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Effect of Thermal and Mechanical Stresses on Air Bearing Surface Deformation (Crown) in Head Gimbal Assembly Process

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Abstract. The Fly Height Gap is the most important factor for Hard Disk Drive reliability because it is one of the key input process variables (KPIVs) for read-write process efficiency in terms of magnetic flux intensity. The Fly Height Gap is the distance between the slider or head and the magnetic surface of a disk while the Hard Disk Drive is operating. A reduced fly height allows information to be written or read back more precisely and such information can be stored in a smaller area. Some fly height stability is achieved with proper suspension loading and shaping the air bearing slider surface (ABS) for desirable aerodynamics characteristics. Fly height is further affected by the physical characteristic of the slider such as the shape of the ABS which often found in conventional slider is curvature along the length of the ABS from leading end to trailing end. The curvature is referred to as "Crown". Crown characteristic is employed to investigate the crown behavior in the HGA process. The experimental result confirms that crown variation was greater due to HGA process. Crown variation was increased significantly after adhesive curing process. Finally, it was maintained after solder jet bonding process. When a suspension flexure is epoxy-bonded to a slider, the epoxy usually contracts as it cure, exerting a force along the slider's length. Furthermore, crown variation among sliders results from temperature changes during adhesive curing process which heated the parts using infrared ray. There is a difference in coefficient of thermal expansion which could give rise to stresses that develop in the HGA during temperature variations and are transferred to the slider body. Once these stresses appear in the slider, the profile of the slider's ABS will be changed. The future work of this research shall be reduction of crown variation in HGA process, the stress analysis shall be performed through Finite Element Method to identify and optimize process parameter (boundary condition).

Keywords: Crown, Fly height, Slider, Air Bearing Surface, Head Gimbal Assembly

1. Introduction

The Hard Disk Drive which is a magnetic storage device is one of the most important components in a computer; whether it is a desktop or a notebook. The disk storage systems are used to store information. The data may be recorded or reproduced on radially spaced data tracks on a surface of the disk. Increased storage density which is determined by the transducer's ability to write and read distinguishable transitions is becoming increasing important. [1] One of the most important parameters in a storage density is the distance between disk surface and the read / write element on the magnetic head during operation of storage system, refer to as "Fly Height". [2] With continuously increasing recording densities, the fly height is decreasing and with be less than 10 nm in the next few years. A reduced fly height allows information to be written or read back more precisely and such information can be stored in a smaller area. Some fly height stability is achieved with proper suspension loading and shaping the air bearing slider surface (ABS) for desirable aerodynamics characteristics. Fly height is further affected by the physical characteristic of the slider such as the shape of the ABS which often found in conventional slider is curvature along the length of the ABS from leading end to trailing end. The curvature is referred to as "Crown". [3] Crown variation is generally one of two types; process or temperature variation. The slider fabrication process results in crown variation from slider to slider. The slider curvature is predefined during a lapping process. Process variation may be greater due to the slider-to-suspension bonding process, the epoxy usually contracts as it cures, exerting a force along the slider's length. The temperature variation will effect on crown in term of the difference in the coefficient of thermal expansion (CTE). Typically, a suspension is usually formed from stainless steel, whereas the slider comprises a substrate such as Al2O3TiC. The suspension material has been observed to expand and contract at a faster rate than the slider material in response to temperature changes. The purpose of this research is to understand the crown behaviour during Head Gimbal Assembly process.

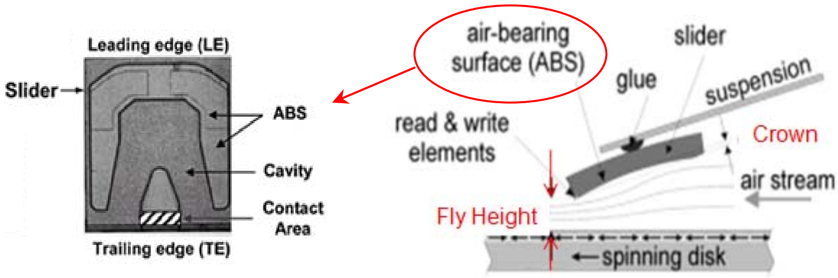


Fig. 1: A Head Disk Interface (HDI) showing flying height, Air Bearing Surface (ABS) and Crown [9]

2. Experimental Result and Discussion

2.1. Head Gimbal Assemble (HGA) Process

During the HGA fabrication process, a slider is bonded to a suspension assembly using some type of adhesive. The quick-setting adhesive was done by using ultra-violet light. Then the adhesive will be completely cured by infrared ray (IR). Finally, there is a need to create an electrical connection between the head and the suspension using some type of solder. The HGA key processes are the following; (a) the adhesive dispensing: dispenses the adhesive and is added to the flexure area where the slider will be attached, (b) the slider bonding: attaches the slider onto the flexure area which was dispensed during the adhesive dispensing process and the adhesive pre-curing done using ultra-violet light, (c) the adhesive curing: the adhesive will be completely cured by infrared ray and (d) the solder jet bonding: the melt solder is applied to connect circuit between slider and suspension pads to connect an electrical circuit.

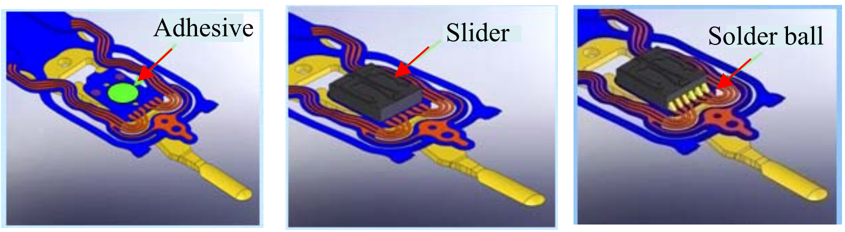
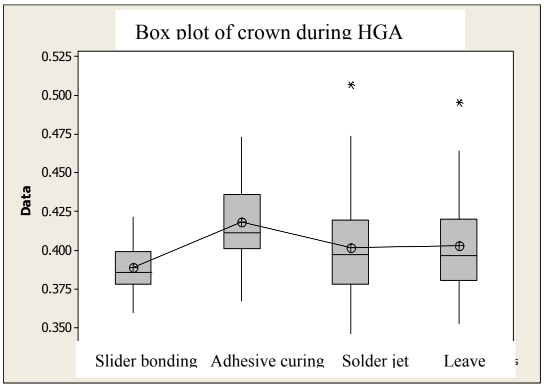


Fig. 2: Head Gimbal Assemble Process Step

2.2. Experimental Result

Crown characterization was performed to study crown change during HGA process; adhesive curing and solder jet bonding. Crown after slider bonding process was assumed to be equal with pre-existing slider crown and there was no change in crown during slider bonding process. Crown data was measured after each process step (slider bonding, adhesive curing and solder jet bonding). As in the case of product A (specific ABS and suspension design), the crown characteristic can be described as following.

- As described previously, crown variation was greater due to the slider-to-suspension bonding process. Crown variation after slider bonding process was only 0.01591 uin and it was increase significantly after adhesive curing process to 0.2618 uin. Finally, it was maintained after solder jet bonding process at 0.3057 uin. This data is plotted in Figure 3 as box plot.
- Higher crown was observed after adhesive bonding process which was the process after slider bonding. Crown mean value after adhesive curing process was significant higher than crown mean value after slider bonding process. Same trend was observed on crown variation (P- 1st Slider bonding 2nd Adhesive curing
This data is plotted in Figure 4.

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One-way ANOVA: Crown during HGA process

Source   DF        SS        MS     F      P
Factor    3  0.016174  0.005391  7.06  0.000
Error   148  0.112942  0.000763
Total   151  0.129117

S = 0.02762   R-Sq = 12.53%   R-Sq(adj) = 10.75%

Level                    N     Mean    StDev
1st_Slider Bonding      38  0.38942  0.01591
2nd_Adhesive curing     38  0.41848  0.02618
3rd_Solder jet          38  0.40167  0.03434
4th_Solder jet_leave 2 h 38  0.40286  0.03057
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Fig. 3: Crown characteristic during HGA process

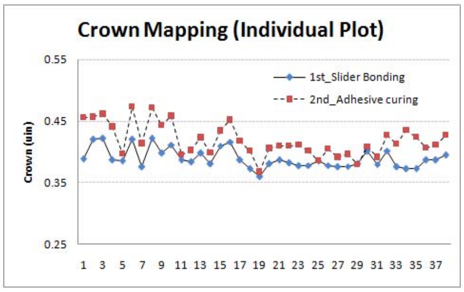


Fig. 4: Crown behavior after adhesive curing

- Lower crown was observed after solder jet bonding process (dash line) which was the process after adhesive curing. The crown mean value after solder jet bonding process was significant lower than crown mean value after adhesive curing process (P-value < 0.05) while variation was maintained the same. This data is plotted in Figure 5.
- Crown value was maintained after solder jet bonding process. There was no significant of crown mean and variation when we left the parts for 2 hrs after solder jet bonding process (P-value < 0.05). This data is plotted in Figure 6.

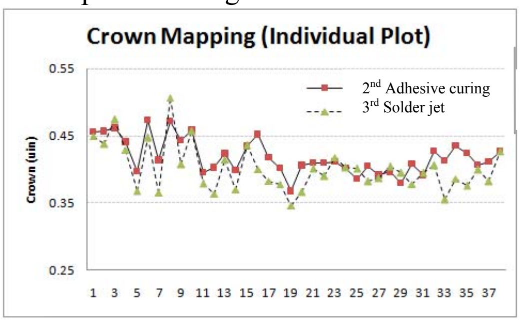


Fig. 5: Crown behavior after solder jetting

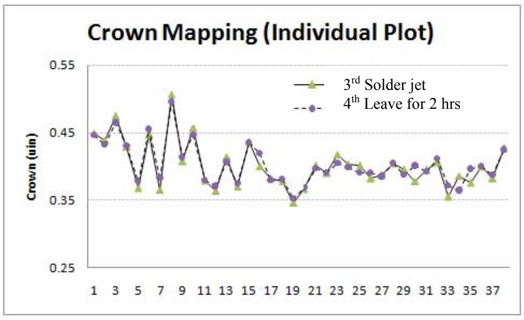


Fig. 6: Crown behavior after leaving the parts for 2 hrs

Crown profile was measured by Wyko NT3300 Phase Shifting Interferometry (PSI) technique which uses the interference of light to produce information on the surface of a sample. After each assembly process step, same samples (10 HGAs) were measured crown profile as shown in Figure 7.

Crown change during assembly process at different location of specific HGA is shown in table 1. At same location (A-B-C-D-E-F), crown change during HGA process can be observed.

Table 1 Crown profile change during assembly process at various ABS location (unit = micro inch)

Process	Location A	Location B	Location C	Location D	Location E	Location F
Slider bonding	0.470	0.466	0.466	0.470	0.470	0.468
Adhesive curing	0.486	0.484	0.486	0.486	0.488	0.486
Solder jet bonding	0.378	0.376	0.376	0.380	0.380	0.380
Leave for 2 hrs	0.368	0.360	0.362	0.366	0.366	0.366

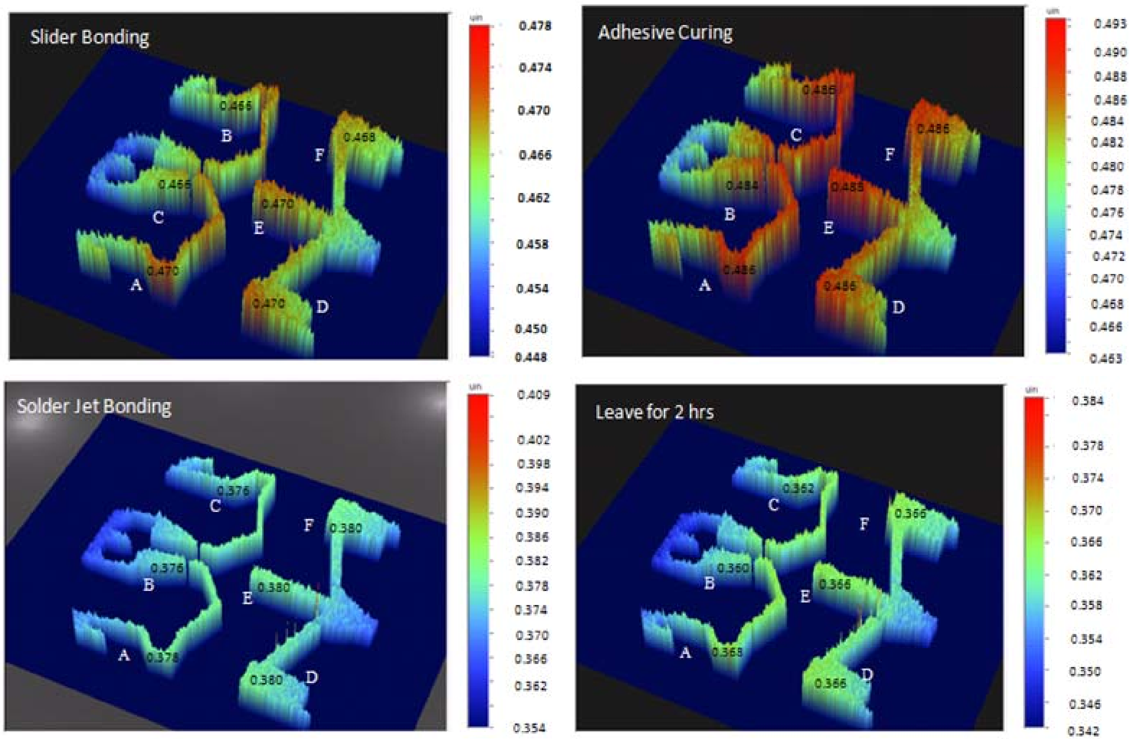
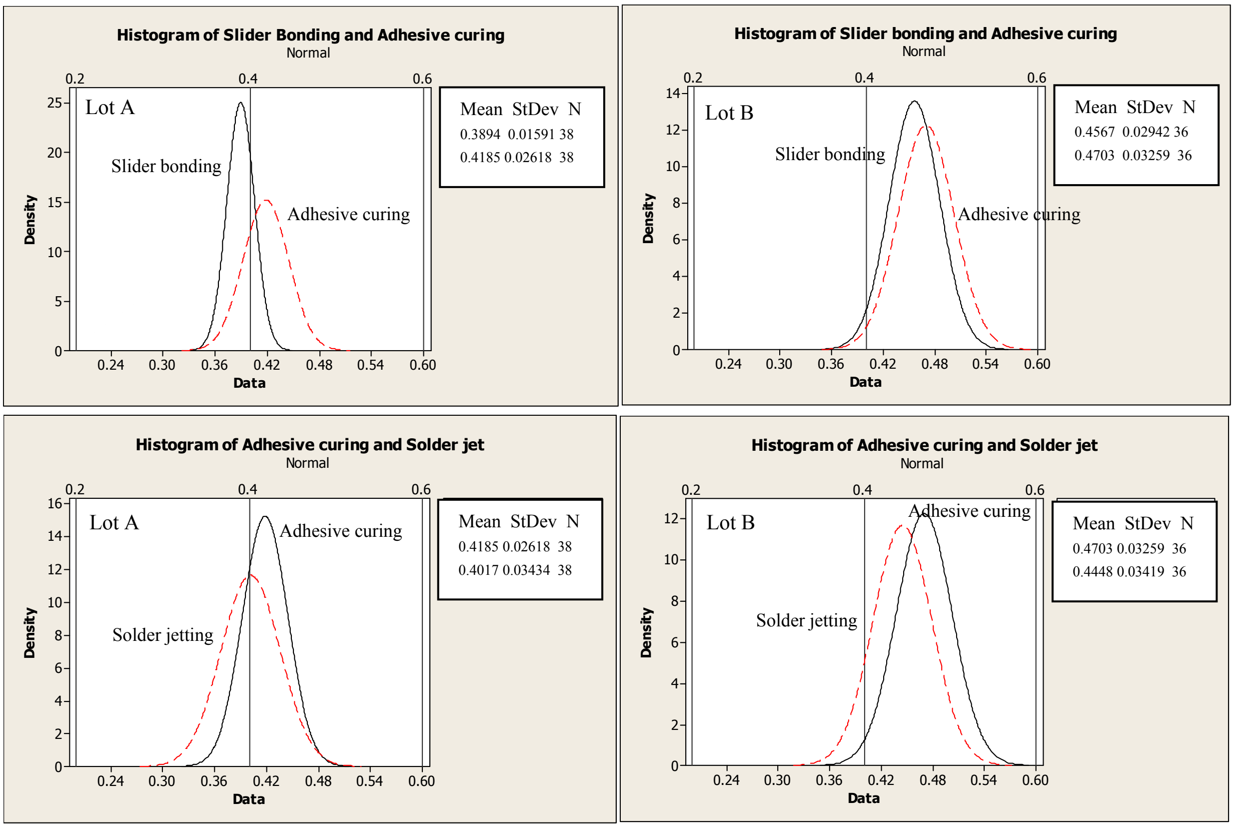


Fig. 5: Crown profile (same part) after each process step, refer the crown value at each location in table 1

Repeated experiment with slider lot B is performed to confirm crown behaviour, same crown change trend was observed on slider lot B. Figure 6 are the histogram for crown behaviour comparison from 2 difference slider lots (A,B) and experimental time frame. There is crown change during HGA process (Adhesive curing and Solder jet bonding). The crown distribution is depended on incoming slider and crown change during HGA process.



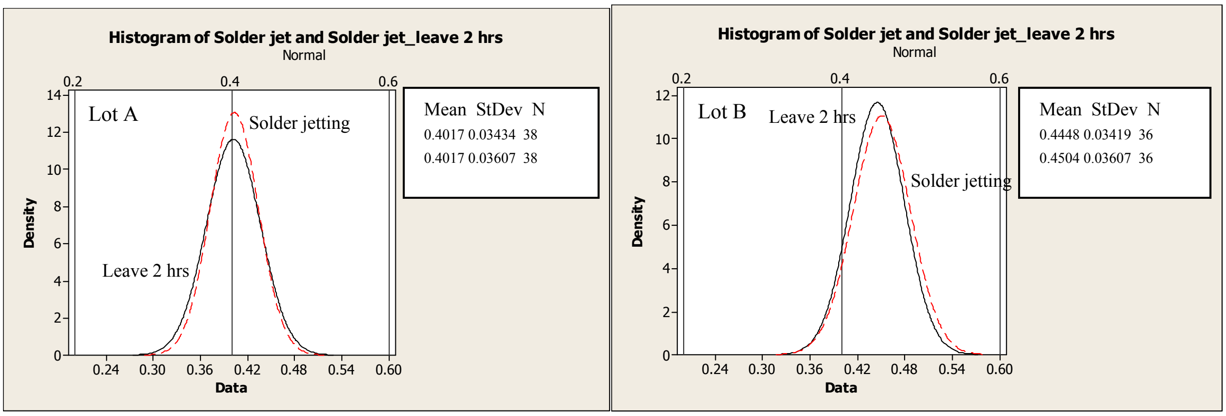


Fig. 6: the histogram for crown behavior comparison from 2 difference slider lots (A,B)

2.3. Discussion and Future Work

This experimental result confirms that crown variation was greater due to the slider-to-suspension bonding process. Crown variation was increase significantly after adhesive curing process (from 0.0159 to 0.0262 uin). Finally, it was maintained after solder jet bonding process at 0.0306 uin. While crown mean was increased significantly after adhesive curing process (from 0.389 to 0.418 uin) then it was maintained after solder jet bonding process at 0.4017 uin. When a suspension flexure is epoxy-bonded to a slider, the epoxy usually contracts as it cure, exerting a force along the slider's length. Furthermore, crown variation among sliders results from temperature changes during adhesive curing process which heated the parts using infrared ray. There is a difference in coefficient of thermal expansion which could give rise to stresses that develop in the HGA during temperature variations and are transferred to the slider body. Once these stresses appear in the slider, the profile of the slider’s ABS will be changed. The future work of this research shall be reduction of crown variation in HGA process, the stress analysis shall be performed through Finite Element Method to identify and optimize process parameter (boundary condition).

3. Acknowledgements

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