The successful of finite element to invent particle cleaning system by air jet in hard disk drive.

Nualpun Jai-Ngam 1, Kaitfa Tangchaichit 1,2

1 Department of Mechanical Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen, 40002, Thailand.
2 Research Unit on Mechanical Component Design, Khon Kaen University, Khon Kaen, 40002, Thailand.

Corresponding author. Tel.: +668-3664-2384; E-mail address: kiatfa@kku.ac.th.

Abstract. Hard Disk Drive manufacturing has faced very challenging with the increasing demand of high capacity drives for Cloud-based storage. Particle adhesion has also become increasingly important in HDD to gain more reliability of storage capacity. The ability to clean on surfaces is more complicated in removing such particles without damaging the surface. This research is aim to improve the particle cleaning in HSA by using finite element to develop the air flow model then invent the prototype of air cleaning system to remove particle from surface. Surface cleaning by air pressure can be applied as alternative for the removal of solid particulate contaminants that is adhering on a solid surface. These technical and economic challenges have driven the process development from traditional way that chemical solvent cleaning. The focus of this study is to develop alternative way from scrub, ultrasonic, mega sonic on surface cleaning principles to serve as a foundation for the development of new processes to meet current state-of-the-art process requirements and minimize the waste from chemical cleaning for environment safety.

1. Introduction

Hard Disk Drive manufacturing has become very challenging with the increasing demand for high capacity drives for Cloud-based storage.

One of the more prevalent reliability issues in disc drive is media failures caused by particle that contaminate the airflow inside the disk drive. To increase recording area density, fly height is lowered and the disk is manufactured as smooth as possible. During disk drive operation, there are serious damage to the data of the disk and the sliders that is result from lowered fly height if a particle were to present between the disc and the slider can cause the damage loss of read and write performance. Liu et al. and others [1] conducted numerical study of the effect of HDD cover and circulating filter, investigating air flow pattern on the entrapment of loose particles inside a thinner and smaller factor HDD.

The process of particle deposition onto surfaces is complex, multifaceted phenomena which Liu et al.[2] studied and found, the deposition can vary and depending on airflow pattern, characteristic of particle and size and Lee et al. [3] studied the relation between particle generation and disk rotational speeds.

ANSYS/CFD software is used on this study to model and solve to design the system. Thongsri et al. [4-5] did numerical simulation of airflow inside microenvironment in order to verify these cleaning functions of the airflow in HDD manufacturing.
Disk drive includes rid housing that encloses a variety of components. The disk are mounted on a spindle motor that cause the disk to spin and the data surfaces of the disks to pass under aerodynamic bearing, disc, and head sliders. The sliders carry transducers, which write information to and read information from the data surfaces of the disks. The sliders are built together to be HSA. (HSA Stack Assembly)

This study is to approach surface cleaning by using air pressure to vacuum and removal of solid particulate contaminants that is adhering to a solid surface on HSA. The study will need to understand the particle trajectory in during drive operating and later develop the system to be removal out the particle before assemble to HDD.

2. Modeling Procedure

2.1 Numerical Analysis
In order to remove particle contamination from solid surfaces, in this study is on HSA aluminium surface, the removal forces that act on the particles should be greater than the attractive adhesion forces. However, the most important adhesion forces are van der Waals forces and electrostatic forces. The strength of the van der Waals forces depends on the particle material as well as the particle size. Therefore, the adhesion strength varies and the required force to remove them can be excessive for the majority of the particles that called air drag force is given by

\[ F_d = 3\pi D V \mu \]  \hspace{1cm} (1)

Where, \( F_d \) : Drag force (Pa), \( \pi \) 3.14, \( D \) : Particle diameter (m), \( V \) : air flow velocity (m/s) and \( \mu \) is air viscosity.

The Airflow drag force relationship to particle diameter and velocity depends on the particle Reynolds number. The Reynolds number [6] for a particle on a surface is given by the following equation

\[ Re = \frac{\omega r^2}{\nu} \]  \hspace{1cm} (2)

where \( \omega \) is the angular velocity (7,200 rpm), \( r \) is the platter disk radius and \( \nu \) is the kinematic viscosity (1.79947 \times 10^{-5}). The Reynolds number of a 44.45 mm radius disc inside an HDD is 83,007.

A transition Reynolds number of more than 4,000 is considered to be turbulent [8]. Thus, the flow inside the HDD is turbulent.

A commercial CFD computer application with the k-\( \varepsilon \) turbulence model is used to determine the particle behavior of the system.

2.2 Air Purge and Vacuum System Simulation
A method of particles detachment by purge and removal particle on HSA component is to inject a clean purge fluid into an inlet of the interface plate then release and remove particles from HSA surface and vacuum particle out of the cleaning system. The size of particle is ranged 0.3 to 1 micrometer. The key contributor to make the particle to be out is air pressure pulse and vibration that is going to agitation to parts and able to release the particle out. Solid work software is using to establish the design of cleaning particle system as shown in Figure 1.
2.2.1 Boundary conditions setting. The inlet boundary was set to total pressure. The pressure was set to 0 Pa. The particles were uniformly injected and equally distributed around HSA surface. Stainless and Aluminium is type of particles for this simulation which is most particles that detect on hard disk interface failure. The initial mass flow rate of these particles was set to be 0.074 lb/s, the velocity of 25 m/s and outlet, the relative static pressure was set to be 0 Pa.

2.2.2 Experimental Procedure. The prototype is set up to valid the number of particle to be removed.
1. Build up prototype as shown in Figure 2. HSA will be 15 units on tray that illustration in Figure 3.
2. Use air cleaning system to clean tested units which are HSAs
3. Test parts and compare two groups of part with and without air particle cleaning
4. Use the particle counts filter to count the number of particle.
5. Get the parts of with and without clean air jet to LPC test.
3 Results and Discussion

3.1 Finite Element Analysis

CFD solver of ANSYS Program is used for this study and gets the result. The result will be 2 sections: the first one is modelling result on how particle trajectory behaviour with air cleaning system. The second part is about the efficiency of particle to be removed out that will be calculated in removal efficiency percentage. The particle velocity profile has shown the most cleaning effective around the center. The result is indicated in the Figure 3 and Table 2.

![Figure 2. Prototype of particle vacuum and purge set up](image)

![Figure 3. Air velocity profile when drive operating at 25 m/s and simulate to cleaning system](image)

**Figure 3.** Air velocity profile when drive operating at 25 m/s and simulate to cleaning system

**Figure 4 (a).** Air velocity profile at top view  
**Figure 4 (b).** Air velocity profile at side view

To focus on the arm pad area, the particle has been studied the behavior. The air purge velocity is higher than the velocity that is running in the drive operating system and air velocity blowing has reported to be flow throughout arm pad area as shown in Figure 4 (a) and Figure 4 (b) which air flow pattern can flow through the arm surface and velocity is measured from model around 25 m/s in average that is target of air flow that desire to be. This number of air flow will not be harmful to the HSA which is fragile for high pressure that mean the pressure will need to be optimum and air flow will need to strength enough to remove particle.

Table 2 is shown the result of particle model that can be removed out from finite element model. The particles were 10000 units in total which are 5000 stainless steel and 5000 aluminum with spherical...
shape, and consisted of various sizes. The large size particle represents 5.0 micrometers particles while small particle represents the 0.2 micrometers particles then tracked through the model where particles have been removed at the outlet. The result is shown particle could be removed over 40% and different location can be varied the efficiency such as at center more of pressure on target can be removed out the particle and efficiency of removal is reduced on the units that far from the center or at Conner. The position of units can be referring to Figure 3 that HSA are total 15 positions in one packaging tray.

3.2 Experimental to valid the Particle Cleaning improvement
Build up the prototype to verify the effectiveness of air particle cleaning system, this prototype is also getting the filter to count the number of particle in difference size such as 0.3 micrometre and 1 micrometre.

The experiment is done for group of non-cleaning by air particle cleaning system and compare with group that clean with air particle cleaning system. Position of HSA is also set to verify the air velocity profile from model.

The result is similarly to the finite element suggestion. The mean and variation of particle that is cleaned by air cleaning system is able to clean out the particle and it is also proven that parts that way far from pressure at center can be cleaned out but cleaning performance is not as good as at center that is directly air flow pressure at center as the result reported in Table 3.

One of cleanliness called for Liquid-borne particle counting (LPC), as the laborious microscopic-count procedure (Brand et al., 1992; Roberts, 1991; Nagarajan. 1990) is used to quantify level of cleanliness improvement. HSAs group that were cleaned by Air particle cleaning, is reported particle average at 4617 counts and standard variation at 203 counts whereas HSA without cleaning by air vacuum and purge were at 5985 counts and standard variation at 918. Further step of the design can be reviewed to be gain the result of getting the optimum pressure for all across the area of tested units.

4. Conclusion
In this research, the numerically investigation on air flow on Hard Disk Drive is studied and applied to invent air imping jet to vacuum , remove and purge particle out. The computational study of HDD airflow characteristics yielded useful information about the basic parameters such as air velocity inside HDD enclosure. This information helped to establish a direction for designing and developing an air jet based particle detachment system for HSAs. CFD techniques, combined with a suitable particle

---

**Table 2. Removal Efficiency of particle vacuum and cleaning machine from Finite Element model**

| Position | Released Particle | Removed Particle | Percentage |
|----------|-------------------|------------------|------------|
| Center   | 10000             | 3986             | 39%        |
| Conner   | 10000             | 328              | 3%         |

---

**Table 3. Removal Efficiency of particle cleaning machine.**

| HSA Position at package container | Without Air cleaning | With Air Cleaning | Percentage of improvement |
|----------------------------------|----------------------|-------------------|--------------------------|
|                                  | Mean | Std | Mean | Std |               |
| Center                           | 127  | 157 | 67   | 154 | 47%           |
| Edge                             | 196  | 339 | 174  | 223 | 11%           |
transport model, proved to be a powerful tool to develop a good mechanical design by which sub-micron sized particles can be removed in order to achieve improved cleanliness.

This is one alternative way to be considered of cleaning method at HDD manufacturing or other industry to be friendly to environment and minimize the use of chemical wet cleaning process.

References
[1] Liu N and He Z 2011 A Numerical Investigation of Particle Trajectory inside Hard Disk Drives vol 47 (IEEE Transactions on magnetics) p 1890-1892
[2] Liu N and Zhang Q 2013 A Numerical Simulation of Particle Trajectory in Thin Hard Disk Drive vol 49 no 6 (IEEE Transactions on magnetics) p 2590-2593
[3] Lee D and Y Hwang 2004 Effect of Disk Rotational Speed on Contamination Particles Generated in a Hard Disk Drive vol 10 no 2 (Microsystem Technologies) p 109–108
[4] Thongsri J and Khaokom A 2014 Successful Simulation of Airflow in the Microenvironment of an Assembly Automation Machine and its Implication vol 931-932 (Advanced Materials Research) p 1063-1067
[5] Thongsri J and Pimsarn M 2015 Optimum airflow to reduce particle contamination inside welding automation machine of hard disk drive production line vol 16 no 3( International Journal of Precision Engineering and Manufacturing) p 509-515
[6] Okajima A 1982 Strouhal Numbers of Rectangular Cylinders vol 123 (Journal of Fluid Mechanics) p 379-398
[7] Wikipedia Reynolds number Retrieved from https://en.wikipedia.org/wiki/Reynolds_number. 10 June 2017.
[8] ANSYS. ANSYS CFX-Solver Theory Guide. 15th ed.,ANSYS,Inc., PA, 2013, Chapter 6, Particle Transport Theory, p 209-279