Proceedings of the 2008 Winter Simulation Conference
S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, J. W. Fowler eds.

THE IMPROVEMENT OF DEFORMATIONS AND CHARATERISTICS OF HGA DURING CLAMPING USING FINITE ELEMENT ANALYSIS

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ABSTRACT

This paper presents the study of Head Gimbal Assembly (HGA) clamping for characteristic parameters measurement which is an important stage of hard disk drive assembly process. During clamping, HGA is deformed. The values of static attitude and gram load which are significant characteristics of HGA are affected and could exceed acceptable values. Consequently, a lot of HGAs are rejected or these might decrease the performance and the read-write precision of hard disk drive. In this research, finite element analysis is performed to study the behaviors of HGA under various clamping forces and configurations for the process development. Results show that using lower clamping force and having rectangular shape for the upper part and with fillet for the lower part of clamping unit have less deformation than the other configurations of clamping. These make considerable improvement of parameter measurement during HGA clamping process efficiently and effectively.

1 INTRODUCTION

Hard disk drive (HDD) is the primary storage location of computer to record and store data by magnetizing ferromagnetic material on the surface of disk platters directionally. Main components of the hard disk drive are classified by working functions and some of these are listed as follows:

- Read-Write Part
- Data Storage Part
- Movement Control Part
- Microelectronic Interconnect Part

Head Gimbal Assembly (HGA) is a main component of the read-write part which is attached to an actuator arm. It is used to support read and write heads attached at the end of slider to read or write data onto the disk platter. The HGA consists of suspension, gimbal and slider head. The suspension is designed to have low stiffness in the pitch and roll direction and high stiffness in the yaw direction. The suspension and the gimbal have essential spring behavior providing a desired vertical force called 'Gram Load' to push the slider towards the disk surface. While the disk is spinning, the slider lifts and flies with extremely close spacing called 'Flying Height' due to air bearing effect. At the same position, the height between the air bearing surface of slider and the base plate is called the 'z-height' as shown in Figure 1. The flying height depends on accuracy and precision of these significant parameters, Gram Load, Roll Static Attitude (RSA), Pitch Static Attitude (PSA), controlled through the HDD assembly process. Changing of flying height can lead to a disk failure in which the slider scrapes across the disk or decreasing the performance and capability of HDD.

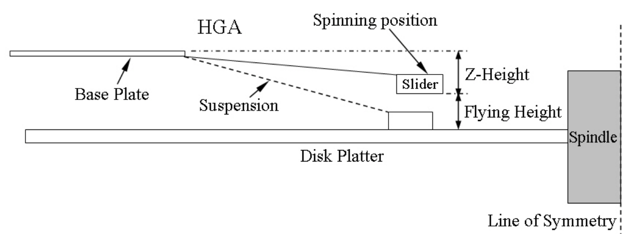


Figure 1: Z-height and flying height spacing

2 HGA CLAMPING IN CHARACTERISTICS MEASUREMENT PROCESS

In the HDD assembly process, it is necessary to measure characteristic parameters of each part before assembled to HDDs and one of the significant components, HGA, must be measured to obtain these parameters. HGA clamping is a necessary and serious stage in the measurement process as shown in Figure 2. The HGA is placed on the lower clamp while the upper clamp moves down to hold the HGA between both clamps with a clamping force as shown in Figure 3. Then the load cell moves down to press on the slider surface until reaching Z-Height position and to measure Gram Load, RSA and PSA at this position which require high precision and accuracy. Unsuitable clamping affects deformation increasing of the HGA and leads to unacceptable exceed parameters. These changing effects cause to reject a number of HGAs in the process or decrease the HDD performance. The study of HGA deformations due to clamping is necessary to avoid these problems. Therefore finite element method is performed as a powerful tool to analyze the HGA deformation behaviors in order to improve the process, design an appropriate clamp and reduce cost of waste parts.

T. Kamnerdtong, S. Chutima, and J. Prarirakwijitr (2007) studied deformations of HGA after clamping using simple modeling of the base plate under various clamping force configurations. Four clamp types were analyzed and compared. Results of this study showed that shape of upper clamp is the most significant factor affecting to deformations of the HGA. The proper clamp which consists of a rectangular upper clamp and none fillet lower clamp gives the smallest deformation of HGA after clamping in the pressure range 100 to 110 MPa.

However, It is not only post clamping deformation but also during clamping deformation affecting the characteristic parameters of HGA. In this research, The full model with complicated geometry and clamping condition of the HGA is performed to analyze and ensure precise results instead of simple base plate model. This analysis uses 2 clamping types and 2 clamping forces in order to analyze deformation behaviors and gram load of the HGA. Results from this analysis will be used to adjust and improve the clamping and measurement process.

3 FINITE ELEMENT ANALYSIS

In this Study, finite element analyses are performed using Abaqus 6.7-1, a powerful finite element software, to analyze deformation behaviors of the HGA. The complication and difficulty of physical shape, material, and condition can be generated easily when using the software and performed on high performance computer to obtain results faster. Contact mechanics using implicit analysis is conducted in the FE software. Details of these procedures and analyses are presented in the following topics.

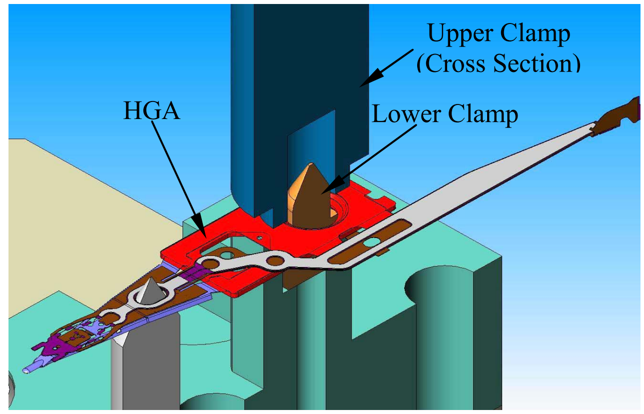


Figure 2: Clamping stage in characteristic parameters measurement process

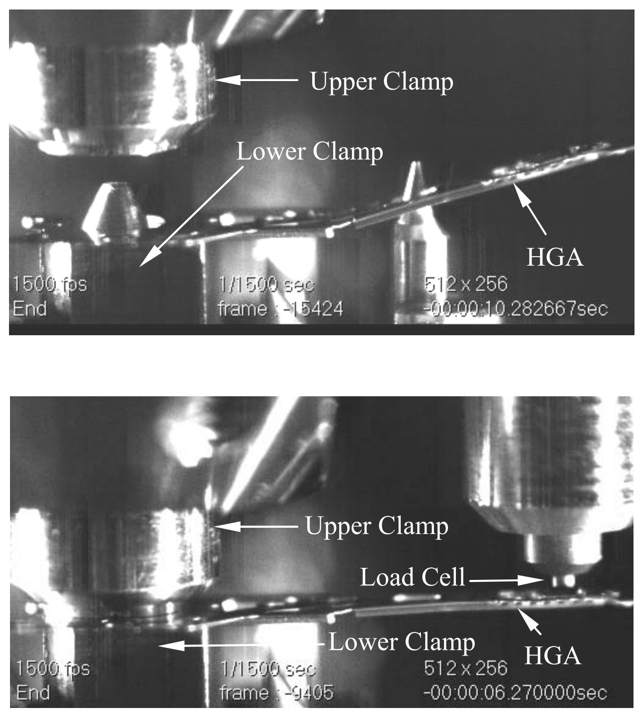


Figure 3: HGA characteristic parameters measurement process

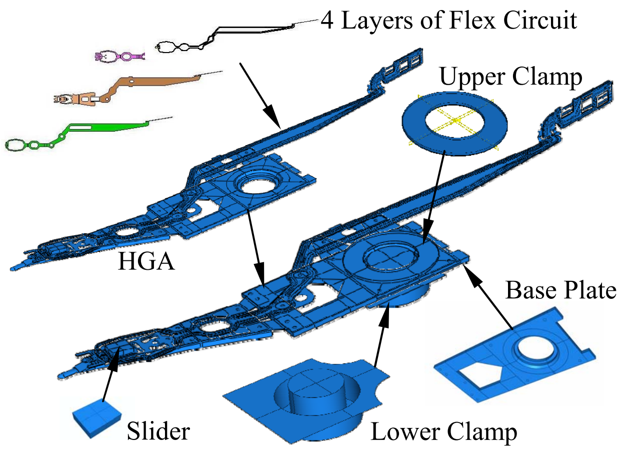


Figure 4: Solid modeling details of clamps and HGA

3.1 Finite Element Model

In this analysis, there are 3 main parts of finite element model which consist of the HGA (including base plate, 4 layers of flex circuit, load beam or suspension and slider), upper and lower clamps. Full 3-D solid modeling details are shown in Figure 4. The HGA part is set to deformable body and the upper and lower clamps are set to be rigid elements (no deformation).

3.1.1 Clamping Conditions

Initial condition for these analyses, contact interaction is set between the HGA and the upper and lower clamps. The details of physical characteristic and figures of various clamps, Type A and B, are shown in Table 1 and Table 2. However, type A clamp is currently used in the manufacturing process and type B clamp is modified from the results of previous research as shown in Figure 5.

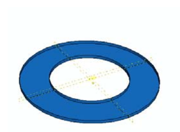
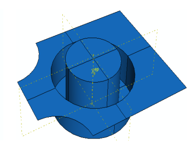
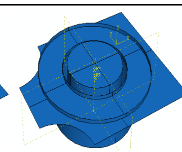
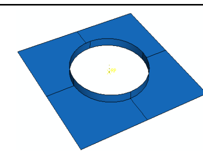
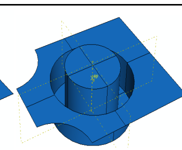
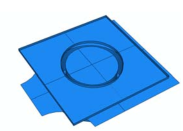
3.1.2 Definition of Interactions and Element Types

Interactions in these analyses are defined as 2 types. First type is tie contact used to weld and attach between components of HGA and the other type, surface to surface contact, is used for the interaction between the HGA and upper and lower clamps. All contact interactions are assumed to be frictionless condition. Elements for the HGA model consist of two element types which are 20-node quadratic brick, reduced integration element for solid or thick parts and 4-node doubly curved shell element for thin parts. For the upper and lower clamps use 4-node rigid shell element assumed to have no deformation. All meshing models are shown in Figure 6.

Table 1: Physical Characteristic of Various Clamps

Clamp	Physical Characteristic of the Upper Clamp	Physical Characteristic of the Lower Clamp
Type A	Circle Type Outer Radius 2.0mm.	2-Corner Fillet
Type B	Square Type Size2×2 mm.	2-Corner Fillet

Table 2: Figures of Various Clamps

Clamp	The Upper Clamp	The Lower Clamp	Characteristic of Clamping
Type A			
Type B			

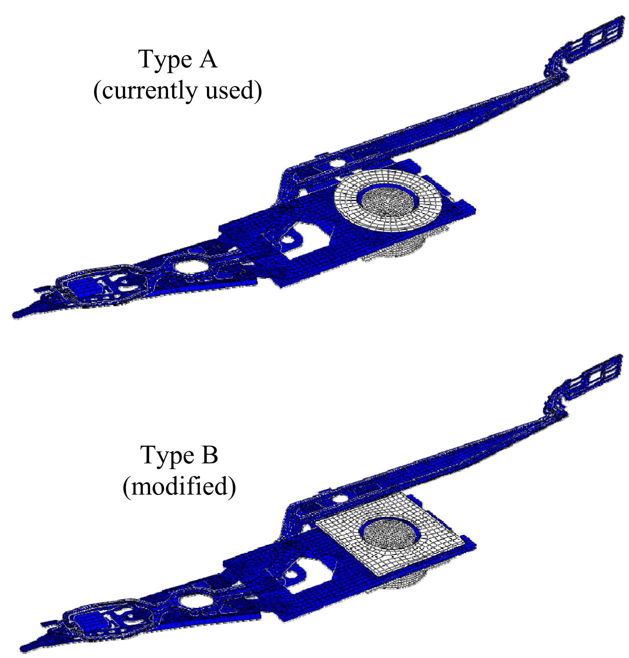


Figure 5: Configurations of type A and type B clamps

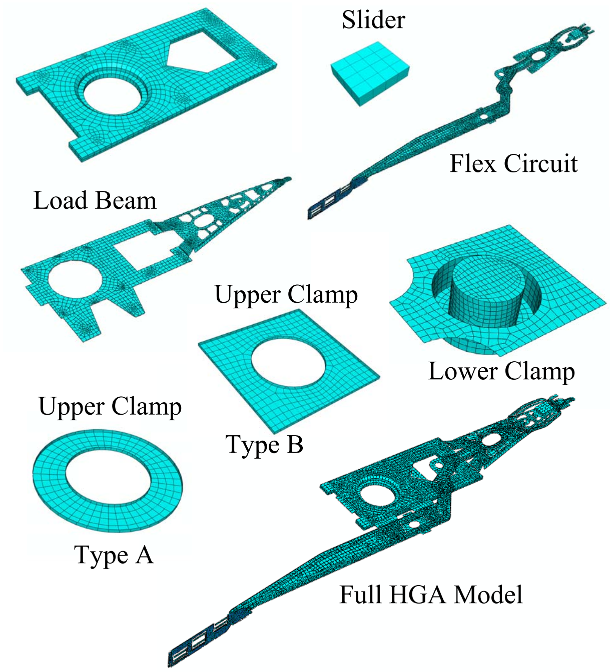


Figure 6: Finite Element Meshing Models

3.2 Boundary Conditions and Loading

3.2.1 Boundary Conditions

Because of both clamps are rigid elements so boundary conditions of them are only defined at reference points as shown in Figure 7. The upper clamp can move only in the vertical direction and the lower clamp is fixed for all directions. For the HGA, boundary conditions are set to prevent the rotation around Z or vertical axis of the base plate of HGA with 2 sets of fixed translation constraints inside the base plate hole in Figure 8.

3.2.2 Loading Conditions

Figure 9 shows clamping force for this simulation applied on the upper clamp using converted uniform pressure to hold the HGA during parameters measurement process. For the clamping step, two clamping pressures are applied for FE analyses, 8 MPa and 100 MPa, respectively. The low clamping pressure of 8 MPa is obtained from converting of a requirement clamping force in the process but the high clamping pressure of 100 MPa is converted from impact force in the current process approximately.

Afterwards, the upper clamp is holding and starting characteristic parameters measurement step. The vertical displacement is applied at the center of slider element until reaching the z-height as shown in Figures 9 and 10 to obtain the gram load and static attitude values.

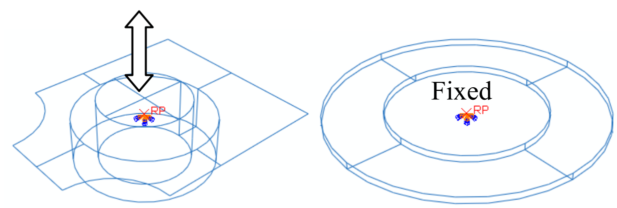


Figure 7: Boundary conditions of lower clamp and upper clamp

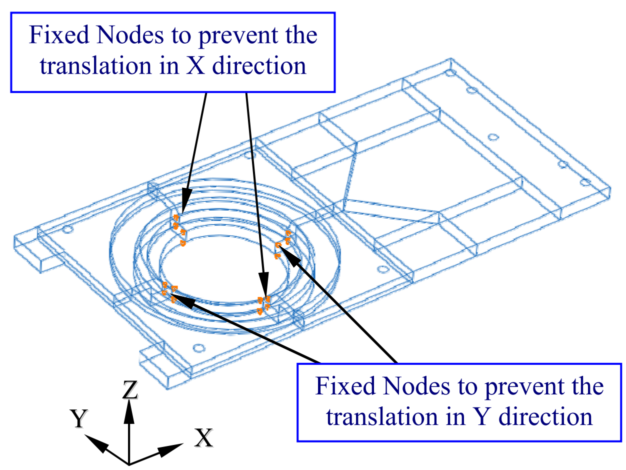


Figure. 8: Boundary conditions of base plate

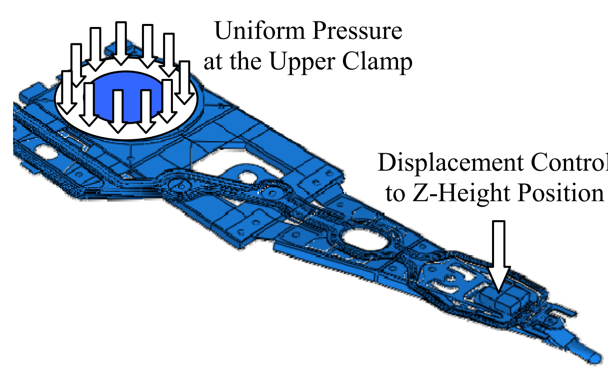


Figure 9: Loading Condition

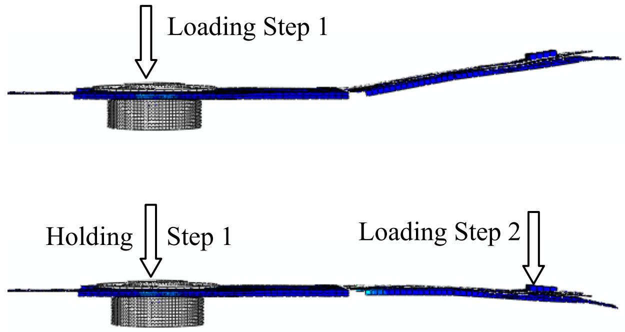


Figure 10: Steps of finite element analysis for characteristic parameters measurement process

4 RESULTS

In this study emphasizes on the deformations of HGA which affected by various clamping following in Table 1 and 2. Three position lines of base plate are considered in the analyses which are longitudinal line, front transverse line and tail transverse line similar to the laser profile scanning of base plate as mentioned in the previous work as shown in Figure 11. Furthermore, gram load and static attitudes are also analyzed and compared in this study.

4.1 Longitudinal Deformation

The results show that longitudinal deformations when using type A clamp are higher than type B clamp in both front and tail sides. However, Bending shape at tail side of type B clamp is negative value because the exceed area of rectangular upper clamp presses on the missing area due to fillet of lower clamp coincidently as shown in Figures 12 and 13. This tail bending effect does not occur in the type A clamp and bend in the positive direction due to ring shape of the upper clamp. Deformation shape of the base plate of type B clamping is a little better than the shape of type A clamping. But, when compared between 8 MPa and 100 MPa clamping pressures, the smaller pressure gives considerable and distinct lower deformation values as shown in Figures 12 and 13.

4.2 Front Transverse Deformation

This front transverse deformations affect the static attitude measurement directly which could twist the suspension or load beam with the slider at the end. Results of analyses show that bending of the front transverse line of type A clamping is deformed more than the type B clamping for both clamping pressures because the upper clamp of type A is ring shape which induces none-uniform pressure distribution in the front transverse line as shown in Figures 14 and 15. But the main effect on tilting of this front end comes from the results of longitudinal deformation due to high clamping pressure.

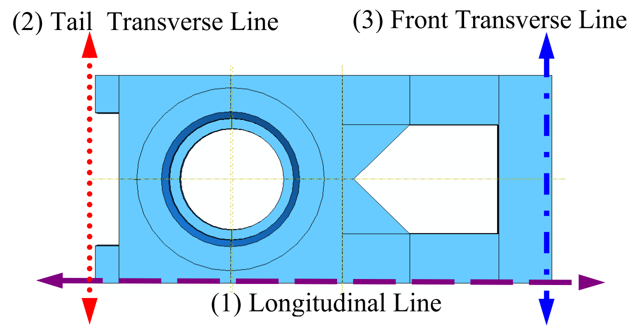


Figure 11: Deformed Positions of the Base Plate (HGA)

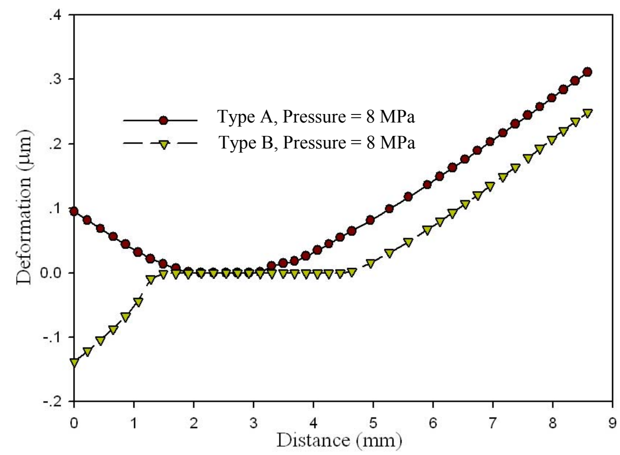


Figure 12: Longitudinal deformations during clamping of type A and B with pressure of 8 MPa

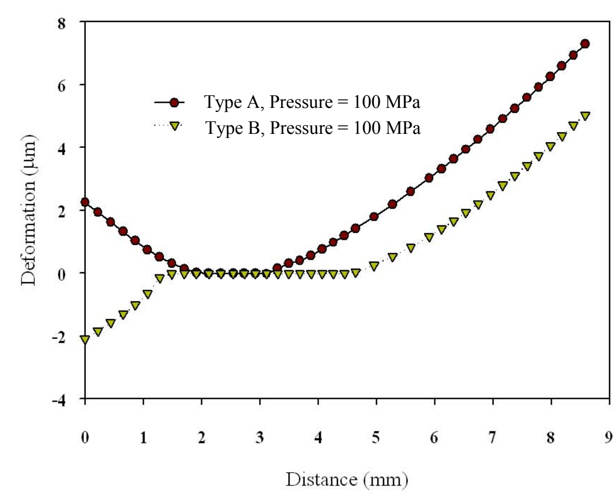


Figure 13: Longitudinal deformations during clamping of type A and B with pressure of 100 MPa

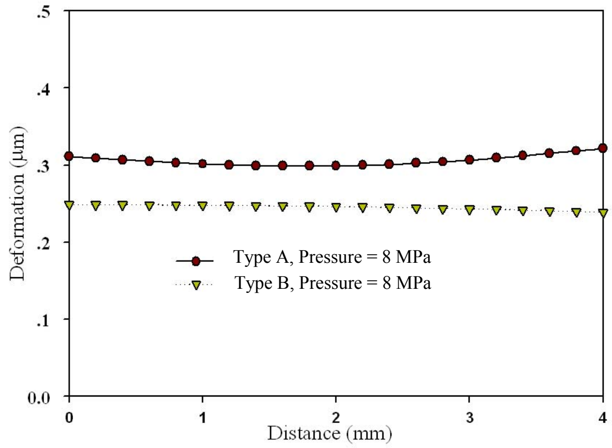


Figure 14: Front transversal deformations during clamping of type A and B with pressure of 8 MPa

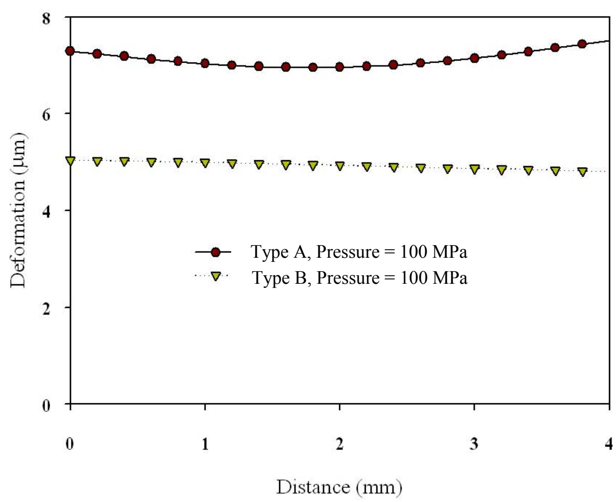


Figure 15: Front transversal deformations during clamping of type A and B with pressure of 100 MPa

4.3 Tail Transverse Deformation

Similar to the deformations from the longitudinal and front transverse lines, the main effect inducing high deformations comes from the high clamping pressure which can bend the base plate of HGA severely. The tail transverse deformations of type A and B clampings are obviously opposite in bending direction because of different shapes of the upper clamps and the missing area due to fillet of lower clamps when clamping together. Results are shown in Figures 16 and 17.

4.4 Equivalent Plastic Strain (PEEQ)

Figures 18 and 19 show equivalent plastic strains (PEEQ) in the base plate of HGA which express that the stress of material exceeds the yield strength causing plastic deformation. These results show that PEEQ value of type A clamping are higher than the value of type B clamping. This means the HGA of type A clamping is more deformed than type B clamping and leads to permanent deformed shape which can not return to the original shape after removing load.

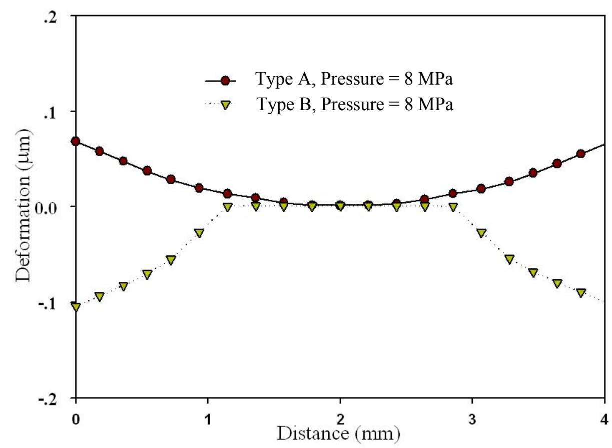


Figure 16: Tail transverse deformations during clamping of type A and B with pressure of 8 MPa

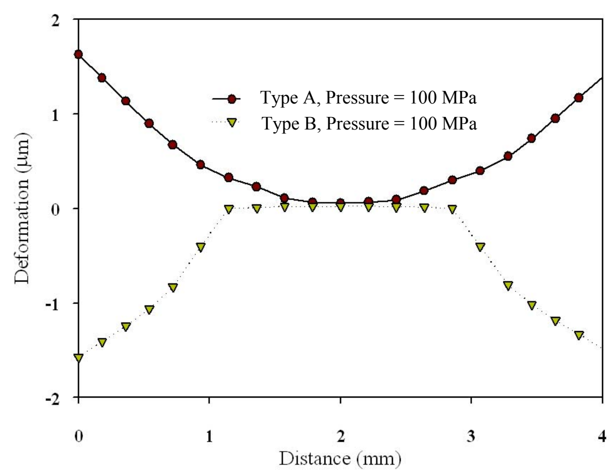


Figure 17: Tail transversal deformations during clamping of type A and B with pressure of 100 MPa

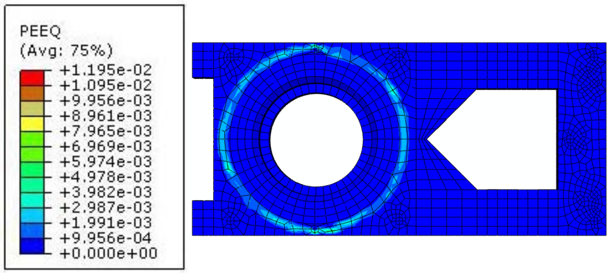


Figure 18: Equivalent Plastic Strain on the Upper Surface of Base Plate due to Type A Clamping with Pressure of 100 MPa

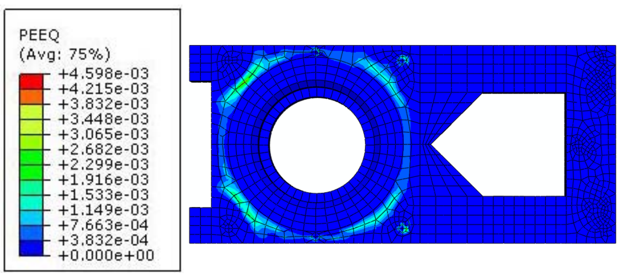


Figure 19: Equivalent Plastic Strain on the Upper Surface of Base Plate due to Type B Clamping with Pressure of 100 MPa

4.5 Gram Load

Results of gram load values and percentage errors when compared to the standard reference value are listed in Table 4. These results show that the lower clamping pressure with type B clamping causes smaller changing of gram load value. However, the gram load values changing due to different clamping types are indistinct when compare with the effect of decreasing clamping pressure.

4.6 Roll Static Attitude (RSA)

Table 5 shows RSA values under various clamping types and pressures. The results show obviously improved RSA due to type B clamping, both clamping pressure, because type B has more uniform pressure distribution and less bending curve on the base plate during clamping which could induce less twist than the other type. The reason of negative RSA values is asymmetry of the HGA shape then the deformation is not symmetry due to twist. However, all RSA values are very small when compare to the standard reference.

4.7 Pitch Static Attitude (PSA)

Table 6 shows PSA values under various clamping types and pressures. These results show obviously improved PSA in both using type B clamping and pressure of 8 MPa. For type B clamping, it can improve the PSA value which is not affected by different clamping pressure and better than type A clamping at all cases.

Table 4 : Gram Load

Pressure (MPa)	**Type of Clamping**	**Gram Load (gram)**	**Percentage Error (%)**
Reference		1.88132	0.000
8	Type A	1.87654	0.249
	Type B	**1.87764**	**0.196**
100	Type A	1.89114	0.523
	Type B	**1.89075**	**0.501**

Table 5 : Roll Static Attitude (RSA)

Pressure (MPa)	**Type of Clamping**	**RSA (Degree)**
Reference		0±0.4
8	Type A	-0.016866
	Type B	**-0.000012**
100	Type A	-0.020150
	Type B	**-0.000010**

Table 6 : Pitch Static Attitude (PSA)

Pressure (MPa)	**Type of Clamping**	**PSA (Degree)**
Reference		1.2608 ± 0.4
8	Type A	1.42134
	Type B	**1.40509**
100	Type A	1.45304
	Type B	**1.40515**

5 CONCLUSION

During HGA clamping for measurement, the main characteristic parameters are affected. Deformations of HGA in every positions from type B clamping are lower than deformations from type A. These deformation results affect to roll static attitude and pitch static attitude obviously but which affect not much to gram load. The rectangular shape of upper type B clamp has contact area more than the ring shape of upper type A clamp which can press all over the base plate area. Therefore, the deformations shape under type B clamping are more uniform than type A. Furthermore, the magnitude of clamping pressure also affect deformations of the HGA because the high clamping pressure causes plastic deformation on the base plate. Consequently, using lower clamping pressure leads to decrease the HGA deformations. The suitable clamping condition for this manufacturing process could use the type B clamping and low clamping pressure enough to hold the HGA such as 8 MPa. These make considerable improvement of parameter measurement during HGA clamping process to reduce cost and time efficiently and effectively.

ACKNOWLEDGMENTS

The authors wish to thank Western Digital (Bang pa-in) Company for helpful information. The HDD Cluster Scholarship from National Electronics and Computer Technology Center (NECTEC) to pursue master degree in Mechanical Engineering at King Mongkut's University of Technology Thonburi is gratefully acknowledged.

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