# Ultrasonics: Applications and Processes

**Ultrasonication is used in many applications, such as homogenizing, disintegration, sonochemistry, degassing or cleaning. Below, you find a systematic overview over the various ultrasonic applications and processes.**

Please check at the items of the following list for more information on each process.

- Homogenizing
  - Dispersing and Deagglomeration
  - Emulsifying
  - Wet-Milling and Grinding
- Disintegration
  - Cell Extraction
  - Hot Water Disinfection
- Sonochemistry
  - Transesterification (Biodiesel)
- Degassing
  - Leak Detection (Bottles and Cans)
- Cleaning (Wire/Strip)

## Easy to Scale Up

Different from other dispersing technologies, ultrasonication can be **scaled up easily** from lab to production size. Laboratory tests will allow to select the required equipment size accurately. When used in final scale, the **process results are identical** to the lab results.

## Robust and Easy to Clean

Ultrasonic power is transmitted into the liquid by the sonotrode. This is a typically rotary symmetric part, that is machined from solid Titanium. This is also the only moving/vibrating wetted part. It is the only part, that is subject to wear and it can be easily replaced within minutes.

## Ultrasonic Homogenizing

Ultrasonic processors are used as homogenizers, to reduce small particles in a liquid to improve uniformity and stability. These particles (disperse phase) can be either solids or liquids. Ultrasonic homogenizing is very efficient for the reduction of soft and hard particles. Laboratory ultrasonic devices can be used for volumes from 1.5mL to approx. 2L. Ultrasonic industrial devices are used for the process development and production of batches from 0.5 to approx 2000L or flow rates from 0.1L to $20m^3$ per hour.

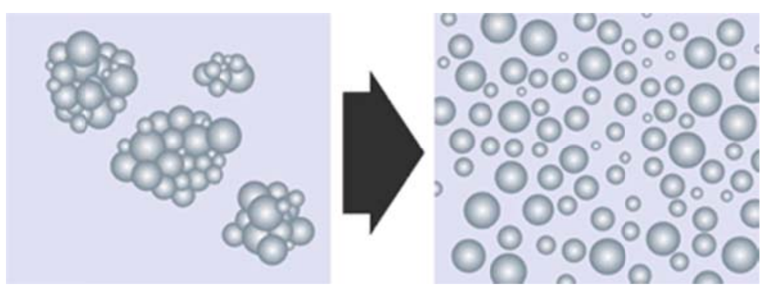
## Ultrasonic Dispersing and Deagglomeration

**The dispersing and deagglomeration of solids into liquids is an important application of ultrasonic devices. Ultrasonic cavitation generates high shear that breaks particle agglomerates into single dispersed particles.**

The mixing of **powders into liquids** is a common step in the formulation of various products, such as paint, ink, shampoo, beverages, or polishing media. The individual particles are held together by attraction forces of various physical and chemical nature, including van der Waals forces and liquid surface tension. This effect is stronger for higher viscosity liquids, such as polymers or resins. The attraction forces must be overcome on order to deagglomerate and disperse the particles into liquid media.

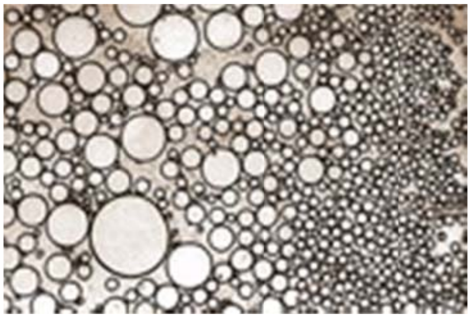
The application of mechanical stress breaks the particle agglomerates apart. Also, liquid is pressed between the particles. Different technologies are commonly used for the dispersing of powders into liquids. This includes high pressure homogenizers, agitator bead mills, impinging jet mills and rotor-stator-mixers.

High intensity ultrasonication is an interesting alternative to these technologies. When sonicating liquids the sound waves that propagate into the liquid media result in alternating high-pressure (compression) and low-pressure (rarefaction) cycles. This applies mechanical stress on the attracting electrostatic forces (e.g. van der Waals forces). Ultrasonic cavitation in liquids causes high speed liquid jets of up to 1000km/h (approx. 600mph). Such jets press liquid at high pressure between the particles and separate them from each other. Smaller particles are accelerated with the liquid jets and collide at high speeds. This makes ultrasound an **effective means for the dispersing** and deagglomeration but also for the milling and fine grinding of micron-size and sub micron-size particles.



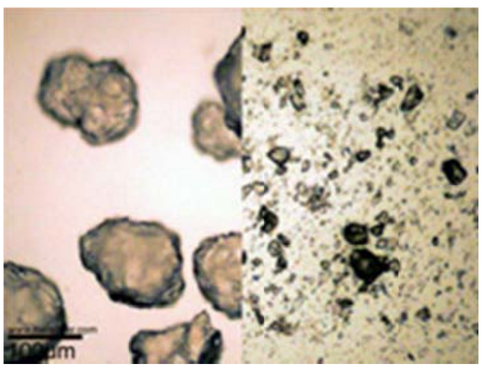
## Ultrasonic Emulsifying

A wide range of intermediate and consumer products, such as cosmetics and skin lotions, pharmaceutical ointments, varnishes, paints and lubricants and fuels are based wholly or in part of emulsions. Emulsions are dispersions of two or more immiscible liquids. Highly intensive ultrasound supplies the power needed to disperse a liquid phase (dispersed phase) in small droplets in a second phase (continuous phase). In the dispersing zone, imploding cavitation bubbles cause intensive shock waves in the surrounding liquid and result in the formation of liquid jets of high liquid velocity. At appropriate energy density levels, ultrasound can well achieve a mean droplet sizes below 1 micron (micro-emulsion).



## Ultrasonic Wet-Milling and Grinding

Ultrasonication is an efficient means for the wet-milling and micro-grinding of particles. In particular for the manufacturing of superfine-size slurries, ultrasound has many advantages, when compared with common size reduction equipment, such as: colloid mills (e.g. ball mills, bead mills), disc mills or jet mills. Ultrasonication allows for the processing of high-concentration and high-viscosity slurries – therefore reducing the volume to be processed. Ultrasonic milling is suitable for processing micron-size and nano-size materials, such as ceramics, alumina trihydrate, barium sulphate, calcium carbonate and metal oxides.



## Ultrasonic Cell Disintegration

Ultrasonic treatment can disintegrate fibrous, cellulosic material into fine particles and break the walls of the cell structure. This releases more of the intra-cellular material, such as starch or sugar into the liquid. In addition to that the cell wall material is being broken into small debris.

This effect can be used for fermentation, digestion and other conversion processes of organic matter. After milling and grinding, ultrasonication makes more of the intra-cellular material e.g. starch as well as the cell wall debris available to the enzymes that convert starch into sugars. It does also increase the surface area exposed to the enzymes during liquefaction or saccharification. This does typically increase the speed and yield of yeast fermentation and other conversion processes, e.g. to boost the ethanol production from biomass.

## Ultrasonic Cell Extraction

The extraction of enzymes and proteins stored in cells and subcellular particles is an effective application of high-intensity ultrasound, as the extraction of organic compounds contained within the body of plants and seeds by a solvent can be significantly improved. Ultrasound has a potential benefit in the extraction and isolation of novel potentially bioactive components, e.g. from non-utilized by-product streams formed in current processes.

## Sonochemical Application of Ultrasonics

Sonochemistry is the application of ultrasound to chemical reactions and processes. The mechanism causing sonochemical effects in liquids is the phenomenon of acoustic cavitation. The sonochemical effects to chemical reactions and processes include increase in reaction speed and/or output, more efficient energy usage, performance improvement of phase transfer catalysts, activation of metals and solids or increase in the reactivity of reagents or catalysts.

The following sonochemical effects can be observed in chemical reactions and processes:

- Increase in reaction speed
- Increase in reaction output
- More efficient energy usage
- Sonochemical methods for switching of reaction pathway
- Performance improvement of phase transfer catalysts
- Avoidance of phase transfer catalysts
- Use of crude or technical reagents
- Activation of metals and solids
- Increase in the reactivity of reagents or catalysts
- Improvement of particle synthesis
- Coating of nanoparticles

## Ultrasonic Transesterification of Oil to Biodiesel

Ultrasonication increases the chemical reaction speed and yield of the transesterification of vegetable oils and animal fats into biodiesel. This allows changing the production from batch processing to continuous flow processing and it reduces investment and operational costs. The manufacturing of biodiesel from vegetable oils or animal fats, involves the base-catalyzed transesterification of fatty acids with methanol or ethanol to give the corresponding methyl esters or ethyl esters. Ultrasonication can achieve a biodiesel yield in excess of 99%. Ultrasound reduces the processing time and the separation time significantly.

## Ultrasonic Degassing of Liquids

Degassing of liquids is an interesting application of ultrasonic devices. In this case the ultrasound removes small suspended gas-bubbles from the liquid and reduces the level of dissolved gas below the natural equilibrium level.

The degassing and defoaming of liquids is required for many purposes, such as:

- Sample preparation **before particle size measurement** to avoid measurement errors
- Oil and lubricant degassing **before pumping** to reduce pump wear due to cavitation
- Degassing of liquid foods, e.g. juice, sauce or wine, to **reduce microbial growth** and increase shelf life
- Degassing of polymers and varnishes before application and curing

When sonicating liquids, the sound waves that propagate from the radiating surface into the liquid media result in alternating high-pressure (compression) and low-pressure (rarefaction) cycles, with rates depending on the frequency. During the low-pressure cycle, the ultrasonic waves can create small vacuum bubbles or voids in the liquid. The large number of small bubbles generates a high total bubble surface area. The bubbles are also well distributed in the liquid. Dissolved gas migrates into these vacuum (low pressure) bubbles via the large surface area and increases the size of the bubbles. The acoustic waves support the touching and coalescence of adjacent bubbles leading to an accelerated growth of the bubbles. The sonication waves will also help to shake bubbles off vessel surfaces and will force smaller bubbles resting below the liquid surface to rise through and release the entrapped gas to the environment.

## Ultrasonic Cleaner in Place

Ultrasound is well known for its cleaning applications, such a surface, part cleaning. The ultrasonic intensity used for dispersing applications is much higher than for typical ultrasonic cleaning. When it comes to the cleaning of the wetted parts of the ultrasonic device, the ultrasonic power can be used to **assist cleaning** during flushing and rinsing, as the ultrasonic **cavitation removes particles** and liquid residues from the sonotrode and from the flow cell walls.