structure, (B.J. Schwarz and Mark H Richardson, October 1999).

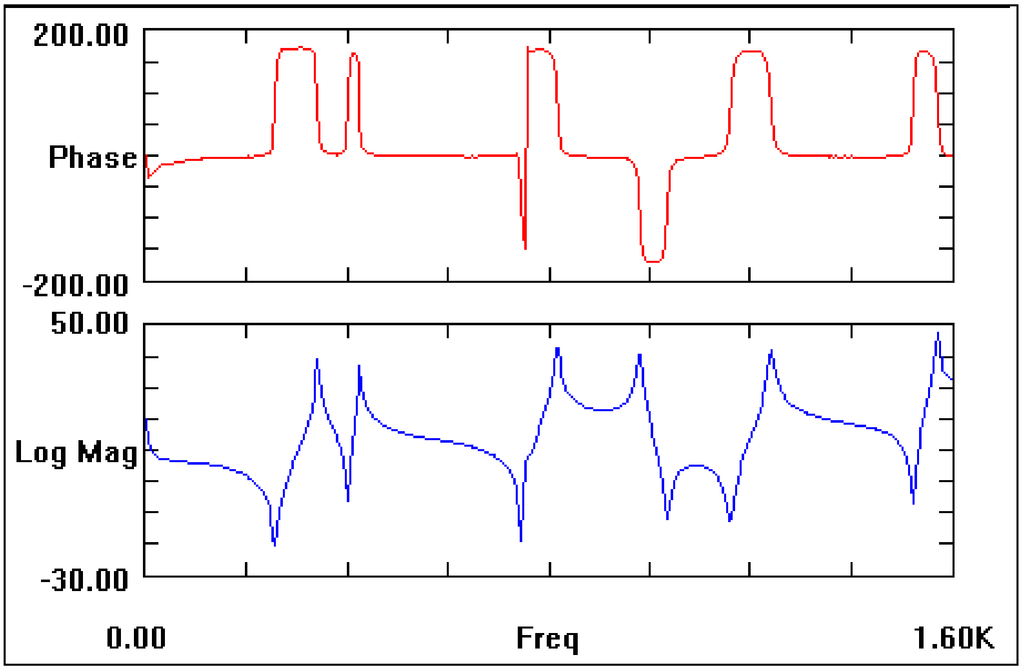

Figure 2.8: An FRF measurement

Sources: Patrick L. McHargue $ Mark H. Richardson 1993

There are several conclusions that can be made the summation of the transform of all excitation force induced Fourier transform. Besides that, the unit of impulse response is obtained by setting the element of the transform excitation vector.

Operational deflection shape can be defined as any force motion at moment in time or at specific frequency. Operating deflection shape is very useful for learn and understanding the absolute dynamic behavior of a component, machine or a structure. Operating deflection shape may lead how to design or to do a modification to the structure by control the noise, vibration, lessen fatigue, reduce wear or to solve some problem. Operating deflection shape can define the existence resonance condition at critical point; this is useful when the modification on the structure do because it needs to be support by few frequency responses. Besides that, operating