FLUID STRUCTURE INTE[illegible]ATION ON PIPELINE T-JOINT

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ABSTRACT

This project has been conducted in an attempt to do simulation of pipeline t-joint for the structure itself and for the structure with fluid flow through in it. The first objective of this project are to determine the dynamic characteristic for modal by determining the natural frequency and mode shape of the t-joint by applying impact on the structure. Besides, the second objective is to determine load profile of fluid structure interface (FSI). This thesis conducted experimentally by giving some impact to certain point for the whole structure for three axes, which analyse by programmable computer in order to know the natural frequency and mode shape of the t-joint pipe. This thesis describes ANSYS technique to predict natural frequency, mode shape and fluid structure interface (FSI). The three dimensional solid modelling of t-joint pipeline was developed using the SOLIDWORK software. The t-joint pipe analysed using its properties and all the elastic supports that resulting the natural frequency and mode shape Results obtained in table form and figure from simulation that shows the mode shape and frequency of the t-joint pipe.

ABSTRAK

Projek ini telah dijalankan di dalam percubaan untuk membuat simulasi terhadap paip t-gabungan untuk struktur itu sendiri dan terhadap struktur bersama cecair yang mengalir di dalamnya. Objektif pertama projek ini adalah untuk menentukan ciri-ciri dinamik untuk modal dengam menentukan frequensi semulajadi dan bentuk mod dengan mengaplikasikan kesan pada struktur. Di samping itu, objektif kedua adalah untuk menentukan pofil muatan structur cecair antara muka (FSI). Tesis ini dijalankan dengan memberi kesan kepada sesetengah titik terhadap seluruh struktur untuk tiga paksi, yang mana dianalisis oleh komputer yang telah diprogramkan untuk mengetahui frekuensi semulajadi dan bentuk mod paip t-gabungan. Tesis ini memperihalkan teknik ANSYS untuk menjangkakan frekuensi semulajadi, bentuk mod dan struktur cecair antara muka (FSI). Model pepejal tiga dimensi paip t-gabungan telah dibina menggunakan perisian SOLIDWORK. Paip t-gabungan telah dianalisis menggunakan ciri-cirinya dan semua sokongan kenyal yang memberi keputusan kepada frequensi semulajadi dan bentuk mod. Keputusan yang telah terhasil berada dalam bentuk jadual dan gambarajah yang menunjukkan frekuensi paip t-gabungan.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The fluid structure interface (FSI) in pipelines system has been investigated experimentally and analysed using ANSYS for many years ago. By analysing the pipeline system using ANSYS, we can see the load profile of fluid structure interface (FSI) clearly. There are many divisions under ANSYS can be used to analysis fluid structure interaction such as fluid flow (FLUENT), fluid flow (CFX), fluid flow (POLYFLOW), fluid flow-blow molding (POLYFLOW) and fluid flow-extrusion (POLYFLOW). Fluid structure interface is a simulation of a structure in the existing of fluid such as gas or water.

Since the simulation to see the interaction between structure and fluid can be apply using computational fluid design (CFD), modal simulation then used to see the deformation of the structure itself. Without fluid flow in the system, the deformation of static pipeline can be measured using modal simulation. In structural engineering, modal analysis uses the overall mass and stiffness of a structure to find the natural frequency of structure. Although modal analysis is usually carried out by computers, it is possible to hand-calculate the period of vibration.

In pipelines system, there are various kind of pipe connected to each other in order to transport fluid from one location to another location. Pipelines system consists of inlets, outlets, the pipe itself and fitting in the pipe. The fluids enter from inlet, flow through the pipe and fitting before leaving from outlet. Fitting consists of bend, T-joint, valve and etc. give different effect in pipelines system for fluid structure interface (FSI).

In a complex pipelines system, the using of pipeline T-joint seems suitable when there is more than one destination for the fluid to be transfer. T-joint has three branches on its body pipe, so at least three destination of fluid can be transfer by connecting pipeline system with t-joint. As we can see, many sizes of pipeline are available in market nowadays. In order to have a large pipelines system, junction like t-joint is a most suitable part for joining the different sizes of pipeline.

T-joint pipeline came from different materials are galvanised iron, polyvinyl chloride (PVC), steel, plastic tubes and etc. Different material has different properties either physical or chemical, which fabricated to match with the substances to be transported. For oil and gas industry, pipeline made from steel or plastic tubes compare to natural gas, pipelines are constructed of carbon steel. Pipelines bring oil and gas produced from offshore wells to shore, often through water several hundred feet deep. The using of steel for oil and gas industry obviously to prevent failure in short period operation

1.2 OBJECTIVES

The first objective of this thesis is to determine the load profile of pipeline T-joint using fluid structure interface analysis. For the case of fluid structure interface (FSI) of force excitation in pipeline T-joint, the fluid needs to be pressurized first to have the results at the junction. This type of system is simple by giving some force to pressurize fluid, and the result can be seen from simulation of pipeline T-joint.

The second objective of this thesis is to determine the dynamic characteristic of pipeline t-joint using modal analysis and modal simulation. Modal is an analysis of the structure itself without any fluid moving in its structure.

1.3 PROBLEM STATEMENT

In pipelines system, the transportation of fluid gives some affect to the pipeline structure and pressure of fluid also. Although the failure such as crack usually happens during the transportation of fluid, it is not too sure that the fluid is the main cause of the accident. Pipeline came in various kinds of materials and has been chosen ideally to withstand the fluid properties.

The fluid flow interacts with inner wall of pipeline T-joint and exerts pressure causes the fluid fluctuates. This situation may cause deformation in the structure and thus alter the flow of the fluid itself. The vibrations in pipeline T-joint then make the structure to become crack.

1.4 SCOPES

i. Use PVC as material
ii. Drawing a pipeline T-joint using SOLIDWORK.
iii. Using ANSYS to find dynamic characteristic and load profile of t-joint.
iv. Conduct an experiment based on modal analysis to measure natural frequency and mode shape.
v. Compare the results between simulation and analysis for modal.

CHAPTER 2

LITERITURE REVIEW

2.1 INTRODUCTION

Flowing substances likes fluids, slurries, powders and masses of small solids transported by using pipelines system. Pipelines are generally the most economical way to transport large quantities of liquids and gases over land and below the sea, such as oil and gas which often has to be transported from offshore production facilities to land based refineries and onwards for final delivery.

Usually, pipeline came out with circular cross-section of hollow design. There are various kinds of pipelines available such as straight pipeline, elbow and T-joint to enable the transportation of substances. As a pipeline ages, the chance of failures increase due to corrosion, external damage, sustained operating pressure or impulses due to cavitation, or fluid hammer. If pipeline carrying water leak bursts, it can be a problem but it usually doesn't harm the environment. However, if a petroleum or chemical pipeline leaks, it can be an environmental disaster.

Public safety and minimizing environmental impact are at the forefront of the life cycle of pipelines, right from construction through to the operation of the systems. Many inspections in build a pipeline system such as material, types of welding and etc. to prevent failure of pipeline. Once the pipeline installed, it will undergo many process and the latest technology utilized to monitor the pipelines to ensure continued safe operation. Simulations and testing also applied before the pipeline construction to see the flow condition in the pipeline and deflection before and after the fluid flow. This method is very effective since we can make sure that a design can be acceptable or not.

2.2 MATERIAL OF PIPELINE

Many factors causes the failures of a pipeline system are material, welding, diameter, substances, valve and place to install the pipeline system. Pipeline is made of different materials based on the fluid to be transported such as oil, gases, chemical, water and etc. Materials used to build pipeline including polyvinyl chloride (PVC), stainless steel pipe, steel pipe, high density polyethylene pipe, (HDPE), ductile iron pipe (DIP).

Pipelines carrying chemicals or oil must be high pressure and resistant to corrosion and carbon iron (C.I) and ductile pipe are the best as corrosion is much higher in petroleum product. While water pipes must contain high pressure and galvanised iron (G.I) pipe, mild steel pipe, polyvinyl chloride (P.V.C) pipe, and compact polyvinyl chloride (C.P.V.C) pipe, concrete pipe are more suitable to transport water.

Polyvinyl chloride pipe (PVC) usually used to transport small amount of substances which usually installed in residents and factories. The PVC pipe used for transport substance pressured range between 160Pa to 200Pa since the wall thickness of structure is thin. For the higher pressure of substance, the other types with thicker wall thickness need to be used.

Chemical properties and physical properties of a pipe is very important part for choosing the correct one. PVC is very corrosion resistant because it is not have electrochemical reaction with acid that come in contact with it. Besides, PVC is not reacting with many types of chemicals that it is known as high chemical resistance. PVC offers excellent rigidity up to the vicinity of its vitreous transition temperature.

2.3 T-JOINT PIPELINE

T-joint pipeline is T-junction pipes which can be consider to have one inlet and two outlets or two inlets and one outlet. Since it is in t-shape, it will give big impact to the fluid pressure when the fluids flow through it. Fluid will change its direction no matter what it come from any inlet. Paritosh R.Vasava stated that t-joint is a component distributes fluid from main pipe to several branching pipes and to accumulate flows from many pipe to a single main pipe.

The changes of direction actually give effect to the fluid pressure as well as fluid flow from laminar to turbulent. The behaviour of fluid flow depends on the inflow and outflow direction and there are three possibility of fluid direction in t-joint pipeline. Firstly, the fluid enters from the main branch and leaves the T-joint from side branch. Secondly, the fluid enters from main branch and one side branch, and then leaves from another side branch. Lastly, the fluid enters from both side branches and leaves through main branch.

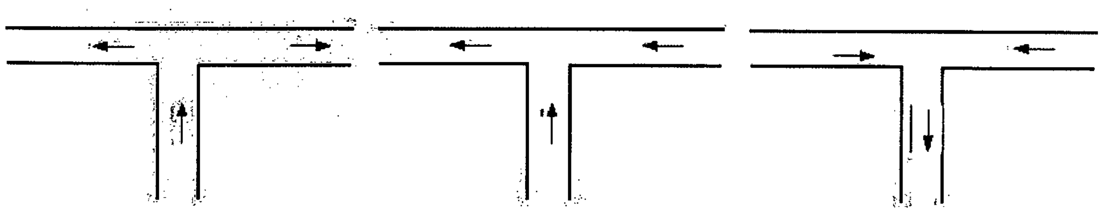

Figure 2.1: Possibilities of fluid entering and leaving the junction

Source : Paritosh R.Vasava (2007)

T-joint come in various angle and it is consider come from the combination of two elbows and sudden contraction. The most popular t-joint in industry is 180 degree angle between main pipe and branch pipe. The different angle between main pipe and branches gives different effect to the pipe and fluid flow through it. This is because the velocity of fluid changes rapidly or slowly based on the angle of the t-joint pipe.

2.4 FLUID FLOW IN T- JOINT PIPELINE

Transportation of substances in pipeline system is a process of fluid movement and interacts with the pipe structure. In pipeline system, the pipeline is not stand alone but device like pump and valve also being installed to help pressurized the fluid. Pump or valve causes the fluid flow with some pressure and interaction between pipeline and fluid happened to make sure that the fluid flow continuously. The fluid then fluctuates with the random pressure thus induced vibration in pipelines system.

If a structure is sufficiently flexible, the structural deformation under the fluid loading will in turn change the fluid force. As the force excitation increase, the systems become resonance when the frequency of structure same with its natural frequency. Variations in the free stream flow or turbulent fluctuations cause unsteady pressure on the structure and fluid. Strong fluid-structure interaction phenomena result when the fluid force on a structure induces a significant response, which in turn alters the fluid force.

Internal flow through a pipe decreases the natural frequency of the pipe. Sufficiently high internal velocity will induce buckling in a pipe supported at both ends since the momentum of fluid turning through a small angle of pipe deflection is greater than the stiffness of the pipe as been carried out by R.D. Blevins (2006). If the pipe is restrained at only one end, the pipe will become unstable. If the pressure and velocity in the pipe oscillates, then the fluid force on the bend will oscillate, causing pipe vibration in response to the internal flow.

The waves have some vibrations when external excitation force acting on the fluid. Forced vibration refers to the motion of the system, which occurs in the presence of external excitation force.

$$\sum F = 0 \qquad (2.1)$$

$$kx + m\ddot{x} = P \sin \omega t \qquad (2.2)$$

where,

P = force excitation

kx = stiffness forces

$m\ddot{x}$ = inertia force

ω = frequency (rad/sec)

For sinusoidal wave,

$$x = A \sin \omega t \qquad (2.3)$$

where,

A = amplitude

ω = frequency (rad/sec)

Systems can be analyzed using the system response to an input to the signal. The response of any system is the sum of the transient and the steady state response. Any system can either be in equilibrium or not in equilibrium. The transient response is the response of the system to a change in equilibrium and steady state is the response when the system is in equilibrium.

Systems consider having steady state response only when the system acted upon by an excitation force. This response cause the amplitude to decrease linearly with time as the external force exerts on system as shown in the steady state response of figure 2.1.

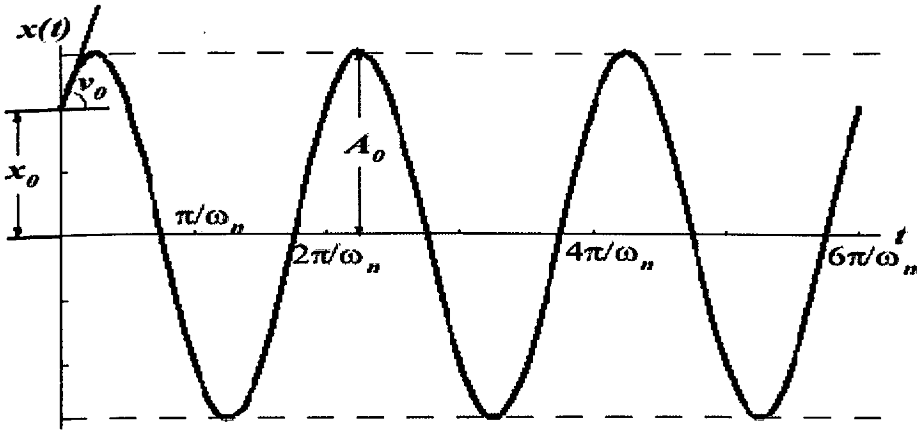

Figure 2.2: Steady-state response

Source: http://www.efunda.com

2.5 FLUID STRUCTURE INTERFACE (FSI)

Fluid–structure interface (FSI) is the interaction between fluids with a solid structure that exerting pressure on it, which is known as fluid structure interaction (FSI). However, when a piping system has certain degrees-of-freedom, severe deviations from classical theory may occur due to motion of the system. Pressure waves exert forces which cause a compliant system to move. The motion causes pressure waves in return. This phenomenon is called Fluid-Structure Interaction (FSI). C.S.W. Lavooj and A.S. TIjsseling,.(1991).

Fluid structure interface (FSI) is essentially a dynamic phenomenon. The pressurized fluid from internal or external pipelines may cause deformation to the inner pipelines structure. This deformation changes the boundary conditions of the fluid flow. Flow components and any resulting forces parallel to the cylinder axis are neglected; all forces are caused by the flow and later cylinder motion component perpendicular to the cylinder axis. (Journée J.M.J and Massie W.W, 2001).

Based on R.D Blevins(2007), the wave velocity is perpendicular to the pipeline As the fluid enters the pipelines system, the interaction between inner wall of pipelines and fluid occur causes the velocity of fluid increase. The increasing of velocity also increases the force that causes the rapid fluctuation occurs. This phenomenon can only occur if a force is exerted on the fluid and this force can only come from the cylinder.

2.6 DYNAMIC CHARACTERISTIC

Natural frequency and mode shape are functions of the structural properties and boundary condition. Each system has a set of natural frequencies and associated mode shapes conditions. Natural frequency will change when the structural properties of a system change but mode shape may not necessarily change. In the study of static and dynamic characteristic of instrument, P M B Subbarao (2010) expressed the view that dynamic characteristic is the relationship between input and output when the measured quantity is varying rapidly.

2.6.1 Natural frequency

Frequency is the number of occurrence per unit time. An object that vibrates at single frequency is producing a pure tone. When frequency of an object matches with natural frequency, the displacements of that structure will reach a maximum that is resonance occur. Frequency can be calculated using equation,

$$\omega = \frac{2\pi}{T} \qquad (2.4)$$

where,

ω = frequency (rad/sec)

T = time (s)

Equation to of frequency use to calculate time,

$$f = \frac{1}{T} \qquad (2.5)$$

where,

f = frequency (Hertz)

T = time (s)

S. Franzetti et al (2008) expressed that resonance is a phenomenon when a system lost its ability to resist. that the resonance phenomenon generates critical condition in structure. At this state, the system is oscillating at highest amplitude where the inertia resistance will cancel the stiffness resistance. At low frequency, the inertia resistance nearly becomes zero. At this instant, the stiffness resistance controls motion.

$$x = \frac{F \sin \omega t}{k - m\omega^2} \qquad (2.6)$$

when $m\omega^2 \sim 0$,

$$x = \frac{F \sin \omega t}{k} \qquad (2.7)$$

The inertia force is proportional to the excitation force. As the increasing of excitation force, the inertia resistance also increases and it will come to an instant where the inertia resistance will cancel the stiffness resistance. As a result, the excitation force will now act on the mass without any resistance. This will cause the mass to oscillate with large amplitude. Resonance occurs at this state, which the frequency system same with the natural frequency. Natural frequency equation is,

$$\omega o = \sqrt{\frac{k}{m}} \qquad (2.8)$$

The further increasing in frequency make the system become isolation. The inertia resistance increase as the frequency increase that will overcome the stiffness resistance. At this point, the system motion is controlled by the mass.

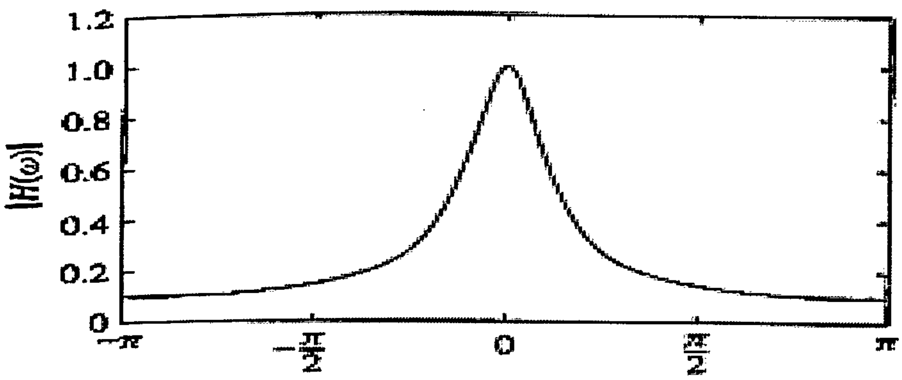

Figure 2.3: Natural frequency

Source: https://engineering.purdue.edu.pdf

Although flow disturbances generated by accidental or normal operation generally attenuate and disappear in hydraulic system with time, occasionally a flow disturbance is amplified that results in severe pressure and flow oscillation. This condition depends on the characteristic of the fluid system and of the excitation. Such oscillation that leads to pressure implication in the fluid system is defined as resonance, also known as self-excited oscillation or auto-oscillation.

2.6.2 Mode shape

The deformed shape of a structure at a specific natural frequency of vibration is termed its normal mode of vibration. Each mode shape is associated with a specific pattern to a natural frequency of a system. The mode shape is determined under the context of free vibration. Ahmed elgamal (2010) stated that steady state vibration at any of the resonant frequencies takes place in the form of a special oscillatory shape, known as the corresponding mode shape.

Mode shape basically shows vibration of a structure and in what pattern it vibrates. Any mode shape only defines relative amplitudes of motion of the different degrees of freedom in the MDOF system. Mode shape can be defined base on below equation.

$$(k = \omega^2 m)u = 0 \qquad (2.9)$$

Where,

ω= frequency (rad/sec)

By replacing the vector 'u' to ϕ_n which, will define the corresponding mode shape.

$$(k = \omega^2 m)\Phi = 0 \qquad (3.0)$$

Number of mode shape of a system depends on the degree of freedom system. For single degree of freedom system, it is has one mode shape and same goes to the other kind of degree of freedom. Based on the Brian J. Schwarz and Mark H. Richardson (1990), the mode shapes are determined by natural frequency, damping and boundary condition. When impact given to the structure, the excitation allows the it to be excited simultaneously, Kenneth A. Ramsey(1989) To find mode shape for second degree of freedom (2-DOF) and multiple degrees of freedom (MDOF), we need to use matrix form. Equation for 2-DOF,

$$\phi_1 = \begin{bmatrix} \emptyset_{11} \\ \emptyset_{21} \end{bmatrix} \qquad (3.1)$$

$$\phi_2 = \begin{bmatrix} \emptyset_{12} \\ \emptyset_{22} \end{bmatrix} \qquad (3.2)$$

Where,

ϕ_1 = mode shape 1

ϕ_2 = mode shape 2

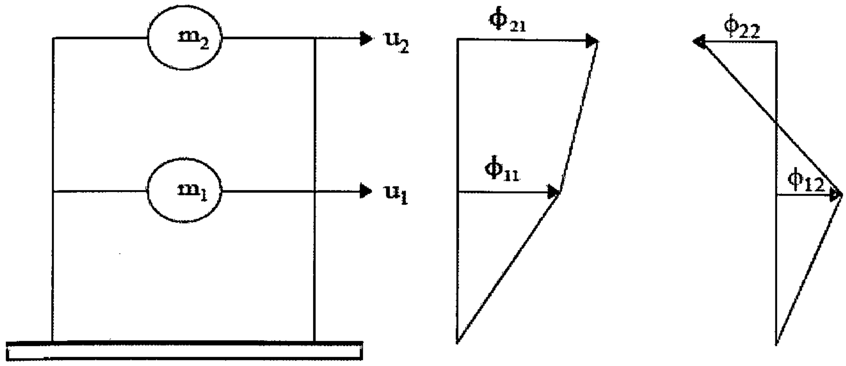

Figure 2.4: Mode shape of 2-DOF

Source: Ahmed Elgamal (2010)

2.6.3 Damping

Damping is the decrease in amplitude with time due to the resistance of the medium to the vibration. Damping occurs progressively as energy is taken out of the system by another force such as friction. Based on Indian institute of technology rooorkee, damping is a phenomenon by which mechanical energy dissipated in dynamic systems.

There are three types of damping exists are over-damped, under-damped and critical-damped. The minimum damping that will prevent or stop oscillation in the shortest amount of time. For critically damped, the damping coefficient is enough that the system just fails to oscillate. Damping more than this is referred to as over damping and less is similarly under-damped.

Figure 2.5: Force vibration with damping

Source: https://www.google.com.my