Boss Tower and Baseplate Flange Optimization

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Abstract The swaging process is commonly used in head stack assembly, which is a process that is undertaken to either reduce or increase the diameter of tubes or rods. In the head stack assembly process, a swage boss engages with an arm hole of E-Block. Current hard disk drives have very small tolerances, requiring the swage effect of new hard disk drives to be reduced to as little as possible. In this study, finite element analysis (FEA) was used to reduce the swage effect. At present, FEA and investigative tests indicate that a significant portion of gram changing through swaging is caused by E-block tip deformation due to swaging. Deformation of the E-block tip is the result of unbalanced swage forces between the tension and compression suspension. Achieving optimization concepts leads to a new swage plate design to reduce the gramload change of the target and to equalize the swage forces. The FEA results found that gramload change of the target decreased by 35% on the tension side, and by 65% on the compression side through swage by boss tower. The HGA torque was not different. The suspension flange was also studied. Subsequently, suspension manufacturing is able to bias the suspension as incoming HGA. The flange deformation might be closer to zero after the swaging process.

1. Introduction
Head stack assembly (HSA) commonly uses the ball swaging process to either reduce or increase the diameter of tubes or rods. As in the HSA process, a swaging process is a common material processing technique used to connect the suspension assembly to the actuator arm (E-Block). The suspension assembly includes a boss tower configured to fit within an aperture in the actuator arm. When a swage ball is passed through the boss tower, the surface of the boss tower is fitted in the arm aperture. The boss tower expands to contact with the aperture surface and create a frictional engagement which connects the suspension assembly to the actuator arm. Presently, hard disk drives (HDD) have very small tolerances due to new read and write technologies such as HAMR and MAMR. Subsequently, the swage effect of new HDDs should be minimized as far as possible. Figure 1 depicts the simple ball swaging process. Meanwhile, Figure 1(a) shows the swage machine in the swaging process, and Figure 1(b) represents the ball passing through the boss. During the ball swaging process, the clamp force squeezes on the top and envil is lowest of the machine to support all HSA. After clamping, the driver pin moves downwards and pushes the ball through the boss at a constant speed controlled by a screw and step motor. However, a vacuum at the envil support is used to keep the ball after it is used. Note that the ball is only used once. The driver pin moves up automatically after being moved down. Many researchers
have attempted to study the swage effect. For instance, Pattaramon concluded that a proper design of the baseplate is needed [1]. Additionally, Tangchaichit and Kaewka showed that retention torque increases if the coefficient of friction between the ball, the baseplate, and the ball velocity increases [2]. Moreover, Kheunkhieo and Tangchaichit created a three-dimensional finite element model to analyze and explain the characteristics of the baseplate and actuator arm deformation that affect the gramload, which in turn affects the ball swaging process, finding that micro swage can reduce the swage effect [3].

![Figure 1](image1.png)

Figure 1. Ball swaging process with three balls; (a) The swage machine in the swaging process; (b) the ball passing through the boss of the baseplate.

Bamrungwongtaree and Mongkolwongrojn showed that HGA torque retention and arm aperture modification was almost linear, while also finding that reduced arm deformation and gap to arm resulted in increased HSA performance [4]. The arm aperture can be modified for manufacturability. Bamrungwongtaree and Mongkolwongrojn found that a non-circular arm aperture was able to reduce the swage effect [5]. Previous research has not compensated the baseplate flange bias before swaging along with optimization of the boss tower.

2. Materials and Methods
This study used SolidWorks to create the micro swage 3D model and used FEA for to investigate the reductions of the swage effect by optimizing the boss tower. Previous studies do not mention the role of the boss tower profile in reducing the swage effect. An initial preliminary decision for the optimization is depicted in Figure 2 which shows the cross section of a standard boss tower and a potential
optimization of the boss tower by the experience. Next, transfer function was used to convert the tip
high and the tip pitch of the baseplate deformation to get the gramload value.

Figure 2. Cross section of a standard boss tower (blue) and a potential optimized boss tower (black).

In order to receive the retention torque or swage torque after the ball is driven through the boss tower,
the baseplate and its attached suspension was securely fastened to the actuator arm pad. The equation
for the swage torque can be derived from:

\[ T = Fr \]  \hspace{1cm} (1)  

As we know that

\[ F = \mu N \]  \hspace{1cm} (2)  

And now consider free body diagram of engagement, as shown in Figure 3.

Figure 3. Free body diagram of swaging engagement.

It can now find the reaction \( N \) following:

\[ N = \int_{s} P_{l} ds \]  \hspace{1cm} (3)  

Substituting (2) into (1) got:

\[ T = \mu \int_{s} P_{l} ds \]  \hspace{1cm} (4)  

Since FEA can be considered the element result, thus consider Figure 4.
Figure 4. Assume the meshed cylinder as element on boss tower.

And now $ds$ can be written in the form:

$$ds = r \frac{L}{N_e} d\theta$$

(5)

Substituting (5) into (4) got:

$$T = \mu \int_0^{2\pi} P_t r \frac{L}{N_e} d\theta$$

(6)

Finally, yield:

$$T = \mu P A \frac{D}{2N_e}$$

(7)

where T is HGA torque out, $\mu$ is the coefficient of friction, $P$ is contact pressure, $A$ is an element area, $D$ is a diameter of swage hole, and $N_e$ is the number of engaged elements. Practically, an average pressure and contact area can substitute in (7) to obtain the HGA torque out.

Figure 5. Finite element model (FE model) of the swaging process.

The FE model of analysis is shown in Figure 5. The flange profile was biased and was used to study deformation by modeling, as shown in Figure 6.
3. Results
This modelling study found that there was no difference between the tension and compression swage forces. Meanwhile, the gramload reduced by 35% on the tension side, and reduced by 65% on the compression side, as shown in Figure 7.

Figure 7. Comparision of gramload changes.

Figure 8 shows the flange deformation along the baseplate length after the baseplate was biased. Table 1 shows the results of the gramload changes and the HGA torque out.

Figure 8. The flange profile biased deformation results: (a) Tension; and (b) compression.

The flange positive and negative biased results reveal that the suspension or HGA prior to swaging can be deformed before assembling to the actuator arm (E-Block), which can reduce the swage effect after assembly. This may offset the arm deformation.
Table 1. FEA results of the biased baseplate and swaged.

| Parameter               | FEA Result |
|-------------------------|------------|
| Retension force (in-oz) |            |
| Tension                 | 12.51      |
| Compression             | 13.81      |
| Gram Change (g)         |            |
| Tension                 | 0.083      |
| Compression             | 0.15       |

Figure 9 shows the tension and compression experiment results after Wyko analysis deflection.

![Figure 9](image)

(a) (b)

Figure 9. Wyko analysis deflection of: (a) Tension; and (b) compression.

4. Conclusion and Discussion

The modelling study results utilized only a single ball swaging, finding that the swage forces of both tension and compression were not different after changing the boss tower profile. However, the gramload change reduced by 35% on the tension side, and reduced by 65% on the compression side. The suspension flange was studied. Therefore, suspension manufacturing is able to bias the suspension as incoming HGA, meaning that the flange deformation may be closer to zero after the swaging process.

![Figure 10](image)

(a) (b) (c)

Figure 10. Recommended baseplate flang profile incoming: (a) Incoming baseplate; (b) clamping state; and (c) after swaging.

The Wyko analysis deflection and FEA deflection analysis results are very similar. It is therefore recommended that the flange of the baseplate in HGA manufacturing as shown in the Figure 10(a).
Nevertheless, a new magnetic recording technology with a very small magnetic size might use either the oval arm hole or the oval boss tower to reduce the swage effect and should be the subject of further study.

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