The Optimization of the Efficiency of the Cleaning System in Hard Drive Industry

Presented in 1st Data Storage Technology Conference (DST-CON 2008)

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Abstract

This paper has proposed the solution to the problem and the improvement of the ultrasonic cleaning system of hard drive product line to be more efficient in cleaning. The basic principle is the understanding of contaminants and particles cleaning system caused by the production line in the process. The statistics principle is proposed for finding the relationship of system's variables. Then, the equation of statistics which is the estimated relationship between the quality variable and process variables was written. This efficiently improves the process in the condition which is suitable for cleaning system. This results in the higher efficiency of cleaning system.

Introduction

Currently, in a hard disk drive, the head flying height, the distance between read-write head and disk surface, has been continually reduced to increase the recording density. At present the flying height is about or below 0.1 μm, this implies that even submicron particles can damage both the slider and disk surfaces, hence lead to failure of the disk drive system. Thus, the cleanliness of the disk and slider surfaces becomes very critical.

The particulate contaminants, such as residual lapping-slurry particles, on magnetic head sliders are generated from manufacturing processes of magnetic head sliders and head gimbals assembly. For instance, the lapping process involves slider polishing on a rotating Sn plate with slurry as a medium. This lapping process generates some Sn smears on the magnetic head sliders, which pose a major problem in industry. In the disk texturing process, the particulate contaminants, such as SiC particles, are generated on disk surfaces. Nowadays, the ultrasonic cleaning is used to remove submicron particles from disk surfaces into industry (Lu et al.,2000). But the usability of the ultrasonic cleaning system, at present, is not sufficiently efficiently with the capability of the system.

Then, this article aims to apply the basic principle of contaminants and cleaning system to be mutually considered with the statistics principle by using the Minitab program. The statistics principle is proposed for considering to find the relationship of system's variables. Then, the equation of statistics

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which is the estimated relationship between the quality variable and process variables was written. This will efficiently improve the process in the condition which is suitable for cleaning system. It makes the ultrasonic cleaning system in factories of hard drives to be more efficient in cleaning. Moreover, the cleaning system can response to the usability of its capacity at the utmost efficiency. This article utilizes LPC (Liquid Particle Count) as the efficiency measurement of cleaning.

Theoretical review

A. Wave Theory of Sound

Ultrasound is a sound with a pitch so high that above the limits of human audibility which is the frequencies range from 20,000 cycles per second or kilohertz (KHz) to over 100,000 KHz called ultrasonic waves. The mathematical theory of sound propagation (Moholkar,2002) is based on three basic equations as follows: The equation of conservation of mass, the Euler equation of motion and the pressure-density relationship of the medium given by equation (1)-(3), respectively

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho v) = 0 \qquad (1)$$

$$\rho\left[\frac{\partial v}{\partial t} + (v.\nabla v)\right] = -\nabla p \qquad (2)$$

$$c^2 = \left(\frac{\partial p}{\partial \rho}\right)_{s=constant} \qquad (3)$$

where ρ is the density of the medium, v is velocity in the acoustic wave, t is time and p is pressure, c is velocity of sound.

The propagation of the acoustic wave in the medium causes small amplitude variations in the pressure, velocity, and density of the medium. The mathematical expression that describes the variation in these properties due to acoustic wave propagation is called *wave equation* (Busnaina and Gale, 1995). A sound wave is a pressure wave traveling with a particular velocity, c which is dependent upon the medium. Pressure is a function of position and time. The equation for the pressure field in a sound wave as follows

(4)

B. Specific Acoustic Impedance

In acoustics, the concept of impedance or more specifically *acoustic impedance* (Moholkar,2002) is the ratio of acoustic pressure and velocity of the particle of the medium.

$$Z = \frac{p}{v} \text{ or } Z = \rho c \qquad (5)$$

C. Acoustic Energy and Intensity

The acoustic intensity is defined as the rate at which energy in the wave crosses a unit area perpendicular to the direction of propagation. The particles of the medium undergo oscillatory motion as the wave propagates. A detailed derivation of the acoustic energy passing through the medium due to propagation of a sinusoidal acoustic wave with amplitude p_0 per unit time per unit area (I) which is values of ultrasonic power are typically presented in terms of acoustic intensity, I which is power per unit area. For a wave propagating in one direction from a source, the intensity is given by (Moholkar, 2002;Busnaina and Gale, 1995).

$$I = \frac{1}{2} Z (\frac{p_0}{Z})^2 = \frac{1}{2} \frac{p_0^2}{Z} \quad (6)$$

Substituting acoustic impedance from equations (5) into equation (6) given by

$$I = \frac{p_0^2}{2\rho c} \quad (7)$$

D. Ultrasonics Cleaning System of the Hard Drive Product Line with Empirical Modeling

- *Process Flow in Cleaning System*

In the basic techinque of the cleaning system, there are three components that are the heart of the system: (1) Wash(clean); (2) Rinse; (3) Boil (dry), as the following process flow.

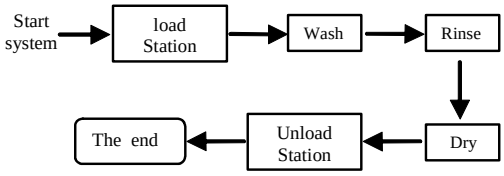

Figure 1. Process flow of cleaning system.

- *Specifying Significant Variables that Effect the Efficiency of Cleaning*

There are many variables that may effect the efficiency of cleaning. According to the investigation of the involved theories assembled with the understanding from the writer and teamwork experiences on cleaning system, have been analysed by the brainstorming of the teamwork to vote for the priorities of the variables which effect the efficiency of cleaning in Figure 2.

According to the analysis by voting for the priorities of the variables as shown in Figure 2, it is discovered significant variables that effect the efficiency of cleaning are *Power and Time*.

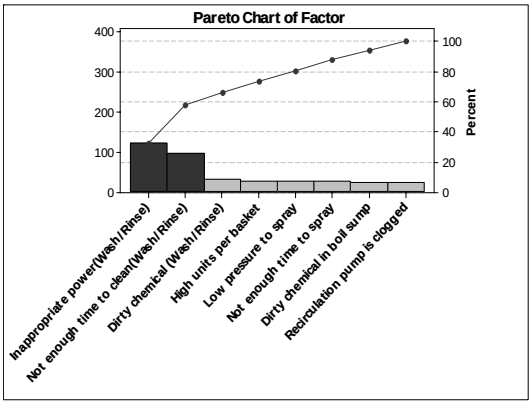

Figure 2. Pareto diagram by Minitab program

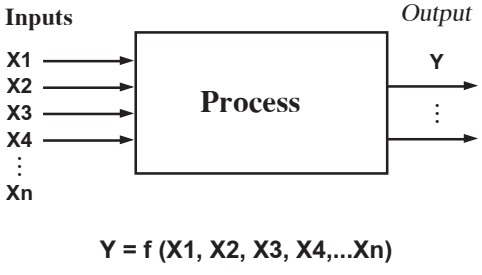

Figure 3. The estimated relationship between the quality variable and process variables.

E. The fundamental Statistics Principle

In Figure 3 it was found that (X1, X2, X3, X4) inputs result in quality characteristics identified by variables Y. In the experiment design, it is required to conduct the experiment systematically in order to find the statistics relationship of variables Y and X in the trial to utilize the experiment resource at the highest efficiency (Supselee).

Design of Experiment

In this article, the statistic principle by Minitab program (Supselee) is used to design the experiment. This needs the understanding of the basic principle on cleaning system for estimating the range of various variables X which are suitable for the cleaning

system. Then, the values low (-1) and high (+1) of experiment are specified as shown in Table I. The two variables which are ranked as the most important ones in Pareto diagram in Figure 2 are determined to find the relationship of system's variables shown in Figure 4.

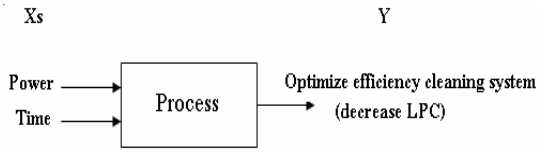

Figure 4. The relationship of system's variables define Y = f (Power, Time).

Table 1. The specification of the variables Xs range suitable for cleaning system.

Setting	Low (-1)	High (+1)	Unit
Ultrasonic power (wash)	500	1000	(W)
Ultrasonic power (Rinse)	500	1000	(W)
Cleaning time	110	150	(S)

The specification of variables X range which are suitable shown in Table 1 is taken for the experiment design shown in Table 2. This is the method of designing: *Stat > DOE > Factorial > Create Factorial Design*. (Manual,2006)

Table 2. Design fraction format experiment by Minitab program.

Run Order	Center Pt	Blocks	Power wash	Power rinse	Time
1	1	1	1000	500	110
2	1	1	1000	1000	150
3	1	1	500	1000	110
4	1	1	500	500	150

Since there are several limitations in the experiment that actually happen in the hard disk drive factory, these limitations effect the production procedure in each experiment. Therefore, the teamwork have to design the experiment for the utmost efficiency by adjusting the specification of variables in RunOrder 2 from Table 2 which is not correspondent with the production procedure to be the Current group in Table 3 instead. The purpose is to analyse every single variables for identifying the significant variables that effect the efficiency of cleaning by comparing with Current group (setting).

Table 3. Experiment table.

Group	Variables		
	Power (Wash)	Power (Rinse)	Time
Current	500W	500W	110s
Group1	500W	500W	150s
Group2	500W	1000W	110s
Group3	1000W	500W	110s

A. Power and Sample size

Baseline data (*sigma=987, medain=1736*) are taken to calculate for the sample size used in the experiment by Minitab program. So as to detect the difference change as target 1 sigma with 94% power of detection and 95% confidence interval. This is the method as follows: *Stat > Power and Sample Size > 2-Level Factorial Design.*

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Power and Sample Size

2-Level Factorial Design

Alpha = 0.05  Assumed standard deviation = 1

Factors:    3   Base Design: 3, 4
Blocks:  none

Center                          Total  Target
Points  Effect  Reps  Runs  Power  Actual Power
     0       1    13    52   0.94      0.942089
```

Result

Table 4. Results of experiment in each groups.

No.	LPC results (0.6 + um)								
	Current	Group1	Group2	Group3	No.	Current	Group1	Group2	Group3
1	3078	1810	2322	2383	8	2872	2561	1859	2868
2	1961	1902	2227	2426	9	2812	1775	3134	2316
3	2068	1380	1929	1741	10	2572	1366	2192	2751
4	2068	1380	1844	2546	11	2301	1699	2274	1421
5	2121	1340	2662	1714	12	2354	1664	2328	2094
6	1917	1385	2545	2465	13	1630	1542	2304	1424
7	2924	1251	1851	2261	**Avg.**	**2360**	**1620**	**2267**	**2185**

In this article, LPC (Liquid Particle Count : $count/cm^2$) is utilized to measure the efficiency of cleaning by using 13 samples per group for experiment which is calculated from topic III (*A.*) above. The results of experiment from Table 4 are applied to plot graph as shown in Figure 5-6 by Minitab program. This is the method as follows: *Stat > ANOVA > One-way (Unstacked) > Graphs > Individual value plot / Box plot*. (Manual,2006)

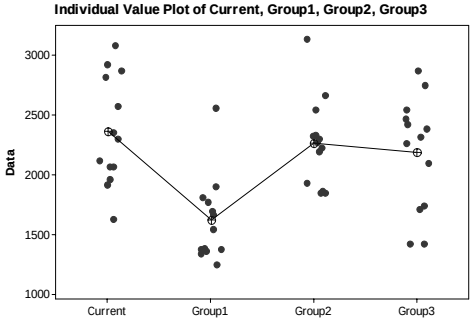

Figure 5. Graph individual value plotted from table 4.

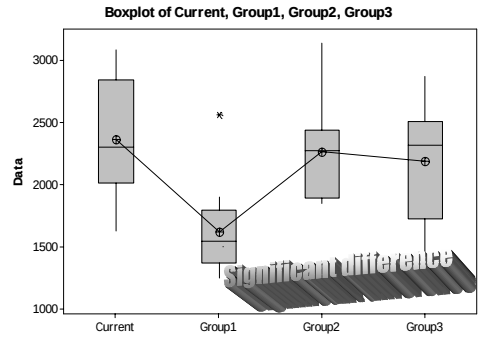

Figure 6. Graph boxplot is the average of LPC in each groups.

Then, the following analysis is implemented for finding significant variables that effect the efficiency of cleaning by Minitab program, as follows: *Stat > DOE > Factorial > Analyze Factorial Design*, shown in Figure 7. (Manual,2006)

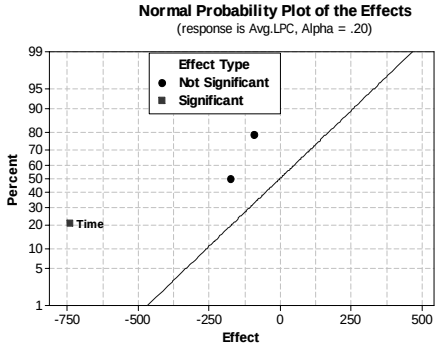

Figure 7. Graph normal probability plot.

Considering from the results of experiment in Table 4, it is found that the average of LPC in Group1 is minimum (1,620) by comparing with Current whose average of LPC is 2,360. It can be concluded that the specification of variables in Group 1 from Table 3 causes the efficiency increase of cleaning system for *estimately 31%*. Then, the mentionable significant variable that effect the

efficiency of cleaning is Time, shown in Figure 7 and meanwhile the setting of power in the Current group which is suitable for the cleaning system causes the insignificance of the power adjustment in Group 2 and Group3 from Table 3. The experiment result in Table 4 is written in the equation of statistics (supselee; Manual, 2006) which is the estimated relationship between the quality variable and process variables, shown in Figure 4 as follows:

Code Equation

Equaation of System's Variable Relation

LPC = 1856-87.5*Power wash-465*Power rinse-370*Time

Conclusions

In this article, the application of knowledge and understanding of cleaning system is considered by assembling with statistics principle by Minitab program for helping design and conduct experiment efficiently and systematically. Also, this is the system that the resource has been made use at the highest efficiency, and that the significant variables effecting the result of cleaning for the expected result can be specified.

This results in the improvement of ultrasonic system in factories of hard drives to be more efficient in cleaning which leads to the improvement of the quality of products. Furthermore, it helps decrease loss and unnecessary dissipation of resource in the experiment.

Acknowledgment

The author would like to thank the National Electronics and Computer Technology Center (NECTEC) of Thailand for financial support and Seagate Technology (Thailand) Ltd. for equipments support for this research. The code of reseach project is HDD 08 - 004 M.

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