Improved Pulse Combustion Technology

Although pulse combustion technology has been known for many years, devices using pulse combustion have not been widely implemented in spite of attractive characteristics such as high heat transfer and combustion intensity, low emissions of nitrogen oxides, high thermal efficiencies, and self-aspiration. The lack of information about fundamental fluid dynamics and combustion processes has caused the design and development of pulse combustors to proceed largely by trial and error, a method that does not guarantee an optimum design.

In a DOE-funded research effort, a wide variety of *in situ* optical diagnostics were applied to an experimental pulse combustor to elucidate reignition, unsteady valve dynamics, and the mixing and combustion processes. A simple model for combining the effects of fluid mixing time and ignition delay time (a property of the fuel used) was developed and will be incorporated into a one-dimensional, nonlinear pulse combustor model. The model incorporates valving dynamics, improved heat transfer estimates, inlet and exhaust decouplers, and a method for determining combustor resonant frequency.

In a complementary effort, the feasibility of using alternative fuels in pulse combustors was established. A modified version of a Rijke pulse combustor was successfully tested using various liquid fuels, including kerosene and No. 2 to No. 6 fuel oils. Combustion efficiencies of more than 99% were obtained when burning fuel oil No. 6.

This new understanding of pulse combustion processes will provide useful knowledge and design guidelines for the development of pulse combustion systems that may capture the inherent advantages of this technology.

Fluid-Elastic Instability in Heat Exchangers

Increasing the fluid pumping rate of shell-and-tube heat exchangers can increase the overall rate of heat transfer. However, a high rate of pumping can often generate fluid-elastic pressure waves at a frequency high enough to be close to the natural frequency of the heat exchanger assembly. When this occurs, tube vibration at high amplitudes is induced and, unless corrected, ultimately leads to heat exchanger failure.

Research in fluid-elastic instability of shell-and-tube heat exchangers was supported by DOE to provide a better understanding of the flow regimes in which an actual heat exchanger must operate to avoid structural failure. Using an instrumented laboratory setup capable of accommodating industrial-sized heat exchangers, pressure drop and tube vibration data from water-flow tests were developed. In cooperation with Heat Transfer Research, actual cases of industrial heat exchanger failures were documented and incorporated into the extensive data base.

A multidimensional flow-velocity model for numerical simulation of shell-side flow distribution was also developed for predicting tube-bundle fluid-elastic instability thresholds and pressure drop. The model was validated using the extensive data base of experimental results and documented cases of actual heat exchanger failure.

Improved understanding of fluid-elastic instability in shell-and-tube heat exchangers should lead to more reliable designs, improved heat-exchanger effectiveness, and subsequent reductions in process energy requirements. Heat exchangers are used extensively in industry, so this work should lead to substantial energy savings nationwide.

Industrial Air-Dryer Membrane

Drying is an energy-intensive process used throughout industry to remove moisture from products. Energy contained in the latent heat of the moisture-laden exhaust from these processes is lost to the atmosphere. With DOE funding, Bend Research developed a membrane-based process to recover this energy from dryer exhaust streams.

In the membrane modules, a compressor draws a vacuum on the permeate side of the membrane, reducing the pressure of the water vapor in the exhaust stream. This creates a driving force that causes the water vapor to cross the membrane. The result is a hot, relatively pure stream of water vapor that is ready to undergo conventional vapor recompression. The water vapor is then sent to a condenser and the latent heat transferred to a convenient heat sink.

The membrane-based process was successfully tested at the Crown Zellerbach paper plant in Wauna, Oregon. The process may be applied to drying a variety of products, such as fertilizer, sugar, paper, and coal. When applied to fluid-bed coal drying, for example, the membrane-based process can recover about 30%