An Explanation of Ultrasonic Cleaning

Ultrasonic cleaning is a result of sound waves introduced into a cleaning liquid by means of a series of "transducers" mounted to the cleaning tank. The sound travels throughout the tank and creates waves of compression and expansion in the liquid. In the compression wave, the molecules of the cleaning liquid are compressed together tightly. Conversely, in the expansion wave, the molecules are pulled apart rapidly. The expansion is so dramatic, that the molecules are ripped apart creating microscopic bubbles. The bubbles are not seen by the naked eye since they are so small and exist for only a split second of time. The bubbles contain a partial vacuum while they exist. As the pressure around the bubbles become great, the fluid around the bubble rushes in, collapsing the bubble very rapidly. When this occurs, a jet of liquid is created that may travel at this very high rate. They rise in temperature to as high as 5000 degrees C, which is roughly the temperature of the surface of the sun. This extreme temperature, combined with the liquid jet velocity provides a very intense cleaning action in a minute area. Because of the very short duration of the bubble expansion and collapse cycle, the liquid surrounding the bubble quickly absorbs the heat and the area cools quickly. As a result, the tank and liquid becomes only warm and does not heat up due to the introduction of parts during the cleaning process.

The Application of Ultrasonic Cleaning

Many articles exist describing "how ultrasonic cleaning works". The goal of this article is to help develop an understanding of the various components that ensure good ultrasonic cleaning.

First, establish a cleaning need, along with a determinantion as to how to measure the level of cleanliness. A few examples of measuring cleanliness include various levels of particle count, miscroscopic inspection, and a variety of adhesion tests, including the clear tape test that has the ability to remove additional contamination. These are just a few examples of cleanliness measurement.

There are seven major concerns related to successful ultrasonic cleaning:

1. **Time**
2. **Temperature**
3. **Chemistry**
4. **Proximity to the transducer/part fixture design**
5. **Ultrasonic output frequency**
6. **Watts per gallon**

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Loading - the volume (configuration) of the part being cleaned

TIME:

Typical cleaning times may vary tremendously - how dirty is the part and how clean is clean.
As a place to start, a normal trial period is two to ten minutes, since very few parts are sufficiently clean within a few seconds. Ultrasonic cleaning is not just a quick dip and zap, it's clean. Pre-cleaning may be required to remove gross contamination or to chemically prepare the parts for a final clean. Some applications require more than one ultrasonic cleaning stage to complete the required cleaning. Ultrasonic agitated rinsing is required in some cases to more thoroughly remove the wash chemicals.

TEMPERATURE/CHEMISTRY:

Temperature and chemistry are closely related. Generally, ultrasonic cleaning in an aqueous solution is optimum at 140 degree F. Some high pH solutions will require the temperature to be higher to enhance the synergistic effect of the chemistry. The chemical pH is a good place to start; however, chemistry is not the subject of this article.

The following should be considered the main components of aqeous ultrasonic cleaning chemistry:

A. Water - hard, soft, DI or distilled
B. pH
C.
Surfactants
Wetting agents
Dispersants
Emulsifiers
Saponifiers
D.
Optional ingredients
Sequestrants
Inhibitors
Buffering agents
Defoamers

The chemical formulation must consider all of the above characteristics.

Some chemicals that are designed for spray cleaning, or that include rust inhibitors, are not suitable for ultrasonic cleaning.

PROXIMITY TO THE TRANSDUCER:

The procedure for ultrasonic cleaning is generally as follows: Put parts in basket and place basket through three or four process steps; ultrasonic wash, spray rinse (optional), immersion rinse, dry. Some parts loaded in baskets can mask or shadow from the radiated surface of the ultrasonic transducers. Most ultrasonic cleaning systems are designed for specific applications. Bottom-mounted transducers or side-mounted transducers are decided upon during the process design stage. Automated systems must specifically address the location of the transducers to insure uniformity of the cleaning. Some parts require individual fixturing to separate the part for cleaning or subsequent processes. Some parts require slow rotating or vertical motion during the cleaning to insure critical cleanliness.

ULTRASONIC OUTPUT FREQUENCY:

Many technical articles claim that high frequencies penetrate more and lower frequencies are more aggressive. The majority of the ultrasonic cleaning that is done in industrial applications today uses 40 kHz as the base frequency. Lower frequencies, such as 20 - 25 kHz, are used for large masses of metal where ultrasonic erosion is of little consequence. The large mass dampens or absorbs a great amount of the ultrasonic cleaning power.

WATTS PER GALLON:

In general, smaller parts, requiring more critical cleaning, require higher watts per gallon to achieve the desired level of cleanliness. Most industrial ultrasonic cleaning systems use watt density from 50 - 100 watts per gallon. However, there is what is known as "the large tank phenomenon", which indicates that tanks over 50 gallons usually requie only about 20 watts per gallon. The only explanation available is a point of diminishing returns with regard to ultrasonic power.

LOADING:

Loading of the part(s) to be cleaned must be considered, with regard to the shape and density. A large dense mass will not allow internal surfaces to be thoroughly cleaned (i.e., metal castings). A rule of thumb for loading is that the load by weight should be less than the weight of half the water volume, i.e., in 5 gallons, approximately 40 lbs. of water, the maximum workload should be less than 20 pounds. In some cases, it is better to ultrasonically clean two smaller loads, rather than one larger load.

The above information is not meant to give all the details to utilize ultrasonic cleaning techniques. This information is to help the process designer gain some insight into the variables of industrial ultrasonic cleaning.