

## การศึกษากระบวนการประกอบหัวอ่าน/เขียนสำเร็จ และหาวัสดุ ของแขนหัวอ่าน/เขียนที่เหมาะสม

### The characterization in the Head Stack Assembly (HSA) During the Swaging Process: Optimization of Actuator Arm Material

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#### บทคัดย่อ

งานวิจัยนี้เป็นการศึกษากระบวนการประกอบหัวอ่าน/เขียนข้อมูล (Head Gimbal Assembly, HGA) เข้ากับ แขนหัวอ่าน/เขียน (Actuator Arm) เพื่อให้ได้ ชุดประกอบหัวอ่าน/เขียนสำเร็จ (Head Stack Assembly, HSA) ซึ่งกระบวนการนี้เรียกว่ากระบวนการประกอบชุดประกอบหัวอ่าน/เขียนสำเร็จ (HSA Swaging process) โดยใช้ลูกบอลยิงผ่านแผ่นฐาน (Base plate) ซึ่งเป็นส่วนประกอบของ HGA เพื่อให้แผ่นฐานขยายตัวและเปลี่ยนรูปร่างอย่างถาวร ยึดติดกับแขนหัวอ่านเขียน โดยในงานวิจัยนี้จะศึกษาหาวัสดุของแขนหัวอ่านเขียนที่เหมาะสม เพื่อเพิ่มประสิทธิภาพของกระบวนการ โดยใช้วิธีทางไฟไนต์เอลิเมนต์ (Finite Element Method) ในการวิเคราะห์ และทำนายพฤติกรรมการเกิดความเค้นของกระบวนการ ซึ่งปัจจุบันวัสดุของแขนหัวอ่านเขียน คือ Aluminum 6061-T6 จึงทำการทดสอบกับอะลูมิเนียม (Aluminum) 5 ชนิดเรียงตามความแข็งแรง คือ 6063-T5, 6063-T6, 6061-T6, 7005-T6 และ 7005-T53 ซึ่งจากการศึกษาพบว่าเมื่อแขนหัวอ่านเขียนใช้วัสดุที่มีความแข็งแรงขึ้น จะทำให้ค่าการต้านทานโมเมนต์บิด (Retention torque) สูงขึ้น อย่างไรก็ตามวัสดุที่ทำให้เกิดค่าต้านทานโมเมนต์บิดสูง และเกิดการเสียรูปของแผ่นฐานต่ำ คือ Aluminum 7005-T6 ดังนั้นวัสดุของแขนหัวอ่าน/เขียน ที่เหมาะสม คือ Aluminum 7005-T6

#### ABSTRACT

This research studied the head stack assembly (HSA) swaging process, focusing on the head gimbal assembly (HGA) and the actuator arm. This process uses a ball which is swaged through a base plate, a component of the HGA, to expand and plastically deform the base plate, causing the base plate to adjoin with the actuator arm. The actuator arm material was investigated to increase the efficiency of manufacturing process. Prediction of the stress behavior was analyzed by Finite Element Method. This research used 5 types of aluminum with different strength such as 6063-T5, 6063-T6, 6061-T6, 7005-T6 and 7005-T53. Among them, Aluminum 6061-T6 is mostly used as an

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actuator arm. The result showed that the retention torque was increased when the actuator arm was stronger. However, the use of Aluminum 7005 T6 as actuator arm showed high torque value and least deformation of base plate. Therefore, Aluminum 7005-T6 was suitable for making the actuator arm.

**คำสำคัญ :** กระบวนการประกอบชุดประกอบหัวอ่าน/เขียนสำเร็จ, ไฟไนต์เอลิเมนต์, วัสดุของแกนหัวอ่านเขียน

**Keywords :** HSA swaging process, Finite Element Analysis, actuator arm material.

## Introduction

Hard disk drives are critical equipments in computers, used for data storage purpose. An induction slider, attached to the end of HGA, was used to store data on the magnetic disk. HGA components, Figure1, are attached to the actuator arm in Figure2 to become a Head Stack Assembly (HAS), Figure3, through the Ball Swaging Process. This process uses a ball with a diameter wider than base plate hole, which is a component in HGA, to swage through the base plate causing it to expand and plastically deform. This deformation creates contact pressure and retention torque between the base plate and the actuator arm, thus adjoin them together.

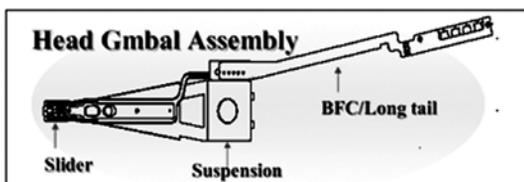


Figure1. HGA

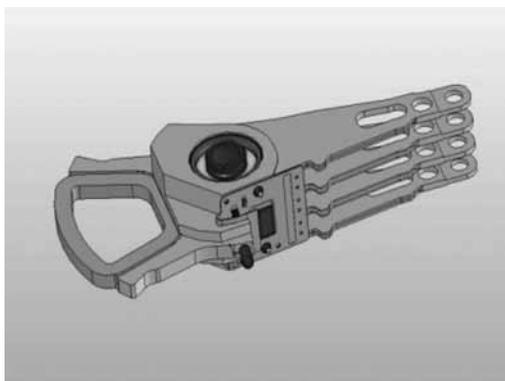


Figure2. Actuator Arm

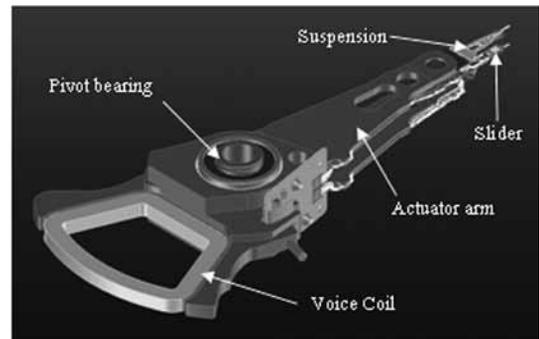


Figure 3. HSA

(Piela, 1992) had studied the Finite Element Method in analyzing the Swaging Process. The results showed that, by using the Finite Element Method, the components' stress, strain, and structure can be compared and analyzed. The author also suggested manufacturers develop the components shape to fit the swaging process so that will create less damage in components. The ball swaging process in HGA components was first published in 1975 by IBM. It was included in the IBM Disclosure Bulletin, titled "Ball Staking of a Transducer Assembly Block to a Positioned Arm", which analyzed retention torque in the product from the Ball Swaging Process (IBM, 1975).

Aoki and Aruga, (2007) had also analyzed the swaging process with Finite Element Method. By comparing the experimental results, it was found that the slider bended upward or downward because of the deformation in 2 conjunctive parts: base plate and actuator arm. Deformation in the base plate was in an

umbrella-like shape (Kamnerdtong and Ekintumas, 2005). The 4 factors considered in the study for predicting stress, strain, and plastic deformation behavior were ball size, velocity, direction, and coefficient of friction between the ball and the base plate. All of these factors have influences on retention torque and bending angle of the base plate. Suggestion regarding the ball size was not to use only one big ball, because, although it may give the component high retention torque, it may also create excessive deformation in the component, thus damaging it. Instead, many balls of various sizes are suggested for the process. In particular, the smallest ones should be swaged through first to create the desired retention torque and reduce the bending angle of the base plate.

Kiatfa and Weerapol (2010) have studied the HGA Swaging Process to determine the optimal ball velocity by using Finite Element Method. The

operational function of the swaging machine is shown in Figure. 4, indicating its key components as follows:

1. Swage Pin : pushes the ball through base plate's hole to press the base plate against the actuator arm
2. Swage Press Clamp : holds the base plate and the actuator arm together while the ball is swaged with a distributed force at 150 – 250 psi
3. Swage Key : supports each level of HGA components and keeps them at fixed distance
4. Swage Ball : the most important element in the Swaging Process. It is made of stainless steel, with a diameter between 0.078 – 0.0823 inch. Number of balls used and their velocity depend on the type of products
5. HGA alignment : keeps HGA in alignment during the Swaging Process

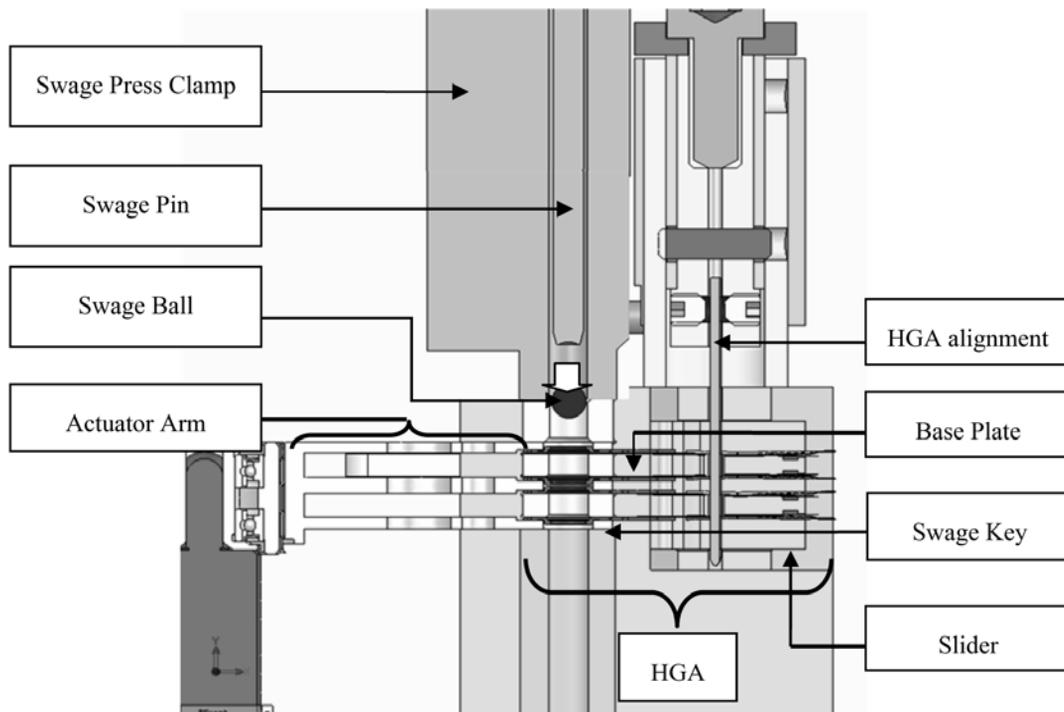


Figure 4 .Swaging Machine Diagram

Moreover, the research elaborated on the stress and strain behaviors during and after the process. In particular, there were 2 types of strain behavior observed while the balls went through the base plate. The first strain was caused by the ball size in the radial

direction through the base plate against the actuator arm creating contact pressure. The second was caused by friction between the ball and the base plate. Both strains created torque and plastic deformation in the base plate, shown in Figure. 5.

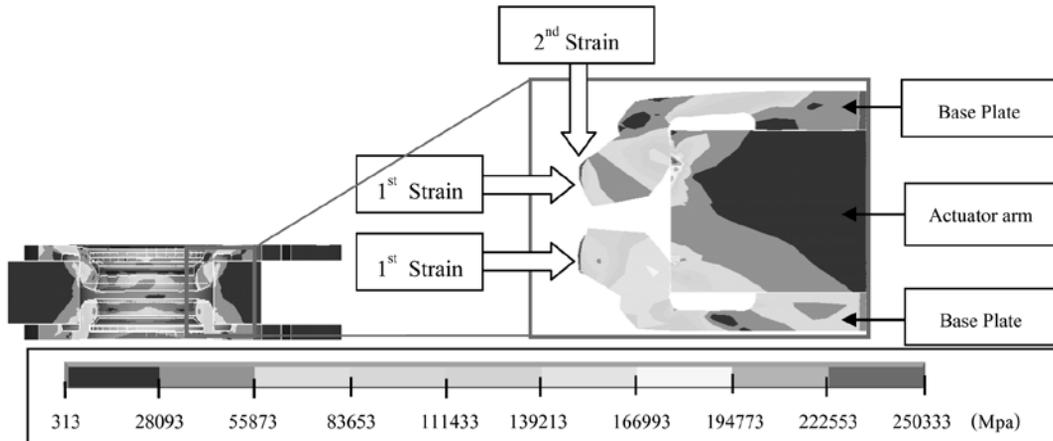


Figure 5. Deformation in the Ball Swaging Process

In that research by Kiatfa & Weerapol (2010), the coefficient of friction occurring between the ball and the base plate as well as the optimal ball velocity was determined. As the coefficient of friction between the ball and the base plate and the ball velocity increased, the retention torque tended to increase. The optimum ball velocity and coefficient of friction between the ball and the base plate are 40 m/s and 0.08, respectively.

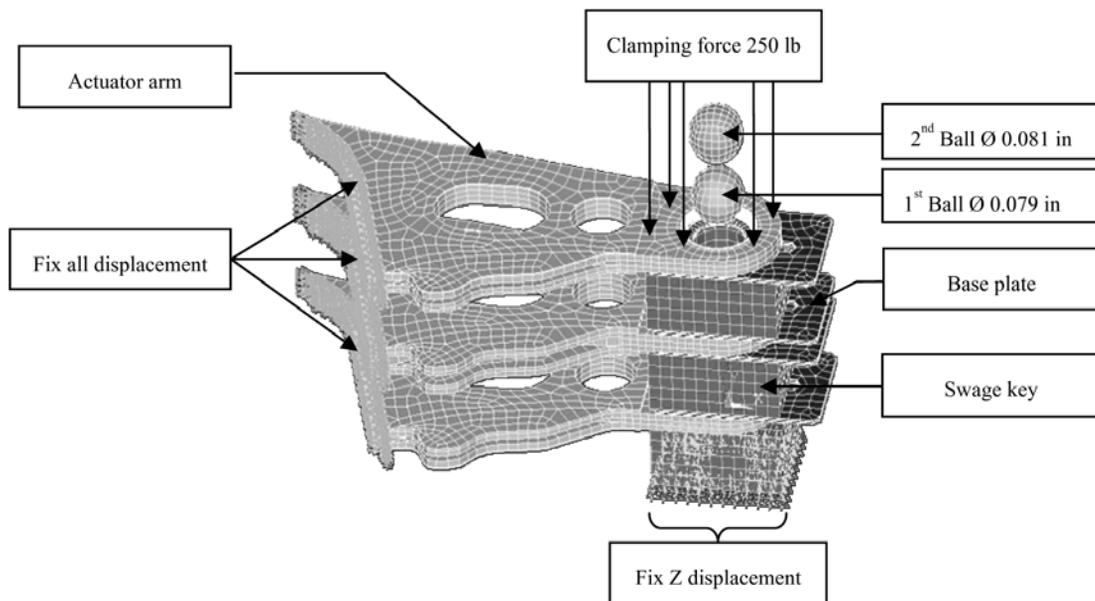
This research followed the research by Kiatfa & Weerapol (2010) previously mentioned, by using the optimal values of ball velocity, coefficient of friction, ball, and the base plate, as the base value in studying the swaging process. The finite element method (FEM) was also used for the analysis and prediction of strain and retention torque, in order to arrive at the most suitable material for an actuator arm.

### The Finite Element Model

The Explicit Dynamic Analysis was used for the analysis of the HSA Swaging Process because it tends to yields accurate results, reduces calculation time, and because the contact surface can also be predetermined. Additionally, this analysis is suitable for solving problems involving impact and crashes. The Finite Element Model is the first step in the analysis. A 3-D model of each component is created and can be grouped into elements as no-node cube. This is because the Explicit Dynamic Analysis does not allow any nodes in the center. The balls are set to be rigid because they have more strength compared to other components in the study. All of these are grouped in the solid element with 8 nodes.

As for the boundary condition of the Finite Element Model, the balls were set at constant downward velocity of 40 m/s and upper distributed clamping force of 250 pound around the top of the arm, as shown in Figure 6.

The material property of the base plate, the actuator arm, and swage key is set to be bilinear isotropic hardening elastic-plastic due to its deformation behavior and the fact that it is suitable for the Explicit Dynamic Analysis. On the other hand, the balls are assumed to have rigid bodies to expedite the simulation, due to their strength compared to other components.



**Figure 6.** The Finite Element Model for the Ball Swaging Process

## Experimental Design

In order to determine the most suitable material to produce an actuator arm, the Finite Element Method was used. Aluminum 6061-T6 is currently used for actuator arms. The experiment was to test 5 types of aluminum at various strengths, in ascending order: 6063-T5, 6063-T6, 6061-T6, 7005-T6, and 7005-T53.

Their properties are listed in Table 1. The objectives of the experiment were to determine the material with highest retention torque and lowest deformation toward the edge of the base plate. The conditions were set as follows:

- $\mu$  between the balls and the base plate was 0.08
- $\mu$  between the actuator arm and the base plate was 0.45
- Ball velocity was 40 m/s

**Table1.** Properties of Each Material Tested for Actuator Arm

Materials	Ultimate Tensile Strength		Tensile Yield Strength (0.2% offset)		Elongation in 50 mm. or 2 in	Ultimate Shear Strength		Modulus of Elasticity		Density 10 <sup>3</sup> kg/m <sup>3</sup> (lb/in <sup>3</sup> )	Poisson's ratio
	MPa	(ksi)	MPa	(ksi)		MPa	(ksi)	GPa	10 <sup>3</sup> (ksi)		
6063-T5	185	27	145	21	12	115	17	69	10	2.70 (0.097)	0.33
6063-T6	240	35	215	31	12	150	22	69	10	2.70 (0.097)	0.33
6061-T6	310	45	275	40	12	205	30	69	10	2.70 (0.098)	0.33
7005-T53	395	57	350	50	15	225	32	72	10.4	2.77 (0.100)	0.33
7005-T6	350	51	290	42	13	215	31	72	10.4	2.78 (0.101)	0.33

The quality of the Ball Swaging Process could be measured by the retention torque and the deformation in the head (HGA) by measuring the deformation at the edge of the base plate, as shown in Figure. 7. The head starts at Head 0 from the bottom base plate, up to Head 3 at the top plate. As shown in the Figure, Head 0 and Head 2 are in the same position and the same goes for Head 1 and Head 3. In general, a Ball Swaging Process with high quality must yield low deformation and high retention torque, which can be determined from the equation below.

$$T = \mu r \int s P ds \quad (1)$$

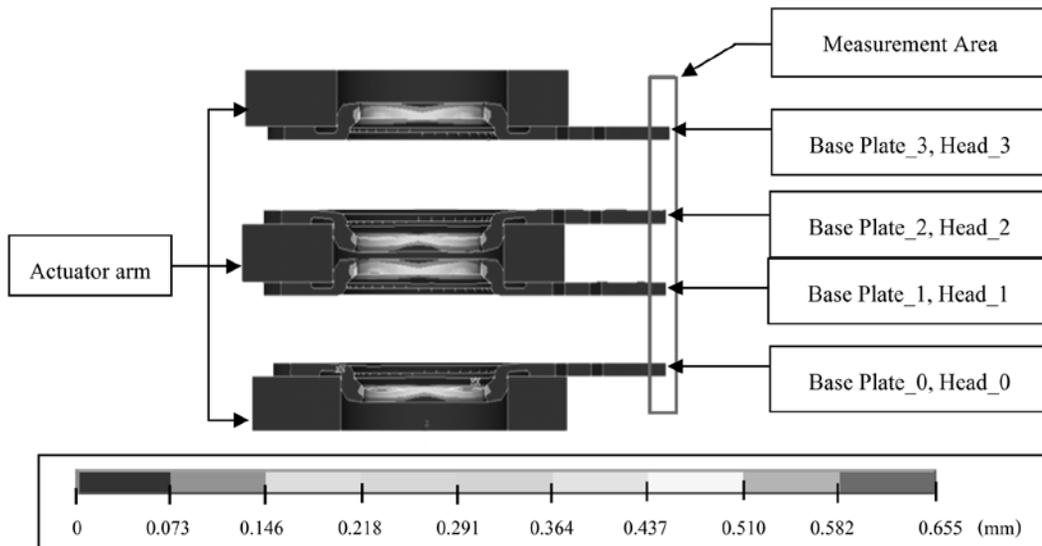
Where: T : Retention Torque

$\mu$  : Coefficient of Friction Between the Base Plate and the Actuator Arm

r : Radius of the Hole on the Base Plate

P : contact pressure on the head

s : Contact Area between the Base Plate and the Actuator Arm

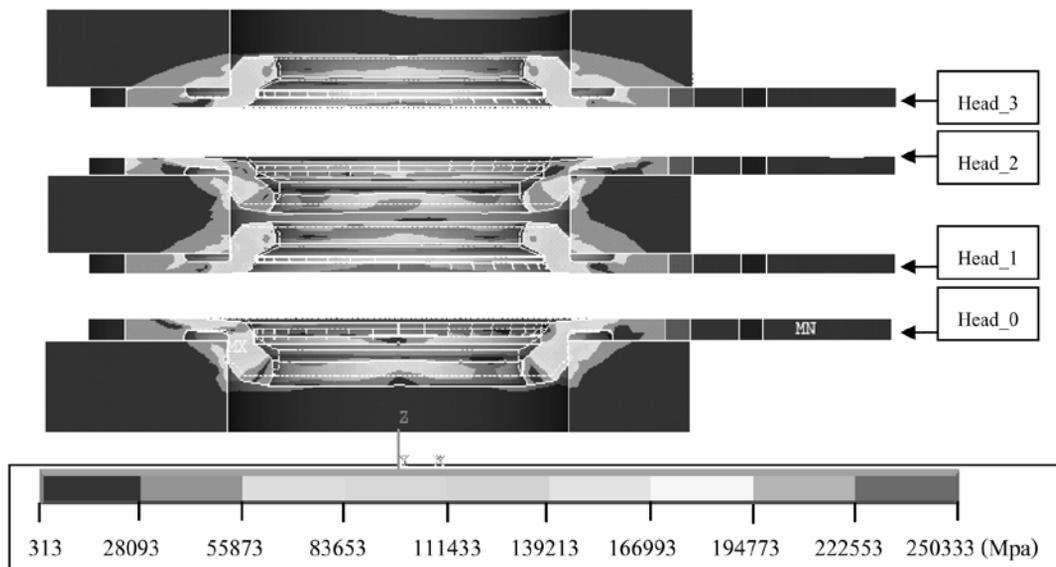


**Figure 7.** Base plate and actuator position and deformation

## Results

After the Ball Swaging Process was completed, it was evident that the ball created plastic deformation in the base plate in the radial direction against the actuator arm. This, in turn, created contact pressure and strain at the point of contact between both parts, as shown in Figure 8. The contact pressure value was used for

retention torque calculation in Equation 1, to determine the attachment quality between parts. Since the base plate was plastically deformed, the suspension adjoined to the base plate would bend and twist in the axial direction. Therefore, a qualified Ball Swaging Process is supposed to yield low deformation in the base plate and high retention torque.



**Figure 8.** Von Misses Strain and plastic deformation in the actuator arm and the base plate

The experimental results to determine the most suitable material for actuator arms by testing 5 types of aluminum at various strength, in ascending order (6063-T5, 6063-T6, 6061-T6, 7005-T6, and 7005-T53), could be divided into 2 parts. Part 1 was the analysis of retention torque in each material. Figure. 9 shows that as the material strength increased, the retention torque also increased. On the other hand, Part 2 was the analysis on deformation in each material. Figure. 10 shows that

the deformation distance did not vary exclusively with material strength. However, it varied with the material of the actuator arm as well as the base plate. The strength of the actuator arm made from Aluminum 7005-T6 was suitable with the base plate made from UNS S30500. Therefore, the deformation around the base plate area was low. It can thus be concluded that the actuator arm made from Aluminum 7005-T6 is suitable with the base plate made from UNS S30500.

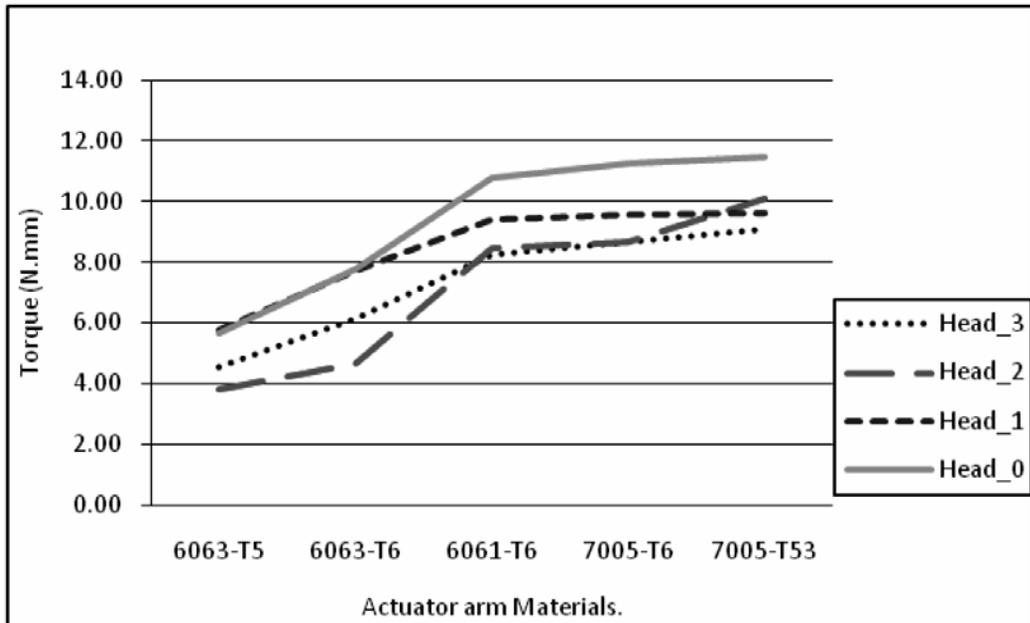


Figure 9. Retention Torque in Various Types of Actuator Arm with different scanning heads

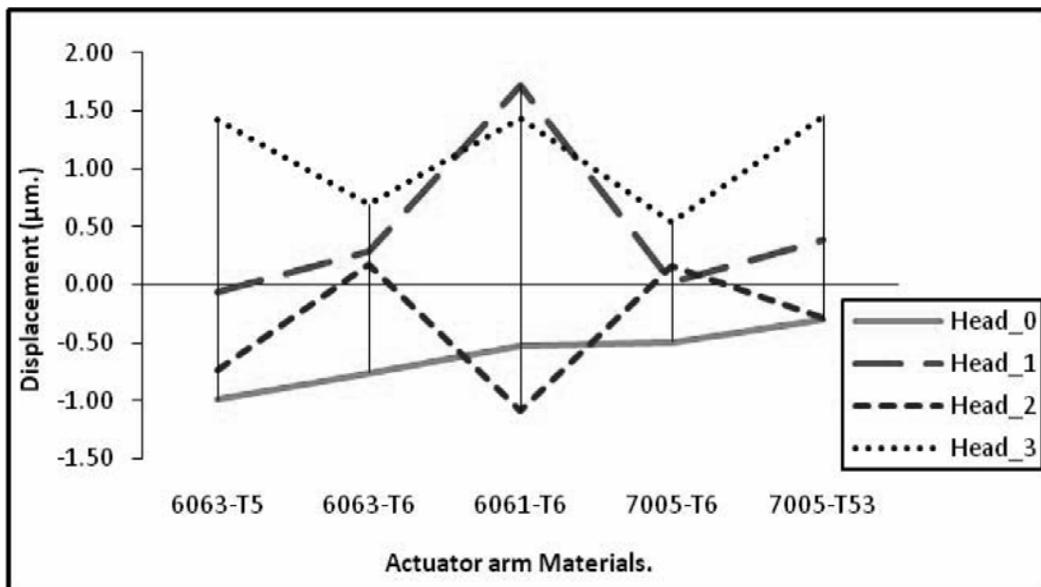


Figure 10. Retention Torque for Various Types of Actuator Arm

## Conclusion

The analysis was done by examining the Ball Swaging Process using the Finite Element Method to determine the most suitable material for actuator arms by testing 5 types of aluminum: 6063-T5, 6063-T6, 6061-T6, 7005-T6, and 7005-T53. The result showed that retention torque increased when the strength of aluminum increased. Specifically, Aluminum 7005-T6 was the type which yielded high retention torque and low deformation around the edge of the base plate.

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