Analysis of The Pipe System to Improve Productivity of Gas

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ABSTRACT

One of the ways to increase productivity of gas did not interfere with their production process that is to increase the number of flowrates and without changing the system configuration of pipelines. Of course, this is will lead to a pipeline to get a dynamic that more than ever so potentially occurring vibration that exceeded limitations that could eventually lead pipes have failed. Analysis done manually with the approach Likelihood of Failure (LOF) method which is a conservative calculations to find out whether vibration that happened still in the tolerance range and done a study on the increase of flowrates influence to force a pipeline especially in the area around SBC (Small Bore Connnection). Analysis done by modeling a numeric to analyze the pipeline in records by using software CAESAR 5.2, and analyze the pipeline dynamically by using software ANSYS Multiphysics 14.0 with variations burden pressure of fluid that flows that had been received by result from previous output ANSYS CFD software. In the bloodstream fluid analysis had been found that the increase flowrates in inlet with pressure that produced by fluid that flows.

I. INTRODUCTION

A. Background

The increase flowrate of fluid in the pipe system can cause the pipe to failed. this is will lead to a pipeline to get a dynamic that more than ever so potentially occurring vibration that exceeded limitations that could eventually lead pipes have failed. The vibratory response of piping system in a function of (1) the piping mechanical natural frequencies which dependent on the pipe diameter, span length, effectiveness of the pipe supports, restraints, guides, anchors, and snubbers, (2) the acoustical resonant frequencies of the piping system which are influenced by the acoustical properties of the fluid, (3) the piping system operational conditions, such as pressure, temperature, flow, multiple unit operation and the kind of operational transient (startup, shutdown,etc), (4) the flow-induced pulsations which are dependent upon the floq velocity, Strouhal numbe, main and branch pipe diamters, and the presence of obstructions such as orifices, valves, condenser, tube, etc, and (5) pulsations generated form reciprocating machinery.

Most dynamic fatigue failure in piping system are caused by individual piping spans vibrating at resonance. The stress in apiping span which is vibrating at resonance is directly proportional to the maximum vibration amplitude (displacement, velocity, or acceleration) in the span. In order to determin if measured vibration amplitudes of piping system are acceptable, the dynamic stresses caused by the vibrations should be compared to the applicable endurance limit for piping material.

II. THEORY

2.1 Fluid
2.2.1 Definiton of Fluid

Fluid is defined as a substance that deforms continuously when acted on by a shearing stress of any *magnitude.* A shearing stress (force per unit area) is created whenever a tangential force acts on a surface. For flow which transpoted in a pipe, we assume that the pipe is completely filled with the fluid being transported. For this condition, gravity may be important (the pipe need not be horizontal), but main driving force is likely to be a pressure gradient along the pipe.

2.2.2 Laminer and Turbulent Flow

For pipe flow the most important dimensionless parameter is the Reynolds number, Re—the ratio of the inertia to viscous effects in the flow. Hence, in the previous paragraph the term flowrate should be replaced by Reynolds number.

$$Re = \frac{\rho V D}{\mu} \quad (1)$$

Where,
V = Average velocity in the pipe (m/s^2)
ρ = Density of fluid (kg/m^3)
D = Diameter of pipe (m)
μ = Dinamic viscosity (N.s/m^2)

A laminer flow is one in which the fluid particles move in smooth layers, or laminas .A turbulent flow is one in which the fluid particles rapidly mix they move along due to random three dimensional velocity fluctuations.

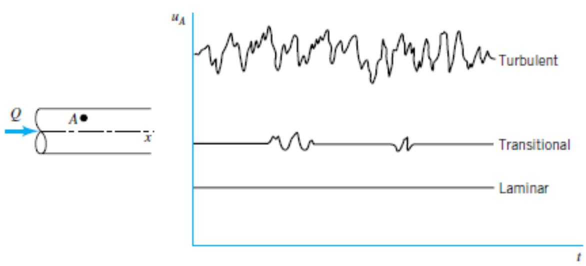


Fig 1. Turbulent, Transitional, and Laminar Flow

The actual transition from laminar to turbulent flow may take place at various Reynolds numbers, depending on how much the flow is disturbed by vibrations of the pipe, roughness of the entrance region, and the like. The flow in a round pipe is laminar if the Reynolds number is less than approximately 2100. The flow in a round pipe is turbulent if the Reynolds number is greater than approximately 4000. For Reynolds numbers between these two limits, the flow may switch between laminar and turbulent conditions in an apparently random fashion (transitional flow).

2.2.3 Analysis of the pipe flow

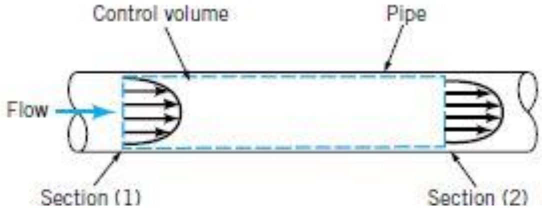


Fig. 2 Control volume in flow pipe

Based on **Fig.2,** A system is defined as a collection of unchanging contents, so the conservation of mass principle for a system is simply stated as time rate of change of the system mass is zero. If no fluid is added, moved or placed between section 1 and 2, the volume of fluid flowing between section 1 and 2 per unit time is fixed, and can be expressed $Q_1 = Q_2$ = constan.

2.2 Vibration

Any motion that repeats itself after an interval of time is called *vibration* or *oscillation*. The following therminology in harmonic motion.

Frequency of oscillation. The number of cycles per unit time is called the *frequency of oscillation* or simply the *frequency* and is denoted by *f*.

Amplitude. The maximum displacement of a vibrating body from its equilibrium position is called the *amplitude* of vibration. Amplitude can measure in three ways :

1. Displacement
2. Velocity
3. Acceleration

Phase Angle, The difference of amplitude in one frequencies.

Vibration can be classified in several ways. Some of the important classifications are as follows.

Free Vibration. If a system, after an initial disturbance, is left to vibrate on its own, the ensuing vibration is known as *free vibration*.

Forced Vibration. If a system is subjected to an external force (often, a repeating type of force), the resulting vibration is known as *forced vibration*. The oscillation that arises in machines such as diesel engines is an example of forced vibration. If the frequency of the external force coincides with one of the natural frequencies of the system, a condition known as *resonance* occurs, and the system undergoes dangerously large oscillations.

2.3 Vibration in Pipe

Actual piping span natural frequencies deviate from the theoretical beam natural frequencies, since the configurations that exist in typical plant piping have boundary conditions that differ from ideal values. Nevertheless, ideal beam theory gives a valuable starting point for understanding piping vibration behavior. The natural frequency of any piping span can be calculated if the frequency factor, the span length, the diameter, wall thickness and the weight per length are known. For a straight uniform piping span, the natural frequency can be calculated using the following relationship:

$$f_o = \frac{\lambda}{2\pi}\sqrt{\frac{gEI}{\mu l^4}} \qquad (2)$$

Where,

F_o = Span natural frequency (Hz)

g = Gravitation constant (386in/sec^2)

E = Modulus of elastiicity (psi)

I = Momen of inertia (in^4)

l = Frequency factor (dimensionless)

μ = Weight per unit length of beam (including fluid and insulation) (lbs/in)

ρ = Density (lbs/in^3)

A= Pipe cross-sectional arean (in^2)

Note that this equation does not include the weight of the fluid and the insulation. The frequency factors (A.) for calculating the first two natural frequencies for ideal straight piping spans are given in terms of the overall span length in Figure 1 .

	Piping Configuration	Frequency Factor		Deflection Stress* Factor		Velocity Stress* Factor	
		1st	2nd	1st	2nd	1st	2nd
L	Fixed-Free	3.52	22.4	366	2295	219	219
L	Simply Supported	9.87	39.5	1028	4112	219	219
L	Fixed - Supported	15.4	50.0	2128	6884	290	290
L	Fixed-Fixed	22.4	61.7	2935	8534	275	290
A+B = L, A=B	L-Bend Out	16.5	97.6	1889	13996	241	301
	L-Bend In	59.4	75.5	7798	9575	276	266
A+B+C = L, A=B=C	U-Bend Out	18.7	111.6	2794	14511	314	273
	U-Bend In	23.7	95.8	3751	8722	332	191
A+B+C = L, A=B=C	Z-Bend Out	23.4	34.2	3522	4133	317	254
	Z-Bend In	22.4	96.8	3524	8933	331	194
A+B+C = L, A=B=C	3-D Bend	20.6	27.8	3987	4752	407	359
	Formula	$f = \frac{\lambda}{2\pi}\sqrt{\frac{gEI}{\mu l^4}}$		$S = K_d y \frac{D}{L^2}\, SCF$		$S = K_v V\, SCF$	
	Reference	Eq. 1		Eq. 10		Eq. 13	

*Steel Piping ($E = 30 \times 10^6$ psi, $\rho = 0.283$ lb/in^3)

Fig.3 Piping factor

2.4 Stress theory

2.4.1 Normal Stress

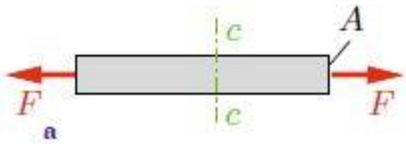


Fig.4 Stress

The force per unit area, or intensify of the force distributed over a given section, is called stress on that section and is denoted by the Greek letter σ (sigma).

$\sigma = F/A$ (3)

Where,

σ = Stress (N/m^2)

F = Force (N)

A = Area (m^2)

Strain is the way engineers represent the distortion of a body. Axial strain (normal strain) in a bar is a measure of the extension of a bar per unit length of the bar before deformation. The following figure shows a bar of initial length *l*o that is extended by the application of a load to the length *l*.

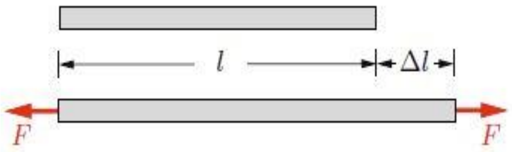


Fig.5 Strain

$$\varepsilon = \frac{\Delta l}{l}. \quad (4)$$

Where,

Δl = elongation (m)

l = intial length (m)

2.4.2 Shear Stress

Shear stress (shear strees) is the stress work in the direction tangential to the surface materials.

$$\tau = \frac{V}{A} \quad (5)$$

Where,

τ = Shear stress (N/m^2)

V = Shear Force (N)

A = Area (m^2)

2.4.3 Von Misses Stress

Von mises stress is static failure criteria calculations. One of the criteria or methods of calculating the stress that occurs in the body so it can be assessed whether the object is safe or not.

$$\sigma_{max} = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2}$$

$$\sigma_{min} = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2} \quad (6)$$

Where,

σ max = maximum von mises stress

σ min = minimum von mises stress

σ_x = von mises stress x axis

σ_y = von mises stress y axis

τ_{xy} = shear stress

2.5 Vibration Analysis Method in Pipe

2.5.1 Likelihood of Failure Method

Likelihood of Failure is a method of calculating conservative to determine whether vibrations occurs still within tolerable limits. LOF is not is the probability of failure and also not measuring instruments of a system failure. calculation LOF based on a simple model to facilitate and use sparingly. The scope of the LOF is identify vibration problems, and analyzing the and provide solutions. LOF not reflect consequences of failure. The consequences of failure is the responsibility of the user. However, LOF calculations can be combined consequences failure to establish all the risks in a system. LOF method introduced by MTD Ltd. through a joint industry involving many oil and gas companies and contractors classroom world.

Calculation methodology with LOF method is:

- Identify the cause of the vibration excitation
- Calculate the value of LOF to the main pipe
- Calculate the value of LOF for SBC

$LOF = \rho v^2/Fv$ (7)

Where,

ρ = density of fluid (kg/m^3)

v = kinematic viscosity (m^2/s)

Fv = Vibration Number

Having obtained the value of LOF, the next set of recommendations based on that value, ie as the following:

LOF ≥ 5 ➔ redesign pipe

5 > LOF ≥ 3 ➔ The main pipeline safety but SBC needs analysis

LOF < 3 ➔ The main pipeline and SBC is safe

2.5.2 Displacement Method

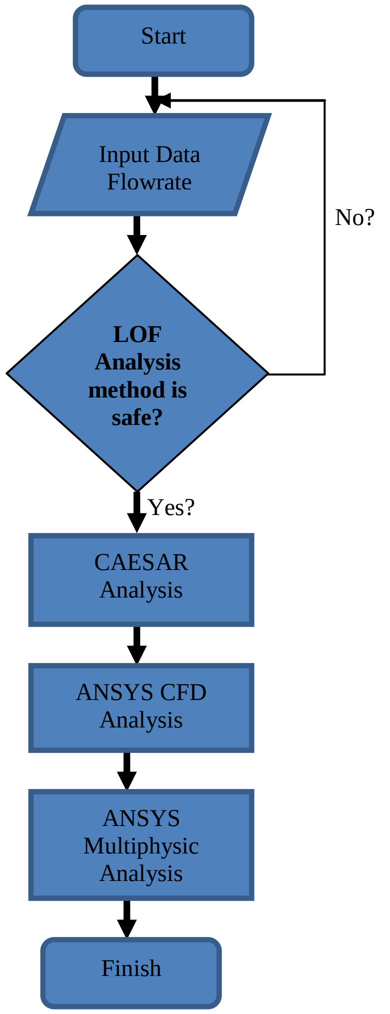
Displacement method is a method to analyzing vibration on the pipe by analyzing scale dynamic deflection due to vibration and then determine whether the displacement caused by the vibration is still within the limits tolerance and permitted. Displacement method regulated in the international standard ANSI ASME Operational and Maintenance Part 3 "Requirements for Preoperational and Initial Start-Up Vibration Testing of Nuclear Power Plant Piping Systems ".

III. Analysis Method

The method used in the vibration analysis This research is a manual method for analyze whether the vibration that takes place with the category received the LOF method, and then combined with numerical methods for static analysis (with software CAESAR) and dynamic analysis (ANSYS software). The structure is modeled according to the circumstances in field and static load force to get a response to two conditions, namely Sustain and Expansion.

To analyze the result of fluid pressure flow in the area around the SBC performed with ANSYS CFD software support, which consists of ANSYS ICEM for modeling and meshing and ANSYS CFX fluid for analysis. at ANSYS CFX is used mainly variations of the data variation flowrates different at the inlet. The next stage after modeling and meshing is the analysis by using ANSYS CFX. If there is an error it should made changes to the model. There are three stages that have to done on analysis using ANSYS CFX. These stages are:

1. Giving boundary condition and enter the fluid properties that have been determined in Pre-ANSYS CFX.
2. Running the ANSYS CFX-Solver.
3. Reading of output results in Ansys CFXPost.



Once we get the data amount of pressure due to fluid flow results from ANSYS output CFD, then we analyze the power structures against the pressure load with using ANSYS Multiphysics. This type of analysis dimanis is selected harmonic analysis because The fluid pressure load on the pipe is continuously.

IV. Conclusion

The method of analysis can be used to analyze the effect of a large increase in the flow of fluid to the pipe strength. The method uses a manual method with LOF calculation method. Then using numerical analysis methods to analyze the strength of the structure using CAESAR software. Then the dynamic analysis by incorporating different flowrate values are then analyzed the increase in flowrate to the large increase in pressure using ANSYS CFD software. After the dynamic power structure is analyzed using ANSYS Multiphysics software. That will generate a von misses stress, to analyze the structural strength of the SBC (Small Bore Connection) area pressure load results obtained.

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