Specifying an Ultrasonic Cleaning System

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Precision cleaning has taken on new importance over the last several years. Increased quality awareness, a trend toward miniaturization, and the use of more sophisticated surface finishes have all focused more attention on the need for improved part-cleaning practices.

Cleaning, in its broadest sense, is almost always a combination of the right chemistry and some kind of mechanical enhancement. For gross cleaning, soaking with agitation is often sufficient. For components that have simple geometries and can be handled individually, mechanical brushing is often effective. Spray cleaning systems are ideal when their directional nature does not create shadowing or other similar problems.

One technology has proven to be very effective in meeting these new manufacturing challenges—ultrasonics. This technology has been actively used in industry for production part cleaning since the 1950s. It has, however, undergone significant evolution to stay ahead of the increasing cleanliness demands of the market. The following paragraphs discuss the physics of ultrasonics, the basic components of an ultrasonic cleaning system and their key attributes, and how to specify equipment appropriate to your application.

BASIC PRINCIPLES

It is useful to understand how an ultrasonic cleaning system works in order to optimize its performance. An ultrasonic generator (see Fig. 1) produces a high-frequency alternating electrical signal, which is applied to a transducer. The transducer has a unique design that causes it to expand when exposed to a positive electrical signal and contract when exposed to a negative signal (see Fig. 2). This expansion and contraction, when introduced into a liquid, is sound. If the frequency is above 18,000 cycles per second it cannot be heard and is called "ultrasonic." As the sound passes through the liquid, it creates areas of high pressure and areas of low pressure. If there is sufficient ultrasonic energy in the liquid, the low-pressure areas drop below the vapor pressure of the liquid, and the liquid is pulled apart creating many microscopic cavities. Subsequent high-pressure areas force these cavities to collapse releasing high levels of "explosive" energy. It is these microexplosions that produce the high levels of cleanliness associated with ultrasonics. This process is called cavitation (see Fig. 3).

Ultrasonic cleaning generates a number of specific advantages for the user. Because it is based on sound, it is omnidirectional; effective cleaning will occur anywhere the cleaning chemistry and the ultrasonics penetrate. This makes it ideal for cleaning parts with cracks, crevices, and blind holes. The intense mechanical activity right at the surface of the part almost always makes ultrasonic cleaning the fastest method. Its ability constantly to bring fresh chemistry to the part also contributes to faster cleaning. Unlike many other cleaning methods, ultrasonics produces results on the part without direct operator intervention in the process. This leads to greater cleaning consistency over time. The effectiveness, speed, and consistency over time all contribute to higher process yields and better field reliability of the products cleaned.

SYSTEM COMPONENTS

There are three basic components of any ultrasonic cleaning system: a tank to hold the chemistry, a generator to create high-frequency electrical energy, and a transducer to convert that electrical energy to mechanical (sound) energy.

A number of parameters that should be considered in specifying a cleaning system for use with ultrasonics will be presented later here. Although all of the items may not pertain to your specific application, each should be considered.

Tank

Construction

Whenever possible tanks should be constructed from 300 series stainless steel. This is resistant to attack by most commercially used cleaning chemistries and stands up well to ultrasonics (see Fig. 4). Material should be a minimum of 14 gauge up to 35 gal and at least 12 gauge above 35 gal. Heliarc welding is preferred for its smoothness and integrity.

Finish

For production cleaning applications a standard 2B mill finish is generally acceptable. In higher precision applications, such as cleaning components for high-reliability electronics or optics, mirror-finished, bright, annealed stainless material is often preferred. If the soil being removed is abrasive (buffing or polishing compounds) or if you will not be using chemistry in the water, consider a hard chromium coating on the surface radiating the ultrasonics.

Size

Tank size should be specified in inches of length, width, and depth needed as free area. The specified size should encompass a volume roughly twice the volume of the parts basket or the part actually being cleaned.

Mounting

Tanks up to 35 gal are often designed to sit on a countertop or to be suspended through one. Tanks can also be designed as free-standing consoles on a common frame with support equipment such as filtration systems.

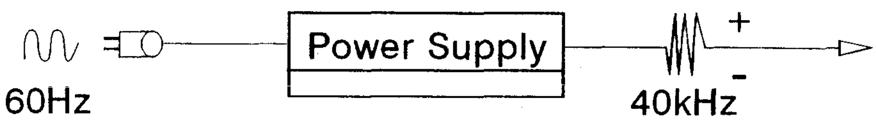

Figure 1. Ultrasonic generator converts 220 V 60 Hz power to 1,500 V 40,000 Hz.

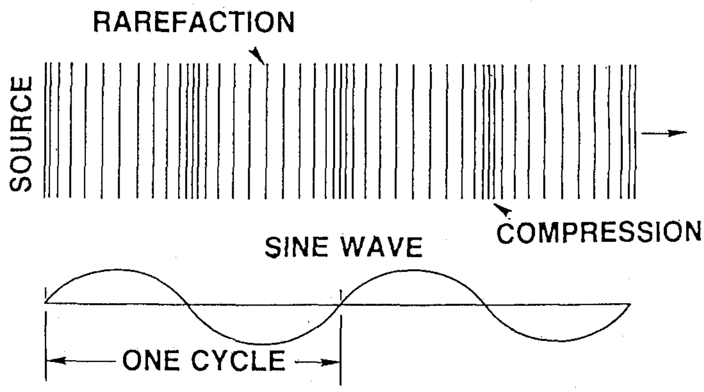

Figure 2. The transducer expands when exposed to a positive signal and contracts when exposed to a negative signal, creating sound waves.

This is the most common implementation on tanks over 35 gal.

Heat

In most applications heat is desirable because it enhances the activity of both the ultrasonics and the chemistry. It should be thermostatically controllable from ambient to 250°F. Up to 10 gal, 200 W/gal is typical; over 10 gal, the requirement drops back toward 100 W/gal. Heaters are generally external to the tank up to 3,000 W. After that, immersion heaters, which extend directly into the cleaning liquid, are usually specified.

Filtration

Recirculation systems with filtration are specified when high levels of particulate are anticipated. These systems can extend bath life significantly and often pay for themselves very quickly. It is necessary to specify the retention level of the filter cartridge. This should be open enough that filters are not changed too often and closed enough to retain particles that can be damaging to the process. Ten-micron retention is a good place to start. Pump flow rates generally should be specified to turn the volume of the tank about four times per hour. Higher rates should be used if soil loading is heavy or if the application requires critical cleanliness.

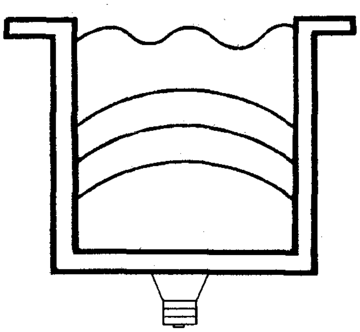

Figure 3. Mechanical energy at 40,000 vibrations per second is introduced into a liquid by a transducer mounted on the bottom of a tank, producing cavitation.

Fittings

All tanks should have drains; some require fill connections. Drains should be sized to drain the tank in a reasonable period of time. One-half in. would be the minimum. Fill connections should be at least one National Pipe Thread (NPT) size smaller than the drain to prevent overflow situations.

Options

There are many possible options to meet specific process needs. Some to consider include covers to retain heat or keep airborne debris out of the tanks, liquid level controls to protect heaters or ultrasonics, workrests to protect the ultrasonic radiating surface, and insulation to retain heat and save energy.

Transducers

Type

There are two basic types of transducers—magnetostrictive and piezoelectric. Magnetostrictive transducers use magnetism to create sound and to operate from 18 to 30 kHz. Piezoelectric transducers (see Fig. 5) use alternating voltage to create sound and to operate from 25 to 800 kHz. Frequencies up to 30 kHz are generally preferred for high-mass parts, whereas frequencies above 30 kHz are most often used for more critical cleaning. As a general statement, the higher the frequency, the smaller the particle that can be effectively removed.

Number

The number of transducers, per se, is not critical. Different manufacturers approach the issue differently, and the number can vary and still produce effective cleaning. There are, however, two factors that are important. First is the Watt density of the ultrasonics. Except for very specialized applications, there should be a minimum of 20 to 25 W of ultrasonic output power per U.S. gallon. Output power is quite difficult to measure accurately. Many companies specify input power assuming an 80 to 85% conversion efficiency. Secondly, the transducers should be distributed over the radiating surface so that sound is transmitted uniformly into the cleaning solution. This second factor tends to increase Watt density on smaller systems.

Mounting

Transducers may be bonded directly to the outside bottom or the side wall of a cleaning tank. This method is generally used on systems up to 40 to 50 gal. An alternate mounting method is to bond the transducers into hermetically sealed boxes, which are then immersed into the tank (see Fig. 6). This method is preferred for larger tanks for maintenance reasons or to retrofit an existing tank with ultrasonics. Most manufacturers have adopted epoxy for the bond between the transducer and the radiating surface, as it provides a uniform junction without airgaps. This

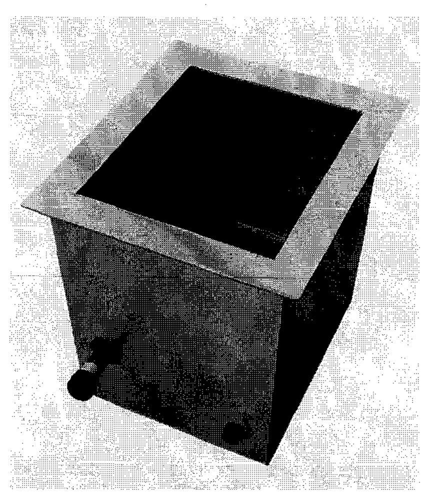

Figure 4. Tank for ultrasonic cleaning.

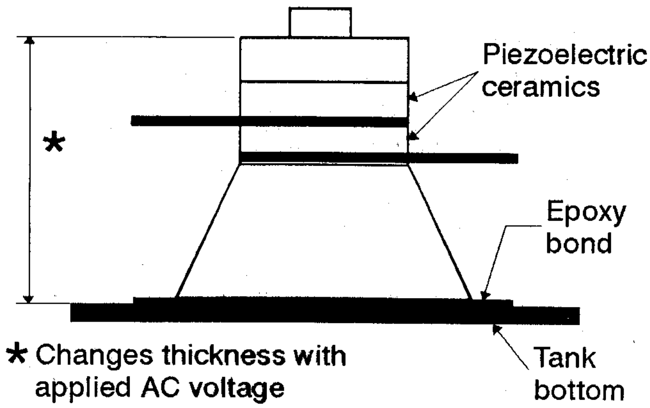

Figure 5. Schematic of a piezoelectric transducer.

is a critical area for reliability, and bonds should be well guaranteed by the manufacturer.

Generators

Power

The maximum output power of a generator in Watts must be matched to the input power of the transducers being driven. Because transducer power is selected based on tank volume, in effect, so is the maximum generator power.

Power Level Control

Most modern ultrasonic generators have provisions to vary the output power. This allows the power to be better matched to the specific application. Some applications require full power to clean, whereas others use reduced power to prevent damage to the parts. Some generators reduce average power by turning the ultrasonic signal off for a brief part of the cycle. This averaging is less effective than reducing overall power amplitude, as delicate parts will still see full power for some part of the cycle and may be damaged. A power indicator is an important feature so that process parameters can be monitored and adjusted as necessary.

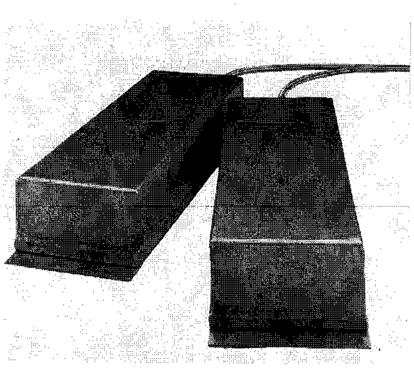

Figure 6. Transducers can be hermetically sealed into boxes and immersed into the tank.

Power Regulation

An ultrasonic generator should have provisions to assure that the selected power level is maintained regardless of changes in input voltage, liquid level, temperature, tank loading, or other process variables. As process requirements become more critical, control should be specified in the 3 to 5% range to assure results as determined in application testing.

Frequency Control

Like power levels, the basic frequency of the generator must match the frequency of the transducers. Generators should have an autotuning feature to assure that the frequency is optimized in spite of changes in bath temperature, liquid level, or tank loading.

Sweep Frequency

This feature "sweeps" the frequency of the generator across a 1 to 2 kHz bandwidth around the basic frequency. This tends to homogenize the sound intensity throughout the tank, leading to more uniform cleaning. Some generators also include the ability to vary the sweep rate, which can improve cleaning, particularly with chemistries that are hard to cavitate.

Packaging

Generator packaging should be designed to keep the circuitry clean and dry. All generators require air for cooling. This should be done in such a way as to exclude airborne contaminants, including moisture, from sensitive electronics. The package should have a broad enough base to be stable if standing alone. Some manufacturers offer standard 19-in. rack-mount packages so that generators may be added to existing enclosures.

Annunciators

The increased control circuitry and the greater range of capabilities on modern generators have led to a greater need for process status indicators. The number and type of indicators should be matched to the complexity of your application. Areas to consider are power on, power level, sweep on, sweep rate, for process control, and over temperature and over current for safety.

Approvals

For operator safety generators should be constructed in accordance with some electrical code, such as National Electrical Code (NEC), and should also meet some safety standard, such as Underwriters Laboratory (UL), ETL Testing Laboratories, or Canadian Standard Association (CSA). Because all ultrasonic generators operate at radio frequencies, they must be tested and meet Federal Communication Commission (FCC) regulations. Regulations should be considered for equipment going overseas, as they vary widely by country.

Options

One option that is often offered and should be considered is remote operation of the generator. Sometimes this is just the on/off function, which permits full control of all functions from a remote location. This is particularly useful in a systems environment.

CONCLUSION

Specifying an ultrasonic cleaning system can be a challenge, especially given the broad range of variables associated with any specific application. Hopefully, the foregoing information will help focus on some of the key areas to consider. In addition, early contact with prospective equipment and chemistry vendors is encouraged. You will find them both cooperative and helpful as they have a vested interest in your success. **MF**