Ultrasonic Cleaning Primer

Theory of Ultrasonics

Ultrasonic cleaning methods are based on the intense agitation of countless bubbles in a cleaning liquid, called "cavitation". When an item is submerged in this solution, cavitation offers highly effective cleaning for both hidden and difficult to reach surfaces. Higher cavitation frequencies are ideal for particle removal without causing damage to substrates.

There are three main components of any ultrasonic cleaning system: a tank for the cleaning liquid, a transducer to convert electrical energy to mechanical energy, and an ultrasonic generator to provide a high frequency electrical pulse.

Transducer and Generators

Essential to any ultrasonic cleaning system, there are two types of transducers: magnetostrictive (nickel or alloys) and electrostrictive (lead zirconate titanate or ceramics). The dimensions of electrostrictive materials are altered when placed in an electrical field of varying voltage, a phenomenon known as the "piezoelectric effect". Magnetostrictive transducers, on the other hand, are constructed of materials that change physical dimensions when placed in a varying magnetic field.

The common factor between the two types of transducers is the intensity of cavitations. Like any sound wave, ultrasonic energy is actually a series of compressions and rarefactions. If sound energy is sufficiently intense, the liquid will be pulled apart during rarefaction, forming small cavities or bubbles. As bubbles collapse and implode throughout the liquid, an extremely effective cleaning force is created, capable of achieving pressure greater than 10,000 psi and temperatures in excess or 20,000°F. With many millions of bubbles collapsing every second, the cumulative effect of cavitation offers intense scrubbing action and accelerates the rate at which surface films are dissolved.

Cavitation is possible only when liquid pressure is reduced to a value lower than its vapor pressure, and thus there must be sufficient power generated by the transducer. The threshold of cavitation refers to the minimum amount of power necessary to achieve cavitation for a particular type of liquid. Only the ultrasonic energy above the threshold contributes to production of cavitation bubbles and thus the process of ultrasonic cleaning.

Above the threshold level, ultrasonic energy increases will result in higher cleaning efficiency, but only to a point. Once the liquid reaches a certain level, it becomes incapable of accepting power increases and the liquid will become elastic – reducing or eliminating further transmission of energy. This is called surface cavitation.

Likewise, there is a threshold below which cavitation will not occur. However, once cavitation occurs, the energy level can be reduced below this threshold and cavitation will be maintained. The sonic range over which cavitation can exist between threshold and maximum frequency is usually a distance of no more than a ratio of 2 or 3 to 1. A tank with only a small volume of liquid over the transducer, for instance, is subject to surface cavitation at very low levels. On the contrary a deep or heavily loaded tank requires a greater level of power for surface cavitation to occur, as well as to achieve an effective level of cavitation for cleaning purposes.

Importance of the Frequency

Noise becomes an issue when the operating level is low, or within the audible range. Below 20 kHz, operating noise may even exceed maximum safety limits as specified by the Occupational Safety and Health Act and other regulatory statutes. Lower, 20-30 kHz frequencies are generally selected for applications which require a higher power level to remove soils from large or heavy parts, or smaller dense parts.

Often used to clean smaller, delicate parts or to remove small particles, higher frequencies are utilized in applications sensitive to damage. There are key factors contributing to improved performance at higher frequencies. The number of cavities increases linearly with an increased frequency, capable of reaching into small areas with a more intense scrubbing action. Size and energy contained in each cavity is reduced when power is held constant, which minimizes potential damage to substrates.

Why an Ultrasonic System?

Ultrasonic cleaning provides many advantages:

- Precision – Because it efficiently penetrates cavities and crevices, ultrasonic energy can clean unlimited types of parts, and is often the only cleaning method that meets specifications.
- Speed – Faster than other cleaning methods, ultrasonic systems quickly remove soils and contamination, cleaning entire assemblies without dismantling.
- Consistency – Whether the pieces to be cleaned are simple or complex, large or small, ultrasonic cleaning offers an unrivaled level of consistency.

Selecting a Cleaning Process and Cleaning Solutions

An application analysis should be performed on parts to be cleaned prior to purchasing an ultrasonic system. This analysis should consider materials of construction, quantity of parts, soils to be removed, and both aqueous and solvent cleaning approaches. This step is vital to ensure an appropriate ultrasonic cleaning system is provided.

Choosing Chemistry

Though all physical properties of a liquid directly affect the ultrasonic cleaning process, vapor pressure, surface tension, viscosity and density have the greatest impact. Because temperature also affects these physical properties, it has an influence on effectiveness of cavitation as well.

Studies have demonstrated that high density, low viscosity, and mid-level surface tension and vapor pressure present the ideal conditions for intense cavitation. Due to temperature effects on these physical properties, the most intense cavitation will occur well below the liquid's boiling point, but not so low as to create low vapor pressure or high surface tension. Each liquid has a different level of optimal cavitation intensity due to different rates of change in temperatures.

An ultrasonic cleaning system should be designed for use specifically with a particular cleaning solution. Aqueous systems typically consist of open tanks which allow parts to be immersed, and a complex system may contain several tanks, recirculating pump and filter systems, rinse and drying stages and other accessories.

Often, systems designed for use with solvents such as vapor degreasers incorporate a means to reclaim the contaminated solvent. Warm solvent vapors coupled with ultrasonic agitation thoroughly removes oil, grease, wax and other solvent soluble soils, with the products emerging from the ultrasonic system clean and dry.

In selecting a proper cleaning solution, several factors should be considered:

- **Effectiveness –** Experimentation may be necessary in choosing the most effective cleaning solution for your application.
- **Simplicity of Use –** Liquids should be evaluated in terms of safety, longevity and simplicity of use.
- **Cost –** A less expensive cleaning solution is not always the most economical choice. Factors including effectiveness, safety, and consistency should all be considered.

Parts Handling

Basket design is another concern in the selection of an ultrasonic cleaner. The design of the basket or containers for holding parts should also be considered, as neither the parts nor the basket should be on the tank bottom. The sum of the parts' cross-sectional areas should not exceed 70% of the tank's cross-sectional area. Incorrect design, or a basket with too high a mass, can negatively impact the performance of even the best ultrasonic cleaning system. If the basket is woven more tightly than 50 mesh screens, it will act as a solid while openings greater than one-quarter inch act as open material.

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