Ultrasonic Applications

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In providing contract-cleaning services, many different types of contaminated parts arrive for cleaning. Once onsite, the parts must be evaluated to determine the optimum cleaning process in terms of effectiveness of cleaning and without damage to the parts. The available cleaning tools are chemical and physical processes, which are typically used in combination. Figure 1 illustrates available cleaning options.

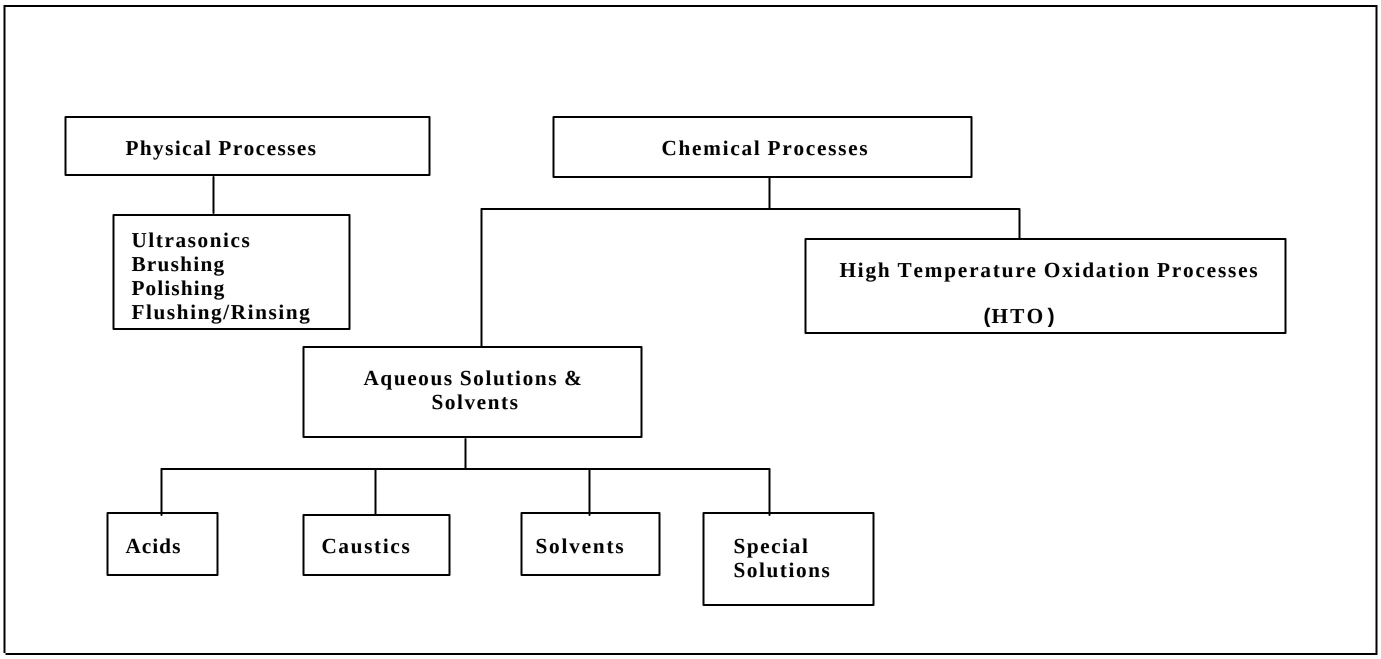

Figure 1: Parts Cleaning Options

Regardless of the type of part and contaminant, the cleaning procedures are usually broken down into gross contaminant removal, polishing, rinsing, and drying. Although drying is an essential and important part of most procedures, the primary focus of this discussion is cleaning; therefore, drying processes will not be discussed.

When developing a cleaning procedure, understanding how the cleaning tools in Figure 1 can be used, or should not be used, will determine whether the process results in effective cleaning and/or damage to the parts being cleaned. *During gross contaminant removal*, it is necessary to realize that this step should be designed to remove large amounts of mainly exterior contamination. The final *polishing* steps can then be used to remove attached scale and, possibly, hidden, microscopic residuals. Regardless of the methods and cleaning tools used, *rinsing* away contaminants as they are loosen and/or released from the part is essential.

Methods used for *gross contaminant removal* will depend on the substrate and the contaminant. For example, if the substrate is metallic, the metallurgy may restrict the cleaning chemicals and/or processes so as not to damage or corrode the metal. The chemical composition of the contaminant will determine removal methods. For example, if the contaminant is organic, then consideration must be given to solubility and reactivity with solvents and/or solutions, or possibly, high temperature oxidation processes, such as ovens. If the part being cleaned has light particulates or oils attached to the surface, then ultrasonics may be used in the initial cleaning step.

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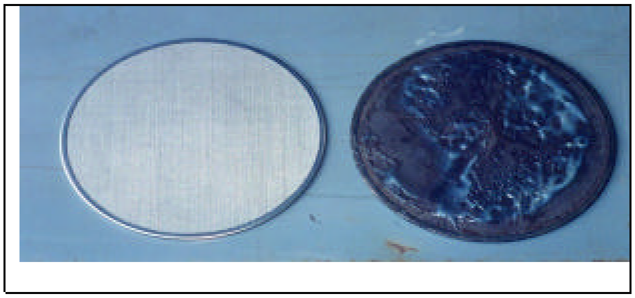

Figure 2: Clean and "grossly" contaminated screens

For the *polishing step*, it is assumed that the only remaining contaminants are whatever could not be dissolved, reacted, burned, or flushed off of the part. However, the residuals could be insoluble precipitants or scale formed from reactions between contaminants & cleaning chemicals. For example, when removing organic scale from a part using a permanganate solution, an insoluble manganese dioxide powder is formed. The powder may be attached to the surface or within small crevices and openings within the part. Since chemical and flushing processes may not be able to successfully remove the trapped particles, a more focused approach may be needed – such as ultrasonics.

During and after cleaning steps, thorough *rinsing* is important. If a chemical process is used in the cleaning, all cleaning chemicals must be removed. If ultrasonic cleaning was used to loosen or break up particles, the residuals must be removed. High-pressure spray, flushing, and ultrasonic rinses are possible options. High-pressure sprays and flushing work well on parts such as pipes and porous cartridges or filters. However, if chemicals, gels, or loosened particles have to be rinsed out of 100µm jet capillaries, a series of ultrasonic rinses could provide the energy and scrubbing action needed to allow rinse liquids to penetrate the small openings.

If ultrasonics is required as a part of the any of the process steps, it is usually because energy is needed to do one or more of the following:

1. "break" large particles into smaller particles
2. "push" cleaning fluids or rinsing liquids into small crevices and openings
3. "scrub" a surface – whether on the exterior of a part or within the structure of the part

Once it is determined that ultrasonics must be used, decisions must be made as to how to setup the process – taking the following factors into consideration:

1. <u>Frequency/power:</u> The type of surface, openings, crevices, and substrates must be considered so that the cavitation provides enough energy to remove the contaminant but not enough to damage the substrate. For example, a 20 KHz ultrasonic unit can be used in cleaning capillaries in a 9"Dx1.5"T spinneret, where as, the same ultrasonic unit could possibly destroy the cell walls on a laser-engraved ceramic gravure roll. In some cases, there are instances where cavitation of the bubbles is not necessary. Instead, "streaming" of the bubbles, energized by the ultrasonic wave along a surface provides a more gentle scrubbing action than with cavitation. Such a situation is seen where sweeping or 100+ KHz frequencies are used on fragile surfaces.
2. <u>Solution/concentration:</u> Knowing the composition of the contaminant and how it is attached to the part will determine whether to use acids, bases, etc. The concentration of the solution will aid in providing cleaning action. Maintaining the correct concentration is important when the purpose of the ultrasonics is to "push" chemicals into crevices & openings so that contact can be made with the contaminant. For example, cross-linked silicone coatings within a 6BCM gravure roll cell, require a particular caustic concentration. If the concentration falls below the optimum value, removal of the cross-linked substance may or may not take place even at extended run times. In another case, if free iron is to be removed from fine screens, certain acid solutions are more appropriate than alkaline solutions.
3. <u>Temperature</u>: Temperature affects the size and formation of the cavitation bubbles. Without proper cavitation, energy will not be provided to "break, push, or scrub" a part. Unless the unit is operating in the optimum temperature range, the cavitation bubbles will not grow to the point of providing the expected energy release upon implosion. It is the "implosion" energy that is "breaking, pushing, or scrubbing" the part. For example, as the temperature of the solution rises to 200°F or higher, water vapor bubbles begin to form. Since these bubbles are formed from energizing the water with heat to the point of vaporization, the vapor (high-pressure) bubbles contain more energy that what is supplied by the compressions within the ultrasonic wave. As a result, the water vapor molecules do not implode to release the needed

cleaning energy. Also, because of the internal heat energy within the bath medium, there is more of a potential to form the water vapor (high pressure) bubbles than the cavitation (low pressure) bubbles which decreases the cleaning potential from ultrasonics. Temperatures in the range of 140°F-180°F are optimum for most cleaning applications. Whether the lower or higher part of the range is used depends on the contaminant, frequency, and type of chemistry being used.

4. Part orientation: In an operating ultrasonic tank, the entire liquid medium is energized and has cleaning potential, but with differences in intensity. However, depending on the volume of the tank and the load, it may be important for the surface being cleaned to be close to and "facing" the radiating surface of the transducers. Also, it may be important to have parts positioned to facilitate the removal of particles knocked loose by the cavitation. For example, a spinneret capillary receives maximum effect from the cavitation when the face of the spinneret "faces" the radiating surface. Having the capillary in a vertical position relative to a horizontal transducer also allows gravity to aid in removing loosened particles from the capillary walls. Since the diameter and shape of a capillary in a spinneret, jet, or die may change from the counterbore (upstream side) to the capillary (downstream side), it is advisable to expose both the capillary and counterbore sides to the ultrasonics. Particles, trapped on the counterbore side, may not be seen from the capillary side.
5. Time: The purpose for ultrasonics in any process step must be considered in determining the time required for cleaning. If implosion of the cavitation bubbles is required to "push" cleaning chemicals into small openings and crevices, then added time may be necessary to allow enough chemicals to come in contact with the contaminant. An example would be pushing alkaline solutions into the silicon-filled 6 BCM pores on the surface of a ceramic roll. Depending on the size of the roll, the cleaning could take several hours. If attached particles were the reason for using ultrasonics, then the time required to "break" the particles up or away from the surface would be measured in minutes.

It is important to note that all of the above parameters must be considered and optimized when using ultrasonics as a cleaning tool. For example, if the solution chemistry is not correct or not concentrated enough, longer processing times may be required. However, long process times will increase labor costs, wear on the equipment, turnaround for the customer, and possibly the potential for damage to the parts. So, it is important to optimize all parameters when ultrasonic cleaning is part of the process.

Given below are examples of how ultrasonics can be used in cleaning applications.

EXAMPLE 1: Screens

In the case of screens, ultrasonics in a chemical bath will "push" the chemicals into spaces between wires in woven or non-woven screens so that appropriate reactions can take place. Also, cavitation would aid in loosening or removing solids attached to the wires and fibers. Soaking or spraying would not allow water to penetrate into the small openings. Figure 3 shows an assortment of woven and non-woven screens. In Figures 4 & 5, microscopic photographs show how the wires and metal fibers are arranged in the woven & non-woven meshes.

Screen cleaning applications generally include ultrasonics during the initial contaminant removal and/or during rinsing. Just as it is important to remove particles that the ultrasonic energy has loosened, it is also important to remove chemicals that may have collected between the wires and fibers. Using a sequence of ultrasonic rinses combined with flushing can provide thorough rinsing of the screens.

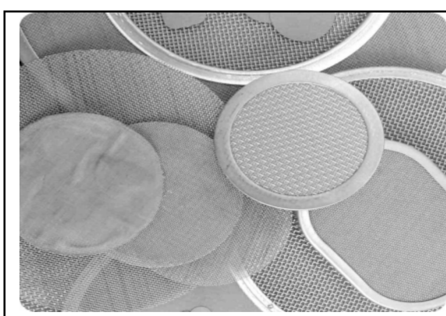

Figure 3: Screen assortment

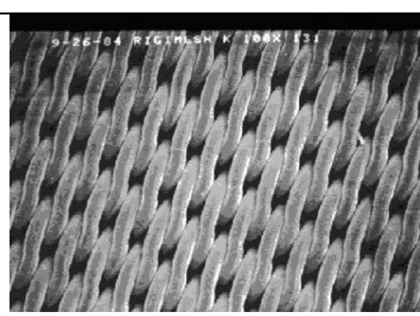

Figure 4: Woven wire mesh media

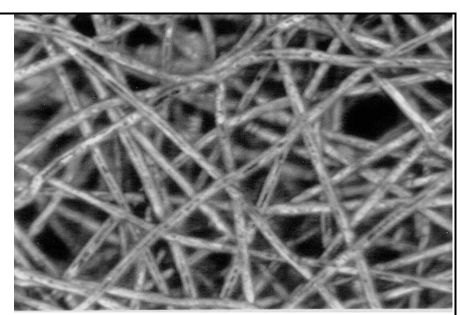

Figure 5: Non-woven fiber metal media

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In Figures 6 & 7, contamination can be seen on the screen wires & fiber metal. A 20KHz ultrasonic unit charged with an alkaline detergent solution was used at ~170°F. After processing the screens in the initial chemical solution, they were rinsed with DI water followed by an ultrasonic rinsing and flushing with DI water.

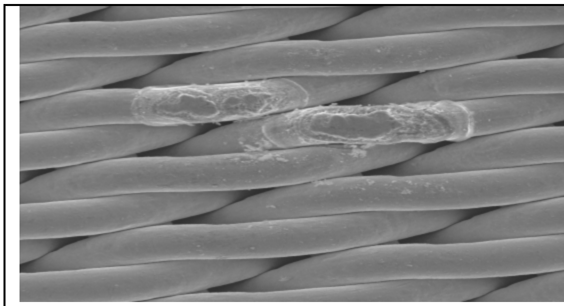

Figure 6: Contaminant on wire mesh media

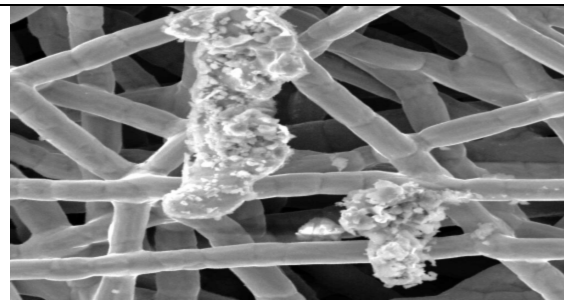

Figure 7: Contaminant on fiber metal media

Example 2: Spinnerets

Figures 8-10 show the progression of a spinneret capillary as it goes through the cleaning process. The spinneret has not been through any cleaning in Figure 8. After a burnout process, Figure 9 shows the particles still attached to the surfaces. Improvement in particle removal can be seen in Figure 10 after the spinneret was processed in a 20KHz ultrasonic unit charged with an acid/surfactant solution.

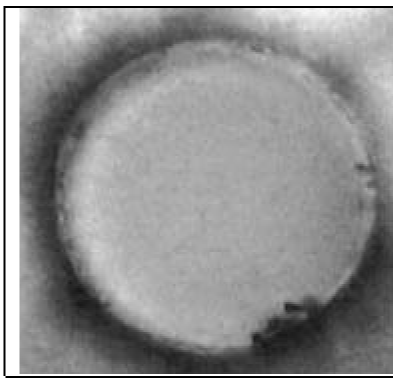

Figure 8: Dirty spinneret hole

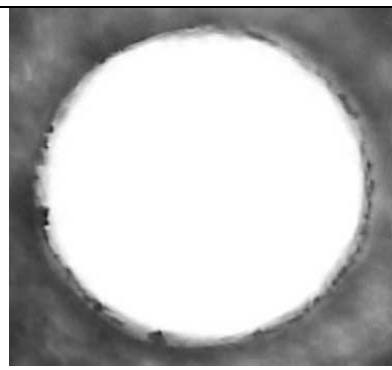

Figure 9: Spinneret hole after oven burnout

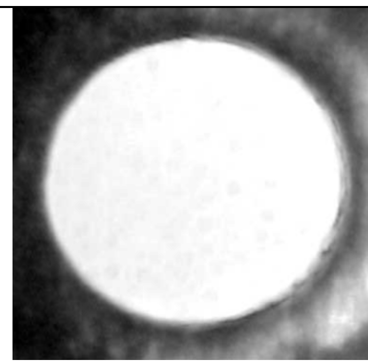

Figure 10: Spinneret hole after ultrasonics

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Biography

Sue L. Reynolds, Vice President/Technology and Senior Chemist, has been with Carolina Filters for 13 years. Her major duties include technical field support, process development and engineering, and technical support for the production facility. She has a Bachelors Degree in Chemistry from Winthrop University and a Masters Degree in Mathematics from the University of South Carolina.