

Preliminary Study on the Effect of Swaging Process Parameter on HSA Pitch Static Attitude in a 2.5-in Hard Disk Drive

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Abstract

This paper is aimed at demonstrating the use of finite element analysis for simulating a swaging process of a head stack assembly (HSA) in a hard disk drive (HDD). The swaging process is a material processing technique used to connect a head gimbals assembly (HGA) to an actuator arm becoming the so-called head stack assembly by using swage balls. The finite element model is 3-dimensional where solid Lagrangian elements and the explicit dynamics simulation are used. The HTI base plate model is chosen for this simulation study. The computational results are compared to those obtained from experimentation and a transfer function for computing pitch static attitude is proposed for future work.

Keywords: Finite element analysis, Swaging process, Hard disk drive, Contact analysis.

1. Introduction

Ball swaging process is one of the most important manufacturing processes in the hard disk drive industries. Such a process is employed to assemble head gimbals assemblies onto an actuator arm resulting in the so-called head stack assembly. A typical HDD swaging process is illustrated in Fig. 1 & 2. The so-called swage boss on the base plate as illustrated in Figure 1, which is the part of a HGA, is inserted into the hole on the arm. Then, it is swaged by stainless steel balls. The swaging ball has a larger diameter than the base plate's inner diameter. The boss and arm are plastically deformed and joined to each

other through frictional contact forces. Jointing strength is defined as retention torque. To hold the HGA in place, the interface between the base plate and actuator arm must develop to have a suitable retention torque value. A specific value of retention torque at the joint is demanded to withstand the vibrations of the actuator arm that was induced by high-speed unstable airflow in the drive. A view of the assembly is shown in Fig. 2.

The swaging process can result in plastic deformation of a HGA base plate and an actuator arm. It also leads to unrecoverable change of the base plate and arm tip geometry consequently leading to deviation of pitch static attitude (PSA)

on sliders. This significantly affects read/write head performances, and alters the desired value of retention torque. Since pitch static attitude and retention torque are the critical parameters affecting the HDD performances, studying the swaging process to determine base plate and arm deformation characteristics, pitch static attitude, and retention torque changes are of general interest.

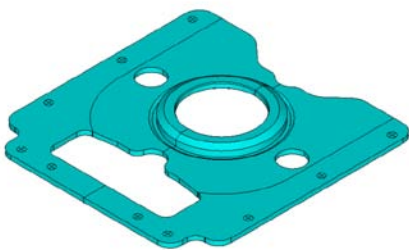


Fig. 1 Baseplate

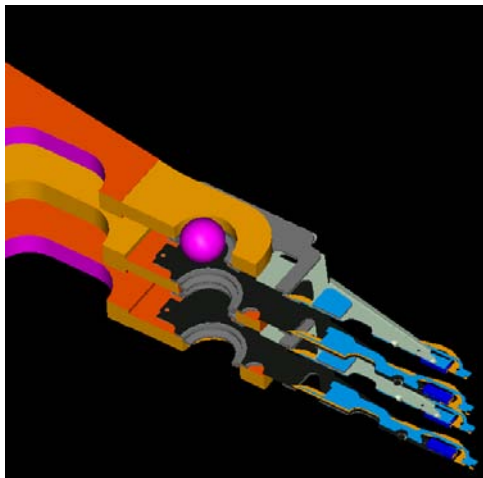


Fig. 2 The assembly for swaging process [2]

Wadhwa [1] analyzed the ball swaging process numerically using an axially symmetric model of the ball swaging process of the in-plane deformation. Aoki and Aruga [2] reported a three-dimensional finite element analysis based on a symmetrical model of an actuator inner arm and two attached base plates and clarified that the baseplate is influenced by the arm deformation

due to the asymmetric stress. Kamnerdtong et al. [3] numerically verified the deformation of the entire arm and HGA. They studied the effects of swaging process parameters including the size, velocity and shooting direction of the swage ball by using an axis-symmetric finite element analysis (FEA). More work relating to a swaging process and finite element contact mechanics can be found in [4-9]. The review of literature however shows that investigating the swaging with bi-directional swaging by using 3-Balls induced PSA and retention torque change are still open.

The aim of this work is to determine the effects from swaging process by initiating a three dimensional finite element model to predict the base plate CTQ and retention torque changes during swaging, then predict the pitch static attitude, and figure out the major contributor of each process parameters. In this work, the swaging process is studied by performing explicit dynamic finite element analysis (FEA) using a commercial program. Both one-sided arm (top and bottom) and two-sides in the assembly are opted as a prototype to be studied. 3-Balls bi-directional swaging process is considered. The ball diameters are 0.0080" (1st pass), 0.0810" (2nd pass), 0.0830" (3rd pass flip) and its velocity maintains constant at 0.7 in/s in the top-to-bottom direction.

2. Finite Element Modeling

The FEA of a swaging process can be thought of as a collection of continua being at the dynamic equilibrium state such that contact constraints (no penetration between bodies) are imposed. With the use of finite element formulation, the contact behavior of such continua

described by non-linear differential equations can be simplified to become a matrix form as: [6]

$$\mathbf{M}\ddot{\mathbf{U}} + \mathbf{K}\mathbf{U} = \mathbf{F} + \mathbf{F}_c \quad (1)$$

where \mathbf{M} is a mass matrix, \mathbf{K} is a stiffness matrix, \mathbf{F} is a vector of external forces, and \mathbf{F}_c is a vector of contacting forces to be determined during the FEA process. Also, the kinematic constraints on contact surfaces are of the form:

$$\mathbf{Q}\mathbf{U} + \mathbf{G} = \mathbf{0} \quad (2)$$

where \mathbf{Q} is a coefficient matrix due to finite element grid, \mathbf{G} is a vector computed from initial gaps of the nodes.

The contact constraints (2) can be dealt with by using classical optimization approach such as the Lagrange multipliers method, the augment Lagrangian method, and the penalty function method.

The finite element model is 3D and a cross section for the ball swaging process of the two outer and inner arms are shown in Figure 3. There are eight parts involved in the swaging process. The model includes an arm tip, base plate with part of hinge, swage key and three swage balls. To deal with the elastic-plastic behavior, the actuator arms made of aluminum (Al) are modeled as bilinear kinematics and the stainless steel baseplates are modeled as bilinear isotropic hardening. The swage keys are modeled as rigid bodies for simplicity while the other components including the swage ball, arm tip, base plates and hinges are deformable parts.

The explicit dynamics simulation consists of two stages i.e. swaging and ejecting clamping. At the first stage, the HGA (base plate and hinge)

and the arm tip are clamped by the keys. The balls pass through the swage hole on the base plate from top to bottom direction by first two balls (size 80,81mils), and pass through from bottom to top direction by the last ball (size 83mils). At the second stage, the keys are removed allowing base plate(s) and hinge(s) and arm to go to final deformation. The Rayleigh damping coefficients (α & β) are also included in the analysis. The FEA program automatically chooses the simulation time step, and it is related to the characteristic length of the finite element mesh and wave propagation speed in the analyzed parts

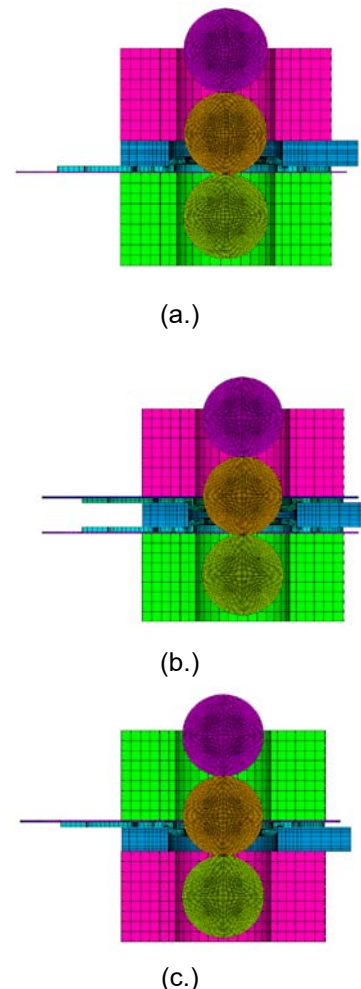


Fig. 3 Cross-section of ball swaging process

The analysis is performed through the following steps. Firstly, a compressive clamping force is applied to the prepared area on top of the spacer key. Next, the swaging ball is driven through only in Z- direction. After the ball passed through, the clamping force is then released after that the spacer key are ejected to allow final deformation of the assembly. The deformation is represented by base plate final deformation where the base plate CTQ was evaluated. In this paper, the HTI base plate model shown in Figure 4 is chosen to investigate.



Figure 4 HTI base plate model



Figure 5 Tip height measurement section

3 Finite Element Results

Figure 5 shows the points that the base plates tip heights were measured. Points A and D are for the outer arms while the others are for the

inner arms. Figure 6 shows the FEA results of base plate and arm tip deformation due to the swaging process induced plastic deformation. For the outer arms, the base plate was bended away from the disk. But for the inner arms, both base plates are bended to the disk. The displacements are exaggerated by 25 times.

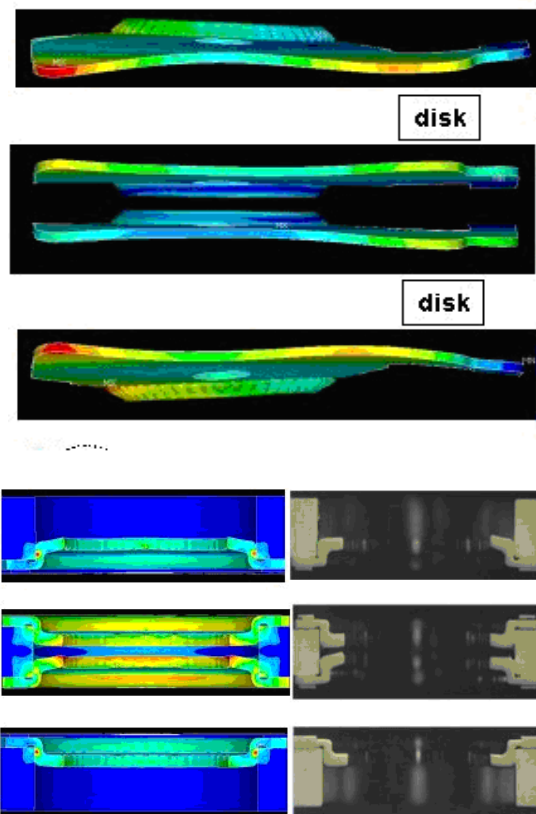


Fig. 6 FEA result model

The values of tip height and tip pitch obtained from both FEA simulation and experimentation are given in Table 1. It can be seen that the computational results are reasonable compared to the testing data.

Table 1. Simulation and experiment results

Parameters		Tip Height (inch)		Tip Pitch (degree)	
		FEA	Actual	FEA	Actual
Head 0	outer arm	0.00018	0.00040	-0.152	-0.219
Head 1	inner arm	-0.00032	-0.00022	0.035	0.030
Head 2	inner arm	0.00029	0.00047	-0.085	-0.055
Head 3	outer arm	0.00041	0.00030	0.311	0.234

4 PSA Estimation

The PSA on the sliders can be estimated by using the PSA deviation due to the tip height that changes due to the swaging process. PSA deviation could be calculated by using the height deviation from trigonometry method from using a constant, nominal PSA and load arm length (FL). Figure 7 shows how the tip height relates to the PSA. Equation (3) is the transfer function of deviate tip height to the deviate PSA.

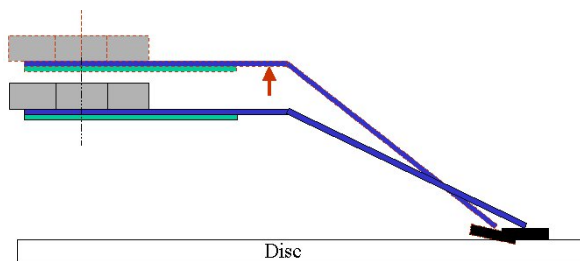


Fig. 7 Relation between tip height and PSA

$$\Delta PSA \text{ (degrees)} = (180/\pi) * \Delta \text{Tip Height} / \text{Load beam length} \quad (3)$$

5 Conclusion

The FE simulation results of a swaging process of a HGA where the HTI base plate model is used are compared with the experiment results. It is found that the present finite element model give reasonable results. This means that it can be used for further investigation. The PSA estimation method is one of the solutions that can

predict the PSA to simplify the FEA method. In this phase, finite element simulation was performed to simulate the ball swaging process by using the commercial FEA software and the numerical result to define the base plate and arm tip deformation to get the tip height value. The next step is to compare between finite element method, PSA estimation and actual data to find the appropriate method for PSA prediction.

6 Acknowledgment

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