

Optimizing Swage Ball's Parameters in the Hard Disk Drive Swaging Process using Finite Element Analysis

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Abstract: Ball swaging process is a general method used in hard disk drive industries to attach Head Gimbal Assemblies (HGAs) to actuator arm. In this process, the swage ball is guided by a pin through the inner base plate's hole in order to deform the base plate to tightly attach to the actuator arm. However, the problem of loose attachment between base plates and actuator arm can still be found in the production line. Although, there are many parameters that have effect on the quality of swaging attachment, this research focuses on the parameters involving the swage ball, one of the most important parts in the process, including ball sizes and the number of balls used. The goal is to develop a method to determine the best combination of ball sizes and number of balls used that would give the best swaging performance for the given model. The three-dimensional finite element model is created and analyzed to estimate the swaging results according to the variation of both parameters. To measure the swaging quality, retention torque at the contact surface between the actuator arm and base plate and the deformation of HGAs are observed at the end of the analysis. By varying the size of the first, second, and third swage balls, the consequent results are treated as the sampling points on the space of consideration. Then, the continuous functions are applied to the sampling points in both the retention torque space and HGAs deformation space. Subsequently, an optimization algorithm is implemented considering both spaces in order to determine the most suitable ball size and quantity for the process. By using the finite element analysis together with an optimization algorithm, the optimal design parameters for a complex problem with multiple conditions of consideration can be easily found.

Keywords: Head Gimbal Assemblies(HGA), Ball swaging process, Finite element method, Optimization

1. Introduction

In the hard disk drive manufacturing process, ball swaging technique is employed to append the head gimbal assembly (HGA) to the actuator arm. The actuator arm is driven by actuator to move across the disk platter in order to place the read-write head to the correct data position. The HGA is used to control the flying height between the read-write head and the disk platter. The HGA consists of three main components including base plate, suspension and slider. In ball swaging process, a sequence of swage balls move through the base plate's hole, and deform it to attach to the actuator arm. The other side of base plate is connected to the suspension, which is a

thin and flexible part in order to control the flying height. And the slider, which is the read-write head, is connected at the end of the suspension

Ball swaging process is a method used to assemble the base plate of HGA to the actuator arm of head stack assembly (HSA). This process consists of three main steps, clamping, swaging and unclamping as shown in Figure 1. In the clamping step, the top key is pressed down to hold base plate and actuator arm together using the general static analysis. In the swaging step, the swage pin is moved down with a constant velocity to push swage balls through the swage hole with the dynamic explicit analysis. In the unclamp step, the clamping force applied on the top key is released with the dynamic explicit analysis.

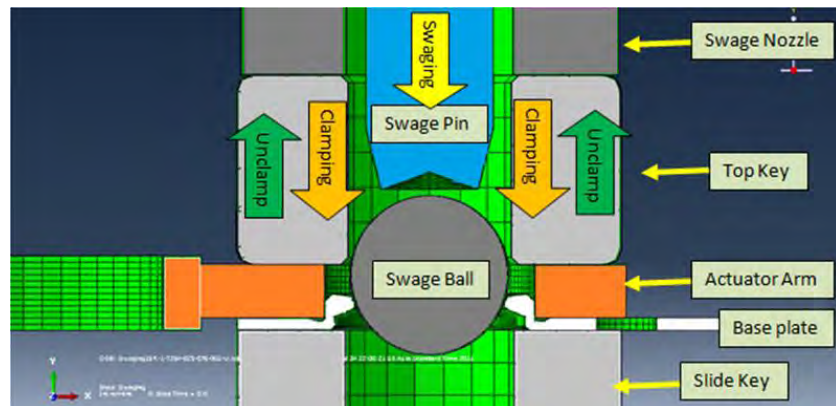


Figure 1 Three main steps of swaging process

In this research, the performance of ball swaging process is measured by the value of retention torque and the deformation of base plate after swaging. The retention torque is a parameter that represents the bonding strength at the contact area between the actuator arm and base plate. The bonding strength directly affects to the accuracy of read-write data to the disk platter. The higher bonding strength reduces the errors during read-write process. The deformation of base plate after ball swaging process is another parameter of interest. The deformation of base plate affect directly to the flying height of slider. With large deformation, the read-write head may lose tracking when the flying height is too high, or it may damage the disk when the flying height is close to zero. For this reason, the deformation of base plate should be carefully controlled and monitor closely.

T. Kamnerdtong, S. Chutima, and K. Ektumas (2005) studies effects of swaging process parameters using variations of ball size, ball velocity, ball direction, and coefficient of friction between the ball and the base plate using finite element analysis. The results of ball size variations from this study show that the larger ball size, the better retention torque is presented, while the deformations of base plate are also increased. The results of this report lead to a new procedure using two or more of smaller swage balls in the swaging process in order to reduce the deformation of base plate and maintain the high value of retention torque.

In this paper, we perform the finite element parametric study by varying the sizes of the first, second, and third swage balls used in the ball swaging process, and develop a method to seek for the optimal combination. The three dimensions model is used in the analysis to attain sampling points of the combination. A continuous function is then applied in order to search the optimal point.

2. Finite Element Modeling

2.1 Modeling

The model used in this paper is the three dimensional model. To reduce the analyzing time, only 1 head is included in the model. The model consists of the following parts: swage nozzle, swage pin, top key, actuator arm, swage ball, base plate, and slide key

The type of every part is assigned separately as discrete rigid bodies and deformable part. The discrete rigid parts are assigned to swage nozzle, top key, swage ball, and slide key. The swage pin, actuator arm, and base plate are defined as deformable parts in order to use for analyzing the results

2.2 Load and Boundary conditions

The swaging process has three main steps which need to specify the loads and boundary conditions separately.

1. Clamping step

Loads:

- The constant force is applied to top key in the vertical axis.

Boundary conditions:

- Top key: all axes are fixed except the vertical moving which starting position contact with upper surface of the actuator arm.
- Actuator arm: all axes are fixed at the end of the actuator arm.
- Slide key: all axes are fixed.

2. Swaging step

Loads:

- The constant velocity is applied to the top of the swage pin in the vertical axis.

Boundary conditions:

- Swage nozzle: all axes are fixed.
- Top key: all axes are fixed at the position after clamping step.
- Actuator arm: all axes are fixed at the end of the actuator arm.
- Slide key: all axes are fixed.

3. Unclamp step

Loads:

- The constant force from the clamping step is removed from Top Key.

Boundary:

- Top key: all axes are fixed at the position before clamping step.
- Actuator arm: all axes are fixed at the end of the actuator arm.
- Slide key: all axes are fixed.

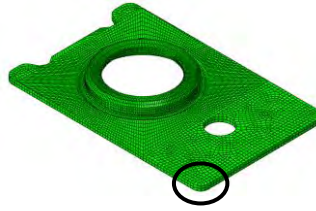
3. Method

To find out the optimal solution of the swage ball's combination, the samples of four swage ball's sizes are selected with uniform increasing diameter of 0.001 inch. The four size samples are defined as ,a", ,b", ,c", and ,d" in the ascending order. The sample ,a" is the smallest dimension of swage ball that starts to have an effect to the performance of attachment between an actuator arm and a base plate. The ,d" sample is the largest dimension starting to decrease the contact force between an actuator arm and a base plate.

The combination of sample swage ball's size is created with four parameters as below.

- n : The number of swage ball used.
- $\Delta B_{n-1,n-2}$: $B_{n-1} - B_{n-2}$, The difference between sizes of ball n-1 and ball n-2
- $\Delta B_{n,n-1}$: $B_n - B_{n-1}$, The difference between sizes of the last ball and ball n-1
- B_n : The diameter of the last swage ball.

With these four parameters, a number of combinations are created in order to verify the analyzing results. However, the cases that have combinations of swage ball using ,a" and ,b" samples as the last swage ball are eliminated from this study, because those combinations are not possible to implement in the production due to low retention torque. Therefore, the combinations studied in this paper are listed as Table 1



*The picture is shown in X400 of the normal displacement

Figure 2 The highest absolute displacement point of the base plate

To find out the optimal solution, we use the deformation of base plate as the initial criteria to remove all combinations, whose displacement values are higher than the specification, out from the consideration. Then, the algorithm searches for the best combination that has the highest value of retention torque.

4. Result

4.1 Swaging with one swage ball

The retention torque is one of the parameters representing the performance of ball swaging process. The Figure 3(a) illustrates that by increasing the swage ball diameter, the retention torque also increases with non-linear relationship.

The second parameter used to consideration is the deformation of base plate. From Figure 3(b), the result shows a tendency that as swage ball's increases, the displacement of the base plate will get smaller as shown in Figure 3(b).

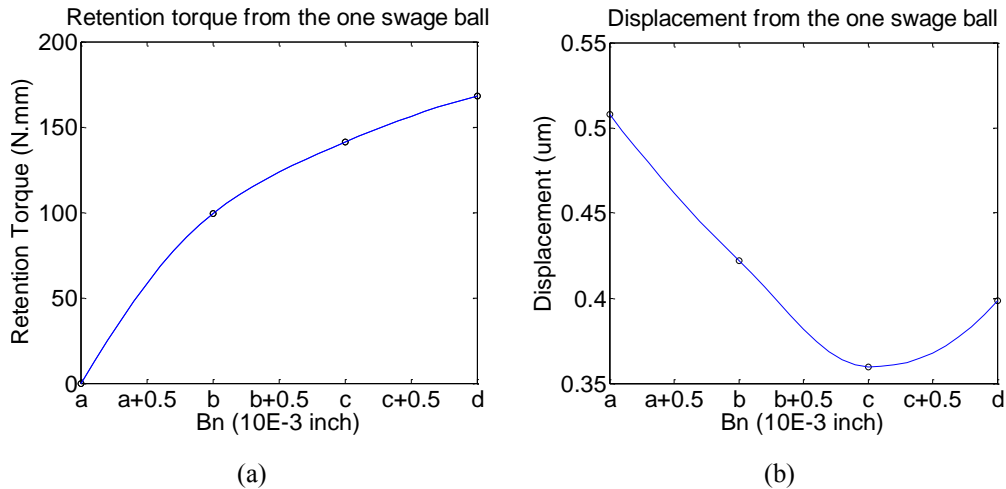


Figure 3 Retention torque curve (a) and displacement (b) of the one swage ball case

4.2 Swaging with two swage balls

From Figure 4 (a), the retention torque results are similar for both cases setting the last swage ball as sample „c” and „d”. The pattern shows that when the sizes of the first swage ball and second swage ball are 0.001 inch different, the retention torque reaches the highest point (Circle (a)).

Figure 4 (b) shows the surface of the displacement results. The circled area shows some abnormal results that the deformation of base plate is less than the case using one swage ball.

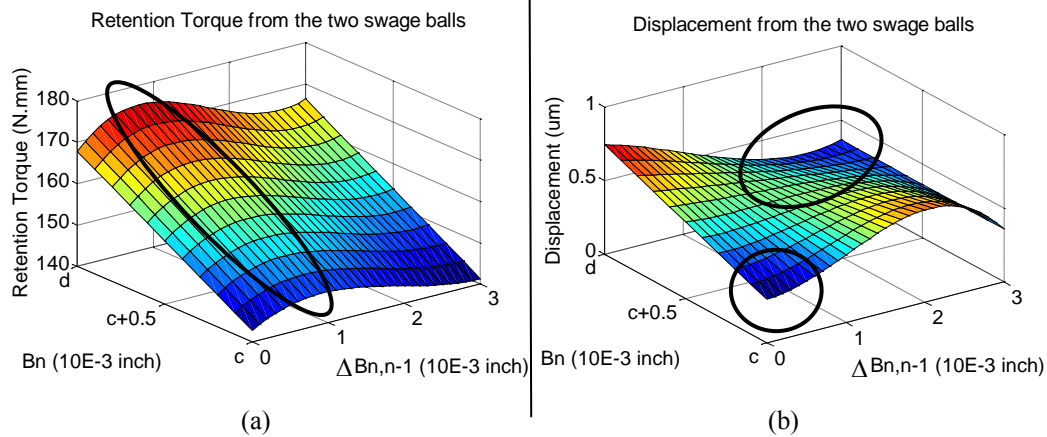


Figure 4 Retention torque (a) and displacement (b) surface of the two swage balls cases

4.3 Swaging with three swage balls

The result of the three swage ball cases shows the same pattern as the two swage ball case that the one step of 0.001 inch difference gives higher torque results than other combinations of three swage balls, as shown in the circled area. The other high retention torques shown in the dashed circle of Figure 5 are the result from the both two swage ball cases and one swage ball cases, because the combinations of those areas have the diameter of swage ball less than the inner diameter of base plate.

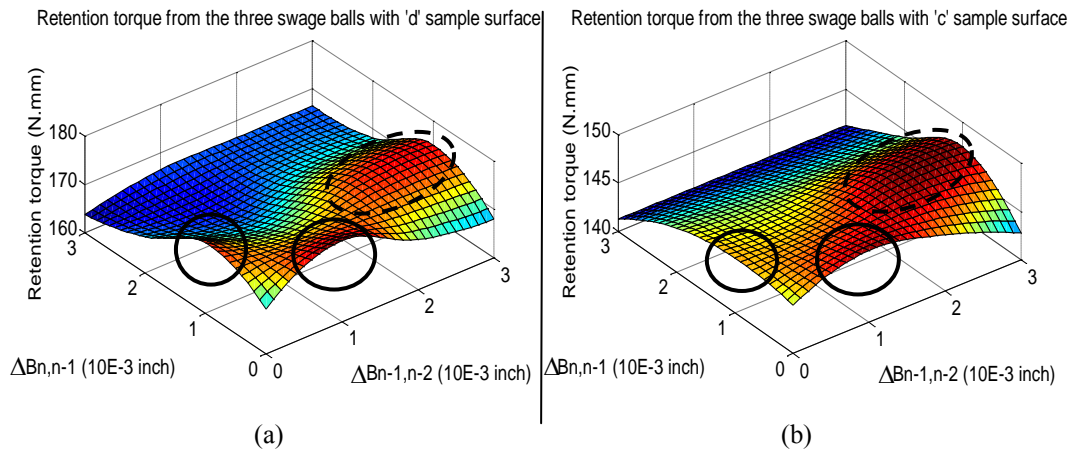


Figure 5 Retention torque surface of 'd'(a) and 'c'(b) sample with the three swage balls cases

The over all of these two surfaces shown in Figure 6 illustrate that the third swage ball increases the deformation of the base plate in any cases. Nevertheless, the black circle area in Figure 6(a) still shows the very low displacement because of the propagation of the abnormal area from the two swage ball cases.

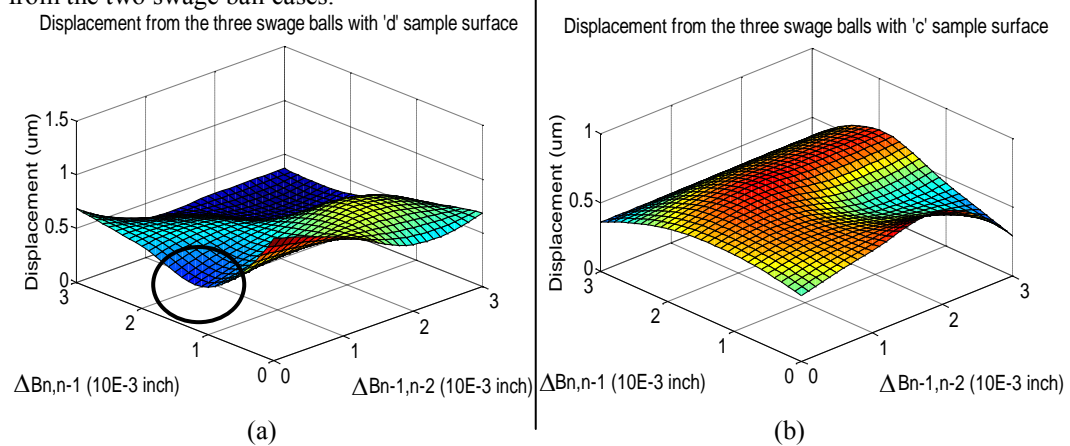


Figure 6 Displacement surface of 'd'(a) and 'c'(b) sample with the three swage balls cases

4.4 The optimization results

The result of all studied cases shows that the best retention torque is 176.7851 N.mm as shown in the item 1 of the Table 2. However, this case also gets high deformation of base plate of 0.9219 μm . Therefore, the second highest retention torque areas of the three swage balls cases are considered as shown in the item 2 of the Table 2. With this condition, we can get the high result of retention torque at 174.6082 N.mm and low deformation of base plate at 0.4421 μm . When we

consider on the two swage balls cases, the best retention torque is 175.2717 N.mm and the displacement at 0.6065 μm as shown in the item 3 of the Table 2. For the one swage ball cases, all retention torque value are smaller than 170 N.mm, so these cases are removed from the considerations.

Table 2 The high retention torque cases

Item No.	n	$\Delta B_{n-1,n-2}$ (10E-3 inch)	$\Delta B_{n,n-1}$ (10E-3 inch)	B_n (10E-3 inch)	Retention torque (N.mm)	Displacement (μm)
1	3	1	0	'd' sample	176.7851	0.9219
2	3	0	1	'd' sample	174.6082	0.4421
3	2	0	0.75	'd' sample	175.2717	0.6065

5. Conclusion

According to the results, the algorithm successfully finds the optimal combination of ball size and quantity to be used in the ball swaging process. The optimizing result shows that if we use two swage balls and three swage balls with the suitable combinations, we can obtain higher retention torque value than when only one swage ball is used. In addition, the results of all cases illustrate that the 0.001 inch difference from the last swage ball has a tendency to get the high retention torque. Besides, the deformation of the base plate has the tendency to increase, when we increase the number of the swage ball used in the ball swaging process. For future study, a more effective way to measure deformation may be explored in order to achieve a more accurate result.

6. Acknowledge

We would like to expose our appreciation to Industry/University Cooperative Research Center (I/UCRC) in HDD Advanced Manufacturing , Institute of Field robotics (FIBO) , King Mongkut's University of Technology Thonburi and National Electronics and Computer Technology Center , National Science and Technology Development Agency for funds and to many research assistants at COCARE, and Western Digital Thailand, who advise and give for any information and to make this research successful.

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