A Study of the Head Stacks Assembly (HSA) during the Swaging Process: Optimization of the Ball Velocity.

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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. There are many variations in parameters which affect the manufacturing process. Therefore, the aim of this research was to study the optimum velocity of the ball in order to increase the efficiency of the manufacturing process. The prediction of the stress behavior during the swaging process was analyzed by using the finite element method. The results showed that the retention torque was increased when both the coefficient of friction between the ball and the base plate and the ball velocity were increased. The optimum parameters that increased the efficiency of the process were found to be a ball velocity and a coefficient of friction between the ball and the base plate with values of 40 m/s and 0.08, respectively.

Keywords: HSA swaging process, Finite element analysis, Head stack assembly

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 onto the magnetic disk. HGA components, Figure 1., are attached to the actuator arm in Figure 2. to become a Head Stack Assembly (HAS), Figure 3., through the Ball Swaging Process. This process uses a ball with 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.

Piela (1992) had studied the Finite Element Method in analyzing the Swaging Process. The results

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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 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", analyzing retention torque in the product from the Ball Swaging Process (IBM, 1975).

Aoki & 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 plastically 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.

In this research, the Finite Element Method (FEM) will be used for the analysis and prediction of stress behavior and retention torque after the Ball Swaging Process. The 2 variables determined in the study were ball velocity and coefficient of friction between the ball and the base plate, in order to find the optimum value and compare the results from the Actual Ball Swaging Process with those from the Finite Element Method.

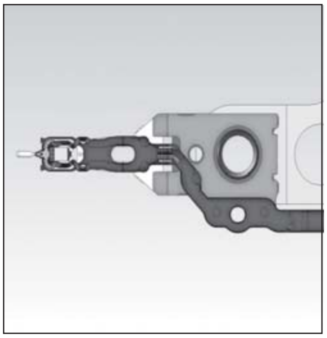


Figure 1. HGA

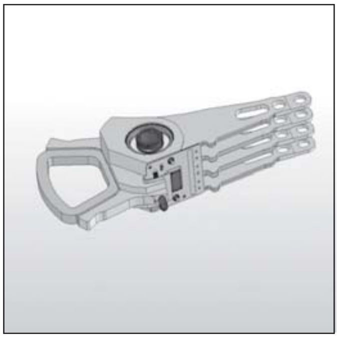


Figure 2. Actuator arm

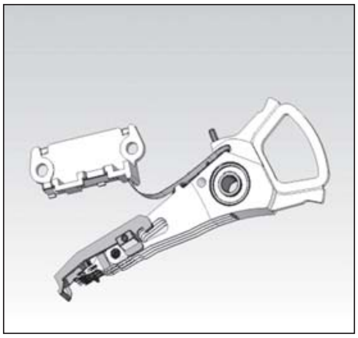


Figure 3. HSA

Equipments required for the assembly of the Swaging Machine, shown in Figure 4., are as follow:

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 was 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 : is 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

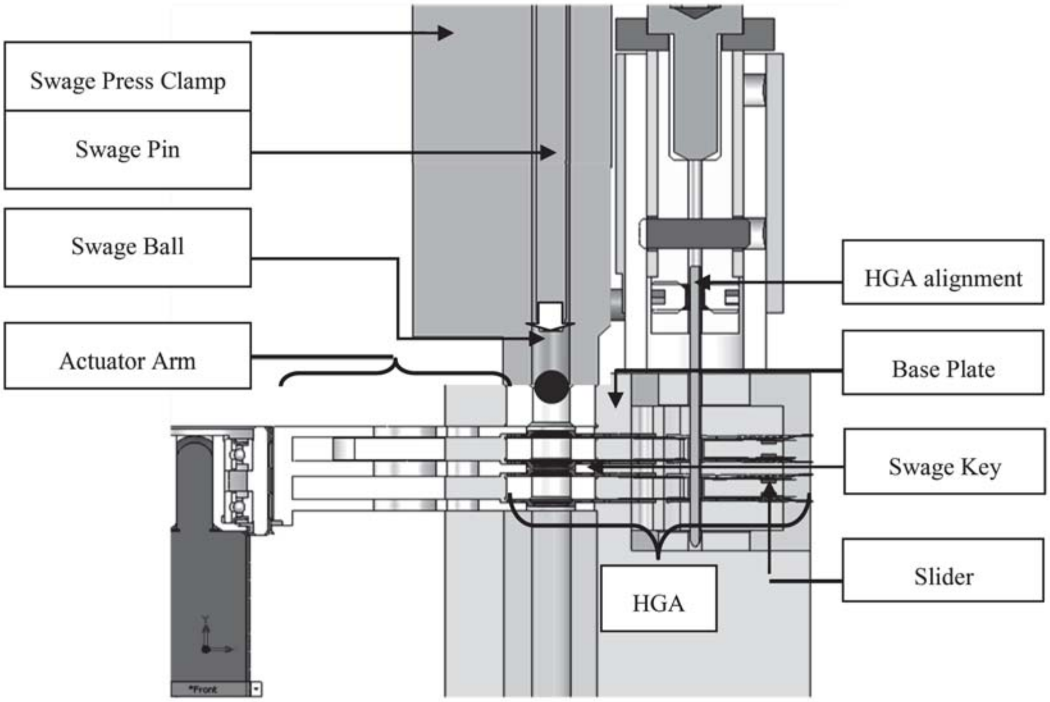


Figure 4. Swaging Machine Structure

The Finite Element Model

The Explicit Dynamic Analysis was used for the analysis of the HSA Swaging Process because it yields accurate results, reduce calculation time, and the contact surface can also be predetermined. Additionally, this analysis is suitable for the solving problems involving impact and crash. 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. They 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 velocity with upper distributed clamping force of 250 pound around the top of the arm, as shown in Figure 5.

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

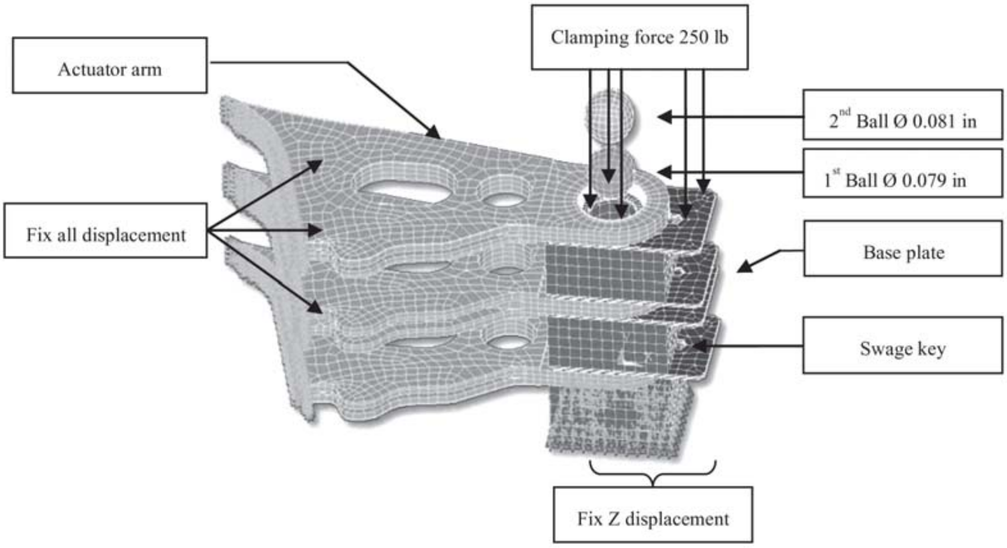


Figure 5. The Finite Element Model for the Ball Swaging Process

Experimental Design

The experimental design was divided into 2 experiments as follow:

Experiment I focuses on determining the most accurate coefficient of friction between the balls and the base plate. This is because the actual coefficient can not be measured; therefore, the Finite Element Analysis was used. The coefficient of friction (μ) between the balls and the base plate was set at 5 values: 0.05, 0.08, 0.1, 0.12, and 0.15, and the retention torque results were then compared to the actual values, to get the closest coefficient of friction value to the actual ones.

Criteria

- μ between the balls and the base plate at 5 values: 0.05, 0.08, 0.1, 0.12, and 0.15
- μ between the actuator arm and the base plate = 0.45
- Ball velocity = 20 m/s

Experiment II the 3 most accurate coefficients of friction from Experiment I was used in Experiment II to find the optimum ball velocity and the most accurate coefficients of friction between the ball and the base plate.

Criteria

- the 3 most accurate μ's between the balls and the base plate
- μ between the actuator arm and the base plate = 0.45
- 6 levels of ball velocity: 10, 20, 30, 40, 50, and 60 m/s

Results

From the Ball Swaging Process analysis with the Finite Element Method, stress and strain behaviors during the process were found. 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 6.

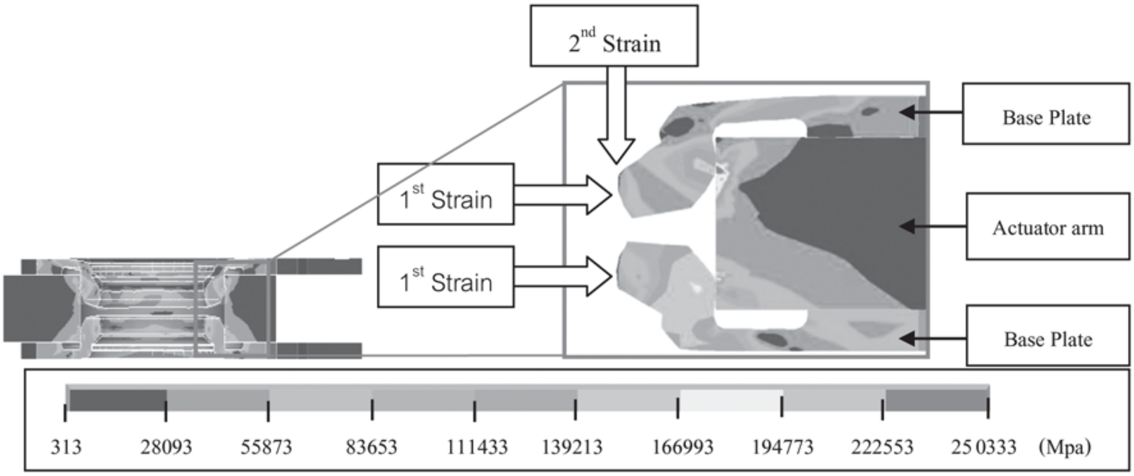


Figure 6. Deformation in the Ball Swaging Process

In this analysis, the retention torque and deformation in the head was measured around the edge of the base plate, see Figure 7. The head starts as Head 0 from the bottom base plate, up to Head 3 at the top plate. As shown in the Figureure, Head 0 and Head 2 are in the same position, and the same 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 Equation 1.

$$T = \mu r f_s \ Pds \qquad (1)$$

Where T : torque
μ : friction coefficient 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

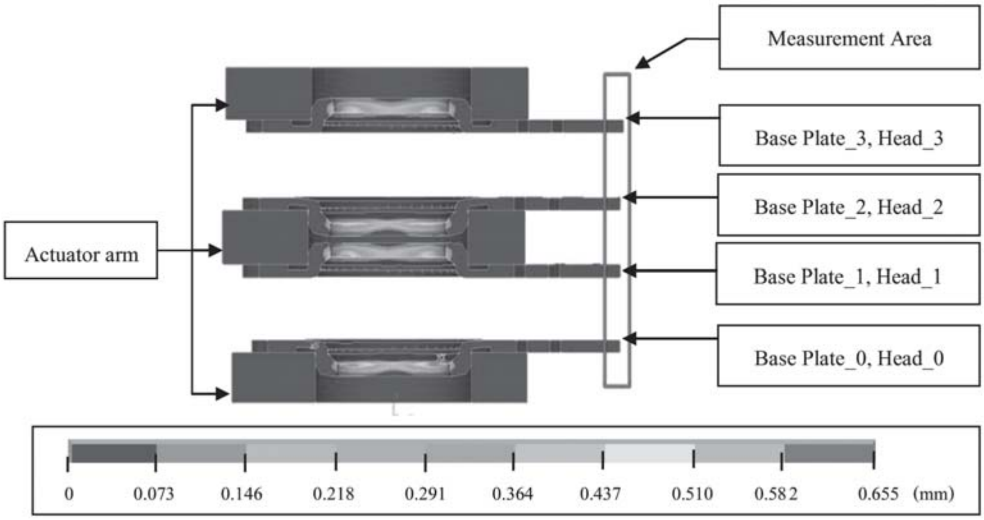


Figure 7. Base plate and actuator position and deformation

After the Ball Swaging Process was completed, 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 on 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. Furthermore, there was bending and axial distortion in the suspension occurred due to its attachment to the base plate, which was plastically deformed. A qualified Ball Swaging Process is supposed to yield low deformation in the base plate and high retention torque.

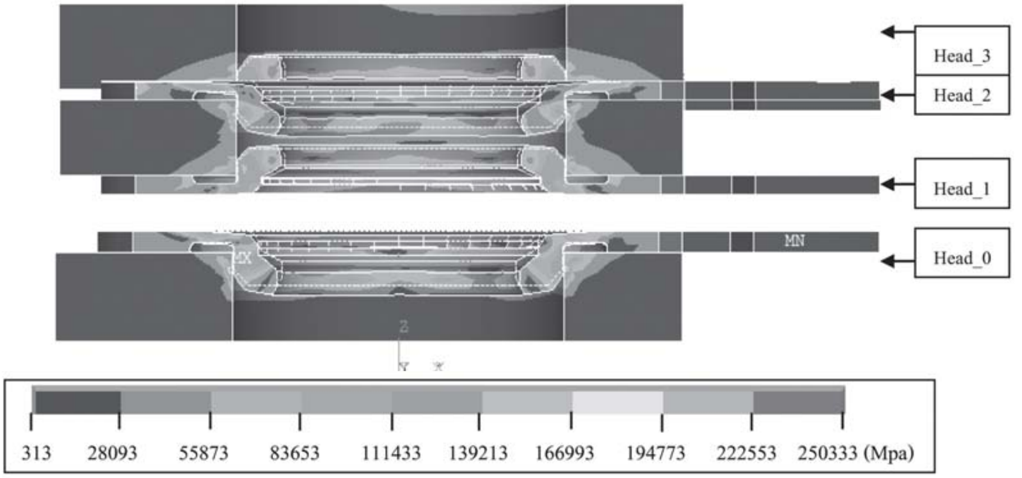


Figure 8. Von Misses Strain and plastic deformation in the actuator arm and the base plate Experimental Results

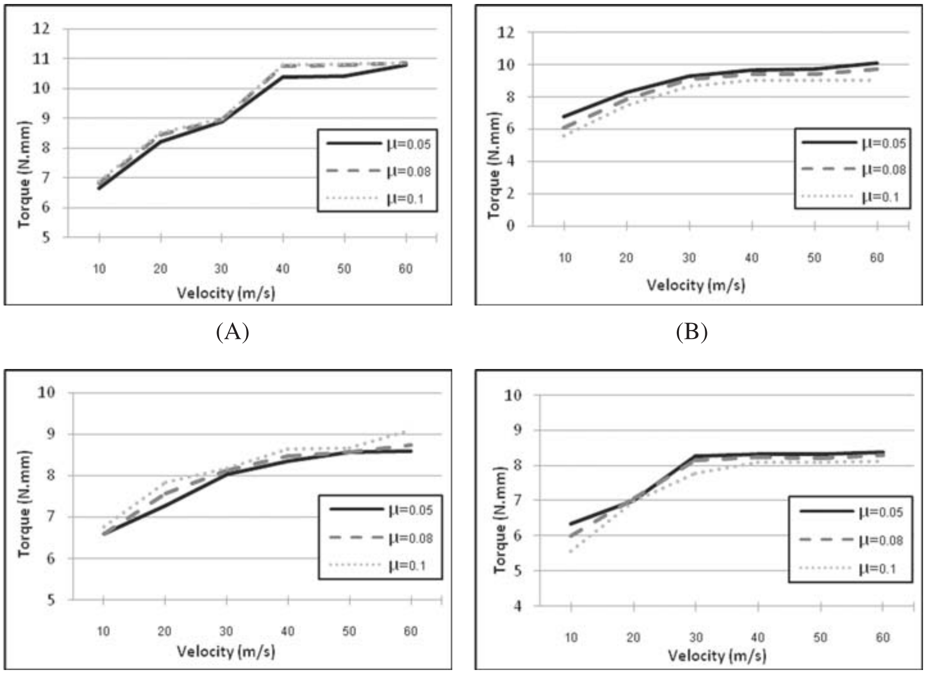
Experimental Results

Table 1 shows retention torque derived from coefficients of friction between the ball and the base plate from Experiment I, which were 0.05, 0.08, and 0.1. The retention torque (*T*) from the Finite Element Method compared to the actual value has less than 10% difference. Therefore, the results are acceptable to be used in the next experiment.

Table 1. Experimental result for coefficients of friction between the ball and the base plate in the Ball Swaging Process

Head	T_{Exp} (N.mm)	μ = 0.05		μ = 0.08		μ = 0.10		μ = 0.12		μ = 0.15	
		$T_{Program}$ (N.mm)	Error (%)	$T_{Program}$ (N.mm)	Error (%)	$T_{Program}$ (N.mm)	Error (%)	$T_{Program}$ (N.mm)	Error (%)	$T_{Program}$ (N.mm)	Error (%)
3	7.72	7.02	-9.11	7.07	-8.46	6.98	-9.64	6.44	-16.62	6.21	-19.60
2	8.79	8.19	-6.82	8.21	-6.55	8.31	-5.47	8.40 -	4.47	8.49	-3.42
1	8.01	8.28	3.33	7.86	-1.84	7.45	-7.03	7.28	-9.06	6.96	-13.16
0	8.48	8.22	-3.08	8.46	-0.23	8.52	0.42	8.59	1.25	8.68	2.41

From Experiment II where we aimed to determine the most accurate ball velocity and coefficient of friction between the ball and the base plate with the Finite Element Method, the experiment was divided into 2 parts. The first part determined the retention torque at various ball velocities in each head. Figure 9. shows that as the ball velocity increased, the retention torque in every head also increased, causing better attachment between the base plate and the actuator arm. At 40, 50, and 60 m/s, resulting retention torques were the same. The second part determined deformation in the head, measured around the plate edge. Displacements at various ball velocities in each head, shown in Figure 10., were compared at the same velocities as the first part. At 40 m/s, there was little displacement in each head; hence it is the optimum ball velocity.

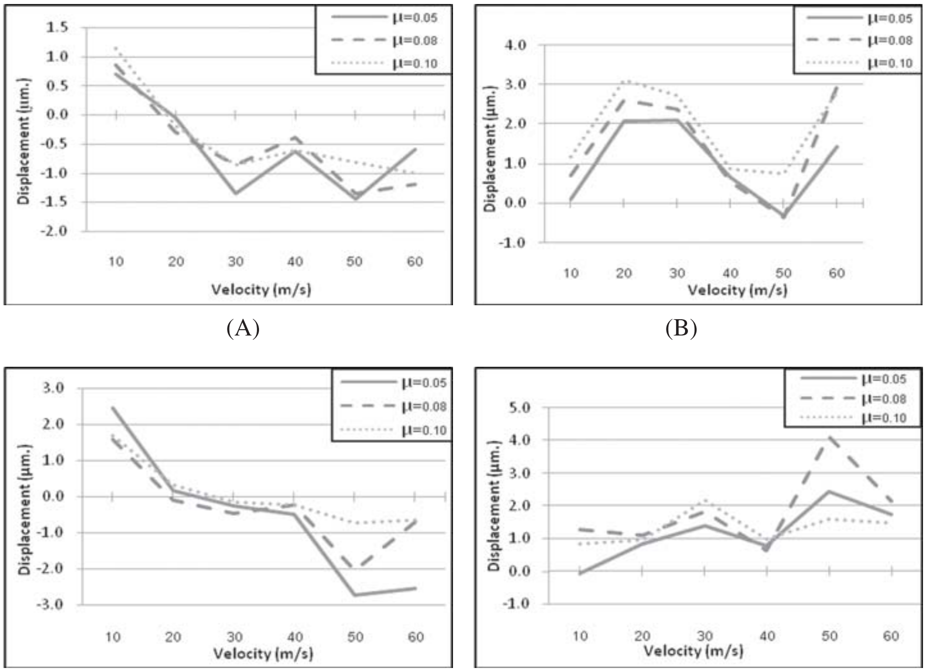


(A) (B)

(C) (D)

Figure 9. Retention Torque at Various Ball Velocity

(A) Head 0 (B) Head 1 (C) Head 2 (D) Head 3



(A) (B)

(C) (D)

Figure 10. Displacement around the plate edge at various ball velocity in each head

(A) Head 0 (B) Head 1 (C) Head 2 (D) Head 3

Conclusion

From the HSA Swaging Process Analysis with the Finite Element Method, we can determine the plastic deformation and stress behavior during and after the actual process. The retention torque from experiments was close to the actual ones from the process. Furthermore, as the coefficient of friction between the ball and the base plate and the ball velocity increased, the retention torque tended to increase. In conclusion, the optimum ball velocity and coefficient of friction between the ball and the base plate are 40 m/s and 0.08, respectively.

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