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Vibration characterisation of a tubular chemical reactor

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Abstract: An essential element of the industry operating system is the chemical reactor the chemical sector employs of the potentially dangerous materials and processes. The chemical sector employs potentially dangerous materials and processes. Thus, negligence or misfortune can easily result in devastating consequences like human health, environment, economy, and the industry's reputation. Therefore, the vibration characterisation of this system is essential and directly associated with its physical properties such as mass, damping, and stiffness. The numerical model is based on the spectral element method, and numerical investigations are conducted regarding the effects of internal fluid on the reactor. This paper concerns the vibration characteristics of a tubular chemical reactor and its vibration signatures represented by the receptance response are used to characterise the reactor dynamic.

Keywords: Tubular chemical reactor, Spectral element, Vibration signature.

1. Introduction

The chemical industry involves using processes such as chemical reactions and refining methods to produce a wide variety of solid, liquid, and gaseous materials covering many industrial sectors. An essential element of the industry operating system is the chemical reactor [1]. Food, pharmaceutical, pigment and polymers, cosmetics industries, wastewater treatment, oil refineries, etc., rely on industrial chemical reactors.

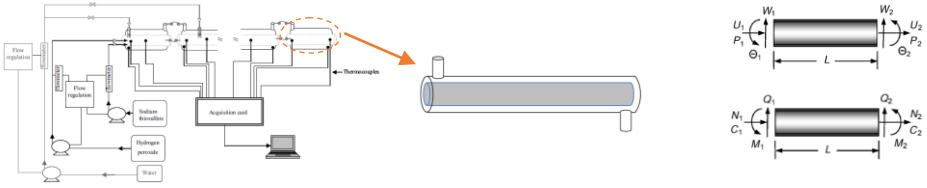
The chemical sector employs potentially dangerous materials and processes. Thus, negligence or misfortune can easily result in devastating consequences - damages to human health, environment, economy, and the industry's reputation [2,3]. Therefore, the verification of correct operation, fault finding, early detection and prevention of incidents, and especially the diagnosis and monitoring of the corresponding physical process are vital for the economic function of industrial production processes. Therefore, monitoring the system with an efficient and low-cost procedure is a challenge because industries have to ensure the quality and the repeatability of the products.

The vibration characterisation of this system is essential to understating structural behaviour, monitoring its integrity, and the chemical process. This paper is concerned with the vibration characteristics of a tubular chemical reactor using the spectral element method [4]. Numerical investigations are conducted to characterise the tubular reactor's vibration signatures.

2. Spectral model and Discussion

The tubular chemical reactor is considered to be a pipeline structure with transverse and axial displacements for the local coordinates represented by w(x, t) and u(x, t), respectively. Figure.1a-c illus-

trate the chemical process where the reactor is inserted, the tubular reactor, and the pipeline element with respective displacement and nodal forces.



(a) (b) (c)

Fig. 1. Tubular reactor: a) chemical process[5]; b) Tubular reactor; c) Model including displacements and nodal force[4] .

Pipeline governing equations in frequency domain considering the pressure and velocity of the internal fluid is expressed as [7],

$$\begin{aligned}(EA+N)u'' - m_p\ddot{u} + F_N w' + F_T = 0\\ EI_p w'''' - Nw'' - m_p\ddot{w} - F_T w' + F_N = 0\end{aligned} \quad (1)$$

where E, L, A, mp, Ip, N, F_N, F_T are Young's modulus, the length of pipeline element, the cross-sectional area of pipeline, the pipeline mass per unit length, the second moment of the cross-sectional area, the axial tensile load, and flow-induced normal and tangential force, respectively. The spectral form of axial and vertical displacement solution is given by

$$u(x,t) = \frac{1}{N}\sum_{n=1}^{N} U_n(x)e^{i\omega t} \quad , \quad w(x,t) = \frac{1}{N}\sum_{n=1}^{N} W_n(x)e^{i\omega t} \quad (2)$$

3. Final Remarks

This paper treats the vibration characteristics of a tubular chemical reactor industry. Also, it presents the numerical model based on the spectral element method. The vibration signature can be used in the system analyses, check the chemical process, and monitor the reactor integrity.

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