IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 04, Issue 05 (May. 2014), ||V6|| PP 33-37

Dent Defect Reduction in Hard Disk Drive Media Disks Using Six Sigma Approach

Keeratipan Damrongseree[1], Wipawee Tharmmaphornphilas[*2]
[1,2]*(Department of Industrial Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand, 10330)*

***Abstract:* -** The objective of this research is to reduce the defectives of dent defect in hard disk drive media disks. The Six Sigma approach is applied to find out the factors which affect the sunray defect statistically and to obtain the optimal setting of each factor. First, defective rate on media disks is 13% and a dent defect on media disk is identified as a major problem with 5.96% defective rate. It is found that a minimal defective rate of cluster defect is achieved with the setting of the stopper height of DSP holder at 17.30 mm, the Positions of Vacuum holder 1 at 26.4 degree and the Positions of Vacuum holder 2 at 155.2 degree. Finally, the process with the optimal machine settings is implemented along with applying work instruction and training. It can reduce the defective rate from 5.96% to 0.98%.

***Keywords:* -** *Dent Defect, Hard Disk Drive Media Disks, Six Sigma Approach, Response Surface Methodology.*

I. INTRODUCTION

Media disk is the most important component in hard disk drives due to its functionality of data storage. Defects in media disks will effect to the drive performance if they are excessive or too large and severe. Some of key issues from those defects are temporary/permanent data damage, poor bit error rate and degradation of recording head when it flies over defects with large height. So, it is necessary to screen them out earlier in the drive test process.

Several studies on the effects of drive performance resulting from defects in media disks. Zhong Z. W. and Gee S. H. [1] found ultrasonic pits and carbon void defects on disks affect 30–40% loss of the recorded magnetic bit signal and proposed the failure analysis tools for finding the root cause. The study of A. H. Tan et al. [2] revealed that media texturing processes with PD particles can produce denser and smoother surface morphology, lesser texturing scratches which results in higher signal-to-noise ratio than that of MD particles.

The hard disk drive assembly process which is in clean room starts with parts cleaning, base deck loading, putting disks, disk separator plates (DSP) and spacer rings sequentially onto the spindle motor, putting the disk clamp on top of disks, putting Head Stack Assembly (HSA) into the base deck and finally covering by top cover. On the other hand, the disassembly process on the failures is backward from the assembly one.

II. METHODOLOGY

The six sigma approach is the tool for improving the process quality [3]. It has been used widely in various fields [4, 5]. Ratnaningtyas and Surendro [4] used a six sigma to improve the information quality of healthcare in hospital. White et al. [5] employed a six sigma to reduce the cycle time for acquiring a new credit account in a finance group. It can be reduced from 49 days to 30 days with $300,000 saving cost annually.

The Six Sigma approach consists of five phases [6] which are define, measure, analyze, improve and control phases (DMAIC). In the Define phase, problems are defined, the goal is set. In the measure phase, measurement system, process capability and key process input variables (KPIVs) are determined. In the Analyze phase, causes of problems are studied and prioritized. Then, the Design of Experiment (DOE) is introduced to screen for significant factors [7, 8]. In the Improve phase, the response surface methodology (RSM) is employed to find the optimal setting of each significant factor [9, 10]. Finally, process is standardized the by using the control chart and plan in the Control phase.

III. DEFINE PHASE

Data on March 2013 shows rework drives of studying product which consist of 4 media disks with 8 recording heads built defective rate related to media about 13%. This rate is 6% higher than the defective rate of prime drives. Pareto chart in Fig. 1 revealed that the most contribution is dent defect type with 40% of total defectives. In addition, it occurs only at the rework drive so this paper focuses on dent defect only.

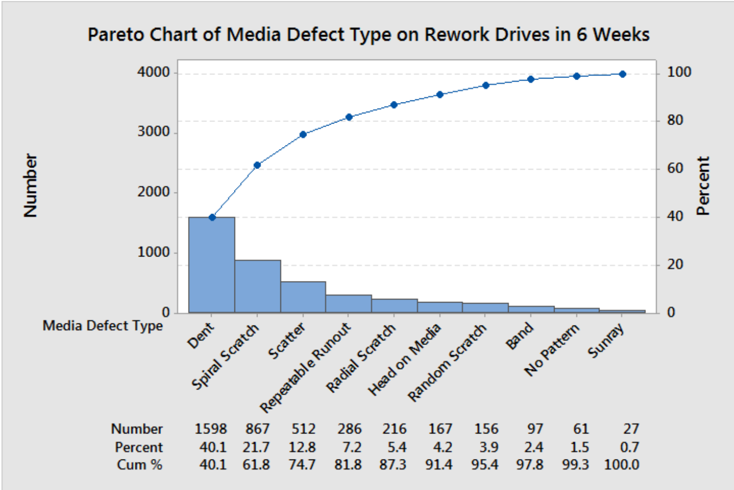

Fig. 1 Pareto chart of media defect type on rework drives in 6 week

IV. MEASURE PHASE

First, all team members brainstorm to list all possible causes of dent defect using a fishbone diagram. Then, media disk data is tracked by disk serial number for both before and after disassembly process. It is found that media mapping of most of failures as Fig. 2 look clean and used to be top disc before disassembling. Therefore, it is suspected that these dent defects may be occurred at disassembly process or assembly one after disassembling.

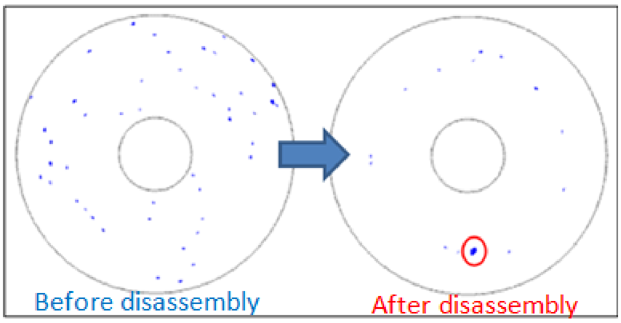

Fig. 2 Microscope result of dent defect

Next, failure analysis is performed to narrow down the root cause. An optical surface analyzer (OSA) is proposed to measure the characteristic of defect based on the principle of reflection and scattering. OSA result in Fig. 3 reveals the large defects on the disk in all 4 modes of OSA. It also shows that the radiuses of these dent defects are closely at 1.32 inches which is the radius of the inner of DSP edge but their angles are various. High power microscope is then confirmed that they are dent on the disk not the bulge as shown in Fig. 4. Based on all results, it is indicated that the dent should be occurred during top DSP removal in disassembly process.

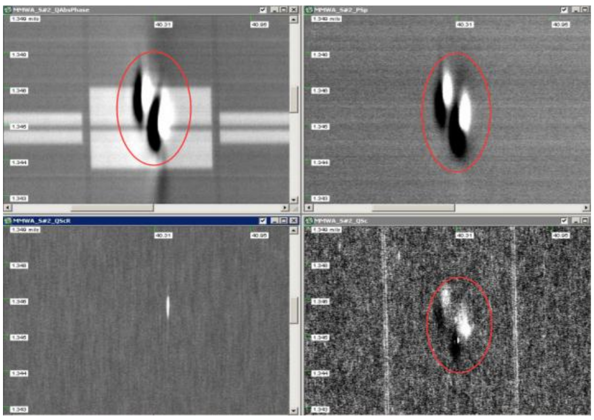

Fig. 3 OSA result of dent defect

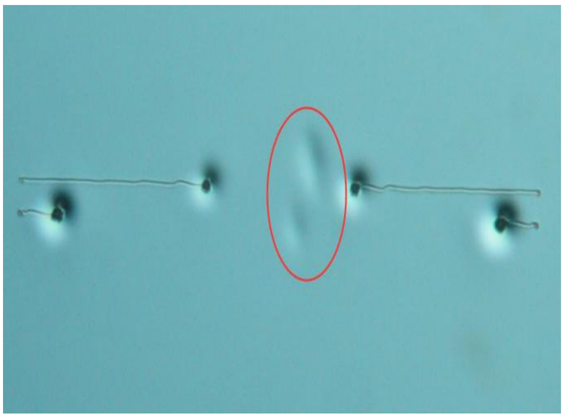

Fig. 4 High power microscope result of dent defect

After scoring on each factor by team members, the ranking of 80% from a Pareto rule leads to 4 machine factors, 2 method factors and 2 material factors. The 4 machine factors are stopper height for DSP removal as shown in Fig. 5 and position of vacuum holder#1 2 and 3 as shown in Fig. 6. While the rest 2 factors from methods which are rubber pusher installation and inspection are improved by setting a new work standard.

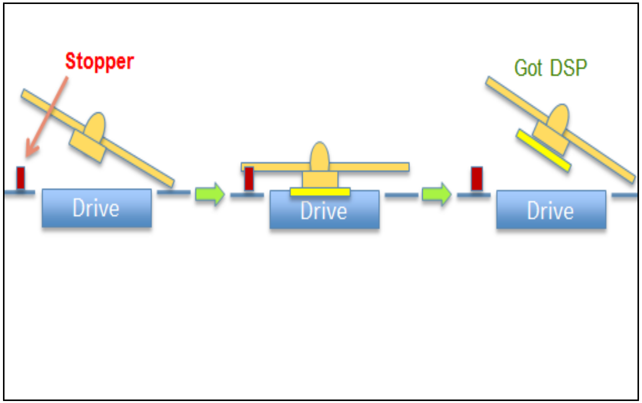

Fig. 5 DSP removal machine

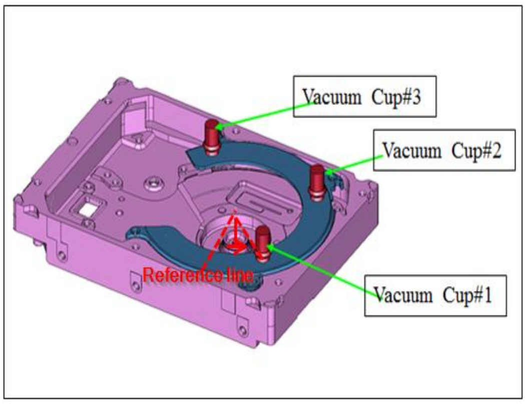

Fig. 6 Positions of DSP holder 1, 2 and 3

V. ANALYZE PHASE

The Design of Experiment is employed to investigate the effect of these 4 factors. The description and levels of each factor are shown in Table 1. Then, a 2^4 full factoral design with a single replicate is introduced to screen the factors. The 4 center points are also added to determine the curvature of response [11] therefore the design has the total of 20 runs. Sample size of 96 drives for each run is determined from 5% significant level with the power of test greater than 90% [12].

Table 1 Factors of a 2^4 full factoral design

Symbol	Factors	Current Setting	Factor level		Unit
			Low (-)	High (+)	
A	Stopper Height for DSP Removal	10.0	5	20	mm
B	Position of Vacuum Holder#1	35.0	20.0	35.0	Degree
C	Position of Vacuum Holder#2	145.0	145.0	160.0	Degree
D	Position of Vacuum Holder#3	210.0	200.0	215.0	Degree

The response variable of this experiment is the dent defective rate which is the proportion response. Bisgaard and Fuller [13] indicated that it would violate the assumption of constant variance. However, Freeman and Turkey's modifications shown in (1) can deal with this problem. So, this paper employs this modification to transform the dent defective rate to F&T transformation.

$$F\&T = \frac{\arcsin\sqrt{\frac{n\hat{p}}{n+1}} + \arcsin\sqrt{\frac{n\hat{p}+1}{n+1}}}{2} \quad (1)$$

Model adequacy checking is necessary before analyzing the experimental results for reliability of analysis. It is checked from the model residuals. Residual plots in Fig. 7 show the residuals align on the straight line with p-value greater than 0.05 in normal probability plot, have no pattern versus fitted values and versus observation orders. This concludes that residuals are independent and normally distributed with stable variance. The experimental results determined by the normal plot of the standard effects shows two main effects which are stopper height for DSP removal (A), position of vacuum holder#2 (C) and the interaction between position of vacuum holder#1 and 2 (BC) affect to dent defect statistically at significant level 0.05 as shown in Fig. 8.

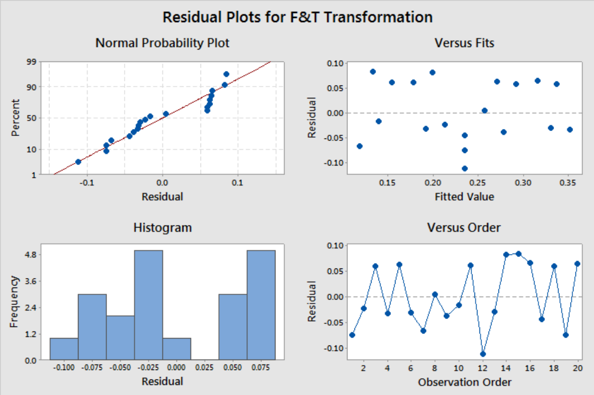

Fig. 7 Residual plots for F&T Transformation

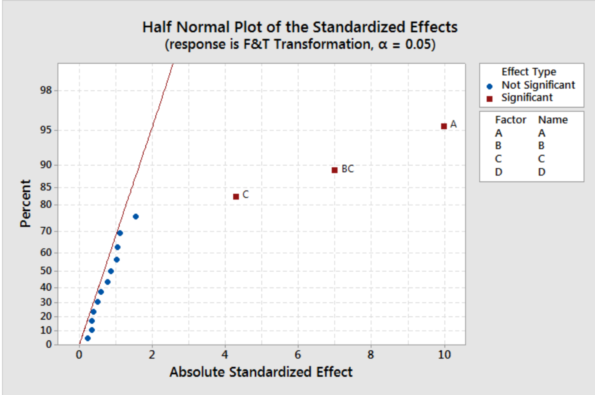

Fig. 8 Normal plots of the standardized effects

VI. IMPROVE PHASE

Response surface methodology (RSM) by Box-Behnken design is proposed to determine the optimal value for each significant factor with respect to minimum defective rate. The Box-Behnken design is beneficial in the lowest number of experiments comparing with other. For 3 factors, it is tested at 3 levels of each factor with additional 3 center points so there are totally 15 experiments. The stepwise regression is then applies to find the relation between factors and response to predict F&T transformations (Y) as shown in (2) which has a strong relation at R-sq (adj) of 85.85%.

$$Y = 27.647 - 0.0332X_A - 0.1391X_B - 0.3274X_C + 0.00101X_C^2 + 0.00096X_A^2 + 0.00092X_B^2 + 0.00058X_BX_C \quad (2)$$

Note: X_A = the stopper height for DSP removal, X_B = position of vacuum holder#1 and X_C = position of vacuum holder#2.

The experimental results are analyzed by including the significant terms given by the stepwise regression into the model. First, model adequacy is guaranteed by the residual plots. Then, the surface plots in Fig. 9 and contour plots in Fig. 10 are performed to illustrate the relation between the dent defective rate and the significant factors. The plots show that the setting that provided the minimal dent defective rate is at the inner zone of each level of the three factors. And also found that dent defective rate is more sensitive for the change of stopper height for DSP removal. Its low level would yield the high dent defective rate because DSP holder can put down too deep and may suck the top DSP or hold DSP tilt and then DSP hits the media disks. Moreover, the proper conditions between position of vacuum holder#1 and 2 that their levels should be opposite would yield the low dent defective rate due to balancing the moment of holding force of vacuum holder.

A response surface optimization concludes that the optimal values are X_A = 17.30 mm, X_B = 26.4 degree and X_C = 155.2 degree. With these settings, defective rate of dent defect is reducing to 2.48%.

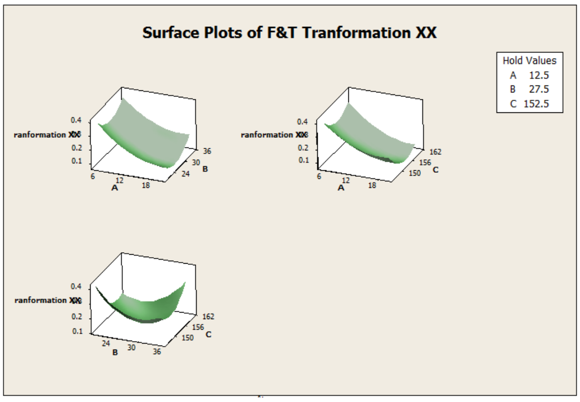

Fig. 9 Surface plots of F&T Transformation

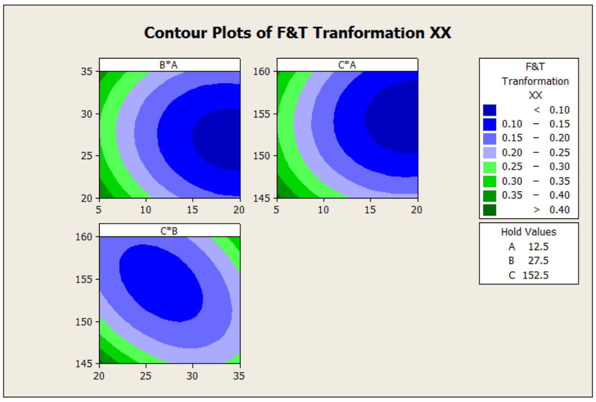

Fig. 10 Contour plots of F&T Transformation

VII. CONTROL PHASE

The optimal setting of 3 factors is implemented in the disassembly to ensure that output from the improve phase is maintained. And control chart is developed to control the process by monitoring yield and defective rate. Based on data from 30 days and 1,000 samples each day, P chart in Fig. 11 shows the average of defective rate of dent defects is 0.98% and all is in the specification. In control plan, Check sheet is implemented to audit shiftly for all 3 factors setting with the developed work instruction and training.

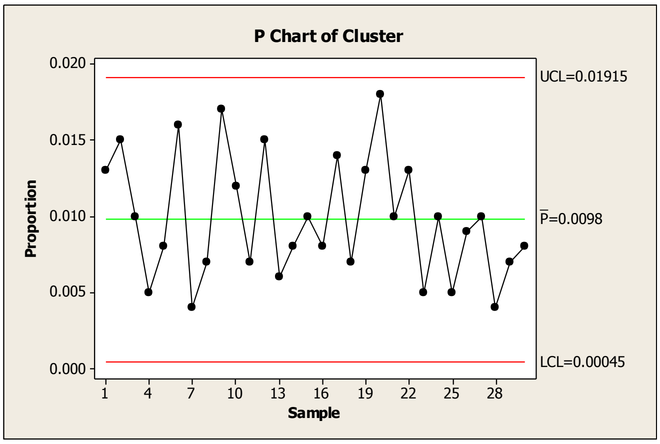

Fig. 11 P Chart of dent defects after improvement

VIII. CONCLUSION

The purpose of this paper is to reduce the defectives in a hard disk drive due to dent defect on media disks. Five phases of a six sigma are implemented to find out the factors which affect the dent defect statistically and the optimal setting of those factors. First, the dent defect on media is identified as the major problem with 5.96% defective rate. Then, a response surface optimization with the Stepwise regression model concludes that the optimal values are 17.30 mm of the stopper height for DSP removal, 26.4 and 155.2 degree of position of vacuum holder#1 and 2 respectively. With the optimal machine settings along with work instruction and training, the defective rate of sunray defect reduces from 5.96% to 0.98%.

REFERENCES

[1] Z.W. Zhong, S.H. Gee, Failure analysis of ultrasonic pitting and carbon voids on magnetic recording disks, *Ceramics International, 30,* 2004, 1619-1622.

[2] A.H. Tan, C.S. Chen, and S. Perng, Effect of media textured surface on defect and noise in hard disk, *Journal of Magnetism and Magnetic Materials, 304,* 2006, 436-438.

[3] P. Pande, and L. Holpp, *What is Six Sigma?* (McGraw-Hill, New York, 2002).

[4] D.D. Ratnaningtyas, and K. Surendro, Information quality improvement model on hospital information system using Six Sigma, *Procedia Technology, 9,* 2013, 1166-1172.

[5] M. White, J.L. Garcia, J.A. Hernandez, and J. Meza, Cycle time improvement by a Six Sigma project for the increase of new business accounts, *International Journal of Industrial Engineering, 16* , 2009, 191-205

[6] R. Does, E.V.D. Heuvela, J.D. Masta and S. Bisgaardb: Comparing nonmanufacturing with traditional application of Six Sigma, *Journal of Quality Engineering, 15,* 2002, 177-182.

[7] S. Meski, S. Ziani, H. Khireddine, S. Boudboub, and S. Zaidi, Factorial design analysis for sorption of zinc on hydroxyapatite, *Journal of Hazardous Materials, 186,* 2011, 1007–1017.

[8] U.A. Dabade, and R.C. Bhedasgaonkar, Casting Defect Analysis using Design of Experiments (DoE) and Computer Aided Casting Simulation Technique, *Procedia CIRP, 7,* 2013, 616 – 621.

[9] A. Pongtrairat, and A. Senjuntichai, Spiral defect reduction of hard disk drive media, *Applied Mechanics and Materials, 421,* 2013, 93-98.

[10] P. Ruthaiputpong, and N. Rojanarowan, Improvement of track zero to increase read/write area in hard disk drive assembly process, *Uncertain Supply Chain Management, 1,* 2013, 165-176.

[11] P. Chutima, *Desing and analysis of experiment* (Chulalongkorn Book, Bangkok 2001, in Thai).

[12] S. Bisgaard, and H.T. Fuller, Sample size estimate for two-level factorial experiments with binary responses, *Center for Quality and Productivity Improvement, 91,* 1992.

[13] S. Bisgaard and H.T. Fuller, Analysis of factorial experiments with defects or defectives as the response, *Center for Quality and Productivity Improvement, 119,* 1994.