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Experimental Study of Vibration on Pipe Conveying Fluid at Different End Conditions for Different Fluid Temperatures

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Abstract- *Dynamic behavior of a copper pipe conveying fluid at different fluid temperatures is investigated experimentally. Three types of supports are used, which are simply support - simply support, fixed – fixed support and fixed – free support. The effect of the support's types on the frequency and the amplitude of vibration for the pipe conveying the fluid are studied for various flow temperature. These vibration characteristics were tested at temperatures 50, 65 and 80 ºC*

Keywords- *Vibration in pipes, dynamic response, frequency, fluid at different temperatures*

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1. Introduction

Piping systems are broadly used to transport fluids in many fields ranging from chemical plants to biological engineering system. The problem of the instability of flexible pipes transporting fluids provides a paradigm for the modelling and analyzing of the instability mechanism of fluid structure interaction systems.
One of the main reasons of breakdown, fires and explosions in plants that have been identified is the failure due piping vibration. For example, the piping failure caused by vibration in a petrochemical plant costed over $114,000,000. [1]. Over than 80 cases of cracks and leakages have been caused by the failure of piping systems [2]. Therefore, it is very crucial to investigate the vibration in piping systems and evaluate the amplitude and the frequency of the vibration to determine if their levels are acceptable. Many practical structures in numerous engineering applications are exposed to flow induced vibration. Such phenomena can affect the integrity of these structures or make them unsafe or uncomfortable for human use.
Zheng et al. [3] investigated numerically the influence of tube vibration on boiling flow of liquid Hydrogen. They built a vibration model based on boiling model of Rensselaer Polytechnic Institute.
Chen et al. [4] investigated the influence of vibration of horizontal pipe on the void fraction of a subcooled boiling flow.
Al-Sahib et al. [5] investigated experimentally and theoretically the influence of welding on the vibration characteristics, since the residual stresses from welding strongly affect the natural frequency of the pipe conveying fluid, for the cases of clamped -clamped and clamped pin pipes. It was found that the clamped-clamped and clamped-pinned pipes are stable at low velocities of the fluid. For relatively high velocities of the fluid (super-critical) the clamped-pinned welded pipe tends to become unstable.
Wang et al. [6] used the commercial software (ADINA) to simulate the vibration of pipes conveying fluid. The slender pipe structures are modelled as shells and the fluid flows are supposed to be three-dimensional (3D) and incompressible. It was found that the evolution trend of natural frequencies with increasing flow velocity is similar as that predicted by the inextensible theory for curved pipes conveying fluid.
Carlsson et al. [7] studied the non-linear effects of transverse wall vibrations on a laminar channel flow, a Newtonian viscous fluid is conned in a channel with flexible walls where the motion of the wall takes the form of either travelling or standing waves. Small amplitude vibrations are considered, and a perturbation approach is

utilized. A pseudo-spectral numerical method is employed to solve the resulting linear system of equations. Resonance is found in the oscillatory flow at a Strohaul number of approximately 0.6. This occurs due to interactions between the forced vibratory flow and a natural mode of the unperturbed flow. In the vicinity of the resonance the mean flow rate decreases strongly for waves travelling in the direction of the channel bulk flow and for standing waves.

Al-Baheli [8] investigated the dynamic behavior of pipe conveying fluid at different cross sections using finite element method. The influence of three types of supports which are flexible, simple and rigid supports, on the vibration characteristic was investigated. The investigations revealed that natural frequency was higher for simply and rigid supports than that of flexible support.

Zhao and Sun [9] used Laplace transform to propose a new transfer matrix for the purpose of analyzing the flow induced vibration of a curved pipe conveying fluid. The method was verified in calculating the critical velocity of the flow. They effect of flow velocity on the natural frequency for cantilevered, clamped and periodic cantilevered pipes.

Hunain [10] investigated numerically using the finite element technique the natural frequency and the critical flow inlet velocity of a simply supported stepped pipe convey fluid. The effect of some design parameters like dimeter ratio, thickness and length ratio was investigated. It was concluded that the natural frequency for the stepped pipe decreases with the increase of flow velocity. Also, the natural frequency was found to increase with the increase of length and diameter ratios.

Forced vibrations may cause certain effects on the heat transfer from two phase systems. Such as heat exchangers, boiling and nuclear reactors, etc. The design of a pipeline transporting heating fluids requires the analysis of the behavior of the pipeline under different operating conditions. This topic is not fully covered in the various design codes. Vibration and stability analysis of such pipelines is an important part of the design process. In order to investigate the hot fluid effects on the vibration of pipes, an experimental study was carried out.

2. Experimental Setup

The experimental rig used to conduct the experiments is shown in Figure 1. It consists of three parts.

1- The heating tank is a stainless-steel tank of dimensions (30 x 30 x60 cm). It has one inlet and outlet for the water. A pressure gauge and temperature sensor are fixed at the top of the tank. Also, a safety valve is fixed at the top of the tank in case of overpressure. A heater of (300) watt is fixed inside the tanks as a heating source for the water. In order to minimize the heat loss, the tank is insulated with a layer of glass wool.

2- The vibrating Pipe is a copper pipe of 60 cm length, 16 mm inner diameter and 1 mm thickness. The two ends are connected to valves to control the fluid entering and leaving the pipe. The pipe is fixed at the ends by supports. Three types of supports are used, which are simply support - simply supports, fixed – Fixed support and Fixed – Free support.

An accelerometer is fixed on the middle of pipe surface and connected to an oscilloscope as shown in Figures 2 and 3, is used to measure the frequency and the amplitude of the vibration of the pipe. The block diagram of measurement procedure is shown in Figure 4

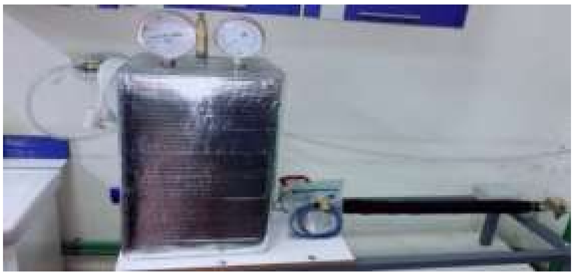

Figure 1: Experimental setup

Figure 2: Accelerometer

Figure 3: Oscilloscope

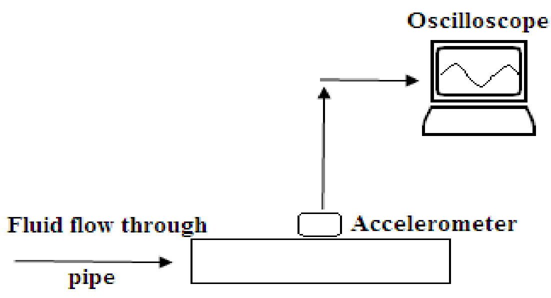

Figure 4: Measurement block diagram

3. Results

This work presents experimental data that indicate a strong relation between the fluid temperature and pipe vibration. In this work, the standard deviation of the frequency-averaged time-series signal, measured using an accelerometer attached to the pipe, is used as the measure of pipe vibration.

Table 1 includes the collected data from the experiments.

Figure 5 shows the effect of the fluid temperature on the frequency of vibration for three types of supports. It is obvious that the frequency of vibration increases with the increase of the fluid temperature. This is can be attributed to the increase of the kinetic energy of the fluid as temperature increases.

The influence of the fluid temperature on vibration amplitude is shown in Figure 6. The amplitude of vibration tends to increase as the fluid temperature increases.

Table 1: The collected data

Fixed – Fixed

Temp. of flow	Frequency	Amplitude
44	0.16666	0.6
54	0.666	0.66
64	0.68	0.8

Fixed-Free

Temp. of flow	Frequency	Amplitude
44	1.1	0.65
54	1.4	0.85
64	2	0.9

Simply Support – Simply Support

Temp. of flow	frequency	Amplitude
44	1	0.6
54	1.33	0.8
64	1.818	0.84

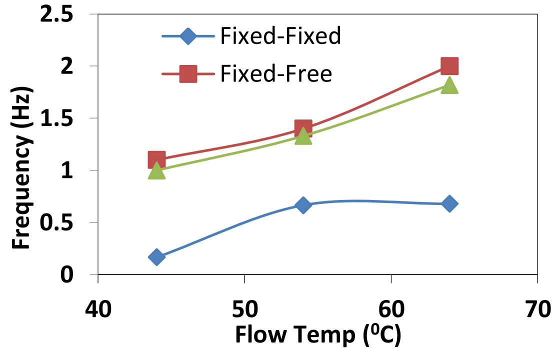

Figure 5: Variation of frequency with flow temperature

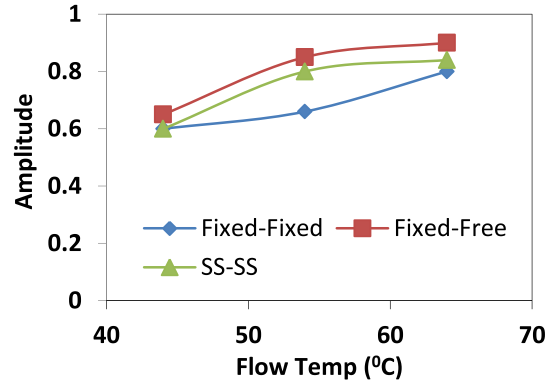

Figure 6: Variation of frequency with flow temperature

Figures 7 and 8 represent the effect of the supports on the frequency of the vibration. The Fixed – Free support has the maximum frequency of the vibration because this type of support can move in y- direction.

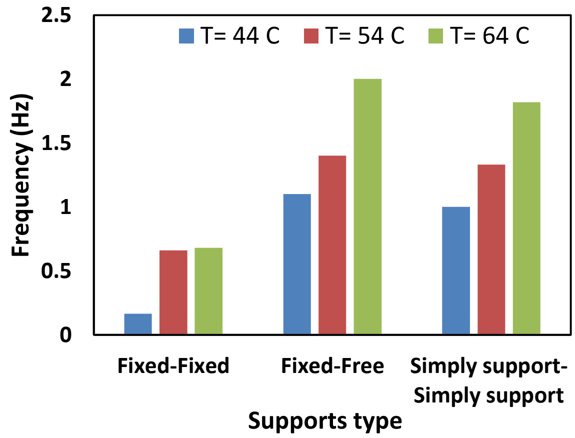

Figure 7: Effect of boundary condition on the frequency

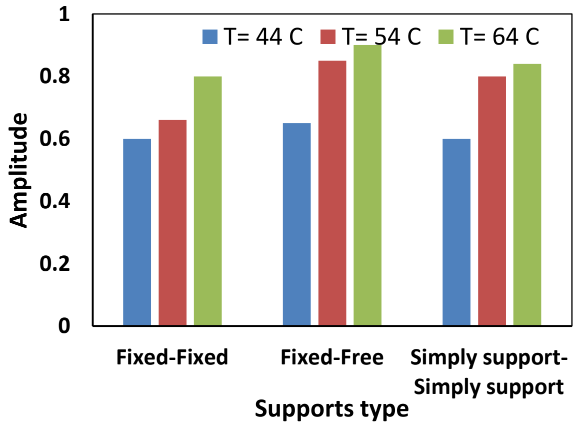

Figure 8: Effect of boundary condition on the amplitude

4. Conclusions

The present work represents an experimental investigation to determine the temperature effect of water flow inside a pipe temperature on frequency and amplitude of the pipe. The main conclusions can be summarized as:

1. The temperature of the fluid has a significant effect on the frequency and the amplitude of the pipe vibration.
2. The frequency of vibration tends to increase as temperature increases. This can be attributed to the higher kinetic energy of the flow of higher temperature
3. The frequency and the amplitude of vibration of fixed- free support are higher than those other types. This is can be attributed to bigger ability of fixed -free support to move in y- direction
4. The type of supports seems to have a slight effect on the amplitude of the vibration.

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