Computer Simulation of Mechanical Response of Suspension Processed by Bending and Heat Treatment

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Abstract

In suspension manufacturing, one of the most important factors is the suspension preload or so called "gramload". Such factor controls the flying height during the operation of the hard drive. The suspensions made of SUS304 stainless steel are formed in a metal die and further adjusted by mechanical bending until the gramload is in a certain range. Finally, fine gramload adjustment is carried out by laser treatment. Although such processing has been commercially applied to suspension production for many years, there is no clear explanation on the principle responsible for the change of the gramload due to bending and laser heat treatment. Therefore, the objective of this work was to study the effect of bending and further heat treatment on the mechanical behavior of thin SUS304 stainless steel sheet using the finite element method. The results of this work can be used explain the mechanical response of the suspension after bending and after heat treatment.

***Keywords**:* Thin Stainless Steel, finite element method, gramload.

1. Introduction

To increase the areal densities in magnetic recording media such as disk in hard drive, many researches have been conducted to obtain a technology to reduce the fly height to only few nanometers or even sub-nanometers. The developed technologies lead to a more susceptible to reliability issues. The current productions of hard drive required 10 nm fly height to be achieved and one of the most important issues is the stability of sliders during operation. Slider is loaded and flying above (or below) the rotating disc during read/write operation. The stability of the slider is controlled by various parameters. The most important one is the suspension preload referred as to "Gramload". Not only the materials properties but also the shape of the hinge of the suspension determines the gramload. Previous study [1] have been focused on 1) the extrinsic materials properties such as the prestress caused by bending and surface roughness and, 2) changes of the shape of the hinge. Both can be adjusted by laser treatment. It is however the surface of the materials of such area does not drastically change in our studied suspensions. Therefore, this study is aimed to better understand what causes the changes of the gramload.

The suspensions used in our study were initially processed by mechanical forming. The gramload values were measured after forming. The suspensions were then subjected to further mechanical adjustment i.e. bending and were finally fine tuned with the laser treatment.

From the view point of materials science, such processing may cause the change of mechanical properties of materials. The materials used for suspension is SUS304 which is the austenitic stainless steel. The microstructure of this material can be altered by plastic deformation and thermal treatment. In the annealed condition, the microstructure of SUS304 mostly consists of austenite. After subjected to plastic deformation, the austenite transformed into α'-martensite. This cause some changes in elastic moduli since the elastic moduli of austenite and martensite are different [2]. One may estimate the elastic modulus of SUS304 consisting of both martensite and austenite by using rule of mixture as given by equation

$$E_{mix} = E_{(\gamma)} X_{(\gamma)} + E_{(\alpha')} X_{(\alpha')} \quad GPa \qquad (1)$$

$$E_{(\gamma)} = 215.7 - 0.0692 \cdot T \quad GPa \qquad (2)$$

$$E_{(\alpha')} = 237.3 - 0.0692 \cdot T \quad GPa \qquad (3)$$

where $X_{(\gamma)}$ is volume fraction of γ
$X_{(\alpha')}$ is volume fraction of α'
$E_{(\gamma)}$ is young's modulus of γ
$E_{(\alpha')}$ is young's modulus of α'
T is temperature (°C)

Although the difference between these values is not significant for most mechanical parts, but in the case of the hard drive suspensions which are fairly thin, such small difference may enough to alter the gramload of the suspension.

Therefore, this study was aimed to understand the role of both mechanical bending and the laser treatment on the changes of suspension shape and elastic modulus which in turn cause the change in gramload.

2. Experimental Procedures

This study was conducted by the measurements of gramload at each step of the processing and the comparison between the measurement gramload values and the simulation gramload values.

2.1 The measurements of gramload

The gramload measurements were carried out after each step which is mechanical forming, mechanical bending adjustment, and laser treatment. For the laser treatment, the average power laser used was 4.355 W. The laser beam profile was TEM_{00} and the beam size was 1 mm. in diameter. Only the hinge area was laser shined. The final measurement of gramload was carried out at various displacements in Z-axis.

2.2 Finite Element Method

Mechanical Simulation

The numerical simulations were performed using finite element simulation software ANSYS V12.0 [3]. Table 1 is the thermophysical and mechanical properties of SUS304. The material was assumed to be isotropic and incompressible during plastic deformation. Strain rate effects are neglected.

Table. 1 the thermophysical and mechanical properties of SUS304

Materials Properties		Unit
Young's Modulus	200	GPa
Poisson's ratio	0.29	MPa
Yeild Strength	250	MPa
Density	7.85	kg/m^3
Thermal expansion	1.20E-05	1/°C
Specific heat	434	J/kg°C

The gramload values of the suspensions were simulated at various conditions in order to study the effect of the difference in the parameters such as shape, and modulus of elasticity on the suspension gramload. Such conditions were listed below.

a) The shapes of two suspensions were different i.e. the bended angles.

b) Two suspensions had identical shapes but the moduli of elasticity of the hinges were slightly different. The assumption of the difference in modulus of elasticity is based on the existence of α'-martensite after mechanical forming.

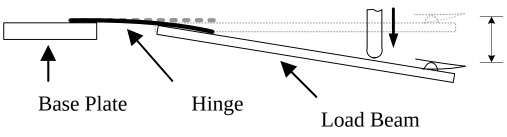

Fig. 1 Mechanical bending adjustment

<u>Thermal Analysis</u>

Thermal analysis was also carried out in order to obtain the temperature distribution and the distortion of the hinge part after laser treatment. The laser beam exhibited Gaussian distribution and thus the simulation assumed average power transmitted into the exposed area according to the equation [4];

$$\bar{q} = \frac{0.865AP}{\pi r^2} \qquad (4)$$

where $\bar{q}$ is the mean heat flux density within the area of the laser beam, A is the absorption of the cold rolled stainless steel to laser was assumed to be 0.374. This value was measured by Bergström *et al.* [5]., P is the laser power, r is laser beam radius. Other assumptions are listed below [6];

a) Heat conduction in the specimen is considered whereas convection between contact boundary is neglected.

b) The latent heat due to phase changes is neglected.

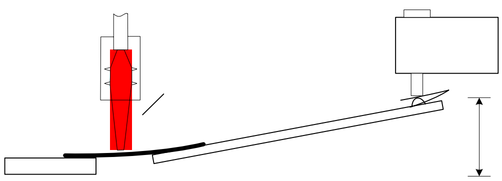

Fig. 2 Heat treatment by laser process

3. Results and Discussion

3.1 Suspension gramload

The suspensions were mechanical formed into the preshape having a much higher bend angle than the final shape. The gramload values at different displacement in Z- axis were measured and plotted in Figure 3. The suspensions were then subjected to further mechanical bending adjustment to obtain the closer values of both final shape and gramload. The bended angles become less after adjustment. The difference in gramload values of suspensions after mechanical forming and those after mechanical adjusted is usually in the range of 1 gram.

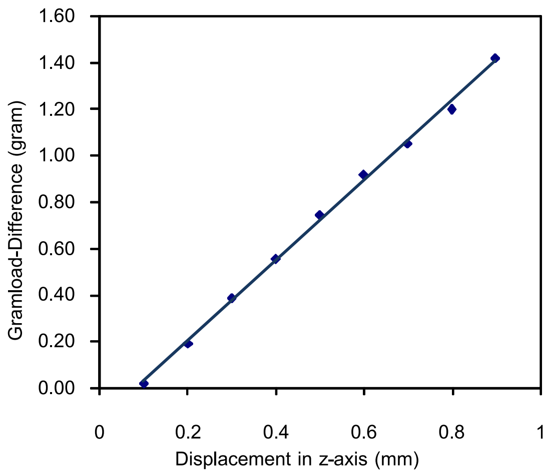

Fig. 3 The plot of the gramload difference versus different displacement in Z-axis. They exhibited linear relationship since the material was in the elastic deformation regime.

Fine gramload adjustment was carried out by laser treatment. This caused small changes in suspension shape and gramload. The changes in bended angles are usually less than 1° whereas the changes of the gramload are in the range of 0.01-0.02 gram.

3.2 Finite Element Method

<u>Mechanical Simulation</u>

a) By using the two suspension models having the difference in the bended angles of the hinges, the simulation results indicated that the gramloads were altered as shown in the plot of the difference in gramload versus the different bended angles in Fig. 4.

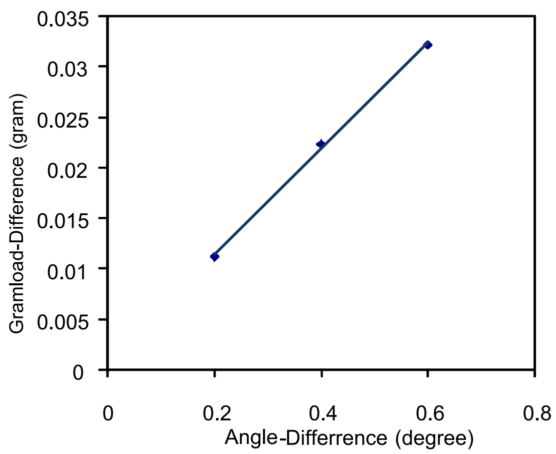

Fig. 4 Simulation results showing the difference in gramload versus the different bended angles.

b) In the case of the two suspensions having identical shapes but their moduli of elasticity were slightly different. The gramload changes significantly as shown in Fig 5.

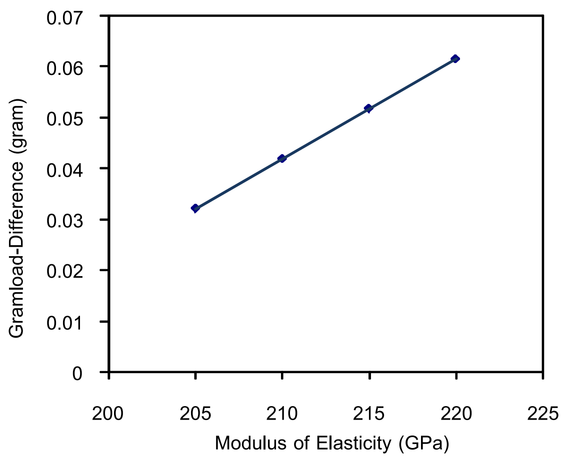

Fig. 5 The difference in gramload versus modulus of elasticity.

According to these results, the changes in gramload due to mechanical bending can be caused by both reasons. The mechanical bending adjustment in the manufacturing process produced a big difference in bended angles i.e. less bended angles and thus smaller in gramload. The plastic deformation accompanied with bending should be high enough to also cause some strain-induced martensite. In this case the gramload should have been increase. However, the gramload actually decrease so that the decrease of gramload is rather caused by the changes of bended angle. The confirmation of strain-induced phase transformation by further microstructure investigation is underway.

Thermal Analysis Results

Figure 6 – 1, 6 - 2 shows the transient temperature distribution on hinge, base plate, and load beam, as a result of the laser treatment for 500 ms. The highest temperature was approximately 366.85˚C. According to the result the retransformation from martensite back into austenite should not take place since previous studies reported that the required temperature for such retransformation is approximately above 550 ˚C. Although the highest simulation temperature seems to be high enough to cause discoloration as suggested by Ref. [7], but it is only few seconds that the material is at the high temperatures. Therefore, oxidation might occur slightly and cannot be detect by naked-eyes.

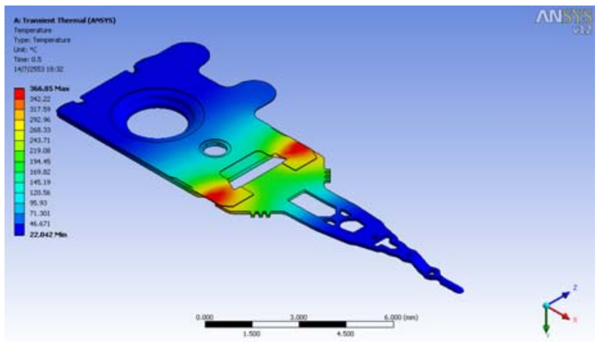

Fig. 6 - 1 The temperature distribution on hinge.

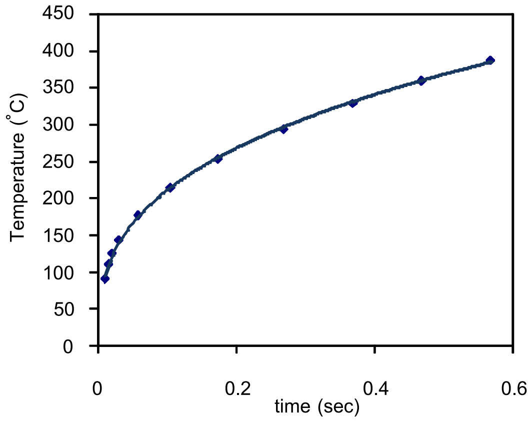

Fig. 6 - 2 Numerical solution of the temperature at the center of the laser heated surface on hinge.

The distortion of the suspension after exposed to the laser is however quite significant (Fig. 7) and thus this can attribute to the change in gramload of the suspension.

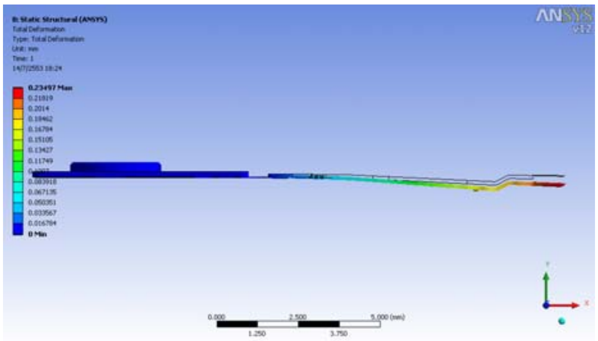

Fig. 7 The distortion of hinge after laser treatment 500 ms.

5. Conclusion

The simulated results showed that some small changes in elastic modulus leaded to significant changes in gramload. The differences in bended angle of the hinge also leaded to changes in gramload difference i.e. gramload decreased as the bending angle decreased. By using a laser treated on the hinge, the contraction during cooling resulted in slightly change of the bended angle and thus gramload could be slightly altered.

6. Acknowledgement

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