Sonic Energy Improves Industrial Separation and Mixing Processes

Challenge

Advanced membrane separation technologies offered improvements over conventional processes, but were not being adopted in industrial operations because of the tendency of ultrafiltration membranes to foul while in service. Considering biotechnology as a case in point, while membrane filtration with micro-sized pores was the separation technology of choice, the protein solutions tended to foul the membranes during filtration. However, none of the techniques commonly used to improve ultrafilter performance, such as high cross-flow velocity, could be used with proteins.

In addition to many applications in biotechnology, enhanced membrane filtration technology has broad potential for other industrial separations processes with fouling problems, such as pharmaceuticals, cosmetics, food, chemicals, ceramics, electronic materials, bioreactors (cell culturing and microbial production), nanomaterials, and municipal water and waste treatment—as well as energetics studies.

The economical conversion of many commodity production lines to environmentally-friendly processes was limited by downstream operations to separate product from biocatalyst, rather than by the complex technology associated with the directed evolution of enzymes. New technology was needed to improve the performance of membrane separations and enable biotechnology and other industrial applications to become more economical.

Innovating Solutions

With DOE EERE SBIR support in 1999 and 2000—and follow-on DOE and other Federal agency SBIR support for specific applications—Resodyn worked to address the membrane-fouling problem by coupling filtration technology with a mechanically-driven, low-frequency acoustic resonator. This new approach—which was distinct from both conventional impeller agitation and ultrasonic mixing—involved acoustic pulses from the resonator impinging on the membrane, creating micro-turbulence near the face of the membrane to assist in keeping the flux of permeate from falling due to the buildup of a resistive gel layer.

Phase I demonstrated the enhancement of permeate flux through a 10,000 molecular weight cut-off membrane from solutions with 1 to 5 percent protein (such as pepsin). Enhancements were most pronounced for conditions with no cross-flow velocity. These are precisely the conditions in which a free enzyme bioreactor would need to function because of the detrimental effect of cross-flow shear on proteins. In Phase II, Resodyn worked to optimize the design of the membrane bioreactor for use in specific industrial processes and to further demonstrate that enzymes proposed for use in these processes are not degraded in the sonic environment. A pilot-scale modulator bioreactor was fabricated and mobilized for continuous testing of the new enzymatic-based process.

Resodyn's acoustic mixing technology works by inducing low-frequency resonant sonic energy in a fluid, resulting in an increased rate of energy dissipation per unit mass of the fluid and allowing rapid and efficient dispersion of solids, gases, and immiscible liquids. The technology is essentially a vessel with no moving parts inside and runs at approximately 60 Hertz. A patented drive system on the outside of the vessel serves as the resonant mechanical driver that radiates an acoustic energy field that mixes the vessel contents.

DOE Small Business Innovation Research (SBIR) support enabled Resodyn to develop a simple, new technology that improves membrane performance by a factor of 5 to 10 compared to conventional mixing, offering far better separations capability for a wide variety of industries and applications.

Resodyn Corporation (Butte, MT) is a small high-technology business whose objective is to develop, manufacture, and sell advanced technologies for high-value industrial processes. To this end, the firm develops new processes and technologies, leverages strategic partnerships, enters into joint ventures, and establishes the infrastructure to manufacture products with both original equipment manufacturers and direct customer sales. Resodyn relies on strategic relationships to provide insight into the technology advances within these companies and enable them to target innovation to the most important areas of growth and need.

www.resodyn.com

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"You end up in essence causing an earthquake within that material," which fluidizes it, says Lawrence Farrar, Resodyn's president, "High-acceleration loads are put on that material."

This research produced a simple new process that has been developed as an advanced mixing technology. Resodyn has been able to demonstrate the commercial viability of the technology that was developed with DOE SBIR support. Today, the company manufactures and sells a laboratory scale mixer and is on track to produce a 5-gallon and a 55-gallon version.

SBIR Impacts

Benefits of ResonantAcoustic® Mixing Technology[1]

- Suitable for mixing gases, liquids, solids, powders, or very viscous compounds (ideal for thermally-sensitive and high-value materials)
- Reduces mixing time by 80-90% yet preserves product quality—so that production cycle times can be reduced or process steps eliminated
- Uses less horsepower (hp) than impeller-type mixing—reducing energy use and expense (e.g., if the required power input for impeller mixing is around 500-700 hp, the power input for ResonantAcoustic® Mixing would be approximately 25 hp)
- Direct scaling from laboratory to production—mixing time would be approximately the same for 0.5 kg and 35 kg of material
- Mixing can occur in any container, including the original shipping container, eliminating the transfer/handling step (particularly desirable for hazardous materials or pharmaceutical compounds)
- Yields greater density by reducing the potential for gas bubbles, which can degrade the overall quality of the material being mixed
- Low localized shear and low heat generation minimize material damage
- No impellers/paddles means reduced/no clean-up or handling of potentially hazardous equipment or material by workers

Innovation

Resodyn's ResonantAcoustic® Mixing (RAM) technology employs low-frequency, high-intensity acoustic energy to create a uniform shear field throughout the entire mixing vessel. The result is rapid fluidization and dispersion of material, yielding a consistent mixture very quickly. This provides a solution for ingredients that are hard to mix—usually high-value—and where clean-up is problematic.

For example, for a propellant manufacturer routinely mixing a material with a viscosity greater than $2x10^6$ centipoise (cP)*, the benefits of using RAM would be:

- Reduced total mix time by 85% (was >24 hours)
- Reduced manufacturing labor >70%
- Eliminated handling of volatile material
- Eliminated pinch-risk from impellers
- Mix-in-case potential to eliminate cast/cure process

Of note, the technology has also been demonstrated to work well for hard-to-wet and highly viscous materials, mixing of solids, and many other applications.

* The viscosity of water is 1 cP; the higher the number, the more viscous the material.

Company Success

One of Resodyn's three main business units is now focused on designing, manufacturing, and marketing ResonantAcoustic® Mixing technology for a variety of applications.

In 2000, Resodyn's revenues were about $1.5 million, with 5 people on staff. In 2008, revenue was about $5.5 million and by the end of 2009 staff was projected to reach more than 30.

Production-scale technology for mixing commercially is now being used by customers with complex mixing applications, including the defense and chemical industries. Testing by Dow Corning using a RAM technology demonstrated that they could mix viscous materials at 100 million CP in five minutes, compared with conventional methods that could take as long as an hour and a half.

Resodyn officials estimate the market potential to be hundreds of millions of dollars, since many industries have very specific mixing needs for the substances they produce. Conventional mixing methods involving impellers would require running equipment at high speeds to produce the desired degree of gas-liquid mass transport (the movement of gas into a liquid during the mixing process)—but the high speeds of the impellers can destroy cells being mixed. Resodyn's technology, however, can produce good gas-liquid mass transport with little or no cell damage.

[1] Benefits calculations will vary widely by mixing application and volume. This listing of general benefits of the technology was compiled from the Resodyn Accoustic Mixer, Inc. website: http://www.resodynmixers.com/technologies/features-benefits.

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