Design of opener shape for improving gimbal tongue shift on y-axis

Warut Klayaubol¹ and Monsak Pimsarn¹,*

¹,¹,*Department of Mechanical Engineering, Faculty of Engineering, King Mongkut’s Institute of Technology Ladkrabang, Bangkok 10520, Thailand.

* Corresponding Author: warut.klayaubol@seagate.com

Abstract
There are four necessary components for testing read-write efficiency of Slider, which are [1] Slider electrical testing machine [2] Fixture, a tool for holding Slider while testing [3] Slider to read and write data in hard disk drive and [4] Opener, a mechanism to open a fixture for loading and unloading Slider. The opener should open a fixture only in x direction but it appears that the opener drives a fixture in both x and y directions which results in misalignment of Slider in a fixture. A poor Slider alignment definitely affects a read-write efficiency of Slider. Therefore, this article will show a study of opener shape that relates to fixture behaviour and also a comparison of four designs of opener-arm angle (15 degrees, -15 degrees, -30 degrees and -40 degrees) by using Finite Element Analysis (FEA). Result shows -40 degrees opener is the best one that can open the fixture only in y direction and meets the design requirement.

Keywords: Opener, Slider

1. Introduction
Nowadays, the competition in data storage technology is very intensive. Quality and price are main factors for customers to select the products. Therefore, Seagate Technology (Thailand) Limited, as the leader of data storage business, needs to research and develop Slider testing processes to deliver products with the best quality for clients. There are four components necessary for testing the read-write efficiency of Slider.

1) Slider electrical testing machine
2) Fixture (a tool for holding Slider while testing)
3) Slider (an element to read & write data in hard disk drive)
4) Opener (a mechanism to open a fixture for loading and unloading Slider)
A result of loading Slider into a fixture showed Slider misalignment about 30 microns. After investigation, it was found that there is a movement of fixture in y direction causing Slider shift from a loading target. This 30-micron misalignments definitely impacts Slider testing performance.

Research and development team had investigated deeply this problem and found that the tip of opener has motion in both x and y directions instead of only x direction as desire. So, when a fixture is opened, it will be moved together with the opener in positive y direction. And it will be moved back in negative y direction when it is closed. Regarding Slider loading sequence, Slider is aligned perfectly with a fixture while it is opened. But while fixture is closing, Slider shifts out from target and results in Slider misalignment. So, the real root cause is a motion of opener tip in y direction.

This study will show a relationship between opener shape and fixture behaviour and also a comparison of four new designs of opener-arm (15 degrees, -15 degrees, -30 degrees and -40 degrees) by using Finite Element Analysis. However, the same failures of this kind of mechanism had been investigated by many researchers, and reported in many literatures. [1] Finite Element Analysis with ANSYS program for optimization by considering stress, weight comparison & reducing of size of connecting rod. [2] Re-design of a failed clutch fork using topology and shape optimization by the response surface method. [3] Finite Element Modeling of structural stainless-steel cross-sections. [4] An automatic Finite Element Modeling for deformation analysis of composite structures. [5] A general mesh smoothing method for Finite Element. [6] Investigation of finite element mesh independence in rate dependent materials. [7] Finite Element Analysis of Stress-Strain Response at the Tool Pin during Friction Stir Process.

Although there are many researches in mechanism failures and shape optimization, but a study in micro motion as the opener is rarely considered. In this research, four new conceptual designs of opener are determined a deformation shape to consider the best design of opener that has the minimum y motion.

2. Method

Finite Element Method (FEM), a numerical method, is used for solving engineering problems. Typically, many engineering problems (structural analysis, heat transfer, fluid flow, mass transport, complicated geometries, loadings and material properties) can be solved by using Finite Element Method.

This paper examined the opener shape by using Finite Element Analysis to study the opener characteristics after opening.

Opener mechanism (micro mechanism) is shown in Figure 2. There is a dowel pin, which does not show in a picture, to constraint the opener at the center hole. So, the opener can rotate around the z-axis.
as red arrow. The external forces, 4.5 N each, are applied to opener arms to activate the opener tip. Then opener tip moves apart in x direction as green arrows.

2. Materials and Methods

![Image: Opener Mechanism]

3. Modeling
In this study, software Solidworks 2019 SP3 is used to create opener models and ANSYS Workbench 2020 R1 is used to analysis the opener behaviour with boundary conditions and meshing element as following.

3.1 Boundary condition
In order to make all models be ready for the experiment. It is necessary to determine boundary conditions. For example: material properties, constraints, loads, and etc., need to be represent the actual condition.

| Materials          | Property 1 (Unit) | Property 2 |
|--------------------|-------------------|------------|
| Stainless Steel 440C | HRC               | 59         |

Mechanical properties of stainless steel 440C are determined as below:
1. Tempering Temperature (°C) = 204
2. Yield Strength (MPa) = 1900
3. Elongation (% in 50 mm) = 4

3.2 Mesh Independence
It is necessary to consider a mesh convergence at preprocessing process in order to get the accurate result from Finite Element Analysis.

Figure 3. x-axis shows numbers of opener meshing elements and y-axis shows opener tip deformation. Therefore, it can be determined that y deformation will converge to the exact value if number of elements is equal to or higher than 15,000 elements onward. Therefore, the minimum element
that can be used for the opener analysis is 15,000 elements in order to reduce the analytical time of ANSYS program and still deliver a reliable result.

Figure 3. Mesh Independence Study

4. Result

4.1 Model Validation

The commercial Finite Element software (ANSYS) was employed to simulate the response of opener with or without geometry defects. The mesh was discretized using the hex dominant element type. A mesh Independence study was also applied until the simulation results showed negligible change with increasing the mesh elements.

Y deformation of visual inspection and Finite Element Analysis shows in Figure 4. Result between visual inspection data and Finite Element Analysis. There is offset value approximately 6 microns.

Figure 4. Visual inspection versus Finite Element Analysis result

Figure 5. Shows result from Finite Element Analysis. The opener tip moves 0.070 mm. in y-axis and stress occurs in both arms, 974.65 MPa, which is still under yield strength of 1,900 MPa. Thus, the deformation is still under elastic zone.
4.2 Design Improvement.
A study is designed to consider parameters as shown in Table 1. Due to a limitation of design packaging, only the opener-arm can be modified. Therefore, the angle of opener-arm is varied from 15 degrees to 40 degrees. Thickness and material (steel sheet grade SST440C) of new designs are maintained the same as existing opener.

Table 2. Parameter for study

| Parameter               | Nominal | Min.  | Max.   |
|-------------------------|---------|-------|--------|
| Alpha angle             |         | 15 degrees | 40 degrees |
| Thickness of Opener     | 0.200 mm. |       |        |
| Material of Opener      | SST 440C |       |        |

Figure 6. An improved version A (15 degrees)
Figure 7. An improved version B (-15 degrees)

Figure 8. An improved version B (-30 degrees)

Figure 9. An improved version B (-40 degrees)

Table 3. Result for FEM Study

| Opener shape       | Y-axis deformation | Von Mises stresses |
|--------------------|--------------------|--------------------|
| Improved version A 15 degrees | 0.0706 mm.        | 1756 Mpa.          |
| Improved version B -15 degrees | 0.0608 mm.        | 1016.4 Mpa.        |
| Improved version B -30 degrees | 0.0457 mm.        | 1295.6 Mpa.        |
| Improved version B -40 degrees | 0.0297 mm.        | 1655.1 Mpa.        |
Table 3. It shows that the more changing of the angle in negative way, the less y deformation of opener tip. An improved version B-40 degree has minimum y deformation of 0.0297 mm. versus 0.0706 mm. (existing opener). However, design B-40 degrees may need to be observed more in term of life time, closing time, and etc.

5. Conclusion
The parameters that are considered by FEM in this study are: 1) the value of y deformation of opener tip, and 2) equivalent (von-Mises) stress of opener body. The maximum y deformation can be improved by revising the angle of opener arm. Therefore, this research can provide the following conclusions.

- Regarding four new conceptual designs of opener, it can be determined that the more changing of the angle in a negative way, the less y deformation of the opener tip.
- Mesh independence, 15,000 elements for mesh quantity, and hex-dominant mesh is enough to make the result convert to an exact value.
- Opener improved version B (-40 degrees) has minimum y deformation of 0.0297 mm. versus 0.0706 mm. (existing opener).
- The maximum stress at the fillet of opener arms should be minimized in order to improve lifetime.

Acknowledgments
This work is a part of current project funded by Seagate Technology (Thailand), Equipment Development Engineering Department.

References
[1] Bharti Y K Singh V Hussain A Singh D Lal S B and Dwivedi S K 2013 International Journal of Scientific and Engineering Research 4(6) 1796-1803
[2] Kaya N Karen I and Öztürk F 2010 Materials and Design 31 3008-3014
[3] Ashraf M Gardner L and Nethercot D A 2006 Thin-Walled Structures 44(10) 1048-1062
[4] Yanga H Xub X and Neumann I 2019 Composite Structures 212 434-438
[5] Durand R Pantoja B G and Oliveira V 2019 Finite Elements in Analysis and Design 158 17-30
[6] Harewood F J and McHugh P E 2006 Computational Materials Science 37 442-453
[7] Jaffarullah M S Low C Y Saudon J B Shaari M S B and Jaffar A 2015 Procedia Computer Science 76 522-527