LOW-FREQUENCY ACOUSTIC MIXING OF COMPLEX AND MULTIPHASE SYSTEMS

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Abstract

An advanced acoustic mixing platform technology, ResonantAcoustic® Mixing (RAM) has been developed for mixing a broad range of multiphase systems that include liquid-solid, liquid-liquid, gas-liquid and solid-solid materials. The advanced, low-frequency vibration mixing technology enables noncontact mixing of hard-to-mix materials that are both problematic and impractical to mix using state-of-the-art methods. Hard to mix materials ranging from 100's of cP to one as high as 100,000,000 cP have been successfully mixed. The mixing is enabled by the application of low frequency acoustic energy (nominally 60 Hz) applied to the vessel from 1 to 100 g of acceleration. The chaotic motions created within the mixing vessel by the RAM cause a great degree of particle to particle disorder, microcell mixing, as well as creating bulk mixing flow in the solid-solid systems.

Acoustic streaming drives mixing in the RAM for non-solid-solid systems, which creates micro-mixing cells throughout the mixing vessel. The characteristic mixing lengths for the RAM technology, operating at 60 Hz is nominally 50 microns. However, the mixing phenomena in solid-solid systems do not rely upon acoustic streaming, but upon particle collisions and the acoustic filed forces propagated throughout the mixing vessel.

A unique feature of the RAM technology is that mixing can be completed on both large and small amounts of material with the same mixing durations. For example, mixing tests that were performed on a highly-viscous material (10,000,000 cP) at two batch sizes, ½ and 120 L, respectively, each mixed for 2 minutes. From these results and for other materials that have been mixed to date, the mixing time is independent of the amount of material being mixed. The power per mass has been characterized for a few materials and it appears that the amount of energy required for mixing is proportional to the mass of material being mixed, while time remains the same. The RAM technology is designed to operate a mechanical system at resonance, which allows efficient application of energy to mix materials.

A distinctive and useful feature of the RAM technology is the ability to mix in a broad range of container configurations, e.g., custom vessels, plastic bags, shipping containers and end use containers. Depending upon the processing requirements and container design, the containers can be heated, cooled, purged, evacuated, or pressurized. Other containers that have been successfully used for mixing include five and thirty gallon shipping containers (plastic and metal).

The work presented includes an overview of the technology, systems mixed, applications, and scalability of the technology for various industrial applications. The universal nature of the RAM technology is of particular utility to the industrial mixing sector because of its ability to mix a broad range of products and systems using a singular configuration, rather than using various impeller and/or vessel configurations as is required by conventional mixing technology.

In addition, a newly developed lumped parameter mixing model has been developed to both analyze and predict mixer performance. The model simplifies the complex mixing problem containing many variables down to three mixing parameters that are determined from the mixers mechanical response.