New Technology for America's Electric Power Industry

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Diagnosis and Control of Flow-Induced Tube Vibration in Heat Exchangers and Steam Generators

Opportunity

Flow-induced vibration and instability continue to be a source of tube failure in heat exchangers and steam generators. Vibration can cause diminished efficiency, fatigue failure, and other forms of damage, including fretting wear and impacting between tubes and supports. This can result in costly shutdowns, repairs, and even entire tube replacement. To address this problem, Argonne National Laboratory has developed a practical means for assessing the damage to heat exchanger tubing and identifying excitation sources. These sources can then be eliminated and component deformation controlled.

Description of Work

At present, it is not possible to predict the coupled tube/fluid interaction using the fundamental principles of fluid dynamics. Argonne has developed advances in applications of turbulent fluid flow theory to provide an alternate pathway for resolving practical tube wear problems. In Argonne's approach, the fluid forces that act on tube arrays in cross-flow are measured. These forces result from the individual motions of the tubes within the tube array. From the fluid forces, fluid damping and stiffness are quantified with respect to their association with coupled tube motion. A characterization of the fluid flow state is then established, based on the measured motion-dependent fluid forces. Design guides and diagnosis techniques can subsequently be provided, based on the flow characterization profile.

Benefits

Much progress has been made in the development and testing of methods for identifying the source of tube vibrations and subsequent wear problems. The end result of this work is the potential for greatly reduced heat exchanger tube repair and replacement costs. Due to the better understanding of flow-induced vibration and associated failure mechanisms, more accurate predictions can be made on the service life of the tube bundle, and replacement work can be scheduled to eliminate costly downtime.

Design Concept

Since the early 1970s, significant progress has been made toward developing a solid understanding of coupled tube/fluid dynamics. The staff at Argonne has 30 years of experience with problems in fluid dynamics and has contributed greatly to the understanding of fluid motion and wear mechanisms. However, the present state of knowledge in this area is far from complete, and this remains one of the most debated and complex topics in the area of fluid/structure interaction. Current work at Argonne targets the identification of the key elements required for application of unsteady flow theory and will provide an immediately applicable design tool for industry to use in addressing flow-induced vibration problems.

Current Status

Present investigations are focusing on the identification of motion-dependent fluid forces for various tube arrangements. Once these forces are known, the unsteady flow model can be analyzed in detail. Integrated analytical and experimental studies have been performed, using tools such as time simulation, power spectral density, and bifurcation diagrams. Tests have also been performed to investigate loosely supported tubes in heat exchangers and steam generators and to verify applications of chaos theory to flow-induced vibrational wear problems. Data obtained in these experiments continue to show consistent agreement with analytical models that have been developed to explain the interactions of tube/fluid dynamics.

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