Experimental and numerical analysis of a tube with clearance-induced impacts

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Abstract. This contribution compares measurements and numerical calculations of the dynamics of a doubly clamped tube with clearance induced impacts. The response of the system is being measured at three points placed all along the tube. This measurements are then compared with the numerical results calculated with an algorithm that combines harmonic balance (HBM) and numerical pseudo arc length continuation (PAC).

Introduction

In pressurize water reactors, steam generators exchange the heat between primary and secondary circuit of the plant. Inside, a bundle of tightly packed U-shaped tubes (see Fig. 1) is used to move the hot primary coolant coming from the core. Meanwhile, an upwards stream develops outside the bundle as the secondary coolant interacts with the tubes. This configuration is reinforced with support plates all along the tubes to prevent them from large amplitude vibrations. While the presence of these supports serves its purpose, it also adds complexity when studying the vibration response of the U-tubes.
In this context, a comparison between the numerical and experimental results on a simplified example is presented : a double clamped tube in bending with a clearance placed in the middle point (as shown in Fig. 2) which will produce impacts in the tube when vibrating. The objective of this study is twofold : firstly, to bring to light the fact that even in the simplest examples (a tube with a single impact point), non linearity effects can be found (existence of multiple dynamic regimes) and therefore must be studied. And, secondly, to use a simple experiment to compare it with the numerical calculations carried out beforehand by the finite element software Cast3M [2], which permits testing a continuation algorithm currently in development. This algorithm uses harmonic balance and pseudo arc length continuation methods to predict the response of nonlinear mechanical systems and its development started within a previous thesis [1].

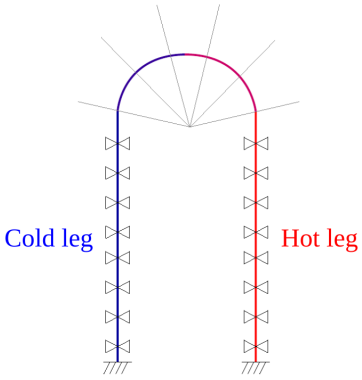

Figure 1: Single U-tube in Steam generator

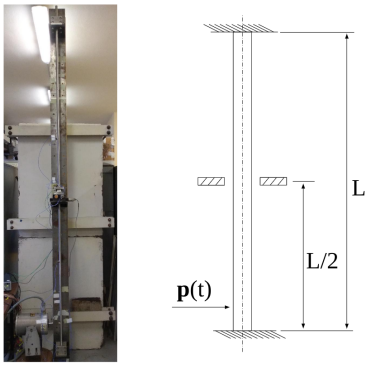

Figure 2: Schematic representation of the experiment

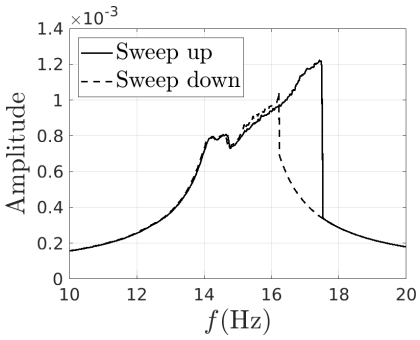

Figure 3: Frequency response at $2L/3$ height

Results and discussion

The experiment carried out consisted of a 2.6m long double clamped tube, with a symmetric central 1mm clearance and a shaker at the base (placed 0.3m from the base). This configuration allows us to change the position of the clearance in the tube section, being able to analyze the effect of the asymmetry on the system response. Accelerations have been measured in three different points placed all along the tube ($L/3$, $L/2$ and $2L/3$). In Fig. 3, it can be observed a frequency sweep up and down at the highest point of the tube. In this figure, a hysteresis effect on the amplitude of the response can be appreciated depending on the direction of the sweep. This phenomenon is characteristic from nonlinear mechanical systems, which gives birth to a range of frequencies where the system can vibrate with multiple amplitudes. Bifurcations due to symmetry breaking and sub-hamonic isolas will be studied both experimentally and numerically on this academic mock-up.

References

[1] Alcorta Galvan, Roberto. (2021) Prediction of non-linear responses and bifurcations of impacting systems : Contribution to the understanding of steam generator vibrations. PhD thesis, Université de Lyon. **https://tel.archives-ouvertes.fr/tel-03406785/**
[2] Cast3M, website **http://www-cast3m.cea.fr/**.