Thermal Damage Improvement of Slider Fixture in Ion Mill Heatless Etching Process by FEM

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Abstract

This paper presents thermal deformation of slider fixture in ion mill heatless etching process by the finite element method. The research objective is to reduce thermal damage of the ion mill heatless etching process. First the process parameters and slider burn defect of the ion mill heatless etching process are studied. Next, a CAD model and mesh are constructed. Boundary conditions for heat transfer analysis are applied on the mesh. Temperature distribution is calculated and set as thermal load for thermal stress analysis. Then thermal deformation is computed. A new model of slider fixture is designed. The thermal deformation of the new model is computed. The results show that the new model reduces thermal deflection 3% and increases real clamp force 2.5 times the old model. The new model will reduce: the burned area on a slider's surface or permanent bending deformation.

Keywords: Thermal Damage, Ion Mill Heatless Etching Process, Finite Element Method

1. Introduction

In Hard Disk Drive (HDD) production, a slider is the major component of Read/Write operation. One important process of the slider fabrication process is the Ion Mill Heatless Etching process. If there is a bad heat transfer in this process the slider will have a burned area on its surface, as shown in Fig. 1, or permanent bending deformation. This effect will generate scrap. The milling process is studied in temperature rise [1-7] and thermal stress [8-11].

This project studies the jig-fixture model relating to thermal damage. Thermal stress and deformation are computed by using the finite element method. Then a model improvement will be done. The new model results are better for heat transfer, and reduce scrap. The result shows that the new model will reduce thermal displacement and increase real clamp force more than the old model. The new model will reduce: the burned area on a slider's surface or permanent bending deformation.

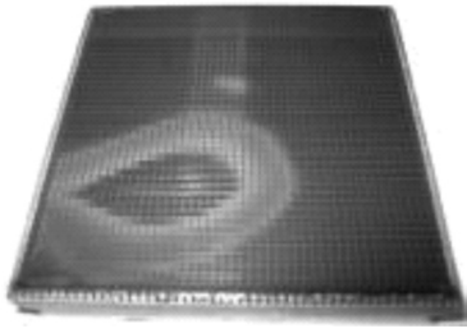

Fig. 1. Burn area on carrier.

2. Methodology

2.1 Theory

Thermal damage behavior can be predicted by solving a heat transfer equation. Then temperature results will be applied in thermal stress analysis. The results of thermal stress analysis will obtain thermal deformation of slider fixture.

2.1.1 Heat transfer analysis

Temperature solutions can be solved from conservation of energy, Eq. (1).

$$\rho c \frac{\partial T}{\partial t} - k\frac{\partial^2 T}{\partial x^2} - k\frac{\partial^2 T}{\partial y^2} - k\frac{\partial^2 T}{\partial z^2} = 0 \qquad (1)$$

Where ρ is density, c is specific heat capacity, k is the thermal conductivity coefficient, and T is the temperature.

Finite element equation, Eq. (2), is derived by using the standard Galerkin method and recurrence relation. [12]

$$\frac{1}{\Delta t}[c]\{T\}_{n+1} = \left(\frac{1}{\Delta t}[c]-[K]\right)\{T\}_n + \{Q\}_c + \{Q\}_h + \{Q\}_{q_s} \qquad (2)$$

2.1.2 Thermal stress analysis

Thermal deformation and stress can be derived from equilibrium equation, Eq. (3a)-(3c), stress-strain relation, Eq. (4a)-(4f), and strain-displacement relation, Eq. (5a)-(5f). [13]

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} = 0 \qquad (3a)$$

$$\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} = 0 \qquad (3b)$$

$$\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \sigma_z}{\partial z} = 0 \qquad (3c)$$

where σ is normal stress and τ is shear stress.

$$\varepsilon_x = \frac{1}{E}\left[\sigma_x - \nu\,(\sigma_y + \sigma_z)\right] \tag{4a}$$

$$\varepsilon_y = \frac{1}{E}\left[\sigma_y - \nu\,(\sigma_x + \sigma_z)\right] \tag{4b}$$

$$\varepsilon_z = \frac{1}{E}\left[\sigma_z - \nu\,(\sigma_x + \sigma_y)\right] \tag{4c}$$

$$\gamma_{xy} = \frac{1+\nu}{E}\tau_{xy} \tag{4d}$$

$$\gamma_{yz} = \frac{1+\nu}{E}\tau_{yz} \tag{4e}$$

$$\gamma_{zx} = \frac{1+\nu}{E}\tau_{zx} \tag{4f}$$

where E is modulus of elasticity, γ is Poisson ratio, ε and γ are normal and shear strain, respectively.

$$\varepsilon_x = \frac{\partial u}{E} \tag{5a}$$

$$\varepsilon_y = \frac{\partial v}{\partial y} \tag{5b}$$

$$\varepsilon_z = \frac{\partial w}{\partial z} \tag{5c}$$

$$\gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \tag{5d}$$

$$\gamma_{yz} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y} \tag{5e}$$

$$\gamma_{zx} = \frac{\partial w}{\partial x} + \frac{\partial u}{\partial z} \tag{5f}$$

where u, v, w are displacement in x, y, and z direction, respectively.

The standard Galerkin method is applied to obtain finite element equation, Eq. 6, for thermal stress analysis. [14]

$$[K]\{\delta\} = \{F_0\} + \{F_t\} \tag{6}$$

where [K] is stiffness matrix, {δ} is displacement matrix, $\{F_0\}$ is thermal load matrix, and $\{F_t\}$ is surface traction matrix.

2.2 Application

Eq. (2) is used to compute thermal distribution. Eq. (6) is then used to calculate thermal deformation and stress distribution on slider fixture during the ion mill heatless etching process. The input data of FEM are the CAD model, material properties, and load. 3D CAD models of slider fixture components are constructed. The symmetric (1/12) model is selected to generate mesh.

Nodes (36, 955) and elements (153, 675) are constructed as shown in Fig. 3, and are not depend on the solution. Material properties are used as presented in Table 1.

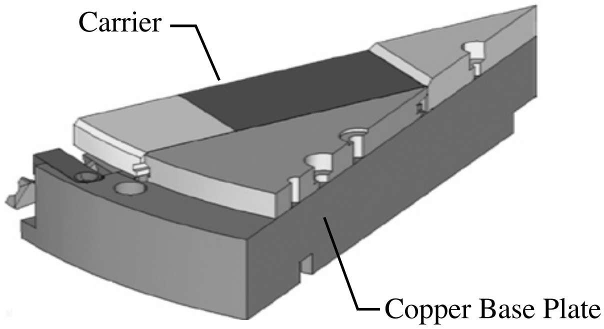

Fig. 2. 1/12 symmetric CAD model.

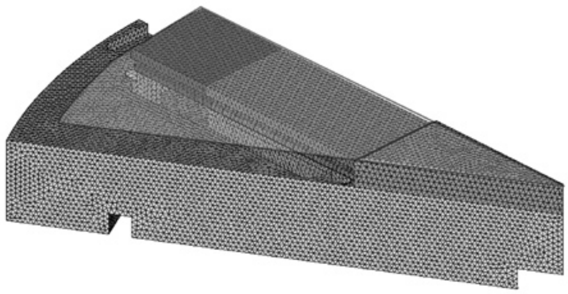

Fig. 3. finite element model of slider fixture.

Table 1 Material properties.

Properties	Material	
	Copper	**Carrier**
E (GPa)	115	204
v	0.31	0.28
α(mm/mm/°C)	17×10^{-6}	10.2×10^{-6}
ρ (kg/m^3)	8,940	7,650
k (W/m/°C)	391	24.2
c (J/kg/°C)	385	460

Boundary conditions of heat transfer analysis are applied as represented in Fig. 4. The temperature sensor at the top surface has a temperature of 45 °C. Chilled water flows past the fin at the bottom surface of copper base plate and makes a convection condition.

Heat transfer analysis is then applied to solve the temperature distribution. Temperature results are applied as thermal loads for thermal stress analysis. Boundary conditions are applied on the mesh. There are displacement loads in the z direction with - 0.02 mm, fixed rotation θ on the symmetric surface, fixed z translation on the bottom surface, and fixed translation in r and z directions along axis, as shown in Fig. 5.

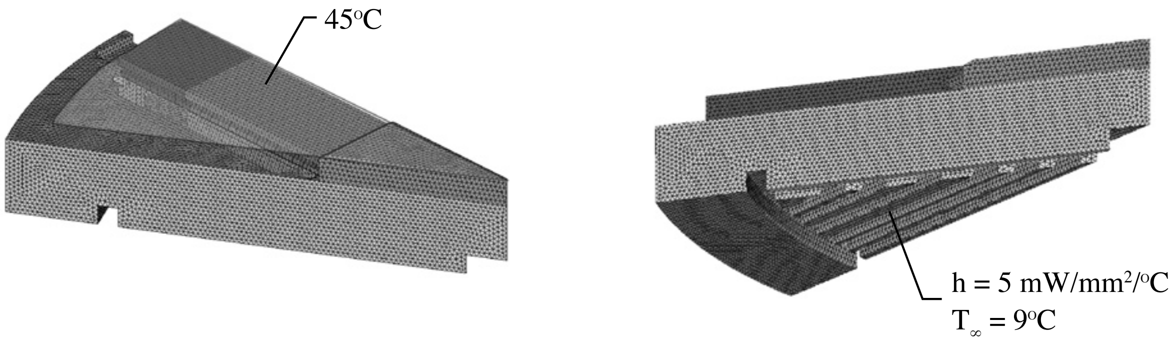

Fig. 4. Boundary condition for heat transfer.

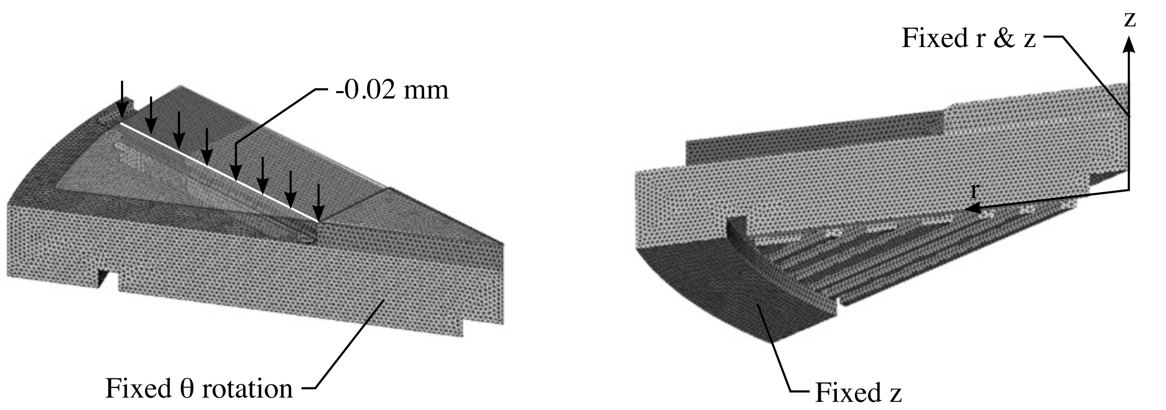

Fig. 5. Boundary conditions of thermal deformation.

Fig. 6 shows thermal deformation contours on the symmetric model. Fig. 7 presents the function of δ/δmax and s/L. L is the length of carrier. Maximum displacement, δmax, will be at s/L = 0.55. The simulation results show that the new model reduces maximum deflection 3%. A prototype of the new model is constructed and tested. A force sensor is installed. The experimental results show that real clamp force of the new model is 2.5 times the old model and reduces thermal damage.

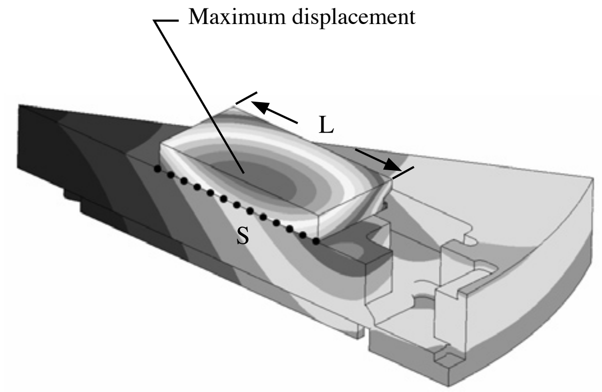

Fig. 6. Thermal deformation on slider fixture.

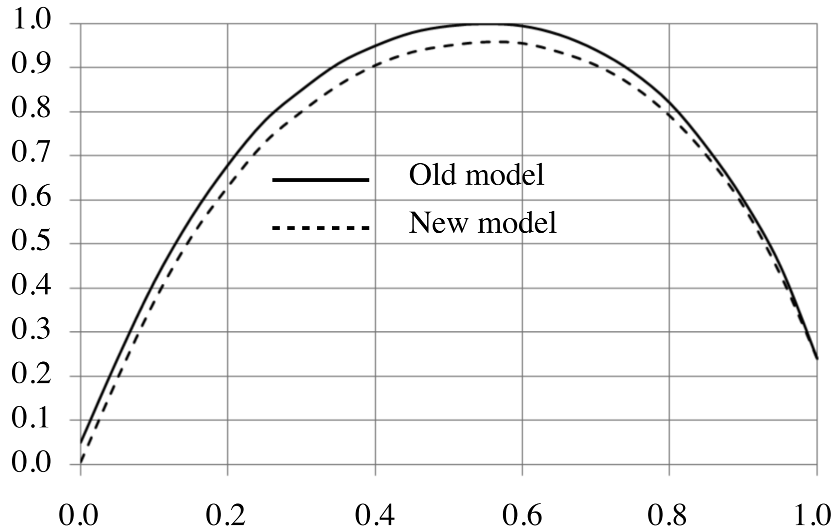

Fig. 7. Graph of δ/δmax and s/L.

3. Conclusions

This project studies thermal damage of slider fixture in the ion mill heatless etching process. The aim is to reduce thermal damage by a finite element method. Process parameters and slider burn defect of the ion mill heatless etching process are studied. Heat transfer analysis is applied on the old model. Temperature results on slider fixture are applied as thermal load for thermal stress analysis. Thermal deformation and stress are computed. A new model of slider fixture is then designed. The thermal deformation of the new model is computed. The results show that the new model reduces thermal deflection 3%. A prototype of the new model is constructed and a force sensor is installed. The experimental results show that the new model increases real clamp force 2.5 times the old model. The new model will reduce: the burned area on a slider's surface, or permanent bending deformation.

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