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Experimental investigation of aeroacoustic characteristics on tube bundle.

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Heat exchangers and boilers are widely used in various applications. High-level sound generation and thermoacoustic instability in these systems can results in serious problems such as plant shut-downs. In this study the aeroacoustic characteristics of tube bundles typically used in heat exchangers was analyzed. The tube bundles can potentially act as a passive control system for instabilities as they can be designed to change the reflection, transmission and absorption of incident sound waves. This paper presents a fundamental experimental study of the aeroacoustic characteristics of two rows of tubes in In-lined and staggered configuration, respectively. The flow duct experimentation is done with multi microphone technique with and without bias flow (through flow). The experimental results are compared with earlier results from a single tube row.
Keywords: Aero-acoustic characteristics, In-line, and Staggered array.

1. Introduction

Combustion instability is a consequence of the interactions between flame/heat source, flow and acoustics, of which thermoacoustic instabilities occur due to the presence of positive feedback between the unsteady heat release rates and the acoustic oscillations. The latter is characterised by large amplitude, low frequency self-excited oscillations that can be detrimental. These instabilities can cause vibrations of mechanical parts, unsteady and enhanced heat fluxes to walls, concentrated thermal and pressure loads leading to fatigue and in extreme cases severe structural damage. To control or eliminate thermoacoustic instabilities, the feedback loop existing between the unsteady heat release rates and the acoustic fluctuations must be broken. This can be done in two ways: by use of active or passive control strategies [1]. Passive control strategies like cavity-backed acoustic liners with bias flow and bulky acoustic dampers like Helmholtz resonator or half-wave and quarter-wave tubes, are all viable control options in large power generation units, especially stationary ones [1]. Unfortunately, these passive control strategies are undesirable in small and compact power generation units like domestic boilers. In a domestic boiler, the heat exchanger is housed within the combustion chamber along with the flame, and so requires no additional space. The use of heat exchangers as an alternative to control thermoacoustic instabilities in combustion systems like domestic boilers is therefore attractive. However, in order to investigate this possibility, it is necessary to have a model for the acoustic behaviour of the combined system of the tube row plus flow. The aim of the present paper is to as a starting point study the acoustic properties of basic tube configurations with through flow.

2. Experiments

The experimental setup consisted of a duct of rectangular cross-section (120mm × 25 mm) and with a wall thickness of 15 mm. Acoustic excitation was provided by two pairs of loudspeakers placed near the upstream and downstream ends of the duct far enough from the sample to ensure that only plane waves incident on the sample. The two samples studied were:

1) In-line array: The tubes are all parallel and equally spaced, consisting of two rows of tubes (3 full cylinders and 2 half cylinders in each row) of diameter 20mm with longitudinal and transverse pitch-to-diameter ratios as 1.3 and 1.5, respectively.
2) Staggered array: The tubes are arranged as triangular arrays of diameter of 20mm with longitudinal and transverse pitch-to-diameter ratios as 1.3 and 1.5, respectively.

Measurements were made for seven flow velocities: 6, 16, 20, 30, 40 and 50 m/s, and with stepped sine acoustic excitation in the range 100 –2000 Hz.

3. Results

The two-port multi-microphone measurement technique was used to determine the scattering matrix of the samples with and without flow.

$$\begin{bmatrix} p_2^+ \\ p_1^- \end{bmatrix} = \begin{bmatrix} T_t^+ & R_t^- \\ R_t^+ & T_t^- \end{bmatrix} \begin{bmatrix} p_1^+ \\ p_2^- \end{bmatrix} \quad (1)$$

where $p\pm$ are the pressure wave amplitudes on the upstream and downstream side of the samples. From the measured transmission and reflection coefficients of the samples, the power balance which is the ratio between the sum of outgoing power to incoming acoustic power, can be calculated. In the presentation, results will be shown comparing scattering matrix components and power balance of the two double row configurations, parallel and staggered, and the single row configuration [2]. The power balance analysis will be used to identify frequency ranges with sound reduction and sound amplification.

References

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