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Ultrasonic and Megasonic Cleaning to Remove Nano-Dimensional Contaminants from Various Disk Drive Components

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Abstract: This study investigates the effect of frequency on cleaning of various disk drive components. The disk drive components used for this study was ceramic spacer, e-coated disk separator, plastic separator and top cover. The frequency used for this study was 58 kHz, 58/132 kHz, 132 kHz, 360 kHz, 470 kHz and 1 MHz. In this study multiple extraction method was used to find the cleanability and erodability of the parts and liquid particle counter was used to measure the particle concentration in the extracted solution. The removal efficiency of various frequencies at final rinse was also studied. The result indicates that 360 kHz frequency at final rinse is optimally suited to remove sub-micron particles from variety of surfaces. The result also indicates that the removal efficiency of 360 kHz frequency at final rinse is high compared to 132 kHz and without any sonics at final rinse. Result shows that cleaning the parts with multiple frequencies gives higher cleanliness and lower erosion compared to single frequency alone.

Keywords: Ultrasonic, Megasonic, Multiple Extraction, Liquid Particle Count, Asymptote Value

I. INTRODUCTION

The constant trend in miniaturizing of components in the disk drive, low fly height and new technology such as HAMR processes to achieve higher capacity disks have created a need for higher cleanliness in disk drive and its associated industries. Hard particles or other contaminants in the disk drive components can be cleaned before assemble it into the disk drive. Otherwise, contamination in the level of sub-micron can cause scratches, smearing in the head and medium leads to disk drive failure. Most of the disk drive industries and its associated industries using the frequency range mostly from 40 kHz to 200 kHz for cleaning of disk drive components. In this study, we have explored the effect of ultrasonics and megasonics cleaning for the removal of nano-dimensional and sub-micron contaminants from various disk drive components.

Megasonic cleaning traditionally refers to use of acoustic fields in the 800 kHz – 1 MHz range to remove contaminants adhered to surfaces immersed in liquid media. However, even fields driven by frequencies in the > 360 kHz regime exhibit virtually all characteristics of conventional megasonics. Megasonic frequency offers the additional benefit of a very thin boundary layer over the immersed surface, which effectively exposes even sub-micron and nano-dimensional particles to the flow of the cleaning liquid. As the frequency increases, the thickness of boundary layer decreases [1, 2]. However, the uni-directionality, and relative gentleness, of megasonic fields has historically limited its application in cleaning of complex and rugged substrates, such as disk drive components and process-tooling components.

A new advancement in megasonic technology, termed “Megasonic sweeping”, has alleviated this short-coming to a large extent, thereby revolutionalizing the field. When the megasonic frequency is swept about its nominal value by ± 5%, the acoustic field becomes essentially more uniform. Even the corners and edges of tanks in systems employing “megasonic sweeping” display acoustic pressure levels equivalent to those prevailing at the centre, in the plane perpendicular to the transducer. Higher input power can now be deployed without concerns over the “fountain” effect in conventional megasonics, where power is primarily concentrated at the center. This key design improvement has suddenly rendered megasonic cleaning more attractive to industries that had previously shunned it [3, 4].

II. EXPERIMENTS

1. Multiple extractions with various frequencies

All experiments were performed in a Class 100 Cleanroom of the Advanced Ceramics Lab, Malaysia. The cleaning evaluations were performed for various frequencies such as 58/132 kHz, 132 kHz, 360 kHz, 470 kHz and 1 MHz. The watt density used for 58/132 kHz, 132 kHz is 31 watts/litter and the watt density used for 360 kHz, 470 kHz and 1 MHz is 57 watts/lit, 46 watts/litter and 69 watts/litter respectively. In this study an enclosed ultrasonic bath-type tank equipped with bottom mounted transducers was used. The temperature was kept at 28 ^{o}C and dissolved oxygen level was maintained around 40%. The disk drive components used for this study was Top cover, ceramic spacer, e-coated DSP and plastic separator as shown in Fig.1.

E-coated DSP Plastic separator Ceramic spacer Top cover

Fig.1 Various disk drive components

The component used for this study was come from the same batch of material so that initial cleanliness was approximately the same. It is also important to note that these parts had been pre-cleaned at their respective vendors. For each frequency the experiments were repeated three times and the average of this value was taken to plot the multiple extraction graphs. The desirable function was set to maximize the cleanability parameter and minimize the erodability parameter. Actually, this translates into increases cleaning action with minimum damage to the part surface.

In any of the ultrasonic cleaning process some of the part materials also removed along with the contaminants that might be on the part by means of cavitation implosions. It is thus believed that the level of cavitation erosion depends on frequency, part material, exposure time and cleaning solution. The purpose of this experimental study was mainly to investigate the effect of various frequencies from ultrasonic to Megasonic range on cleanability and erodability parameters using ultrasonic multiple extraction method.

An ultrasonic multiple extractions define the cleanliness and cleanability of a part as measured using ultrasonic extraction to remove residual contamination [4]. In this method the parts were subjected repeatedly to the same contamination extraction procedure. The frequency used for the final extraction was 132 kHz with 60 watts/gallon. The ultrasonic extraction method utilizes ultrasonic energy to extract particles from a part and the particle concentration in the extraction solution was measured using liquid particle counter (LPC). The particle counter used for this study was particle measuring system (PMS^{TM}) and LiQuilaz SO2. This counter can measure the particle sizes from 0.2 um to 2 um. The size of the particles reported for this study was >0.3 um.

2. Effect of frequency at final rinse

The effectiveness of various frequencies with 360 kHz, 132 kHz and no ultrasonics at final rinse in removing submicron and nano-dimensional particles from various disk drive components was studied. After washing, the disk drive components were subjected to 132 kHz extraction and the particles in the extracted solution were measured using liquid particle counter. The experimental conditions used for this study was as shown below.

1. 58 kHz wash with surfactant → 58/132 kHz DI rinse → 132 kHz DI rinse → 360 kHz DI rinse → LPC
2. 58 kHz wash with surfactant → 58/132 kHz DI rinse → 132 kHz DI rinse → DI rinse w/o any sonic → LPC
3. 58 kHz wash with surfactant → 58/132 kHz DI rinse → 132 kHz DI rinse → 132 kHz DI rinse → LPC

The surfactant used for this study was 1% CC 2000x. The cleaning efficiency is quantified and presented in terms of its dependence on acoustic frequency for particle size >0.3 um.

III. RESULTS AND DISCUSSION

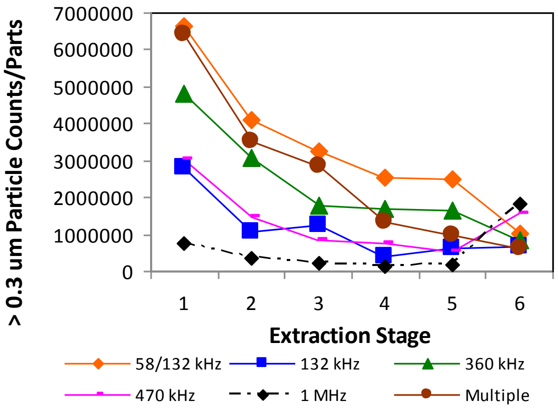

Fig.2 Multiple-extraction comparison of various acoustic frequencies with respect to particle removal efficiency and erosion propensity for e-coated DSP

In Fig. 2, particle-count data are presented for an e-coated DSP component, comparing the extraction efficiencies and erosion characteristics of five frequencies in the regime from ultrasonics to megasonics —58/132 kHz, 132 kHz, 360 kHz, 470 kHz and 1 MHz. Counts are shown as a function of various stages of extraction on the X-axis. The slope of the curves indicates cleaning efficiency, and the asymptotic level indicates degree of erosion. While both 58/132 kHz (patented dual frequency) and 360 kHz frequencies exhibit the steepest initial slope, hence highest initial cleaning where as 470 kHz and 1 MHz exhibits the lowest asymptote, hence lowest erosion.

The result also shows that multiple frequency sequence, i.e 58 kHz → 58/132 kHz →132 kHz → 360 kHz → 360 kHz gives lower particle counts, hence high final cleaning compared to single frequency. The frequency 132 kHz shows only fair amount of particle removal compared to other frequencies. As the frequency increases the cavitational force required to remove the particles decreases but the acoustic streaming force increases. It is thus believed that cavitation intensity is the most important factor and acoustic streaming supports for contamination removal. That is the reason why multiple frequencies with 360 kHz at final rinse gives higher removal efficiency compared to all other frequencies tested.

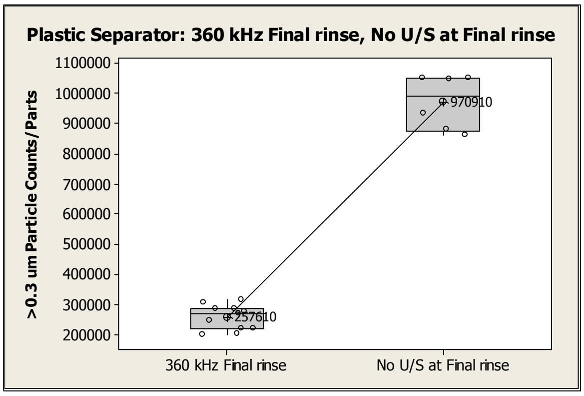

Fig. 3 Effect of 360 kHz frequency at final rinse for plastic separator

In Fig. 3, the particle-count data are presented for a plastic separator disk drive component, comparing with and without 360 kHz at final rinse. The parts were analysed using LPC after subjecting it to with and without 360 kHz at final rinse. The result clearly indicates that 360 kHz at final rinse is quite effective in removing sub-micron particles from plastic separator.

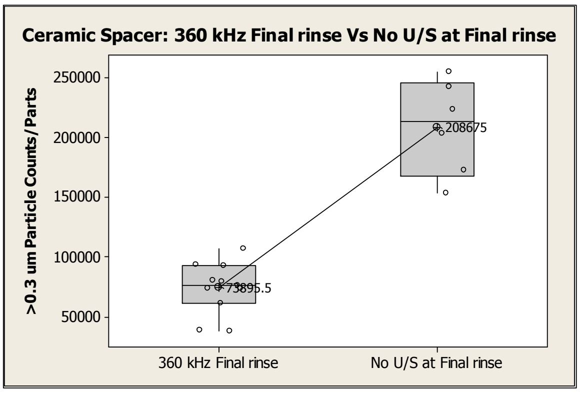

Fig. 4 Effect of 360 kHz frequency at final rinse for ceramic spacer

The particle counts obtained for 360 kHz at final rinse comparing with no ultrasonics at final rinse is shown in Fig. 4 for ceramic spacer. The data clearly indicates that rinsing with Megasonic frequency such as 360 kHz gives lower particle counts, hence high cleaning efficiency compared to without any sonics at final rinse.

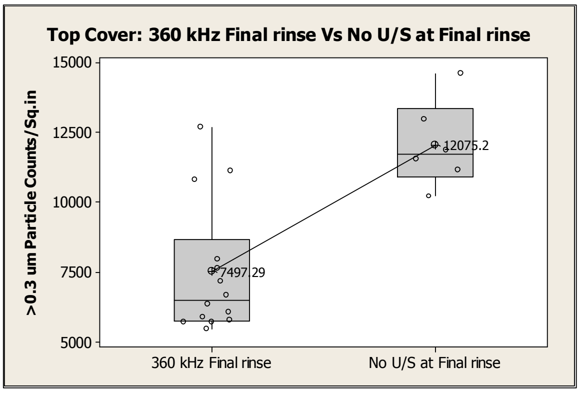

Fig. 5 Effect of 360 kHz frequency at final rinse for top cover

The particle count data obtained for top cover and e-coated DSP is shown in Fig. 5-6. The removal efficiency is high for 360 kHz frequency compared to no ultrasonics and 132 kHz at final rinse for both top cover and e-coated DSP.

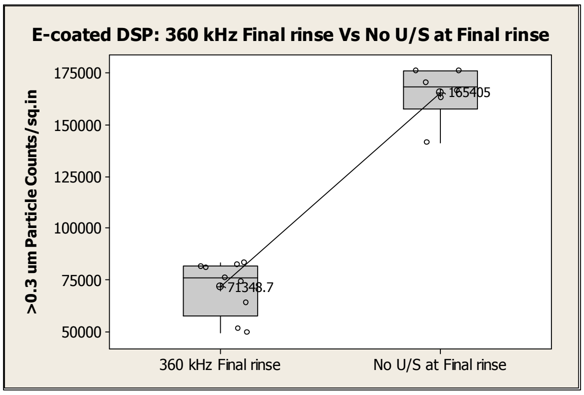

Fig. 6 Effect of 360 kHz frequency at final rinse for E-coated DSP

The particle counts obtained for no ultrasonics at final rinse is almost two times higher than 360 kHz for both top cover and e-coated DSP.

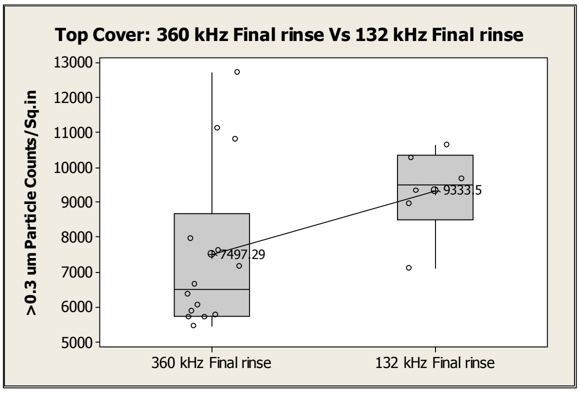

Fig. 7 Effect of 360 kHz frequency at final rinse vs 132 kHz for top cover

In Fig. 7, the particle-count data are presented for a top cover disk drive component, comparing with 360 kHz and 132 kHz at final rinse. The parts were analysed using LPC after subjecting it to 360 kHz and 132 kHz at final rinse. The result clearly indicates that 360 kHz at final rinse is quite effective in removing sub-micron particles from top cover. The particle counts obtained for 360 kHz at final rinse is much lower, hence higher cleaning efficiency than 132 kHz.

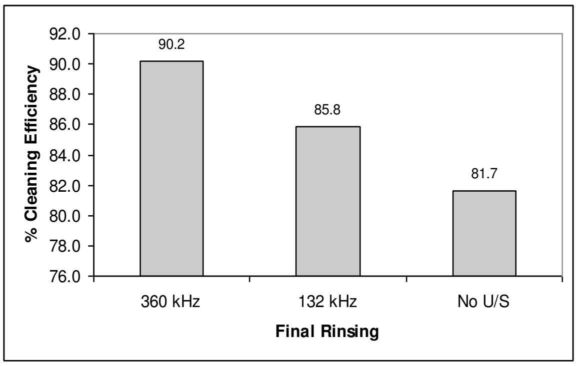

Fig. 8 Cleaning Efficiency comparison of various acoustic frequencies for top cover for particle sizes > 0.3 um

In order to compare the specific efficiencies of various acoustic frequencies in removing particles, the liquid particle counts were measured before and after subjecting them to cleaning processes. The data obtained for top cover is summarized in Figure 8. It is evident from these results that:

- Ultrasonic frequencies with 360 kHz Megasonic at final rinse gives higher removal efficiency for all the disk drive components tested compared to 132 kHz and no sonics

- Ultrasonic frequencies with 132 kHz at final rinse gives lower sub-micron removal efficiency compared to 360 kHz megasonics but gives higher removal efficiency than without sonics at final rinse.

- DI rinsing without any sonics at final rinse gives lower removal efficiency compared to 360 kHz and 132 kHz.

Intermediate frequencies (in the 100-200 kHz range) are characterized by low cavitation intensities, as well as relatively weak acoustic streaming forces; however, they do supplement each other, and the net particle-removal forces are correspondingly high.

V. CONCLUSION

The experimental data demonstrate that megasonic frequency 360 kHz is optimally suited for removal of sub-micron particles from variety of surfaces. The removal efficiency for 360 kHz frequency at final rinse is high compared to 132 kHz and without any sonics at final rinse. High frequencies such as 470 kHz and 1 MHz may bring down the asymptote value further without any cavitation erosion. It is an additional benefit that cavitation erosion is virtually absent at such high frequencies. An overriding concern regarding uni-directionality of megasonic fields has been addressed satisfactorily through the innovation of sweep-frequency megasonics. Overall, precision cleaning industries mainly disk drive industries and its associated industries should make use of state of the art 360 kHz frequency to achieve higher cleanliness level for cleaning of disk drive and other components. In future the effect of 360 kHz frequency can be tested for other applications also.

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