Basics of Ultrasonic Cleaning Technology 2004-4 2012/9/18

**True Ultrasonic Cleaning Technology: The Market Creates the Direction of Evolution The exploding Asian market for cleaning equipment is demanding bold and sharp changes in ultrasonic cleaning technology and applied ultrasonic technology.　Intense competition will give birth to new technologies.**

**Third Generation Ultrasonic Cleaning Technology and Applications 2004**

**(1) Larger ultrasonic diaphragm**

1. Larger Ultrasonic Vibration Plates   
   The most significant feature of this field is the larger size of ultrasonic transducers that are compatible with glass substrates.  
    Since ultrasonic transducers are composed of many piezoelectric elements connected in parallel, their larger size naturally requires technological innovations in the attachment of the transducers and in inspection in general.  
    It is not enough to simply bond a large number of elements to a large plate.  
    Currently, in response to the increasing size of glass substrates, we are working on the practical application of 3600W to 9600W and their combinations for the 7.5 generation.  
    At the extreme end of the spectrum of ultrasonic cleaning equipment with cavity enhancement systems using spherical cavities, a number of cleaning equipment with ultrasonic reflective surface designs of only 75 mm are now in practical use.
2. Review of ultrasonic frequencies   
   The effectiveness of ultrasonic waves has long been questioned in this field. An extreme example is the MHz ultrasonic spray or shower, in which ultrasonic waves are applied to a spray for cleaning.  
    It is true that I was the first person in Japan to put this technology to practical use 15 years ago and obtained a patent for it, but at the time I could not solve a certain problem, and I withdrew from the project myself. However, I could not solve a certain problem at that time, and I withdrew from the project myself.  
    The frequency of 1.5 MHz is linear, but because of its high frequency, it has a high defoaming capability, and a large amount of fine bubbles of less than 1 mm are generated from the vibrating plate surface, efficiently absorbing and blocking ultrasonic waves.  
    At the same time, bubbles adhere to the vibrating plate surface, forming a reflective surface, resulting in an empty oscillation state, and leading to the destruction of the vibrating plate.  
    To prevent this, a high-speed water flow (turbulent flow) is created on the diaphragm surface to remove the air bubbles that cause the empty oscillation.  
    Although the diaphragm (element) is protected, the turbulence and the large amount of liquid supplied to the diaphragm generate more bubbles, effectively eliminating the MHz.  
    Currently, in LCD glass substrate cleaning, the ultrasonic waves generated by the MHz diaphragm do not reach the glass substrate at all, and it appears that the glass substrate is merely cleaned with an intense shower of pure water.  
    Moreover, the effective range of the MHz spray cleaning is only less than 10 m, and the cleaning time per unit area of glass substrate is only a few seconds.  
    The time the substrate is in the cleaning tank is longer, though. (These problems have been solved by the author.)  
    In the first place, MHz entered this field before cavitation enhancement systems (third generation ultrasonic cleaning) were put to practical use in many fields, and due to the adverse effects of the misuse of low frequency gas nebula type cavities.  
    Now, I recommend simultaneous wide-area multiplexing up to 535 KHz with 50 KHz, 80 KHz, and 130 KHz as basic frequencies for the efficient use of spherical nebula cavities for ultrasonic cleaning of increasingly larger glass substrates and the like. The impact force of the cavities can be controlled, and it is a mistake to try to solve this problem by reducing the output power or raising the frequency to an extreme level (e.g., to MHz) to avoid damage.  
    To reduce the output is to reduce the number of cavities and lose the cleaning effect, and to evacuate to extreme high frequencies is to lose the impact force of individual cavities.  
    As substrates become larger, more delicate, and more precise, the cleaning power expected from the cleaning object must also be increased.  
    However, the smaller the foreign matter, the greater the adhesion per unit area.  
    What is required here is a cavitation control technology that can generate a larger number of cavities with the necessary positive and negative impact force = cleaning power in a more uniform and stable manner, without causing damage.  
    Although it is not possible to go into too much detail here due to the number of pages, some ultrasonic cleaning designers are oblivious to the nature of glass in glass cleaning.  
    More than 99% of the glass used for liquid crystal displays passes through ultrasonic waves.  
    Reflected waves cannot be formed by themselves.  
    If this is the case, where should the glass be placed in relation to the vibrating plate in ultrasonic cleaning?  
    (To be precise, this question is incorrect.) Or, what position from the reflective surface can the glass   
   pass through to be cleaned?  
    The idea that ultrasonic cleaning is possible when the glass substrate is passed over the diaphragm is exactly the first generation of ultrasonic cleaning thinking.

**(2) Ultrasonic Cleaning in the Semiconductor Field**

Basically, the approach is the same as in the field of liquid crystals. We will focus on the application of ultrasonic cavities.  
 While we are fully aware of the importance of hardware, we believe that what is lacking now, or what has been stagnant for the past 20 years, is the software aspect of ultrasonic cleaning technology.

1. Silicon wafer manufacturing field   
   MHz seems to be in full swing, but there are persistent dissatisfaction with its cleaning power: as mentioned above, MHz usually generates tiny gas nebula-shaped cavities and countless air bubbles under pure water, making it difficult to clean larger and larger wafers.  
    Less than 10% of the ultrasonic energy reaches the liquid surface. Therefore, the amount of dissolved oxygen corresponding to the size of the wafer should be controlled to promote the generation of only spherical cavities to enhance cleaning power. In this case, care should be taken because the cavities move perpendicularly to the vibrating plate. However, the author recommends simultaneous multiple waves of 80 KHz and 130 KHz to 535 Hz on the premise that damage is controlled. a new powerful, dense, high acoustic pressure ultrasonic wave that solves the problems of MHz has been created.
2. Ultrasonic etching is considered to be a new cavity application technology in the device manufacturing field, etc.   
   Flux cleaning of 50~00μ gap (adhesion area) of high density flip-flop chips by 10MHz ultrasonic waves has also been successfully performed.  
    Ultrasonic deburring and simultaneous precision cleaning of large numbers of packages is another new cavity-applied technology in this field.

**(3) Computer-related fields and mobile communication devices**

25-40 KHz is difficult to use due to ultrasonic cavities, which conversely cause microscopic damage and contamination.

Therefore, the author has developed and utilized high acoustic pressure wide-area simultaneous multiple waves up to 535 KHz with basic frequencies of 50 KHz and 80 KHz. 1200 W to 7200 W with ultrasonic output density of 1 W/cm2 and 2 W/cm2 class are used in this field, as well as for cleaning, as micro burrs are also a cause of defects, Naturally, they are also used for deburring.

**(4) Automotive industry-related fields**

This is an area in which there is a relatively high demand for strong cleaning.  
 However, there are two directions of development in this field as well.  
 One is toward larger and more powerful machines, and the other is toward smaller, faster, and more precise machines.  
 Compared to other fields, inquiries for ultrasonic deburring are larger, and ultrasonic cleaning and deburring of metals, plastics, ceramics, and composite materials in general has grown to be one of our mainstay products.  
 Here, we will discuss a typical example of continuous vacuum [reduced pressure] ultrasonic cleaning deburring, which is experiencing remarkable growth.  
 This is a new form of ultrasonic cleaning. (Patent pending)

**Continuous vacuum [reduced pressure] ultrasonic deburring**   
The author has developed an ultrasonic cleaning system that cleans large quantities of clothes without moving them while they are packed in a basket or on hangers, and in a short time of about 2 minutes. The author has also developed a short-time ultrasonic cleaning system for high-temperature, high-pressure filters with several thousand layers of metal mesh of a few microns, which was said to be impossible with ultrasonic waves. The principle is basically the same.

It is well known that air in the liquid affects the performance of ultrasonic cleaning (whether or not the proper measures are taken is another matter!) ) Air bubbles, whether large or small, on the surface or inside the object to be cleaned can cause cleaning failures. Bubbles, whether large or small, can cause cleaning problems. Of course, if the gas does not move, the cleaning solution will not be fully immersed in it.

Ten years ago, the author presented a method of continuous cleaning by first placing the cleaned material in a vacuum to remove air from the interior and surface of the material, and then introducing a liquid from which dissolved gases have been removed. The disadvantage of this method was that the cleaned material would be released back into the air when it was transferred to the next tank, making continuous non-air contact ultrasonic cleaning impossible. Last year, in collaboration with a major Japanese valve body manufacturer, we developed and successfully commercialized a continuous vacuum [reduced pressure] ultrasonic deburring and cleaning system for valve bodies.

Several valve bodies are placed vertically in a cassette 700 mm long and flowed on a conveyor.  
 Tact time is 70 seconds. The first tank is a vacuum (decompression) treatment tank.   
The second tank is an ultrasonic deburring tank with two   
25KHz to 535KHz, 3600W ultrasonic transducers on   
both sides of the cleaning tank.  
 Two units of 3600W are synchronized and resonantly oscillated. The ultrasonic sound pressure is constantly monitored by a U-sonic ultrasonic cleaning power meter developed by our company, and an alarm is issued if the sound pressure is too high or too low. The controlled sound pressure is 20-25V.  
 The third tank is a rinse tank. There are shutters between the tanks to prevent the cleaned materials from coming into contact with the air, including during movement.  
 We call it a submerged ultrasonic cleaner [SUB-MERGING].  
 The same method is basically used for cleaning not only valve bodies but also various engine blocks (including F1). Before the experiment, the cleaned items are moved up and down in the liquid, and all items with even the slightest air bubbles remaining or complicated shapes, which may cause such bubbles, are vacuum treated and then ultrasonically (3rd generation) cleaned.

**New Era, Development of Ultrasonic Cleaning Technology**

The author believes that we are now in the vortex of new developments in ultrasonic cavitation application technology.  
 Ultrasonic cleaning is differentiating itself into larger and smaller sizes and higher performance based on more precise measurement and control.  
 One area of development, deburring, will create a large market.  
 In addition, ultrasonic etching, ultrasonic grain polishing, ultrasonic high-speed pulverization, ultrasonic organic synthesis, ultrasonic garment cleaning, and ultrasonic applications for foodstuffs are just a few of the new applications that will develop in the next 10 years.  
 We are convinced that the key to this development lies in the third generation of ultrasonic cleaning technology with cavity enhancement systems.

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