Ultrasonic deburring and cleaning technology for high quality press products

Session 1: Overview and Basics of Ultrasonic Cleaning Technology

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1. What is ultrasonic cleaning?

A major reason for the 30-year stagnation of ultrasonic cleaning technology is due to a misunderstanding of the basic understanding of what ultrasonic cleaning is. Ultrasonic cleaning systems have made rapid progress in accordance with advances in peripheral technologies and user demands. Transport technology, instrumentation technology, and sheet metal welding technology. However, there has been no significant change in the basic content of ultrasonic cleaning technology, with a few exceptions. Even though the appearance and transport technology have changed, ultrasonic cleaning technology cannot meet the demands of the times unless there is a fundamental innovation in ultrasonic cleaning technology.

In order to fully utilize the innovative ultrasonic cleaning technology for the new era, it is first necessary to have a deep understanding of what ultrasonic cleaning is, why it removes dirt and why it does not, and to dispel any misunderstandings about its principles.

The author has witnessed the rapid development of Chinese cleaning equipment manufacturers over the past 20 years. Although the equipment manufacturing technology of Japanese manufacturers is admittedly superior, there does not seem to be a significant difference between Japanese and Chinese manufacturers in terms of ultrasonic cleaning technology. The main reason for this is the depth of understanding of ultrasonic cleaning technology.

Without a proper understanding of ultrasonic cleaning technology, Japanese cleaning equipment manufacturers will not be able to respond to the competition for development of cleaning technology in China, where up to 4,000 Chinese cleaning equipment manufacturers and major cleaning equipment manufacturers employing more than 2,000 people each are competing. This could also be a drag on the international competitiveness of the Japanese press industry, which is their customer.

It is impossible to develop applications without understanding the basics. This paper is intended to help you understand the basics of proper ultrasonic cleaning techniques.

Ultrasonic cleaning is a cleaning method that emits powerful ultrasonic waves into a liquid and utilizes the impact force generated when cavities are created and extinguished. If cavities are not generated, it cannot be called ultrasonic cleaning. In other words, ultrasonic cleaning is a technology that uses cavities generated by ultrasonic waves for cleaning. Therefore, in order to understand and effectively use ultrasonic cleaning, it is essential to correctly understand cavities and the phenomenon of their generation and annihilation (cavitation).

A powerful sound wave of 20 KHz or higher, i.e., ultrasonic waves, is irradiated into the liquid. When the sound pressure changes above a certain level in the liquid, so-called cavities are generated. Cavities are composed of many vacuum nuclei (microcavities), and their overall size varies depending on the frequency and the magnitude of the sound pressure change, but at a practical level, the size is about 100 microns to 10 millimeters. The overall size varies depending on the frequency and the magnitude of the sound pressure change, but at the practical level, the size ranges from about 100 microns to 10 mm. In order to distinguish cavities from cavities generated by sound pressure changes other than ultrasound, the author calls them cavities (microvacuum nuclei).

At 25 KHz, cavities (microvacuum nuclei) reach their maximum size in about 1/50,000 of a second and disappear in the next 1/50,000 of a second. During cavity growth, a shock wave (positive shock wave) is generated around the cavity from the cavity center to the outside. During annihilation, conversely, a shock wave (negative shock wave) toward the center of the cavity is generated. This is repeated 50,000 times per second.

(New technology) Dissolved oxygen level Low 1mg/l or less

**Photo** 1**:** Gas nebula cavity (faint) 0.5 mm in diameter

**Photo** 2 Spherical nebular cavity (strong) 3-6 mm in diameter

Enlarged view

Enlarged view

(Conventional) Dissolved oxygen High 4-8 mg/l

Ultrasonic cleaning technology utilizes the physical phenomena of cavity creation and annihilation, positive and negative shock waves, for cleaning.

**2, Ultrasonic Cleaning Technology The Biggest Misconception**

The biggest misconception in ultrasonic cleaning technology is the illusion that the visible bubbles, which are generated when ultrasonic waves are applied to a liquid, are cavities (groups of microvacuum nuclei) generated by the ultrasonic waves described above. Most cleaning solvents other than water contain large amounts of air. In the majority of alcohols, chlorinated solvents, hydrocarbon solvents, and other solvents that can be and are used for cleaning, the oxygen dissolved content is 10 mg/ℓ or higher. When the solvents are irradiated with powerful ultrasonic waves, the pressure change causes the dissolved air to deflate and form bubbles, which burst at the surface of the rising liquid! It does not disappear or shrink in the liquid. This is called ultrasonic gas aeration. The air that has escaped from the liquid is re-dissolved from the liquid surface, and the bubble generation phenomenon by ultrasonic waves, ultrasonic bubbling (or ultrasonic gas aeration), persists. The good news is that the tiny bubbles of air that are generated at this time originate from the vibrating surface of the ultrasound and serve to effectively absorb and block the ultrasound waves. They do not generate the cavities that would otherwise be generated by ultrasound.

**In non-water ultrasonic cleaners without measures to reduce dissolved air, more than 99% of the ultrasonic energy disappears at the diaphragm surface!** (Author's measurement)

I think the reason this has not been a problem in non-water cleaning is that the solvents themselves had a certain degree of cleaning power, and thus have been overlooked, but these are not rough times. Cavities generated by ultrasonic waves are high-speed phenomena that are created and extinguished more than 20,000 times per second, and are not visible to the human eye as bubbles. It is not a phenomenon that is visible to the human eye as bubbles, etc.

## [Photo 3

**When visible bubbles are observed during ultrasonic oscillation, the ultrasonic tank should be considered to have disappeared, as most of the ultrasonic energy is not used.**

## 2. Importance of Cavitation Control

The author calls the early ultrasonic cleaners, in which ultrasonic cleaning is considered possible if the object to be cleaned is placed above the ultrasonic transducer, the first generation of ultrasonic cleaners. Then, in response to the importance of cavities in ultrasonic cleaning, ultrasonic cleaners that attempt to control cavities in the ultrasonic cleaning tank are called second-generation ultrasonic cleaners. In this section, we will briefly discuss cavity control in second-generation ultrasonic cleaners. This is the basis of all ultrasonic cleaning system design, and I am convinced that no new era of ultrasonic cleaning design can be achieved without understanding and practicing this concept.

## Photo 4] Second-generation ultrasonic cleaning system Example of cavitation distribution

## (1) Control of cavitation generation position

In an ultrasonic cleaning tank (the same applies to ultrasonic spray), it is an extremely important basic technology to determine where and how cavitation is generated in a stable manner. The position and shape of the cavitation distribution are determined by the frequency, type of liquid, temperature, depth of liquid, placement of transducers, direction of liquid flow, temperature distribution, etc., as well as the type of material to be cleaned.　The basic distribution of cavitation can be horizontal, vertical, grid, even, or cylindrical, etc., depending on the purpose. The ultrasonic cleaning engineer and the user must clarify the purpose of each ultrasonic bath, and share the distribution of cavitation in each bath and the method of checking it. If the liquid depth is unstable or not theoretically supported, it can be assumed that the basics of cleaning design have not been established.

## (2) Control of cavitation generation density

Cavities in ultrasonic cleaning do not occur on a surface. They occur at points. There is a distance between cavities, and multiple cavities do not occur attached to each other. In general degreasing cleaning, however, the spaces between cavities cause defects in so-called precision cleaning. Therefore, efforts are made to increase cavity density in various ways. Or, efforts are made to increase the distance traveled by the cavities. We are making a lot of efforts to improve the ultrasonic waveform, oscillation efficiency, liquid injection efficiency, output per unit area, and the method of attaching the vibrating elements to reduce the amount of wasted liquid, etc.　The latest ideas for ultra-compact, high-speed, high-density ultrasonic cleaning are an extension of this concept.

## (3) Cavitation impact force control

If the positive and negative impact forces of the cavities are too weak, the cleaning cannot be done; if they are too strong, they damage the object to be cleaned, resulting in defective products. Naturally, if the impact force of the cavity cannot be controlled, it is impossible to design ultrasonic cleaning.　Recently, ultrasonic cleaning objects have become more and more precise and delicate, and the range of cavity selection has become narrower. However, if you have a better understanding of cavities in ultrasonic cleaning, you will have a better understanding of how to control the impact force. In general, the impact force of a cavity is proportional to the pressure of the liquid and inversely proportional to the frequency, vapor pressure of the liquid, and amount of dissolved air.　The impact force of the cavity is proportional to the mass of the liquid that the cavity removes (attracts) in a unit of time, so once the principle is understood, it is clear what to control. Cavitation control in ultrasonic cleaning equipment is an important basic technology in ultrasonic cleaning design. It is impossible to introduce a new ultrasonic cleaning technology without controlling the cavitation.

## 3. Third Generation Ultrasonic Cleaning Technology [Basic Idea]

Before seeking specific new technology for each application, I would like to talk about ultrasonic cleaning, which is the backbone of new technology. The principle is important, and the applications are unlimited, depending on the object. This is the basic technology that the author discovered and put to practical use for the first time in the world during the CFC era, and has been refining under the banner of "CFC free" (presented by the author at the 1993 Washington International Conference). （Without precise cavity control, this cleaning technology will not provide the required performance, and in some cases will lead to the destruction of the ultrasonic transducer and a significant reduction in cleaning power. However, without this technology, we believe that innovation in cleaning technology for the new era would not be possible.

**This is called the third generation of cleaning technology, the Cavitation Enhancement System.**

## (1) Cavitation enhancement system

Ultrasonic cleaning equipment that controls the dissolved amount of air in the liquid according to the purpose, based on the premise of an ultrasonic tank that precisely controls cavitation, is called ultrasonic cleaning equipment with a cavitation enhancement system (third-generation ultrasonic cleaning equipment).　The ultrasonic cleaner with a cavitation enhancement system (third-generation ultrasonic cleaner) is called an ultrasonic cleaner with a cavitation enhancement system (third-generation ultrasonic cleaner). The ultrasonic cleaning technology of the future is inconceivable without controlling the dissolved oxygen content (hereinafter, for the sake of measurement technology, we will substitute dissolved oxygen). When the dissolved oxygen content is more than a few ppm, in other words, in the case of general water and water-based ultrasonic cleaning, **gas nebula cavities** are generated. In the case of **gas nebula cavities**, the speed of movement of the liquid at the time of cavity formation and annihilation is slow, and as a result, the impact force is extremely weak.　　In addition, the cavities themselves move only a short distance (within a few millimeters), resulting in severe cleaning irregularities. Although this is better than ultrasonic cleaning equipment that generates visible bubbles, it is not suitable for the ultrasonic cleaning equipment that will compete for precision in the future.　Therefore, the **spherical nebula cavity** should be used for future ultrasonic cleaning. Ultrasonic cleaning that uses these **spherical nebula cavities** stably and efficiently by controlling the amount of dissolved oxygen in the liquid is called the third-generation ultrasonic cleaning and cavitation enhancement system.

It is difficult to imagine modern ultrasonic cleaning and deburring technologies for precision presses, as well as ultrasonic polishing technology, an advanced form of these technologies, without this cavitation-enhancing technology. (Continued from Part 2)