UOIT – Atef Mohany CRD

CRD Title: Investigation of the Dynamic Response of CANDU Fuel Bundle Due to Acoustic Pressure Pulsations in the HTS Piping System

Overview

This project is in collaboration with COG (CANDU Owners Group). The main objectives of this project are to experimentally investigate the effectiveness of passive acoustic damping devices on the attenuation of acoustic pressure pulsations in piping systems and to numerically simulate the dynamic response of CANDU fuel bundles due to acoustic pressure pulsations. The traditional designs of passive acoustic damping devices are typically very large making their implementation in existing industrial facilities problematic in many cases. Therefore, this research focuses on designing and testing a series of acoustic dampers aimed at use in industrial installations. The devices are significantly smaller than traditional designs to maximize their usefulness in industrial applications, and are capable of being used in arrays. They are distributed throughout the piping system in order to minimize their size and be capable of damping numerous acoustic modes to accommodate changing operating conditions. The numerical simulation of the CANDU fuel bundle are performed using INDAP (Incremental Nonlinear Dynamics Analysis Program) which is an in-house general purpose finite element program capable of simulating the nonlinear dynamics of nuclear and power equipment subjected to fluid excitations.

Program Results /Highlights

Experimental Part:

The experimental part of this project is conducted using two different experimental loops. The first loop is an air loop, as shown schematically in Figure 1, and it is designed so that different acoustic damping devices placements along the standing wave could be tested. This includes the pressure anti-node (zero location), pressure node (λ/4 location) and a midpoint between the former two positions (λ/8 location). The flow is driven by a centrifugal air blower and the maximum flow velocity achievable in this experimental set-up is 25 m/s. An absorptive muffler was utilized to eliminate the acoustical effects of the blower. A flow control valve is utilized to adjust the flow velocity through the test section. The experimental setup is designed to excite acoustic resonance using an excitation source located either upstream or downstream of the damping devices. Test sections with two different diameters, namely 101.6 mm (4 in.) and 152.4 mm (6 in.), were experimentally tested. The lengths tested include 2.235 m (88 in.), 3.353 m (132 in.) and 4.47 m (176 in.). The acoustic pressure is measured by means of ¼" phase matched pressure microphones which are flush mounted on the inner wall of the pipeline.

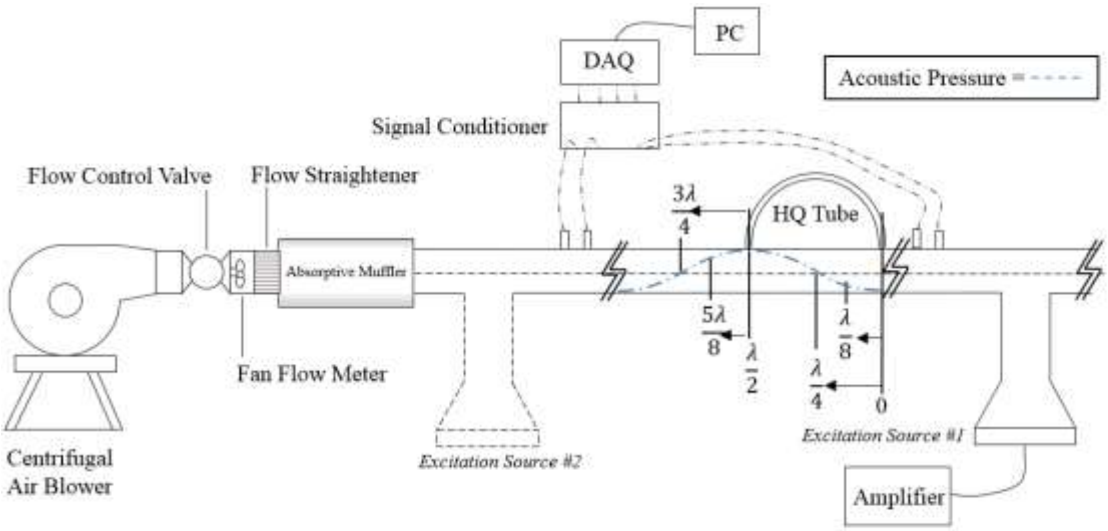


Figure 1 - Schematic of the experimental set-up for the air loop pipeline system

The results show that the use of multiple passive control devices in strategic locations along the pipeline achieved a pressure pulsation suppression of 25 dB. Figure 2 shows the effect of placing multiple Helmholtz Resonators (HR) with different volumes along the pipeline on the acoustic transmission loss. Figure 3 shows the sound attenuation achieved using one Hershel-Quincke device. In both cases, acoustic pressure pulsations were excited at 150 Hz which is similar to that generated by the primary heat transport pumps in some CANDU reactors.

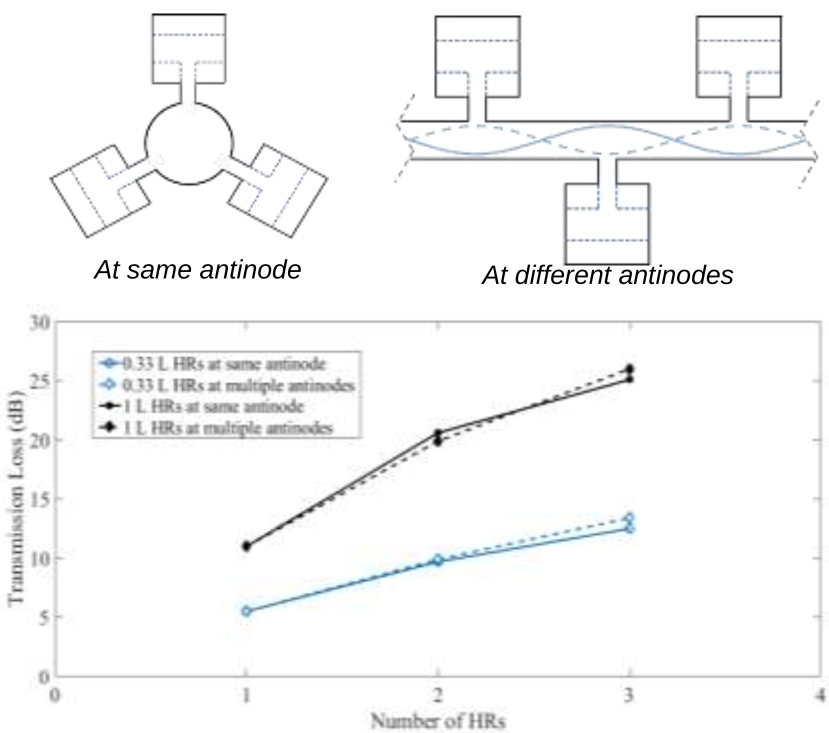


Figure 2: Effect of HR volume and location along the piping system on the transmission loss

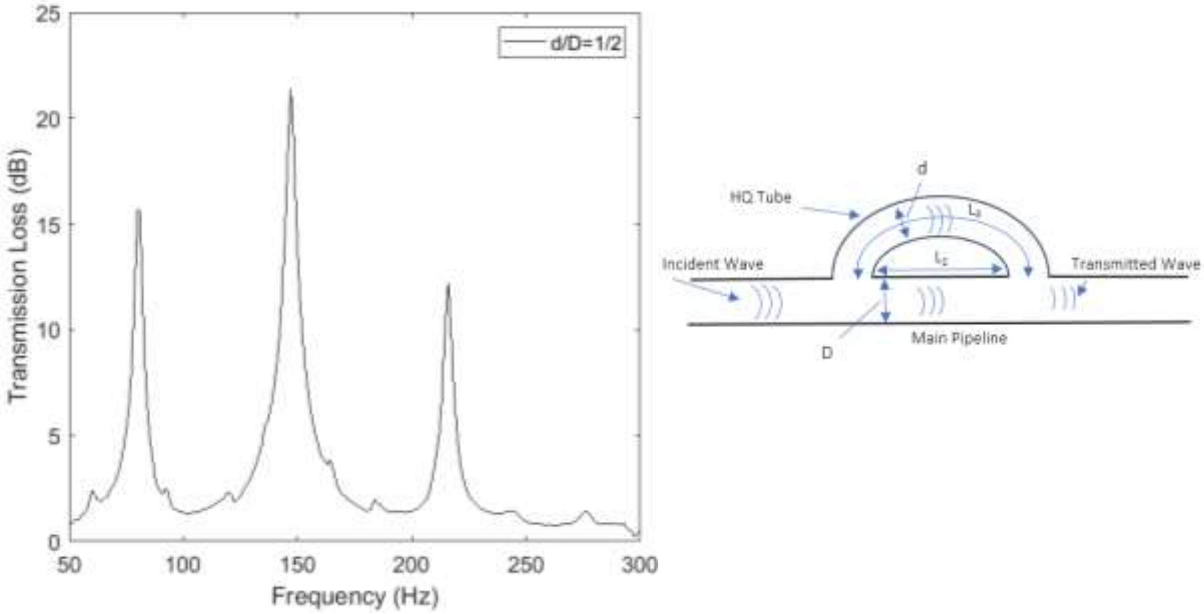
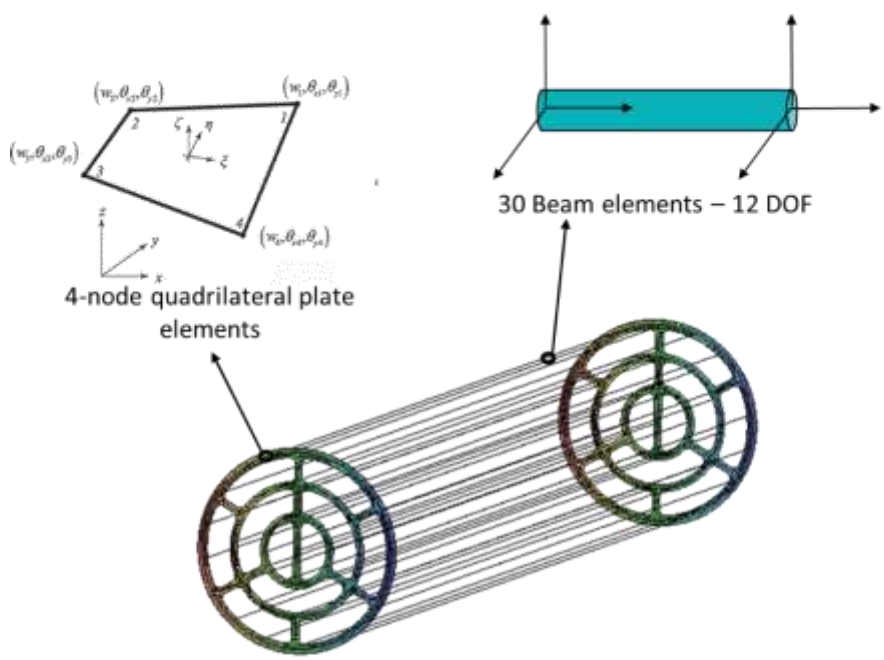


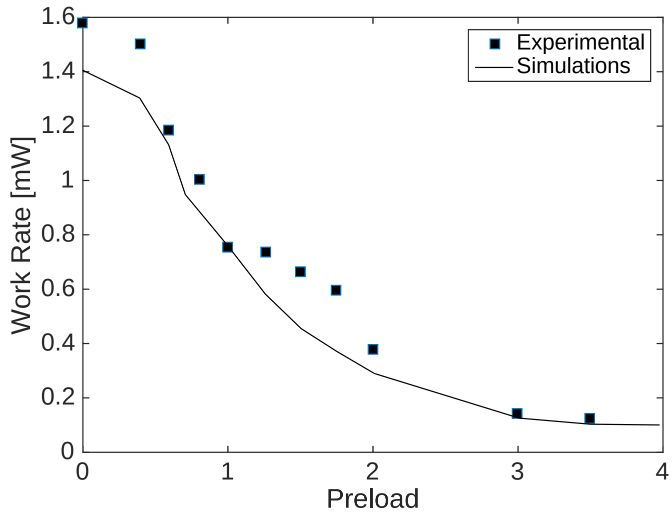
Figure 3: Effect of Herschel-Quincke placement along the piping system on the acoustic transmission loss

Numerical Part

To discretize the fuel bundle 3D block elements is usually utilized but it results in a very large number of elements and nodes. Such approach were utilized successfully in investigating the static response of the fuel system. However, for the case of simulating dynamic response for large number of time steps, such approach needs very large running time. Therefore, a reduced-order model is utilized in this work. The model represents the fuel rods by 30 beam elements each of which has 12 degrees of freedom. In addition the endplates is discretized by 1222 plate elements. A four-node isoparametric quadrilateral element was used to model both endplates. The 37 rods were coupled with the two endplates by utilizing common 74 nodes between the beam element and plate element.



A comparison between the work rate obtained from the current numerical simulations with that obtained experimentally by Yetisir and Fisher (1997) is shown in the following figure:



Cases with Realized outcomes to Industry

N/A at the moment

Research Facilities and Equipment

The second experimental loop of this project is a water loop, shown schematically in the figure below. The length of the test section is about 6 m and its diameter is 4 inch. The maximum flow rate achievable in this test section is 7 m/s (i.e. 56 kg/s), which is far more than what is expected in a CANDU fuel channel.

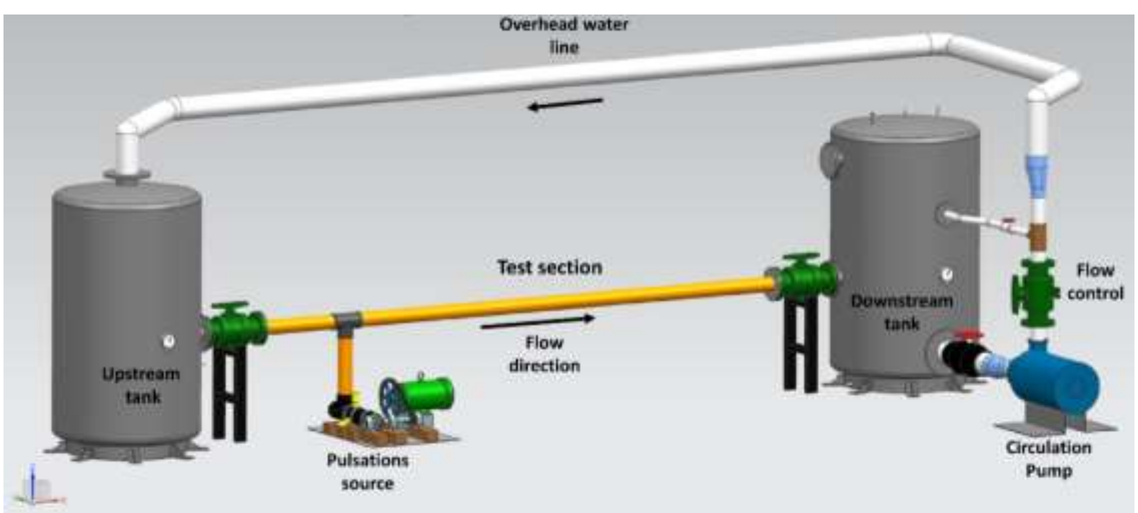


Figure 6: 3D CAD of the water loop that was commissioned for this project

Current HQP

Degree/Position	Applicant	Co-Applicant
Post-Doctor	1	0
PhD	1	1
MASc	2	0
Undergraduate Research Student	0	1
Totals	**4**	**2**

HQP that Graduated

MASc	1	1
Undergraduate Research Student	2	1
Totals	**3**	**2**

Publications /Journal Papers

1. T. Lato and A. Mohany, (2018), "Control of resonant excitation in piping systems", 9th International Symposium on Fluid-Structure Interactions, Flow-Sound Interactions, Flow-Induced Vibration & Noise, July 8 - 11, Toronto, Canada.
2. T. Lato and A. Mohany, (2018), "Passive damping of pressure pulsations in pipelines using Herschel-Quincke tubes", submitted to Journal of Sound and Vibrations, Ref# JSV-D-18-01812.
3. K. Sachedina and A. Mohany, (2018), "A review of pipeline monitoring and periodic inspection methods", Pipeline Science and Technology, Vol. 2, No. 3, pp. 187 – 201.
4. K. Sachedina, A. Mohany, M. Hassan, (2018), "Suppression of acoustic resonance in pipelines using Helmholtz Resonators", 9th International Symposium on Fluid-Structure Interactions, Flow-Sound Interactions, Flow-Induced Vibration & Noise, July 8 - 11, Toronto, Canada.
5. O. Elbanhawy, M. Hassan, A. Mohany, (2018), "A model of fully flexible tube bundle dynamics", 9th International Symposium on Fluid-Structure Interactions, Flow-Sound Interactions, Flow-Induced Vibration & Noise, July 8 - 11, Toronto, Canada.
6. A. Moksyakov, O. Elbanhawy, M. Hassan, A. Mohany, (2018), "Simulation of fluid forces in fuel bundles", 9th International Symposium on Fluid-Structure Interactions, Flow-Sound Interactions, Flow-Induced Vibration & Noise, July 8 - 11, Toronto, Canada.

Interactions /Consultations to Industry

We are in touch with the Technical Advisory Committee (TAC) and copies of the papers were shared with them prior to publication to provide their feedback on the work.